# Request for Proposal
# RFP-4650-19-DH

# Design Services for Improvements to Hogchute Reservoir Dam, Spillway, and Outlet Works

**RESPONSES DUE:**
June 14, 2019 prior to 3:30 PM
***Accepting Electronic Responses Only***
***Responses Only Submitted Through the Rocky Mountain E-Purchasing System (RMEPS)***
**https://www.rockymountainbidsystem.com/default.asp**
**(Purchasing Representative does not have access or control of the vendor side of RMEPS. If website or other problems arise during response submission, vendor MUST contact RMEPS to resolve issue prior to the response deadline. 800-835-4603)**

**PURCHASING REPRESENTATIVE:**
Duane Hoff Jr., Senior Buyer
duaneh@gjcity.org
970-244-1545

This solicitation has been developed specifically for a Request for Proposal intended to solicit competitive responses for this solicitation, and may not be the same as previous City of Grand Junction solicitations. All offerors are urged to thoroughly review this solicitation prior to submitting. Submittal by **FAX, EMAIL or HARD COPY IS NOT ACCEPTABLE** for this solicitation.

# REQUEST FOR PROPOSAL

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# <u>REQUEST FOR PROPOSAL</u>

## SECTION 1.0: ADMINISTRATIVE INFORMATION & CONDITIONS FOR SUBMITTAL

**1.1 Issuing Office:** This Request for Proposal (RFP) is issued by the City of Grand Junction. All contact regarding this RFP is directed to:

**<u>RFP QUESTIONS:</u>**
Duane Hoff Jr., Senior Buyer
duaneh@gjcity.org

**1.2 Purpose:** The purpose of this RFP is to obtain proposals from qualified professional design/engineering firms to provide design services for the Improvements to Hogchute Reservoir Dam, Spillway, and Outlet Works Project.

**1.3 The Owner:** The Owner is the City of Grand Junction, Colorado and is referred to throughout this Solicitation. The term Owner means the Owner or his authorized representative.

**1.4 Site Visit/Briefing:** A site visit is not scheduled for this Request for Proposal due to the access road being closed because of snow.

**1.5 Compliance:** All participating Offerors, by their signature hereunder, shall agree to comply with all conditions, requirements, and instructions of this RFP as stated or implied herein. Should the Owner omit anything from this packet which is necessary to the clear understanding of the requirements, or should it appear that various instructions are in conflict, the Offeror(s) shall secure instructions from the Purchasing Division prior to the date and time of the submittal deadline shown in this RFP.

**1.6 Submission:** <u>Please refer to section 5.0 for what is to be included.</u> <u>***Each proposal shall be submitted in electronic format only, and only through the Rocky Mountain E-Purchasing website (https://www.rockymountainbidsystem.com/default.asp).***</u> <u>*This site offers both "free" and "paying" registration options that allow for full access of the Owner's documents and for electronic submission of proposals.*</u> <u>*(Note: "free" registration may take up to 24 hours to process. Please Plan accordingly.)*</u> Please view our "**Electronic Vendor Registration Guide"** at http://www.gjcity.org/business-and-economic-development/bids/ for details. For proper comparison and evaluation, the City requests that proposals be formatted as directed in Section 5.0 "Preparation and Submittal of Proposals." Submittals received that fail to follow this format may be ruled non-responsive. (Purchasing Representative does not have access or control of the vendor side of RMEPS. If website or other problems arise during response submission, vendor **<u>MUST</u>** contact RMEPS to resolve issue prior to the response deadline. **800-835-4603**).

**1.7 Altering Proposals:** Any alterations made prior to opening date and time must be initialed by the signer of the proposal, guaranteeing authenticity. Proposals cannot be altered or amended after submission deadline.

**1.8 Withdrawal of Proposal:** A proposal must be firm and valid for award and may not be withdrawn or canceled by the Offeror for sixty (60) days following the submittal deadline date, and only prior to award. The Offeror so agrees upon submittal of their proposal. After award this statement is not applicable.

**1.9 Acceptance of Proposal Content:** The contents of the proposal of the successful Offeror shall become contractual obligations if acquisition action ensues. Failure of the successful Offeror to accept these obligations in a contract shall result in cancellation of the award and such vendor shall be removed from future solicitations.

**1.10 Addenda:** All questions shall be submitted in writing to the appropriate person as shown in Section 1.1. Any interpretations, corrections and changes to this RFP or extensions to the opening/receipt date shall be made by a written Addendum to the RFP by the City Purchasing Division. Sole authority to authorize addenda shall be vested in the City of Grand Junction Purchasing Representative. Addenda will be issued electronically through the Rocky Mountain E-Purchasing website at www.rockymountainbidsystem.com. Offerors shall acknowledge receipt of all addenda in their proposal.

**1.11 Exceptions and Substitutions:** All proposals meeting the intent of this RFP shall be considered for award. Offerors taking exception to the specifications shall do so at their own risk. The Owner reserves the right to accept or reject any or all substitutions or alternatives. When offering substitutions and/or alternatives, Offeror must state these exceptions in the section pertaining to that area. Exception/substitution, if accepted, must meet or exceed the stated intent and/or specifications. The absence of such a list shall indicate that the Offeror has not taken exceptions, and if awarded a contract, shall hold the Offeror responsible to perform in strict accordance with the specifications or scope of services contained herein.

**1.12 Confidential Material:** All materials submitted in response to this RFP shall ultimately become public record and shall be subject to inspection after contract award. "**Proprietary or Confidential Information"** is defined as any information that is not generally known to competitors and which provides a competitive advantage. Unrestricted disclosure of proprietary information places it in the public domain. Only submittal information clearly identified with the words "***Confidential Disclosure***" and uploaded as a separate document shall establish a confidential, proprietary relationship. Any material to be treated as confidential or proprietary in nature must include a justification for the request. The request shall be reviewed and either approved or denied by the Owner. If denied, the proposer shall have the opportunity to withdraw its entire proposal, or to remove the confidential or proprietary restrictions. Neither cost nor pricing information nor the total proposal shall be considered confidential or proprietary.

**1.13 Response Material Ownership**: All proposals become the property of the Owner upon receipt and shall only be returned to the proposer at the Owner's option. Selection or rejection of the proposal shall not affect this right. The Owner shall have the right to use all ideas or adaptations of the ideas contained in any proposal received in response to this RFP, subject to limitations outlined in the entitled "Confidential Material". Disqualification of a proposal does not eliminate this right.

**1.14 Minimal Standards for Responsible Prospective Offerors:** A prospective Offeror must affirmably demonstrate their responsibility. A prospective Offeror must meet the following requirements.

- Have adequate financial resources, or the ability to obtain such resources as required.
- Be able to comply with the required or proposed completion schedule.
- Have a satisfactory record of performance.
- Have a satisfactory record of integrity and ethics.
- Be otherwise qualified and eligible to receive an award and enter into a contract with the Owner.

**1.15 Open Records:** Proposals shall be received and publicly acknowledged at the location, date, and time stated herein. Offerors, their representatives and interested persons may be present. Proposals shall be received and acknowledged only so as to avoid disclosure of process. However, all proposals shall be open for public inspection after the contract is awarded. Trade secrets and confidential information contained in the proposal so identified by offer as such shall be treated as confidential by the Owner to the extent allowable in the Open Records Act.

**1.16 Sales Tax:** The Owner is, by statute, exempt from the State Sales Tax and Federal Excise Tax; therefore, all fees shall not include taxes.

**1.17 Public Opening:** Proposals shall be opened in the City Hall Auditorium, 250 North 5th Street, Grand Junction, CO, 81501, immediately following the proposal deadline. Offerors, their representatives and interested persons may be present. Only the names and locations on the proposing firms will be disclosed.

## SECTION 2.0: GENERAL CONTRACT TERMS AND CONDITIONS

**2.1. Acceptance of RFP Terms:** A proposal submitted in response to this RFP shall constitute a binding offer. Acknowledgment of this condition shall be indicated on the Letter of Interest or Cover Letter by the autographic signature of the Offeror or an officer of the Offeror legally authorized to execute contractual obligations. A submission in response to the RFP acknowledges acceptance by the Offeror of all terms and conditions including compensation, as set forth herein. An Offeror shall identify clearly and thoroughly any variations between its proposal and the Owner's RFP requirements. Failure to do so shall be deemed a waiver of any rights to subsequently modify the terms of performance, except as outlined or specified in the RFP.

**2.2. Execution, Correlation, Intent, and Interpretations:** The Contract Documents shall be signed by the Owner and Firm. By executing the contract, the Firm represents that they have familiarized themselves with the local conditions under which the Services is to be performed, and correlated their observations with the requirements of the Contract Documents. The Contract Documents are complementary, and what is required by any one, shall be as binding as if required by all. The intention of the documents is to include all labor, materials, equipment, services and other items necessary for the proper execution and completion of the scope of services as defined in the technical specifications and drawings contained herein. All drawings, specifications and copies furnished by the Owner are, and shall remain, Owner property. They are not to be used on any other project.

**2.3. Permits, Fees, & Notices:** The Firm shall secure and pay for all permits, governmental fees and licenses necessary for the proper execution and completion of the services. The

Firm shall give all notices and comply with all laws, ordinances, rules, regulations and orders of any public authority bearing on the performance of the services. If the Firm observes that any of the Contract Documents are at variance in any respect, he shall promptly notify the Owner in writing, and any necessary changes shall be adjusted by approximate modification. If the Firm performs any services knowing it to be contrary to such laws, ordinances, rules and regulations, and without such notice to the Owner, he shall assume full responsibility and shall bear all costs attributable.

**2.4. Responsibility for those Performing the Services:** The Firm shall be responsible to the Owner for the acts and omissions of all his employees and all other persons performing any of the services under a contract with the Firm.

**2.5. Payment & Completion:** The Contract Sum is stated in the Contract and is the total amount payable by the Owner to the Firm for the performance of the services under the Contract Documents. Upon receipt of written notice that the services is ready for final inspection and acceptance and upon receipt of application for payment, the Owner's Project Manager will promptly make such inspection and, when they find the services acceptable under the Contract Documents and the Contract fully performed, the Owner shall make payment in the manner provided in the Contract Documents. Partial payments will be based upon estimates, prepared by the Firm, of the value of services performed and materials placed in accordance with the Contract Documents. The services performed by Firm shall be in accordance with generally accepted professional practices and the level of competency presently maintained by other practicing professional firms in the same or similar type of services in the applicable community. The services and services to be performed by Firm hereunder shall be done in compliance with applicable laws, ordinances, rules and regulations.

**2.6. Protection of Persons & Property:** The Firm shall comply with all applicable laws, ordinances, rules, regulations and orders of any public authority having jurisdiction for the safety of persons or property or to protect them from damage, injury or loss. Firm shall erect and maintain, as required by existing safeguards for safety and protection, and all reasonable precautions, including posting danger signs or other warnings against hazards promulgating safety regulations and notifying owners and users of adjacent utilities. When or where any direct or indirect damage or injury is done to public or private property by or on account of any act, omission, neglect, or misconduct by the Firm in the execution of the services, or in consequence of the non-execution thereof by the Firm, they shall restore, at their own expense, such property to a condition similar or equal to that existing before such damage or injury was done, by repairing, rebuilding, or otherwise restoring as may be directed, or it shall make good such damage or injury in an acceptable manner.

**2.7. Changes in the Services:** The Owner, without invalidating the contract, may order changes in the services within the general scope of the contract consisting of additions, deletions or other revisions. All such changes in the services shall be authorized by Change Order/Amendment and shall be executed under the applicable conditions of the contract documents. A Change Order/Amendment is a written order to the Firm signed by the Owner issued after the execution of the contract, authorizing a change in the services or an adjustment in the contract sum or the contract time.

**2.8. Minor Changes in the Services:** The Owner shall have authority to order minor changes in the services not involving an adjustment in the contract sum or an extension of the contract time and not inconsistent with the intent of the contract documents.

**2.9. Uncovering & Correction of Services:** The Firm shall promptly correct all services found by the Owner as defective or as failing to conform to the contract documents. The Firm shall bear all costs of correcting such rejected services, including the cost of the Owner's additional services thereby made necessary. The Owner shall give such notice promptly after discover of condition. All such defective or non-conforming services under the above paragraphs shall be removed from the site where necessary and the services shall be corrected to comply with the contract documents without cost to the Owner.

**2.10. Acceptance Not Waiver:** The Owner's acceptance or approval of any services furnished hereunder shall not in any way relieve the proposer of their present responsibility to maintain the high quality, integrity and timeliness of his services. The Owner's approval or acceptance of, or payment for, any services shall not be construed as a future waiver of any rights under this Contract, or of any cause of action arising out of performance under this Contract.

**2.11. Change Order/Amendment:** No oral statement of any person shall modify or otherwise change, or affect the terms, conditions or specifications stated in the resulting contract. All amendments to the contract shall be made in writing by the Owner.

**2.12. Assignment:** The Offeror shall not sell, assign, transfer or convey any contract resulting from this RFP, in whole or in part, without the prior written approval from the Owner.

**2.13. Compliance with Laws:** Proposals must comply with all Federal, State, County and local laws governing or covering this type of service and the fulfillment of all ADA (Americans with Disabilities Act) requirements. Firm hereby warrants that it is qualified to assume the responsibilities and render the services described herein and has all requisite corporate authority and professional licenses in good standing, required by law.

**2.14. Debarment/Suspension:** The Firm herby certifies that the Firm is not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Governmental department or agency.

**2.15. Confidentiality:** All information disclosed by the Owner to the Offeror for the purpose of the services to be done or information that comes to the attention of the Offeror during the course of performing such services is to be kept strictly confidential.

**2.16. Conflict of Interest:** No public official and/or Owner employee shall have interest in any contract resulting from this RFP.

**2.17. Contract:** This Request for Proposal, submitted documents, and any negotiations, when properly accepted by the Owner, shall constitute a contract equally binding between the Owner and Offeror. The contract represents the entire and integrated agreement between the parties hereto and supersedes all prior negotiations, representations, or agreements, either written or oral, including the Proposal documents. The contract may be amended or modified with Change Orders, Field Orders, or Amendment.

**2.18. Project Manager/Administrator:** The Project Manager, on behalf of the Owner, shall render decisions in a timely manner pertaining to the services proposed or performed by the Offeror. The Project Manager shall be responsible for approval and/or acceptance of any related performance of the Scope of Services.

**2.19. Contract Termination**: This contract shall remain in effect until any of the following occurs: (1) contract expires; (2) completion of services; (3) acceptance of services or, (4) for convenience terminated by either party with a written *Notice of Cancellation* stating therein the reasons for such cancellation and the effective date of cancellation at least thirty days past notification.

**2.20. Employment Discrimination:** During the performance of any services per agreement with the Owner, the Offeror, by submitting a Proposal, agrees to the following conditions:

2.20.1. The Offeror shall not discriminate against any employee or applicant for employment because of race, religion, color, sex, age, disability, citizenship status, marital status, veteran status, sexual orientation, national origin, or any legally protected status except when such condition is a legitimate occupational qualification reasonably necessary for the normal operations of the Offeror. The Offeror agrees to post in conspicuous places, visible to employees and applicants for employment, notices setting forth the provisions of this nondiscrimination clause.

2.20.2. The Offeror, in all solicitations or advertisements for employees placed by or on behalf of the Offeror, shall state that such Offeror is an Equal Opportunity Employer.

2.20.3. Notices, advertisements, and solicitations placed in accordance with federal law, rule, or regulation shall be deemed sufficient for the purpose of meeting the requirements of this section.

**2.21. Immigration Reform and Control Act of 1986 and Immigration Compliance:** The Offeror certifies that it does not and will not during the performance of the contract employ illegal alien services or otherwise violate the provisions of the Federal Immigration Reform and Control Act of 1986 and/or the immigration compliance requirements of State of Colorado C.R.S. § 8-17.5-101, *et.seq.* (House Bill 06-1343).

**2.22. Ethics:** The Offeror shall not accept or offer gifts or anything of value nor enter into any business arrangement with any employee, official, or agent of the Owner.

**2.23. Failure to Deliver:** In the event of failure of the Offeror to deliver services in accordance with the contract terms and conditions, the Owner, after due oral or written notice, may procure the services from other sources and hold the Offeror responsible for any costs resulting in additional purchase and administrative services. This remedy shall be in addition to any other remedies that the Owner may have.

**2.24. Failure to Enforce:** Failure by the Owner at any time to enforce the provisions of the contract shall not be construed as a waiver of any such provisions. Such failure to enforce shall not affect the validity of the contract or any part thereof or the right of the Owner to enforce any provision at any time in accordance with its terms.

**2.25. Force Majeure:** The Offeror shall not be held responsible for failure to perform the duties and responsibilities imposed by the contract due to legal strikes, fires, riots, rebellions, and acts of God beyond the control of the Offeror, unless otherwise specified in the contract.

**2.26. Indemnification:** Offeror shall defend, indemnify and save harmless the Owner and all its officers, employees, insurers, and self-insurance pool, from and against all liability, suits, actions, or other claims of any character, name and description brought for or on account of any injuries or damages received or sustained by any person, persons, or property on account of any negligent act or fault of the Offeror, or of any Offeror's agent, employee, sub-contractor or supplier in the execution of, or performance under, any contract which may result from proposal award. Offeror shall pay any judgment with cost which may be obtained against the Owner growing out of such injury or damages.

**2.27. Independent Firm:** The Offeror shall be legally considered an Independent Firm and neither the Firm nor its employees shall, under any circumstances, be considered servants or agents of the Owner. The Owner shall be at no time legally responsible for any negligence or other wrongdoing by the Firm, its servants, or agents. The Owner shall not withhold from the contract payments to the Firm any federal or state unemployment taxes, federal or state income taxes, Social Security Tax or any other amounts for benefits to the Firm. Further, the Owner shall not provide to the Firm any insurance coverage or other benefits, including Workers' Compensation, normally provided by the Owner for its employees.

**2.28. Nonconforming Terms and Conditions:** A proposal that includes terms and conditions that do not conform to the terms and conditions of this Request for Proposal is subject to rejection as non-responsive. The Owner reserves the right to permit the Offeror to withdraw nonconforming terms and conditions from its proposal prior to a determination by the Owner of non-responsiveness based on the submission of nonconforming terms and conditions.

**2.29. Ownership:** All plans, prints, designs, concepts, etc., shall become the property of the Owner.

**2.30. Oral Statements:** No oral statement of any person shall modify or otherwise affect the terms, conditions, or specifications stated in this document and/or resulting agreement. All modifications to this request and any agreement must be made in writing by the Owner.

**2.31. Patents/Copyrights:** The Offeror agrees to protect the Owner from any claims involving infringements of patents and/or copyrights. In no event shall the Owner be liable to the Offeror for any/all suits arising on the grounds of patent(s)/copyright(s) infringement. Patent/copyright infringement shall null and void any agreement resulting from response to this RFP.

**2.32. Venue**: Any agreement as a result of responding to this RFP shall be deemed to have been made in, and shall be construed and interpreted in accordance with, the laws of the City of Grand Junction, Mesa County, Colorado.

**2.33. Expenses:** Expenses incurred in preparation, submission and presentation of this RFP are the responsibility of the company and can not be charged to the Owner.

**2.34. Sovereign Immunity:** The Owner specifically reserves its right to sovereign immunity pursuant to Colorado State Law as a defense to any action arising in conjunction to this agreement.

**2.35. Public Funds/Non-Appropriation of Funds:** Funds for payment have been provided through the Owner's budget approved by the City Council/Board of County Commissioners for the stated fiscal year only. State of Colorado statutes prohibit the obligation and expenditure of public funds beyond the fiscal year for which a budget has been approved. Therefore, anticipated orders or other obligations that may arise past the end of the stated Owner's fiscal year shall be subject to budget approval. Any contract will be subject to and must contain a governmental non-appropriation of funds clause.

**2.36. Collusion Clause:** Each Offeror by submitting a proposal certifies that it is not party to any collusive action or any action that may be in violation of the Sherman Antitrust Act. Any and all proposals shall be rejected if there is evidence or reason for believing that collusion exists among the proposers. The Owner may or may not, at the discretion of the Owner Purchasing Representative, accept future proposals for the same service or commodities for participants in such collusion.

**2.37. Gratuities:** The Firm certifies and agrees that no gratuities or kickbacks were paid in connection with this contract, nor were any fees, commissions, gifts or other considerations made contingent upon the award of this contract. If the Firm breaches or violates this warranty, the Owner may, at their discretion, terminate this contract without liability to the Owner.

**2.38. Performance of the Contract:** The Owner reserves the right to enforce the performance of the contract in any manner prescribed by law or deemed to be in the best interest of the Owner in the event of breach or default of resulting contract award.

**2.39. Benefit Claims:** The Owner shall not provide to the Offeror any insurance coverage or other benefits, including Worker's Compensation, normally provided by the Owner for its employees.

**2.40. Default:** The Owner reserves the right to terminate the contract in the event the Firm fails to meet delivery or completion schedules, or otherwise perform in accordance with the accepted proposal. Breach of contract or default authorizes the Owner to purchase like services elsewhere and charge the full increase in cost to the defaulting Offeror.

**2.41. Multiple Offers:** If said proposer chooses to submit more than one offer, THE ALTERNATE OFFER must be clearly marked "Alternate Proposal". The Owner reserves the right to make award in the best interest of the Owner.

**2.42. Cooperative Purchasing:** Purchases as a result of this solicitation are primarily for the Owner. Other governmental entities may be extended the opportunity to utilize the resultant contract award with the agreement of the successful provider and the participating agencies. All participating entities will be required to abide by the specifications, terms, conditions and pricings established in this Proposal. The quantities furnished in this proposal document are for only the Owner. It does not include quantities for any other jurisdiction. The Owner will be responsible only for the award for our jurisdiction. Other participating entities will place their own awards on their respective Purchase Orders through their purchasing office or use their purchasing card for purchase/payment as authorized or agreed upon between the provider and the individual entity. The Owner accepts no liability for payment of orders placed by other participating jurisdictions that choose to piggy-back on our solicitation. Orders placed by participating jurisdictions under the terms of this solicitation will indicate their specific delivery and invoicing instructions.

**2.43. Definitions:**

2.43.1. "Offeror" and/or "Proposer" refers to the person or persons legally authorized by the Consultant to make an offer and/or submit a response (fee) proposal in response to the Owner's RFP.

2.43.2. The term "Services" includes all labor, materials, equipment, and/or services necessary to produce the requirements of the Contract Documents.

2.43.3. "Firm" is the person, organization, firm or consultant identified as such in the Agreement and is referred to throughout the Contract Documents. The term Firm means the Firm or his authorized representative. The Firm shall carefully study and compare the General Contract Conditions of the Contract, Specification and Drawings, Scope of Services, Addenda and Modifications and shall at once report to the Owner any error, inconsistency or omission he may discover. Firm shall not be liable to the Owner for any damage resulting from such errors, inconsistencies or omissions. The Firm shall not commence services without clarifying Drawings, Specifications, or Interpretations.

2.43.4. "Sub-Contractor is a person or organization who has a direct contract with the Firm to perform any of the services at the site. The term Sub-Contractor is referred to throughout the contract documents and means a Sub-Contractor or his authorized representative.

**2.44. Public Disclosure Record:** If the Proposer has knowledge of their employee(s) or sub-proposers having an immediate family relationship with an Owner employee or elected official, the proposer must provide the Purchasing Representative with the name(s) of these individuals. These individuals are required to file an acceptable "Public Disclosure Record", a statement of financial interest, before conducting business with the Owner.

## SECTION 3.0: INSURANCE REQUIREMENTS

**3.1** Insurance Requirements: The selected Firm agrees to procure and maintain, at its own cost, policy(s) of insurance sufficient to insure against all liability, claims, demands, and other obligations assumed by the Firm pursuant to this Section. Such insurance shall be in addition to any other insurance requirements imposed by this Contract or by law. The Firm shall not be relieved of any liability, claims, demands, or other obligations assumed pursuant to this Section by reason of its failure to procure or maintain insurance in sufficient amounts, durations, or types.

Firm shall procure and maintain and, if applicable, shall cause any Sub-Contractor of the Firm to procure and maintain insurance coverage listed below. Such coverage shall be procured and maintained with forms and insurers acceptable to The Owner. All coverage shall be continuously maintained to cover all liability, claims, demands, and other obligations assumed by the Firm pursuant to this Section. In the case of any claims-made policy, the necessary retroactive dates and extended reporting periods shall be procured to maintain such continuous coverage. Minimum coverage limits shall be as indicated below unless specified otherwise in the Special Conditions:

(a) Worker Compensation: Firm shall comply with all State of Colorado Regulations concerning Workers' Compensation insurance coverage.

(b) General Liability insurance with minimum combined single limits of:

ONE MILLION DOLLARS ($1,000,000) each occurrence and
ONE MILLION DOLLARS ($1,000,000) per job aggregate.

The policy shall be applicable to all premises, products and completed operations. The policy shall include coverage for bodily injury, broad form property damage (including completed operations), personal injury (including coverage for contractual and employee acts), blanket contractual, products, and completed operations. The policy shall include coverage for explosion, collapse, and underground (XCU) hazards. The policy shall contain a severability of interests provision.

(c) Comprehensive Automobile Liability insurance with minimum combined single limits for bodily injury and property damage of not less than:

ONE MILLION DOLLARS ($1,000,000) each occurrence and
ONE MILLION DOLLARS ($1,000,000) aggregate

(d) Professional Liability & Errors and Omissions Insurance policy with a minimum of:

ONE MILLION DOLLARS ($1,000,000) per claim

This policy shall provide coverage to protect the Firm against liability incurred as a result of the professional services performed as a result of responding to this Solicitation.

With respect to each of Consultant's owned, hired, or non-owned vehicles assigned to be used in performance of the Services. The policy shall contain a severability of interests provision.

**3.2** Additional Insured Endorsement: The policies required by paragraphs (b), and (c) above shall be endorsed to include the Owner and the Owner's officers and employees as additional insureds. Every policy required above shall be primary insurance, and any insurance carried by the Owner, its officers, or its employees, or carried by or provided through any insurance pool of the Owner, shall be excess and not contributory insurance to that provided by Firm. The Firm shall be solely responsible for any deductible losses under any policy required above.

## SECTION 4.0: SPECIFICATIONS/SCOPE OF SERVICES

**4.1. General/Background:** The City of Grand Junction owns and operates Hogchute Dam Reservoir (aka: Carson Lake), DAMID 420127. Hogchute Dam is located in Mesa County, Colorado within the Grand Mesa National Forest on Kannah Creek. The reservoir was approved for construction in May of 1947 by the State Engineer with construction of the dam being completed in November 1947.

The elevation of the reservoir site is approximately 9,800 feet AMSL. The structural height of the dam is 56-ft with a normal storage capacity of 637 acre-feet of water behind an earthen embankment situated across the natural drainage path of Kannah Creek. The reservoir provides water storage for domestic use, downstream irrigation use, and for fishing recreation.

The Hogchute Reservoir Dam is classified as a high hazard jurisdictional dam as defined by Colorado Dam Safety of the Division of Water Resources. A high hazard rating was given to Hogchute in the year 2015 as a result of completion of an inundation mapping study that took into account new residential development downstream of the reservoir. Currently, the dam is rated as “Conditionally Satisfactory”. As a result, all work performed on the dam is subject to review and approval by the State Dam Safety Engineer. The dam has a concrete emergency spillway structure (poor condition) located on the north side of the embankment (right end of dam) that discharges into an earth-lined open channel. Water is supplied to Carson Reservoir from the upper reaches of the Kannah Creek drainage basin which is estimated at 7,300 acres, as well as, a natural spring with average inflows of 1.8 cfs.

Hogchute Reservoir is typically at full capacity by June 1st in a normal precipitation year with snow melt and the natural spring providing the inflows. The reservoir is usually drained to about 300 – 400 ac-ft during the winter months to accommodate the inflows from snow melt and the natural spring inflows. Currently, the reservoir has no SEO imposed storage level restrictions and is classified as “Conditional Full Storage”. However, the dam is being operated with City imposed level restrictions until the hydrology study and dam rehabilitation process is complete.

In 2017 the SEO performed a Comprehensive Dam Safety Evaluation (CDSE) to assess the overall safety of the dam and provide the City with guidance in planning needed dam improvements. The report provides potential failure modes (PFM) that this structure could develop or has developed.

In 2018, RJH Consultants completed a “Dam Safety Evaluation Report”, dated January 2019. The overall objectives of the work were to investigate and address the SEO’s concerns about the safety of the dam, and identify if additional PFM’s exist and to provide a basis for the future dam rehabilitation design. The scope included identification of PFMs to be addressed (1) immediately, (2) long term, and (3) review completeness of PFMs. To accomplish these objectives, the following tasks were completed; (Task 1) Preliminary Hydrology Study, and (Task 2) Seepage & Geotechnical investigations. The results of the safety evaluation will serve as the basis for scoping dam rehabilitation work in this RFP.

**Historic Design Specifications:** Based on the 1947 construction drawings, which are included within, the reservoir's outlet works is controlled by two 20" hydraulically operated gate valves. The two gate valves in operation today are believed to be the original valves and are fully operational. However, it is currently unknown if the valves provide a water tight seal when in the closed position. Each valve is attached to a 20" I.D. welded steel pipe within the trash-rack structure with 2" air vent pipes at each valve. Both 20" steel pipes join together into one 30" I.D. welded steel outlet pipe about 18-ft downstream of the valves. The outlet flow capacity is rated at 134 cfs.

The 1947 construction drawings also show a 12" emergency gate valve that is located between the two 20" gate valves. Currently, the City doesn't know if this 12" gate valve is still in-place or if it has been removed and plated off. In the valve control house, there is no hydraulic devices or equipment that would suggest this 12" gate valve exists.

The current valve control house is located on the crest of the dam. The dam crest is not the original location for the valve control house. The original valve control house was located at the outfall structure on the downstream side of the dam. The foundation of the old valve control house is still there today. The valve control house was relocated to the dam crest and new hydraulic piping installed to the gate valves in 1988. The RJH investigation and study confirms the old piping from the original valve control house is contributing to seepage through the dam embankment. Specifically, it appears to be a ¾ inch pipe that's assumed to be part of the old "reservoir level gauge piping" installed along the top of the outlet pipe within the concrete encasement that was part of the old valve control house.

**Present RFP Purpose:** The City of Grand Junction, in cooperation with the Colorado Dam Safety SEO, is seeking to verify the preliminary Hydrology Study (Dam Safety Report, Hogchute Dam – Jan. 2019) and create a final Hydrology Report based on the latest updates to "Dam Safety Rules (2CCR-402-1)". Once the Hydrology report has been updated, a complete revised design of the spillway and outlet works is desired. The following task elements are:

1) Review the Preliminary Hydrology Report – Hogchute Dam Safety Evaluation Project (January 2019) and update spillway requirements per Dam Safety Rules (2CCR-402-1) and complete a "Final" Hydrology Report.

2) Completion of demolition, design and construction drawings for the following:
   a. Demolition of valve control house on dam crest
   b. Demolition of existing trash rack structure, outlet valves, and dual 20-inch steel pipes
   c. Removal of existing downstream concrete outlet structure
   d. Demolition of the existing concrete spillway section
   e. Design new upstream trash rack, outlet works, valving, air vents, and piping
   f. Design new spillway per results of final hydrology report
   g. Design new downstream outlet structure
   h. Design new upstream staff gauge
   i. Cured-in-Place Piping (CIPP) for the 30" I.D. steel outlet pipe (Approx. 300-ft of pipe)

j. Design of new downstream toe-drain seepage collection system
k. Instrumentation: reservoir level data collection system
l. Stormwater Management Plan
m. Reclamation Work Plan

3) Complete design requirements in support of the following desired changes:
   a. The City desires to change the configuration of the outlet piping on the upstream side of the dam by removing the two 20” hydraulically operated gate valves and the dual 20” pipes, and replacing this dual pipe configuration with one 30” I.D. steel pipe and install a new 30” diameter manually operated slide-gate style outlet valve with a new trash-rack structure.
   b. Improvements to the downstream outlet works to reduce the potential for embankment erosion and to include the toe-drain discharge pipes for seepage monitoring and discharge measurements.
   c. Design properly sized spillway structure to prevent overtopping of the dam crest during the Inflow Design Flood (IDF).
   d. Design downstream embankment toe-drain system to include sand filter collection system to address embankment seepage, high foundation pressures and concentrated leak erosion along the outlet conduit.
   e. Install infrastructure and data collection instrument(s) for measuring the reservoir’s water surface level. (City to discuss in more depth with Consultant what are the best instrumentation options are for measuring reservoir water levels and downloading the data)
   f. Complete environmental wetland delineation study and report around the dam embankment to be submitted to the U.S. Army Corps of Engineers for a Nationwide Permit.

As a result, the City of Grand Junction is requesting proposals from qualified applicants to complete design, specifications, and permitting requirements for construction in summer/fall of 2020.

## 4.2. Special Conditions/Provisions:

**4.2.1 Price/Fees:** Project pricing shall be all inclusive, to include, but not be limited to: labor, materials, equipment, travel, design, drawings, engineering work, shipping/freight, licenses, permits, fees, etc.

Provide a <u>not to exceed</u> cost using Solicitation Response Form found in Section 7, accompanied by a complete list of costs breakdown.

All fees will be considered by the Owner to be <u>negotiable.</u>

**4.2.2 Codes:** All designs shall be in accordance with applicable State and Federal regulations, accepted standard practices, and the State of Colorado’s Rules and Regulations for Dam Safety and Dam Construction (latest version).

In the fall of 2017, the City of Grand Junction completed a comprehensive site survey of the dam, spillway, and outlet structures. This survey data, along with the control points, will be available to the Consultant. Additional survey requirements will be provided upon request to the City. Requests for additional survey data to be collected from the project area shall be received by the end of September, 2019.

Consultant is responsible for identifying, contacting and acquiring all necessary U.S. Army Corps, U.S. Forest Service, and State Engineer's Office permits as determined for the scope of dam improvements.

Consultant is responsible for any and all wetlands boundary survey reports necessary for the U.S. Army Corp Wetlands delineation mapping.

### 4.3. Specifications/Scope of Services:

**Consultant Responsibilities:** The scope of work shall include the following:

- **<u>Task 1 – Hydrology Study Evaluation:</u>**

  A. Perform a final hydrology study using the Colorado/New Mexico REPS tool to determine the probable maximum flood (PMF) and evaluate the adequacy of the existing spillway structure and determine if the reservoir's spillway needs to be enlarged. With the dam recently reclassified to a High Hazard structure, the spillway needs to be evaluated to verify it has the required capacity for passing the IDF.

    - As a starting point, use the preliminary Hydrology report included from the Dam Safety Evaluation Report, Hogchute Dam (RJH Consultant's, Jan. 2019)
    - Utilize the newest revision to the Dam Safety Rules (2CCR-402-1)

  B. Prepare a final hydrologic report for Hogchute Dam.

- **<u>Task 2 – Complete design requirements for the following:</u>**

  a. Demolition:

    i. Valve control house on dam crest

    ii. Existing outlet trash rack structure, 20" outlet valves, air vent piping, hydraulic piping, and the 20" dual outlet pipes

    iii. Downstream outlet structure

    iv. Concrete spillway structure

    v. Existing staff gauge

  b. New Construction:

    i. Design new spillway per results of final hydrology report.

    ii. Design new upstream trash rack, outlet works, valving, air vents, and piping.

    iii. Design new downstream outlet structure.

iv. Design new upstream staff gauge.

v. Cured-in-Place Pipe (CIPP) for the 30" I.D. steel outlet pipe (Approx. 300-ft of pipe).

vi. Design new downstream embankment toe-drain seepage collection system and address the existing ¾" pipe conduit that is currently conveying water through the dam embankment.

c. New Instrumentation:

i. Reservoir water surface level monitoring equipment. The Consultant shall work closely with the City on what will be the best system for the City to use in order to download weekly/monthly reservoir level measurements from a pressure transducer or similar device.

d. Provide budgetary construction cost estimates at the 30% and 90% complete stages.

**Task Three: Construction Phase Services**

**Bidding Phase:** After Completion of the plans, the City will bid the project out, however the consultant shall be available for technical questions and provide to the City appropriate addenda. Consultant shall participate in the pre-bid meeting (if required), however presence at the bid opening is not required.

**Construction Phase:** Firm shall provide construction support and inspection services in 2020 for the construction phase of the project.

- **Proposed Schedule:**

1. Hogchute (Carson) Reservoir expected to be at or near full-restricted capacity – June, 2019.
2. May 17th, City advertises a RFP for Consultant selection to design and produce a construction package with plans and specifications that will address the design improvements necessary for a high hazard dam. Detailed 90% construction plans and specifications completed by January 31, 2020.
3. Project kick-off meeting July 17, 2019 with Consultant, City and SEO. This meeting to be held in Grand Junction.
4. Consultant starts review and update of Hydrology Report – Hogchute Dam Safety Evaluation Project – July 15, 2019.
5. Carson Reservoir (Hogchute Dam) snow free in summer 2019 if further examination and surveying are required (July-Oct 2019).
6. Consultant submits Task 1, Final Hydrology Report to the City on August 16, 2019. The City will share the Hydrology Report with the SEO.

7. Consultant schedules meeting in late August/early September with the SEO and the City to discuss the Final Hydrology Report prior to start of spillway design work.  This meeting to be held in Grand Junction.
8. Consultant submits 30% Task 2 construction package to City on September 30, 2019 for review.  The City will share the 30% plans with the SEO.
9. In October 2019, with 30% construction plans complete, the City advertises a mandatory on-site pre-bid meeting with Firm's who are interested in submitting a bid to construct the Hogchute Dam improvements. <u>Only Firms in attendance will be allowed to submit bids on the final construction package in Spring 2020.  The City's Consultant is required to attend this on-site pre-bid meeting to help answer Firm's questions.</u>
10. Consultant submits 90% complete Task 2 construction package with construction plans, specifications, permits and summary report to the City on January 31, 2020.  The City will share the 90% construction package with the SEO.
11. Consultant schedules a mid-February 2020 meeting with the SEO and the City to review and discuss the 90% complete construction package, specifications and permitting status.  This meeting to be held in Grand Junction.
12. Consultant submits 100% complete construction package to City on March 31, 2020.
13. In April, 2020, the City advertises for construction bids.
14. Construction of improvements to Hogchute Dam begins in June, 2020.

**4.4. Site Visit/Briefing:** A site visit is not scheduled for this Request for Proposal due to the access road being closed because of snow.

**4.5. <u>Attached Documents:</u>**

1. Hogchute (Carson Lake) Reservoir Vicinity Map
2. State Dam Safety Engineer's Inspection Report – September, 2018 (Most recent inspection report)
3. 1947 Construction Plans (Colo. Dam Safety Drawing C-454)
4. State of Colorado, Comprehensive Dam Safety Evaluation Report (2018)
5. Dam Safety Evaluation Report, Hogchute Dam (RJH Consultant's, Jan. 2019)
6. Preliminary Hydrology Study & Spillway Evaluation, Jan 2019, Appendix C
7. Geotechnical Data Report, Jan 2019, Appendix D
8. Seepage Investigation Daily Field Reports (Daily Site Reports, Permeability Results & Laboratory Testing Results), Jan 2019, Appendix E

**4.6. RFP Tentative Time Schedule:**

| | |
|---|---|
| • Request for Proposal available: | May 17, 2019 |
| • Inquiry deadline, no questions after this date: | May 31, 2019 |
| • Addendum Posted: | June 7, 2019 |
| • Submittal deadline for proposals: | June 14, 2019 |

- Owner evaluation of proposals: June 17-21, 2019
- Interviews (if required) June 27, 2019
- Final selection: June 28, 2019
- Contract execution: July 8, 2019
- Work begins no later than: July 15, 2019

**4.7. Questions Regarding Scope of Services:**

Duane Hoff Jr., Senior Buyer
duaneh@gjcity.org

## SECTION 5.0: PREPARATION AND SUBMITTAL OF PROPOSALS

**Submission:** ***Each proposal shall be submitted in electronic format only, and only through the Rocky Mountain E-Purchasing website (https://www.rockymountainbidsystem.com/default.asp).*** *This site offers both "free" and "paying" registration options that allow for full access of the Owner's documents and for electronic submission of proposals.* *(Note: "free" registration may take up to 24 hours to process. Please Plan accordingly.)* Please view our "**Electronic Vendor Registration Guide"** at http://www.gjcity.org/BidOpenings.aspx for details. (Purchasing Representative does not have access or control of the vendor side of RMEPS. If website or other problems arise during response submission, vendor **MUST** contact RMEPS to resolve issue prior to the response deadline **800-835-4603**). For proper comparison and evaluation, the City requests that proposals be formatted as directed in Section 5.0 "Preparation and Submittal of Proposals." Offerors are required to indicate their interest in this Project, show their specific experience and address their capability to perform the Scope of Services in the Time Schedule as set forth herein. For proper comparison and evaluation, the Owner requires that proposals be formatted **A** to **F**:

**A.** **Cover Letter:** Cover letter shall be provided which explains the Firm's interest in the project. The letter shall contain the name/address/phone number/email of the person who will serve as the firm's principal contact person with Owner's Contract Administrator and shall identify individual(s) who will be authorized to make presentations on behalf of the firm. The statement shall bear the signature of the person having proper authority to make formal commitments on behalf of the firm. By submitting a response to this solicitation the Firm agrees to all requirements herein.

**B.** **Qualifications/Experience/Credentials:** Proposers shall provide their qualifications for consideration as a contract provider to the City of Grand Junction and include prior experience in similar projects.

**C.** **Strategy and Implementation Plan:** Describe your (the firm's) interpretation of the Owner's objectives with regard to this RFP. Describe the proposed strategy and/or plan for achieving the objectives of this RFP. The Firm may utilize a written narrative or any other printed technique to demonstrate their ability to satisfy the Scope of Services. The narrative should describe a logical progression of tasks and efforts starting with the initial steps or tasks to be accomplished and continuing until all proposed tasks are fully described and the RFP objectives are accomplished. Include a **time schedule** for completion of your firm's implementation plan and an estimate of time commitments from Owner staff.

**D.** **References:** A minimum of three (3) **references** with name, address, telephone number, and email address that can attest to your experience in projects of similar scope and size.

**E.** **Fee Proposal:** Provide a not to exceed cost using Solicitation Response Form found in Section 7, accompanied by a complete list of costs breakdown.

**F.** **Additional Data (optional):** Provide any additional information that will aid in evaluation of your qualifications with respect to this project.

## SECTION 6.0: EVALUATION CRITERIA AND FACTORS

**6.1 Evaluation:** An evaluation team shall review all responses and select the proposal or proposals that best demonstrate the capability in all aspects to perform the scope of services and possess the integrity and reliability that will ensure good faith performance.

**6.2 Intent:** Only respondents who meet the qualification criteria will be considered. Therefore, it is imperative that the submitted proposal clearly indicate the firm's ability to provide the services described herein.

Submittal evaluations will be done in accordance with the criteria and procedure defined herein. The Owner reserves the right to reject any and all portions of proposals and take into consideration past performance. The following parameters will be used to evaluate the submittals (in no particular order of priority):

- Responsiveness of submittal to the RFP
- Understanding of the project and the objectives
- Experience/Demonstrated capability
- Necessary resources
- Strategy & Implementation Plan
- References
- Fees

Owner also reserves the right to take into consideration past performance of previous awards/contracts with the Owner of any vendor, Firm, supplier, or service provider in determining final award(s).

The Owner will undertake negotiations with the top rated firm and will not negotiate with lower rated firms unless negotiations with higher rated firms have been unsuccessful and terminated.

**6.3 Oral Interviews:** Interviews are not anticipated for this solicitation process. However, the Owner reserves the right to invite the most qualified rated proposer(s) to participate in oral interviews, if needed.

**6.4 Award:** Firms shall be ranked or disqualified based on the criteria listed in Section 6.2. The Owner reserves the right to consider all of the information submitted and/or oral presentations, if required, in selecting the project Firm.

## SECTION 7.0: SOLICITATION RESPONSE FORM

**RFP-4650-19-DH Design Services for Improvements to Hogchute Reservoir Dam, Spillway, and Outlet Works**

*Offeror must submit entire Form completed, dated and signed*.

1) **Not to exceed cost to provide design services for the Design Services for Improvements to Hogchute Reservoir Dam, Spillway, and Outlet Works for labor, materials, equipment, travel, design, drawings, engineering work, shipping/freight, licenses, permits, fees, etc. per specifications:**

**NOT TO EXCEED COST** $____________________

**WRITTEN:______________________________________________________________dollars.**

-----------------------------------------------------------------------------------------------------------
*The Owner reserves the right to accept any portion of the services to be performed at its discretion*
-----------------------------------------------------------------------------------------------------------

The undersigned has thoroughly examined the entire Request for Proposals and therefore submits the proposal and schedule of fees and services attached hereto.

This offer is firm and irrevocable for sixty (60) days after the time and date set for receipt of proposals.

The undersigned Offeror agrees to provide services and products in accordance with the terms and conditions contained in this Request for Proposal and as described in the Offeror's proposal attached hereto; as accepted by the Owner.

Prices in the proposal have not knowingly been disclosed with another provider and will not be prior to award.

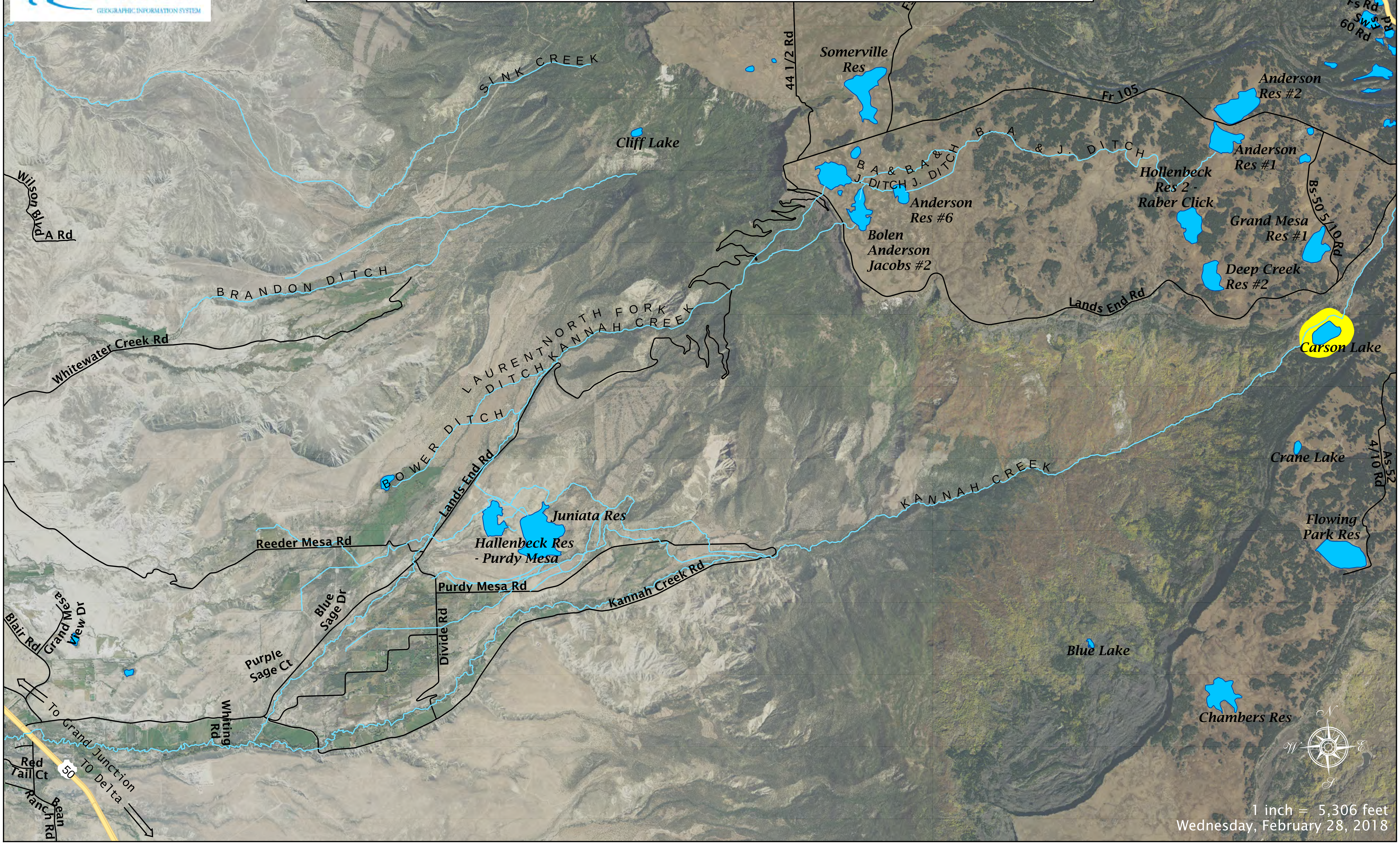
- Prices in this proposal have been arrived at independently, without consultation, communication or agreement for the purpose of restricting competition.
- No attempt has been made nor will be to induce any other person or firm to submit a proposal for the purpose of restricting competition.
- The individual signing this proposal certifies they are a legal agent of the offeror, authorized to represent the offeror and is legally responsible for the offer with regard to supporting documentation and prices provided.
- Direct purchases by the City of Grand Junction are tax exempt from Colorado Sales or Use Tax. Tax exempt No. 98-903544. The undersigned certifies that no Federal, State, County or Municipal tax will be added to the above quoted prices.
- City of Grand Junction payment terms shall be Net 30 days.
- Prompt payment discount of ________ percent of the net dollar will be offered to the Owner if the invoice is paid within ___________ days after the receipt of the invoice.

RECEIPT OF ADDENDA: the undersigned Firm acknowledges receipt of Addenda to the Solicitation, Specifications, and other Contract Documents. State number of Addenda received: ___________

It is the responsibility of the Proposer to ensure all Addenda have been received and acknowledged.

| | |
|---|---|
| ______________________________<br>Company Name – (Typed or Printed) | ______________________________<br>Authorized Agent – (Typed or Printed) |
| ______________________________<br>Authorized Agent Signature | ______________________________<br>Phone Number |
| ______________________________<br>Address of Offeror | ______________________________<br>E-mail Address of Agent |
| ______________________________<br>City, State, and Zip Code | ______________________________<br>Date |

# Hogchute Reservoir (aka Carson Lake) - Vicinity Map



# ENGINEER'S INSPECTION REPORT

INSPECTOR: JAB

OFFICE OF THE STATE ENGINEER - DIVISION OF WATER RESOURCES - DAM SAFETY BRANCH — 1313 SHERMAN STREET, ROOM 818, DENVER, CO 80203, (303) 866-3581

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| DAM NAME: | HOGCHUTE | T: 120S R: 0960W S: 22 | | COUNTY: | MESA | DATE OF INSPECTION: | 9/5/2018 |
| DAM ID: | 420127 YRCompl: 1947 | DAM HEIGHT(FT): | 53.0 | SPILLWAY WIDTH(FT): | 140.0 | PREVIOUS INSPECTION: | 10/23/2017 |
| CLASS: | High hazard | DAM LENGTH(FT): | 620.0 | SPILLWAY CAPACITY(CFS): | 2400.0 | NORMAL STORAGE (AF): | 637.0 |
| DIV: | 4 WD: 42 | CRESTWIDTH(FT): | 18.0 | FREEBOARD (FT): | 7.0 | SURFACE AREA(AC): | 35.0 |
| EAP: | 1/31/2015 | CRESTELEV(FT): | 9890.0 | DRAINAGE AREA (AC.): | 6240.0 | OUTLET INSPECTED: | 9/11/2008 |

**CURRENT RESTRICTION:** -- NONE --

| | | | |
|---|---|---|---|
| OWNER: | CITY OF GRAND JUNCTION | OWNER REP.: | LEE COOPER |
| ADDRESS: | 250 N. 5TH STREET | CONTACT NAME: | LEE COOPER |
| | GRAND JUNCTION CO 81501-0000 | CONTACT PHONE: | (970) 256-4155X |

INSPECTION PARTY: Lee Cooper, Slade Connell — Jason Fuller, Jackie Blumberg

REPRESENTING: City of Grand Junction — DWR

**FIELD CONDITIONS OBSERVED**

WATER LEVEL: BELOW DAM CREST ____ FT. Below Spillway ____ FT. GAGE ROD READING ____

GROUND MOISTURE CONDITION: ☐ DRY ☑ WET ☐ SNOWCOVER OTHER just below spill

DIRECTIONS: MARK AN X FOR CONDITIONS FOUND AND UNDERLINE WORDS THAT APPLY

## UPSTREAM SLOPE

**PROBLEMS NOTED:** ☐ (0)NONE ☑ (1)RIPRAP - MISSING, SPARSE, DISPLACED, WEATHERED ☐ (2) WAVE EROSION - WITH SCARPS

☐ (3) CRACKS WITH DISPLACEMENT ☐ (4) SINKHOLE ☐ (5) APPEARS TOO STEEP ☐ (6) DEPRESSIONS OR BULGES ☐ (7) SLIDES

☐ (8) CONCRETE FACING - HOLES, CRACKS, DISPLACED, UNDERMINED ☐ (9) OTHER

(1) Basalt riprap has been displaced by anglers in some areas, exposing the silty clay embankment beneath. No erosion or surface abnormalities were observed. The face exhibits a generally even surface.

CONDITIONS OBSERVED: ☐ Good ☐ Acceptable ☐ Poor

## CREST

**PROBLEMS NOTED:** ☐ (10) NONE ☐ (11) RUTS OR PUDDLES ☐ (12) EROSION ☐ (13) CRACKS - WITH DISPLACEMENT ☐ (14) SINKHOLES

☐ (15) NOT WIDE ENOUGH ☐ (16) LOW AREA ☐ (17) MISALIGNMENT ☑ (18) IMPROPER SURFACE DRAINAGE ☐ (19) OTHER

(18) The cross-slope of the crest appears flat and may not drain toward the reservoir; the area by the outlet operator building appears crowned, so that drainage is conveyed both toward the reservoir and downhill sides.
A good layer of gravels covers the surface, which is uniform along the entire alignment.

CONDITIONS OBSERVED: ☐ Good ☐ Acceptable ☐ Poor

## DOWNSTREAM SLOPE

**PROBLEMS NOTED:** ☐ (20) NONE ☐ (21) LIVESTOCK DAMAGE ☐ (22) EROSION OR GULLIES ☐ (23) CRACKS - WITH DISPLACEMENT ☐ (24) SINKHOLE

☐ (25) APPEARS TOO STEEP ☐ (26) DEPRESSIONS OR BULGES ☐ (27) SLIDE ☐ (28) SOFT AREAS ☑ (29) OTHER grade break

(29) Minor grade break/small bench exists ~1/4 way up the slope from the outlet basin, consistent with 1947 plans.
Boulder sized basalt riprap covers the entire slope, with smaller pieces in the groin and near the toe. Surface is generally even.

CONDITIONS OBSERVED: ☐ Good ☐ Acceptable ☐ Poor

## SEEPAGE

**PROBLEMS NOTED:** ☐ (30) NONE ☐ (31) SATURATED EMBANKMENT AREA ☐ (32) SEEPAGE EXITS ON EMBANKMENT

☐ (33) SEEPAGE EXITS AT POINT SOURCE ☑ (34) SEEPAGE AREA AT TOE ☐ (35) FLOW ADJACENT TO OUTLET ☐ (36) SEEPAGE INCREASED / MUDDY

**DRAIN OUTFALLS SEEN** ☐ No ☐ Yes Show location of drains on sketch and indicate amount and quality of discharge. ☐ (37) FLOW INCREASED / MUDDY ☐ (38) DRAIN DRY / OBSTRUCTED

☐ (39) OTHER

Left toe drain outfall is submerged within the outlet dicharge basin and cannot be measured. Likely the outfall from the 8-inch tile toe drain shown in 1947 plans.

(34) Small plastic pipe drains the seepage area behind the outlet headwall where seepage ponds in the rocks. Typically discharges ~5 gpm. Not field measured.

Two small seepage channels exiting from the willows on the right bank were dry during today's inspection.

Brief Discussion of CDSE Seepage Study:
CDSE investigation work conducted on August 8th and 9th included delicate, deliberate and focused removal of riprap from the toe and around the abandoned hydraulic operator building to confirm the source for seepage was indeed a broken hydraulic line. A geotechnical investigation was initiated July 23rd to characterize the embankment materials and locate the groundwater table. The boreholes were completed as piezometers. The City intends to measure the piezometer levels several times per week during reservoir lowering/subsequent infilling to establish correlation to reservoir levels (including response lag). Toe piezometer installation is scheduled the week of September 17th to explore artesian conditions encountered in crest BH-101 and embankment instability due to foundation uplift PFM.

A combined rating of acceptable and poor is assigned, given current seepage issues but taking in to account progress to date on the CDSE study.

CONDITIONS OBSERVED: ☐ Good ☒ Acceptable ☒ Poor

## OUTLET

**PROBLEMS NOTED:** ☐ (40) NONE ☐ (41) NO OUTLET FOUND ☐ (42) POOR OPERATING ACCESS ☐ (43) INOPERABLE

☐ (44) UPSTREAM OR DOWNSTREAM STRUCTURE DETERIORATED (45) OUTLET OPERATED DURING INSPECTION ☐ YES ☑ NO

**INTERIOR INSPECTED** ☑ (120) NO ☐ (121) YES ☐ (46) CONDUIT DETERIORATED OR COLLAPSED ☐ (47) JOINTS DISPLACED ☑ (48) VALVE LEAKAGE

☐ (49) OTHER

(48) Constant discharge from the outlet is attributable to breaks in the air vents on both gates; discharge rate appears to be increasing over time. 2008 video inspection shows areas where rust has been ground out and coated.

The concrete control building on the crest is deteriorated on the reservoir side, with exposed rebar. However, this does not affect the safety of the dam.
Concrete headwall at outfall is bowed outward and restrained by cables. Rebar is exposed adjacent to and right of the conduit.
Right lower portion of steel appears to be delaminating near outfall.

CDSE Discussion:
A single 4-inch air vent buried in the upstream slope bifurcates into two 2-inch lines to vent the two gates. The control was moved from the small concrete building at the toe to the crest and new hydraulic lines were run to the gates in 1988. No as-builts exist for the work. Water movement is audible and visibly ponding just upstream from the abandoned control house wall. The source investigation performed on August 9th revealed what appeared to be a broken hydraulic line.

The outlet is overdue for inspection. However, inspection may be deferred to 2020 as part of the CDSE study. A combined rating of acceptable and poor is assigned, considering current conditions but taking in to account progress to date on the CDSE study.

CONDITIONS OBSERVED: ☐ Good ☒ Acceptable ☒ Poor

## SPILLWAY

**PROBLEMS NOTED:** ☐ (50) NONE ☐ (51) NO EMERGENCY SPILLWAY FOUND ☐ (52) EROSION WITH BACKCUTTING ☐ (53) CRACK - WITH DISPLACEMENT

☐ (54) APPEARS TO BE STRUCTURALLY INADEQUATE ☐ (55) APPEARS TOO SMALL ☐ (56) INADEQUATE FREEBOARD ☐ (57) FLOW OBSTRUCTED

☑ (58) CONCRETE DETERIORATED / UNDERMINED ☐ (59) OTHER

The crest structure is not level and water enters the spillway beneath the crest through cracks. A hydrology and spillway adequacy study is included in the ongoing and upcoming CDSE work. A combined rating of acceptable and poor is assigned, considering current spillway issues but taking in to account progress to date on the CDSE study.

CONDITIONS OBSERVED: ☐ Good ☒ Acceptable ☒ Poor

## MONITORING

EXISTING INSTRUMENTATION FOUND ☐ (110) NONE ☑ (111) GAGE ROD ☐ (112) PIEZOMETERS ☐ (113) SEEPAGE WEIRS / FLUMES

☐ (114) SURVEY MONUMENTS ☑ (115) OTHER outlet basin drain outfall & discharge flume

MONITORING OF INSTRUMENTATION ☐ (116) NO ☑ (117) YES PERIODIC INSPECTIONS BY: ☑ (118) OWNER ☐ (119) ENGINEER

The seepage drain, discharge flume and reservoir levels are monitored with regularity, but not reported. We discussed monitoring the piezometers that will be placed the week starting July 23 (as part of the geotechnical investigation program) in addition to toe piezometers placed the week of September 17. Monitoring should occur monthly when reservoir levels are static, with measurement frequency increasing to once or twice per week during lowering (and subsequent infilling) next year.

A combined rating of acceptable and poor is assigned, given the current lack of monitoring data but taking in to account our discussion of enhanced monitoring as part of the CDSE study.

CONDITIONS OBSERVED: ☐ Good ☒ Acceptable ☒ Poor

## MAINTENANCE AND REPAIRS

**PROBLEMS NOTED:** ☐ (60 NONE ☐ (61) ACCESS ROAD NEEDS MAINTENANCE ☐ (62) LIVESTOCK DAMAGE

☑ (63) BRUSH ON UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, TOE ☐ (64) TREES ON UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, TOE

☐ (65) RODENT ACTIVITY ON UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, TOE ☑ (66) DETERIORATED CONCRETE - FACING, OUTLET, SPILLWAY

☑ (67) GATE AND OPERATING MECHANISM NEED MAINTENANCE ☐ (68) OTHER

(63) Keep spillway clear of willows.
(66) Spillway crest concrete is deteriorated, undermined and not level.
(67) A review of previous EIRs and discussion in the field indicate that gate leakage is increasing.

A combined acceptable and poor rating is retained considering current conditions, but understanding the CDSE study is currently underway.

CONDITIONS OBSERVED: ☐ Good ☒ Acceptable ☒ Poor

*Go to next page for Overall Conditions and Items Requiring Actions*

ENGINEER'S INSPECTION REPORT

DAM NAME: HOGCHUTE

DATE.: 9/5/2018

DAM I.D.: 420127

## OVERALL CONDITIONS

Hogchute Dam received acceptable/poor ratings for seepage, outlet, spillway monitoring and maintanence due to existing conditions. A conditional satisfactory rating is assigned, as the City has selected an engineer to conduct a Comprehensive Dam Safety Evaluation study to investigate seepage and outlet issues at the downstream toe and inform a rehabilitation design. The geotechnical phase of the work was initiated on July 23 and will continue September 17th. Riprap removal for inspection along the toe area also revealed a broken hydraulic line and the likely source of seepage around the old operator building. We appreciate the City of Grand Junction conducting this study and thank you for completing the EAP template as part of the investigative drilling phase of the work. We look forward to working with you and your engineer on subsequent phases of the study and ultimate rehabilitation of the dam.

An Emergency Action Plan template was provided to your Engineer on July 17th as part of the requirements for drilling activities to be conducted on the dam for CDSE purposes. Please ensure your Engineer provides an updated copy of the EAP to our offices.

Your dedication to maintaining a safe and functional dam is commendable.

Based on this Safety Inspection and recent file review, the overall condition is determined to be:

☐ (71) SATISFACTORY ☑ (72) CONDITIONALLY SATISFACTORY ☐ (73) UNSATISFACTORY

## ITEMS REQUIRING ACTION BY OWNER TO IMPROVE THE SAFETY OF THE DAM

The State Engineer, by providing this dam safety inspection report, does not assume responsibility for any unsafe condition of the subject dam. The sole responsibility for the safety of this dam rests with the reservoir owner or operator, who should take every step necessary to prevent damages caused by leakage or overflow of waters from the reservoir or floods resulting from a failure of the dam.

**MAINTENANCE - MINOR REPAIR - MONITORING**

- ☐ (80) PROVIDE ADDITIONAL RIPRAP:
- ☑ (81) LUBRICATE AND OPERATE OUTLET GATES THROUGH FULL CYCLE: annually
- ☑ (82) CLEAR TREES AND/OR BRUSH FROM: spillway
- ☐ (83) INITIATE RODENT CONTROL PROGRAM AND PROPERLY BACKFILL EXISTING HOLES:
- ☐ (84) GRADE CREST TO A UNIFORM ELEVATION WITH DRAINAGE TO THE UPSTREAM SLOPE:
- ☐ (85) PROVIDE SURFACE DRAINAGE FOR:
- ☑ (86) MONITOR: submit your available drain and reservoir measurements; monitor piezometers and reservoir levels as discussed for CDSE study
- ☑ (87) DEVELOP AND SUBMIT AN EMERGENCY ACTION PLAN: ensure your Engineer completes template provided July 18; distribute to the appropriate entities
- ☐ (88) OTHER
- ☐ (89) OTHER

**ENGINEERING - EMPLOY AN ENGINEER EXPERIENCED IN DESIGN AND CONSTRUCTION OF DAMS TO:** (Plans and Specifications must be approved by State Engineer prior to construction.)

- ☐ (90) PREPARE PLANS AND SPECIFICATIONS FOR REHABILITATION OF THE DAM:
- ☐ (91) PREPARE AS -BUILT DRAWINGS OF:
- ☐ (92) PERFORM A GEOTECHNICAL INVESTIGATION TO EVALUATE THE STABILITY OF THE DAM:
- ☐ (93) PERFORM A HYDROLOGIC STUDY TO DETERMINE REQUIRED SPILLWAY SIZE:
- ☐ (94) PREPARE PLANS AND SPECIFICATIONS FOR AN ADEQUATE SPILLWAY:
- ☐ (95) SET UP A MONITORING SYSTEM INCLUDING WORK SHEETS, REDUCED DATA AND GRAPHED RESULTS:
- ☑ (96) PERFORM AN INTERNAL INSPECTION OF THE OUTLET: this year; may defer to 2020 as part of CDSE investigation
- ☑ (97) OTHER: continue the subsequent phases of your CDSE investigation study
- ☐ (98) OTHER:
- ☐ (99) OTHER:

## SAFE STORAGE LEVEL: RECOMMENDED AS A RESULT OF THIS INSPECTION

- ☐ (101) FULL STORAGE
- ☑ (102) CONDITIONAL FULL STORAGE
- ☐ (103) RECOMMENDED RESTRICTION
- ☐ (104) CONTINUE EXISTING RESTRICTION

FT. BELOW DAM CREST
FT. BELOW SPILLWAY CREST
FT. GAGE HEIGHT
NO STORAGE-MAINTAIN OUTLET FULLY OPEN

REASON FOR RESTRICTION

ACTIONS REQUIRED FOR CONDITIONAL FULL STORAGE ~~OR CONTINUED STORAGE AT THE RESTRICTED LEVEL:~~

(81), (82), (86), (87), (96) and (97)

Engineer's Signature ____________ INSPECTED BY

Owner's Signature ____________ OWNER/OWNER'S REPRESENTATIVE

DATE: 9/6/18

## GUIDELINES FOR DETERMINING CONDITIONS

### CONDITIONS OBSERVED - APPLIES TO UPSTREAM SLOPE, CREST, DOWNSTREAM SLOPE, OUTLET, SPILLWAY

GOOD
In general, this part of the structure has a near new appearance, and conditions observed in this area do not appear to threaten the safety of the dam.

ACCEPTABLE
Although general cross-section is maintained, surfaces may be irregular, eroded, rutted, spalled, or otherwise not in new condition. Conditions in this area do not currently appear to threaten the safety of the dam.

POOR
Conditions observed in this area appear to threaten the safety of the dam.

### CONDITIONS OBSERVED - APPLIES TO SEEPAGE

GOOD
No evidence of uncontrolled seepage. No unexplained increase in flows from designed drains. All seepage is clear. Seepage conditions do not appear to threaten the safety of the dam.

ACCEPTABLE
Some seepage exists at areas other than the drain outfalls, or other designed drains. No unexplained increase in seepage. All seepage is clear. Seepage conditions observed do not currently appear to threaten the safety of the dam.

POOR
Seepage conditions observed appear to threaten the safety of the dam. Examples:
1) Designed drain or seepage flows have increased without increase in reservoir level.
2) Drain or seepage flows contain sediment, i.e., muddy water or particles in jar samples.
3) Widespread seepage, concentrated seepage, or ponding appears to threaten the safety of the dam.

### CONDITIONS OBSERVED - APPLIES TO MONITORING

GOOD
Monitoring includes movement surveys and leakage measurements for all dams, and piezometer readings for High hazard dams. Instrumentation is in reliable, working condition. A plan for monitoring the instrumentation and analyzing results by the owner's engineer is in effect. Periodic inspections by owner's engineer.

ACCEPTABLE
Monitoring includes movement surveys and leakage measurements for High and Significant hazard dams; leakage measurements for Low hazard dams. Instrumentation is in serviceable condition. A plan for monitoring instrumentation is in effect by owner. Periodic inspections by owner or representative. OR, NO MONITORING REQUIRED.

POOR
All instrumentation and monitoring described under "ACCEPTABLE" here for each class of dam, are not provided, or required periodic readings are not being made, or unexplained changes in readings are not reacted to by the owner.

### CONDITIONS OBSERVED - APPLIES TO MAINTENANCE AND REPAIR

GOOD
Dam appears to receive effective on-going maintenance and repair, and only a few minor items may need to be addressed.

ACCEPTABLE
Dam appears to receive maintenance, but some maintenance items need to be addressed. No major repairs are required

POOR
Dam does not appear to receive adequate maintenance. One or more items needing maintenance or repair has begun to threaten the safety of the dam.

### OVERALL CONDITIONS

SATISFACTORY
The safety inspection indicates no conditions that appear to threaten the safety of the dam, and the dam is expected to perform satisfactorily under all design loading conditions. Most of the required monitoring is being performed.

CONDITIONALLY SATISFACTORY
The safety inspection indicates symptoms of structural distress (seepage, evidence of minor displacements, etc.), which, if conditions worsen, could lead to the failure of the dam. Essential monitoring, inspection, and maintenance must be performed as a requirement for continued full storage in the reservoir.

UNSATISFACTORY
The safety inspection indicates definite signs of structural distress (excessive seepage, cracks, slides, sinkholes, severe deterioration, etc.), which could lead to the failure of the dam if the reservoir is used to full capacity. The dam is judged unsafe for full storage of water.

### SAFE STORAGE LEVEL

FULL STORAGE
Dam may be used to full capacity with no conditions attached.

CONDITIONAL FULL STORAGE
Dam may be used to full storage if certain monitoring, maintenance, or operational conditions are met.

RESTRICTION
Dam may not be used to full capacity, but must be operated at some reduced level in the interest of public safety.

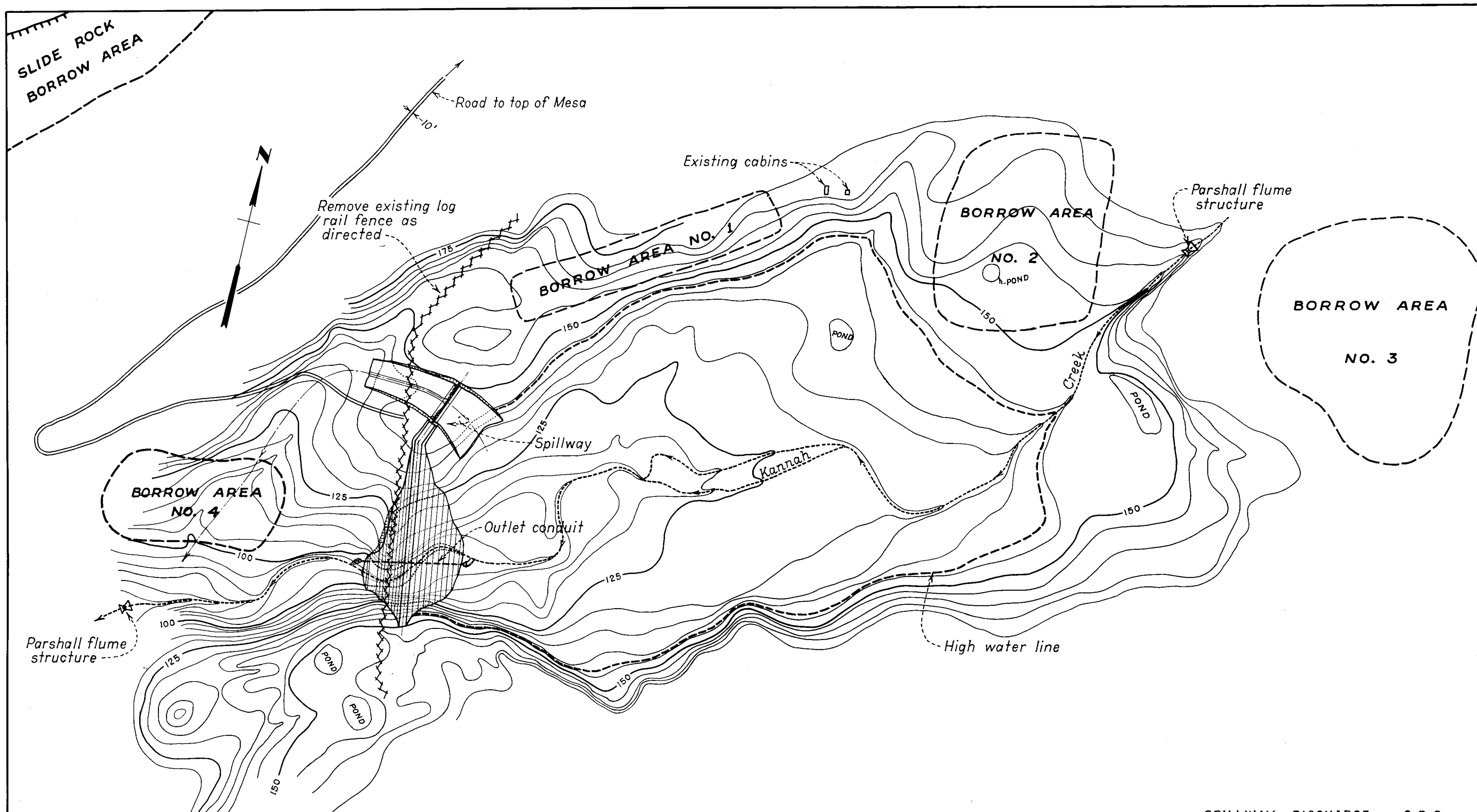
### HAZARD CLASSIFICATION OF DAMS

High hazard
Loss of human life is expected in the event of failure of the dam, while the reservoir is at the high water line.

Significant hazard
Significant damage to improved property is expected in the event of failure of the dam while the reservoir is at the high water line, but no loss of human life is expected.

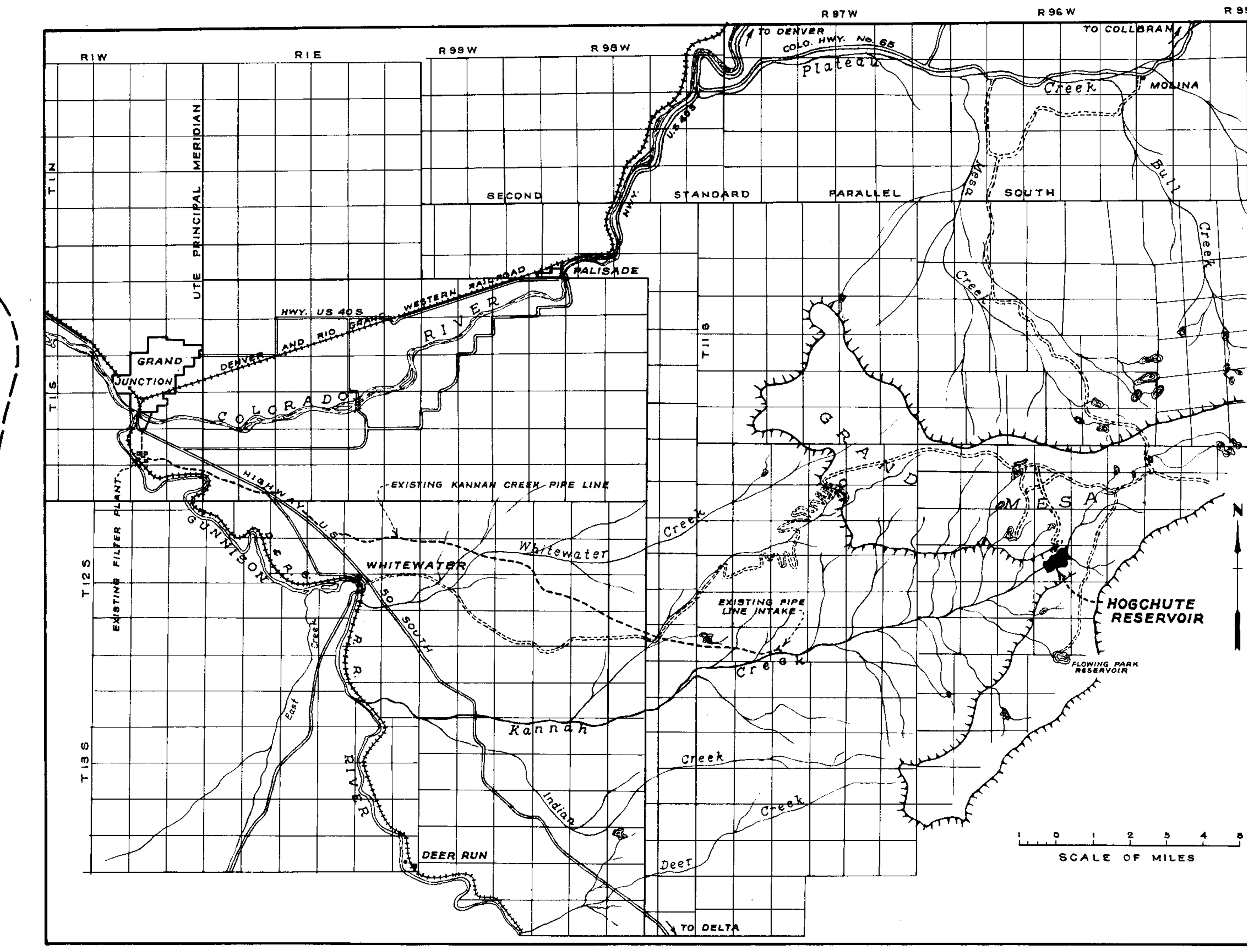
Low hazard
Loss of human life is not expected, and damage to improved property is expected to be small, in the event of failure of the dam while the reservoir is at high water line.

NPH hazard - No loss of life or damage to improved property, or loss of downstream resource is expected in the event of failure of the dam while the reservoir is at the high water line.

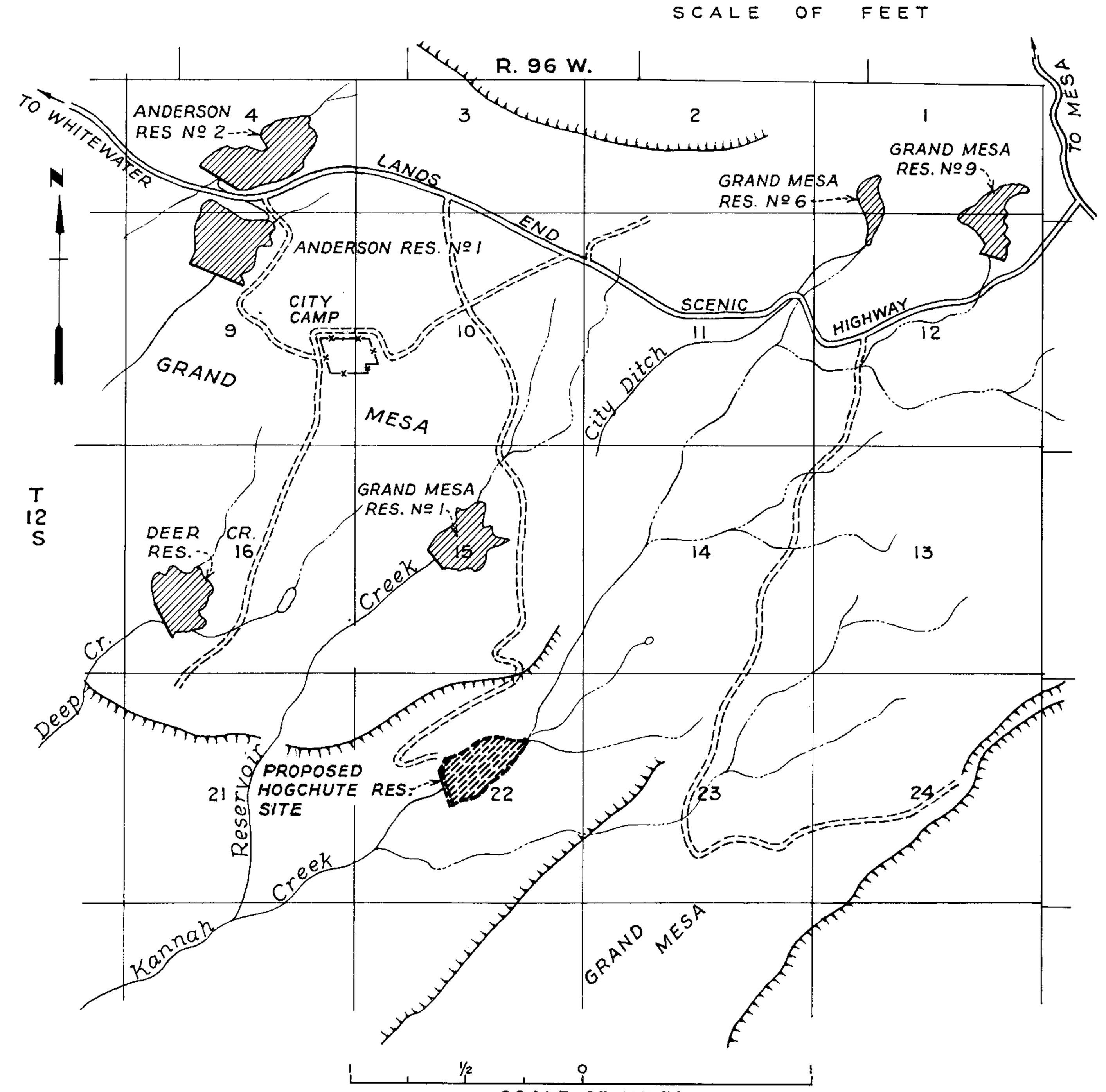



## GENERAL PLAN

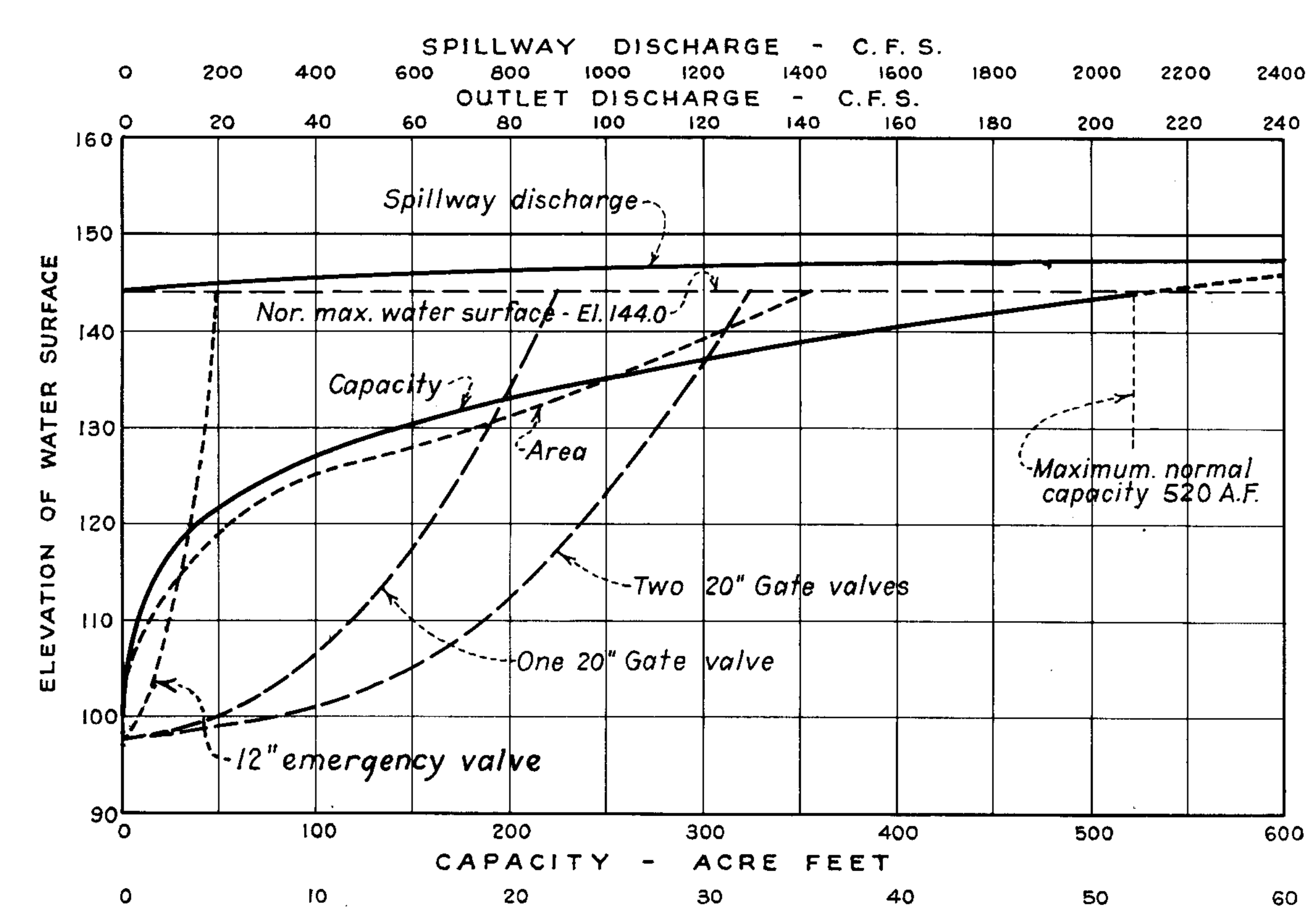
SCALE OF FEET




## VICINITY MAP




## LOCATION MAP




## AREA, CAPACITY AND DISCHARGE CURVES

## NOTES

Reservoir site is entirely within the limits of the Grand Mesa National Forest. All clearing operations, cutting and disposal of timber, shall be performed in accordance with rules and regulations prescribed by the Forest Supervisor

Altitude of reservoir site is approximately elevation 9250

## REFERENCE DRAWINGS

| | |
|---|---|
| VICINITY MAP AND GENERAL PLAN | 705-30 |
| PLAN, PROFILE AND SECTIONS | 705-31 |
| OUTLET WORKS - VALVE CONTROL HOUSE | 705-32 |
| TRASHRACK STRUCTURE AND SPILLWAY DETAILS | 705-33 |
| PARSHALL FLUME - PLAN, SECTIONS AND DETAILS | 705-34 |

Approved on the 24 day of May 1947

By [signature] STATE ENGINEER

By ______ DEPUTY

CITY OF GRAND JUNCTION

R. J. TIPTON AND ASSOCIATES INC., ENGINEERS

DENVER, COLORADO

**IMPROVEMENTS TO WATER SUPPLY SYSTEM**

**HOGCHUTE RESERVOIR**

**VICINITY MAP AND GENERAL PLAN**

DRAWN N.L.L. APPROVED [signature] R. J. TIPTON AND ASSOCIATES INC.

TRACED L.W.M. APPROVED [signature] DIRECTOR OF PUBLIC WORKS AND PLANNING

CHECKED N.L.L. APPROVED [signature] CITY MANAGER

DENVER, COLORADO MAY 1947 705-30

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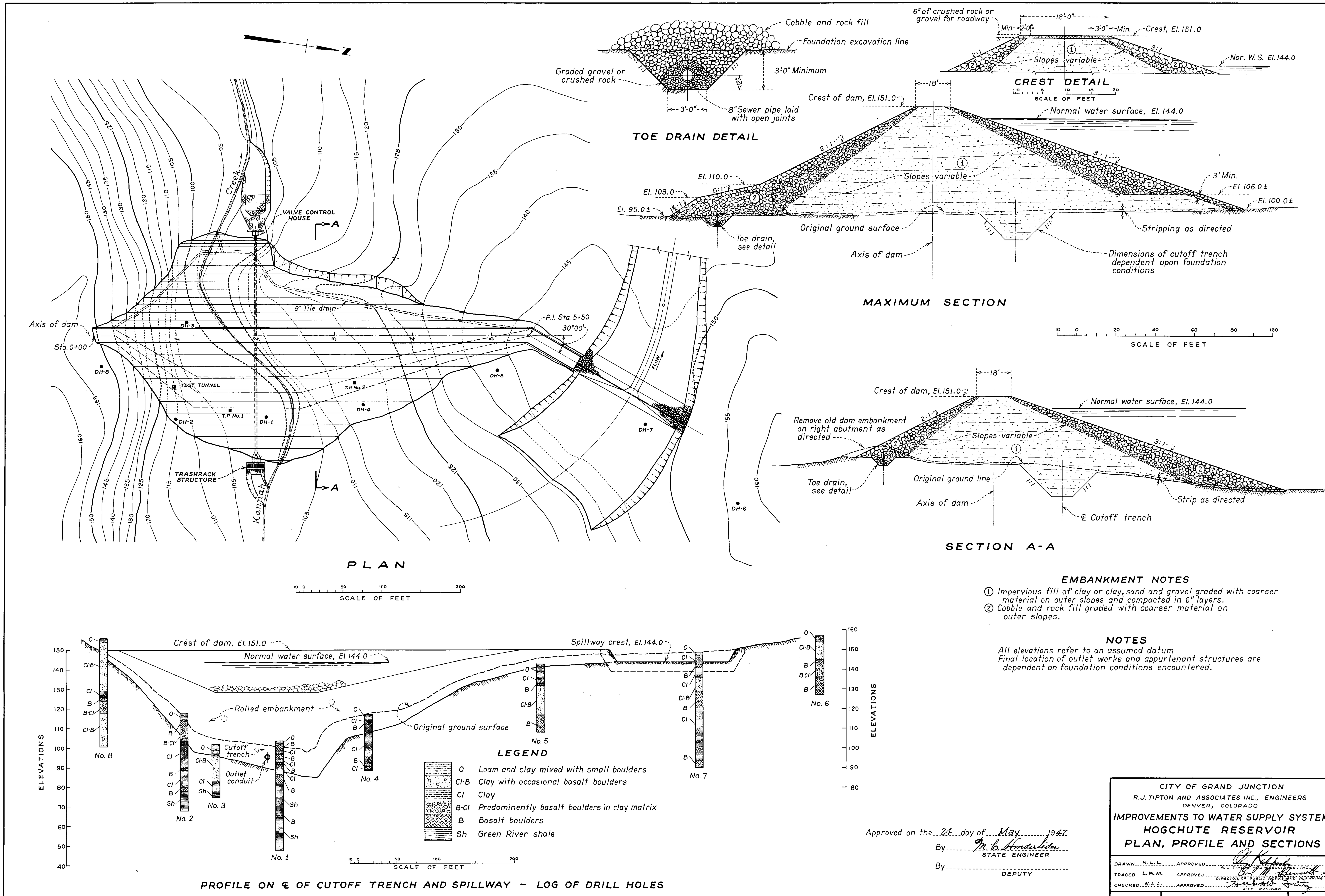
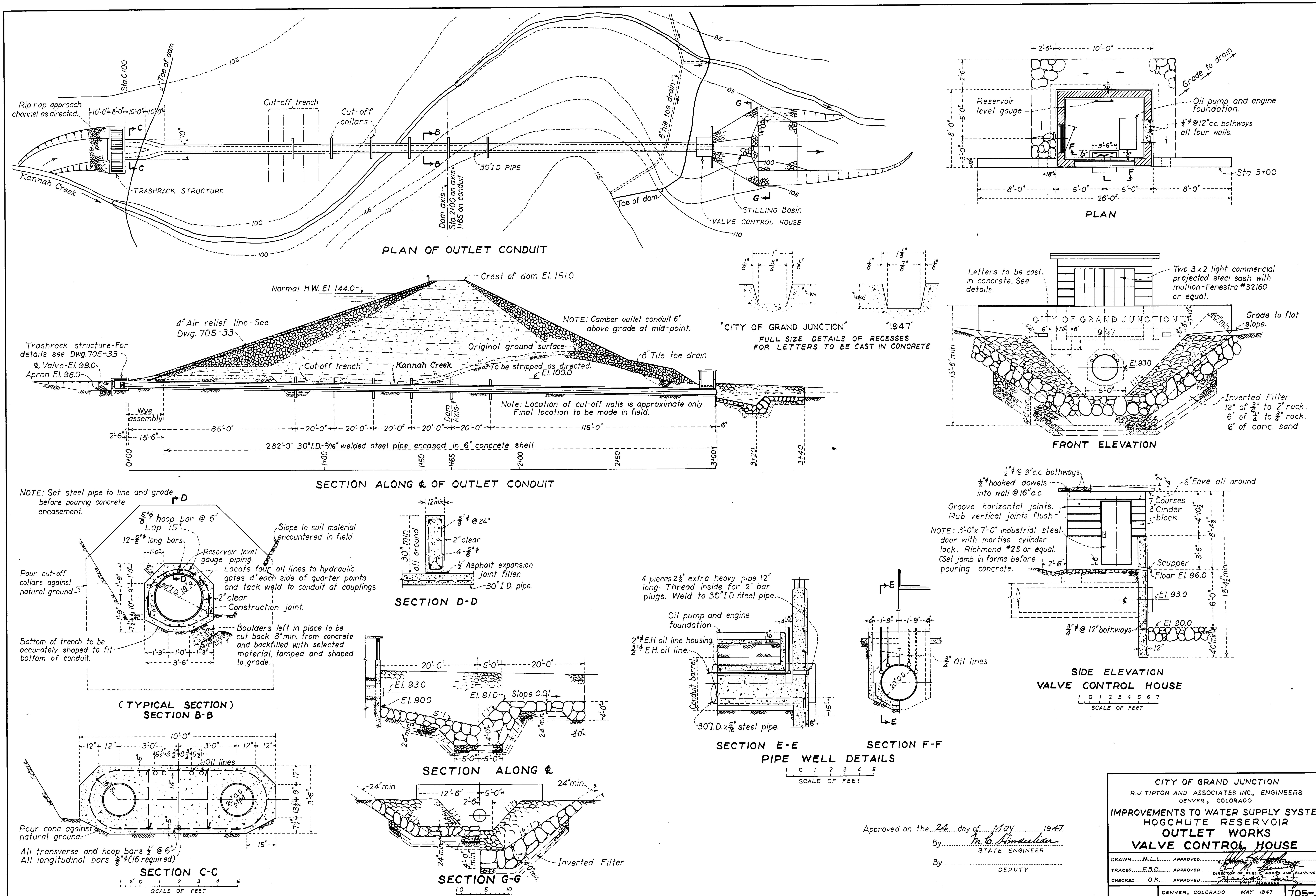


TOE DRAIN DETAIL
Cobble and rock fill
Foundation excavation line
Graded gravel or crushed rock
3'0" Minimum
8" Sewer pipe laid with open joints
CREST DETAIL
6" of crushed rock or gravel for roadway
Crest, El. 151.0
Nor. W.S. El. 144.0
Slopes variable
SCALE OF FEET
MAXIMUM SECTION
Crest of dam, El. 151.0
Normal water surface, El. 144.0
El. 110.0
El. 103.0
El. 95.0 ±
Toe drain, see detail
Original ground surface
Axis of dam
3' Min.
El. 106.0 ±
El. 100.0 ±
Stripping as directed
Dimensions of cutoff trench dependent upon foundation conditions
SECTION A-A
Remove old dam embankment on right abutment as directed
Original ground line
Strip as directed
℄ Cutoff trench
PLAN
Axis of dam
Sta. 0+00
P.I. Sta. 5+50
30°00'
8" Tile drain
VALVE CONTROL HOUSE
TRASHRACK STRUCTURE
TEST TUNNEL
Creek
Kannah
EMBANKMENT NOTES
① Impervious fill of clay or clay, sand and gravel graded with coarser material on outer slopes and compacted in 6" layers.
② Cobble and rock fill graded with coarser material on outer slopes.
NOTES
All elevations refer to an assumed datum
Final location of outlet works and appurtenant structures are dependent on foundation conditions encountered.
PROFILE ON ℄ OF CUTOFF TRENCH AND SPILLWAY - LOG OF DRILL HOLES
Crest of dam, El. 151.0
Normal water surface, El. 144.0
Spillway crest, El. 144.0
Rolled embankment
Original ground surface
Cutoff trench
Outlet conduit
ELEVATIONS
LEGEND
O Loam and clay mixed with small boulders
Cl-B Clay with occasional basalt boulders
Cl Clay
B-Cl Predominently basalt boulders in clay matrix
B Basalt boulders
Sh Green River shale
Approved on the 24 day of May 1947
By M. C. Hinderlider STATE ENGINEER
By DEPUTY
CITY OF GRAND JUNCTION
R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO
IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
PLAN, PROFILE AND SECTIONS
DRAWN N.L.L.
TRACED L.W.M.
CHECKED N.L.L.
DENVER, COLORADO MAY 1947
705-31


C-454




Approved on the 24 day of May 1947
By M. C. Hinderlider
STATE ENGINEER
By ..................
DEPUTY

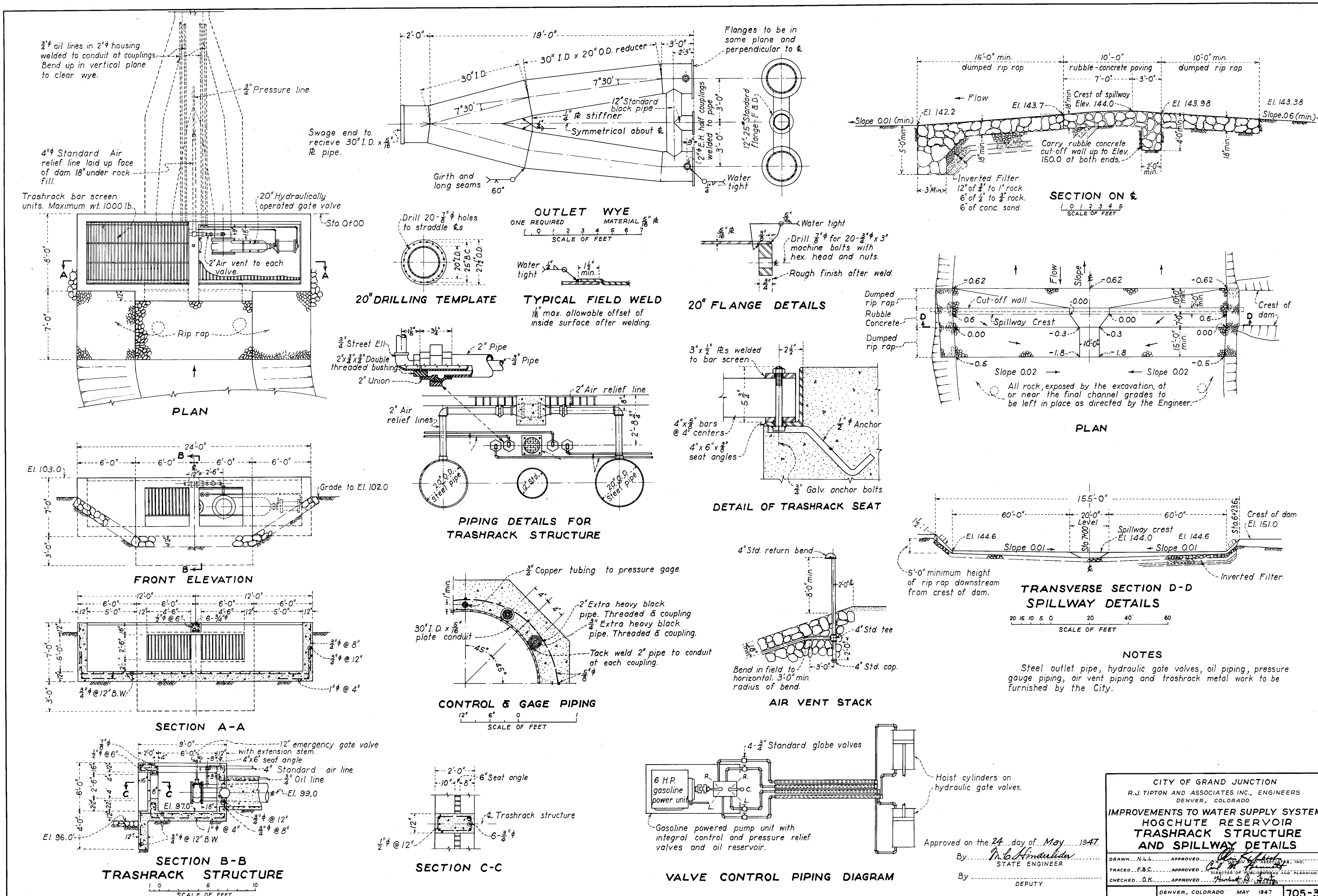
CITY OF GRAND JUNCTION
R. J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO

IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
OUTLET WORKS
VALVE CONTROL HOUSE

DRAWN N.L.L. APPROVED R. J. Tipton and Associates
TRACED F.B.C. APPROVED DIRECTOR OF PUBLIC WORKS AND PLANNING
CHECKED O.K. APPROVED CITY MANAGER

DENVER, COLORADO MAY 1947 705-32

C-454


PLAN
FRONT ELEVATION
SECTION A-A
SECTION B-B
TRASHRACK STRUCTURE
SCALE OF FEET
OUTLET WYE
ONE REQUIRED
20" DRILLING TEMPLATE
TYPICAL FIELD WELD
1/16" max. allowable offset of inside surface after welding.
20" FLANGE DETAILS
PIPING DETAILS FOR TRASHRACK STRUCTURE
DETAIL OF TRASHRACK SEAT
CONTROL & GAGE PIPING
SECTION C-C
AIR VENT STACK
VALVE CONTROL PIPING DIAGRAM
SECTION ON ℄
PLAN
TRANSVERSE SECTION D-D
SPILLWAY DETAILS
NOTES
Steel outlet pipe, hydraulic gate valves, oil piping, pressure gauge piping, air vent piping and trashrack metal work to be furnished by the City.
Approved on the 24 day of May 1947
By M. C. Hinderlider
STATE ENGINEER
By
DEPUTY
CITY OF GRAND JUNCTION
R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO
IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
TRASHRACK STRUCTURE
AND SPILLWAY DETAILS
DRAWN N.L.L.
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DIRECTOR OF PUBLIC WORKS AND PLANNING
CITY MANAGER
DENVER, COLORADO MAY 1947
705-33

C-454

STATE OF COLORADO, DIVISION OF WATER RESOURCES, DAM SAFETY BRANCH

# Comprehensive Dam Safety Evaluation Report

## Hogchute (aka Carson Lake) Dam, DAMID 420127

High Hazard

Mesa County, CO

Water Division 4, Water District 42

**Revised: February 6, 2018**

# Table of Contents

## APPENDICES

# 1. PROCESS OVERVIEW, EXECUTIVE SUMMARY, AND SAFE STORAGE LEVEL DETERMINATION

The Comprehensive Dam Safety Evaluation (CDSE) report is a Colorado Dam Safety tool to consider all available information about a particular dam within a Potential Failure Modes Analysis (PFMA) and Semi-Quantitative Risk Assessment (SQRA) framework to determine the Safe Storage Level in accordance with Colorado Revised Statute 37-87-107, which assigns the State Engineer the responsibility to determine the safe storage level for all reservoirs in the State. The CDSE process has been developed by Colorado Dam Safety along with dam engineering and risk assessment expert consultants, and is generally based on the U.S. Bureau of Reclamation's *Best Practices in Dam and Levee Risk Assessment* (2015) and FEMAP-1032 *Evaluation and Monitoring of Seepage and Internal Erosion (2015)*.

## 1.1. Dam Safety "Risk" and CDSE Process Overview

In a dam safety context, "Risk" is a product of the ***Likelihood*** of a specific potential dam failure mode (PFM) and the *Consequences* following the occurrence of that PFM. The CDSE endeavors to quantify the overall Risk of a given dam by assigning relative values to both the Likelihood and Consequences of all plausible PFMs through a highly detailed review of all "known" information, while also acknowledging the existence and potential impact of "unknown" variables.

The CDSE process starts with a detailed review of State Engineer's Office (SEO) dam safety files including: construction history, past investigations and analyses, performance history (past inspections & incidents), and monitoring results (seepage, piezometers, etc.). All of the researched and documented information is then used to evaluate industry-standard PFMs and generate a list of plausible PFMs for the subject dam. Each PFM includes a detailed description of mechanisms by which dams can and do fail, with detailed steps that must occur from initiation to dam failure. For each PFM, adverse and positive factors are considered by the evaluation team and an overall Likelihood is assigned. "Unknown" variables are factored into the evaluation by assigning a Confidence rating for each PFM. "Poor" and "Medium" Confidence ratings are typically accompanied by actions that could be taken to raise the overall confidence rating of the PFM. Once the Likelihood level is assigned, a Consequence level is determined and assigned. The dam safety industry generally determines Consequences with potential lives lost or "Population At Risk" (PAR) in the downstream floodplain, though impacts to infrastructure and/or environmental damages could also be considered.

Each PFM is then plotted on a Risk Chart based on the assigned Likelihood and Consequence levels as a means of determining which PFMs are most alarming ("Risk Driving") from a dam and public safety perspective. The Risk Driving PFMs will tend to plot higher and further to the right of the Risk Chart, while non-Risk Driving PFMs will be lower and further to the left. The Risk Chart can also be used as a prioritization tool when extensive repairs are anticipated for a given dam or portfolio of dams.

The CDSE report serves as a single summary document for a given dam. The report includes a summary of the dam history, key properties of the dam, expected consequences of dam failure, emergency preparedness, and key risk factors associated with the dam based on the PFMA results.

## 1.2. CDSE Summary for Hogchute (aka Carson Lake) Dam

For Hogchute Dam, 26 PFMs were evaluated with the "Risk-Driving" PFMs identified as:

PFM #2: Backward Erosion Piping through the Embankment,

PFM #7: Contact Erosion through the Foundation,

PFM #12 Concentrated Leak Erosion along the Conduit,

PFM #13 Concentrated Leak Erosion into the Conduit,

PFM #15 Overtopping, and

PFM #26 Outlet Gate(s) Fail to Open

These risk-driving PFMs were then thoroughly evaluated by a team of engineers including the Colorado Dam Safety Chief and two dam safety engineers within Colorado Dam Safety. Section 3 of this report contains a summary of the PFMA results. The individual PFM worksheets including adverse and positive factors that were considered for each PFM are included in Appendix A.

### *1.2.1. <u>Likelihood Level Assignments</u>*

*By consensus of the group, **a HIGH Likelihood of failure was assigned to PFM #12 Concentrated Leak Erosion into the Conduit, PFM #15 Overtopping, and PFM #25 Outlet Gate(s) Fail to Open**, when the reservoir is at full storage*. A HIGH Likelihood means the fundamental condition of defect is known to exist, indirect evidence suggests it is plausible, and ***key evidence is weighted more heavily toward likely than unlikely*.**

*By consensus of the group, **a MODERATE Likelihood of failure was assigned to PFM #2 Backward Erosion Piping through the Embankment, PFM #7 Contact Erosion through the Foundation, and PFM # 13 Concentrated Leak Erosion into the Conduit**, when the reservoir is at full storage**.*** A MODERATE Likelihood means the fundamental condition of defect is known to exist, indirect evidence suggests it is plausible, but ***key evidence is weighted more heavily toward unlikely than likely*.**

A summary description of PFM Likelihood ratings is provided for reference in Appendix F.

The HIGH and MODERATE Likelihood of these PFMs were predominantly driven by direct and indirect evidence indicating that each PFM is credible, poses a significant risk to the safety of the dam, and that action is needed to either reduce the risk or better define the risk. Key evidence supporting these determinations include:

- Long history of observed seepage at the downstream toe of the dam behind the outlet pipe headwall (PFMs #2, #7, and #12).
- Long history of observed seepage along the downstream right abutment (PFMs #2, and #7).
- Suspected air vent penetration broken and causing up to 3cfs infiltration into the outlet pipe (PFM #13).

- No known hydrology study on file (PFM#15).
- Concern over long-term integrity of hydraulic controls and unknown condition of the outlet gates and intake structure (PFM #26)

### *1.2.2. Consequence Level Assignment*

*By consensus of the group, all of the HIGH and MODERATE Likelihood PFMs fall in Level 2 or Level 3 consequences.* Level 2 consequences indicate a magnitude of downstream discharge results in moderate property damage with possible direct loss of life in the range of 1 to 10. Level 3 results in moderate property damage with direct loss of life in the range of 10 to 100. For each PFM, the determination of consequence level 2 or 3 was estimated by the anticipated full or only partial breach of the dam, respectively.

### *1.2.3. Required Risk Reduction Actions*

The combination of a HIGH or MODERATE Likelihood and LEVEL 2 or 3 Consequences warrants risk reduction measures to improve the safety of the dam. However, risk-driving PFMs #12 and #15, and #3 and #7 fall into the Confidence Level of POOR or POOR to MEDIUM, indicating that specific information is lacking in order to adequately characterize the risk of the project (Section 4.5, FEMA P-1032, May 2015). For PFMs #13 and #26, the Confidence Level is MEDIUM to STRONG may require immediate action to reduce the risk. The Strong component of this split ranking indicates compelling evidence of an ongoing or active failure mode, while the Medium level indicates additional information is needed to adequately assess the risk.

For Colorado Dam Safety, one risk reduction measure is impose a storage restriction in accordance with the State Engineer's authority and responsibility to protect the downstream public per CRS 37-87-107. Based on engineering judgment, consideration of all information detailed herein, and in good faith, ***Colorado Dam Safety has determined that a storage restriction for Hogchute Dam is not warranted at this time. However, diligence must be shown to obtain additional information to increase the confidence of all the risk-driving PFMs identified in this CDSE study.***

By consensus of the group, the Actions and Due Dates in Table 3.2 are measures necessary to either reduce the risk of failure of the dam by a PFM or requirements for obtaining additional information to increase the Confidence Level of a PFM. ***Compliance with the Actions shown in Table 3.2 by the associated Due Date is required to reduce the risk in a timely manner. Failure to do so, may result in a storage restriction action by the State Engineer to reduce or remove the risk associated with each identified PFM.***

A summary of Risk Reduction Action requiring an engineer are provided in Table 5.2.1 *Dam Failure Likelihood Reduction Actions*

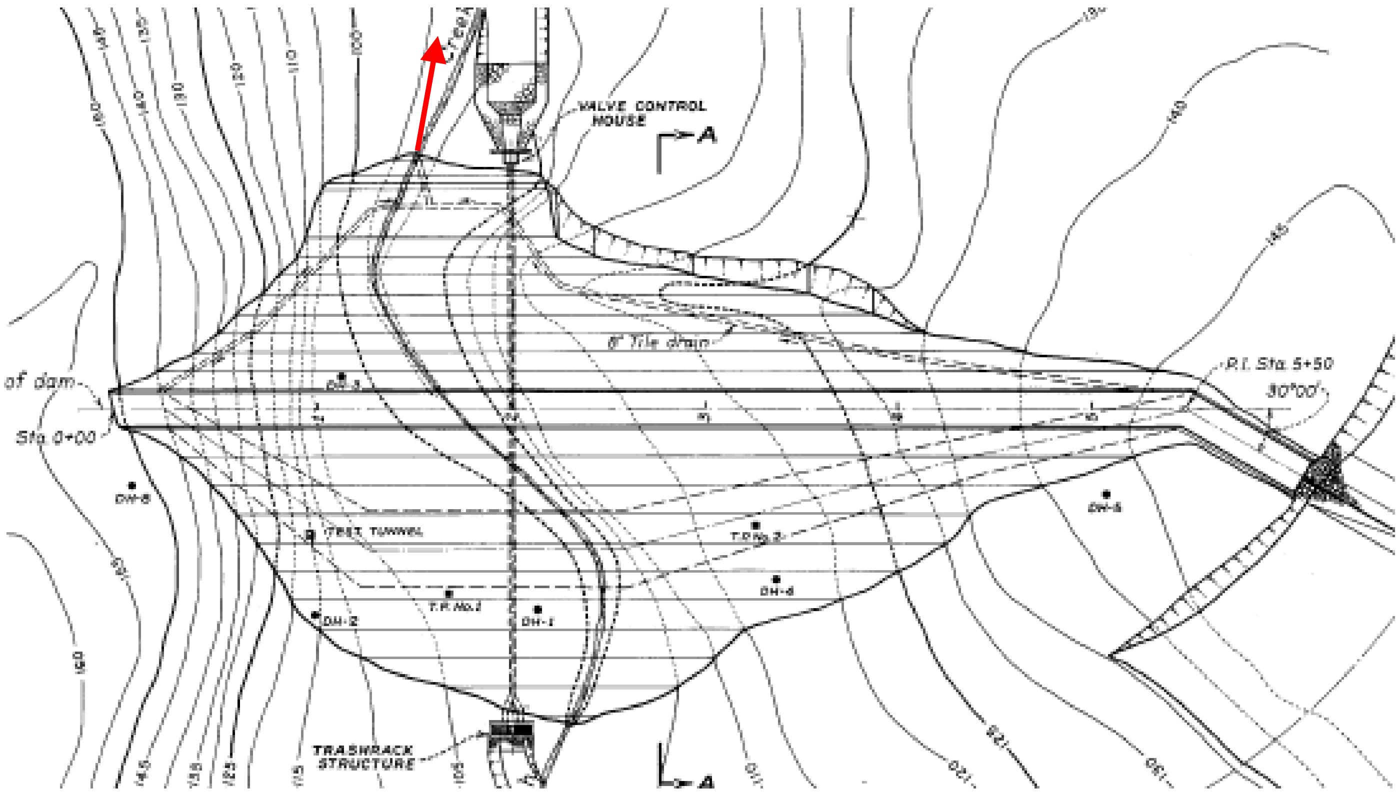
# 2. BACKGROUND DOCUMENTATION

## 2.1. Summary of Facility - Current Configuration - General Summary Only

| Feature | Description |
|---|---|
| Dam Name | Hogchute, aka Carson Lake |
| State of Colorado DAMID | 420127 |
| Dam Owner | City of Grand Junction |
| Dam Purpose | Municipal and Irrigation |
| Type of Dam | EARTHEN, Homogeneous impervious core (Zone 1) with upstream and downstream cobble and rock fill shells (Zone 2). Cutoff trench, offset upstream of dam axis. |
| Hazard Classification | High |
| County | Mesa |
| Nearest Town | Whitewater |
| UTMx. UTMy | 230460.5, 4320830.6 |
| River or Stream | Kannah Creek |
| ***Dam Geometry*** | |
| Dam Structural Height | 56 ft |
| Dam Hydraulic Height | 56 ft |
| Crest Length | 620 ft |
| Crest Width | 18 ft |
| Dam Crest Elevation | 9,890 ft |
| ***Reservoir*** | |
| Surface Area | 35 acres at normal high waterline |
| Normal Capacity | 637 acre-feet |
| Maximum Capacity | 765 acre-feet |
| Pool of Record | Unknown. |
| ***Outlet Works*** | |
| Outlet Description | 30-inch, Welded Steel Pipe; Two 20-inch hydraulic gates<br>One 12-inch gate emergency valve between outlet wye (See C-454, Sht 705-33) |

| Feature | Description | |
|---|---|---|
| Outlet Capacity | 134 cfs | |
| Drawdown time | - | |
| ***Spillway*** | | |
| Drainage Basin Area | 6,240 acres | |
| Total Spillway Capacity | 2,400 cfs in DAMS database; 7500 cfs per original design report (1947). | |
| Capacity / Sq mi | - | |
| | ***Principal Spillway*** | ***Emergency Spillway*** |
| Type | - | Ungated, open channel |
| Width | - | 140 ft |
| Freeboard | - | 7 feet |
| Discharge Capacity | - | 2,400 cfs? |

## 2.2. Summary of Construction History

| Date | C # | Brief Description |
|---|---|---|
| 1947 | C-454 | • Plans and specifications submitted May 1947.<br>• State Engineer Hinderlider signed approval block on C-454 May 1947<br>• Work began July 1947<br>• Winter shutdown 1947 planned, but all work completed (by letter) on dam by November 15, 1947<br>• No follow-up as-constructed drawings or other documentation in file. |
| 1972 | - | • DWR Inspection Report: "In 1972, a new outlet control was established. The gates are hydraulically operated. The operating gear is in a shed on the upstream crest". |
| 1988 | - | <br>• Toe drain discharge excavated and extended into 40-downstream along left side of discharge channel (red arrow above)<br>• Seepage from right side behind headwall "traced to the tubes which were installed for reservoir level gauge in the old valve house" (letter from City of Grand Junction to Jim Norfleet, Nov 14, 1988).<br>• Headwall repaired and tie-back cable installed. |

## 2.3. Summary of Investigations, Designs, & Analyses

| Report Type | In File? (Y/N) | Author, Date | Brief Summary |
|---|---|---|---|
| ***Hazard Classification*** | | | |
| National Dam Safety Program Hazard Classification Determination | Yes | Van Sciver, 1979 | • Limited hazards based on aerial flight photography<br>• Moderate hazard rating (Significant hazard per 2007 Rules and Regs)<br>• Qp at dam estimated at 8,516 cfs |
| Hazard Re-evaluation | Yes | Ahrens, 1985 | • Qp at dam estimated at 7,193 cfs<br>• Moderate rating; No change |
| Inundation Mapping Study | Yes | City of GJ, 2015 | • Qp at dam estimated at 28,927 cfs (per Froehlich, 2008 and WA State, 2007 methods)<br>• New residential development since last evaluations<br>• High Hazard rating |
| ***Spillway*** | | | |
| | No | | See Section 5.1 Summary of Key Risk Factors for summary of known information |
| | | | |
| ***Geotechnical*** | | | |
| Geology | No | | Colorado Geological Survey GoogleEarth KML file indicates dam is situated on Landslide deposits with bordering units of Green River Formation to the north and Glacial drift to the south. |
| Subsurface | No | | Eight borehole logs contained on C-454, Sht 705-31<br>See Section 5.1 Summary of Key Risk Factors for summary of known information |
| Seismicity | No | | PGA = 0.1591g per USGS<br>See Section 5.1 Summary of Key Risk Factors for summary of known information |
| Stability | No | | |
| Seepage | No | | See Section 5.1 Summary of Key Risk Factors for summary of known information |
| Filter design | No | | |
| ***Outlet Works*** | | | |
| | Y | C-454 (1947) | Outlet works design drawings only. |
| | | | |
| | | | |

## 2.4. Summary of Performance History, Incidents & Significant Noted Deficiencies

| Date | Description of Deficiency | Action Taken | Resolved? | Reference |
|---|---|---|---|---|
| 1971 and 1972 | • First inspections of dam both note seepage from right toe of dam above outlet structure<br>• 1972 inspection notes seepage between outlet pipe and concrete and penetration through headwall | | | A. Pearson, Dam Safety inspection reports |
| 1975, 1976 | • Similar observations of seepage noted | | | DWR inspection reports |
| 8/12/1975 | • DWR Inspection Report: "In 1972, a new outlet control was established. The gates are hydraulically operated. The operating gear is in a shed on the upstream crest". | | | |
| 1977 | • Inspection report notes condition of outlet works "good-recently redone" | | | |
| 1984 | • First inspection report to denote abandoned Control House at downstream toe of dam. Inspection indicates valve operation controls are on the upstream slope.<br>• Seepage from right toe of dam noted. | | | B. Ahrens, DWR inspection report |
| 1985 – 1987 | • Inspection reports note generally same conditions for seepage from right toe and seepage and deteriorating conditions at downstream headwall. | | | |
| 1985-1987 | • First inspection reports with observation of deteriorating spillway crest and water flowing under "rubble concrete paving" (description from C-454, Sht 705-33) | | | |
| 1988 | • Inspection report: Exposed rebar around outlet pipe penetration through headwall | | | J. Norfleet |
| 1988 | • **Summary of repairs by City of Grand Junction:**<br>2. THE CREW THEN LOCATED THE END OF THE TOE DRAIN PIPE AND FOUND THAT IT WAS SUBMERGED 2 FEET BELOW THE STREAM BED LEVEL.<br>IN AN EFFORT TO PROVIDE AS MUCH DRAINAGE CAPABILITY AS POSSIBLE THE PIPE WAS EXTENDED DOWNSTREAM 40 FEET, THIS STILL LEAVES THE END OF THE PIPE SUBMERGED HOWEVER IT DOES ALLOW FOR SOME RELIEF OVER THE ORIGINAL POINT OF EXIT.<br>3. SEEP WATER AROUND THE OLD VALVE HOUSE WAS TRACED TO THE TUBES WHICH WERE INSTALLED FOR RESERVOIR LEVEL GAUGE IN THE OLD VALVE HOUSE, THIS SOURCE OF WATER WAS SEALED OFF AND THE SEEP WATER WAS REDUCED TO LESS THAN 1/2 GALLON PER MINUTE. | | | City of Grand Junction, November 14, 1988 |

| Date | Description of Deficiency | Action Taken | Resolved? | Reference |
|---|---|---|---|---|
| 1989, 1990, 1991, 1992, 1993, 1995, 1996 | Inspection Reports<br>• Seepage from right toe above outlet pipe headwall; generally consistent observations.<br>• No notes of observing left side toe drain outfall<br>• Deterioration of downstream headwall continues<br>• Outlet works difficult to operate, but acceptable.<br>• Some observations and distinction between "right abutment" versus area behind headwall seepage. | | | J. Norfleet |
| 1997 | • Observation of seepage from outlet pipe penetration through headwall (not mentioned in recent previous years, but likely occurring). | | | J. Norfleet |
| 1998 | • Toe drain extension found and photographed along left edge of discharge channel. | | | J. Norfleet |
| 1998 | • "left toe drain submerged in outlet channel, but flowing"<br>• Right abutment seepage and behind headwall observed | | | J. Norfleet |
| 1999, 2000, 2002 | • Seepage observations lean toward right abutment seepage is source of ponded water behind headwall | | | G. Jackson |
| 2004 | • Generally same observations from previous years. | | | G. Jackson |
| 2006 | • Note that left toe drain outfall is submerged. | | | G. Jackson |
| 2008 | • Internal inspection of the outlet pipe.<br>• Inspection Report:<br>  o Video inspection revealed air vent leakage (approx. 1.8 cfs) observed<br>  o No photos of air vent leak in file. | | | G. Jackson |
| 2010 | • No significant changes reported | | | G. Jackson |
| 2011 | • No significant changes reported | | | G. Jackson |
| 2013 | • Concern noted that operation of the outlet increases seepage behind the headwall | | | G. Jackson |
| 2013 | • Follow-up inspection to exercise valves and observe seepage<br>  o Both valves exercised through full range<br>  o No observed increase in seepage | | | G. Jackson |

| Date | Description of Deficiency | Action Taken | Resolved? | Reference |
|---|---|---|---|---|
| 2015 | • Improved drainage behind headwall | | | G. Jackson |
| 2016, 2017 | • Owner directed to engage engineer to investigate seepage and outlet works deficiencies and plan for repair. | | | G. Jackson |

## 2.5. Summary of Operations

| Type | Y/N | Description | Adequacy/ Confidence |
|---|---|---|---|
| ***Owner Participation*** | | | |
| Owner Dam Safety Program | N | No formal program in place. | Acceptable |
| Dam Caretakers | Y/N | No one on-site, but approximately weekly visits to the dam. | Acceptable |
| Owner Inspections | Y | Owner performs site inspections during routine water release adjustment and maintenance | Acceptable |
| Owner Monitoring of Instruments | Y/N | Owner indicates seepage monitoring, but no known data reduction or submittal to CO Dam Safety | Poor |
| ***Outlet Operations*** | | | |
| Upstream Control | Y | Two hydraulically operated gate valves. | Acceptable |
| Routine Exercising | N | | Poor |
| Routine Internal Inspections | Y | Last internal inspection in 2008; due in 2018 | Good |
| ***Reservoir & Spillway Operations*** | | | |
| Normal Operating Procedures | Y | Reservoir fills and spills in spring due to normal runoff.<br>Reservoir lowered during irrigation season<br>Outlet fully closed in fall to retain next spring runoff. | Acceptable |
| Pool of Record | | Unknown | Acceptable |
| Spillway Activated Normally | | Yes | Acceptable |

## 2.6. Summary of Monitoring & Instrumentation

| Instrumentation Type | Monitoring Frequency | Reporting to SEO? | Analysis of Data? | Discussion of Trends |
|---|---|---|---|---|
| Staff gage | Unknown | No | No | Welds on hydraulic lines casing; generally unreadable |
| Survey Monuments | No Known | | | |
| Piezometers | None | | | |
| Seepage | Unknown | No? / Unknown | Unknown | See above |
| Other | | | | |

# 3. POTENTIAL FAILURE MODES ANALYSIS

### 3.1. PFM Brainstorm/Screening List

| PFM Suite | PFM # | PFM Name | General PFM Description | PFM Carried Forward or Remote | Justification for Carried Forward (Credible) or Remote (Non-Credible) |
|---|---|---|---|---|---|
| Internal Erosion Through Embankment | 1. | Concentrated Leak Erosion through Embankment | a crack above an abrupt change in rock slope on an abutment, an hydraulic fracture crack in a low stress zone in the core, a desiccation crack, differential settlement cracking, a frost damaged layer at a winter shutdown level, the boundary in the embankment created by a closure section, defects due to animal burrows or roots | Remote | No evidence of concentrated embankment seepage in field or from file review. |
| | 2. | Backward Erosion Piping through Embankment | a low plasticity (PI<7) layer or zone through the core, dispersive soil | Carry Forward | Historic seepage emerging from downstream toe of dam behind the outlet pipe headwall; Downstream shell may not be filter compatible with core of dam. |
| | 3. | Contact Erosion through Embankment | pervious zone above core, embankment overlying pervious foundation | Carry forward | Historic seepage emerging from downstream toe of dam behind the outlet pipe headwall and along right abutment. |
| | 4. | Suffusion/Suffosion through Embankment | presence of internally unstable soil | Carry forward | No evidence, but need to verify before assigning remote |
| Internal Erosion Through Foundation | 5. | Backward Erosion Piping through Foundation | a continuous pervious, low plasticity (PI<7) layer through the foundation, direct entrance into pervious layer, open exit or heave/blowout, dispersive soil | Remote | No evidence of PFM in field or from file review<br>Clay foundation likely has PI>7<br>This PFM could also be captured in PFM#7 below. |
| | 6. | Concentrated Leak Erosion through Foundation | a crack above an abrupt change in rock slope, an hydraulic fracture crack in a low stress zone, differential settlement cracking, crack due to collapsible soil, karstic features, open or erodible bedrock discontinuities | Remote | No evidence of PFM in field or from file review |
| | 7. | Contact Erosion through Foundation | Flow through pervious foundation layer underlying fine-grained confining layer: Foundation seepage path consisting of a system of high-porosity interconnected and open rock fractures, solution cavities, open coarse material, or a fault system | Carry Forward | Historic seepage emerging from downstream toe of dam behind the outlet pipe headwall ;<br>Original drill logs (C-545) show potentially gap-graded clay/rock foundation |
| | 8. | Suffusion/Suffosion through Foundation | presence of internally unstable soil | Remote | No evidence of PFM in field or from file review |
| Internal Erosion of Embankment Into Foundation | 9. | Concentrated Leak Erosion | Coarse open-work foundation soils (gravels/cobbles), voids, karstic features, untreated open rock fracture | Remote | No evidence of PFM in field or from file review |
| | 10. | Backward Erosion Piping | a low plasticity (PI<7) layer near the core base, filter incompatibility between embankment and foundation soils, dispersive soil | Remote | No evidence of PFM in field or from file review |
| Internal Erosion of Embankment at *Contact* | 11. | Concentrated Leak Erosion | Hydraulic fracture occurs along low stress zones (along a steep wall or low compaction zones) or gap developing due to settlement of dam fill adjacent to rigid structure | Remote | No evidence of PFM in field or from file review |
| Internal Erosion *along* Conduit | 12. | Concentrated Leak Erosion | Examples of a defect along a conduit include a crack, void, or zone of low compaction density due to shape of conduit or presence and configuration of seepage collars | Carry Forward | Historic seepage emerging from downstream toe of dam behind the outlet pipe headwall. |
| Internal Erosion *into* Conduit/Drain | 13. | Concentrated Leak Erosion | Examples of a defect along a conduit include a crack, hole, open pipe joint, slots/perforations cut too large for surrounding soil, or other opening that is in a strategic part of the embankment and below the phreatic surface. This hole may be in alignment with an existing flaw in the embankment along the conduit that connects to the reservoir | Carry forward | Suspected air vent penetration broken and causing up to 3 cfs infiltration into outlet pipe. |
| Internal Erosion *out of* Conduit | 14. | Concentrated Leak Erosion | Examples of a defect along a conduit include a crack, hole, open pipe joint, slots/perforations cut too large for surrounding soil, or other opening that is in a strategic part of the embankment and below the phreatic surface. This hole may be in alignment with an existing flaw in the embankment along the conduit that connects to the reservoir | Carry forward | Need to verify before assigning remote.<br><br>Need to compare findings with PFM#13 |
| Overtopping | 15. | Overtopping | Example causes for exceeding spillway capacity include undersized spillway, debris blockage, misoperation, or failure of a gate hoist/chain/valve | Carry forward | Large spillway with relatively small drainage area, but Low Confidence without hydrology study. |

| PFM Suite | PFM # | PFM Name | General PFM Description | PFM Carried Forward or Remote | Justification for Carried Forward (Credible) or Remote (Non-Credible) |
|---|---|---|---|---|---|
| Spillway Failure due to Erosion | 16. | Erosion of Unlined Channel | Overflow duration, depth, and velocity initiate head-cutting erosion of the earthcut spillway channel | Remote | Spillway located on natural abutment; Remote chance of eroding to stream level. |
| | 17. | Undercutting of Spillway Structure | Failure of the structural portion of the spillway | Remote | Evidence of crest structure deterioration, but spillway located on natural abutment; Remote chance of eroding to stream level. |
| Reservoir Landslide/Seiche Leading to Overtopping | 18. | Reservoir Landslide/Seiche Leading to Overtopping | The size and velocity of the landslide mass is sufficient to create a wave/seiche that overtops the dam with multiple waves. | Carry forward | Need to verify before assigning remote |
| Static Slope Stability | 19. | Rise in Phreatic Level Causes Deformations that Exceed Freeboard | Phreatic level rises due to filter or toe drain clogging, long-duration flood loading, saturation of slope from surface run-on or precipitation infiltration. | Carry forward | Need to verify before assigning remote |
| | 20. | Slump Reduces Seepage Path Leading to Internal Erosion | Phreatic level rises due to filter or toe drain clogging, long-duration flood loading, saturation of slope from surface run-on or precipitation infiltration - > Deformations are less than freeboard, but seepage and internal erosion initiates through the slide mass / scarp. | Carry forward | Need to verify before assigning remote |
| | 21. | Rapid Drawdown Failure of Upstream Slope | The reservoir is lowered faster than pore pressures can dissipate in upstream materials. Consider that freeboard is very large once reservoir is drawndown, and thus deformations would need to be great to lead to loss of reservoir. | Carry forward | Need to verify before assigning remote |
| **Seismic Deformation** | 22. | Dynamic Deformation Greater than Freeboard | Significant reduction in foundation strength due to liquefaction of low plasticity and cohesionless soils. Also consider cohesive, plastic soils susceptible to significant strength loss due to strain-softening. | Carry forward | Need to verify before assigning remote |
| | 23. | Differential Settlement Leads to Transverse Cracking | Differential settlement (less than freeboard) caused by foundation and embankment irregularities including abrupt change in foundation depth or density, abrupt change in embankment height due to valley shape, collapsible soils | Carry forward | Need to verify before assigning remote |
| | 24. | Dynamic Separation at Contact Leads to Internal Erosion | Separation at contact between embankment and rigid structure (concrete section, spillway or retaining wall, steep rock abutment) due to differential dynamic response | Remote | No rigid structures for this PFM. Deformation can be captured in PFM#22 and/or |
| **Outlet Works** | 25. | Outlet Gate(s) Fail to Close | Uncontrolled release of reservoir through the outlet conduit. Other PFMs may initiate, but not due to failure of outlet gates to close. | Remote | Concern over long-term integrity of hydraulic controls. Unknown condition of outlet gates and intake structure. |
| | 26. | Outlet Gate(s) Fail to Open | Unable to release reservoir causes long-term normal storage that can lead to favorable conditions for initiation of other PFMs. | Carry Forward | Concern over long-term integrity of hydraulic controls. Unknown condition of outlet gates and intake structure. |

## 3.2. Risk Driving Potential Failure Modes Summary Table[1]

| PFM # | PFM Name | Likelihood | Confidence | Actions | Initial Date | Due Date |
|---|---|---|---|---|---|---|
| 2 | Backward Erosion Piping through Embankment | **Moderate** | Poor to Medium | Seepage Investigation; attempt to trace and isolate source(s) of seepage | DD/MM/YYYY | DD/MM/YYYY |
| | | | | Geotechnical investigation included drilling, sampling, and soil index testing of Zone 1 material | DD/MM/YYYY | DD/MM/YYYY |
| | | | | Piezometer installation in Zone 1 | DD/MM/YYYY | DD/MM/YYYY |
| | | | | Improve seepage collection and monitoring | DD/MM/YYYY | DD/MM/YYYY |
| 7 | Contact Erosion through Foundation | **Moderate** | Poor to Medium | Same Actions as PFM#2 | DD/MM/YYYY | DD/MM/YYYY |
| | | | | Add foundation depth drilling and sampling | DD/MM/YYYY | DD/MM/YYYY |
| 12 | Concentrated Leak Erosion *along* the Conduit | **High** | Poor | Same Actions as PFM#2 | DD/MM/YYYY | DD/MM/YYYY |
| 13 | Concentrated Leak Erosion *into* the Conduit | **Moderate** | Medium to Strong | Drain the reservoir to investigate the air vent connection(s) | DD/MM/YYYY | DD/MM/YYYY |
| | | | | Perform internal inspection of the outlet to confirm condition<br>• With storage to confirm leakage into/out of conduit<br>• Without storage to observe dewatered dry conduit | DD/MM/YYYY | DD/MM/YYYY |
| 15 | Overtopping | **High** | Poor | Perform hydrology study to determine IDF and spillway adequacy. | DD/MM/YYYY | DD/MM/YYYY |
| 26 | Outlet Gate(s) Fail to Open | **High** | Medium to Strong | Drain the reservoir and investigate the condition of the hydraulic controls. Decide whether to repair or replace. | DD/MM/YYYY | DD/MM/YYYY |

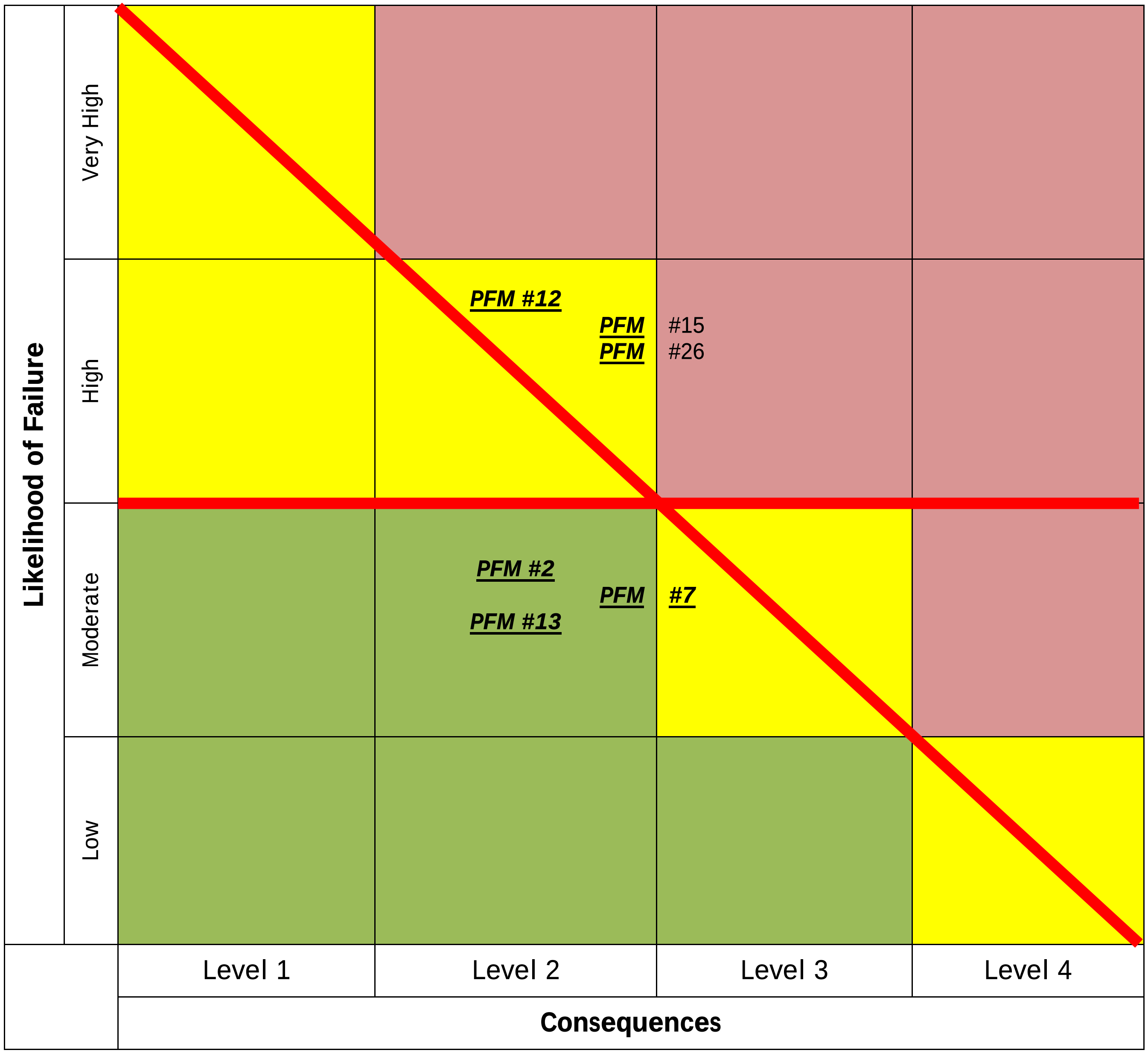
[1] Potential Failure Modes judged Very High, High, Moderate Likelihood require actionable items to reduce probability of failure and reduce consequences associated with that Potential Failure Mode. Actions for Very High, High, and Moderate likelihood will be tracked until the PFM's fall into the Low or Remote category.

## 3.3. Non-Risk Driving Potential Failure Modes Summary Table[2]

| PFM # | PFM Name | Likelihood | Confidence | Actions |
|---|---|---|---|---|
| 3 | Contact Erosion through Embankment | | Poor | • Pursue this PFM after geotechnical investigation and only if PFM#2 likelihood and confidence increases. |
| 4 | Suffusion/Suffosion through Embankment | | Poor | • Pursue this PFM if geotechnical investigation likelihood supports PFM as credible. |
| 14 | Concentrated Leak Erosion out of Conduit | | Poor | • Pursue this PFM only if internal inspection of outlet supports PFM as credible. |
| 18 | Reservoir Landslide/Seiche Leading to Overtopping | | Poor | • Geological site and seismic evaluations needed. Pursue only if future analysis supports PFM as credible. |
| 19 | Rise in Phreatic Level Causes Deformations that Exceed Freeboard | | Poor | • Static slope stability evaluation required for High hazard dam. Pursue this PFM if geotechnical investigation likelihood supports PFM as credible. |
| 20 | Slump Reduces Seepage Path Leading to Internal Erosion | | Poor | • Static slope stability evaluation required for High hazard dam. Pursue this PFM if geotechnical investigation likelihood supports PFM as credible. |
| 21 | Rapid Drawdown Failure of Upstream Slope | | Poor | • Pursue this PFM if geotechnical investigation likelihood supports PFM as credible. |
| 22 | Dynamic Deformation Greater than Freeboard | | Poor | • Seismic evaluation required for High hazard dam. Pursue this PFM if geotechnical investigation likelihood supports PFM as credible |
| 23 | Differential Settlement Leads to Transverse Cracking | | Poor | • Seismic evaluation required for High hazard dam. Pursue this PFM if geotechnical investigation likelihood supports PFM as credible |

[2] PFM's judged Low or Remote may require inspection & monitoring as part of normal dam safety and operations routines.

## 3.4. Risk Chart Summary



# 4. DAM FAILURE CONSEQUENCES & PREPAREDNESS

## 4.1. Summary of Consequences Estimation[3]

### 4.1.1. *Seepage-Induced ("Sunny Day") Dam Breach Analysis*

| Item | Description |
|---:|---|
| Dam & Reservoir Parameters | See file memo "Hazard Classification Review" dated December 14, 2015 |
| Breach Estimation Methodology | Froehlich, 2008 |
| Breach Parameters | Breach bottom width, Hb = 23.2 ft<br>1H:1V side slopes<br>Time to failure, tf = 0.31 ft<br>Initial water surface elevation at time of breach = 9,883 ft |
| $Q_p$ | 27,650 cfs just below dam. |
| Population At Risk (PAR) | <100 |
| Social Vulnerability Index (SVI) | - |

| ***Anticipated Infrastructure Impacts*** | | | |
|---|---|---|---|
| ***Infrastructure Description*** | ***Distance from Dam*** | ***Routed Peak Flow*** | ***Peak Arrival Time*** |
| See Inundation Mapping, 2015 | | | |
| | | | |

### 4.1.2. *Precipitation-Induced Dam Breach Analysis*

| Item | Description |
|---:|---|
| Dam & Reservoir Parameters | ***Precipitation-Induced dam breach map has not been developed*** |
| Breach Estimation Methodology | |
| Breach Parameters | |
| $Q_p$ | |
| Population At Risk (PAR) | |
| Social Vulnerability Index (SVI) | |

[3] Primary purpose at this time is to ensure evaluation of proper hazard classification and emergency preparedness. Decision statement does not directly consider consequences at this time.

| *Anticipated Infrastructure Impacts* | | | |
|---|---|---|---|
| ***Infrastructure Description*** | ***Distance from Dam*** | ***Routed Peak Flow*** | ***Arrival Time*** |
| See Inundation Mapping, 2015 | | | |
| | | | |

### 4.1.3. Life loss & Infrastructure Impacts Estimation by PFM

| PFM # | Life Loss Potential (PAR) | Estimated Infrastructure Impacts | Discussion of Warning Time | Level |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

## 4.2. Summary of Emergency Preparedness

| Item | Description | Comments |
|---|---|---|
| ***Document Date & Description*** | | |
| Format | Owners EAP Format, dated January 2015 | Acceptable |
| Inundation Mapping | Yes, included in EAP | Good |
| Contact information | Up to date in EAP | Acceptable |
| Exercise Frequency | No known EAP exercise | |
| ***Site access during emergency*** | | |
| Roads | Seasonal; Closed in winter | |
| Equipment access | Seasonal; Heavy Equipment access from FS Road | |
| Accessible during spillway/outlet operation | The dam and outlet works at cutoff from the main access route during spillway operation. Access to the dam would be difficult during high flows. | |
| ***Security*** | | |
| General site security | Dam is located on Forest Service land; Public Access area | |
| Outlet operators | Offsite; City of Grand Junction Public Works | |
| ***Emergency Supplies*** | | |
| Materials Availability | | |
| Equipment Availability | | |

# 5. KEY CONCLUSIONS & RISK REDUCTION

### 5.1. Summary of Key Risk Factors

| Risk Factor | Description | PFM # | Confidence |
|---|---|---|---|
| ***Hydrologic*** | | | |
| Flood Potential (rain depth/duration, %PMP, flood frequency, etc) | No hydrology studies in file.<br>Quotes from original 1947 Design Report:<br>• A flood with a frequency of once in 200 years was adopted for design of the spillway<br>• "…flow at the dam site would be about 1040 cfs…"<br>• It was also assumed in the design that, in addition to the peak flow tributary to the dam site, all of the small dams upstream failed, and their entire contents…passed the Hogchute Reservoir during a period of three hours".<br>• "…required capacity of approximately 4,500 cfs with a 2-foot freeboard, and a total capacity of 7,500 cfs before the dam would be overtopped."<br>Spillway stage-discharge contained in Table 3. | #15 | Poor.<br><br>No known hydrology study. |
| Geotechnical | | | |
| Foundation conditions | Eight (8) borehole logs contained on C-454, Sht 705-31<br>• Mixture of clay and clay with basalt boulders | #7 | Poor |
| Foundation treatment | • General construction specifications<br>• No record of construction | #7 | Poor |
| Embankment soils | Notes on C-454, Sht 705-31:<br>1. Zone 1 impervious fill of clay or clay, sand and gravel graded with coarser material on outer slopes and compacted in 6" layers.<br>2. Zone 2 cobble and rock fill graded with coarser material on outlet slopes. | #2 | |
| Settlement | No known settlement | - | |
| Slope Stability | • C-454 denotes grade break and bench on lower downstream slope.<br>• 2017 noted only slight grade break and no bench.<br>• No other mention of slope concerns in file history. | #19-23 | |
| Seepage | • Right abutment seepage and standing water behind headwall; uncertain if related or separate sources.<br>• Combined left and right toe drain with combined outfall along left side of discharge channel. | #1-11 | |
| Filter Compatibility | • Unknown | | |
| Other | | | |

| Risk Factor | Description | PFM # | Confidence |
|---|---|---|---|
| ***Seismic*** | | | |
| Peak Ground Acceleration (PGA): 2% in 50-YR (use PGA curve) USGS Geohazards Website | PGA = 0.1591g ; No known analysis | #22-23 | |
| Susceptibility to liquefaction (foundation soils, Freeboard) | unknown | | |
| ***Outlet Works*** | | | |
| Pressure flow? | No | #12-14 | |
| Concrete encasement / carrier pipe? | Concrete encased; placed in panels with reinforcement and construction joints. | | |
| Filter diaphragm or collar? | No known filter diaphragm | | |
| Anti-seep collars | Yes, six (6) collars, 1-ft thick, 30-inch all around outlet pipe concrete encasement with asphalt expansion joint filler all around. | | |
| Conduit material | 30-inch I.D. 5-16" welded steel pipe | | |
| Water-tight joints | Specifications call for coal tar coating at all welded joints. | | |
| Valve location | Upstream | | |
| Trash rack? | Yes, concrete intake structure with trashrack. | | |
| Drawdown time | No known, but could be estimated. | | |
| Gates exercised regularly thru full cycle? | No, but both gates exercised through full cycle in 2013 | | |
| Other | | | |
| ***Spillway*** | | | |
| Record Flow | Unknown | | |
| Erosion potential | Earthen channel with some erosion observed. | | |
| Mechanical gates or fuse plug? | No | | |
| Slope failure/landslide susceptibility? | Unlikely | | |
| ***Reservoir Operations*** | | | |
| Normal Seasonal Reservoir Operations | Unknown | | |

| Risk Factor | Description | PFM # | Confidence |
|---|---|---|---|
| Record Pool | Generally fills and spills annually | | |
| Caretaker on site? | No, but weekly site visits during the irrigation year | | |
| Regular owner inspections? | Yes, through normal operations. | | |
| ***Emergency Preparedness*** | | | |
| EAP current? | Yes, 2015 | | |
| Inundation mapping current? | Yes, 2015 | | |
| EAP exercised? | No | | |
| Other | | | |

## 5.2. Risk Reduction Actions[4]

### 5.2.1. *Dam Failure Likelihood Reduction Actions*[5]

| PFM # | Required Action | Action Level/Threshold |
|---|---|---|
| 2, 7, and 12 | Retain an engineer to:<br>SEEPAGE<br>• Oversee seepage investigation; attempt to trace and isolate source(s) of seepage.<br>• Find and asses condition of toe drain outfall from left side of outlet headwall.<br>GEOTECHNICAL<br>• Drilling and sampling program to support PFM likelihood and confidence | Develop plan to meeting Action Dates in Table 3.2 |
| 13, 26 | OUTLET WORKS<br>• Drain the reservoir to investigate air vent connection(s) and condition of outlet gates.<br>• Perform internal inspection of outlet pipe. | Benefit of engineering oversight, but not required. |
| 15 | Retain an engineer to perform a spillway hydrologic adequacy study. | Develop plan to meeting Action Dates in Table 3.2 |
| 19-23 | Retain an engineer to perform a thorough geotechnical investigation and analysis of the existing embankment, including but not limited to:<br>• Drilling and sampling program<br>• Static and seismic slope stability evaluation | Develop plan to meeting Action Dates in Table 3.2 |

### 5.2.2. *Consequence Reduction Actions*[6]

| PFM # | Required Action | Action Level/Threshold |
|---|---|---|
| | | |

[4] Based on PFMA. Actions and thresholds assigned to focus effort in future inspections.
[5] "Dam Failure Likelihood Reduction Actions" include any actions that target reducing the *likelihood* of a given PFM. When completed, the action should result in a lower value for a given PFM on the *Y-axis* of the Risk Chart (Table 3.4). Actions could be temporary or permanent and might include physical changes to the dam, reservoir operational changes, or information-gathering such as engineering investigations & analyses.
[6] "Consequence Reduction Actions" include any actions targeting reducing the *impacts or consequences* of a given PFM. When completed, the action should result in a lower value for a given PFM on the *X-axis* of the Risk Chart (Table 3.4). Actions could be temporary or permanent and might include EAP updates, identification of high flow condition warnings & thresholds, acquisition of construction materials or equipment for emergency responses, or improvements to site access.

## 5.3. Inspection & Monitoring Checklist[7]

| Required Inspection or Monitoring Action | Action Level/Threshold | PFM # |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

[7] Based on PFMA. Actions and thresholds assigned to focus effort in future inspections.

### 5.4. Summary of Operations & Maintenance Recommendations[8]

| Location | Concerns | Actions | Initial Date | Due Date |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

[8] Conditions observed that do not directly relate to a PFM, but could lead to dam safety concerns or expensive repairs if left unattended.

# Appendix A
# Worksheets for Developed PFMs

## 1. Worksheets for Risk-Driving PFM(s)

a. *PFM #2: Backwards Erosion Piping through Embankment*

| PFM Worksheet Template | | | | | |
|---|---|---|---|---|---|
| **PFM #** | 2 | **PFM Name** | Backwards Erosion Piping through Embankment | | |
| | | | | | |
| **PFM Executive Summary** | | | | | |
| **PFM Likelihood** | Moderate | Likelihood Definition | PFM Date | 06 February 2018 | |
| **Confidence** | Poor to Medium | Confidence Definition | PFM Participants | City of Grand Junction<br>Colorado Dam Safety | |
| **Consequences** | Level 2 | Consequence Definition | | | |

**PFM *Likelihood* Decision: Key Factor Summary Statement**

The key adverse factors of observed seepage at the downstream toe and lack of embankment soils and construction record lead the team to a likelihood of Moderate.

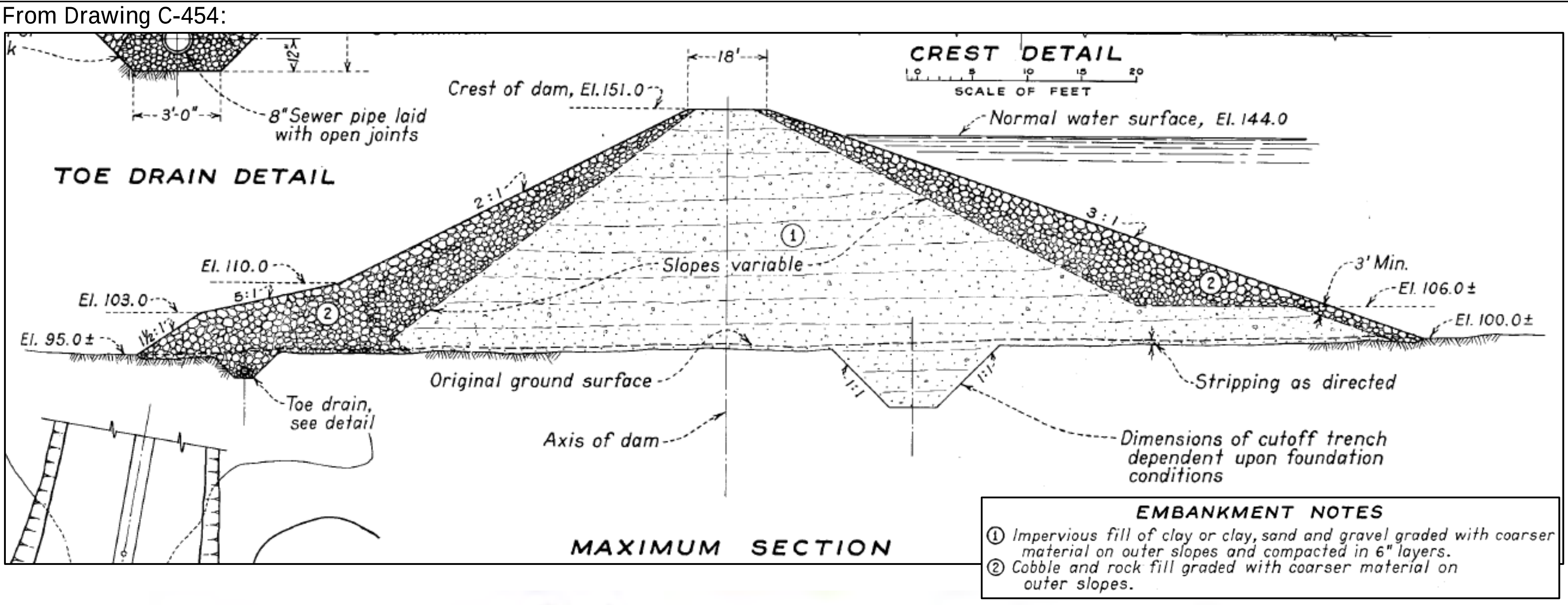
**PFM *Confidence* Decision: Key Factor Summary Statement (list of possible further analysis or information to collect)**

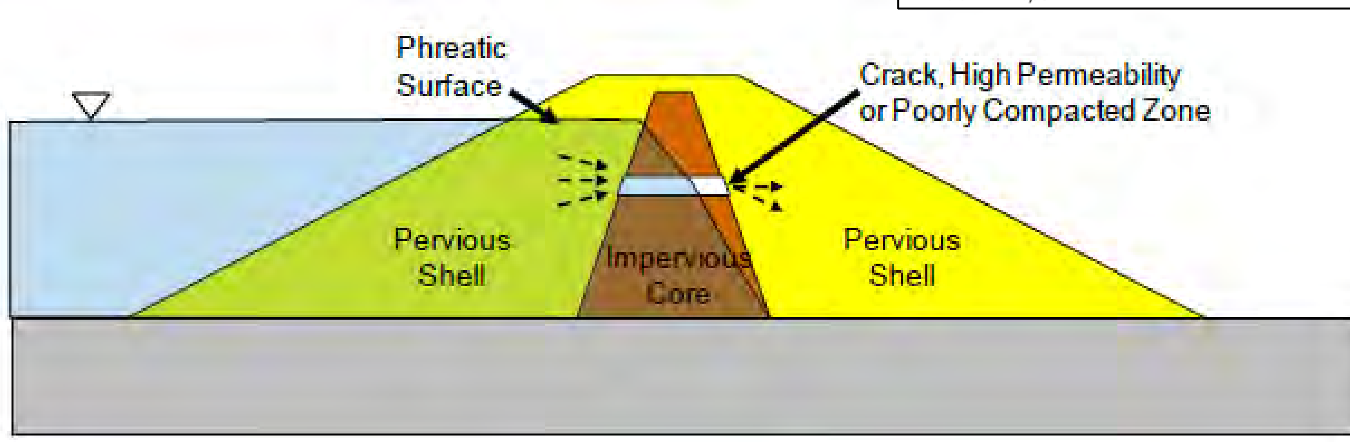
Poor to Medium. The source and cause of observed seepage at the downstream toe is unknown. There is benefit to collecting additional information to increase the confidence in this PFM as a credible failure mode. Additional information may include, but is not limited to:

- Seepage Investigation; attempt to trace and isolate source of seepage
- Geotechnical investigation included drilling, sampling, and soil index testing of Zone 1 material
- Piezometer installation in Zone 1
- Improve seepage collection and monitoring

**PFM Sketch**

From Drawing C-454:




**PFM Event Tree Description**

| PFM Suite: Internal Erosion through Embankment | |
|---|---|
| **PFM #2** | Backward Erosion Piping through Embankment |
| Initiation:<br>(flaw exists/seepage velocity is high enough to erode material) | • Reservoir level rises to Normal Storage level at Spillway Crest[1].<br>• A low plasticity layer exists through the Zone 1 embankment core.<br>• Increased seepage develops through the Zone 1 core[2].<br>• Seepage exit gradient and resulting velocity of flow through the low plasticity layer[2] is sufficient to erode embankment material. |
| Continuation:<br>(unfiltered exit) | • No effective filter is present to prevent removal of eroded material.<br>• Eroded material exits at interface between Zone 1 core and Zone 2 rock/cobble shell[3]. |
| Progression:<br>(roof/sidewalls support the flaw; no flow limiting; no self-healing) | • Erosion progresses, embankment materials are capable of holding a roof.<br>• No *features are present to restrict flow*[4] through the *defect*[2], which allows the defect to enlarge.<br>• There is no *self-healing material*[5] in the upstream portion of the seepage path.<br>• Erosion pipe forms and progresses toward the upstream face, eventually reaching the reservoir. |
| Intervention: | • Developing failure mode is not detected, or if detected, intervention is unsuccessful. |
| Breach: | • Flow through the pipe increases, pipe enlarges.<br>• Uncontrolled release of the reservoir occurs due to gross. enlargement of pipe or collapse of crest above pipe sufficient for water to flow over the embankment.<br>• Embankment erodes down to *stream level*[6].<br>• Downstream consequences result. |

[1] Define a threshold reservoir level below which it is judged that there is insufficient head to initiate the internal erosion. Alternatively, define this as the normal annual maximum pool or a flood pool (if flood load is being considered separately).

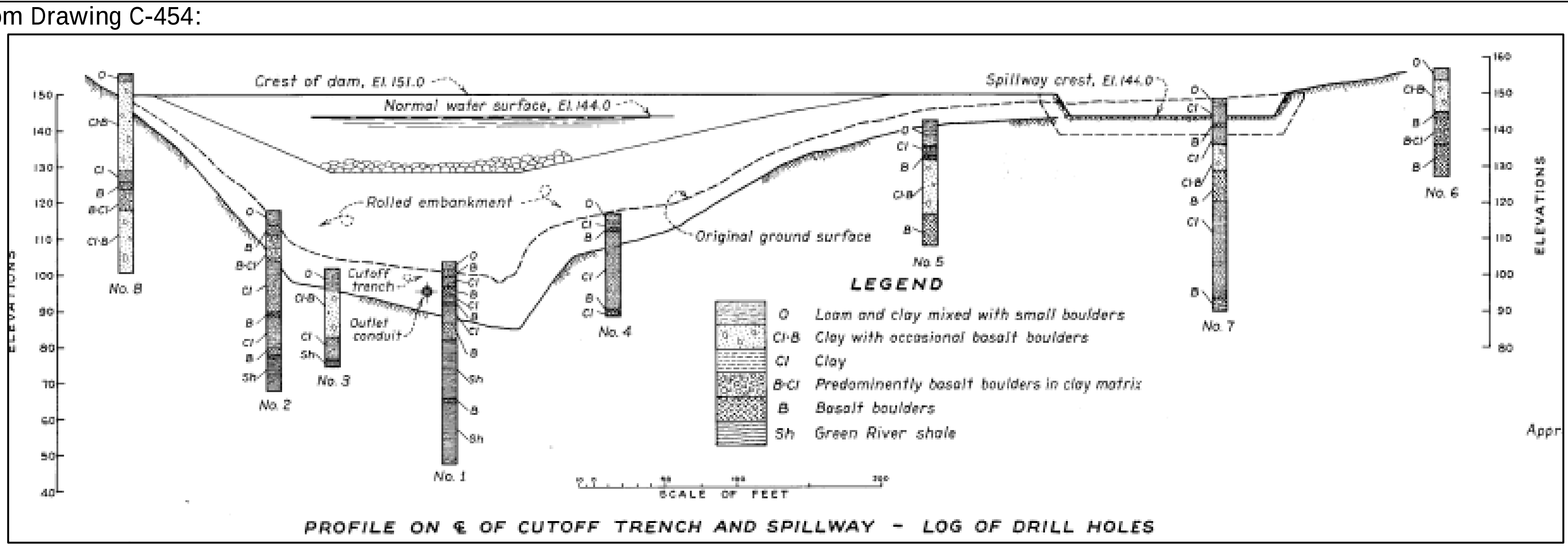
| |
|---|
| [2] Define the defect as specifically as possible. Example defects that may initiate Backward Erosion Piping include:<br>o a continuous, low plasticity (PI<7) layer or zone through the core, dispersive soil<br>[3] Indicate proximity of suspected exit location of defect if known.<br>[4] Flow limiters are natural or manmade, non-erodible features within an embankment that would prevent gross enlargement of a developing pipe, such as a cutoff wall.<br>[5] Specify any self-healing characteristic or feature, if present, that would need to be ineffective. Crackstopper zones in embankments may be an engineered cohesionless, filter-like material upstream of the core, or a granular upstream shell that is fine-grained enough to flow into pipe. Self-healing can also occur due to filter gradation of eroding material relative to gradation of filtering material (see "some erosion" boundary per Foster and Fell, 2001) or size of defect.<br>5 The bottom of the breach may be different from stream level depending on particular circumstances; adjust as necessary. |

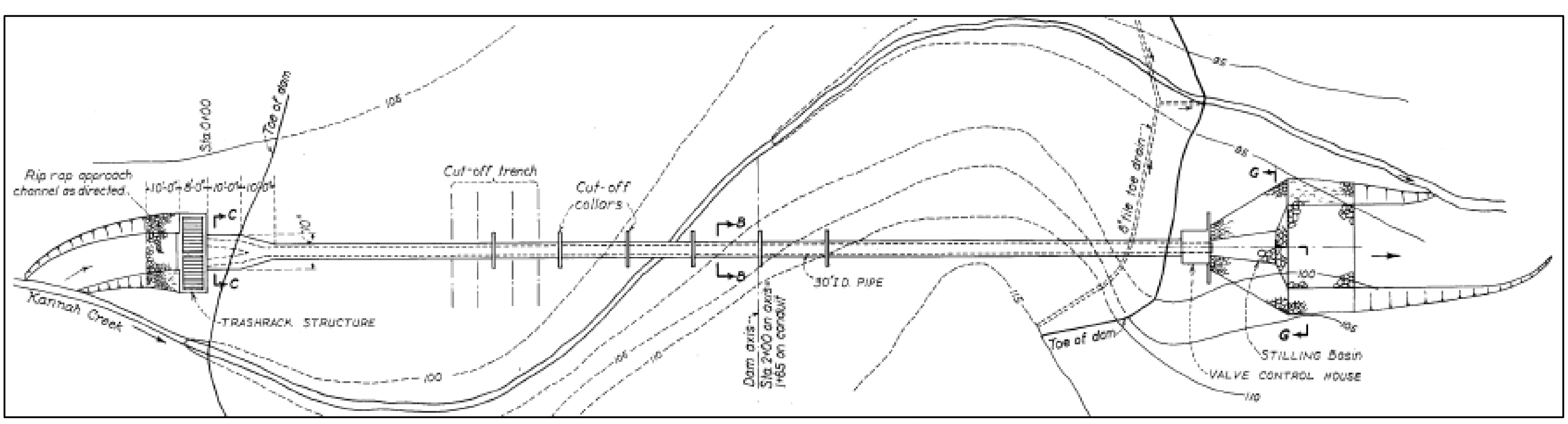
| PFM #2 Internal Erosion through Embankment Factors | | |
|---|---|---|
| **Event Tree Node** | **Adverse Factors (PFM More Likely to Occur)** | **Positive Factors (PFM Less Likely to Occur)** |
| Initiation | • Reservoir fills annually to normal storage level at crest of emergency spillway.<br>• Seepage flow observed at downstream toe<br>• Zone 1 material described in C-454 as "impervious fill of clay or clay, sand and gravel" could potentially have layer of low plasticity soil.<br>• | • Full storage historically not held for long period (possibly not long enough for steady state phreatic surface to develop).<br>• The intent of Zone 1 construction was "impervious fill".<br>• Seepage always observed clear. |
| Continuation | • No filter incorporated into original design. | • Zone 2 could be filter compatible with Zone 1 core. |
| Progression | • Zone 1 on upstream slope difficult to inspect for sinkholes and seepage entry points (because overlain by Zone 2).<br>• Unknown if Zone 1 could support a roof (soil classification, PI, etc.)<br>• Unknown thickness and gradation of Zone 2. | • Zone 2 could potentially be flow limiting.<br>• |
| Intervention | • Dam is remote; no continuous monitoring | • Public access<br>• City of Grand Junction routine inspections. |
| Breach | • Breach occurs. | • Zone 2 shells could potentially prevent full breach of dam |

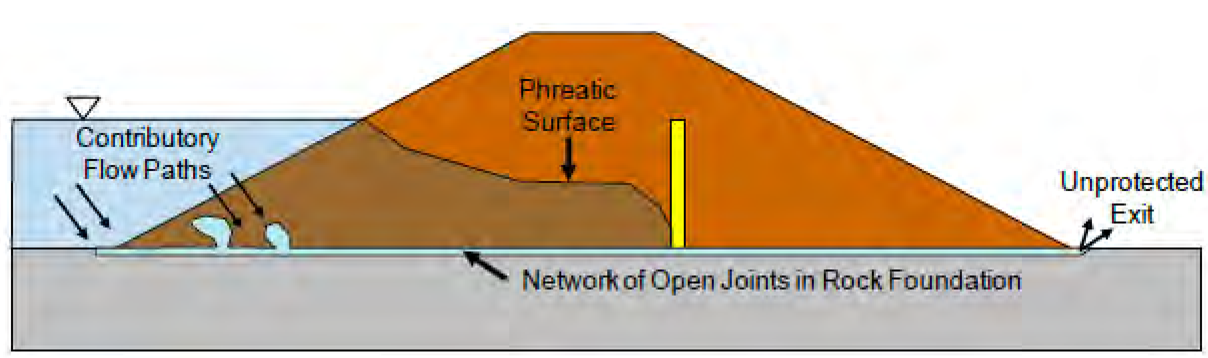
*b. PFM #7: Contact Erosion through Foundation*

| PFM Worksheet Template | | | | |
|---|---|---|---|---|
| **PFM #** | 7 | **PFM Name** | Contact Erosion through Foundation | |
| | | | | |
| **PFM Executive Summary** | | | | |
| **PFM Likelihood** | Moderate | Likelihood Definition | PFM Date | 06 February 2018 |
| **Confidence** | Poor to Medium | Confidence Definition | PFM Participants | City of Grand Junction |
| **Consequences** | Level 2 or 3 | Consequence Definition | | Colorado Dam Safety |
| **PFM *Likelihood* Decision: Key Factor Summary Statement** | | | | |
| The key adverse factors of observed seepage at the downstream toe and lack of embankment soils and construction record lead the team to a likelihood of Moderate. | | | | |
| **PFM *Confidence* Decision: Key Factor Summary Statement (list of possible further analysis or information to collect)** | | | | |
| Poor to Medium. The source and cause of observed seepage at the downstream toe is unknown. There is benefit to collecting additional information to increase the confidence in this as a credible failure mode. Additional information may include, but is not limited to:<br>• Seepage Investigation; attempt to trace and isolate source of seepage<br>• Geotechnical investigation included drilling, sampling, and soil index testing of Zone 1 material<br>o Include foundation depth drilling and sampling for this PFM<br>• Piezometer installation in Zone 1<br>• Improve seepage collection and monitoring | | | | |
| **PFM Sketch** | | | | |

From Drawing C-454:




**PFM Event Tree Description**

| PFM Suite: Internal Erosion through Foundation | |
|---|---|
| **PFM # 7** | Contact Erosion through Foundation |
| Initiation:<br><br>(flaw exists/seepage velocity is high enough to erode material) | • Reservoir level rises to Normal Storage level at Spillway Crest[1].<br>• *A defect*[2] exists through the foundation: A zone of pervious foundation underlying Zone 1 embankment material<br>• Contact erosion develops *through/along* the *defect*[2].<br>• Seepage gradient *through/along* the *defect*[2] is sufficient to erode adjacent foundation material, given the *direction*[3] of the exiting seepage. Seepage is believed to exit horizontally at the downstream toe. |
| Continuation:<br><br>(unfiltered exit) | • No effective filter is present to prevent removal of eroded material.<br>• Eroded material exits at the downstream toe *behind the outlet headwall and from the right abutment*[4]. |
| Progression:<br><br>(roof/sidewalls support the flaw; no flow limiting; no self-healing) | • Erosion progresses, *foundation*[5] materials are capable of holding a roof.<br>• No *features are present to restrict flow*[6] through the *defect*[2], which allows the defect to enlarge. |

| | |
|---|---|
| | • There is no *self-healing material*[7] in the upstream portion of the scour/seepage path.<br>• Erosion pipe forms and progresses toward the upstream face, eventually reaching the reservoir. |
| Intervention: | • Developing failure mode is not detected, or if detected, intervention is unsuccessful. |
| Breach: | • Flow through the pipe increases, pipe enlarges.<br>• Embankment breaches due to gross enlargement of pipe or collapse of crest above pipe sufficient for water to flow over the embankment.<br>• Embankment erodes down to *stream level*[8].<br>• Downstream consequences result. |

[1] Define a threshold reservoir level below which it is judged that there is insufficient head to initiate the internal erosion. Alternatively, define this as the normal annual maximum pool or a flood pool (if flood load is being considered separately).
[2] Define the defect as specifically as possible. A defect may be a series or combination of several conditions required for initiation. Example defects that may initiate Contact Erosion include:
- Flow through pervious foundation layer underlying fine-grained confining layer
- Pervious foundation seepage path may be a system of high-porosity interconnected and open rock fractures, solution cavities, shallow open coarse material, or a fault system

[3] Consider whether the exit is vertical/up or horizontally out. It is easier to erode from a horizontal exit.
[4] Indicate proximity of suspected exit location of defect if known. Exit may be significantly downstream of dam
[5] Adjust roof supporting material as appropriate. May be a hard or cohesive foundation layer, overlying embankment, concrete slab beneath a structure, etc.
[6] Flow limiters are natural or manmade, non-erodible features within the foundation that would prevent gross enlargement of a developing pipe, such as a cutoff wall, bedrock or hardpan features, size of fractures, etc.
[7] Specify any self-healing characteristic or feature, if present, that would need to be ineffective. Crackstopper zones in foundation may be an engineered cohesionless, filter-like material overlying the foundation (upstream of core), or a granular upstream shell that is fine-grained enough to flow into pipe. Self-healing can also occur due to filter gradation of eroding material relative to gradation of filtering material or size of defect.
[8] The bottom of the breach may be different from stream level depending on particular circumstances; adjust as necessary.

**PFM #7 Contact Erosion through Foundation Factors**

| Event Tree Node | Adverse Factors (PFM More Likely to Occur) | Positive Factors (PFM Less Likely to Occur) |
|---|---|---|
| Initiation | • Reservoir fills annually to normal storage level at crest of emergency spillway.<br>• Seepage flow observed at downstream toe<br>• Foundation drill logs in C-454 show possible pervious layers (Predominantly basalt boulders in clay matrix, B-Cl, for instance)<br>• Original stream channel meanders through foundation<br>• Horizontal gradient *is sufficient* to erode adjacent material?<br>  o Avg gradient, i = 45/300 = 0.15 | • Full storage historically not held for long period (not long enough for steady state phreatic surface to develop).<br>• The intent of Zone 1 construction was "impervious fill".<br>• Seepage always observed clear<br>• Construction Specifications for foundation preparation (although generally generic)<br>• Cut-off trench could cutoff or lengthen seepage path<br>• Horizontal gradient *is not sufficient* to erode adjacent material? |
| Continuation | • No filter incorporated into original design. | • Zone 2 shell could be filter compatible Zone 1 core?<br>• Toe drain exists at downstream toe |
| Progression | • Zone 1 on upstream slope difficult to inspect for sinkholes and seepage entry points.<br>• Unknown thickness and gradation of Zone 2.<br>• Unknown if Zone 1 could support a roof (soil classification, PI, etc.) | • Zone 2 likely flow limiting.<br>• |
| Intervention | • Dam is remote; no continuous monitoring | • Public access<br>• City of Grand Junction routine inspections. |
| Breach | • Breach occurs. | • Zone 2 shells could potentially prevent full breach of dam |

c. *PFM #12: Internal Erosion Along the Conduit*

| PFM Worksheet Template | | | |
|---|---|---|---|
| **PFM #** | 12 | **PFM Name** | Internal Erosion *Along* the Conduit |

**PFM Executive Summary**

| | | | | |
|---|---|---|---|---|
| **PFM Likelihood** | High | Likelihood Definition | PFM Date | 06 February 2018 |
| **Confidence** | Poor | Confidence Definition | PFM Participants | City of Grand Junction<br>Colorado Dam Safety |
| **Consequences** | Level 2 | Consequence Definition | | |

**PFM *Likelihood* Decision: Key Factor Summary Statement**

The key adverse factors of observed seepage at the downstream toe and known potential defects around embedded conduit without the benefit of a filtered seepage exit lead the team to a likelihood of High.

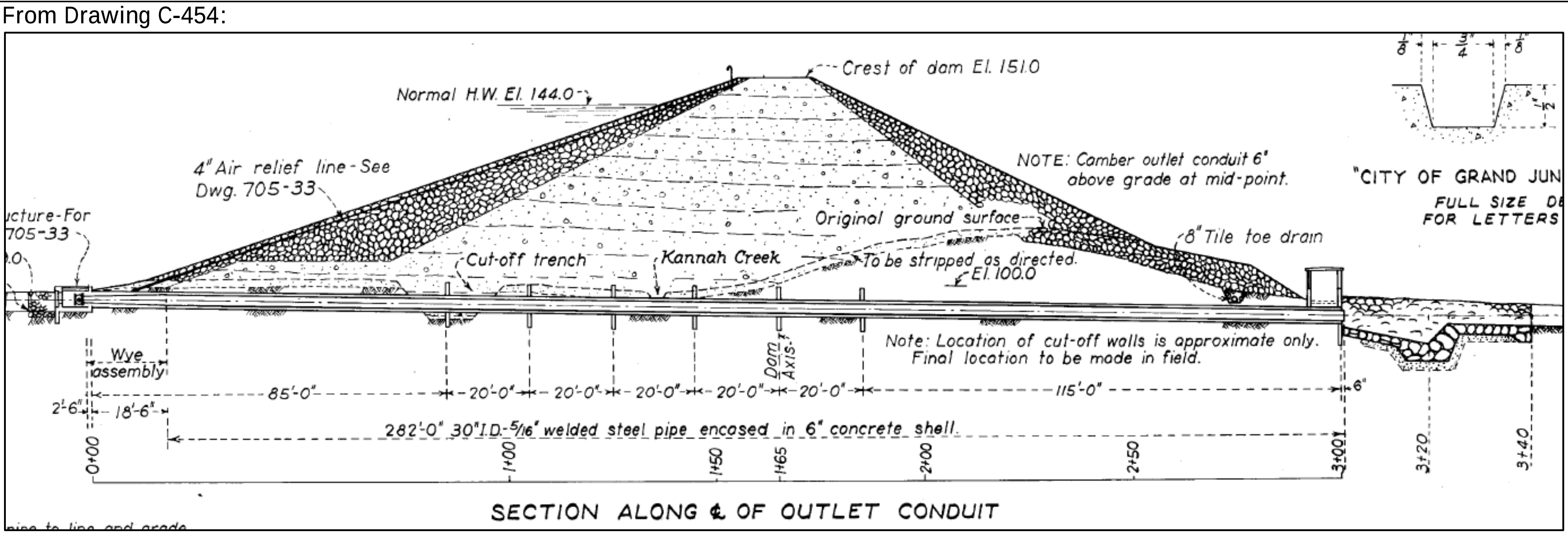
**PFM *Confidence* Decision: Key Factor Summary Statement (list of possible further analysis or information to collect)**

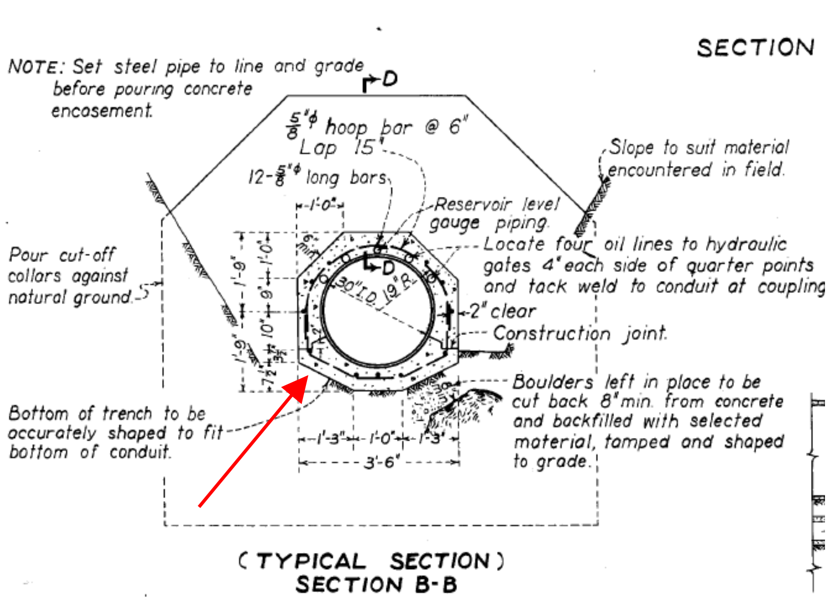
Poor. The source and cause of observed seepage at the downstream toe is unknown. There is benefit to collecting additional information to increase the confidence in this as a credible failure mode. Additional information may include, but is not limited to:

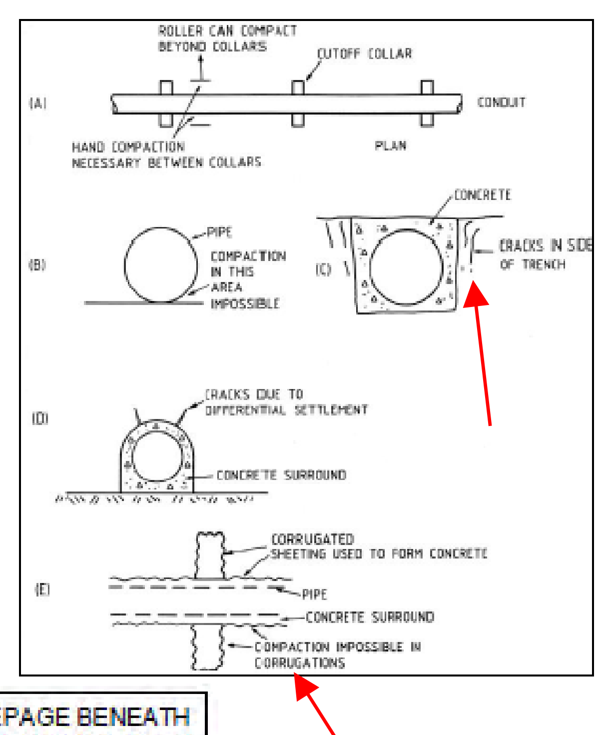
- Seepage Investigation; attempt to trace and isolate source of seepage
- Geotechnical investigation included drilling, sampling, and soil index testing of Zone 1 material
- Piezometer installation in Zone 1
- Improve seepage collection and monitoring

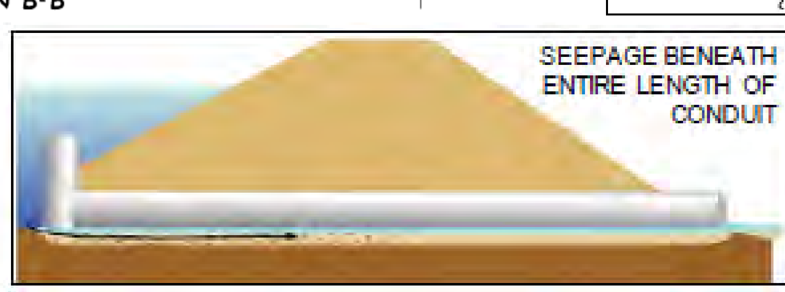
**PFM Sketch**

From Drawing C-454:




**PFM Event Tree Description**

| PFM Title: Internal Erosion Along the Conduit | |
|---|---|
| **PFM #12** | Concentrated Leak Erosion or Backward Erosion Piping Along Conduit |
| Initiation:<br>(flaw exists/seepage velocity is high enough to erode material) | • Reservoir level rises Normal Storage level at Spillway Crest[1].<br>• The initial construction of the dam resulted in a *defect*[2] in the backfill along the entire length (i.e., continuous) of the contact with the outlet conduit leading to *concentrated leak erosion*[3] along the conduit.<br>• Seepage gradient and resulting velocity of flow is sufficient to erode backfill material along the conduit. |
| Continuation:<br>(unfiltered exit) | • No effective filter is present at the seepage exit to prevent removal of eroded material.<br>• Eroded material exits at the downstream toe *behind the outlet headwall and from the right abutment*[4]. |
| Progression: | • Erosion progresses, embankment materials are capable of holding a roof. |

| | | |
|---|---|---|
| (roof/sidewalls support the flaw; no flow limiting; no self-healing) | • No *features are present to restrict flow*[5] along the conduit, which allows the seepage path to enlarge.<br>• There is no *self-healing material*[6] in the upstream portion of the seepage path.<br>• Erosion pipe forms and progresses toward the upstream face, eventually reaching the reservoir. | |
| Intervention: | • Developing failure mode is not detected, or if detected, intervention is unsuccessful. | |
| Breach: | • Flow through the pipe increases, pipe enlarges.<br>• Uncontrolled release of the reservoir occurs due to gross enlargement of pipe or collapse of crest above pipe sufficient for water to flow over the embankment.<br>• Embankment erodes down to *stream level*[7].<br>• Downstream consequences result. | |

[1] Define a threshold reservoir level below which it is judged that there is insufficient head to initiate the internal erosion. Alternatively, define this as the normal annual maximum pool or a flood pool (if flood load is being considered separately).
[2] Examples of a defect along a conduit include a crack, void, or zone of low compaction density due to shape of conduit or presence and configuration of seepage collars (CONCENTRATED LEAK EROSION).
[3] This could in some cases be considered BACKWARD EROSION PIPING if there is a continuous zone of low plasticity, cohesionless, erodible soils/backfill along the conduit that is loose because of the above-described potential defects.
[4] Consider configuration of exit of seepage along a conduit. Open exit, horizontal/vertical exit, heave or blowout required?
[5] Flow limiters are natural or manmade, non-erodible features within the embankment or foundation that would prevent gross enlargement of a developing pipe, such as a cutoff wall, bedrock or hardpan features, grout curtain, size of fractures, etc.
[6] Specify any self-healing characteristic or feature, if present, that would need to be ineffective. Crackstopper zones in embankments may be an engineered cohesionless, filter-like material upstream of the core, or a granular upstream shell that is fine-grained enough to flow into pipe. Self-healing can also occur due to filter gradation of eroding material relative to size of defect.
[7] The bottom of the breach may be different from stream level depending on particular circumstances; adjust as necessary.

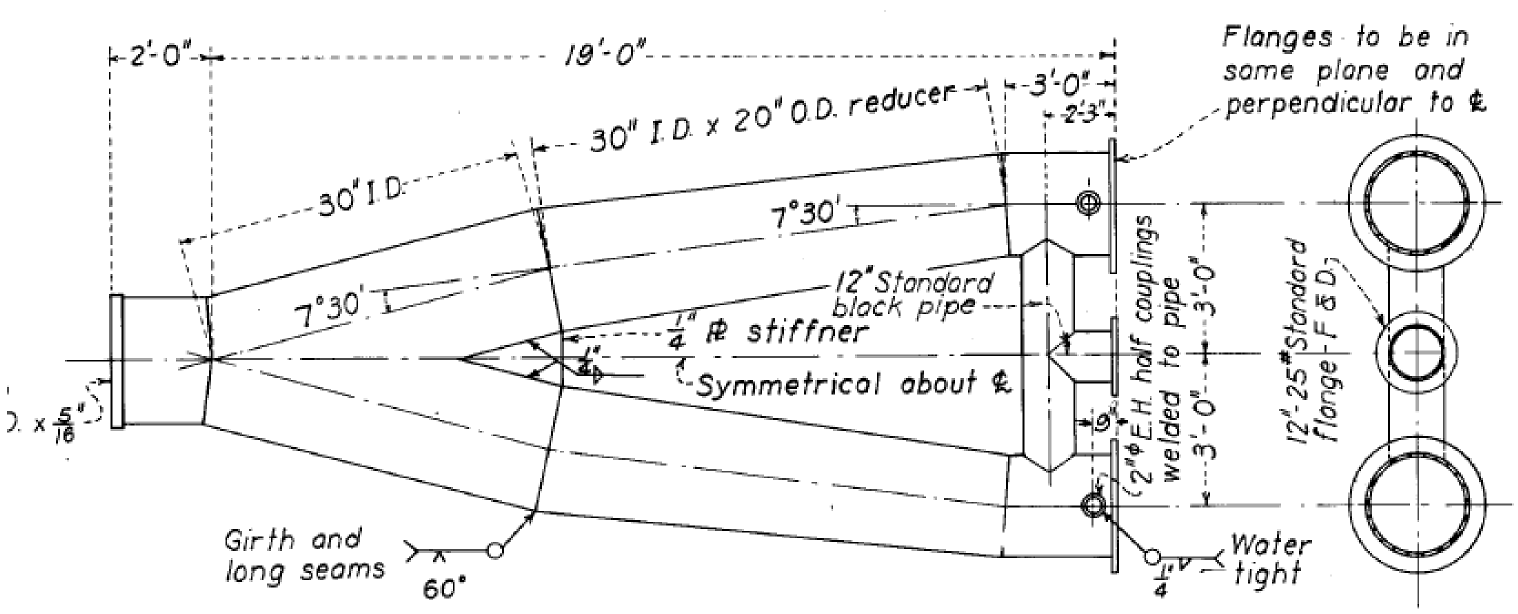
**PFM #12 Internal Erosion Along Conduit Factors**

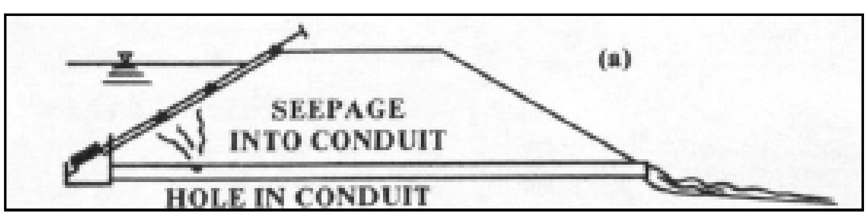
| Event Tree Node | Adverse Factors (PFM More Likely to Occur) | Positive Factors (PFM Less Likely to Occur) |
|---|---|---|
| Initiation | • Reservoir fills annually to normal storage level at crest of emergency spillway.<br>• Seepage flow observed at downstream toe<br>• Potentially poor compaction around cutoff collars (see red arrows above)<br>• Trench excavation low stress zones (see red arrows above)<br>• Unique shape of conduit concrete encasement (poor compaction, low stress/compaction zones)<br>• | • Full storage historically not held for long period (not long enough for steady state phreatic surface to develop).<br>• Intent of construction drawings and specifications was to cutoff seepage with cutoff collars<br>• Seepage always observed clear |
| Continuation | • No filter incorporated into original design. | • Zone 2 shell could be filter compatible Zone 1 core? |
| Progression | • Zone 1 on upstream slope difficult to inspect for sinkholes and seepage entry points.<br>• Unknown if Zone 1 could support a roof (soil classification, PI, etc.) | • Zone 2 likely flow limiting |
| Intervention | • Dam is remote; no continuous monitoring | • Public access<br>• City of Grand Junction routine inspections. |
| Breach | • Breach occurs. Full breach of dam likely associated with this PFM. | • |

d. *PFM #13: Internal Erosion Into the Conduit*

| PFM Worksheet Template | | | | |
|---|---|---|---|---|
| **PFM #** | 13 | **PFM Name** | Internal Erosion *Into* the Conduit | |
| | | | | |
| **PFM Executive Summary** | | | | |
| **PFM Likelihood** | Moderate | Likelihood Definition | PFM Date | 06 February 2018 |
| **Confidence** | Medium to Strong | Confidence Definition | PFM Participants | City of Grand Junction |
| **Consequences** | Level 2 | Consequence Definition | | Colorado Dam Safety |
| **PFM *Likelihood* Decision: Key Factor Summary Statement** | | | | |
| The key adverse factors of suspected/known air vent open joint discharging into the outlet conduit lead the team to a likelihood of Moderate: the fundamental condition or defect exists and the failure mode is plausible. | | | | |
| **PFM *Confidence* Decision: Key Factor Summary Statement (list of possible further analysis or information to collect)** | | | | |
| Medium to Strong. The source and cause of observed seepage at the downstream toe is unknown. There is benefit to collecting additional information to increase the confidence in this as a credible failure mode. Additional information may include, but is not limited to:<br>• Drain the reservoir to investigate the air vent connection(s)<br>• Perform internal inspection of the outlet to confirm condition<br>o With storage to confirm leakage into/out of conduit<br>o Without storage to observe dewatered dry conduit | | | | |
| **PFM Sketch** | | | | |

From Drawing C-454:




**PFM Event Tree Description**

| **PFM #13** | **PFM Title: Internal Erosion Into the Conduit[1]** |
|---|---|
| Initiation:<br>(flaw exists/seepage velocity is high enough to erode material) | • Reservoir level rises Normal Storage level at Spillway Crest[1].<br>• The *conduit*[1] has a *defect*[3]: Suspected/known air vent open joint.<br>• Seepage gradient and resulting velocity of flow is sufficient to initiate *scour or backward erosion piping*[4] of the embankment material into the conduit. |
| Continuation:<br>(unfiltered exit) | • No effective filter is present along the seepage path to prevent removal of eroded material.[5]<br>• Eroded material exits *into the conduit and transported to outlet channel.*[6]. |
| Progression:<br>(roof/sidewalls support the flaw; no flow limiting; no self-healing) | • Erosion progresses upstream, embankment materials are capable of holding a roof.<br>• No *features are present to restrict flow*[7] which allows the seepage path to enlarge.<br>• There is no *self-healing material*[8] in the upstream portion of the seepage path.<br>• Erosion pipe forms and progresses toward the upstream face[9], eventually reaching the reservoir. |
| Intervention: | • Developing failure mode is not detected, or if detected, intervention is unsuccessful. |
| Breach: | • Flow through the erosion pipe increases, pipe enlarges.<br>• Uncontrolled release of the reservoir occurs due to gross enlargement of erosion pipe or collapse of crest above erosion pipe sufficient for water to flow over the embankment.<br>• Embankment erodes down to *stream level*[10].<br>• Downstream consequences result. |

[1] Specify whether PFM is for erosion into an outlet conduit or drain pipe.
[2] Define a threshold reservoir level below which it is judged that there is insufficient head to initiate the internal erosion. Alternatively, define this as the normal annual maximum pool or a flood pool (if flood load is being considered separately).
[3] Examples of a defect along a conduit include a crack or open pipe joint. Examples of a defect along a drain include slots/perforations cut too large for surrounding soil, collapsed pipe, rusted holes, or open joints. Defect occurs at a location below the phreatic surface.
[4] Depending on the characteristics of the embankment material the erosion mechanism may either be backward erosion (for low plasticity, PI<7, soils) or scour for more plastic soils.

[5] Seepage into a conduit is rarely filtered; however, drain (perforated or slotted) pipes are usually constructed in a filter envelope.
[6] State location where seepage and eroded material may exit (within an impact basin, toe drain weir box, manhole/inspection well, or daylight exit [e.g. within a flowline]).
[7] Flow limiters are natural or manmade, non-erodible features within the embankment or foundation that would prevent gross enlargement of a developing pipe, such as a cutoff wall, bedrock or hardpan features, grout curtain, size of fractures, etc.
[8] Specify any self-healing characteristic or feature, if present, that would need to be ineffective. Crackstopper zones in embankments may be an engineered cohesionless, filter-like material upstream of the core, or a granular upstream shell that is fine-grained enough to flow into pipe. Self-healing can also occur due to filter gradation of eroding material relative to size of defect.
[9] Stoping (vertical erosion) may occur above the conduit/drain eventually creating a sinkhole in the downstream slope. For loss of reservoir, this PFM only considers erosion that progresses upstream intercepting the reservoir.
[10] The bottom of the breach may be different from stream level depending on particular circumstances; adjust as necessary.

**PFM #13 Internal Erosion Into Conduit Factors**

| Event Tree Node | Adverse Factors (PFM More Likely to Occur) | Positive Factors (PFM Less Likely to Occur) |
|---|---|---|
| Initiation | • Reservoir fills annually to normal storage level at crest of emergency spillway.<br>• Known air vent leakage into conduit from 2008 internal inspection video<br>• High gradient (full head) and contact with embankment Zone 1? | • Full storage historically not held for long period.<br>• No other known defects in conduit<br>• Conduit is encased in concrete<br>• 2008 Video inspection shows otherwise (other than air vent) acceptable condition of conduit<br>• High gradient (full head), but limited embankment coverage of air vent defect? |
| Continuation | • Contact with Zone 1 material? | • Little to no contact with Zone 1 material? |
| Progression | • Zone 1 on upstream slope difficult to inspect for sinkholes and seepage entry points. | • Air vent diameter (2-inches) flow limiting/restriction. |
| Intervention | • Dam is remote; no continuous monitoring | • Public access<br>• City of Grand Junction routine inspections. |
| Breach | • Breach occurs. Full breach of dam likely associated with this PFM? | • |

*e. PFM #15: Overtopping*

| PFM Worksheet Template | | | | |
|---|---|---|---|---|
| **PFM #** | 15 | **PFM Name** | Overtopping | |
| | | | | |
| **PFM Executive Summary** | | | | |
| **PFM Likelihood** | High | Likelihood Definition | PFM Date | 06 February 2018 |
| **Confidence** | Poor | Confidence Definition | PFM Participants | City of Grand Junction<br>Colorado Dam Safety |
| **Consequences** | Level 2 or 3 | Consequence Definition | | |

**PFM *Likelihood* Decision: Key Factor Summary Statement**

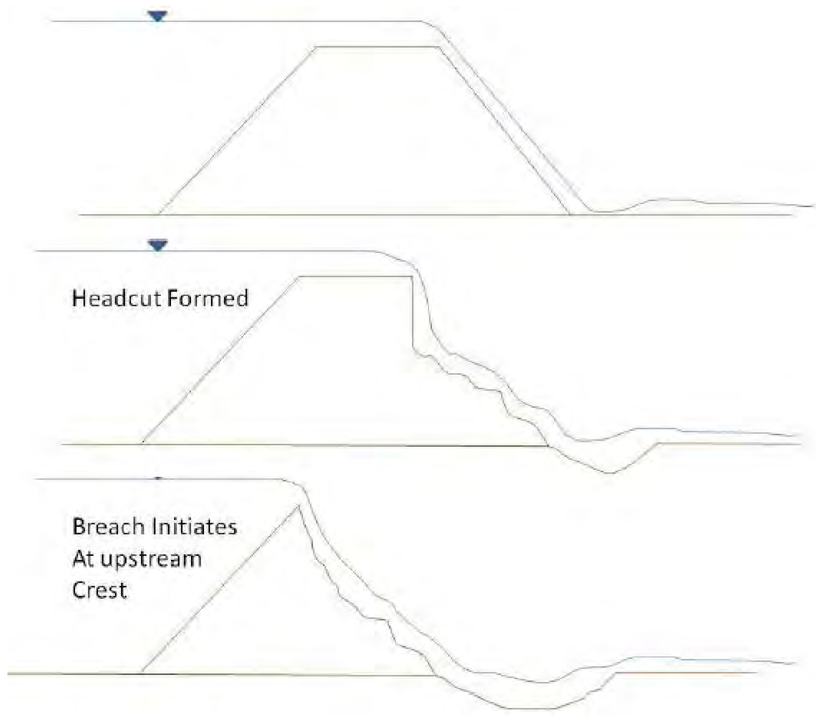
The key adverse factors of unknown inflow design flood (IDF) and spillway adequacy lead the team to a likelihood of High.

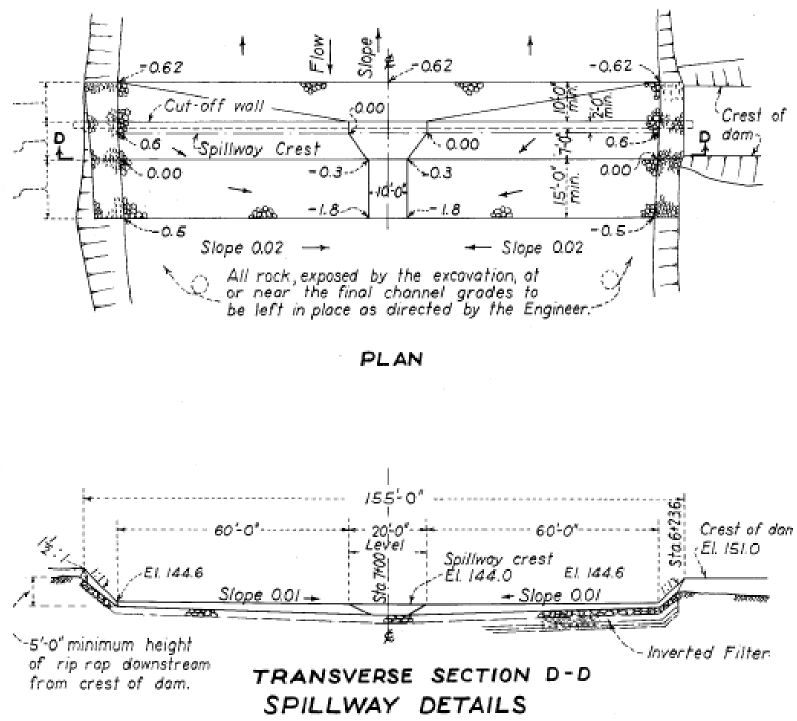
**PFM *Confidence* Decision: Key Factor Summary Statement (list of possible further analysis or information to collect)**

Poor. Benefit of performing a hydrology study to determine IDF and spillway adequacy.

**PFM Sketch**

From Drawing C-454:




**PFM Event Tree Description**

| PFM #15 | PFM Title: Overtopping |
|---|---|
| Initiation: | • A flood up to and including the Inflow Design Flood[1] occurs.<br>• Reservoir level rises to the *Spillway crest elevation 144.0 (per C-454)*[2].<br>• The *spillway capacity is exceeded*[3] and reservoir level rises to *Elevation 151 (per C-454)* [4] initiating overtopping of the *embankment/abutment*.<br>• Overflow duration, depth, and velocity cause erosion of the *downstream face/abutment* of the dam. |
| Continuation: | • The downstream portion of the dam is eroded by head-cutting from the downstream toe. |
| Progression: | • The duration of the flow is long enough to permit the erosion to progress upstream eventually eroding the crest. |
| Intervention: | • The overtopping is not observed; or if detected, methods to stop the overtopping and erosion are not deployed in time and as a result, intervention is unsuccessful. |
| Breach: | • Down-cutting of the embankment crest leads to breach by widening and deepening of the head-cut channel in the dam.<br>• Embankment erodes down to *stream level*[5].<br>• Downstream consequences result. |

[1] State what flood event is taken as the inflow design flood.
[2] Define spillway crest elevation. This may be a gated spillway or uncontrolled overflow.
[3] Example causes for exceeding spillway capacity include undersized spillway, debris blockage, misoperation, or failure of a gate hoist/chain/valve. Different PFMs may be warranted for different spillway capacity defects.
[4] Define lowest elevation at which point overtopping of the erodible portion of the embankment or abutment would occur.
[5] The bottom of the breach may be different from stream level depending on particular circumstances; adjust as necessary.

**PFM #15 Overtopping Factors**

| Event Tree Node | Adverse Factors (PFM More Likely to Occur) | Positive Factors (PFM Less Likely to Occur) |
|---|---|---|
| Initiation | • Reservoir fills annually to normal storage level at crest of emergency spillway.<br>• No known hydrology study; so IDF and spillway adequacy unknown. | • No evidence of full spillway flow in history of dam |
| Continuation | • Unknown thickness/gradation of Zone 2<br>• Is dam crest level in the event of overtopping? | • Armored Zone 2 downstream slope |
| Progression | • | • |

| | | |
|---|---|---|
| Intervention | • Dam is remote and overtopping may not be observed. | • Public access<br>• City of Grand Junction routine inspections.<br>• Routine NWS storm tracking nearby |
| Breach | • Breach occurs. | • Zone 2 shells could potentially prevent full breach of dam |

*f. PFM #26: Outlet Gate(s) Fail to Open*

| PFM Worksheet Template | | | | |
|---|---|---|---|---|
| **PFM #** | 26 | **PFM Name** | Outlet Gate(s) Fail to Open | |
| | | | | |
| **PFM Executive Summary** | | | | |
| **PFM Likelihood** | High | Likelihood Definition | PFM Date | 06 February 2018 |
| **Confidence** | Medium to Strong | Confidence Definition | PFM Participants | City of Grand Junction<br>Colorado Dam Safety |
| **Consequences** | Level 2 or 3 | Consequence Definition | | |

**PFM *Likelihood* Decision: Key Factor Summary Statement**

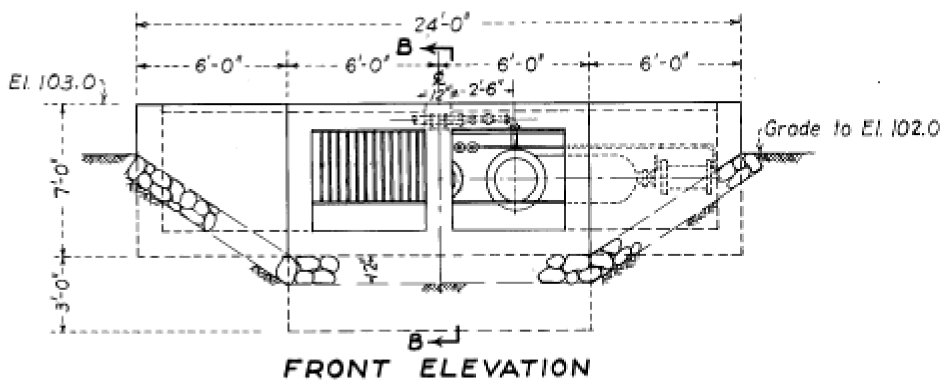
The key adverse factors of known concerns with reliability of the outlet gate(s) hydraulic controls and the potential for other PFMs to initiate with the inability to withdraw the reservoir lead the team to a likelihood of High.

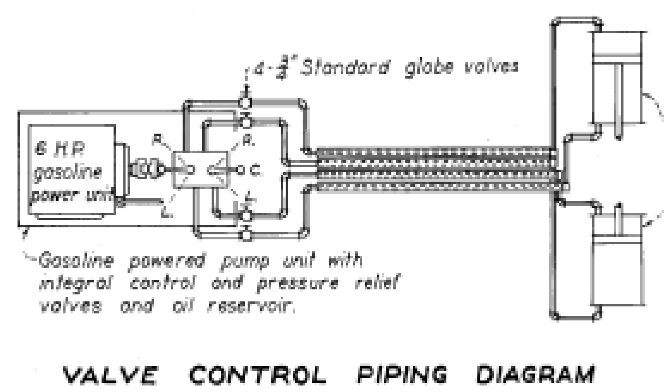
**PFM *Confidence* Decision: Key Factor Summary Statement (list of possible further analysis or information to collect)**

Medium to Strong. Potential benefit to drain the reservoir and investigate the condition of the hydraulic controls. Decide whether to repair or replace.

**PFM Sketch**

From Drawing C-454:




**PFM Event Tree Description**

| PFM #25 | PFM Title: Outlet Gate(s) Fail to Close |
|---|---|
| Initiation: | • Reservoir level rises to the *Spillway crest elevation*.<br>• The outlet gates fail to open.<br>• Other PFMs are initiated with reservoir at this elevation |
| Continuation: | • Repair of hydraulic operator in unsuccessful.<br>• Attempt to manually open the outlet gates is unsuccessful.<br>• Other PFMs continue. |
| Progression: | • Reservoir cannot be drawn down through the outlet conduit<br>• Progression of other PFMs cannot be mitigated by drawdown of the reservoir. |
| Intervention: | • Other means of drawing down the reservoir (pumps, siphons, divers, etc) are unsuccessful so intervention of other PFMs is unsuccessful. |
| Breach: | • Dam breaches by other PFMs.<br>• Embankment erodes down to *stream level*[5].<br>• Downstream consequences result. |
| [1]S | |

**PFM #26 Outlet Gate(s) Fail to Open Factors**

| Event Tree Node | Adverse Factors (PFM More Likely to Occur) | Positive Factors (PFM Less Likely to Occur) |
|---|---|---|
| Initiation | • Reservoir fills annually to normal storage level at crest of emergency spillway.<br>• Dependence on hydraulic operation; no manual override or operation.<br>• Unable to drawdown reservoir and prevent initiation of other PFMs<br>• Historic concerns with reliable operation of hydraulic controls. | • Redundant valves, so it is possible only one valve fails to open. |
| Continuation | • No known means to manually open gates. | • Diver could possibly manually operate bypass valve? |
| Progression | • Other PFMs progress without lowering of reservoir.<br>• | • |
| Intervention | • Time to mobilize and activate other means is likely slower than progression of other PFMs | • Slowly progressing PFMs could possibly be mitigated with pumping or siphoning of reservoir. |
| Breach | • Breach occurs. | • |

## 2. Worksheets for Non-Risk Driving PFMs

a. *PFM #3: Contact Erosion through Embankment*

<*Paste PFM Worksheets that were developed but identified as non-Risk driving as image*>

b. *PFM #4: Suffusion/Suffosion through Embankment*

<*Paste PFM Worksheets that were developed but identified as non-Risk driving as image*>

c. *PFM #14: Concentrated Leak Erosion out of Conduit*

<*Paste PFM Worksheets that were developed but identified as non-Risk driving as image*>

d. *PFM #18: Reservoir Landslide/Seiche Leading to Overtopping*

<*Paste PFM Worksheets that were developed but identified as non-Risk driving as image*>

e. *PFM #19: Rise in Phreatic Level Causes Deformations that Exceed Freeboard*

<*Paste PFM Worksheets that were developed but identified as non-Risk driving as image*>

f. *PFM #20: Slump Reduces Seepage Path Leading to Internal Erosion*

<*Paste PFM Worksheets that were developed but identified as non-Risk driving as image*>

g. *PFM #21: Rapid Drawdown Failure of Upstream Slope*

<*Paste PFM Worksheets that were developed but identified as non-Risk driving as image*>

h. *PFM #22: Dynamic Deformation Greater than Freeboard*

<*Paste PFM Worksheets that were developed but identified as non-Risk driving as image*>

i. *PFM #23: Differential Settlement Leads to Transverse Cracking*

# Appendix B
# Site Orientation Photographs


*Photo 1: Site map; 2016 aerial image*

*Photo 1:  View looking upstream at spillway crest, 12/11/2017*

*Photo 2: Upstream slope; Outlet hydraulics control building at center of dam on upstream edge of dam crest.*

*Photo 3: Downstream slope; Zone 2 material per C-454*


*Photo 4: Downstream outlet headwall.*

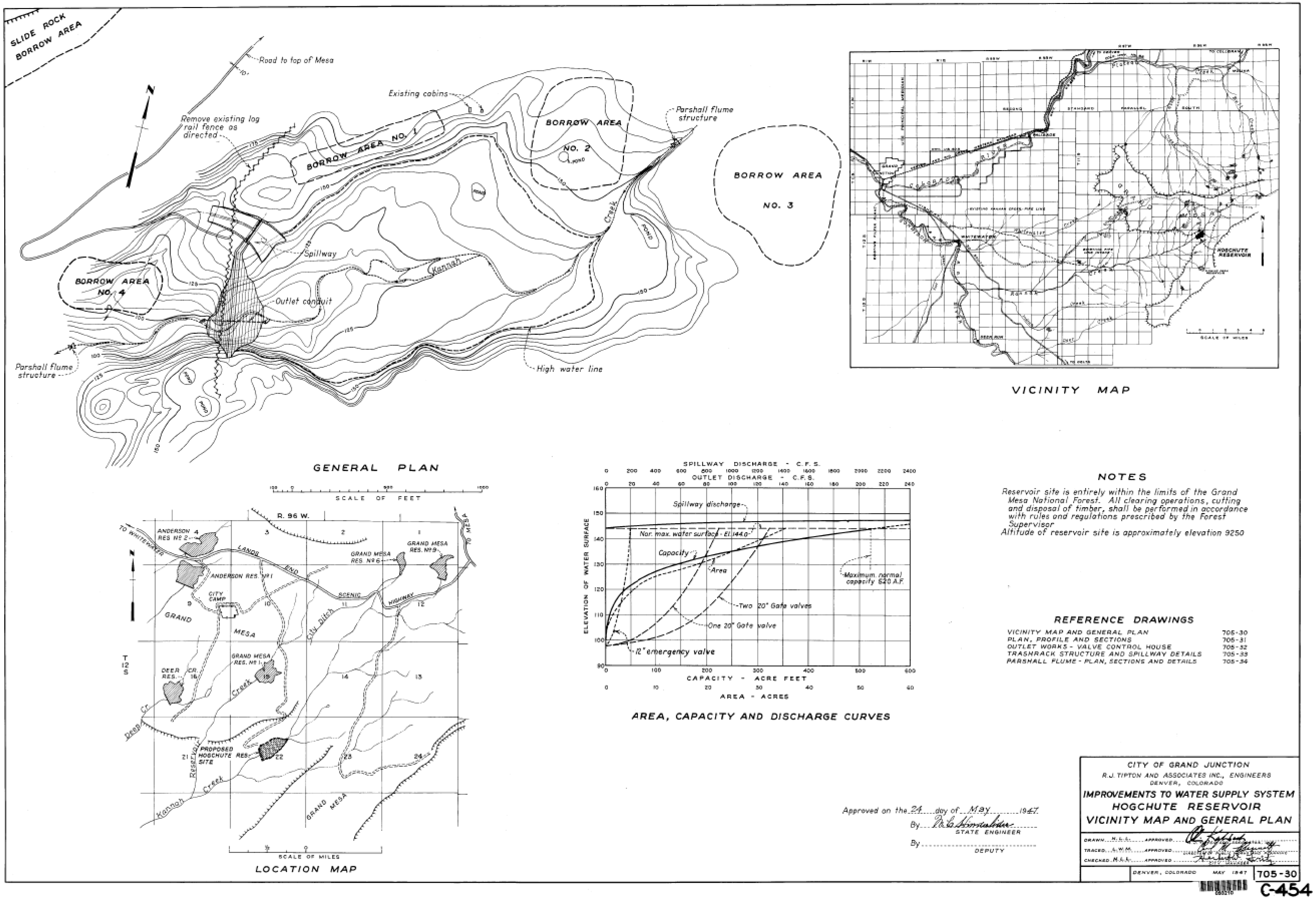
*Photo 5: Downstream outlet pipe headwall.*

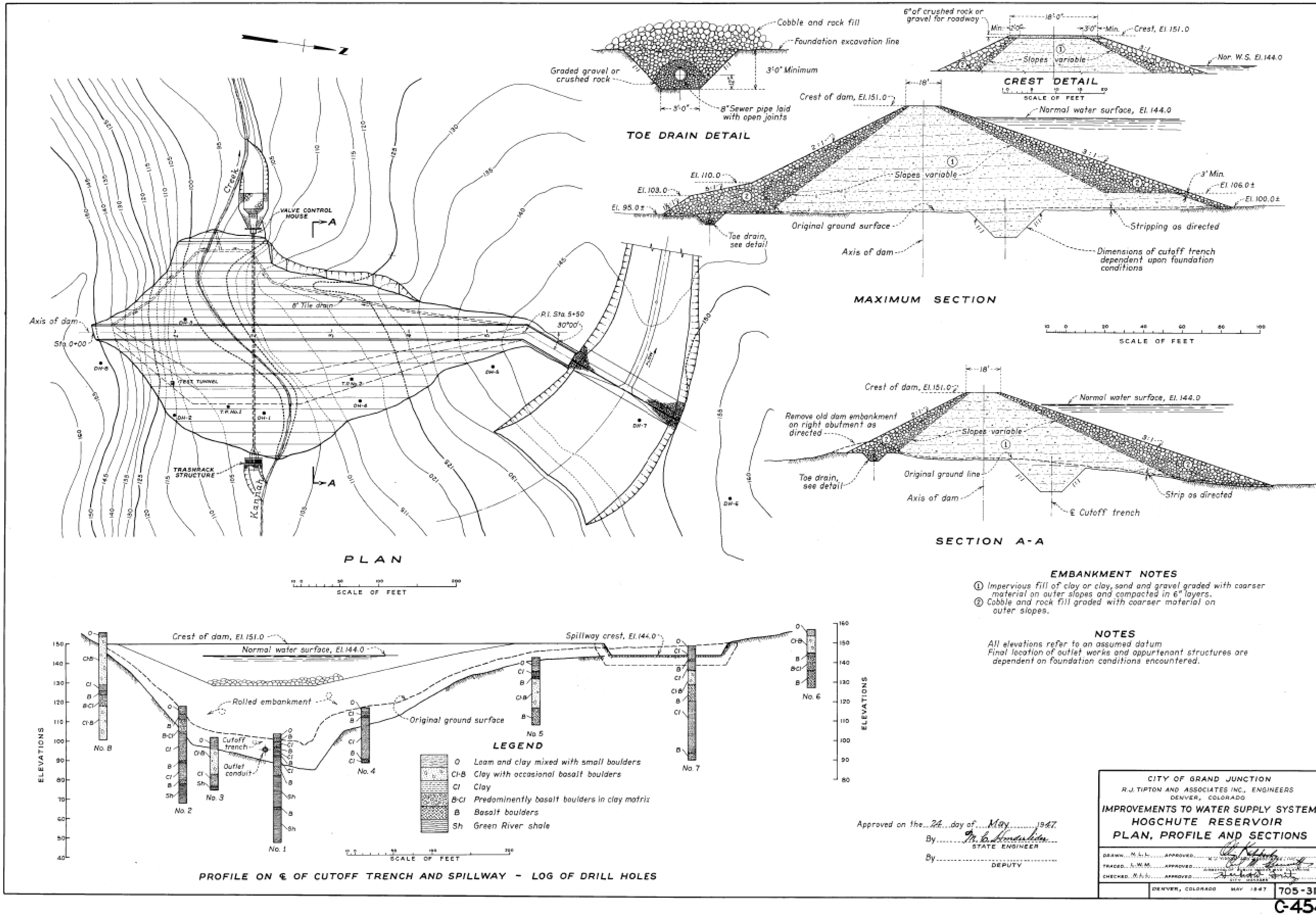
*Photo 6: Abandoned outlet hydraulics control building foundation behind headwall.*

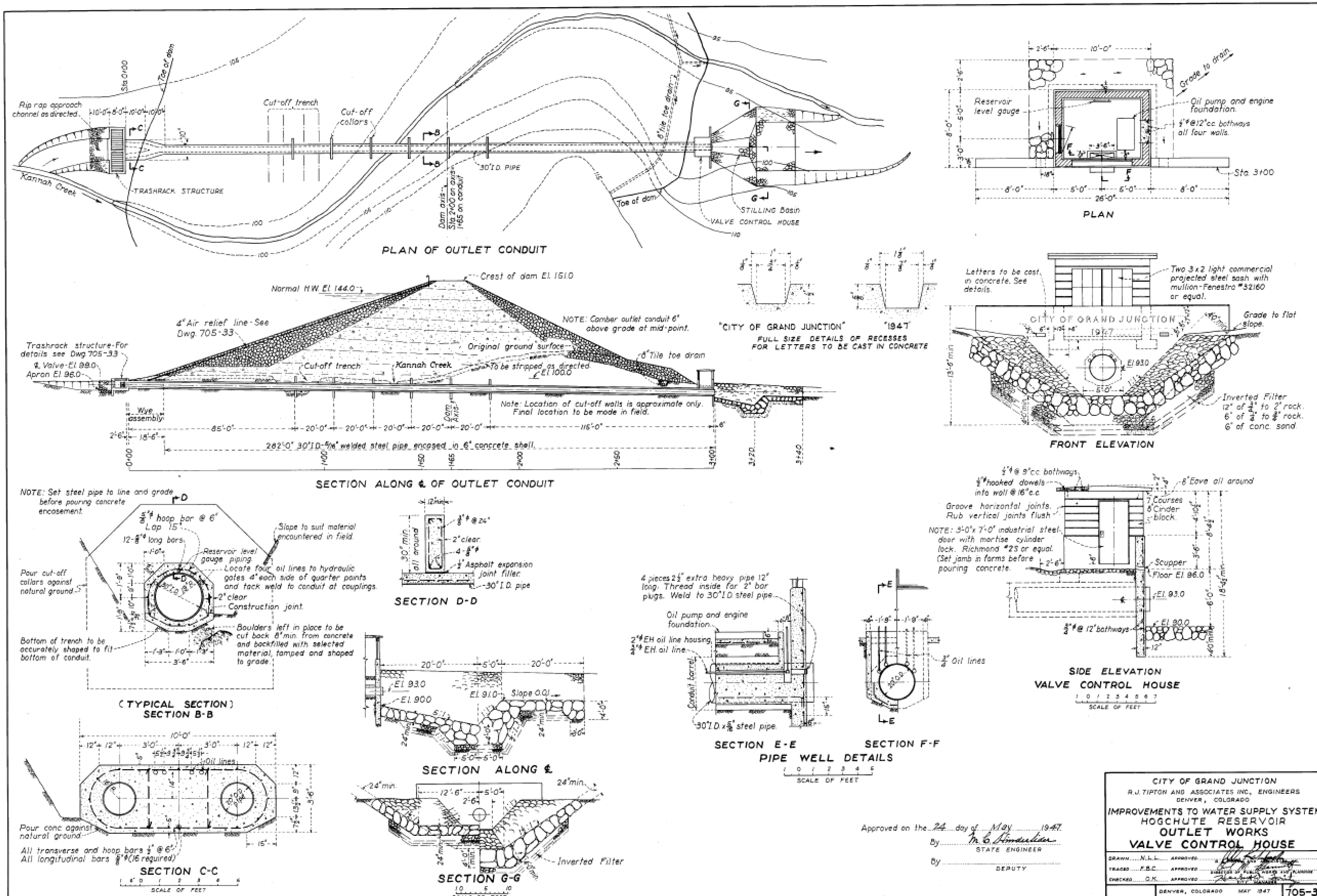
*Photo 7: Collection and monitoring pipe from right side of outlet headwall.*

*Photo 11: Seepage behind right side of outlet headwall.*

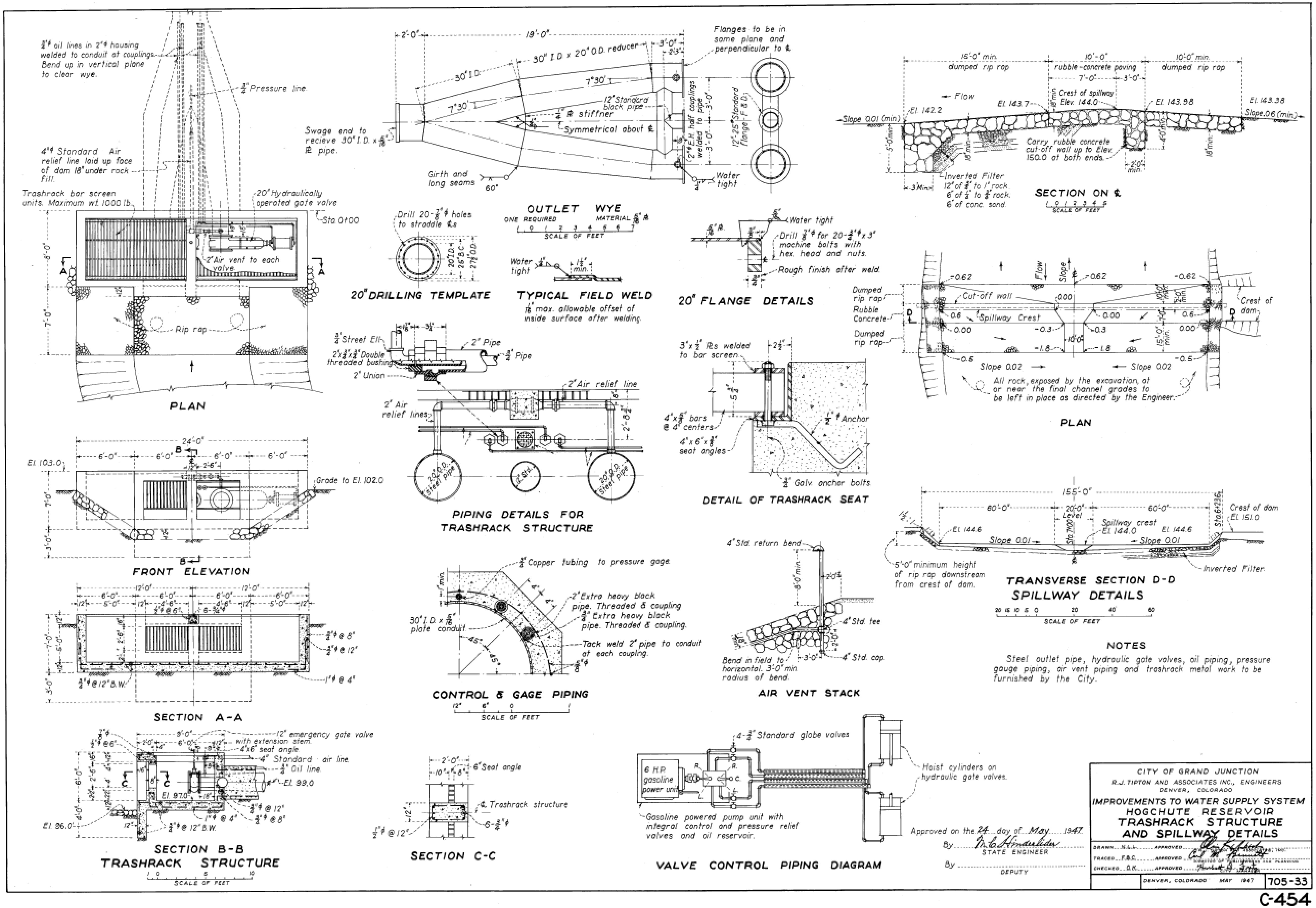
# Appendix C
# Pertinent Drawings


SLIDE ROCK BORROW AREA
Road to top of Mesa
Existing cabins
Remove existing log rail fence as directed
BORROW AREA NO. 1
BORROW AREA NO. 2
POND
Parshall flume structure
BORROW AREA NO. 3
Spillway
BORROW AREA NO. 4
Outlet conduit
Kannah Creek
Parshall flume structure
High water line
GENERAL PLAN
SCALE OF FEET
VICINITY MAP
HOGCHUTE RESERVOIR
WHITEWATER
SCALE OF MILES
R. 96 W.
TO WHITEWATER
TO MESA
ANDERSON RES. No 2
ANDERSON RES. No 1
LANDS END SCENIC HIGHWAY
GRAND MESA RES. No 6
GRAND MESA RES. No 9
CITY CAMP
GRAND MESA
City Ditch
GRAND MESA RES. No 1
DEER CR. RES.
Deep Cr.
Creek
PROPOSED HOGCHUTE RES. SITE
Reservoir
Kannah Creek
GRAND MESA
T 12 S
SCALE OF MILES
LOCATION MAP
SPILLWAY DISCHARGE - C.F.S.
OUTLET DISCHARGE - C.F.S.
ELEVATION OF WATER SURFACE
Spillway discharge
Nor. max. water surface - El. 144.0
Capacity
Area
Maximum normal capacity 520 A.F.
Two 20" Gate valves
One 20" Gate valve
12" emergency valve
CAPACITY - ACRE FEET
AREA - ACRES
AREA, CAPACITY AND DISCHARGE CURVES
NOTES
Reservoir site is entirely within the limits of the Grand Mesa National Forest. All clearing operations, cutting and disposal of timber, shall be performed in accordance with rules and regulations prescribed by the Forest Supervisor
Altitude of reservoir site is approximately elevation 9250
REFERENCE DRAWINGS
VICINITY MAP AND GENERAL PLAN 705-30
PLAN, PROFILE AND SECTIONS 705-31
OUTLET WORKS - VALVE CONTROL HOUSE 705-32
TRASHRACK STRUCTURE AND SPILLWAY DETAILS 705-33
PARSHALL FLUME - PLAN, SECTIONS AND DETAILS 705-34
Approved on the 24 day of May 1947
By STATE ENGINEER
By DEPUTY
CITY OF GRAND JUNCTION
R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO
IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
VICINITY MAP AND GENERAL PLAN
DENVER, COLORADO MAY 1947
705-30
C-454


TOE DRAIN DETAIL
Cobble and rock fill
Foundation excavation line
Graded gravel or crushed rock
3'0" Minimum
8" Sewer pipe laid with open joints
CREST DETAIL
6" of crushed rock or gravel for roadway
Crest, El. 151.0
Slopes variable
Nor. W.S. El. 144.0
SCALE OF FEET
MAXIMUM SECTION
Crest of dam, El. 151.0
Normal water surface, El. 144.0
El. 110.0
El. 103.0
El. 95.0±
Slopes variable
3' Min.
El. 106.0±
El. 100.0±
Original ground surface
Toe drain, see detail
Stripping as directed
Axis of dam
Dimensions of cutoff trench dependent upon foundation conditions
SECTION A-A
Remove old dam embankment on right abutment as directed
Original ground line
Strip as directed
℄ Cutoff trench
PLAN
Axis of dam
Sta. 0+00
VALVE CONTROL HOUSE
6" Tile drain
P.I. Sta. 5+50
30°00'
TEST TUNNEL
TRASHRACK STRUCTURE
Creek
EMBANKMENT NOTES
① Impervious fill of clay or clay, sand and gravel graded with coarser material on outer slopes and compacted in 6" layers.
② Cobble and rock fill graded with coarser material on outer slopes.
NOTES
All elevations refer to an assumed datum
Final location of outlet works and appurtenant structures are dependent on foundation conditions encountered.
Crest of dam, El. 151.0
Normal water surface, El. 144.0
Spillway crest, El. 144.0
Rolled embankment
Original ground surface
Cutoff trench
Outlet conduit
ELEVATIONS
LEGEND
O Loam and clay mixed with small boulders
Cl-B Clay with occasional basalt boulders
Cl Clay
B-Cl Predominently basalt boulders in clay matrix
B Basalt boulders
Sh Green River shale
PROFILE ON ℄ OF CUTOFF TRENCH AND SPILLWAY - LOG OF DRILL HOLES
Approved on the 24 day of May 1947
By STATE ENGINEER
By DEPUTY
CITY OF GRAND JUNCTION
R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO
IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
PLAN, PROFILE AND SECTIONS
DENVER, COLORADO MAY 1947
705-31
C-454


PLAN OF OUTLET CONDUIT
Rip rap approach channel as directed.
Cut-off trench
Cut-off collars
TRASHRACK STRUCTURE
Kannah Creek
30" I.D. PIPE
Dam axis - Sta. 2+00 on axis 1+65 on conduit
Toe of dam
STILLING Basin
VALVE CONTROL HOUSE
Sta. 0+00
Crest of dam El. 151.0
Normal H.W. El. 144.0
4" Air relief line - See Dwg. 705-33
NOTE: Camber outlet conduit 6" above grade at mid-point.
Trashrack structure - For details see Dwg. 705-33
℄ Valve - El. 99.0
Apron El. 96.0
Original ground surface
To be stripped as directed.
6" Tile toe drain
Note: Location of cut-off walls is approximate only. Final location to be made in field.
Wye assembly
282'-0" 30" I.D. - 5/16" welded steel pipe encased in 6" concrete shell.
SECTION ALONG ℄ OF OUTLET CONDUIT
"CITY OF GRAND JUNCTION"
"1947"
FULL SIZE DETAILS OF RECESSES FOR LETTERS TO BE CAST IN CONCRETE
PLAN
Reservoir level gauge
Grade to drain
Oil pump and engine foundation.
Sta. 3+00
Letters to be cast in concrete. See details.
Two 3 x 2 light commercial projected steel sash with mullion - Fenestra #32160 or equal.
CITY OF GRAND JUNCTION
1947
Grade to flat slope.
Inverted Filter
FRONT ELEVATION
NOTE: Set steel pipe to line and grade before pouring concrete encasement.
Slope to suit material encountered in field.
Pour cut-off collars against natural ground
Reservoir level gauge piping
Locate four oil lines to hydraulic gates 4" each side of quarter points and tack weld to conduit at couplings.
Construction joint.
Boulders left in place to be cut back 8" min. from concrete and backfilled with selected material, tamped and shaped to grade.
Bottom of trench to be accurately shaped to fit bottom of conduit.
(TYPICAL SECTION) SECTION B-B
SECTION D-D
SECTION ALONG ℄
SECTION C-C
Pour conc. against natural ground
All transverse and hoop bars 1/2" @ 6". All longitudinal bars 5/8" Ø (16 required)
SECTION G-G
Inverted Filter
4 pieces 2 1/2" extra heavy pipe 12" long. Thread inside for 2" bar plugs. Weld to 30" I.D. steel pipe.
Oil pump and engine foundation.
SECTION E-E
SECTION F-F
PIPE WELL DETAILS
8" Eave all around
Groove horizontal joints. Rub vertical joints flush
NOTE: 3'-0" x 7'-0" industrial steel door with mortise cylinder lock. Richmond #25 or equal. (Set jamb in forms before pouring concrete.
Scupper
Floor El. 96.0
SIDE ELEVATION
VALVE CONTROL HOUSE
SCALE OF FEET
Approved on the 24 day of May 1947.
STATE ENGINEER
DEPUTY
CITY OF GRAND JUNCTION
R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO
IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
OUTLET WORKS
VALVE CONTROL HOUSE
DENVER, COLORADO MAY 1947
705-32

C-454


PLAN
FRONT ELEVATION
SECTION A-A
SECTION B-B
TRASHRACK STRUCTURE
OUTLET WYE
20" DRILLING TEMPLATE
TYPICAL FIELD WELD
20" FLANGE DETAILS
PIPING DETAILS FOR TRASHRACK STRUCTURE
DETAIL OF TRASHRACK SEAT
CONTROL & GAGE PIPING
SECTION C-C
AIR VENT STACK
VALVE CONTROL PIPING DIAGRAM
SECTION ON ℄
PLAN
TRANSVERSE SECTION D-D
SPILLWAY DETAILS
NOTES
Steel outlet pipe, hydraulic gate valves, oil piping, pressure gauge piping, air vent piping and trashrack metal work to be furnished by the City.
Approved on the 24 day of May 1947
By M. C. Hinderlider
STATE ENGINEER
By
DEPUTY
CITY OF GRAND JUNCTION
R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO
IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
TRASHRACK STRUCTURE
AND SPILLWAY DETAILS
DENVER, COLORADO MAY 1947
705-33
C-454

# Appendix D
# Pertinent Geotechnical References

<*Insert images of pertinent geotechnical information*>

# Appendix E
# Pertinent Instrumentation Locations & Readings

<*Insert images of pertinent instrumentation monitoring records*>

# Appendix F
# PFM Likelihood, Confidence and Consequence Definition Tables

## 1. Likelihood Definition Table

| ***PFM Failure Likelihood Rating*** | ***Failure Likelihood Description[9]*** | ***Possible Actions to Reduce Probability of Failure*** | ***Possible Actions to Reduce Consequences*** |
|---|---|---|---|
| **VERY HIGH**<br><br>An active failure mode is in process or likelihood of a failure is judged to be extremely high, such that immediate actions are necessary to reduce risk.<br><br>*Should be accompanied by a High Confidence. | There is direct evidence or substantial indirect evidence to suggest it is occurring and/or is likely to occur (or a flood or an earthquake with an annual exceedance probability more frequent (greater) than 10E-2 would likely cause failure. | High Confidence<br>• Immediate draining of reservoir under SEO Authority<br>• Emergency actions to avoid failure<br>• Expedite investigations and designs<br>• Zero Storage with Expedited Compliance Plan to Complete Investigations, Designs, and Construct Repairs,<br>• OR issue Breach Order | • Ensure that emergency action plan is current and functionally tested for initiating event.<br>• Initiate intensive emergency management and situation reports based on continuous monitoring.<br>• Develop early warning system specific to PFM. |
| **HIGH**<br><br>Potential failure mode is judged to present very serious risks, due to high probability of failure, which justifies an urgency in actions to reduce risk. | The fundamental condition of defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily toward likely than unlikely (or a flood or an earthquake with an AEP between 10E-4 and 10E-2) would likely cause failure. | Moderate to High Confidence<br>• SEO Storage Restriction to mitigate PFM.<br>• Strict Deadlines for Compliance Plan to Complete Investigations, Designs, and Construct Repairs.<br>• Conduct Heightened Monitoring specific to PFM.<br><br>Low Confidence<br>• Strict Deadline Expedited, high priority Compliance Plan to complete investigations & Studies to increase Confidence in PFM and justify further actions.<br>• Conduct Heightened Monitoring specific to PFM. | • Ensure that emergency action plan is current.<br>• Complete EAP functional exercise for initiating event. |

[9] Use this column to differentiate AEP's between High, Significant, and Low Hazard Dams in the future.

| ***PFM Failure Likelihood Rating*** | ***Failure Likelihood Description[9]*** | ***Possible Actions to Reduce Probability of Failure*** | ***Possible Actions to Reduce Consequences*** |
|---|---|---|---|
| **MODERATE**<br><br>Potential failure mode appears to be dam safety deficiency that poses a significant risk of failure, and actions are needed to better define risks or to reduce risks. | The fundamental condition of defect is known to exist; indirect evidence suggests it is plausible; and key evidence is weighted more heavily towards unlikely than likely (or a flood or an earthquake with an AEP between 10E-5 and 10E-4 would likely cause failure. | <u>High Confidence</u><br>• Engineering judgment to consider possible storage restriction OR conditional full storage.<br>• Conduct Heightened Monitoring specific to PFM.<br><br><u>Low to Moderate Confidence</u><br>• Strict Dates for Compliance Plan to complete investigations and analyses to increase confidence in PFM and support justification for remediation and remediation design, as appropriate.<br>• Conduct Heightened Monitoring specific to PFM. | • Ensure that emergency action plan is current and functionally tested for initiating event. |
| **LOW**<br><br>Potential failure mode(s) appear to indicate a potential concern, but do not indicate a pressing need for action. | The possibility cannot be ruled out, but there is no compelling evidence to suggest it has occurred or that a condition or flaw exists that could lead to its development (or a flood or an earthquake with an AEP more remote than 10E-5 would likely cause failure). | <u>Moderate to High Confidence</u><br>• Use Engineering Judgment to consider Conditional Full Storage OR Full Storage<br>• Long term monitoring & instrumentation towards PFM to assess for worsening conditions.<br><br><u>Low Confidence</u><br>• Plan to complete investigations to increase confidence in PFMs.<br>• Determine whether action can wait until after the next comprehensive review of the dam and appurtenant structures. | |
| **REMOTE**<br><br>Potential Failure mode(s) at the facility do not appear to present significant risks, and there are no apparent dam safety deficiencies. | Several events must occur concurrently or in series to create failure. Most, if not all, events are unlikely to very unlikely, and failure potential is negligible or non-credible. The failure probability is unlikely to change with additional investigations or study. | <u>Moderate to High Confidence</u><br>• Full Storage<br>• Continue routine dam safety risk management activities, normal operation, and maintenance.<br>• Keep PFMs on list to indicate have been evaluated. | |

**2. Confidence Definition Table**

| ***Confidence Level*** | ***Description*** |
| --- | --- |
| Strong | The team is confident in the order of magnitude for the assigned category and, it is unlikely that additional information would change the estimate. |
| Medium | The team is relatively confident in the order of magnitude of the assigned category, but key additional information might possibly change the estimate |
| Poor | The team is not confident in the order of magnitude for the assigned category, and it is entirely possible that additional information would change the estimate. |

**3. Consequence Definition Table**

## Consequences Categories

| | |
|---|---|
| **Level 0:** | No significant impacts to the downstream population other than temporary minor flooding of roads or land adjacent to the river. |
| **Level 1:** | Downstream discharge results in limited property and/or environmental damage. Although life-threatening releases occur, direct loss of life is unlike due to severity of location of the flooding, or effective detection and evacuation. |
| **Level 2:** | Downstream discharge results in moderate property and/or environmental damage. Some direct loss of life is likely, related primarily to difficulties in warning and evacuating recreationists/ travelers and small population centers (in the range of 1 to 10). |
| **Level 3:** | Downstream discharge results in significant property and/or environmental damage. Large direct loss of life is likely, related primarily to difficulties in warning and evacuating recreationists/ travelers and smaller population centers, or difficulties evacuating large population centers with significant warning time (in the range of 10 to 100). |
| **Level 4:** | Downstream discharge results in extensive property and/or environmental damage. Extensive direct loss of life can be expected due to limited warning for large population centers and/or limited evacuation routes. |

RJH CONSULTANTS, INC.

*GEOTECHNICAL AND*
*WATER RESOURCES ENGINEERING*

# DAM SAFETY EVALUATION REPORT

## HOGCHUTE DAM (AKA CARSON LAKE)
## DAM ID 420127
### MESA COUNTY, COLORADO

Submitted to
**City of Grand Junction**
250 North 5th Street
Grand Junction, CO 81501

Submitted by
**RJH Consultants, Inc.**
9800 Mt. Pyramid Court, Suite 330
Englewood, Colorado 80112
303-225-4611
www.rjh-consultants.com

January 2019
Project 18115

COLORADO REGISTERED PROFESSIONAL ENGINEER
GARRETT O. JACKSON
29302
2/4/19

Garrett O. Jackson, P.E.
Project Manager

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## APPENDICES

# SECTION 1 – INTRODUCTION

## 1.1 General

The City of Grand Junction (City) owns and operates Hogchute Dam (DAMID 420127), located in Mesa County, Colorado, approximately 22 miles east-southeast of Grand Junction (Figure 1.1). The dam is a 56-foot-high earth structure that impounds Carson Lake on Kannah Creek at an elevation (El.) 9,800 feet in the Grand Mesa National Forest. The reservoir provides water storage for domestic use, irrigation, and fishing recreation.

The dam was constructed in 1947 with a low-permeability earthen core protected by upstream and downstream rock shells of gravels, cobbles, and boulders. The outlet works consists of two 20-inch welded steel pipes with hydraulic slide gates at the upstream toe of the dam. The 20-inch pipes converge within the dam into a single 30-inch conduit that discharges into a rock-lined basin at the downstream toe of the dam. The 1947 design drawings (Appendix A) show a 12-inch gate installed on a 12-inch pipe between the 20-inch conduits. The drawings also show an 8-inch tile toe drain composed of what is described as "sewer pipe laid with open joints" under the downstream rock shell. The unlined emergency spillway is located at the north (right) end of the dam. No construction records are available, so the configuration and function of the 12-inch gate are not known. Similarly, the details of the toe drain materials and construction are unknown.

## 1.2 Project Background

In 1988, the City relocated the outlet control from the downstream toe to the crest of the dam. The outlet valve hydraulic controls were housed in a new concrete building constructed on the dam crest, and the old concrete outlet valve control building at the downstream toe was demolished. The outlet conduit concrete headwall and the concrete floor slab and walls of the old control building (connected to the headwall) were left in place at the toe of the dam. Concurrent with the relocation of the outlet controls, the City extended the toe drain discharge pipe into the outlet discharge basin with an 8-inch PVC pipe. The work to move the outlet controls and extend the toe drain discharge is described in a letter dated November 14, 1988 from the City to the Colorado Division of Water Resources, which includes some photographs of the work (Appendix A).

In 2015, the Colorado Office of the State Engineer (SEO) changed the dam's hazard classification to high hazard, based on inundation mapping performed by the City and the estimated impacts of a simulated dam failure on downstream development that had occurred since construction of the dam. In about 2014, the City began coordinating with the SEO to rehabilitate the outlet works and implement other dam safety improvements.

## 1.3 Comprehensive Dam Safety Evaluation

In 2017, the SEO performed a Comprehensive Dam Safety Evaluation (CDSE) to assess the overall safety of the dam and provide the City with guidance in planning dam improvements. The CDSE was performed to either reduce or better define several perceived risks to the dam, including:

- A long history of observed seepage at the downstream toe of the dam behind the outlet pipe headwall.
- A long history of observed seepage on the downstream right abutment.
- Suspected broken air vent penetrations causing up to 3 cubic feet per second (cfs) infiltration into the outlet conduit.
- No known hydrology study on file.
- Concern over the long-term integrity of hydraulic controls and unknown condition of the outlet gates and intake structure.

The CDSE program developed by the SEO is modeled after the semi-quantitative risk analysis procedure developed by the U.S. Bureau of Reclamation (Reclamation). The analysis includes thorough review of available records for a dam, followed by identification of credible Potential Failure Modes (PFMs). A PFM is defined as a specific chain of events leading to failure, where failure is defined as the uncontrolled release of water (not necessarily complete breaching of the dam). The PFMs are evaluated by a team of experienced dam safety engineers with respect to both the likelihood and the consequences of the PFM occurring at the subject dam, based on the team's understanding of the dam's vulnerabilities. Consideration of unknown variables and recognition of the need for more information is incorporated in the evaluation by assigning a "Confidence Level" to the PFM. PFMs judged to have a remote "Likelihood of occurring at the dam are not carried forward for further evaluation. PFMs that are carried forward are plotted on a Risk Chart for comparison, and to identify PFMs that are most alarming (Risk Driving) and PFMs that are of lesser concern (Non-Risk Driving).

The SEO's report of the CDSE for Hogchute Dam is included in Appendix B. The Risk Chart Summary from the CDSE report is shown on Figure 1.2. The SEO identified a total of twenty-six credible PFMs for Hogchute Dam. As described in the CDSE report, selection of the credible PFMs was based on a thorough consideration and evaluation of the dam's known and suspected vulnerabilities. In our opinion, the list of PFMs selected for evaluation appears reasonable for Hogchute Dam. Of the twenty-six selected credible PFMs, six were identified as Risk Driving (plotted on Figure 1.2), and nine others were identified as Non-Risk Driving (not shown on the Risk Chart Summary). The remaining eleven PFMs were assigned a Likelihood of "Remote" and were not carried forward for further evaluation.

In the field of dam safety risk analysis, "risk" is defined as the product of the Likelihood of failure and the Consequences of failure. The Risk Chart Summary shown on Figure 1.2 depicts the Likelihood of dam failure increasing from bottom to top on the vertical axis and the estimated Consequences of dam failure increasing from left to right on the horizontal axis. The diagonal red line indicates that a high Likelihood of failure may be tolerable in some cases where the estimated consequences of failure are very low (upper left corner of the chart). As the consequences of the dam's failure increase, the acceptable Likelihood of failure must decrease correspondingly. The horizontal red line is the boundary between Moderate and High Likelihoods of failure. Reclamation calls the Risk Chart a "Risk Matrix" and uses the matrix to show that risk increases moving diagonally from the yellow cells toward the upper right-hand corner of the matrix. Hence the urgency of addressing potential failure modes plotting in those cells increases. Similarly, risks decrease moving diagonally from the yellow cells toward the lower left-hand corner of the matrix, and the need and urgency to address those PFM's also decreases. The materials for the Reclamation 2015 training course, *Best Practices in Dam and Levee Safety Risk Analysis* (Reclamation, 2015) include the following statements:

> "In the case of semi-quantitative risk analyses, potential failure modes with estimated risks plotting in cells entirely below both red … lines with high confidence should be kept under review and properly managed. This requires continued monitoring and evaluation. Similarly, potential failure modes with risks plotting in cells above the red … lines represent risks that likely exceed risk guidelines and require action to reduce or better define risk."

As seen on Figure 1.2, the following Risk Driving PFMs plot above both the diagonal and horizontal red lines, indicating that these PFMs warrant immediate attention to reduce or better characterize the risk.

- PFM #12 – Concentrated leak erosion along the outlet conduit.
- PFM #15 – Overtopping.
- PFM #26 – Outlet gates fail to open.

The remaining three Risk Driving PFMs plot blow the red lines on Figure 1.2, indicating reduced urgency in the need for addressing them. However, the PFMs plotting below the red lines must still be evaluated so the risk can be properly managed.

- PFM #2 – Backward erosion piping (BEP) through the embankment.
- PFM #7 – Contact erosion through the foundation.
- PFM #13 – Concentrated leak erosion into the outlet conduit.

## 1.4 RJH Scope of Work

RJH Consultants, Inc (RJH) was retained to provide professional services for this Dam Safety Evaluation Project (Project) to assist the City in investigating, identifying, and documenting the seepage conditions and the condition and operation of the outlet works at Hogchute Dam. The overall objectives of the work were to address the SEO's concerns about the safety of the dam and to provide a basis for the future dam rehabilitation design. This Project does not include any engineering analyses or engineering design calculations. Our efforts were focused on the following objectives:

1. Bring the dam into compliance with current SEO requirements for high hazard dams by identifying and taking actions to respond to the SEO's list of immediate concerns as presented in the CDSE report. These actions are specifically necessary to avoid a storage restriction.
2. Identify PFMs that must be addressed immediately to ensure the safety of the dam and the public.
3. Identify PFMs that are less urgent, but should be addressed in the City's long-term improvements plan to preserve the safety of the dam.
4. Evaluate the completeness of the list of PFMs considered in the CDSE to identify any additional PFMs pertinent to Hogchute Dam.
5. Provide suggestions for the recommended scope of a future dam rehabilitation plan.

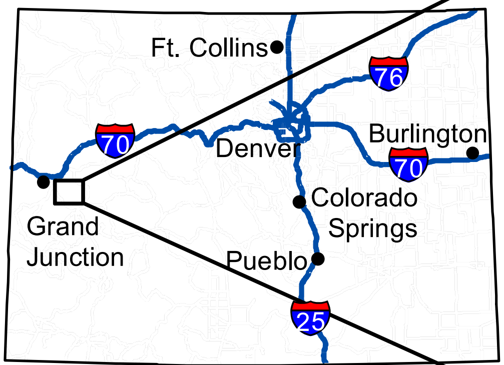
To accomplish these objectives, RJH's work scope included the following tasks:

- Task 1 – Hydrology study to define the Inflow Design Flood (IDF) for the dam and to assess the adequacy of the existing spillway.
- Task 2 – Seepage and geotechnical investigations to identify and evaluate seepage conditions, gather geotechnical data for design of the dam rehabilitation, and install piezometers at the dam.
- Task 3 – Outlet works assessment (this task was deleted from the Project).

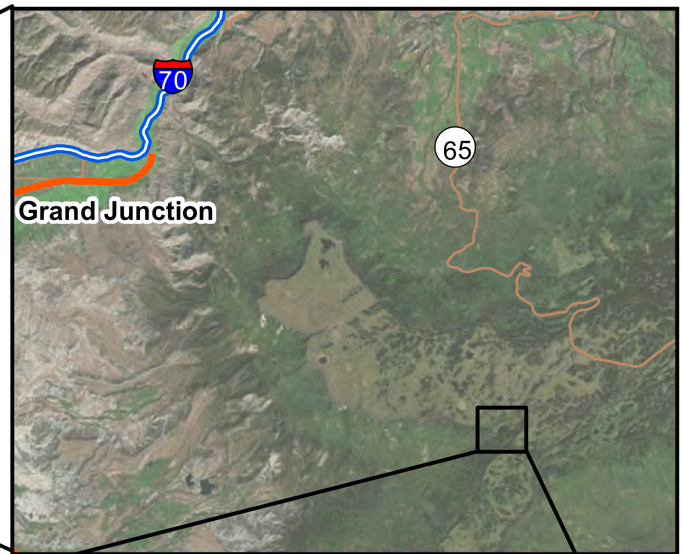
- Task 4 – Dam Safety Evaluation Report

The Task 3 outlet works assessment originally listed in the City's Request for Proposals included pressure testing of the existing outlet works conduit, video inspection of the existing outlet conduit interior, and visual assessment of the existing outlet gates and outlet intake structure. The outlet works assessment task was eliminated from the scope of this safety evaluation phase for the following reasons:

- Pressure testing of the existing outlet works was judged to pose an unacceptable risk of fracturing the outlet conduit's concrete encasement and/or the embankment fill outside the encasement. The relatively limited information the pressure test could have provided did not justify the estimated cost and potential risk of the test.
- The visual evaluation of the outlet gates and intake structure can best be performed when the reservoir is empty. The Project could not be started early enough in the year for draining the reservoir to be practical from a water management perspective. The City intends to rehabilitate the outlet works, which would eliminate the need for the visual evaluation of the existing gates. With concurrence from the SEO, draining the reservoir will be delayed until the start of the rehabilitation construction, and the interior video inspection of the outlet conduit will be performed after the new outlet works conduit and gate system is constructed.




**PROJECT VICINITY MAP**
**(NOT TO SCALE)**



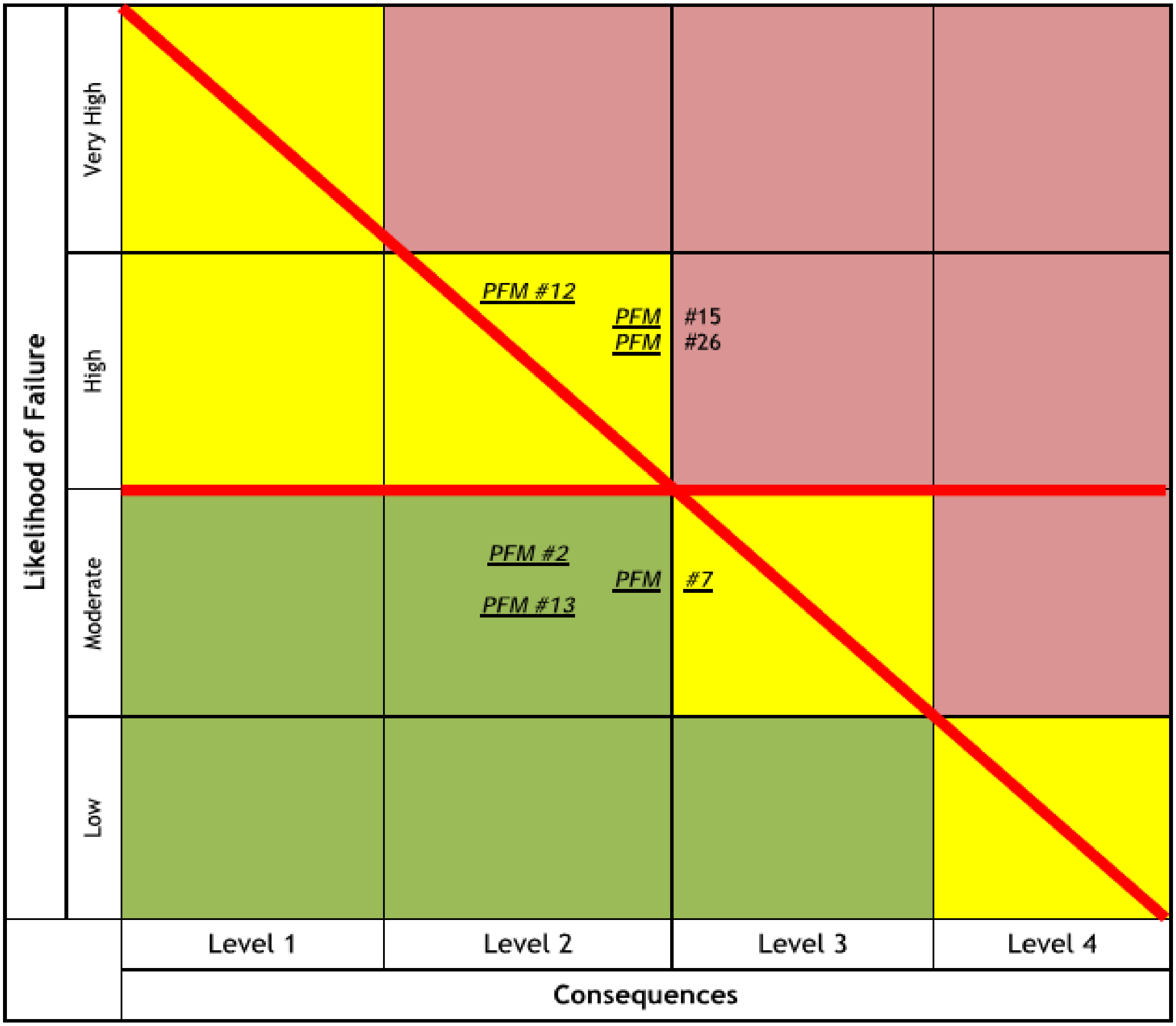

**PROJECT LOCATION MAP**
**(NOT TO SCALE)**


N

**SITE LOCATION MAP**
**(NOT TO SCALE)**

| | | | |
|---|---|---|---|
| City of Grand Junction Colorado | RJH Consultants, Inc. | HOGCHUTE DAM SAFETY EVALUATION | SITE VICINITY MAP |
| | | PROJECT NO. 18115 | January 2019 **Figure 1.1** |

P:\18115 - Hogchute Dam Safety Evaluation\Engineering\GIS\Geotech\Final_Eval_Report\Site Vicinity Map.mxd




Source: Comprehensive Dam Safety Evaluation Report, Hogchute Dam, DAMID 420127, State of Colorado Division of Water Resources, 2018

| | | | |
|---|---|---|---|
| City of Grand Junction Colorado | RJH Consultants, Inc. | HOGCHUTE DAM<br>SAFETY EVALUATION | CDSE RISK CHART<br>SUMMARY |
| | | PROJECT NO. 18115 | January 2019 **Figure 1.2** |

P:\18115 – HOGCHUTE DAM SAFETY EVALUATION\CAD\FIGURES\MONITORING WELLS\RISK CHART.DWG 1/2/2019 4:13 PM

# SECTION 2 – SEO REQUIREMENTS FOR IMMEDIATE ACTION

## 2.1 Background and Review of Required Actions

Based on the CDSE, the SEO listed several specific requirements for the City to bring Hogchute Dam into compliance with the state dam safety standards for high hazard dams.

A PFM with a High or Moderate Likelihood of occurring, combined with a consequence estimate that includes the potential for significant property damage and direct loss of life, warrants risk reduction measures to improve the safety of the dam. All of the Hogchute PFMs that were assigned a High or Moderate Likelihood of occurring are associated with significant property damage and the potential for direct loss of life. These are the Risk Driving PFMs shown on Figure 1.2. However, not all of these PFMs could be assigned their Likelihood of occurring with strong confidence. For several PFMs, additional specific information is required to adequately characterize the risk. Table 5.2.1 of the CDSE report provided a list of measures required to reduce the risk of dam failure or requirements for obtaining additional information to increase the Confidence Level of the PFM. The SEO's required actions and the City's response actions are summarized in Table 2.1.

**TABLE 2.1**
**REQUIRED RISK REDUCTION ACTIONS**

| PFM # | Required Action | Action Level, Action Date, and Action Taken |
|---|---|---|
| 2, 7, 12 | Retain an Engineer to:<br>Seepage<br>• Oversee seepage investigation; attempt to trace and isolate source(s) of seepage.<br>• Find and assess condition of toe drain outfall from left side of outlet headwall.<br>Geotechnical<br>Drilling and sampling program to support PFM Likelihood and confidence. | Develop plan to meet requirements.<br>No Action Date assigned.<br>This Project meets these requirements. |
| 13, 26 | Outlet Works<br>• Drain the reservoir to investigate air vent connection(s) and condition of outlet gates.<br>• Perform internal inspection of outlet pipe. | Benefit of engineering oversight, but not required.<br>No Action Date assigned.<br>The planned outlet works rehabilitation will meet these requirements. |
| 15 | Retain an engineer to perform a spillway hydrologic adequacy study. | Develop plan to meet requirements.<br>No Action Date assigned.<br>This Project meets this requirement. |

| PFM # | Required Action | Action Level, Action Date, and Action Taken |
|---|---|---|
| 19-23 | Retain an engineer to perform a thorough geotechnical investigation and analysis of the existing embankment, including but not limited to:<br>• Drilling and sampling program.<br>• Static and seismic slope stability evaluation. | Develop plan to meet requirements.<br>No Action Date assigned.<br>This Project meets the drilling and sampling requirement.<br>The planned dam rehabilitation design project will meet the slope stability evaluation requirements. |

## 2.2 Risks and Consequences of Inaction

Paragraph 1.2.1 of the CDSE report states, "The HIGH and MODERATE Likelihood of these PFMs were predominantly driven by direct and indirect evidence indicating that each PFM is credible, poses a significant risk to the safety of the dam, and that action is needed to either reduce the risk or better define the risk." Paragraph 1.2.3 of the CDSE report states, "Compliance with the Actions shown in Table 2.2 by the associated Due Date is required to reduce the risk in a timely manner. Failure to do so may result in a storage restriction action by the SEO to reduce or remove the risk associated with each PFM."

Lack of response to the SEO's requirements summarized above in Table 2.1 would likely result in a storage restriction for Hogchute Dam based in part on some PFMs for which the Likelihood of occurring was assigned with relatively weak confidence. Completion of this Project meets the SEO's requirements to provide sufficient information and better define the risk of the identified PFMs.

# SECTION 3 – HYDROLOGIC STUDY AND SPILLWAY EVALUATION

## 3.1 Evaluation Summary

RJH performed a preliminary hydrology study to accomplish the following objectives:

- Identify the IDF, which is the maximum inflow to the reservoir to be expected as a result of the design storm event occurring in the reservoir's drainage basin.
- Evaluate the adequacy of the existing spillway to convey the IDF without overtopping the dam.

The study was performed in general conformance with Section 5.4.2 of the SEO Rules and Regulations for Dam Safety and Dam Construction (Rules) (SEO, 2007).

RJH estimated precipitation depths in the Carson Lake drainage basin for the general storm and local storm Probable Maximum Precipitation (PMP) events. The general storm represents a large area, long-duration storm event typically associated with a major synoptic weather feature. The local storm represents an intense, short-duration storm that typically occurs over smaller areas than the general storm. RJH followed the SEO guidelines and procedures for computing PMP depths required to develop the IDF. PMP estimates were developed using both the Colorado and New Mexico Regional Extreme Precipitation Study tool (REPS) and the applicable National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Report (HMR-49).

## 3.2 Conclusion and Recommendations

Based on the results of the preliminary hydrology study, the existing Hogchute Dam spillway can safely pass the IDF from the general storms calculated using both the REPS tool and HMR-49. However, the existing spillway is inadequate to pass the IDF from the local storm predicted by either the REPS tool or HMR-49. The results of the spillway adequacy evaluation are summarized in Table 3.1. The Preliminary Hydrologic Study is included as Appendix C of this Report.

The preliminary hydrology study was performed following the conservative guidelines provided by the SEO for estimating an IDF. The preliminary study confirmed that the existing spillway is inadequate; however, some model input parameters could likely be adjusted to better represent details of the drainage basin and to incorporate improved modeling methods. Such adjustments could reduce the estimated IDF. A detailed revised hydrologic study should be performed as part of the dam rehabilitation design to refine the IDF estimate for sizing of the required spillway.

**TABLE 3.1**
**HOGCHUTE DAM SPILLWAY ADEQUACY EVALUATION**

| Storm Event | Peak Inflow (cfs) | Inflow Volume (ac-ft) | Peak Outflow (cfs) | Maximum WSE (ft) | Residual Freeboard (ft) | Overtopping Depth (ft) | Overtopping Duration (hours) |
|---|---|---|---|---|---|---|---|
| General storm HMR | 8,793 | 6,430 | 5,578 | 9,900.8 | 1.2 | -- | -- |
| Local storm HMR | 25,782 | 3,928 | 25,408 | 9,905.6 | -- | 3.6 | 2.0 |
| General storm REPS Tool | 9,456 | 6,507 | 6,358 | 9,901.3 | 0.7 | -- | -- |
| Local storm REPS Tool | 35,097 | 4,937 | 34,629 | 9906.9 | -- | 4.9 | 2.5 |

# SECTION 4 – GEOTECHNICAL AND SEEPAGE INVESTIGATION

## 4.1 Geotechnical Investigation

From July 23 through 28, 2018 and from September 17 through 22, 2018, RJH conducted a geotechnical investigation to collect soil samples for laboratory analyses and to install piezometers at the dam. The field and laboratory test data and the piezometer data are to be used to support the future design of the dam rehabilitation. The locations of the geotechnical investigation borings are shown on Figure 4.1. The results of the investigation and laboratory testing are included as Appendix D of this Report.

### *4.1.1 Drilling, Sampling, and Testing Program*

Vertical borings in the dam core were advanced from the dam crest using hollow-stem augers. During auger advancement, sampling was generally performed at 2.5-foot intervals, but frequencies ranged from 8-foot intervals to continuously, depending on the presence of cobbles and boulders. Auger refusal was encountered in all dam crest borings because of interpreted cobbles and boulders within the embankment fill and foundation. Boring B-102B was terminated due to auger refusal at about 5 feet deep. This boring was backfilled with cement-bentonite grout. Standard Penetration Test (SPT) and California sample blowcounts were recorded in conjunction with soil samples collected in the borings.

Cobbles and boulders were anticipated to be encountered in borings in the native materials at the dam's downstream toe, so the drillers switched to a Symmetrix drive casing advancer, an air-hammer drilling method, for the second round of drilling. During casing advancement, sampling was generally performed at 2.5-foot intervals but frequencies ranged from 5-foot intervals to continuously, based on casing limitations, at greater depths. SPT and California tube blowcounts were recorded in conjunction with soil samples obtained at these test locations.

For all borings, the ability to sample coarse particles was limited by the sampler sizes and sampling techniques; the collected samples likely underestimate the actual subsurface percentages of gravels, cobbles, and boulders. Bedrock was not encountered in any of the borings. Recovered split-spoon samples were placed in sealed plastic bags to help preserve the natural moisture content of the material. Samples recovered from California samplers were generally capped and sealed with vinyl tape, unless insufficient material was recovered, and these samples were placed in sealed plastic bags to help preserve the natural moisture content. One successful undisturbed Shelby tube sample was capped and sealed with vinyl tape. Bulk samples collected from auger cuttings were placed in either sealed plastic bags or canvas sample bags.

RJH observed drilling procedures, recorded relevant drilling information, photographed and visually classified soil samples, and prepared a field log of each boring. In the field, soil samples were classified in general accordance with ASTM D2488 (visual-manual method).

RJH performed 13 field tests to evaluate the permeability characteristics in the embankment fill, dam foundation soil, and native soil. In-situ permeability testing consisted of rising head and falling head tests over test intervals ranging between 0 and 21.0 feet in length.

Laboratory tests were performed on representative samples of soil collected from the borings. A series of consolidated undrained triaxial shear strength tests (TX-CU) was performed on the one undisturbed Shelby tube sample collected from the dam native colluvial foundation in Boring B-103. Permeability tests and a consolidation test were also conducted on the Shelby tube sample. Index tests, corrosion tests, dispersivity tests, resistivity tests, sulfate concentration, and unconfined compressive strength tests were conducted on the remaining samples.

#### *4.1.2 Piezometer Installation and Monitoring*

Open-standpipe monitoring wells were installed in all borings, except B-102B. The piezometers were generally installed in pairs, one on the dam crest and one at the downstream toe, to provide data on the location of the water table within the dam. B-105B(P) was installed a second piezometer at the dam toe paired with B-102A(P). The deeper instrument will likely provide more useful data than a piezometer at the toe of the relatively low embankment below B-103(P). After installation, all monitoring wells were developed to remove groundwater and drilling water from the well and sand or gravel pack.

All piezometers were measured during the fieldwork and following all instrument installation. RJH, the City, and the SEO all measured the piezometers at various times and shared the measurements for this Report.

#### *4.1.3 Summary and Conclusions*

The 1947 design drawings indicate that the embankment core was to be constructed of “impervious fill of clay or clay, sand and gravel,” graded with the coarser materials on the outer slopes. The upstream and downstream shells were to be composed of cobble and rock graded with the coarser material on the outer slopes.

Based on field observations and drilling logs, the first foot of embankment fill (dam core) was crushed gravel road base. The remaining embankment fill consisted of clayey sand with gravel (SC), clayey gravel with sand (GC), clayey sand (SC), and poorly graded gravel with clay and sand (GP-GC). The maximum recovered particle size was 4 inches. The composition and maximum particle size observed in the recovered samples may have been influenced by the size of the samplers; difficult drilling and sampling conditions were encountered that are likely indicative of larger cobbles or boulders within the embankment fill.

## 4.2 Seepage Investigation

On August 8 and 9, 2018, RJH conducted a seepage investigation to identify seepage sources at the downstream toe of the dam. The investigation was specifically designed to locate and expose the source of the water observed flowing under the toe of the downstream rock shell and pooling behind the headwall of the old outlet valve control house remnants. A secondary purpose was to locate and assess the condition of the existing toe drain discharge pipe. Field reports of the investigation are included as Appendix E.

### *4.2.1 Investigation of Water Under Downstream Rock Shell*

A Caterpillar 320N backhoe equipped with a thumb was used to carefully remove the existing riprap and rock shell material at the toe of the dam over the outlet conduit. Rock was removed to expose the ground for about 20 feet along and on both sides of the concrete-encased conduit upstream of the old valve control house slab and headwall, as shown on Figure 4.2. The top of the concrete encasement was encountered at a depth of approximately 10 feet to 15 feet below the elevation of the natural ground on each side of the conduit. The 8-inch sewer pipe toe drain shown on the design drawings was not encountered in the excavation.

No wetness or evidence of seepage was observed on the left (south) side of the outlet conduit. The concrete encasement was observed to be founded in a stiff clayey soil stratum.

The excavation on the right (north) side of the conduit filled with water to about 1 foot deep for its entire open length along the conduit, as shown on Figure 4.3 (photo). Water appeared to be draining from the soil around the encased conduit and from beneath the old building slab. Some of the water drained out of the excavation to the downstream channel through an existing sump at the right end of the conduit headwall, but the 4-inch PVC pipe into the sump was several inches above the bottom of the excavation. The sump was removed, and a drainage channel was excavated around the right end of the headwall to drain more water from the excavation and facilitate the inspection.

The excavation was allowed to drain overnight and was observed to be essentially dry the following morning. Clear water was flowing freely into the downstream end of the excavation from beneath the old control building slab at an estimated rate of approximately 4 to 5 gallons per minute (gpm), as shown on Figure 4.4. The soil was cleaned off the concrete encasement to expose the concrete and no water was observed flowing from or along the conduit. The area at the downstream end of the concrete encasement at the headwall was cleaned out by hand and clear water was observed flowing from an approximately ¾-inch hole in the top of the concrete encasement under the slab, as shown on Figure 4.4.

The 1947 design drawings show "reservoir level gauge piping" to be installed along the top of the steel conduit within the concrete encasement (Figure 4.5). The level gauge was apparently mounted to the inside of the valve control building wall at the downstream end of the outlet conduit. A patch in the concrete floor of the old slab above the location where the water is flowing from the hole in the encasement could be evidence of a past repair to the level indicator.

No water was observed seeping from the natural ground on the right side of the excavation, but a very minor, barely discernable amount of water was emerging slowly from a single location in the clayey foundation at the upstream right (northeast) corner of the excavation. This water is likely water draining slowly from the stiff wet clay at the upstream end of the excavation. The location of the existing sewer pipe toe drain is unknown, but the minor inflow from the upstream end of the excavation could also be associated with the toe drain.

Two old seepage channels have been noted in the willows at the top of the hill to the north and several feet downstream of the old headwall. No water was flowing in these channels at the time of the seepage investigation. However, the near-surface ground in the willows above these channels was wet where it was disturbed by the excavator tracks. Since the wetness was observed only in the near-surface soil horizon, and no additional wetness was observed in the excavation wall between this horizon and the wet clay foundation stratum, it appears this water is likely shallow perched water and not seepage under the dam.

To prevent water from continuing to pool behind the old headwall, the sump liner and 4-inch PVC pipe removed during the excavation were re-installed. The PVC pipe is situated at about the bottom of the excavation to discharge water from the excavation to the sump installed in the channel riprap downstream of the headwall. The remainder of the excavation on both sides of and above the outlet conduit was then backfilled by replacing the large rocks and riprap and restoring the dam slope to its approximate pre-investigation condition.

#### 4.2.2 Existing Toe Drain Discharge Pipe

The 1947 design drawings show a toe drain consisting of 8-inch tile sewer pipe "laid with open joints" under the downstream toe of the dam (see Figure 4.2). The construction details and the effectiveness of the toe drain are unknown. In 1988, the City located the toe drain discharge pipe and extended it with PVC pipe around the left side of the outlet conduit headwall to the outlet discharge basin. A PVC pipe leading from the dam toe into the left side of the basin has been documented on SEO inspection reports, and this pipe appears to match the City's photographs of the pipe that was extended from the toe drain to the discharge basin.

The existing toe drain pipe was not encountered during this seepage investigation. The pipe visible in the outlet discharge basin is considered to be the toe drain discharge pipe. However, this pipe is completely inundated in the basin and cannot be inspected without draining the basin. This pipe should be inspected when the basin is drained during the outlet works rehabilitation construction.

#### 4.2.3 Summary and Conclusions

The water historically observed flowing under the rock toe and pooling behind the old concrete headwall appears to be originating from a hole in the top of the concrete outlet encasement. In our opinion, this hole appears to be the remnant of a reservoir level gauge line within the concrete encasement extending from the downstream end of the outlet conduit to the reservoir. There was no evidence of measurable seepage at the downstream toe of the dam.


LEGEND

◉ MONITORING WELL

◈ BORING BACKFILLED WITH CEMENT–BENTONITE GROUT

NOTES:

1. AERIAL IMAGERY WAS OBTAINED FROM MICROSOFT BING, IMAGERY DATE UNKNOWN.
2. GROUND SURFACE TOPOGRAPHY DATA PROVIDED BY CITY OF GRAND JUNCTION, CO. HORIZONTAL DATUM IS NAD83 AND VERTICAL DATUM IS NAVD88.
3. LOCATIONS OF MONITORING WELLS AND BORINGS WERE OBTAINED FROM HANDHELD GPS UNIT AND HAVE NOT BEEN SURVEYED.

REPRODUCE IN COLOR

| | | | |
|---|---|---|---|
| City of Grand Junction Colorado | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | GEOTECHNICAL INVESTIGATION BORING AND PIEZOMETER LOCATIONS |
| | | PROJECT NO. 18115 | January 2019 — **Figure 4.1** |

# SECTION 5 – POTENTIAL FAILURE MODES EVALUATION

## 5.1 Risk Driving Potential Failure Modes

For Risk Driving PFMs, the combination of Likelihood, Consequence Level, and Confidence Level indicates an alarming degree of risk from a dam safety and public safety perspective. Risk Driving PFMs require timely actions to reduce the risk and may require obtaining specific additional information to better characterize the risk. By undertaking this Dam Safety Evaluation Project, the City has completed the required actions and obtained the necessary information to address most of the Risk Driving PFMs. Analyses to be performed for the dam rehabilitation design phase of the Project will provide the necessary additional information for evaluation of the remaining Risk Driving PFMs.

To evaluate the PFMs, RJH followed the procedure of the CDSE. Based on the results of our investigation and review of the PFMs, we listed the factors indicating that each PFM was more likely to cause failure of the dam (Positive factors) and the factors indicating the PFM was less likely to cause failure (Adverse factors). RJH then recommended a Likelihood and Confidence rating for each PFM. Our assessment of the current status of the Risk Driving PFMs for Hogchute Dam is summarized below and in Table 5.1.

### *5.1.1 PFM #2 – Backward Erosion Piping through the Embankment*

Backward erosion piping (BEP) can occur where a low-plasticity (plastic index less than about 7) soil zone or layer extends through the dam core, or where dispersive soil materials are present. Seepage emerging at the downstream end of the preferential flowpath can carry erodible soils from within the embankment, creating an expanding void that can collapse and cause failure of the dam. A similar BEP process can develop in the foundation soils. This PFM was carried forward for investigation because of concerns that the water observed flowing under the riprap at the downstream dam toe could be from seepage through the dam core or foundation, and that the rocky downstream shell material might not provide adequate filtering protection to prevent erosion and piping. This PFM was assigned a Likelihood of “Moderate” with a Confidence Level of “Poor to Medium” in the CDSE.

#### *5.1.1.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- Water flowing under the rocks at the downstream toe of the dam could be uncontrolled erosive seepage.

- Wetness observed periodically on the natural hillside north of the outlet discharge channel could be uncontrolled seepage.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- No evidence of embankment or foundation erosion has been observed since the dam was completed in 1947.
- The materials encountered during the geotechnical investigation consisted of generally low-plasticity clayey dam core and foundation soils with PI of about 11. These soils are generally not susceptible to erosion and piping.
- The results of the laboratory tests indicate the embankment and foundation soils are non-dispersive.
- During the seepage investigation, the concrete-encased outlet conduit and the natural foundation at the toe of the dam were exposed, and the suspected "seepage" was identified as water discharging from a hole in the top of the outlet conduit encasement. It appears that the hole in the encasement is the remnant of a reservoir level indicator line extending within the concrete encasement from the downstream end of the conduit to the reservoir.
- Minor wetness was observed at the top of the right (north) side of the investigation excavation. In our opinion, the wetness is shallow perched water in the natural ground downstream of the dam toe.
- A very minor amount (not measurable) of water was observed percolating into the bottom of the excavation at the northeast corner. In our opinion, this water is either water stored in the clay soils or possibly water from the area of the existing open-joint toe drain buried in the dam toe. No other seepage was observed.

#### *5.1.1.2 PFM Recommendation:*

RJH recommends that PFM #2 be reclassified with a Likelihood of "Low" and a Confidence Level of "Strong", as shown on Table 5.1.

### *5.1.2 PFM #7 – Contact Erosion Through the Foundation*

This PFM exists when seepage flow occurs through a pervious foundation layer underlying a confining layer composed of fine-grained soil. The situation can usually be observed as a foundation seepage path consisting of a system of high-porosity interconnected and open rock fractures, solution cavities, open coarse soil material, or a fault system. This PFM was brought forward for evaluation because of concerns for the historic "seepage" at the downstream toe behind the old valve control building headwall. Additionally, the original boring logs included in the 1947 design drawings showed potentially gap-graded clay/rock foundation materials, which could be internally unstable. The PFM was assigned a Likelihood of "Moderate" with a Confidence Level of "Poor to Medium" in the CDSE.

#### *5.1.2.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- Water flowing under the rocks at the downstream toe of the dam could be uncontrolled erosive seepage.
- Potentially gap-graded foundation soils could be subject to internal instability and facilitate erosive seepage.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- The water observed pooling behind the headwall at the downstream toe is coming from what is, in our opinion, the remnants of a reservoir level indicator line within the concrete encasement. RJH did not identify any other indications of seepage in the excavation at the downstream toe of the dam.
- The materials encountered in the three borings on the dam crest indicate the rocky embankment fill is underlain by a thick clayey stratum. During the seepage investigation, the outlet conduit concrete encasement was observed to be founded in the clayey foundation stratum. The three borings in the native material along the toe of the dam also encountered a thick, stiff, and generally erosion-resistant clay stratum. No borings could be advanced through the clayey foundation into the underlying shale bedrock to define the depth of the clayey foundation.
- The clay under the embankment fill includes substantial fractions of sand, gravel, cobbles, and boulders (as would be expected for a landslide material), but there was no evidence of continuous permeable layers or discontinuities that could form preferential seepage paths and facilitate erosion at the contact between the embankment fill and the underlying foundation clay.
- The undifferentiated landslide deposits of the natural foundation could include localized regions of gap-graded materials. However, several gap-graded regions would need to be contiguous before they could result in a relatively continuous layer of internally unstable soils that could create a seepage path. Also, the seepage would need to exit the ground before it could carry eroded soils out of the foundation. No

evidence of seepage emerging from such a zone in the foundation has been observed in the more than 70 years since the dam was constructed.

#### *5.1.2.2 PFM Recommendation*

RJH recommends that PFM #7 be reclassified with a Likelihood of "Low" and a Confidence Level of "Medium to Strong", as shown on Table 5.1.

### *5.1.3 PFM #12 – Concentrated Leak Erosion Along the Conduit*

This PFM occurs when a defect exists along a penetration through the dam, such as an outlet or other conduit. The defect could be a crack or void in the surrounding fill materials. Defects can also be associated with zones of low compaction density due to the shape of the penetration or the presence and configuration of seepage collars. The PFM was brought forward because of concerns about the historic "seepage" emerging from the downstream toe behind the old control building headwall. The PFM was assigned a Likelihood of "High" with a Confidence Level of "Poor" in the CDSE.

#### *5.1.3.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- Water flowing under the rocks at the downstream toe of the dam could be uncontrolled erosive seepage.
- Defects in the core fill material or zones of low compaction density could exist due to the presence of the concrete anti-seep collars. Cracking of the dam core or defects in the conduit that can discharge water from the pipe into the surrounding fill could facilitate development of unfiltered seepage along the conduit.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- The water observed during the seepage investigation flowing under the rocks at the dam toe is from what is, in our opinion, the remnants of a reservoir level indicator line within the concrete encasement, and not from seepage along the conduit.
- No evidence of any leakage or wetness along the conduit was observed in the seepage investigation excavation.
- The 1947 design drawings indicate the conduit was constructed with "anti-seep" collars, which are now known to facilitate embankment cracking and seepage. However, no evidence of seepage in the area of the conduit has been observed.

- Cracking of the fill adjacent to anti-seep collars can be pronounced when the collars are square. The collars at Hogchute dam are beveled at 45 degrees on the upper corners, which will alleviate some of the stresses that can cause cracking in the fill.
- This PFM is unlikely to develop more than 70 years after the dam was constructed, unless conditions within the dam change.

#### *5.1.3.2 PFM Recommendation*

RJH recommends that PFM #12 be reclassified with a Likelihood of "Low to Moderate" and a Confidence Level of "Strong", as shown on Table 5.1. In our opinion, because of the presence of the anti-seep collars, this PFM will continue to pose a possible threat to the dam until defensive measures are implemented to prevent erosion along the conduit. Monitoring should be continued, as discussed in Section 6.1 of this report.

### *5.1.4 PFM #13 – Concentrated Leak Erosion into the Conduit*

Leakage into the conduit occurs when a defect exists along the conduit that permits water to enter the pipe through the surrounding soils, eroding the soils into the pipe. Such a defect could include a crack, hole, or open joint in the conduit; slots or perforations cut too large for the surrounding soil; or other opening in a strategic part of the embankment and below the phreatic surface. The defect may be in alignment with an existing flaw in the embankment along the conduit that connects to the reservoir. This PFM was brought forward because of concern that the suspected broken outlet gate air vent penetrations through the embankment were causing up to 3 cfs of flow into the conduit and could be allowing embankment material to erode into the conduit. The PFM was assigned a Likelihood of "Moderate" with a Confidence Level of "Medium to Strong" in the CDSE.

#### *5.1.4.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- The suspected broken outlet gate air vents could be facilitating erosion of the embankment core material.
- The leakage of about 3 cfs is likely capable of eroding even the cohesive soils in the dam core.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- No easily erodible materials were encountered in the embankment core during the geotechnical investigation.
- Based on the 1947 design drawings, it appears that the outlet air vents are located within the rock shell on the upstream slope, and not within the embankment core.
- No evidence of eroded embankment soils has been detected in the outlet discharge channel or in the flume downstream of the dam.

#### *5.1.4.2 PFM Recommendation*

The City plans to design a rehabilitated outlet works that will eliminate this PFM. RJH recommends that the current rating of PFM #13 be maintained with a Likelihood of "Moderate" and a Confidence Level of "Medium to Strong" until the outlet works rehabilitation is completed. Continued monitoring of the leaking air vent discharge is warranted, as discussed in Section 6.1 of this report. Although there is no direct evidence of erosion, neither is there direct evidence that erosion cannot occur.

### *5.1.5 PFM #15 – Overtopping*

This PFM occurs when the spillway is incapable of passing the reservoir inflow to prevent the dam from being overtopped. This can happen if the spillway capacity is inadequate for the inflow, the spillway is partly or wholly obstructed, the spillway and outlet works system is mis-operated, or if a spillway gate hoist, lift chain, or valve fails. This PFM was brought forward because no formal hydrologic study and spillway assessment has been performed for Hogchute Dam. The Likelihood assigned for this PFM in the CDSE is "High", and the Confidence Level is "Poor."

#### *5.1.5.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- A preliminary hydrology study was performed to assess the adequacy of the existing spillway. Based on the results of the study, the existing spillway does not have adequate discharge capacity to prevent the dam from being overtopped during the local storm Probable Maximum Flood (PMF).

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- The rock shells on the upstream and downstream slopes may provide some degree of protection against embankment erosion when the dam is overtopped.

#### *5.1.5.2 PFM Recommendation*

RJH recommends that the Likelihood of PFM #15 be maintained as "High" and that the Confidence Level be increased to "Strong", as shown on Table 5.1, until the spillway can be improved.

### *5.1.6 PFM #26 – Outlet Gates Fail to Open*

This PFM results in the inability to release the reservoir contents, causing long-term storage that could lead to conditions favorable for initiation of other PFMs. This PFM was brought forward because of concern for the long-term integrity of the existing hydraulic gate controls and for the unknown condition of the outlet gates and intake structure. The Likelihood assigned for this PFM in the CDSE is "High", and the Confidence Level is "Medium to Strong."

#### *5.1.6.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- The condition and reliability of the existing outlet controls are unknown.
- The suspected broken outlet gate air vents indicate some degree of deterioration has likely occurred.
- Beavers occasionally obstruct the bypass ditch.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- The reservoir is generally maintained full or nearly full for most of the year, and the reservoir inflow can normally be bypassed around the dam when necessary to avoid activating the spillway. A full or nearly full reservoir is the usual static loading condition for the dam.
- There is no history of significant spillway obstruction, and there is no indication the spillway is prone to becoming obstructed.
- It is unlikely that the dam would be subjected to the unusual loading conditions of a long-term elevated reservoir level unless four circumstances all occur simultaneously: 1) a significant inflow event, 2) the spillway is obstructed, 3) the reservoir bypass control is inoperable, and 4) the outlet gates cannot be opened. It is unlikely that all four unusual circumstances could exist concurrently.

#### *5.1.6.2 PFM Recommendation*

The City plans to proceed with designing a rehabilitated outlet works system that will correct this PFM. RJH recommends the Likelihood of PFM #26 be maintained as "High" and the Confidence Level be maintained as "Medium to Strong", as shown on Table 5.1, until the outlet works rehabilitation is completed.

## 5.2 Non-Risk Driving Potential Failure Modes

The Non-Risk Driving PFMs were not assigned Likelihood ratings in the CDSE, and all of the Non-Risk Driving PFMs were assigned a Confidence Level of "Poor." These PFMs were carried forward from the initial screening process primarily because of a lack of adequate information to justify eliminating them from consideration as "Remote." It was felt that the information collected in addressing the Risk Driving PFMs would permit a more reliable Likelihood and Confidence Level assignment. Table 3.3 of the CDSE report recommends that all the Non-Risk Driving PFMs be pursued further only if the activities of the Dam Safety Evaluation or other analyses indicate that the specific PFM is credible. By undertaking the Dam Safety Evaluation Project, the City completed the required actions and obtained the necessary information to address the Non-Risk Driving PFMs. Our assessment of the current status of the Non-Risk Driving PFMs for Hogchute Dam is summarized below and in Table 5.1.

### *5.2.1 PFM #3 – Contact Erosion Through the Embankment*

This PFM occurs when seepage erosion takes place along the contact between the embankment core and a pervious zone above the core or the embankment core and a pervious foundation zone. The CDSE report states "Pursue this PFM after geotechnical investigation and only if PFM #2 likelihood and confidence increase."

#### *5.2.1.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- Seepage over or under the embankment core could erode the core and/or the foundation.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- Based on the 1947 design drawings and observations during the recent geotechnical investigation, the top of the dam core was constructed to within a foot of the elevation of the dam crest, or about 6 feet above the elevation of the spillway crest. Significant flow over the core can only occur if the dam is overtopped.

- During the geotechnical investigation, only the relatively thick zone of low-plasticity clay was encountered beneath the dam core. It is probable that any layers of permeable material between the core and the foundation were removed during the original dam construction so the core could be constructed in direct contact with the clayey foundation.
- The water identified during the seepage investigation flowing under the rocks at the downstream toe of the dam is not from seepage through the dam or foundation.

#### *5.2.1.2 PFM Recommendation*

As described above, the geotechnical investigation results indicate the recommended likelihood for PFM #2 should be reduced to “Low to Remote”, and the recommended confidence should be increased to “Medium to Strong.” RJH recommends that the Likelihood for PFM #3 be reduced to “Low to Remote”, with the recommended Confidence Level of “Medium to Strong”, as shown on Table 5.1.

### *5.2.2 PFM #4 – Suffusion/Suffosion Through the Embankment*

Suffusion and suffosion (internal instability) occur when finer soil particles are eroded out of a matrix of larger particles, leaving coarsened zones or voids that could permit increased erosion and/or collapse. A continuous seepage path, sufficient seepage velocity, and a seepage exit are required to sustain this erosion mechanism. The CDSE report states “Pursue this PFM if geotechnical investigation likelihood supports PFM as credible.”

#### *5.2.2.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- Internally unstable embankment and/or foundation soils could form preferential seepage paths and facilitate erosive seepage.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- The borings on the dam crest and at the dam toe encountered no evidence of voids, significant zones of clean coarse materials, or other potentially continuous defects in the dam core or foundation.
- The matrix soils observed between the coarser gravel particles were generally of sufficient plasticity to inhibit or reduce the potential for erosion.

- No evidence of seepage exiting the dam core has been detected since the dam was constructed.

#### *5.2.2.2 PFM Recommendation*

Seepage analyses to be completed for the dam rehabilitation design will provide information on the potential and remedy for internally unstable soils. Construction activities to rehabilitate or replace the existing toe drain and collect seepage will permit intercepting any regions of suffusion or suffosion to cut off seepage erosion. RJH recommends that the Likelihood for PFM #4 be assigned as "Low to Remote", with the recommended Confidence Level of "Medium to Strong", as shown on Table 5.1.

### *5.2.3 PFM #14 – Concentrated Leak Erosion Out of the Conduit*

The CDSE report states "Pursue this PFM only if internal inspection of outlet supports PFM as credible." Rather than perform a pressure test and an internal inspection of the existing outlet conduit, the City intends to design a new outlet works with a lined conduit to eliminate this PFM.

#### *5.2.3.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- Defects in the outlet conduit and encasement could allow outlet discharges to leak into the fill around the conduit and cause erosion of the fill.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- This PFM is unlikely to develop unless conditions in the outlet conduit change, e.g. a defect in the steel conduit and the bituminous coating opens and permits leakage from the conduit into the surrounding soil.
- Based on the 2008 video inspection of the conduit interior, the existing pipe coating was intact and in generally acceptable condition.
- No evidence of leakage out of the conduit was observed during the seepage investigation. No indications of erosion along the outside of the concrete encasement have been observed.
- Defects in the conduit that would permit leakage out of the conduit would also permit leakage into the conduit. No evidence of infiltration into the conduit has been observed.

#### *5.2.3.2 PFM Recommendation*

RJH recommends that PFM #14 be assigned a Likelihood of "Low to Moderate" with a Confidence Level of "Poor", as shown on Table5.1. As discussed in Section 6.1 of this report, continued monitoring for evidence of seepage and erosion is warranted until the new outlet works is constructed.

### *5.2.4 PFM #18 – Reservoir Landslide/Seiche Leading to Overtopping*

This PFM reflects concern that natural slopes around the reservoir rim may not be stable enough to prevent a landslide into the reservoir. The CDSE states "Geological site and seismic evaluations needed. Pursue only if future analysis supports PFM as credible."

#### *5.2.4.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- A landslide into the reservoir could produce a wave large enough to overtop the dam.
- The Grand Mesa is known to experience periodic landslides, which can be very large.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- No large landslides have occurred in the Carson Lake basin in recorded history.

#### *5.2.4.2 PFM Recommendation*

The geologic site assessment and seismic evaluations will be performed as part of the dam rehabilitation design scope. Until the studies are completed, RJH recommends that PFM #18 be assigned a Likelihood of "Moderate" with a Confidence Level of "Poor", as shown on Table 5.1.

### *5.2.5 PFM #19 – Rise in Phreatic Level Causes Deformation that Exceeds Freeboard*

This PFM develops when the phreatic level within the dam rises from clogging of a filter or toe drain, long-duration flood loading, or saturation of the slope from surface run-on or precipitation infiltration. Such a prolonged state of higher-than-normal saturation could cause the downstream slope to fail into or through the dam crest, which could decrease the freeboard and permit overtopping of the dam. The CDSE report states "Static slope stability evaluation required for high hazard dam. Pursue this PFM if geotechnical investigation likelihood supports PFM as credible."

#### *5.2.5.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- A prolonged state of unusually high saturation due to an elevated phreatic surface could weaken the embankment and cause a slope failure into or through the dam crest.
- The condition and effectiveness of the existing toe drain are not known, so the drain's potential effect on the phreatic surface cannot be evaluated at this time.
- The elevation and duration of the pool of record (the maximum historic reservoir surface level) is not known, so the dam's past performance under long-term or other flood loading conditions cannot be evaluated.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- According to the 1947 design drawings, Hogchute Dam does not have a filter zone that could become plugged and cause an elevated phreatic surface within the dam.
- The normal hydraulic loading condition is with the reservoir level at or nearly at the spillway crest elevation.
- Conditions observed during the seepage investigation at the downstream toe appear to confirm the design drawings, which show a substantial zone of free-draining rock buttressing the dam core. Surface run-on or precipitation infiltration are not likely to contribute significantly to an elevated phreatic surface.
- The buttressing rock shells can be expected to provide support to prevent slumping of the core zone that would result in loss of freeboard.

#### *5.2.5.2 PFM Recommendation*

The required slope stability analyses will be performed as part of the rehabilitation design phase of the project. Until the studies are completed, RJH recommends that PFM #19 be assigned a Likelihood of "Low to Moderate" with a Confidence Level of "Poor", as shown on Table 5.1.

### *5.2.6 PFM #20 – Slump Reduces Seepage Path Leading to Internal Erosion*

This PFM will occur if the conditions of PFM #19 develop to a lesser degree. The failed slope may not extend into the crest and cause a loss of freeboard, but a slump could shorten the seepage path and accelerate seepage and erosion through the dam. Similar to PFM #19, the CDSE report states "Static slope stability evaluation required for high hazard dam. Pursue this PFM if geotechnical investigation Likelihood supports PFM as credible."

#### *5.2.6.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- A slope failure could accelerate seepage and erosion through the dam.
- The existing downstream slope does not exactly match the slope shown on the drawings, indicating a slump may have occurred.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- Based on site observations, the dam is constructed generally in accordance with the 1947 design drawings, with the exception that the clayey core material includes significantly higher amounts of gravels, cobbles, and boulders than is indicated on the drawings.
- The clayey core appears to be relatively strong and is buttressed on the upstream and downstream sides by high-strength free-draining rocky shells.
- While the existing downstream slope does not exactly match the slope shown on the drawings, there are no other indications (increased or turbid seepage, cracking on the crest, etc.) that the slope has moved or is likely to move. The slope configuration noted in the CDSE could be due to the 1988 excavation at the downstream toe.

#### *5.2.6.2 PFM Recommendation*

Seepage and stability analyses will be performed as part of the dam rehabilitation phase of the project to evaluate the safety of the slopes. Until the studies for the dam rehabilitation design are completed, RJH recommends that PFM #20 be assigned a Likelihood of "Low to Moderate" with a Confidence Level of "Poor", as shown on Table 5.1.

### 5.2.7 PFM #21 – Rapid Drawdown Failure of Upstream Slope

A rapid drawdown slope failure occurs when the reservoir level is lowered so rapidly that the pore pressures in the saturated upstream slope cannot dissipate quickly enough to compensate for the removal of the water's weight on the slope. The excess pressures within the dam destabilize the upstream slope, and the slope can fail. The CDSE report states "Pursue this PFM if geotechnical investigation Likelihood supports PFM as credible."

#### 5.2.7.1 PFM Evaluation

Positive Factors (indications that the PFM is more likely to cause dam failure):

- There is no evidence that the upstream slope of the clayey core is protected by a filter to prevent the core material from migrating into the open rock zone during rapid drawdown.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- Based on field observations and the 1947 design drawings, the upstream slope of the dam core is buttressed by a substantial zone of strong rock materials that will allow water to drain freely as the reservoir level is lowered.
- The reservoir is routinely lowered about 10 feet in the fall, and no evidence of slope instability has been observed.
- Based on the laboratory test results, the core material likely has sufficient plasticity to resist the expected low seepage forces that could destabilize the slope during rapid drawdown.

#### 5.2.7.2 PFM Recommendation

Slope stability analyses under the rapid drawdown loading condition will be performed as part of the dam rehabilitation phase of the project. Until the studies are completed, RJH recommends that PFM #18 be assigned a Likelihood of "Low to Moderate" with a Confidence Level of "Poor", as shown on Table 5.1.

### 5.2.8 PFM #22 – Dynamic Deformation Greater Than Freeboard

This PFM reflects the possibility that there could be a significant reduction in foundation strength due to earthquake-induced liquefaction of low-plasticity and cohesionless materials. It is also possible that cohesive, plastic soils in the foundation could be susceptible to significant strength loss during or following an earthquake due to strain-softening. The CDSE report states "Seismic evaluation required for High hazard dam. Pursue this PFM if geotechnical investigation Likelihood supports PFM as credible."

#### *5.2.8.1 PFM Evaluation*

- Positive Factors (indications that the PFM is more likely to cause dam failure):
- The dam's susceptibility to seismic deformation due to liquefaction or other loss of soil strength is not known.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- No soils that could be considered susceptible to liquefaction were encountered in the embankment or foundation during the geotechnical and seepage investigations.

#### *5.2.8.2 PFM Recommendation*

Evaluation of the dam and foundation material strength properties and, if needed, a seismic deformation analysis should be conducted as part of the slope stability analyses during the rehabilitation design phase of the project. Until the studies are completed, RJH recommends that PFM #22 be assigned a Likelihood of "Low to Moderate" with a Confidence Level of "Poor", as shown on Table 5.1.

### *5.2.9 PFM #23 – Differential Settlement Leads to Transverse Cracking*

Differential settlement in the embankment and/or foundation soils is frequently associated with embankment cracking or regions of low-stress concentrations in the embankment or foundation. Such cracking and softened zones generally occur where the embankment fill height changes abruptly over a short distance, over abrupt changes in the foundation depth, geometry, or density, over collapsible soils, or over irregularities such as conduits. The CDSE report states "Seismic evaluation required for High hazard dam. Pursue this PFM if geotechnical investigation Likelihood supports PFM as credible."

#### *5.2.9.1 PFM Evaluation*

Positive Factors (indications that the PFM is more likely to cause dam failure):

- According to the 1947 drawings, the Hogchute Dam design included some elements that are now known to make a dam susceptible to differential settlement and the development of cracking and low-stress concentrations. These elements include significant changes in the foundation geometry and the inclusion of concrete anti-seep collars on the outlet conduit encasement.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- Differential settlement of the embankment or foundation soils is frequently manifested as cracking of the dam crest. However, no cracking or settlement has been observed at the dam in the more than 71 years since construction was completed.

#### *5.2.9.2 PFM Recommendation*

Evaluation of seismic and other conditions that could lead to embankment cracking will be conducted during the rehabilitation phase of the Project. Until the studies are completed, RJH recommends that PFM #23 be assigned a Likelihood of "Low to Moderate" with a Confidence Level of "Poor", as shown on Table 5.1.

## 5.3 New Potential Failure Mode

During drilling for the geotechnical investigation, the apparent water table was encountered at different elevations in borings B-101 (about El. 9847), B-102A (about El. 9860), and B-103 (about EL 9876). In B-101 and B-102, water rose within the auger casings above the apparent elevation of the groundwater. Piezometer readings in B-101(P) and B-102(P) taken after completion of drilling and instrument installation indicate the water levels had stabilized in both borings at nearly the same elevation (about El. 9862 to 9863). Groundwater in piezometer B-103(P) had dropped below the bottom of the piezometer casing (about El. 9880).

### *5.3.1 PFM Description*

The difference in the elevations of the apparent saturated zones between borings and the measured rise in water levels within the auger casings during drilling could indicate a possible condition of elevated pore water pressures in the foundation. A PFM can exist when a confining layer of low-permeability soil overlies a foundation zone of more permeable soils in hydraulic contact with the reservoir. This PFM is typically a concern for foundations that contain a layer of erodible non-cohesive materials confined below a layer of less-erodible clayey material, as described for PFM #7. If the high foundation pressures exist downstream of the dam toe, and if the overburden stresses are inadequate to confine the pressures, bulging, heaving, fracturing, or blowout of the overburden can occur, initiating erosion of the foundation materials. Drilling or excavating into a zone of elevated foundation pressures could also release the pressures and cause erosion in the foundation.

### 5.3.2 PFM Discussion

Although the possible existence of this PFM is cause for concern, several factors tend to indicate the elevated foundation pressures may not constitute a credible PFM for the dam. To properly characterize the risk, a potential failure mode analysis should be performed. The chain of events leading to failure and the factors defining the event tree nodes (initiation, continuation, progression, intervention, and ultimate failure) specifically for Hogchute Dam are not well understood at this time. For the purpose of this Project, RJH followed the CDSE procedure of listing Positive and Adverse Factors for a preliminary assessment of the PFM.

The planned drilling for installation of piezometers at the dam toe posed a risk that elevated foundation pressures could be released, possibly endangering the dam. Therefor, to reduce the hydrostatic head on the foundation, the City drew the reservoir level down by about ten feet prior to drilling.

### 5.3.3 PFM Evaluation

Positive Factors (indications that the PFM is more likely to cause dam failure):

- Drilling records indicate the possibility that elevated foundation pore pressures could exist.
- The effectiveness of the existing toe drain in relieving foundation pressures is unknown.
- No seepage or piezometer monitoring program is in place to document conditions over time.
- Recently installed piezometers are too new to provide a meaningful data history.
- Drilling or other construction activities at the dam toe could possibly release pressures and cause erosion of the foundation.

Adverse Factors (indications that the PFM is less likely to cause dam failure):

- No evidence of surface disturbance such as uplift, heave, boils, or fracturing has been observed in the more than 70 years since the dam was constructed.

- No evidence of surface seepage has been observed downstream of the dam. Water flowing under the rock toe is from a leaking reservoir level indicator line, and is not foundation or embankment seepage. Wetness in the willows at the top of the right outlet channel bank appears to be shallow perched water and is not considered to be associated with seepage through the embankment or foundation.
- No zones of erodible foundation soils were encountered in any of the recent piezometer boreholes on the dam crest and at the downstream toe.
- No indications of high foundation pore pressures were noted in the City's 1988 report of extending the existing toe drain discharge pipe.
- The apparently elevated foundation pressures may have been the transitory effects of drilling disturbance and could stabilize at a lower level with time.
- With the reservoir level lowered about ten feet, no artesian or semi-artesian conditions were encountered during installation of the three piezometers at the dam toe.

### *5.3.4 PFM Recommendation*

In our opinion, there is insufficient information available at this time to determine why the elevated foundation pore pressures exist and if the condition would constitute a credible PFM. The piezometers on the dam crest were installed in August, and twelve readings were obtained after the instruments were completed. The piezometers at the dam toe were installed in late September, and only a few readings could be taken before the site became inaccessible for the winter. A longer record of piezometer readings is required to make a valid assessment of the foundation pressures.

The recommended actions for collecting and monitoring seepage discussed in Section 6 of this Report would provide additional information required to characterize and manage the possible risk of this PFM. For the present, RJH recommends designating this condition as non-Risk Driving PFM #5a – Foundation Erosion from Release of High Foundation Pressures. RJH recommends this PFM be assigned a Likelihood of Low to Moderate with a Consequence Level of 2 and a Confidence Level of Poor as shown in Table 5.1. As discussed in Section 6.1, RJH recommends diligent monitoring of the piezometers, careful evaluation of the instrument data, and regular physical inspection of the site while additional information is obtained during the dam rehabilitation design and construction phases of the project.

# TABLE 5.1
# PFM EVALUATION SUMMARY

| PFM # | PFM Name | CDSE | | Recommended | |
|---|---|---|---|---|---|
| | | Likelihood | Confidence | Likelihood | Confidence |
| **Risk Driving PFMs** | | | | | |
| 2 | BEP through the Embankment | Moderate | Poor to Medium | Low to Remote | Strong |
| 7 | Contact Erosion through the Foundation | Moderate | Poor to Medium | Low | Medium to Strong |
| 12 | Concentrated Leak Erosion along the Conduit | High | Poor | Low to Moderate | Strong |
| 13 | Concentrated Leak Erosion into the Conduit | Moderate | Medium to Strong | Moderate | Medium to Strong |
| 15 | Overtopping | High | Poor | High | Strong |
| 26 | Outlet Gate(s) Fail to Open | High | Medium to Strong | High | Medium to Strong |
| **Non-Risk Driving PFMs** | | | | | |
| 3 | Contact Erosion through Embankment | --- | Poor | Low to Remote | Medium to Strong |
| 4 | Suffusion/Suffosion through Embankment | --- | Poor | Low to Remote | Medium to Strong |
| 14 | Concentrated Leak Erosion out of Conduit | --- | Poor | Low to Moderate | Poor |
| 18 | Reservoir Landslide or Seiche Leading to Overtopping | --- | Poor | Moderate | Poor |
| 19 | Rise in Phreatic Level Causes Deformations that Exceed Freeboard | --- | Poor | Low to Moderate | Poor |
| 20 | Slump Reduces Seepage Path Leading to Internal Erosion | --- | Poor | Low to Moderate | Poor |
| 21 | Rapid Drawdown Failure of Upstream Slope | --- | Poor | Low to Moderate | Poor |
| 22 | Dynamic Deformation Greater than Freeboard | --- | Poor | Low to Moderate | Poor |
| 23 | Differential Settlement Leads to Transverse Cracking | --- | Poor | Low to Moderate | Poor |
| 5a | Foundation Erosion from Release of Foundation Pressures | --- | --- | Low to Moderate | Poor |

## 5.4 Revised Risk Chart Summary

Figure 3.4 of the CDSE Report is reproduced as Figure 5.1 of this Report to show graphically the recommended revisions to the Likelihood ratings of the Risk Driving and Non-Risk Driving PFMs. The assigned Consequence Level of the Risk Driving PFMs does not change, even when the Likelihood is revised. To simplify the evaluation of the Non-Risk Driving PFMs, all were conservatively assumed to fall into the Consequence Level range of 2 to 3.

## 5.5 Summary and Conclusions

### *5.5.1 Risk Driving PFMs*

Based on the Dam Safety Evaluation work described above, the Likelihoods of three of the Risk Driving PFMs have decreased, and the revised PFMs now plot with substantially increased confidence well below both of the red lines of the Risk Summary Chart. The Likelihoods of the remaining three Risk Driving PFMs have not changed.

- PFM #15 (overtopping) plotted above both red lines on the CDSE Risk Summary Chart, meaning this PFM poses a high risk to the dam. The Likelihood of this PFM has not decreased, and the Confidence Level that this PFM could occur has increased. Its position on the Revised Risk Summary Chart indicates that the City should take action to immediately reduce the risk. We recommend that the City maintain the reservoir level at least 5.5 feet below the existing spillway crest until the spillway can be enlarged during the dam rehabilitation project.
- PFM #13 (concentrated leak erosion into the conduit) is plotted below both red lines in the CDSE report, and the risk for this PFM is unchanged. PFM #26 (outlet gates fail to open) plotted above the red lines of the CDSE matrix, and the Likelihood of this PFM occurring remains unchanged. PFMs #13 and #26 plot in chart boxes that indicate the PFMs must be properly managed to control the risk. Rehabilitation of the outlet works by lining the conduit, as planned by the City, will eliminate these PFMs.
- PFMs #2 (BEP through the embankment), #7 (contact erosion through the foundation), and #12 (concentrated leak erosion along the outlet conduit), are plotted within the green boxes on the CDSE Risk Summary Chart, indicating that these PFMs are considered to pose relatively little immediate risk to the dam. As a result of this Dam Safety Evaluation, the Likelihoods of these three PFMs have decreased, as shown on the Revised Risk Summary Chart of Figure 5.1. The Confidence Level associated with these lowered Likelihoods has increased; however, these PFMs must still be monitored so they can be appropriately managed until they can be eliminated.

Design and construction of the recommended erosion protection rehabilitation measures could eliminate these PFMs.

### *5.5.2 Non-Risk Driving PFMs*

Based on our evaluation of the Non-Risk Driving PFMs, it is our opinion that all of them, even with a conservatively high estimated Consequence Level, plot well below both red lines on the Revised Risk Summary Chart of Figure 5.1.

- PFMs #3 (contact erosion through the embankment) and #4 (suffusion/suffusion through the embankment) have a high enough Confidence Level to consider changing their Likelihood to "Remote" and eliminating them.
- PFM #5a is not sufficiently understood at this time to permit confident characterization of the risk. Based on our field observations and current understanding, this PFM is presently considered a Non-Risk Driving PFM with a Likelihood of Low to Moderate, a Consequence Level of 2, and a Confidence Level of Poor. Although this new PFM currently plots well below both red lines on the Revised Risk Summary Chart, the low confidence and relatively high consequence estimates indicate the City should take actions to obtain the information necessary to better define and reduce the risk by monitoring the new piezometers, as discussed in Section 6.1. The recommended actions to implement a program of seepage collection and instrumentation monitoring will likely provide the necessary information for managing the risk associated with this PFM.
- The analyses to be performed during the dam rehabilitation design phase of the project will provide the information required for final evaluation of the remaining Non-Risk Driving PFMs.


Source: Comprehensive Dam Safety Evaluation Report, Hogchute Dam, DAMID 420127, State of Colorado Division of Water Resources, 2018

# SECTION 6 – NECESSARY ACTIONS

## 6.1 Recommended Immediate Actions

RJH recommends that the City take the following actions as soon as practical to address critical PFMs and improve the dam's safety.

### *6.1.1 Spillway*

The discharge capacity of the spillway must be increased to prevent overtopping of the dam during the design storm (PFM #15). Until the spillway improvements are completed during the dam rehabilitation, RJH recommends that the City maintain the reservoir level at least 5.5 feet below the existing spillway crest.

### *6.1.2 Outlet Works*

The outlet works must be rehabilitated to reduce the potential for embankment erosion due to leakage (PFMs #13 and #14) and to improve the efficiency and dependability of the outlet gates (PFM #26).

### *6.1.3 Interim Monitoring*

The City should implement a program of diligent monitoring during the period while the dam rehabilitation design is developed and constructed.

- The new piezometers should be monitored at least twice monthly whenever the instruments are accessible. These data will be valuable in the design of the erosion protection and seepage collection features recommended for the dam rehabilitation.
- The reservoir level should be recorded at least monthly during the winter and whenever the piezometers are monitored. The reservoir level readings should be recorded with the piezometer data.
- Internal erosion of the embankment or foundation is a concern common to PFMs #12 (concentrated leak erosion along the conduit), #13 (concentrated leak erosion into the conduit), #14 (concentrated leak erosion out of the conduit), and #5a (foundation erosion from release of foundation pressures). Monitoring for evidence of these PFMs should be ongoing until the outlet works improvements and the erosion protection features recommended for the dam rehabilitation are constructed. Monitoring for these PFMs should consist generally of visual observations of the

quantity and clarity of water discharged through the outlet conduit when the gates are closed, flowing under the rocks at the downstream toe, and in the wet area on the right bank of the outlet channel. Any indications of cloudiness in the flow must be reported immediately. Any indications of new seepage or changes in the ground surface downstream of the dam (such as bulging, cracking, or heaving) must be reported immediately.

- The quantity of water flowing under the rock toe should be measured at the sump with a container and a stopwatch and recorded with the piezometer monitoring data. Any observable cloudiness or increases in quantity must be reported immediately.
- Visual observation of the dam crest and the general area along and downstream of the dam toe should also be made, especially for indications of eroded material (depressions on the crest or sand/silt deposits in the outlet discharge basin or the measuring flume). The visual observations should be made whenever the piezometers are read, and comments describing the observed conditions should be recorded on the piezometer monitoring forms.

The piezometer and flow monitoring data should be recorded for plotting and evaluation by an engineer.

## 6.2 Recommended Actions for Future Consideration and Planning

RJH recommends that the City include the following actions in their capital improvements planning to address other PFMs and reduce the risk of dam failure. These actions should be incorporated into the design for the dam rehabilitation project.

### *6.2.1 Seepage Collection*

All seepage should be collected for regular monitoring. Improvement or replacement of the existing toe drain along with collection of other seepage could be combined with other recommended actions to address PFM #5a (high foundation pressures), PFM #12 (concentrated leak erosion along the outlet conduit), and PFM #14 (concentrated leak erosion out of the conduit).

### *6.2.2 Erosion Protection*

The embankment core should be protected from erosive seepage along the outlet conduit or from defects associated with the concrete anti-seep collars. Erosion protection design and construction could be combined with other work items like rehabilitation of the outlet works and improved seepage collection to manage or eliminate several PFMs, including PFM #12 (erosion along the conduit), PFM #21 (rapid drawdown failure), and PFM #23 (erosion associated with differential settlement and cracking).

### *6.2.3 Long-Term Instrumentation Monitoring*

The dam rehabilitation design should include an Instrumentation and Monitoring Plan, as required by the SEO. This plan should include requirements for monitoring all instrumentation at the dam for the life of the dam, including special monitoring requirements as the reservoir is refilling after construction. Generally, the required instrumentation for a High Hazard dam will include:

- Reservoir level gage rod.
- Piezometers.
- Seepage collection.
- Dam crest movement monuments.

The frequency of monitoring and reporting requirements will be set by the SEO. Currently, the SEO Rules (Rule 15.2) require that High Hazard dams must be monitored by the dam owner at least twice a month, whenever the reservoir is more than half-full.

## 6.3 Risks of Inaction

### *6.3.1 Spillway*

#### *6.3.1.1 Overtopping*

The existing spillway is not adequate to pass the required inflow to the reservoir. The runoff from the IDF is predicted to overtop the dam, which could cause the dam to fail, endangering the lives of people in the downstream floodplain. The dam could also overtop to a lesser degree during smaller storms.

The rock shells on the slopes of the dam would provide a degree of protection against failure during overtopping. The degree of possible protection is difficult to quantify, and a more sophisticated analyses would be required to evaluate the probability of failure by overtopping.

#### *6.3.1.2 Impacts to Other Dams*

The runoff models used to calculate the inflow to Carson Lake were based on conservative approximations that included failure of both Grand Mesa #8 and Grand Mesa #9 dams upstream of Hogchute dam during the design storm. A more detailed analysis would be required to determine if either or both of these dams needs to be upgraded to high hazard status.

### *6.3.2 Outlet Works*

#### *6.3.2.1 Continued Deterioration*

The increasing discharge from the outlet conduit with the outlet gates closed indicates that some degree of deterioration is likely occurring. The gates are at present functional, but there is no way of knowing if the increase in discharge is from the presumed broken air vents or from increasing gate leakage. There are no isolation features on the existing gates, so failure of the gates or gate seals would likely necessitate draining the reservoir to make repairs.

#### *6.3.2.2 Continued Leakage*

Failure to rehabilitate the outlet works will allow the existing leakage from the improperly abandoned reservoir level gauge to persist, will prevent isolation and measurement of seepage to detect the development of any additional seepage, and could permit concentrated seepage into or out of the conduit to develop (PFMs #13 and #14).

### *6.3.3 Erosion Protection*

Failure to protect the embankment core from erosive seepage could permit development of internal erosion. The erosion could be initiated by changing conditions in the dam interior or foundation or by cracking of the core at the existing concrete cutoff collars on the outlet conduit (PFMs #12, #22, and #23).

## 6.4 Consequences of Inaction

### *6.4.1 Storage Restriction*

Failure to increase the Hogchute Dam spillway discharge capacity will likely result in a storage restriction to maintain the Carson Lake reservoir level low enough to prevent the dam from overtopping during the design flood.

### *6.4.2 Impacts to Other Dams*

Failure to increase the spillway capacity could result in an order from the SEO to investigate the spillway capacities and embankment stability of Grand Mesa #8 and Grand Mesa #9 dams.

### *6.4.3 Continued Uncertainty*

#### *6.4.3.1 Outlet Works*

Failure to rehabilitate the outlet works will likely not result in a storage restriction, but would cause continued uncertainty, continued concern about developing PFMs, and probable future repairs to the system that could be preempted by the rehabilitation.

#### *6.4.3.2 Dam Core*

Failure to provide erosion protection for the dam core would allow the uncertainties associated with several seepage PFMs to persist.

# SECTION 7 – BUDGETARY COST ESTIMATES FOR NECESSARY ACTIONS

RJH developed an Opinion of Probable Construction Cost (OPCC) for the recommended dam rehabilitation items to assist the City in capital projection estimates. The OPCC presented in Table 7.1 is considered a Class 5 estimate as defined by the Association for the Advancement of Cost Estimating and ASTM E2516-11: *Standard Classification for Cost Estimate Classification Systems.* This class designation is used when the design is less than 2 percent complete. The actual project costs could range from about 50 percent lower to 100 percent higher than the estimate. Class 5 estimates are appropriate for screening project concepts, but do not typically provide reliable design and construction budget estimates.

The Base Construction Subtotal (BCS) shown on Table 7.1 is the sum of the estimated construction costs for the primary work elements. Additional project costs are estimated as factored percentages of the BCS.

- Additional costs to the Contractor include mobilization and demobilization, bonds, and insurance. These costs are estimated as percentages of the BCS and are added to the BCS to produce the estimated Direct Construction Subtotal (DCS).
- The OPCC is the sum of the DCS, construction contingencies, and engineering and administration costs, which includes the following allowances:
  - 40 percent of the DCS to account for construction contingencies. This also includes an allowance for items that cannot be defined at the concept design phase, unit price and quantity variations, and variable market conditions. Based on our experience, this percentage is appropriate for a concept-level design and will decrease as the Project is better defined in subsequent stages of design.
  - 12 percent of the DCS to account for design engineering including investigations, surveys, analyses, and design documents.
  - 10 percent of the DCS for construction engineering and testing.
  - 2 percent of the DCS for legal fees.
  - 2 percent of the DCS for environmental permitting.

Our cost opinions were developed by estimating the likely scopes of primary elements of the recommended work and applying costs developed from the following sources:

- Published and unpublished bid price data for similar work.
- Published and unpublished construction cost data for similar work.

- Our previous experience and judgment.

Actual costs will be affected by a number of factors that are currently undetermined, such as supply and demand for the types of construction required at the time of bidding, the Project location, changes in material supplier costs, changes in labor rates, competitiveness of contractors and suppliers, availability of qualified bidding contractors, changes in applicable regulatory requirements, and changes in design standards. Conditions and factors arising as the Project proceeds from concept screening through bidding and construction may result in construction costs that differ significantly from the estimate provided in this Report.

**TABLE 7.1**
**HOGCHUTE DAM ESTIMATED REHABILITATION COSTS**

| Task | Estimated Cost ($) |
|---|---|
| Enlarge existing spillway[1] | 152,000 |
| Rehabilitate outlet works | 664,000 |
| Construct erosion protection and seepage collection system | 834,000 |
| **Base Construction Subtotal (BCS)** | **1,650,000** |
| | |
| Contractor mobilization and demobilization (10% of BCS) | 165,000 |
| Contractor’s bonds and insurance (1.5% of BCS) | 24,750 |
| **Direct Construction Subtotal (DCS)** | **1,839,750** |
| | |
| Construction contingencies (40% of DCS) | 735,900 |
| Design engineering (12 % of DCS) | 220,770 |
| Construction engineering and testing (10% of DCS) | 183,975 |
| Legal fees (2% of DCS) | 36,795 |
| Environmental permitting (2% of DCS) | 36,795 |
| | |
| **Opinion of Probable Construction Cost (OPCC)** | **3,053,985** |

Note:
1. Assume approximately 165-foot wide spillway channel and crest structure. The actual spillway size will be determined by the required discharge capacity.

# SECTION 8 – DAM SAFETY EVALUATION CONCLUSIONS AND RECOMMENDATIONS

## 8.1 Conclusions

The purposes of the CDSE conducted by the SEO were to reduce or better define the perceived risks and to provide guidance for a rehabilitation design for Hogchute Dam. In support of the CDSE, this Dam Safety Evaluation Project has generally provided the necessary information and identified additional information required to better characterize the risks and develop recommendations for a basis for the scope of the future rehabilitation of the dam.

## 8.2 Recommended Scope for Dam Rehabilitation Design

Based on our knowledge of Hogchute Dam and our experience as dam design engineers, RJH recommends that the scope of the project's dam rehabilitation design phase include the following primary items:

1. Modify the spillway to safely pass the required IDF.
2. Perform required seepage and embankment stability analyses and the site assessment to evaluate the safety of the dam. The loading conditions to be considered will be developed in the required pre-design meeting with the SEO.
3. Rehabilitate the outlet works to remove the operational and safety issues with the existing bifurcated conduit and the deteriorated gates and vents.
4. Design erosion protection measures to prevent the dam core from damage by erosive seepage.
5. Evaluate the need for protecting the core against erosion during rapid drawdown of the reservoir.
6. Implement seepage control features to collect all seepage for monitoring, including rehabilitation or replacement of the existing toe drain.
7. Develop an instrumentation monitoring and reporting program.

### 8.3 Recommended Risk Management Actions

Based on the results of this Dam Safety Evaluation Project, the City's risk management activities should be guided by the following considerations:

1. PFMs #2 (BEP through the embankment), #3 (contact erosion through the embankment), and #4 (suffusion/suffusion through the embankment) have been essentially eliminated from consideration as plausible potential failure modes. The actions recommended for rehabilitation of the dam will address the remaining uncertainty for these PFMs so they can be considered as remotely likely to occur.
2. PFM #15 (overtopping) will be corrected by the recommended spillway modifications. Interim risk management will be accomplished through maintaining the reservoir level 5.5 feet below the existing spillway crest to provide adequate freeboard until the spillway modifications are constructed.
3. PFMs #26 (outlet gates fail to open) and #13 (concentrated leak erosion into the conduit) will be eliminated with the planned outlet works rehabilitation.
4. PFMs #7 (contact erosion through the foundation), #12 (concentrated leak erosion along the conduit), and #14 (concentrated leak erosion out of the conduit) will be managed through design and construction of the recommended seepage collection and erosion protection on the downstream side of the dam core.
5. The required engineering analyses for the recommended dam rehabilitation actions will provide the information necessary for a more complete evaluation of the following PFMs:
    a. PFM #18 (reservoir landslide or seiche leading to overtopping) will be addressed through the required geologic and seismic evaluations.
    b. PFMs #19 (rise in phreatic level causes deformations that exceed freeboard), #20 (slump reduces seepage path leading to internal erosion), and #21 (rapid drawdown failure of the upstream slope) will be addressed with the slope stability analyses.
6. PFM #5a (foundation erosion through release of high foundation pressures) will be addressed with the information obtained through design and construction of the seepage collection system.
7. The recommended interim and long-term monitoring programs will facilitate early detection of developing dam safety problems and will enable the City to actively manage risk though timely response to potential concerns.

# SECTION 9 – REFERENCES

Colorado Division of Water Resources (2018). *Comprehensive Dam Safety Evaluation Report, Hogchute (aka Carson Lake) Dam,* DAMID 420127 February.

Colorado Office of the State Engineer (SEO) (2007). *Rules and Regulations for Dam Safety and Dam Construction*, January.

U.S. Bureau of Reclamation (Reclamation) (2015). *Best Practices in Dam and Levee Safety Risk Analysis,* A Joint Publication by U.S. Department of Interior, Bureau of Reclamation, and U.S. Army Corps of Engineers, version 4.0, July.

# APPENDIX A

## BACKGROUND DOCUMENTS

### A.1 1947 DESIGN DRAWINGS

### A.2 1988 LETTER FROM CITY TO COLORADO DIVISION OF WATER RESOURCES

# APPENDIX A.1

## 1947 DESIGN DRAWING

# APPENDIX A.2

## 1988 LETTER FROM CITY TO COLORADO DIVISION OF WATER RESOURCES

# APPENDIX B

## COMPREHENSIVE DAM SAFETY EVALUATION REPORT FOR HOGCHUTE DAM, COLORADO OFFICE OF THE STATE ENGINEER, FEBRUARY 2017

# APPENDIX C

## HYDROLOGY REPORT AND SPILLWAY EVALUATION

# APPENDIX D

## GEOTECHNICAL DATA REPORT

# APPENDIX E

## SEEPAGE INVESTIGATION DAILY FIELD REPORTS

# APPENDIX A

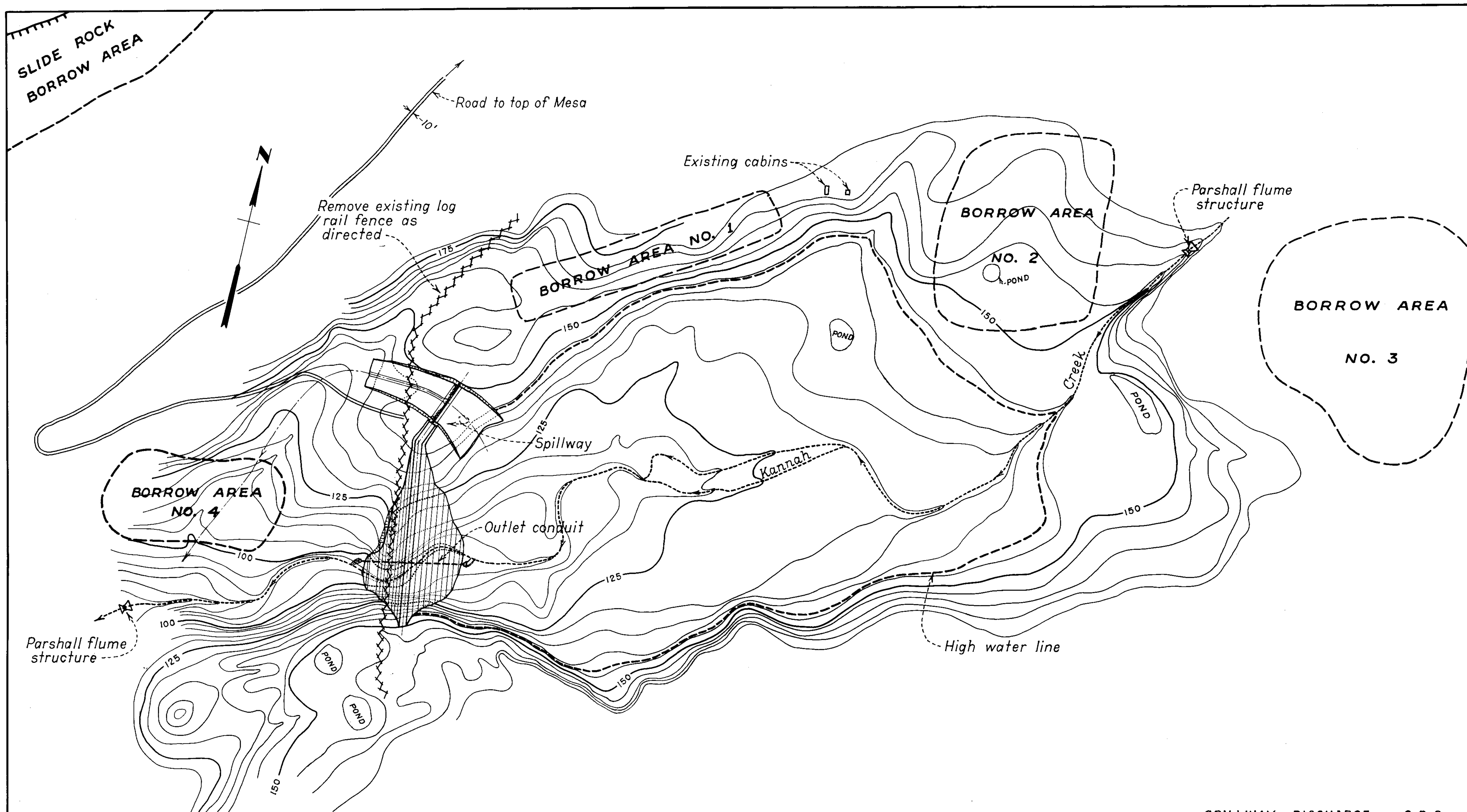
# BACKGROUND DOCUMENTS

## A.1 1947 DESIGN DRAWINGS

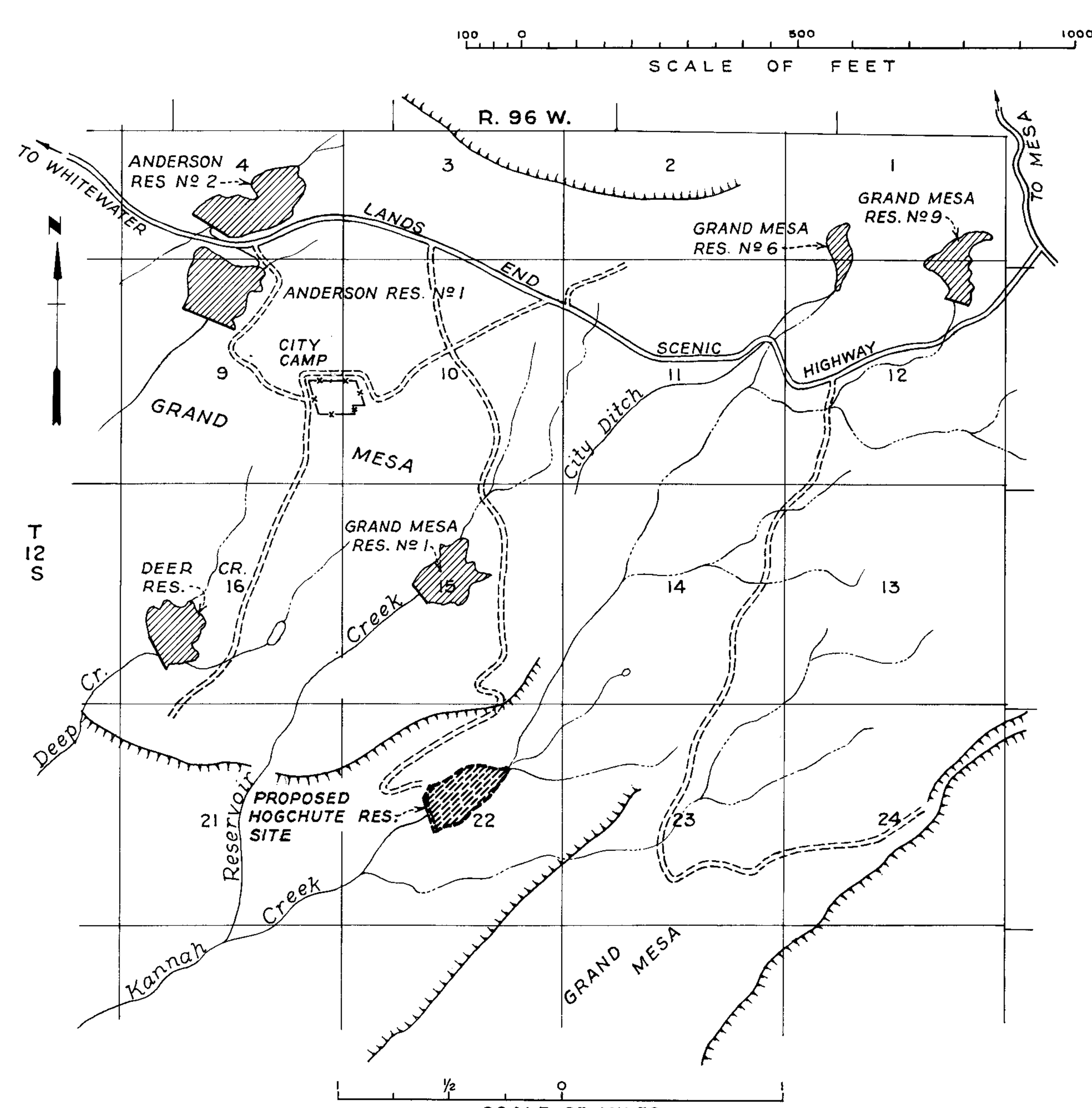
## A.2 1988 LETTER FROM CITY TO COLORADO DIVISION OF WATER RESOURCES

# APPENDIX A.1

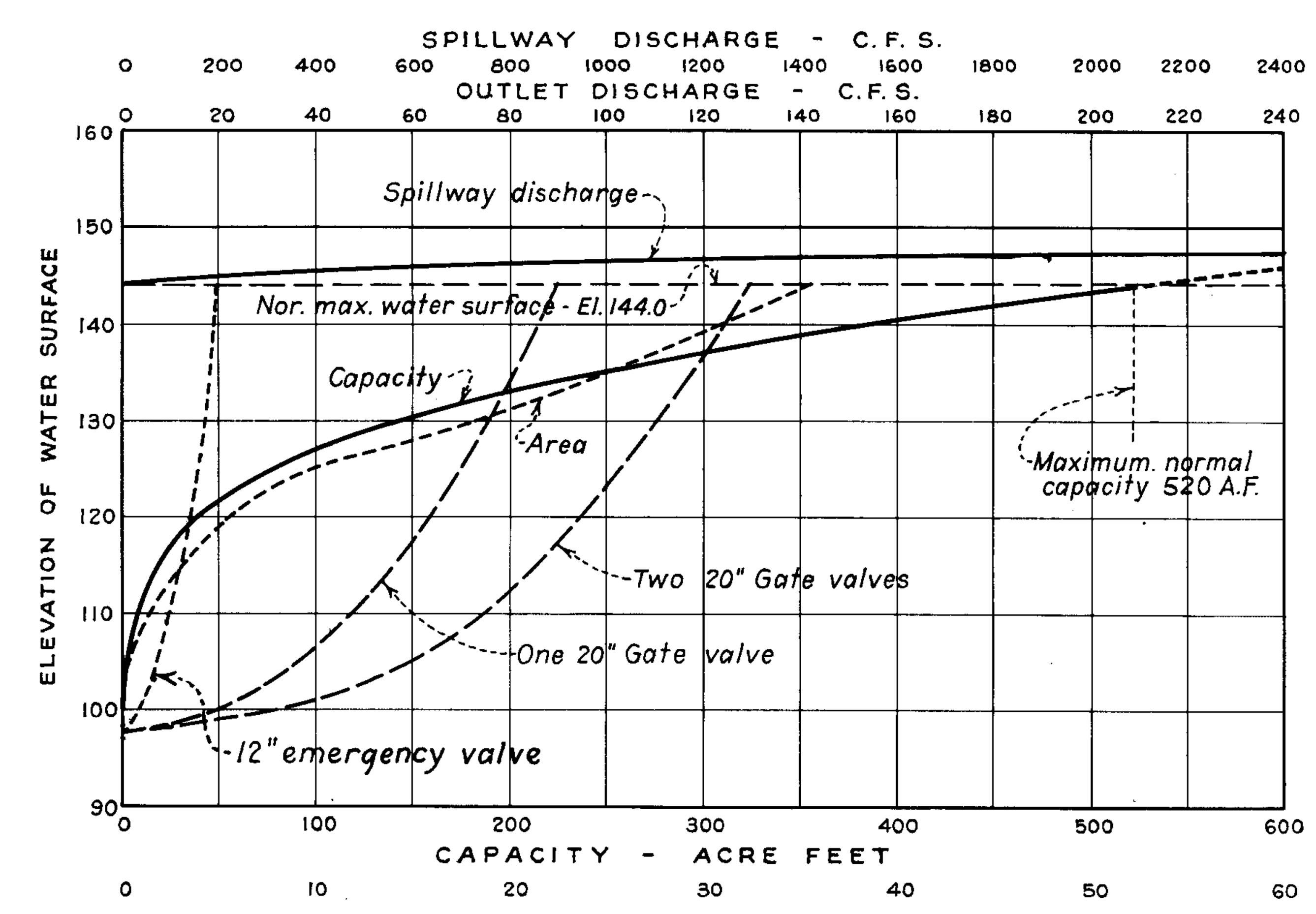
## 1947 DESIGN DRAWING



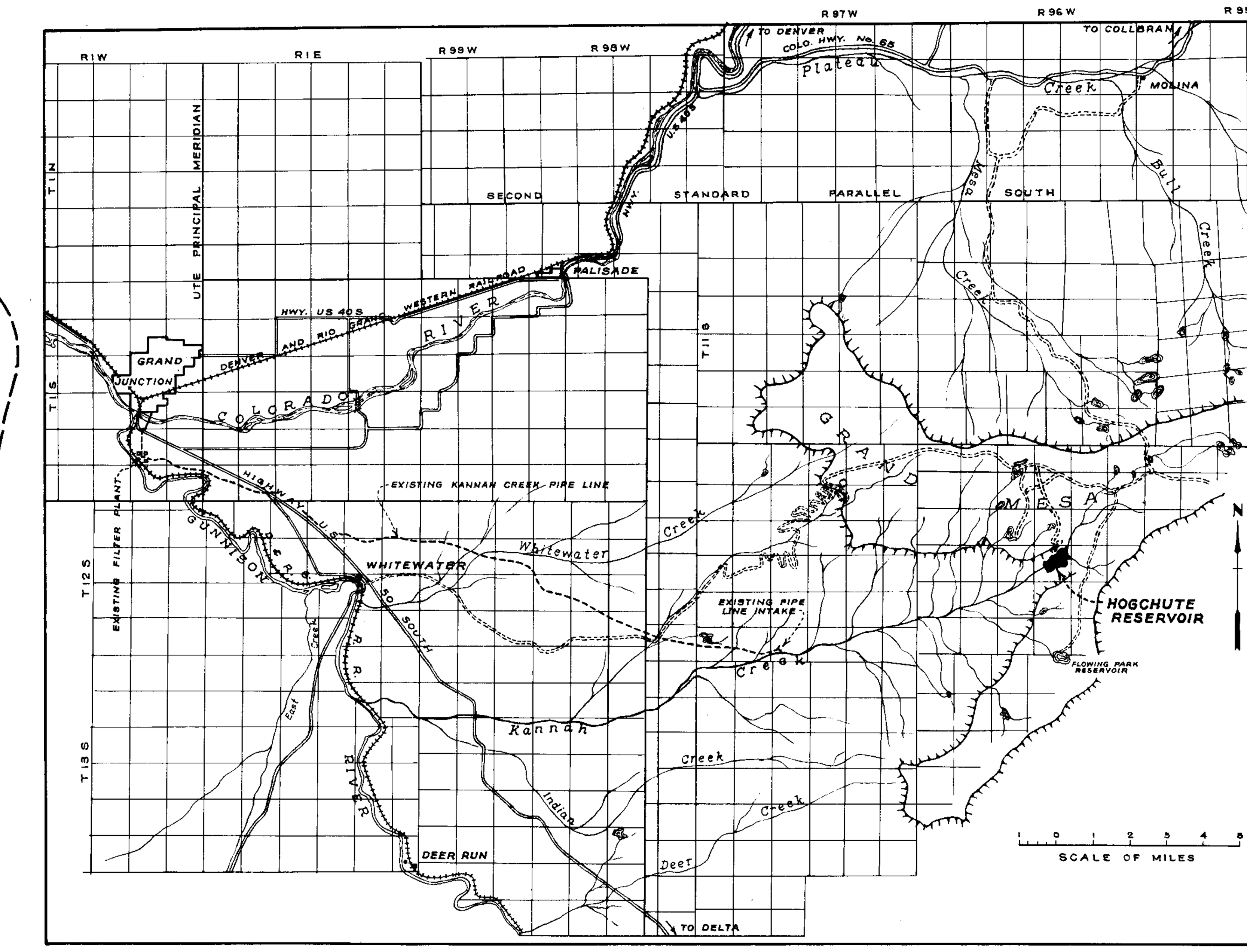

## GENERAL PLAN




## LOCATION MAP




## AREA, CAPACITY AND DISCHARGE CURVES




## VICINITY MAP

## NOTES

Reservoir site is entirely within the limits of the Grand Mesa National Forest. All clearing operations, cutting and disposal of timber, shall be performed in accordance with rules and regulations prescribed by the Forest Supervisor

Altitude of reservoir site is approximately elevation 9250

## REFERENCE DRAWINGS

| | |
|---|---|
| VICINITY MAP AND GENERAL PLAN | 705-30 |
| PLAN, PROFILE AND SECTIONS | 705-31 |
| OUTLET WORKS - VALVE CONTROL HOUSE | 705-32 |
| TRASHRACK STRUCTURE AND SPILLWAY DETAILS | 705-33 |
| PARSHALL FLUME - PLAN, SECTIONS AND DETAILS | 705-34 |

Approved on the 24 day of May 1947

By [signature] STATE ENGINEER

By ______ DEPUTY

CITY OF GRAND JUNCTION

R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO

**IMPROVEMENTS TO WATER SUPPLY SYSTEM**
**HOGCHUTE RESERVOIR**
**VICINITY MAP AND GENERAL PLAN**

DRAWN N.L.L. APPROVED [signature] R.J. TIPTON AND ASSOCIATES INC.
TRACED L.W.M. APPROVED [signature] DIRECTOR OF PUBLIC WORKS AND PLANNING
CHECKED N.L.L. APPROVED [signature] CITY MANAGER

DENVER, COLORADO MAY 1947 705-30

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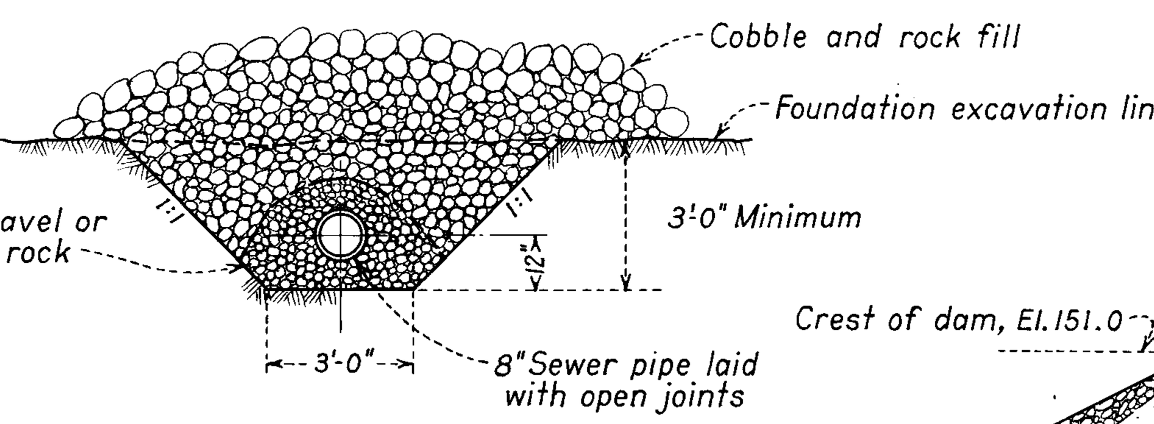
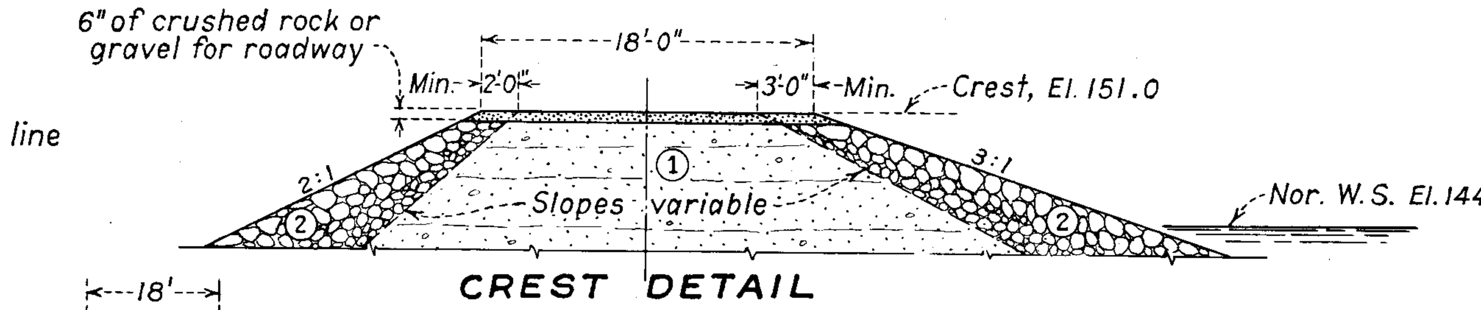
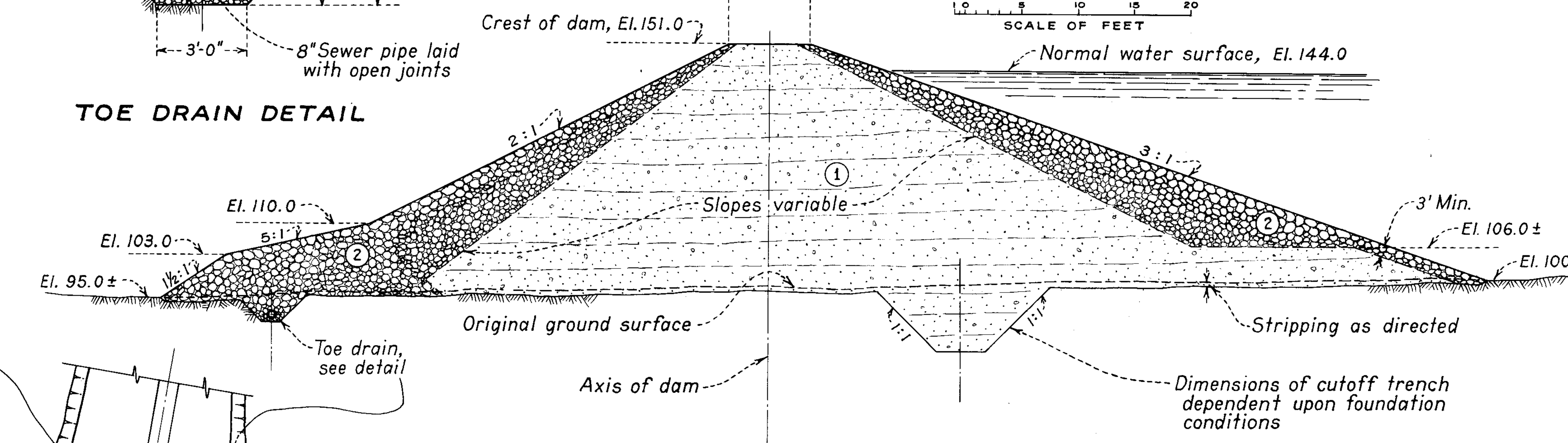



TOE DRAIN DETAIL



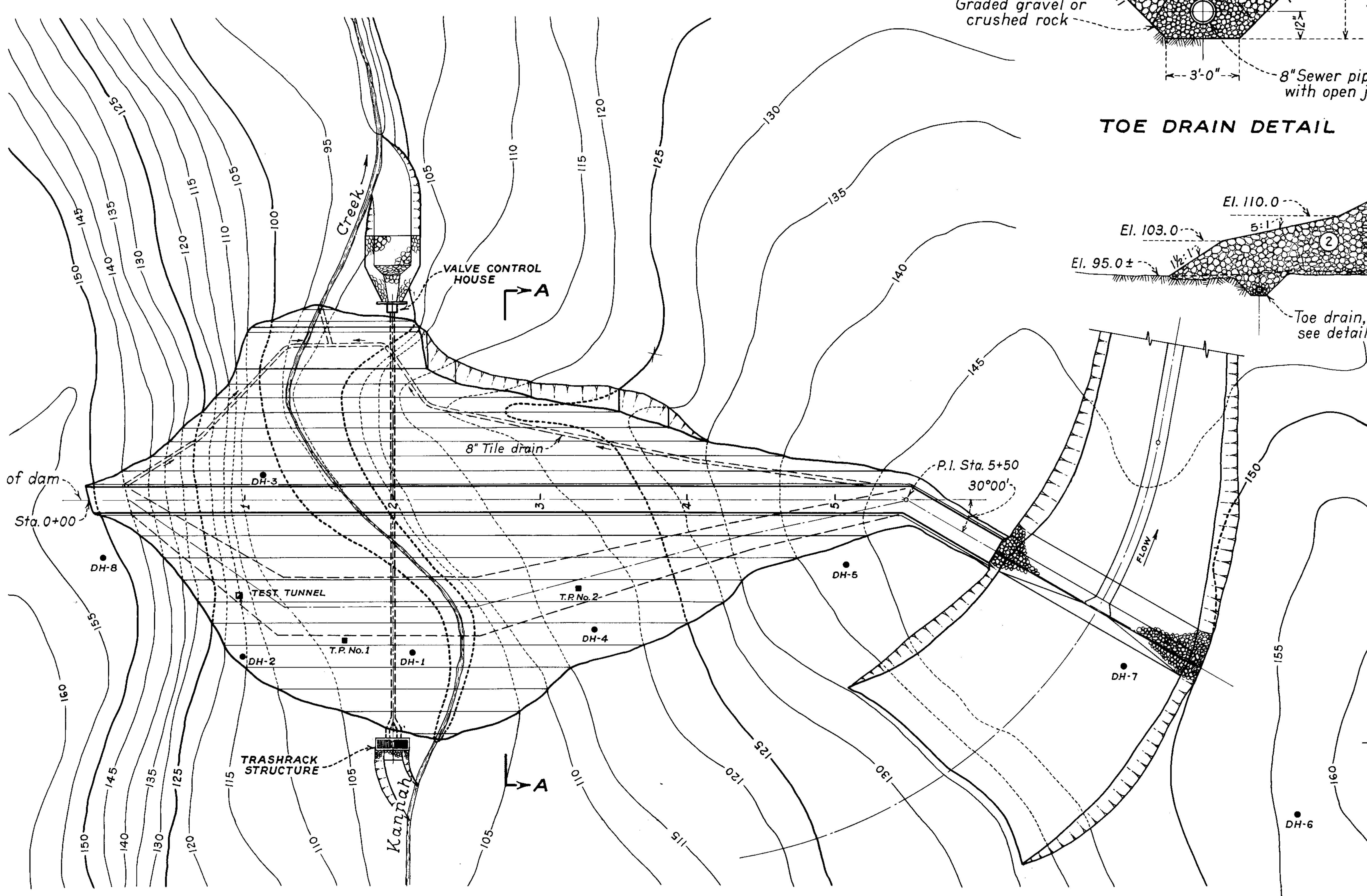

CREST DETAIL

SCALE OF FEET



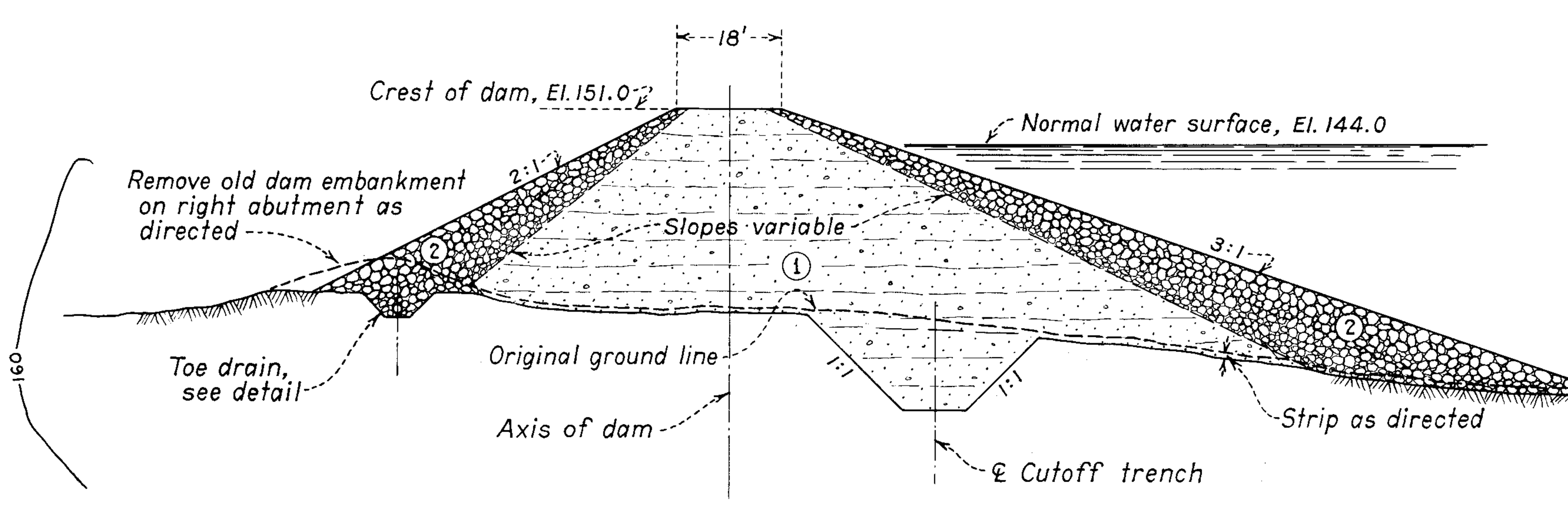

MAXIMUM SECTION

SCALE OF FEET




PLAN

SCALE OF FEET



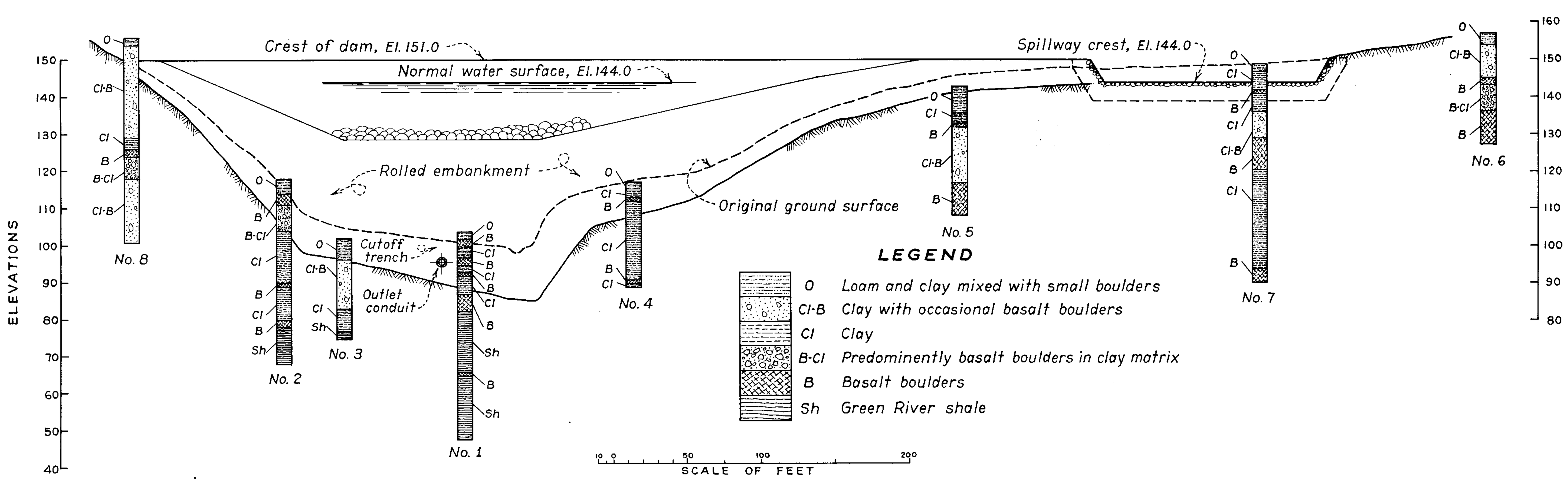

SECTION A-A

## EMBANKMENT NOTES

1. Impervious fill of clay or clay, sand and gravel graded with coarser material on outer slopes and compacted in 6" layers.
2. Cobble and rock fill graded with coarser material on outer slopes.

## NOTES

All elevations refer to an assumed datum
Final location of outlet works and appurtenant structures are dependent on foundation conditions encountered.




### LEGEND

| | |
|---|---|
| O | Loam and clay mixed with small boulders |
| Cl-B | Clay with occasional basalt boulders |
| Cl | Clay |
| B-Cl | Predominently basalt boulders in clay matrix |
| B | Basalt boulders |
| Sh | Green River shale |

PROFILE ON ℄ OF CUTOFF TRENCH AND SPILLWAY - LOG OF DRILL HOLES

Approved on the 24 day of May 1947

By M. C. Hinderlider
STATE ENGINEER

By
DEPUTY

CITY OF GRAND JUNCTION
R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO

IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
PLAN, PROFILE AND SECTIONS

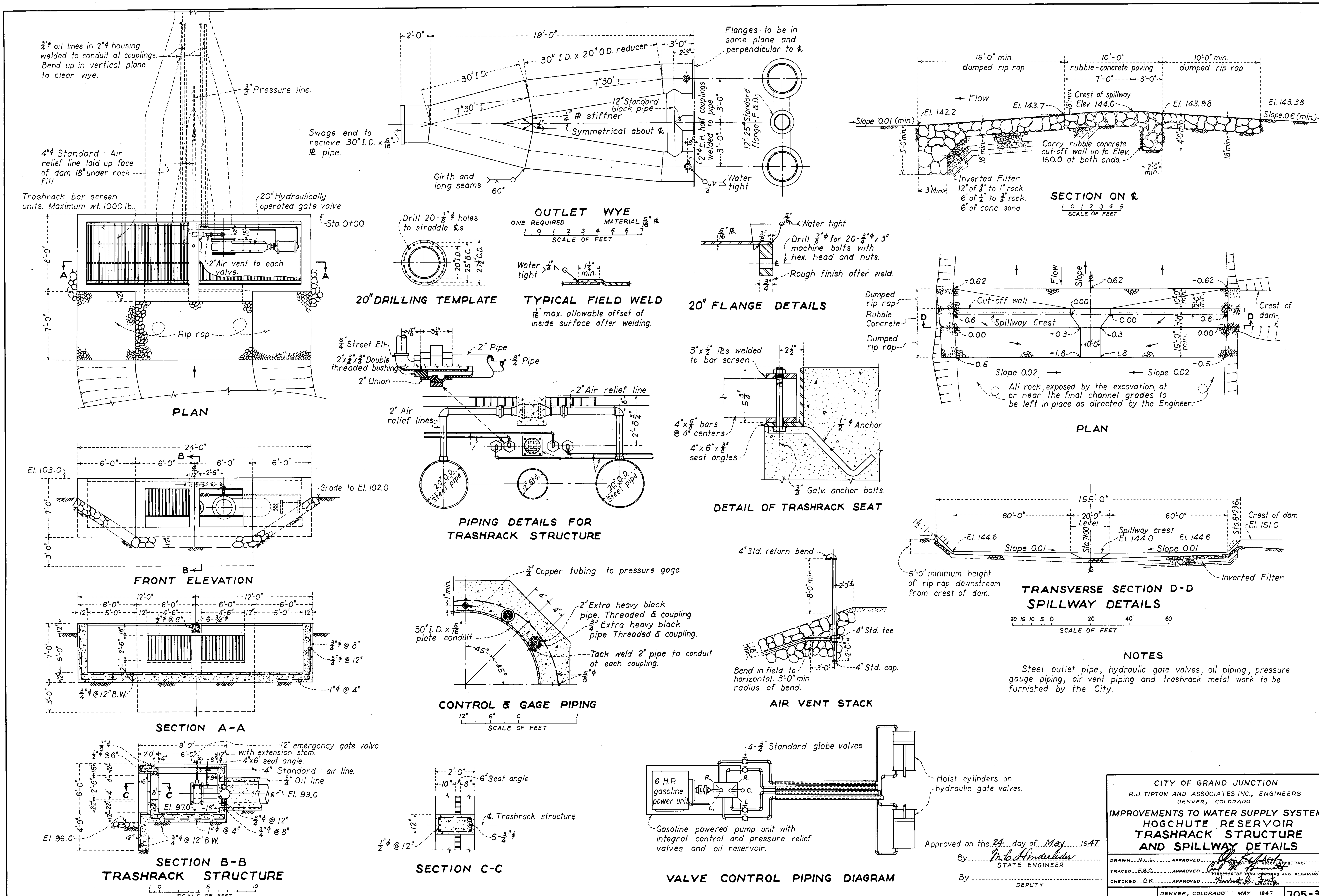
DRAWN N.L.L. APPROVED R.J. TIPTON AND ASSOCIATES, INC.
TRACED L.W.M. APPROVED DIRECTOR OF PUBLIC WORKS AND PLANNING
CHECKED N.L.L. APPROVED CITY MANAGER

DENVER, COLORADO MAY 1947 705-31

C-454


PLAN OF OUTLET CONDUIT
Rip rap approach channel as directed
Cut-off trench
Cut-off collars
TRASHRACK STRUCTURE
Kannah Creek
30" I.D. PIPE
Dam axis Sta. 2+00 on axis 1+65 on conduit
8" tile toe drain
Toe of dam
STILLING Basin
VALVE CONTROL HOUSE
Sta. 0+00
Toe of dam
SECTION ALONG ℄ OF OUTLET CONDUIT
Normal H.W. El. 144.0
Crest of dam El. 151.0
4" Air relief line - See Dwg. 705-33
NOTE: Camber outlet conduit 6" above grade at mid-point.
Original ground surface
Trashrack structure - For details see Dwg. 705-33
℄ Valve - El. 99.0
Apron El. 96.0
Cut-off trench
Kannah Creek
To be stripped as directed.
El. 100.0
8" Tile toe drain
Note: Location of cut-off walls is approximate only. Final location to be made in field.
Wye assembly
282'-0" 30" I.D. - 5/16" welded steel pipe encased in 6" concrete shell.
"CITY OF GRAND JUNCTION"
"1947"
FULL SIZE DETAILS OF RECESSES FOR LETTERS TO BE CAST IN CONCRETE
PLAN
Reservoir level gauge
Grade to drain
Oil pump and engine foundation.
1/2" ϕ @ 12" c.c. bothways all four walls.
Sta. 3+00
FRONT ELEVATION
Letters to be cast in concrete. See details.
Two 3 x 2 light commercial projected steel sash with mullion - Fenestra #32160 or equal.
Grade to flat slope.
CITY OF GRAND JUNCTION
1947
El. 93.0
Inverted Filter 12" of 3/4" to 2" rock. 6" of 1/4" to 3/4" rock. 6" of conc. sand.
NOTE: Set steel pipe to line and grade before pouring concrete encasement.
5/8" ϕ hoop bar @ 6" Lap 15"
12 - 5/8" ϕ long bars
Reservoir level gauge piping.
Locate four oil lines to hydraulic gates 4" each side of quarter points and tack weld to conduit at couplings.
2" clear
Construction joint.
Slope to suit material encountered in field.
Pour cut-off collars against natural ground.
Bottom of trench to be accurately shaped to fit bottom of conduit.
Boulders left in place to be cut back 8" min. from concrete and backfilled with selected material, tamped and shaped to grade.
(TYPICAL SECTION) SECTION B-B
SECTION D-D
Asphalt expansion joint filler.
30" I.D. pipe
SECTION ALONG ℄
El. 93.0
El. 90.0
El. 91.0
Slope 0.01
SECTION C-C
Oil lines
Pour conc. against natural ground.
All transverse and hoop bars 1/2" @ 6". All longitudinal bars 5/8" ϕ (16 required)
SCALE OF FEET
SECTION G-G
Inverted Filter
4 pieces 2 1/2" extra heavy pipe 12" long. Thread inside for 2" bar plugs. Weld to 30" I.D. steel pipe.
Oil pump and engine foundation.
2" ϕ E.H. oil line housing.
3/4" ϕ E.H. oil line.
Conduit barrel
30" I.D. x 5/16" steel pipe.
3/4" Oil lines
SECTION E-E
SECTION F-F
PIPE WELL DETAILS
SIDE ELEVATION VALVE CONTROL HOUSE
1/2" ϕ @ 9" c.c. bothways
1/2" ϕ hooked dowels into wall @ 16" c.c.
8" Eave all around
Groove horizontal joints. Rub vertical joints flush
7 Courses 8" Cinder block.
NOTE: 3'-0" x 7'-0" industrial steel door with mortise cylinder lock. Richmond #2S or equal. (Set jamb in forms before pouring concrete.
Scupper
Floor El. 96.0
El. 93.0
El. 90.0
3/4" ϕ @ 12" bothways
Approved on the 24 day of May 1947
By M. C. Hinderlider STATE ENGINEER
By DEPUTY
CITY OF GRAND JUNCTION
R. J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO
IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
OUTLET WORKS
VALVE CONTROL HOUSE
DRAWN N.L.L. APPROVED
TRACED F.B.C. APPROVED DIRECTOR OF PUBLIC WORKS AND PLANNING
CHECKED O.K. APPROVED CITY MANAGER
DENVER, COLORADO MAY 1947
705-32

C-454




## NOTES

Steel outlet pipe, hydraulic gate valves, oil piping, pressure gauge piping, air vent piping and trashrack metal work to be furnished by the City.

Approved on the 24 day of May 1947

By M. C. Hinderlider
STATE ENGINEER

By ............ DEPUTY

CITY OF GRAND JUNCTION
R. J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO

IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
TRASHRACK STRUCTURE AND SPILLWAY DETAILS

DRAWN N.L.L. APPROVED R. J. TIPTON AND ASSOCIATES, INC.
TRACED F.B.C. APPROVED DIRECTOR OF PUBLIC WORKS AND PLANNING
CHECKED O.K. APPROVED CITY MANAGER

DENVER, COLORADO MAY 1947 | 705-33

C-454

# APPENDIX A.2

## 1988 LETTER FROM CITY TO COLORADO DIVISION OF WATER RESOURCES

Hogchute WD-42

City of Grand Junction. Colorado 81501
250 North Fifth St.,

Hogchute
Dist 42

JAMES NORFLEET, ENGINEER
DIVISION OF WATER RESOURCES
DIVISION 4, MONTROSE COLORADO
PO. BOX 456, MONTROSE CO. 81402

NOVEMBER 14, 1988

DEAR JIM:

ENCLOSED YOU WILL FIND A COPY OF MY YEAR END REPORT OF THE CITY OF GRAND JUNCTION WATER SUPPLY MAINTENANCE AND A BRIEF OVERVIEW OF THE 1989 PROJECTS.

THE RESERVOIR MAINTENANCE PROGRAM WAS REDUCED TO A MINIMUM THIS YEAR DUE TO OTHER MORE PRESSING PROJECTS WHICH REQUIRED THE ATTENTION OF THE LABOR CREW WE NORMALLY USE IN THE RESERVOIR PROGRAM.

WE HAD HOPED TO GET THE #1 ANDERSON RESERVOIR MAINTENANCE COMPLETED THIS YEAR, HOWEVER WE JUST STARTED ON IT WHEN THE FIRST SNOW CAME AND THE CREW WAS ASSIGNED TO OTHER PROJECTS SO WE WILL FINISH THE NEEDED WORK IN 1989.

THE ONLY OTHER AREA WHERE WE WILL NEED TO BE CONCERNED WITH IS THE RODENT CONTROL AS WE WERE UNABLE TO GET THE NORMAL APPLICATION WORK ACCOMPLISHED THIS YEAR, WE WILL HOWEVER MAKE EVERY EFFORT TO DO THIS AS EARLY NEXT YEAR AS WEATHER AND SOIL CONDITIONS WILL ALLOW US TO DO SO.

I HAD SINCERELY HOPED TO GET BACK WITH YOU AND MAKE TIME FOR A FISHING TRIP THIS FALL ? I JUST HAVE NO GOOD EXCUSES, HOWEVER MAYBE NEXT YEAR WE CAN GET TOGETHER.

SINCERELY:

RALPH STERRY
SPECIAL PROJECTS COORDINATOR

RECEIVED
NOV 16 1988
BY DIVISION 4

NOVEMBER 14, 1988

1988 YEAR END REPORT OF WATER SUPPLY EFFORTS AND RESERVOIR MAINTENANCE

PROGRESS ON RESERVOIR MAINTENANCE FOR THE YEAR OF 1988 HAS [illegible] MINIMUM DUE TO OTHER PROJECT COMMITMENTS AND THE REDUCED CREW TIME AVAILABLE IN THE EARLY SPRING AND SUMMER.

WHILE WE FEEL THAT PROGRESS ON MAINTENANCE REPAIRS WERE AT A MINIMUM THIS YEAR WE DID ACCOMPLISH SEVERAL OTHER MUCH NEEDED PROJECTS WHICH HAVE BEEN PUT OFF FOR SEVERAL YEARS. PROJECTS AS FOLLOWS:

1. REPLACEMENT OF THE [illegible] LINE CROSSOVER LOCATED JUST NORTH OF WHITEWATER.

2. EVALUATION OF THE [illegible] LINE ROUTE OF [illegible] FROM WHITEWATER HILL TO THE WATER PLANT [illegible].

[illegible] OF THE [illegible] OF BOTH [illegible] LINES.

4. INSTALLATION OF A CONCRETE [illegible] SETTLING AREA AND RETAINING WALL AT THE [illegible] LOCATED NORTH OF WHITEWATER TO PREVENT FURTHER EROSION AND DAMAGE TO THE IRRIGATION DITCH.

5. DEVELOPMENT AND CONSTRUCTION OF A PARKING AND TOILET FACILITY ALONG WITH DEVELOPING A PICNIC AREA AT THE CITY WATER INTAKE ON KANNAH CREEK, FUNDED IN PART BY THE DIVISION OF WILDLIFE AND BUILT BY THE CITY CREW.

[illegible]

7. [illegible] OF THE [illegible] IN LATE OCTOBER.

RESERVOIR REPAIRS

1. CARSON RESERVOIR REPAIRS WERE MADE TO THE END OF THE OUTLET PIPE AND THE TOE DRAIN, [illegible] WAS EXTENDED DOWNSTREAM 10 FEET.

THE [illegible] PIPE RETAINING WALL WAS CARRIED BACK TO THE OLD VALVE HOUSE TO PREVENT FURTHER DOWNSTREAM EROSION AND A SEEP WATER MONITOR PIPE WAS INSTALLED AT THE NORTH END OF RETAINING WALL.

A PARKING AND PICNIC AREA WITH TOILET FACILITIES WAS ALSO BUILT AT CARSON THIS YEAR FUNDED BY THE FOREST SERVICE AND BUILT BY THE CITY CREW.

2. ANDERSON RESERVOIR #1 TEMPORARY REPAIRS [illegible] PART OF THE BREACHED AREA ALONG THE AUXILIARY DIKE WAS MADE AND SOME BLADE LEVELING OF THE RESERVOIR [illegible] WAS ACCOMPLISHED.

FINAL MAINTENANCE REPAIRS WILL BE ACCOMPLISHED IN THE SUMMER OF 1989.

3. RODENT CONTROL WILL BE PLANNED FOR THE SPRING AND SUMMER OF 1989 AS OTHER PROGRAMS PREVENTED THE CREW FROM GETTING BACK TO THE GRAND MESA PROGRAM THIS FALL.

PROPOSED 1989 RESERVOIR MAINTENANCE

1. BRUSH REMOVAL ON THE DOWNSTREAM [illegible] OF [illegible] MESA RESERVOIR.

2. TOE DRAIN PIPE EXTENSION AT HALLENBECK (PURDY MESA) RESERVOIR.
3. REPAIR OF THE WEIR BETWEEN JUNIATA AND PURDY MESA RESERVOIRS.
4. BRUSH AND WEED REMOVAL ALONG THE JUNIATA AND PURDY MESA RESERVOIR MAIN CREST AREA'S.
5. BRUSH REMOVAL AND CLEANING ALONG THE DITCH LINES AS NEEDED
6. FINISH THE MAINTENANCE REPAIRS STARTED AT ANDERSON #1 RESERVOIR.
7. ADD RIP-RAP, LEVEL THE CREST AND DIG A CHANNEL BELOW THE OUTLET PIPE OF ANDERSON #6 RESERVOIR.
8. CLEAN AND MAKE NEEDED REPAIRS ALONG THE FULL LENGTH OF THE B.A.J. DITCH
9. START MAINTENANCE ON THE CHAMBERS RESERVOIR PROVIDING TIME AND FUNDS ARE AVAILABLE
10. CONTINUE WITH THE RODENT CONTROL PROGRAM.

88-Y-E-R

District 42

NOVEMBER 14, 1988

RE: BRIEF REPORT OF FINDING ON CARSON RESERVOIR REPAIRS.

1. THE CITY CREW REMOVED THE OLD VALVE HOUSE BUILDING AND RUN CABLES THROUGH THE RETAINING WALL THEN AROUND THE VALVE HOUSE FOOTER TO PREVENT FURTHER DOWNSTREAM DEFLECTION OF THE OUTLET PIPE AND DOWNSTREAM TOE RETAINER WALL.

2. THE CREW THEN LOCATED THE END OF THE TOE DRAIN PIPE AND FOUND THAT IT WAS SUBMERGED 2 FEET BELOW THE STREAM BED LEVEL.
IN AN EFFORT TO PROVIDE AS MUCH DRAINAGE CAPABILITY AS POSSIBLE THE PIPE WAS EXTENDED DOWNSTREAM 40 FEET, THIS STILL LEAVES THE END OF THE PIPE SUBMERGED HOWEVER IT DOES ALLOW FOR SOME RELIEF OVER THE ORIGINAL POINT OF EXIT.

THE STREAM BED SLOPE BELOW CARSON DOES NOT ALLOW FOR THE DESIRED PIPE GRADE FOR MORE THAN 200 FEET DOWNSTREAM THEREFORE THE PIPE WAS ENDED AT A POINT WHICH WE FELT WOULD RELIEVE THE WATER WITH THE LEAST AMOUNT OF BACK PRESSURE SHORT OF COMPLETELY REDESIGNING THE EXISTING TOE DRAIN.

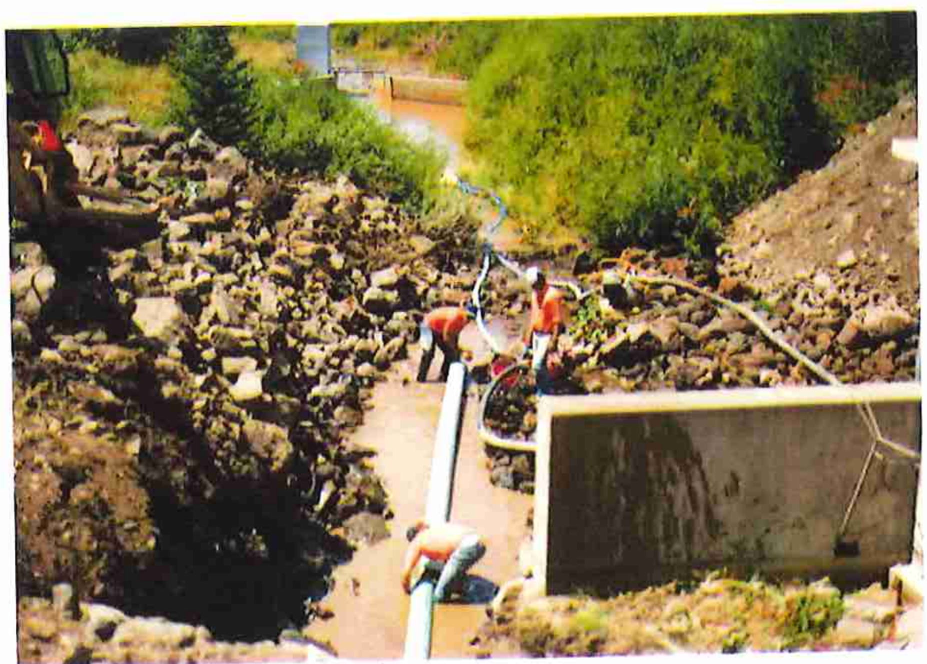
3. SEEP WATER AROUND THE OLD VALVE HOUSE WAS TRACED TO THE TUBES WHICH WERE INSTALLED FOR RESERVOIR LEVEL GAUGE IN THE OLD VALVE HOUSE, THIS SOURCE OF WATER WAS SEALED OFF AND THE SEEP WATER WAS REDUCED TO LESS THAN 1/2 GALLON PER MINUTE.

A PIPE WAS THEN INSTALLED FROM THE ACCUMULATIVE POINT BEYOND THE RETAINER WALL SO THE FLOW OF SEEP WATER CAN BE MEASURED, THIS PIPE IS LOCATED AT THE NORTH END OF THE RETAINER WALL.

4. REPAIR OF THE CONCRETE RETAINER WALL AROUND THE OUTLET PIPE WAS COMPLETED BY USING NATIVE STONE CEMENTED IN PLACE THEN THE RIP-RAP WAS REESTABLISHED TO PREVENT EROSION.

ENCLOSED ARE PICTURES OF THIS MAINTENANCE REPAIR.

Excavation of existing toe drain outfall



Extension of toe drain

Hogchute
W.Div 4, W.Dist 42

Old valve house removed & toe drain extension complete


Repaired headwall

Hogchute
W.Div 4, W. Dist 42

# APPENDIX C

## HYDROLOGY REPORT AND SPILLWAY EVALUATION

*GEOTECHNICAL AND*
*WATER RESOURCES ENGINEERING*

# HYDROLOGY REPORT

## HOGCHUTE DAM (AKA CARSON LAKE)
## DAM ID 420127

**MESA COUNTY, COLORADO**

Submitted to
**City of Grand Junction**
250 North 5th Street
Grand Junction, CO 81501


Submitted by
**RJH Consultants, Inc.**
9800 Mt. Pyramid Court, Suite 330
Englewood, Colorado 80112
303-225-4611
www.rjh-consultants.com


January 2019
Project 18115

COLORADO REGISTERED PROFESSIONAL ENGINEER
GARRETT O. JACKSON
1/4/19
29302


Garrett O. Jackson, P.E.
Project Manager

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**LIST OF FIGURES**



**APPENDICES**

# SECTION 1 - INTRODUCTION

## 1.1 General

The purpose of the Hogchute Dam Safety Evaluation Project (Project) is to investigate, identify, and document the existing conditions of the dam to provide a basis for developing a future dam rehabilitation plan. RJH Consultants, Inc. (RJH) was retained by the City of Grand Junction (City) to provide engineering services required to perform the dam safety evaluation. A key component of the dam safety evaluation is performing hydrologic analyses to evaluate the adequacy of the existing spillway to convey the inflow design flood (IDF) without overtopping the dam.

## 1.2 Objective

The objectives of this Hydrology Report (Report) are as follows:

- Identify the IDF.
- Obtain approval of the IDF by the Colorado Office of the State Engineer (SEO) for use in evaluation of the existing spillway and for use in potential rehabilitation of the spillway.
- Evaluate the adequacy of the existing spillway to convey the IDF without overtopping the dam.

This Report is prepared to be consistent with Section 5.4.2 of the State of Colorado, *Rules and Regulations for Dam Safety and Dam Construction* (Rules) (SEO, 2007).

## 1.3 Scope of Work

The scope of work completed for this Report includes:

1. Delineated the drainage basin and subbasins.
2. Developed hydrologic modeling parameters.
3. Developed probable maximum precipitation (PMP) event precipitation depths.
4. Developed simplified dam breach parameters for Grand Mesa #8 Dam (Grand Mesa #8) and Grand Mesa #9 Dam (Grand Mesa #9).
5. Developed a HEC-HMS hydrologic model of the drainage basin including cascading failures of Grand Mesa #8 and Grand Mesa #9 dams.

6. Developed the IDF hydrograph using the HEC-HMS model.
7. Developed a simplified rating curve for the existing Hogchute Dam spillway.
8. Performed reservoir and spillway routing of the IDF using the HEC-HMS model.
9. Prepared this Report.

## 1.4 Authorization

RJH performed the work described in this Report in accordance with the terms and conditions of the contract between RJH and the City executed on June 26, 2018.

## 1.5 Project Personnel

The following RJH personnel are responsible for the work described in this Report:

| | |
|---|---|
| Project Manager: | Garrett Jackson, P.E. |
| Lead Hydrologic Engineer: | Eric Hahn, P.E. |
| Staff Engineers: | Brittany Bender, E.I.<br>Adam Merook, E.I. |
| Senior Independent Review: | John Blair, P.E. |

# SECTION 2 – PROJECT DESCRIPTION

## 2.1 Location and Background

The City owns and operates Hogchute Dam (DAMID 420127), located in Mesa County, Colorado, approximately 22 miles east-southeast of Grand Junction. The dam is a 56-foot-high earth structure that impounds Carson Lake on Kannah Creek at an elevation (El.) of about 9,900 feet in the Grand Mesa National Forest. The reservoir impounded by Hogchute Dam is referred to as Carson Lake and provides water storage for domestic use, irrigation, and fishing recreation. The site location is shown on Figure 2.1.

The dam was constructed in 1947, with a low-permeability earthen core protected by upstream and downstream rock shells of gravels, cobbles, and boulders. The outlet works consists of two, 20-inch welded steel pipes with hydraulic slide gates at the upstream toe of the dam. The 20-inch pipes converge within the dam into a single 30-inch conduit that discharges into a rock-lined pool at the downstream toe of the dam. There appears to also be a 12-inch outlet gate installed between the two 20-inch gates, but the configuration and use of this gate are not clear. An unlined emergency spillway is located at the north (right) end of the dam, and some deterioration of the spillway crest and channel has occurred.

In 2015, the SEO changed the dam’s hazard classification to high hazard, based on inundation mapping performed by the City to assess the impacts of a potential dam failure on downstream development that had occurred since construction of the dam.

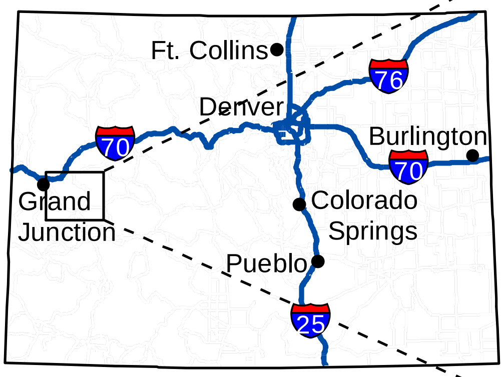
## 2.2 Dam and Reservoir Characteristics

The embankment has an approximate upstream slope of 2.5to 3 horizontal to 1 vertical (H:V), a crest width of about 18 feet, and a downstream slope of about 2H:1V. The crest is approximately 620 feet long. The reservoir has a storage capacity of 520 acre-feet (ac-ft) at maximum normal pool, which correlates to El. 9902. The maximum normal pool of the reservoir is controlled by the unlined emergency spillway.

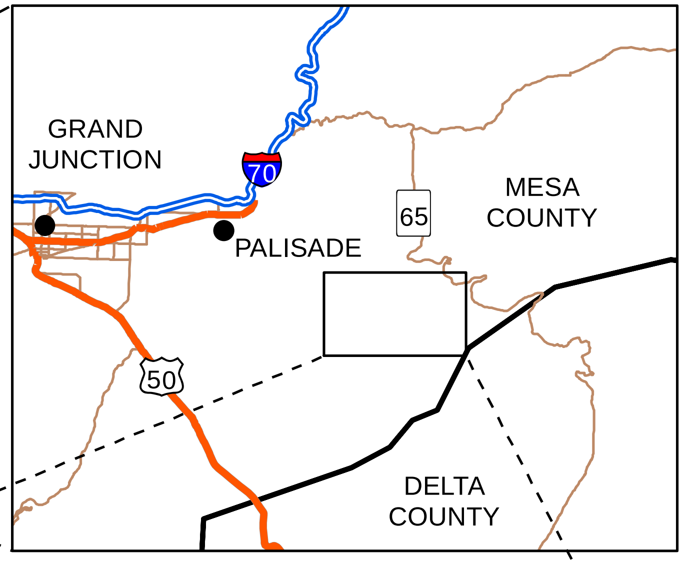
Key characteristics of the dam and reservoir are provided in Table 2.1.

# TABLE 2.1
# DAM AND RESERVOIR CHARACTERISTICS

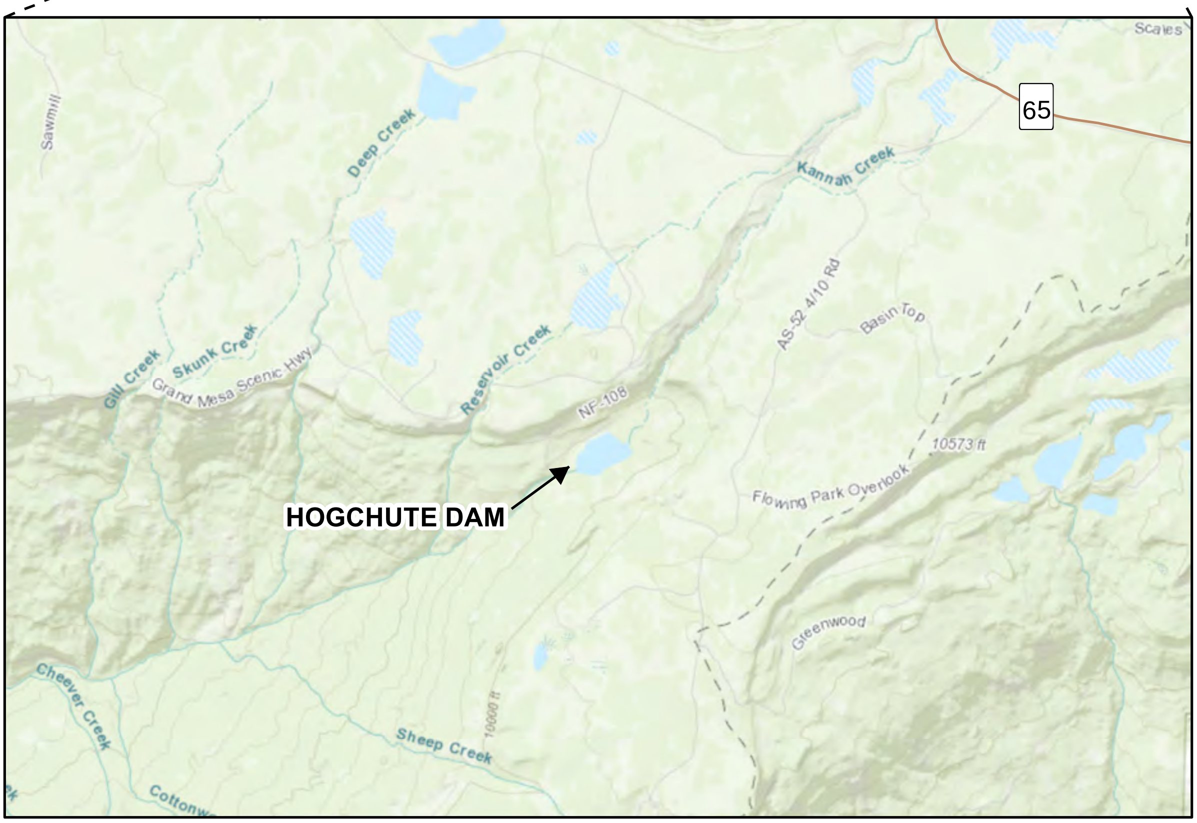
| | |
|---|---|
| Active Storage Volume | 520 ac-ft |
| Surface Area at Normal Pool | 52.5 acres |
| Spillway Invert El. | 9895 ft |
| Dam Crest El. | 9902 ft |
| Dam Height | 51 ft |




**PROJECT VICINITY MAP**
**(NOT TO SCALE)**




**PROJECT LOCATION MAP**
**(NOT TO SCALE)**




N

**SITE LOCATION MAP**
**(NOT TO SCALE)**

| THIS DOCUMENT MUST BE REPRODUCED IN COLOR | | HOGCHUTE DAM HYDROLOGY REPORT | SITE LOCATION MAP |
|---|---|---|---|
| | | PROJECT NUMBER 18115 | January 2019 **Figure 2.1** |

P:\18115 - Hogchute Dam Safety Evaluation\Engineering\GIS\Figures\Figure 2.1 Site Location.mxd

# SECTION 3 - AUTHORITY AND CLASSIFICATION

## 3.1 State Engineer's Authority

By Colorado State statute, Hogchute Dam is subject to the regulatory authority of the SEO. The dam and reservoir are located in Water Division 4, District 42.

## 3.2 Size Classification

According to SEO Rules (SEO, 2007), Hogchute Dam is classified as a "Large Dam" because it has a height greater than 50 feet.

## 3.3 Hazard Classification

The SEO hazard classification is based upon the potential property damage and/or loss of life that could occur in the unlikely event of a dam failure. Based on previous dam breach analyses performed by the City, Hogchute Dam is currently classified as a high hazard dam. Loss of human life is expected to result from failure of a high hazard dam.

# SECTION 4 - GENERAL BASIN CHARACTERISTICS

## 4.1 Basin Delineation

The Hogchute Dam drainage basin encompasses approximately 11.9 square miles. The drainage basin was delineated using a U.S. Geological Survey (USGS) 10-meter Digital Elevation Model (DEM) imported into the ArcGIS computer program. The drainage basin was subdivided into two subbasins (i.e., upper and lower) based on topography and Grand Mesa #8 and Grand Mesa #9. The upper basin drains into Grand Mesa #8 and subsequently into Grand Mesa #9. The lower basin drains directly into Carson Lake. Dividing a watershed into subbasins is appropriate for watersheds with hydraulic facilities like reservoirs, because it facilitates refined hydrologic routing through the facilities and more realistic runoff timing and attenuation predictions.

The drainage basin and subbasins are shown on Figure 4.1. Relevant basin parameters are provided in Table 4.1. Calculations are provided in Appendix A.

**TABLE 4.1**
**BASIN PARAMETERS**

| Basin | Area ($mi^2$) | L (mi)[1] | $L_{ca}$ (mi)[2] | Maximum Elev. (ft) | Minimum Elev. (ft) | Slope (ft/mi)[3] |
|---|---|---|---|---|---|---|
| Upper | 3.58 | 4.49 | 1.27 | 10,897 | 10,648 | 55.6 |
| Lower | 8.33 | 5.65 | 3.25 | 10,878 | 9,887 | 175.3 |

Notes:
1. Length of longest watercourse.
2. Length along primary watercourse from subbasin outlet to a point opposite of the centroid of the drainage basin.
3. Slope along the longest watercourse.

## 4.2 Basin Characteristics

The topography of the basin generally slopes downward from northeast to southwest toward Carson Lake. The basin is located at the top of the Grand Mesa plateau, and the overall slope of the drainage basin is relatively mild for a high-elevation dam located in the Rocky Mountains.

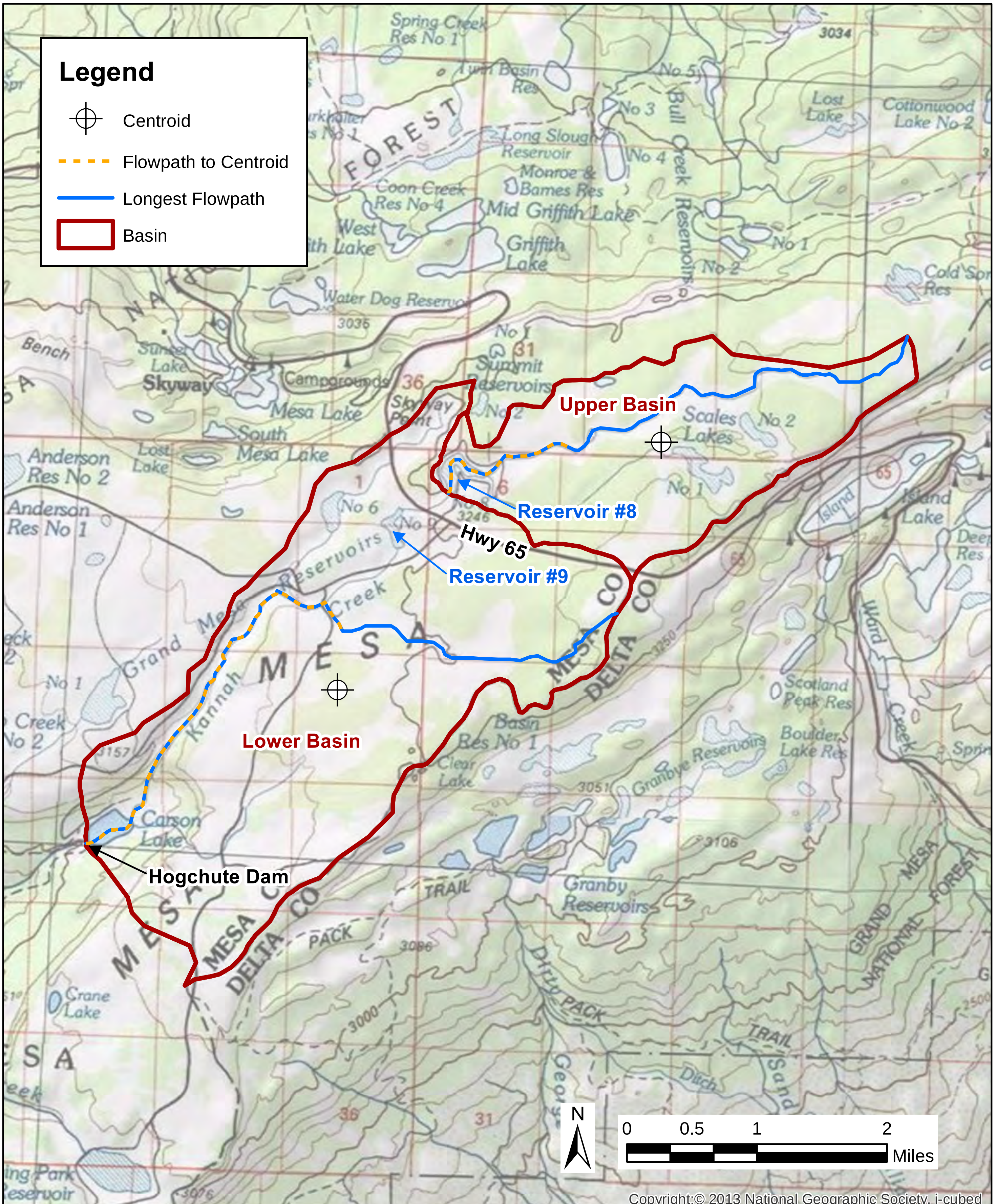
The entire drainage is located within Grand Mesa National Forest. The majority of the vegetation in the basin consists of medium to tall native grasses with light to moderately dense tree growth. There is no development or any significant impervious areas in the basin other than Carson Lake and several other small reservoirs. Future development in the basin is not anticipated because it is located within a national forest.

Soils data for the drainage basin was obtained from the Natural Resources Conservation Service (NRCS) on-line Web Soil Survey (WSS). Surficial soils within the basin primarily consist of cobbly loam and stony loam. NRCS hydrologic soil groups are primarily C and D soils.

State Highway 65 (Highway 65) extends across the north portion of the lower basin. The height of the Highway 65 embankment across the basin ranges from about 2 to 15 feet high. The section of Highway 65 embankment that crosses Kannah Creek is about 2 feet high.

Grand Mesa #8 dam is located on Kannah Creek directly upstream of Highway 65. The dam is classified by the SEO as a small size, significant-hazard dam. The dam consists of a homogenous earthfill embankment that is approximately 22 feet high. Riprap slope protection is located on both the upstream and downstream slopes. The maximum normal storage capacity of the reservoir is 400 ac-ft at El. 10642.6. The existing spillway consists of an unlined 40-foot-wide open channel on native rock at the left abutment of the dam. We understand that the dam overtopped in the 1980s during a flood event, which caused some erosion of the crest, but apparently did not result in a full breach.

Grand Mesa #9 dam is located on Kannah Creek directly downstream of Highway 65. Grand Mesa #9 dam consists of an earthen embankment that is approximately 15 feet high. The SEO classifies the dam as a small, low hazard structure. The maximum normal storage capacity of the reservoir is 268 ac-ft at El. 10616. The existing spillway consists of a 15-foot-wide unlined earthen channel at the right abutment of the dam.





| | | |
|---|---|---|
| THIS DOCUMENT MUST BE REPRODUCED IN COLOR | RJH CONSULTANTS, INC. | HOGCHUTE DAM HYDROLOGY REPORT |
| | | BASIN MAP |
| | | PROJECT NUMBER 18115 |
| | | January 2019 |
| | | **Figure 4.1** |

P:\18115 - Hogchute Dam Safety Evaluation\Engineering\GIS\Figures\Figure 4.1 Basin Parameters.mxd

# SECTION 5 - PRECIPITATION

## 5.1 General

RJH estimated precipitation depths for the general storm and local storm PMP events. The general storm represents a large area, long-duration storm event typically associated with a major synoptic weather feature. The local storm represents an intense, short-duration storm that typically occurs over smaller areas than the general storm.

RJH followed SEO guidelines and procedures for computing PMP depths required to develop the IDF. PMP estimates were developed using both the Colorado and New Mexico Regional Extreme Precipitation Study Tool (REPS Tool) and National Oceanic and Atmospheric Administration (NOAA) Hydrometeorological Report (HMR). The REPS Tool is currently in a "roll-out" phase, and the SEO has requested precipitation evaluations be performed using both the REPS Tool and HMR method for comparative purposes during the roll-out phase. Calculations for estimating PMP depths are provided in Appendix B.

## 5.2 Regional Extreme Precipitation Study Tool

RJH followed the REPS Tool Trial Guidance Document (October 2, 2018) to develop the general storm and local storm PMP depths. The REPS Tool is a GIS-based tool that runs as a toolbox in ArcGIS. The REPS Tool calculates PMP depths for numerous durations for the general storm and local storm for a user-entered GIS shapefile. Output is written to a GIS grid and attribute table, which can be viewed in ArcGIS. PMP depths calculated using the REPS Tool for the general storm and local storm are presented in Tables 5.1 and 5.2, respectively.

**TABLE 5.1**
**REPS TOOL GENERAL STORM PMP**

| Duration (hours) | Precipitation (inches) |
|---|---|
| 1.0 | 1.2 |
| 2.0 | 2.0 |
| 3.0 | 2.9 |
| 6.0 | 5.0 |
| 12.0 | 8.1 |
| 24.0 | 9.3 |
| 48.0 | 13.8 |
| 72.0 | 14.1 |

**TABLE 5.2**
**REPS TOOL LOCAL STORM PMP**

| Duration (hours) | Precipitation (inches) |
|---|---|
| 0.083 | 0.70 |
| 0.25 | 1.81 |
| 1.0 | 4.64 |
| 2.0 | 7.61 |
| 3.0 | 7.61 |
| 6.0 | 7.61 |

## 5.3 Hydrometeorological Report Method

The general storm and local storm PMP depth were estimated using *Hydrometeorological Report No. 49 Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages* (HMR-49) (NOAA, 1984).

RJH followed the step-wise procedure provided by HMR-49 to develop the general storm PMP. The basin was geospatially located on the 24-hour, 10-square-mile convergence PMP index map (HMR-49 Figure 2.13) and a precipitation depth was recorded. Convergence PMP depths for other durations were obtained from a table of ratios in HMR-49 based on the 24-hour duration. The basin was geospatially located on the 24-hour, 10-square-mile orographic PMP index map (HMR-49 Figure 3.11) and a precipitation depth was recorded. Orographic PMP depths for other durations were obtained from a table of ratios in HMR-49 based on the 24-hour duration. The total PMP depths were calculated by adding the convergence and orographic PMP depths. Depth-area reduction factors were not applied, because the size of the overall watershed is not significantly larger than 10 square miles. A summary of cumulative general storm PMP estimates is provided in Table 5.3.

**TABLE 5.3**
**HMR GENERAL STORM PMP**

| Duration (hours) | Precipitation (inches) |
|---|---|
| 1.0 | 1.9 |
| 2.0 | 3.7 |
| 3.0 | 5.1 |
| 6.0 | 7.7 |
| 12.0 | 10.8 |
| 24.0 | 14.5 |
| 48.0 | 19.2 |
| 72.0 | 21.4 |

The local storm PMP (i.e., "thunderstorm" PMP) was computed using the 1-hour, 1-square-mile, 5,000-foot-elevation cumulative PMP index map in HMR-49. The basin was geospatially located on the 1-hour, 1-square-mile PMP index map and the precipitation depth was obtained. Based on depth-duration factors contained in Table 5.4 of HMR-49, the local storm PMP values for 0.25, 0.5, 0.75, 1, 2, 3, 4, 5, and 6 hours were identified. Precipitation depths were then reduced by 24 percent to account for elevation impacts based on guidance presented in HMR-49. Depth-area reduction factors were applied based on Figure 4.9 in HMR-49. A summary of cumulative local storm PMP estimates is provided in Table 5.4

**TABLE 5.4**
**HMR LOCAL STORM PMP**

| Duration (hours) | Precipitation (inches) |
|---|---|
| 0.083 | 1.4 |
| 0.25 | 3.1 |
| 1.0 | 4.9 |
| 2.0 | 5.6 |
| 3.0 | 6.1 |
| 6.0 | 6.9 |

## 5.4 Application of HMR PMP Depths

The SEO allows an adjustment of the PMP depths estimated using the applicable HMR. Based on the SEO Rules ( SEO, 2007), the governing IDF depths for the Hogchute Dam basin are equal to 0.7 and 0.9 times the HMR PMP depths for the general storm and local storm, respectively. Adjusted PMP depths calculated for the general storm and local storm are presented in Tables 5.5 and 5.6, respectively.

## TABLE 5.5
## ADJUSTED HMR GENERAL STORM PMP

| Duration (hours) | Precipitation (inches) |
|---|---|
| 1.0 | 1.3 |
| 2.0 | 2.6 |
| 3.0 | 3.6 |
| 6.0 | 5.4 |
| 12.0 | 7.6 |
| 24.0 | 10.2 |
| 48.0 | 13.4 |
| 72.0 | 15.0 |

## TABLE 5.6
## ADJUSTED HMR LOCAL STORM PMP

| Duration (hours) | Precipitation (inches) |
|---|---|
| 0.083 | 1.3 |
| 0.25 | 2.8 |
| 1.0 | 4.4 |
| 2.0 | 5.0 |
| 3.0 | 5.5 |
| 6.0 | 6.2 |

# SECTION 6 – HYDROLOGIC PARAMETERS

## 6.1 General

Rainfall-runoff modeling requires the input of several hydrologic parameters including loss rate, base flow, and unit hydrograph parameters. Hydrologic parameters were developed in accordance with the SEO, *Hydrologic Basin Response Parameter Estimate Guidelines* (HBRPEG) (SEO, 2008) and are described in the following sections.

## 6.2 Losses

The portion of rainfall that does not contribute to runoff is lost to interception, evaporation, surface retention, and infiltration. HBRPEG recommends using the Initial and Uniform Loss Rate method for the PMP event. The Initial and Uniform Loss Rate method uses a two-step loss procedure that consists of initial losses at the beginning of the storm event followed by uniform losses after the initial loss is satisfied. This procedure requires the development of three parameters: initial loss (STRTL), uniform loss rate (CNSTL), and percentage of impervious basin area (RTIMP).

- Initial Loss (STRTL): The STRTL represents the portion of rainfall that is lost through initial infiltration (II) to the point of ground saturation and surface retention losses (IA). Surface retention losses were obtained from Table 8 of the HBRPEG (SEO, 2008), based on the slope and percentage of vegetation in each subbasin. We assumed zero initial infiltration because of saturation from snowmelt or other antecedent conditions, which is a reasonable assumption for high-altitude drainage basins.
- Uniform Loss Rate (CNSTL): The CNSTL represents the steady state infiltration of rainfall into saturated soils. Uniform loss rates are based on the soil types and vegetative cover in the basin. RJH obtained NRCS soil survey data in ArcGIS format. Using ArcGIS, a list of NRCS soil types and corresponding areas was developed, and bare ground hydraulic conductivity values (XKSAT) values were identified based on textural information for each soil type. A weighted average bare ground XKSAT value was then computed for each basin. An adjustment factor was applied for vegetative cover based on Figure 8 in the HBRPEG (SEO, 2008).
- Percent Impervious Area (RTIMP): The effective RTIMP represents directly connected impervious area within the basin. Potential impervious areas include rock outcrops, parking lots, roof tops, paved roads, and lakes/reservoirs. The only

significant impervious area in the basin is Carson Lake and several small reservoirs which accounts for less than 5 percent of the basin.

A summary of loss parameters for the Initial and Uniform Loss Rate method is presented in Table 6.1. Calculations for the PMP precipitation losses are provided in Appendix C.

**TABLE 6.1**
**INITIAL AND UNIFORM LOSS RATE PARAMETERS**

| Basin | Surface Retention (IA) (inches) | Initial Infiltration (II) (inches) | Initial Loss (STRTL) (inches) | Uniform Loss Rate (CNSTL) (in/hr) | Impervious Area (RTIMP) (%) |
|---|---|---|---|---|---|
| Upper | 0.6 | 0 | 0.6 | 0.07 | 1.4 |
| Lower | 0.6 | 0 | 0.6 | 0.08 | 4.1 |

## 6.3 Unit Hydrograph Parameters

A unit hydrograph is the direct runoff hydrograph resulting from a unit 1-inch depth of excess rainfall produced by a storm of uniform intensity and specified duration over a given basin. The HBRPEG (SEO, 2008) recommends using the synthetic unit hydrographs presented in the U.S. Bureau of Reclamation (Reclamation), *Flood Hydrology Manual* (Reclamation, 1989). The Hogchute Dam basin is located near the boundary of the Rocky Mountain and Colorado Plateau regions. Basin vegetation consisting of native grasses and pine forests more closely aligns with typical vegetation in the Rocky Mountain region. For the purposes of unit hydrograph selection, RJH identified that the watershed has characteristics representative of the Rocky Mountain region as defined in the HBRPEG (SEO, 2008) and the Flood Hydrology Manual (Reclamation, 1989).

The synthetic unit hydrographs presented in the Flood Hydrology Manual (Reclamation, 1989) are primarily governed by lag time, which is a parameter that identifies the temporal distribution of the unit hydrograph relative to the temporal distribution of the storm. The lag time is characterized by the ratio of flow length to the mean velocity of flow and is impacted by basin characteristics such as shape of the drainage basin, slope of the main channel, channel roughness and geometry, and storm pattern. The lag times for each subbasin were calculated using the following lag time equation from Flood Hydrology Manual (Reclamation, 1989):

$$L_g = 26 * K_n * [(L * L_{ca})/S0.5]^{0.33}$$

Where $L_g$ = lag time (hours)
$L$ = length of longest watercourse (miles)
$S$ = overall slope of L (feet/mile)
$L_{ca}$ = length along "L" to a point opposite the centroid of the drainage basin (miles)
$K_n$ = a lumped parameter representing resistance to overland flow from the drainage basin incorporating the weight of various components of flow resistance along the entire flow path "L"

The Reclamation unit hydrograph procedure requires the selection of an appropriate $K_n$ value, which is a measure of run-off delay due to terrain and surface obstructions. Low $K_n$ values are indicative of short runoff delays and high peak runoff flows.

Kn values were evaluated using both specific index storms presented in the Flood Hydrology Manual and ranges of values presented in HBRPEG. RJH selected $K_n$ value that were generally in the lower portion of the recommended ranges because the basin does not contain thick forest like some typical Rocky Mountain basins. A summary of $K_n$ parameters is presented in Table 6.2.

**TABLE 6.2**
**$K_n$ VALUES FOR ROCKY MOUNTAIN REGION**

| Storm Event | Selected $K_n$ Value |
|---|---|
| General Storm PMP | 0.15 |
| Local Storm PMP | 0.05 |

Using these $K_n$ values, lag times were calculated for each storm. Lag times are presented in Table 6.3. Calculations for lag times are presented in Appendix D.

**TABLE 6.3**
**LAG TIMES**

| Basin | Storm Event | $L_g$ (hours) |
|---|---|---|
| Upper | General PMP | 3.57 |
| | Local PMP | 1.19 |
| Lower | General PMP | 4.35 |
| | Local PMP | 1.45 |

The lag times were used in the HEC-HMS model to calculate the unit hydrographs based on S-graphs (i.e., a form of a dimensional unit hydrograph) for the general storm PMP and local storm PMP presented in Flood Hydrology Manual (Reclamation, 1989).

# SECTION 7 - PRECIPITATION RUNOFF AND ROUTING ANALYSIS

## 7.1 General

This section presents the inflow runoff and reservoir routing modeling results for the Hogchute Dam basin. The basin parameters, hydrologic parameters, and precipitation data discussed in the preceding sections were input into a U.S. Army Corps of Engineers' (USACE) HEC-HMS rainfall-runoff computer model to develop the inflow hydrograph for each storm.

## 7.2 Reservoir Routing

Three reservoirs were included in the HEC-HMS model: Grand Mesa #8, Grand Mesa #9, and Carson Lake. The required HEC-HMS inputs for modeling a reservoir and spillway include an elevation-capacity relationship for the reservoir and a spillway rating curve. Reservoir routing for all of the reservoirs was performed assuming that each reservoir was at maximum normal pool (i.e., spillway invert) at the beginning of the precipitation event. Storage and routing impacts associated with the Highway 65 embankment were neglected. The storage along Kannah Creek upstream and below the top of the Highway 65 embankment is about 2 ac-ft, which is negligible compared to IDF volumes.

Elevation-capacity and spillway rating curve information for Grand Mesa #8 was obtained from the 1985 dam rehabilitation drawings. The spillway rating curve was extrapolated beyond the dam crest using the spillway rating curve best-fit equation presented on the drawings. Total discharge capacity for flows that exceed the capacity of the spillway were estimated using a broad-crested weir equation in HEC-HMS to calculate additional flows over the dam crest.

Elevation-capacity information for Grand Mesa #9 was estimated from SEO data between the maximum normal pool and dam crest. Elevation-capacity information below the maximum normal pool and above the dam crest was calculated using Mesa County LiDAR data. The spillway rating curve and the discharge capacity for flows that exceed the capacity of the spillway were estimated using broad-crested weir equations in HEC-HMS.

Elevation-capacity information for Carson Lake was obtained from the 1947 dam design drawings provided by the City. The elevation-discharge capacity of the existing spillway at Carson Lake was calculated using the spillway capacity curve from the 1947 design drawings. Total discharge capacity for flows that exceed the capacity of the spillway were estimated using a broad-crested weir equation to calculate additional flows over the dam crest.

Elevation-capacity and spillway rating curve information is provided in Appendix E.

## 7.3 Dam Breach Parameters

Grand Mesa #8 and #9 dams will both overtop during the IDF event. We conservatively assumed that overtopping would result in a breach of each dam. RJH evaluated breach parameters using the Froehlich method in accordance with recommendations from the SEO Guidelines based on dam size and storage intensity. Input parameters were developed based on available design drawings and LiDAR data. A summary of breach parameters is presented in Table 7.1.

**TABLE 7.1**
**SUMMARY OF BREACH PARAMETER ESTIMATESOVERTOPPING FAILURE**

| Parameter | Grand Mesa Dam #8 | Grand Mesa Dam #9 |
|---|---|---|
| Average Breach Width, $B_f$ | 97.6 | 71.4 |
| Bottom Breach Width, $B_b$ | 77.6 | 56.4 |
| Breach Formation Time, $t_f$ | 0.84 | 0.7 |
| Breach Side Slopes, z (ZH:1V) | 1 | 1 |

Dam breach parameter calculations are provided in Appendix F.

## 7.4 Channel Routing

Channel routing is used to account for timing impacts and attenuation of a flood wave as it travels through a channel or river. Channel routing parameters were developed using the Muskingum-Cunge methodology for the portion of Kannah Creek between Grand Mesa #9 and Carson Lake. The Muskingum-Cunge method is typically used for well-defined channel reaches without significant backwater effects, which is appropriate for the mountain streams like Kannah Creek.

The Muskingum-Cunge method requires the identification of channel geometry, reach length, channel slope, and Manning's "n" roughness value. Channel geometry was defined using the eight-point method, which consists of assigning eight points to define an appropriate shape for the cross section. An eight-point cross section was developed using Mesa County LiDAR data. A Manning's "n" value was estimated based on aerial photography. Additional information for the Muskingum-Cunge parameter development is provided in Appendix G.

### 7.5 HEC-HMS Models

RJH used the precipitation data estimated from HMR-49 and the REPS Tool combined with hydrologic and routing parameters to construct the HEC-HMS rainfall-runoff computer models to evaluate the inflow runoff hydrographs and reservoir routing. The storms were modeled in HEC-HMS as "frequency storms" with an intensity position of 50 percent. The intensity position follows the "balanced storm" approach recommended by the SEO, *Dam Safety Project Review Guide* (SEO, 2016) and REPS Tool User's Manual (SEO, 2018). The following model runs were developed in the HEC-HMS model:

- General storm event based on HMR-49
- Local storm event based on HMR-49
- General storm event based on REPS Tool
- Local storm event based on REPS Tool

A summary of the results of the HEC-HMS computer models is provided in Table 7.2. The IDF inflow hydrographs for the local and general storm PMP events using HMR-49 are shown on Figure 7.1. The IDF inflow hydrographs for the local and general storm PMP events using the REPS Tool are shown on Figure 7.2. A schematic of the HEC-HMS model is presented on Figure 7.3. The input data, calculations, and HEC-HMS output results are provided in Appendix H.

**TABLE 7.2**
**HEC-HMS RESULTS AT HOGCHUTE DAM**

| Storm Event | Peak Inflow (cfs) | Inflow Volume (ac-ft) | Peak Outflow (cfs) | Maximum WSE (ft) | Residual Freeboard (ft) | Overtopping Depth (ft) | Overtopping Duration (hours) |
|---|---|---|---|---|---|---|---|
| General storm HMR | 8,793 | 6,430 | 5,578 | 9,900.8 | 1.2 | -- | -- |
| Local storm HMR | 25,782 | 3,928 | 25,408 | 9,905.6 | -- | 3.6 | 2.0 |
| General storm REPS Tool | 9,456 | 6,507 | 6,358 | 9,901.3 | 0.7 | -- | -- |
| Local storm REPS Tool | 35,097 | 4,937 | 34,629 | 9,906.9 | -- | 4.9 | 2.5 |

Based on the results of the HEC-HMS models, the local storm governs compared to the general storm when using HMR-49. The existing spillway has insufficient capacity to convey the IDF developed using HMR-49. Hogchute Dam would overtop for about 2 hours up to a maximum of about 3.6 feet.

The local storm also governs compared to the general storm when using the REPS Tool. The existing spillway has insufficient capacity to convey the IDF developed using the REPS Tool. Hogchute Dam would overtop for about 2.5 hours up to a maximum of about 4.9 feet.

The spillway evaluation only considered the hydraulic capacity of the existing spillway, and evaluations considering potential erosion and scour of the embankment and the unlined spillway were not performed. These evaluations will be performed in the future as part of the dam rehabilitation design.

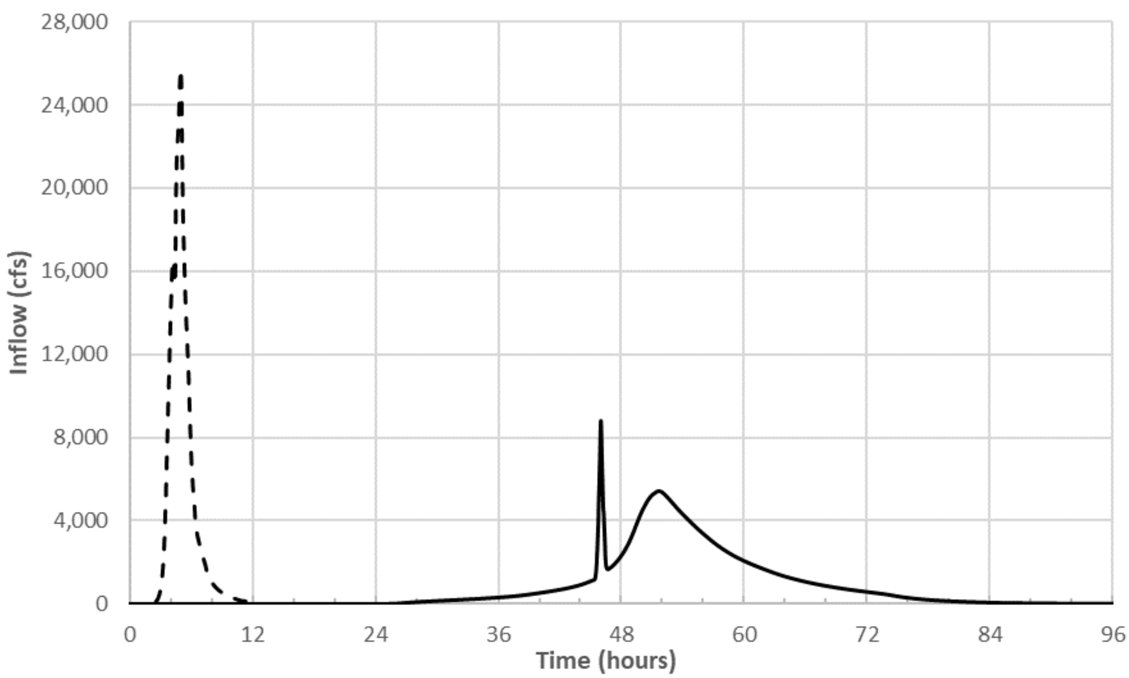



**Figure 7.1: Inflow Hydrographs for HMR-49**

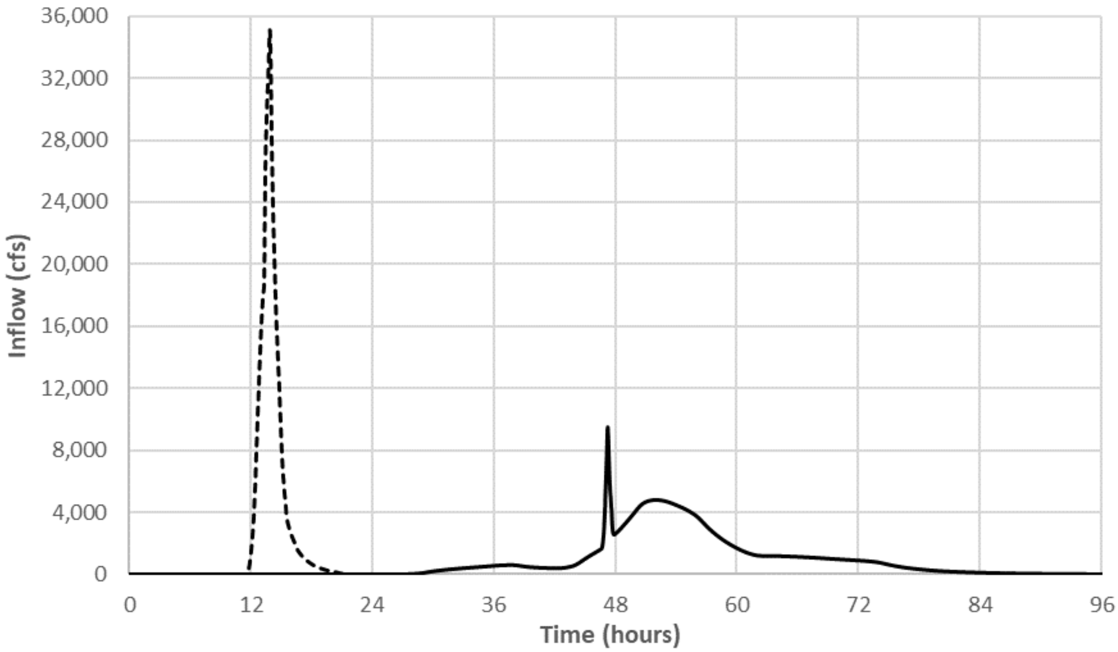
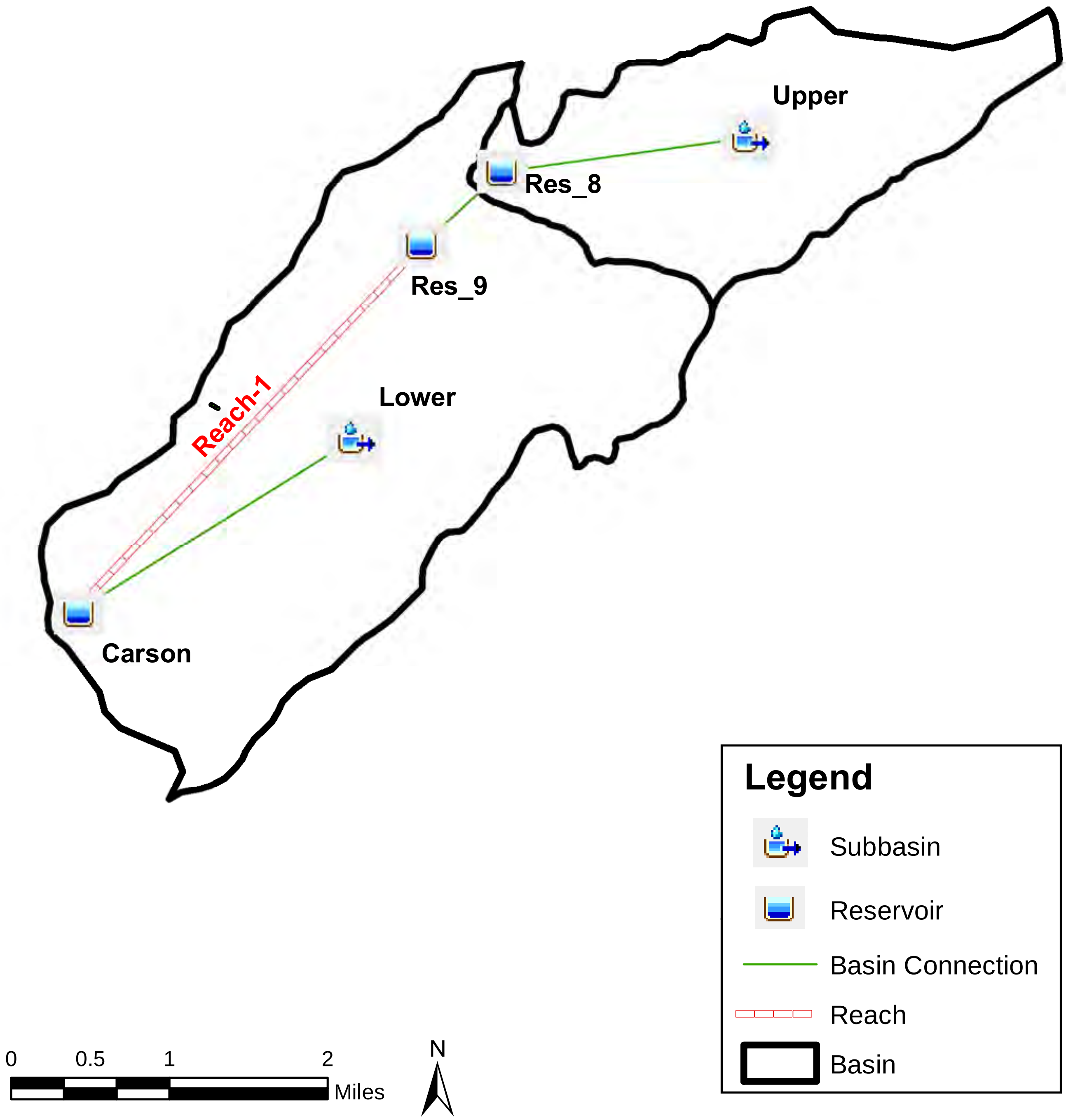



**Figure 7.2: Inflow Hydrographs for REPS Tool**

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**Datum: NAVD 1988**

RJH CONSULTANTS, INC.

HOGCHUTE DAM HYDROLOGY REPORT

HEC-HMS SCHEMATIC

PROJECT NUMBER 18115

January 2019

**Figure 7.3**

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# SECTION 8 - SUMMARY AND CONCLUSION

A summary of the hydrologic analyses and conclusions from the analyses are provided below:

1. The entire Hogchute Dam drainage basin is located in the Grand Mesa National Forest. Future development within the basin is not anticipated and was not considered in this evaluation.
2. Precipitation from both general and local storm events was estimated using HMR-49 and the SEO's REPS Tool. Storm runoff was routed through the reservoir using HEC-HMS to evaluate the adequacy of the existing spillway.
3. The existing emergency spillway can safely pass the runoff from the general storms predicted by both the HMR and the REPS precipitation models without overtopping the dam.
4. The existing emergency spillway does not have adequate discharge capacity to prevent the dam from being overtopped during either of the modeled local storms. The dam will be overtopped for about 2 hours to a maximum depth of about 3.6 feet during the HMR-49 local storm. The dam will be overtopped for about 2.5 hours to a maximum depth of about 4.9 feet during the REPS local storm.

# SECTION 9 - REFERENCES

Colorado Office of the State Engineer (SEO) (2018). *Regional Extreme Precipitation Study Tools – REPS PMP Tool and MetPortal PF Tool – Trial Use Guidance Document.*

Colorado Office of the State Engineer (SEO) (2008). *Hydrologic Basin Response Parameter Estimation Guidelines,* George V. Sabol, Revised May 2008.

Colorado Office of the State Engineer (SEO) (2007). *Rules and Regulations for Dam Safety and Dam Construction.*

Hansen, E.M et al (NOAA)(1984*). Hydrometeorological Report No. 49, Probable Maximum Precipitation Estimates, Colorado River and Great Basin Drainages.*

NRCS soils data downloaded from NRCS Web Soil Survey: websoilsurvey.nrcs.usda.gov/.

SEO*, Dam Safety Project Review Guide* (SEO, 2016) and REPS Tool User's Manual (SEO, 2018)

U.S. Bureau of Reclamation (Reclamation) (1989). *Flood Hydrology Manual, Arthur G. Cudworth*.

# APPENDIX A

## BASIN PARAMETERS

| Project | 18115 | Page | 1/3 |
|---|---|---|---|
| Date | 12/10/2018 | By | ATMerook |
| Checked | 12/10/18 | By | EMH |
| Approved | 12/13/18 | By | GOJ |

RJH CONSULTANTS, INC.

Client City of Grand Junction

Subject Hogchute Dam Hydrology – Basin Parameters

**Required:**

Evaluate the following basin parameters:
- Basin area
- Basin centroid location
- Longest flowpath, $L$
- Flowpath opposite basin centroid, $L_{CA}$
- Basin slope, $S$

**Assumptions**

1.) Use RJH calculation package "Hogchute Dam Hydrology – Basin Delineation" dated 12/3/2018
2.) Use ESRI ArcMap 10.4.1
3.) Use USGS topographic maps provided in ArcMap

**Results:** (see p.2-3)

| Parameter | Upper | Lower |
|---|---|---|
| Area ($mi^2$) | 3.58 | 8.33 |
| $L$ (mi) | 4.49 | 5.65 |
| $L_{CA}$ (mi) | 1.27 | 3.25 |
| $S$ (ft/mi) | 55.6 | 175.3 |

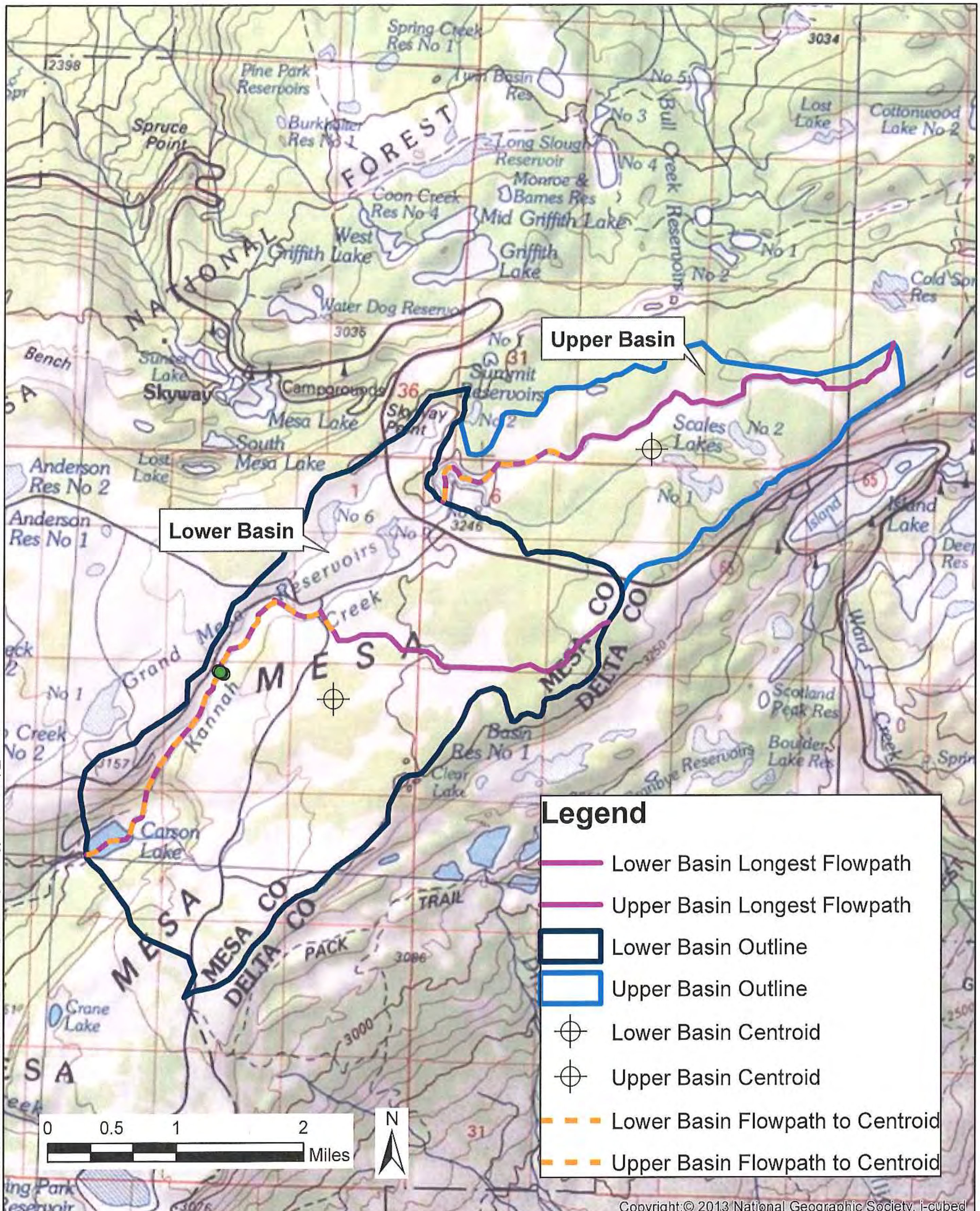
**Hogchute Dam Safety Evaluation - Hydrology**
**Project No. 18115**

| | | | |
|---|---|---|---|
| By: | ATMerook | Date: | 12/5/2018 |
| Checked: | EMH | Date: | 12/7/18 |
| Approved: | | Date: | |

**BASIN CHARACTERISTICS**

| Basin | Area ($mi^2$) | L (mi) | $L_{ca}$ (mi) | Max. Elev (ft) | Min. Elev (ft) | Slope (ft/mi) | $L*L_{ca}/S^{0.5}$ |
|---|---|---|---|---|---|---|---|
| Upper Basin | 3.58 | 4.49 | 1.27 | 10,897 | 10,648 | 55.6 | 0.77 |
| Lower Basin | 8.33 | 5.65 | 3.25 | 10,878 | 9887 | 175.3 | 1.39 |

3/3




P:\18115 - Hogchute Dam Safety Evaluation\Engineering\GIS\Figures\Hydrology Work Map_2.mxd

| | | | |
|---|---|---|---|
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| | | PROJECT NUMBER 18115 | December 2018 **Figure** |

# APPENDIX B

# PRECIPITATION DEPTHS

## B.1 PMP FROM HMR49

## B.2 PMP FROM REPS TOOL

# APPENDIX B.1

# PMP FROM HMR49

Project 18115 Page 1/20
Date 10/8/18 By BJB
Client City of Grand Junction
Checked 10/19/18 By EMH
Subject Hogchute Dam Hydrology - PMP from HMR 49
Approved By 10/22/18

Objective: Determine the general and local depths for the Probable Maximum Precipitation (PMP) storm event for Hogchute Dam.

Assumptions:

1) Use Hydrometeorological Report No. 49 by the National Oceanic and Atmospheric Administration (NOAA).

2) The basin size is 11.9 $mi^2$ as seen in RJH Calc. Package "Hogchute Dam Hydrology - Basin" dated 7/19/18. ✓

3) The basin centroid is located at 39.022 °N and 108.061° W.

Results:

| Duration | General Storm PMP Depth (in.) ✓ | Local Storm PMP Depth (in.) ✓ |
|---|---|---|
| 5 min | — | 1.4 |
| 15 min | — | 3.1 |
| 30 min | — | 4.1 |
| 1 hr. | 1.9 | 4.9 |
| 6 hr. | 4.7 | 6.9 |
| 12 hr. | 10.8 | - |
| 24 hr. | 14.5 | - |
| 48 hr. | 19.2 | - |
| 72 hr. | 21.4 | - |

Analysis:

- HMR 49 provides a table for general storm PMP computations for the Colorado River and Great basin (see pg. 3).
  - → This includes depths for durations of 6, 12, 24, 48, & 72 hrs.
  - → The month of September was picked, as this month yielded the greatest depths and reduction percentages, which is more conservative. ✓
  - → See pages 4-12 for additional analysis for the computation table
- HMR 49 provides a table for local storm PMP computations for the average depth PMP (see pg. 13).

Analysis (cont.):

→ This includes depths for durations of 15 min, 30 min, 45 min, and 1, 2, 3, 4, 5, 6 hrs.

→ See pages 14-19 for additional analysis for the computational table.

- 1 hr., 2 hr., & 3 hr. durations for the General Storm:

→ 1 hr. = 25% of 6 hr (see pg. 20)

= .25 (7.7)

= 1.9" ✓

- 5 min. duration for the Local Storm:

→ 5 min = 45% of 15 min (see pg. 20)

= .45 (3.1)

= 1.4" ✓

3/20
10/16/18 EMH

Table 6.1.--General-storm PMP computations for the Colorado River and Great basin

Drainage Hogchute Dam  Area 11.9 mi$^2$ ~~(km$^2$)~~

Latitude 39.0219, Longitude -108 of basin center

Month Sept.

| Step | | 6 | 12 | 18 | 24 | 48 | 72 | |
|---|---|---|---|---|---|---|---|---|
| | | Duration (hrs) | | | | | | |
| **A. Convergence PMP** | | | | | | | | |
| 1. Drainage average value from one of figures 2.5 to 2.16 | 13.6 in. ~~(mm)~~ | | | | | | | |
| 2. Reduction for barrier-elevation [fig. 2.18] | 38 % | | | | | | | |
| 3. Barrier-elevation reduced PMP [step 1 X step 2] | 8.4 in. ~~(mm)~~ | | | | | | | |
| 4. Durational variation [figs. 2.25 to 2.27 and table 2.7]. | | 70 | 87 | 94 | 100 | 114 | 120 | % |
| 5. Convergence PMP for indicated durations [steps 3 X 4] | | 5.9 | 7.3 | 7.9 | 8.4 | 9.6 | 10.1 | in. ~~(mm)~~ |
| 6. Incremental 10 mi$^2$ (26 km$^2$) PMP [successive subtraction in step 5] | | 5.9 | 1.4 | 0.6 | 0.5 | 1.2 | 0.5 | in. ~~(mm)~~ |
| 7. Areal reduction [select from figs. 2.28 and 2.29] | | 100 | 100 | 100 | 100 | 100 | 100 | % |
| 8. Areally reduced PMP [step 6 X step 7] | | 5.9 | 1.4 | 0.6 | 0.5 | 1.2 | 0.5 | in. ~~(mm)~~ |
| 9. Drainage average PMP [accumulated values of step 8] | | 5.9 | 7.3 | 7.9 | 8.4 | 9.6 | 10.1 | in. ~~(mm)~~ |
| **B. Orographic PMP** | | | | | | | | |
| 1. Drainage average orographic index from figure 3.11a to d. | 6.1 in. ~~(mm)~~ | | | | | | | |
| 2. Areal reduction [figure 3.20] | 100 % | | | | | | | |
| 3. Adjustment for month [one of figs. 3.12 to 3.17] | 100 % | | | | | | | |
| 4. Areally and seasonally adjusted PMP [steps 1 X 2 X 3] | 6.1 in. ~~(mm)~~ | | | | | | | |
| 5. Durational variation [table 3.6] | | 30 | 57 | 80 | 100 | 157 | 185 | % |
| 6. Orographic PMP for given durations [steps 4 X 5] | | 1.8 | 3.5 | 4.9 | 6.1 | 9.6 | 11.3 | in. ~~(mm)~~ |
| **C. Total PMP** | | | | | | | | |
| 1. Add steps A9 and B6 | | 7.7 | 10.8 | 12.8 | 14.5 | 19.2 | 21.4 | in. ~~(mm)~~ |

2. PMP for other durations from smooth curve fitted to plot of computed data.

3. Comparison with local-storm PMP (see sec. 6.3).

HMR 49

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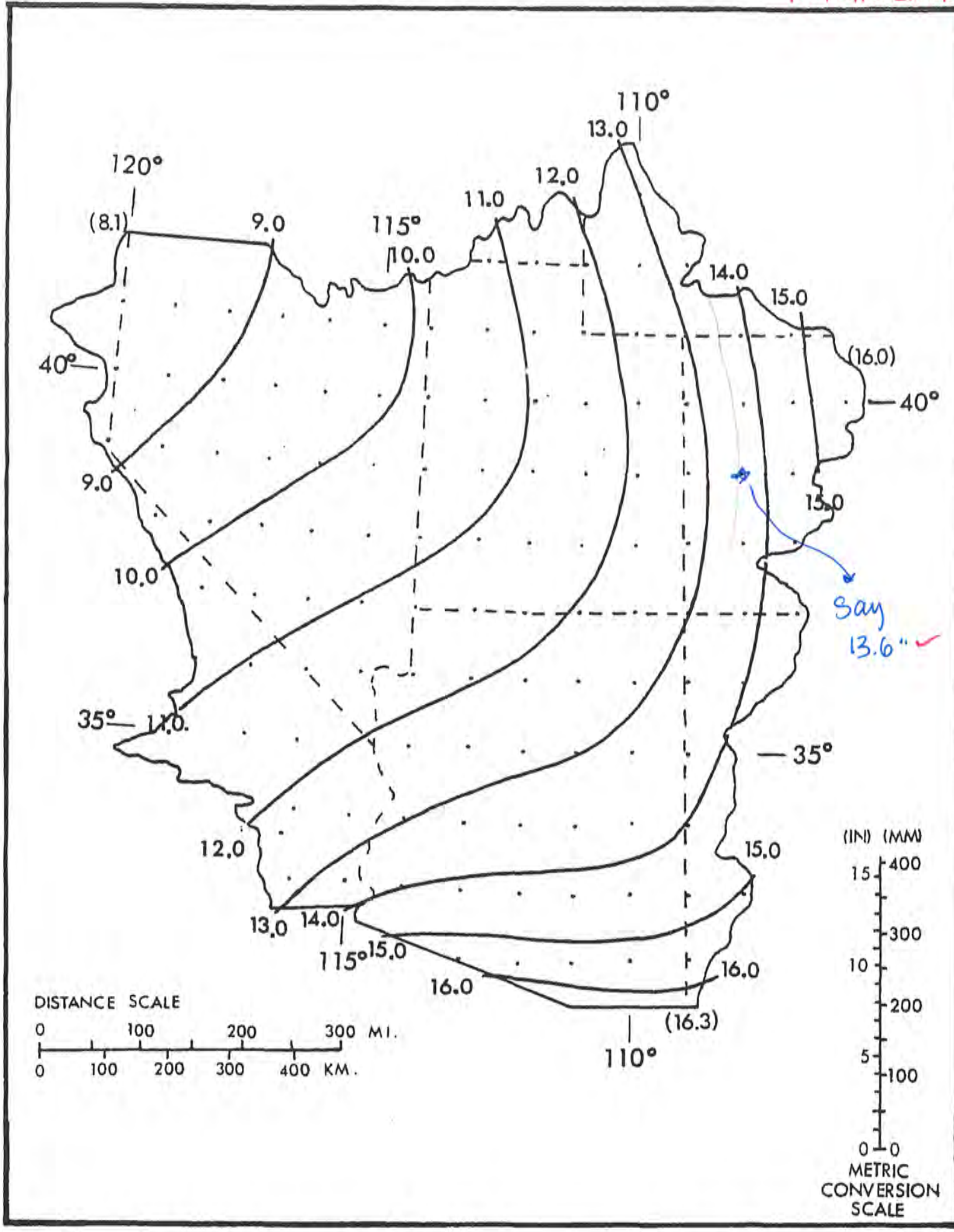


*Figure 2.13.--1000-mb (100-kPa) 24-hr convergence PMP (inches) for 10 mi$^2$ (26 km$^2$) for September. Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.*

HMR 49

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10/16/18 EMH

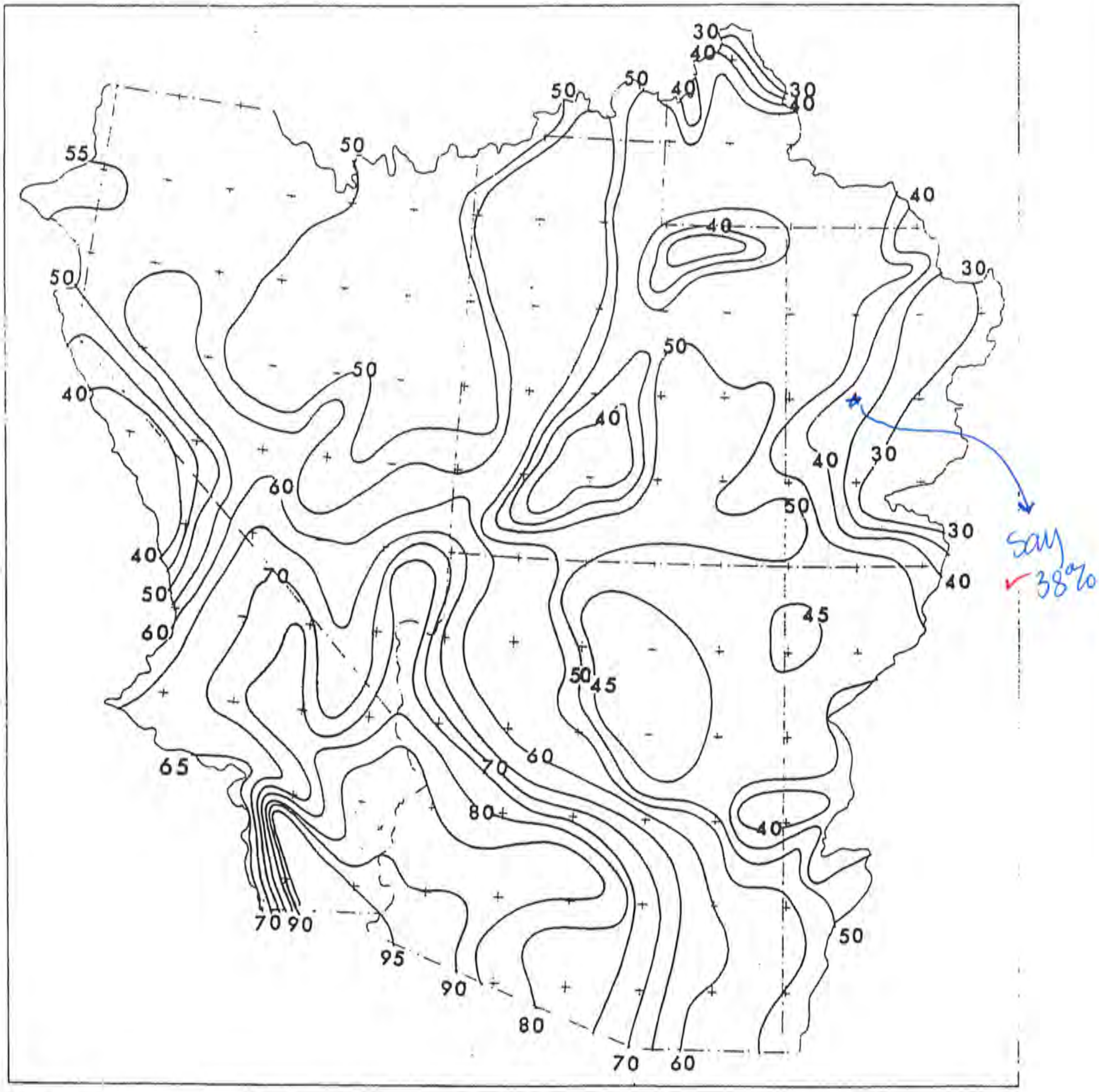


*Figure 2.18.--Percent of 1000-mb (100-kPa) convergence PMP resulting from effective elevation and barrier considerations. Isolines drawn for every five percent.*

HMR 49

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10/16/18 EMH

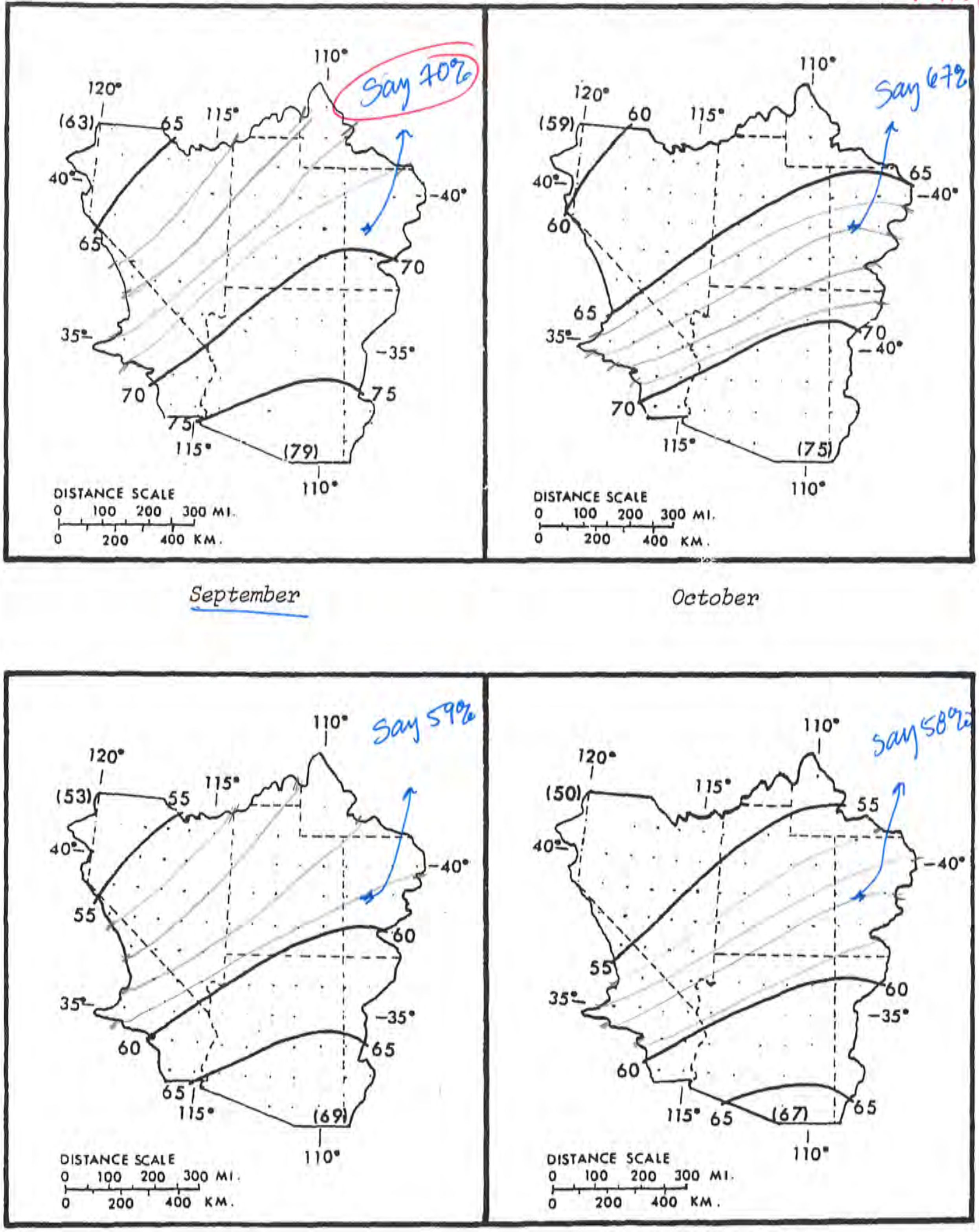


*Figure 2.27.*--Regional variation of 6/24-hr ratios by month (percent). Values in parentheses are limiting values and are to facilitate extrapolation beyond the indicated gradient.

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For the range of 6/24-hr ratios included in figures 2.25 to 2.27, depth-duration values in percent of 24-hr amounts are found in table 2.7. The regional ratio maps, and the depth-duration curves presented in figure 2.20 were used in adjusting the major storm data to 24-hr amounts listed in table 2.1.

Table 2.7.--Durational variation of convergence PMP (in percent of 24-hr amount).

| Duration (Hrs) | | | | | | Duration (Hrs) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 12 | 18 | 24 | 48 | 72 | 6 | 12 | 18 | 24 | 48 | 72 |
| 50 | 76 | 90 | 100 | 129 | 150 | 66 | 84 | 93 | 100 | 116 | 124 |
| 51 | 77 | 90 | 100 | 128 | 148 | 67 | 85 | 94 | 100 | 116 | 123 |
| 52 | 77 | 90 | 100 | 127 | 146 | 68 | 85 | 94 | 100 | 115 | 122 |
| 53 | 77 | 91 | 100 | 127 | 144 | 69 | 86 | 94 | 100 | 115 | 121 |
| 54 | 78 | 91 | 100 | 126 | 142 | | | | | | |
| 55 | 78 | 91 | 100 | 125 | 140 | 70 | 87 | 94 | 100 | 114 | 120 |
| 56 | 79 | 91 | 100 | 124 | 138 | 71 | 87 | 95 | 100 | 114 | 119 |
| 57 | 79 | 92 | 100 | 123 | 137 | 72 | 88 | 95 | 100 | 113 | 118 |
| 58 | 80 | 92 | 100 | 122 | 135 | 73 | 88 | 95 | 100 | 113 | 118 |
| 59 | 80 | 92 | 100 | 121 | 134 | 74 | 89 | 95 | 100 | 112 | 117 |
| | | | | | | 75 | 89 | 96 | 100 | 112 | 116 |
| 60 | 81 | 92 | 100 | 120 | 132 | 76 | 90 | 96 | 100 | 111 | 115 |
| 61 | 81 | 92 | 100 | 120 | 131 | 77 | 90 | 96 | 100 | 110 | 114 |
| 62 | 82 | 93 | 100 | 119 | 129 | 78 | 91 | 96 | 100 | 110 | 114 |
| 63 | 82 | 93 | 100 | 118 | 128 | 79 | 92 | 97 | 100 | 109 | 113 |
| 64 | 83 | 93 | 100 | 117 | 126 | | | | | | |
| 65 | 84 | 93 | 100 | 117 | 125 | 80 | 92 | 97 | 100 | 109 | 113 |

Note: For use, enter first column (6 hr) with 6/24-hr ratio from figures 2.25 to 2.27.

## 2.5 Areal Reduction for Basin Size

For operational use, basin average values of convergence PMP are needed rather than 10-mi$^2$ (26-km$^2$) values. Preferably, the method for reducing 10-mi$^2$ (26-km$^2$) values to basin average rainfalls should be derived from depth-area relations of storms in the region. However, all general storms in the region include large proportions of orographic precipitation.

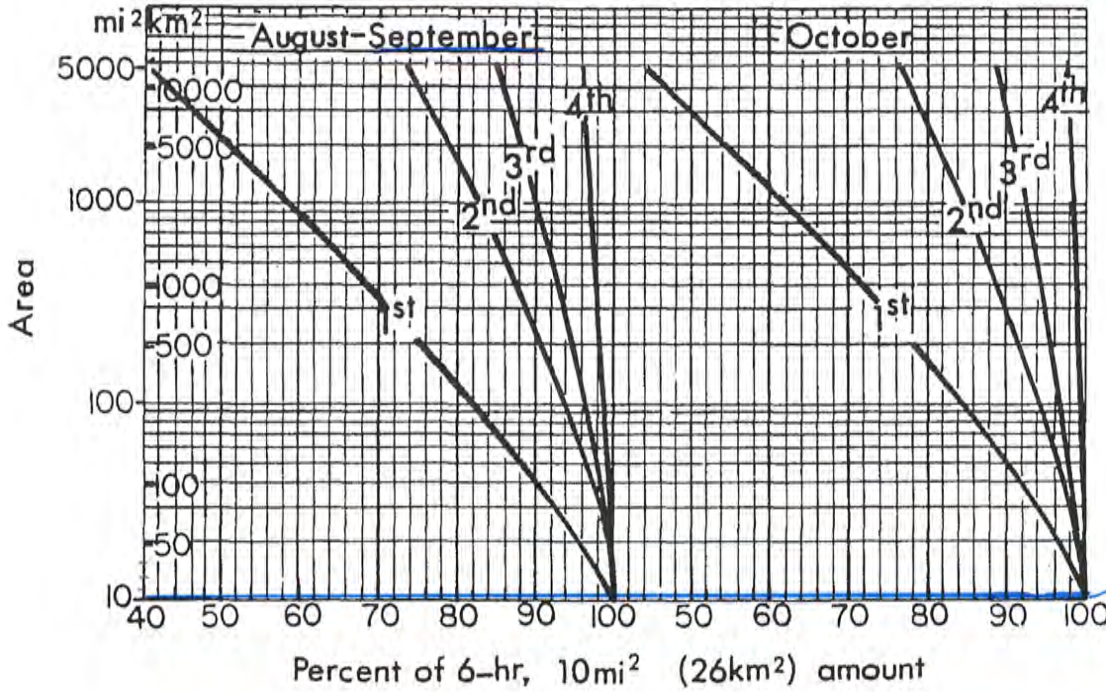
Our solution was to use generalized depth-area relations developed for PMP estimates within bordering zones in the Central and Eastern United States (Riedel et al. 1956). The smoothed areal variations adopted for the Southwestern States are shown in figures 2.28 and 2.29 for each month or a combination of months where differences are insignificant.

Figures 2.28 and 2.29 give depth-area relations that reduce 10-mi$^2$ (26-km$^2$) convergence PMP for basin sizes up to 5,000 mi$^2$ (12,950 km$^2$) for each month. Areal variations are given for the 4 greatest (1st to 4th) 6-hr PMP increments. After the 4th increment no reduction for basin size is required. Application of these figures will become clear through consideration of an example of PMP computation in chapter 6.

HMR 49

8/20

10/16/18 EMH




100%

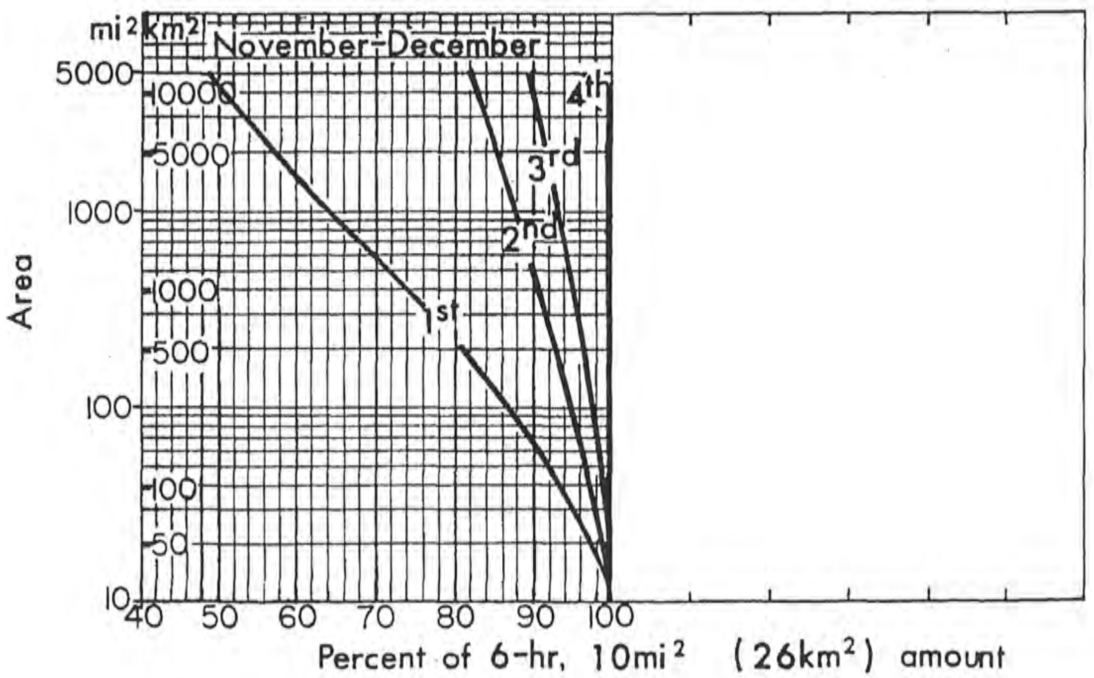



*Figure 2.29.--Depth-area variation for convergence PMP for first to fourth 6-hr increments.*

HMR 49

Say 6.1" ✓

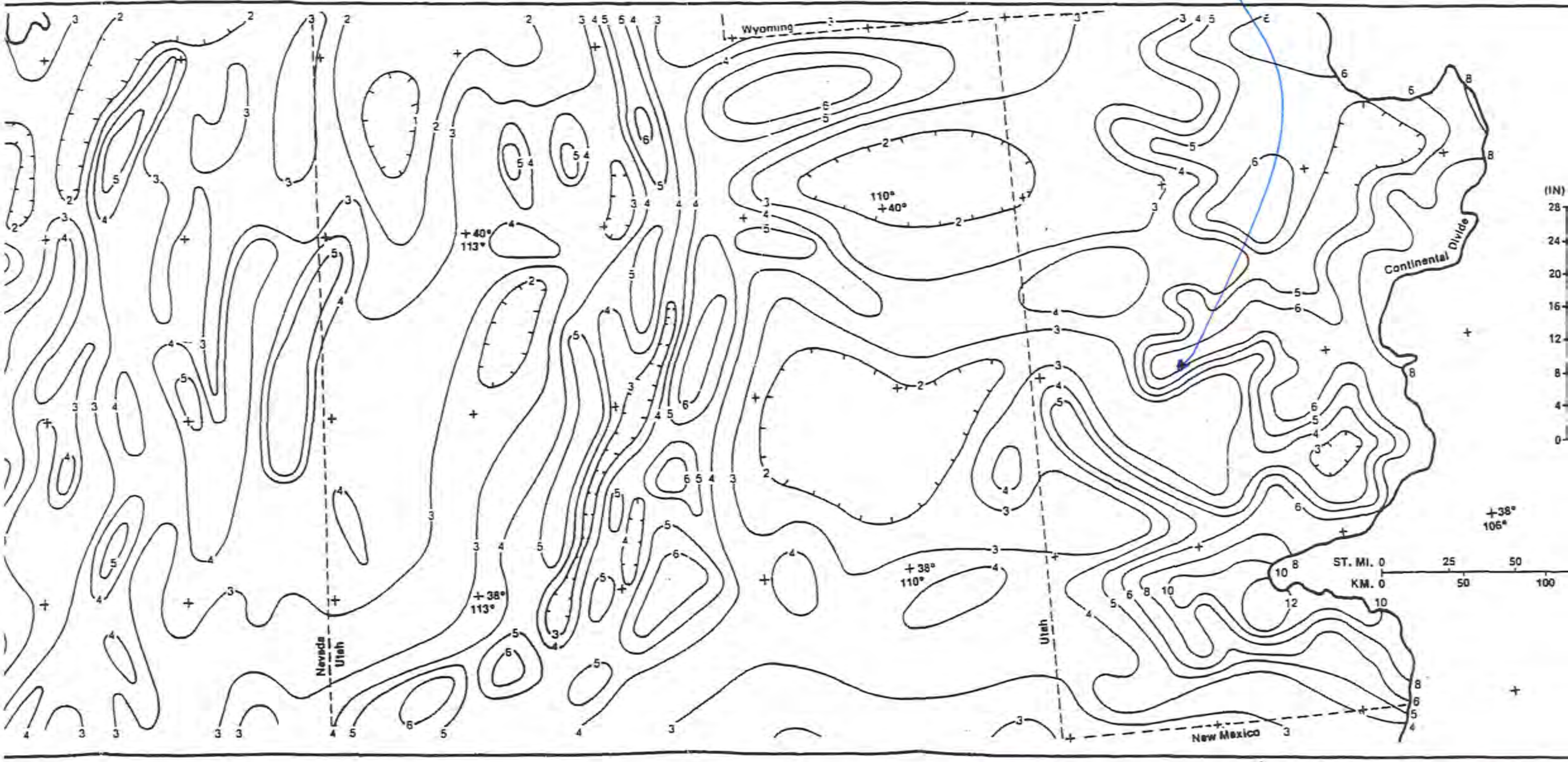



FIGURE 3.11b (Revised) — 10-mi² (26-km²) 24-hr orographic PMP index map (inches), north-central

✓ 10/6/18 EMH

9/20

HMR 49

10/20

10/16/18 EMH

100%

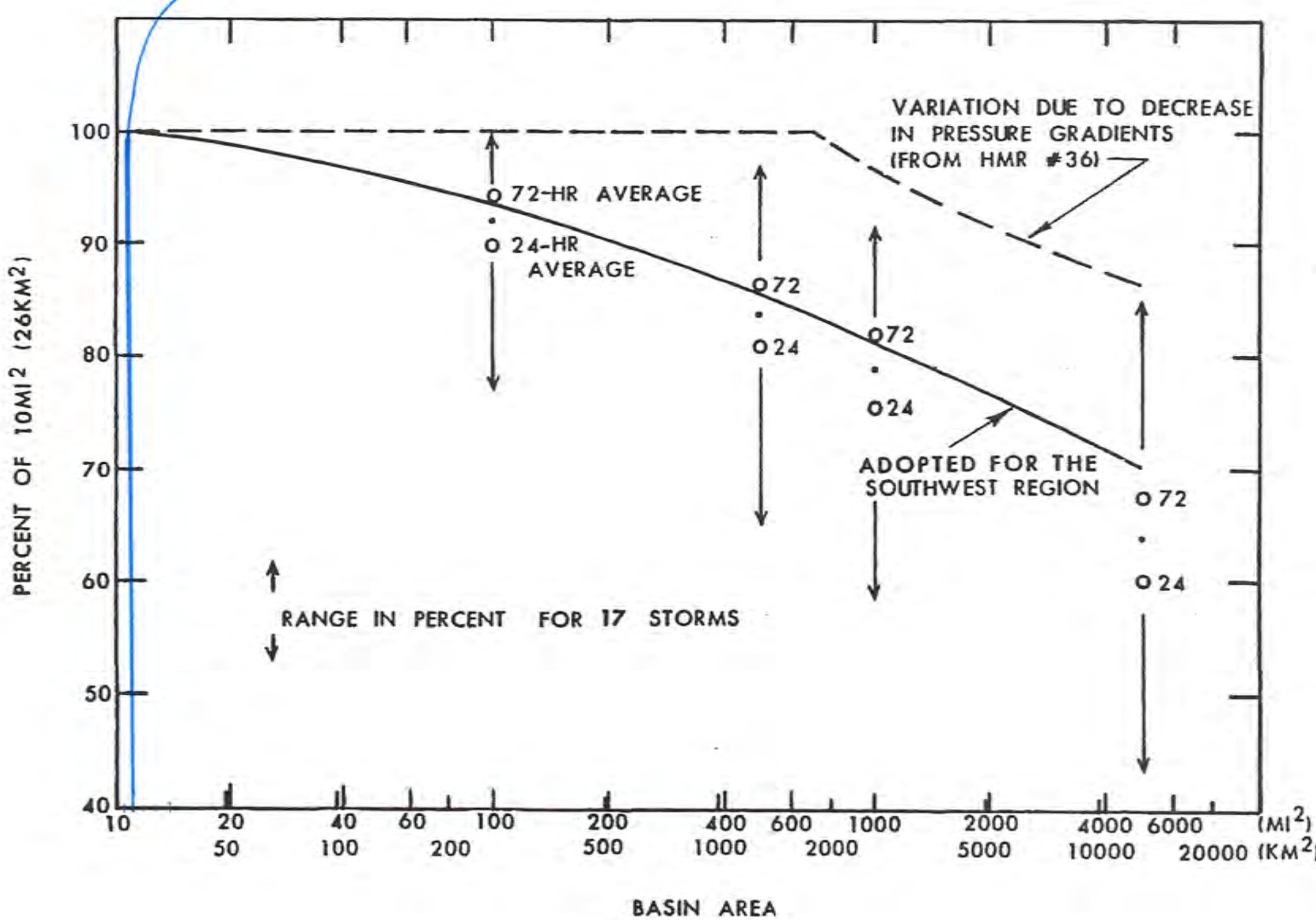
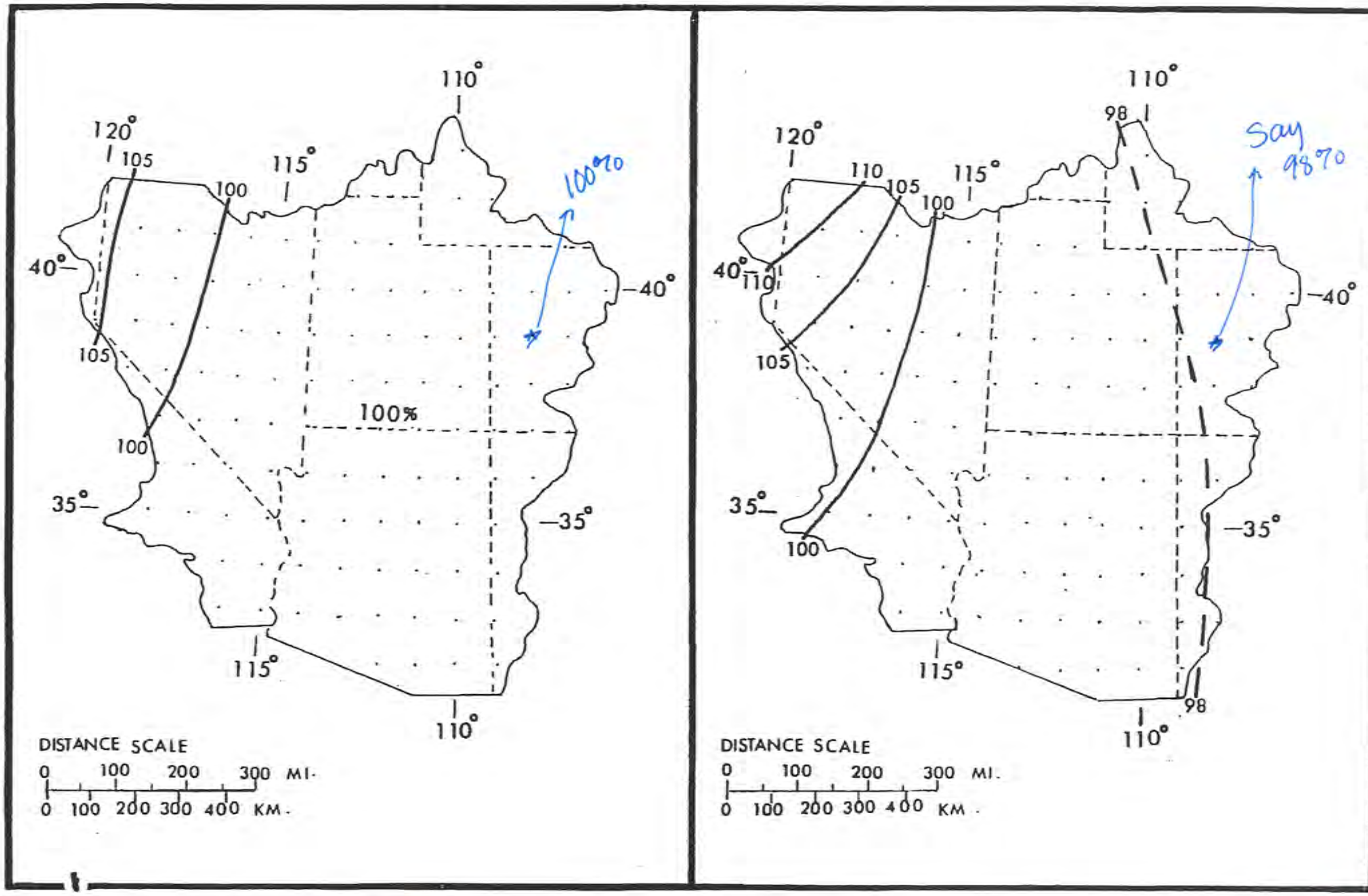



*Figure 3.20.--Variation of orographic PMP with basin size.*

HMR 49

11/20

10/18/18 EMH




September

October

*Figure 3.16.--Seasonal variation in 10-mi$^2$ (26-km$^2$) 24-hr orographic PMP for the study region (in percent of values in figure 3.11).*

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10/16/18 EMH 12/20

Table 3.9.--Durational variation of orographic PMP

| Latitude °N | Percent of 24-hr value | | | | | |
|---|---|---|---|---|---|---|
| | 6 hr | 12 | 18 | 24 | 48 | 72 |
| 42 | 28 | 55 | 79 | 100 | 161 | 190 |
| 41 | 29 | 56 | 79 | 100 | 160 | 189 |
| 40 | 30 | 57 | 80 | 100 | 159 | 187 |
| 39 | 30 | 57 | 80 | 100 | 157 | 185 |
| 38 | 31 | 58 | 81 | 100 | 155 | 182 |
| 37 | 32 | 59 | 81 | 100 | 152 | 177 |
| 36 | 33 | 60 | 82 | 100 | 149 | 172 |
| 35 | 34 | 61 | 82 | 100 | 146 | 167 |
| 34 | 35 | 62 | 83 | 100 | 143 | 162 |
| 33 | 36 | 63 | 84 | 100 | 139 | 157 |
| 32 | 37 | 64 | 84 | 100 | 135 | 152 |
| 31 | 39 | 66 | 85 | 100 | 132 | 146 |

# 4. LOCAL-STORM PMP FOR THE SOUTHWESTERN REGION AND CALIFORNIA

## 4.1 Introduction

This chapter provides generalized estimates of local or thunderstorm probable maximum precipitation. By "generalized" is meant that mapped values are given from which estimates of PMP may be determined for any selected drainage.

### 4.1.1 Region of Interest

Local-storm PMP was not included in the "Interim Report, Probable Maximum Precipitation in California" (HMR No. 36). During the formulation of the present study, we decided that the local-storm part of the study should include California west of the Sierra Nevada. It was also noted that PMP for summer thunderstorms was not considered west of the Cascade Divide in the Northwestern Region (HMR No. 43). As stated in the latter report, "No summer thunderstorms have been reported there (west of the Divide) of an intensity of those to the east, for which the moisture source is often the Gulf of Mexico or Gulf of California. The Cascade Divide offers an additional barrier to such moisture inflows to coastal areas where, in addition, the Pacific Ocean to the west has a stabilizing influence on the air to hinder the occurrence of intense summer local storms." Therefore, it was necessary to establish some continuation of the Cascade Divide into California so that the local-storm PMP definition would have continuity between the two regions.

The stabilizing influence of the Pacific air is at times interrupted by the warm moist tropical air from the south pushing into California, although it is difficult to determine where the limit of southerly flow occurs. General storms having the tropical characteristic of excessive thunderstorm rains are observed as far north as the northern end of the Sacramento Valley. Thus, a northern boundary has been selected for this study, excluding that portion of

HMR 49

✓10/16/18 EM/H 13/20

Table 6.3A.--Local-storm PMP computation, Colorado River, Great Basin and California drainages. For drainage average depth PMP. Go to table 6.3B if areal variation is required.

Drainage Hogchute Dam Area 11.9 ✓ $mi^2$ ~~($km^2$)~~
Latitude 39.0219 Longitude -108.061 Minimum Elevation 9890 ✓ ft ~~(m)~~

Steps correspond to those in sec. 6.3A.

1. Average 1-hr 1-$mi^2$ (2.6-$km^2$) PMP for drainage [fig. 4.5]. 7.9 ✓ in. ~~(mm)~~

2. a. Reduction for elevation. [No adjustment for elevations up to 5,000 feet (1,524 m): 5% decrease per 1,000 feet (305 m) above 5,000 feet (1,524 m)]. 24 ✓ %

   b. Multiply step 1 by step 2a. 7.9(1-.24) = 6.0 ✓ in. ~~(mm)~~

3. Average 6/1-hr ratio for drainage [fig. 4.7]. 1.3 ✓

| Step | 1/4 | 1/2 | 3/4 | 1 | 2 | 3 | 4 | 5 | 6 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Duration (hr) | | | | | | | | | |
| 4. Durational variation for 6/1-hr ratio of step 3 [table 4.4]. | 74 | 89 | 95 | 100 | 114 | 121 | 125 | 128 | 130 | % ✓ |
| 5. 1-$mi^2$ (2.6-$km^2$) PMP for indicated durations [step 2b X step 4]. | 4.4 | 5.3 | 5.7 | 6.0 | 6.8 | 7.3 | 7.5 | 7.7 | 7.8 | ✓ in. ~~(mm)~~ |
| 6. Areal reduction [fig. 4.9]. | 71 | 77 | 79 | 81 | 83 | 84 | 86 | 87 | 88 | % ✓ |
| 7. Areal reduced PMP [steps 5 X 6]. | 3.1 | 4.1 | 4.5 | 4.9 | 5.6 | 6.1 | 6.5 | 6.7 | 6.9 | ✓ in. ~~(mm)~~ |

8. Incremental PMP [successive subtraction in step 7]. ___ ___ ___ ___ ___ ___ in. (mm)

   ___ ___ ___ ___ } 15-min. increments

9. Time sequence of incremental PMP according to:

   Hourly increments [table 4.7]. ___ ___ ___ ___ ___ ___ in. (mm)

   Four largest 15-min. increments [table 4.8]. ___ ___ ___ ___ in. (mm)

Not needed
Want results as cumulative PMP

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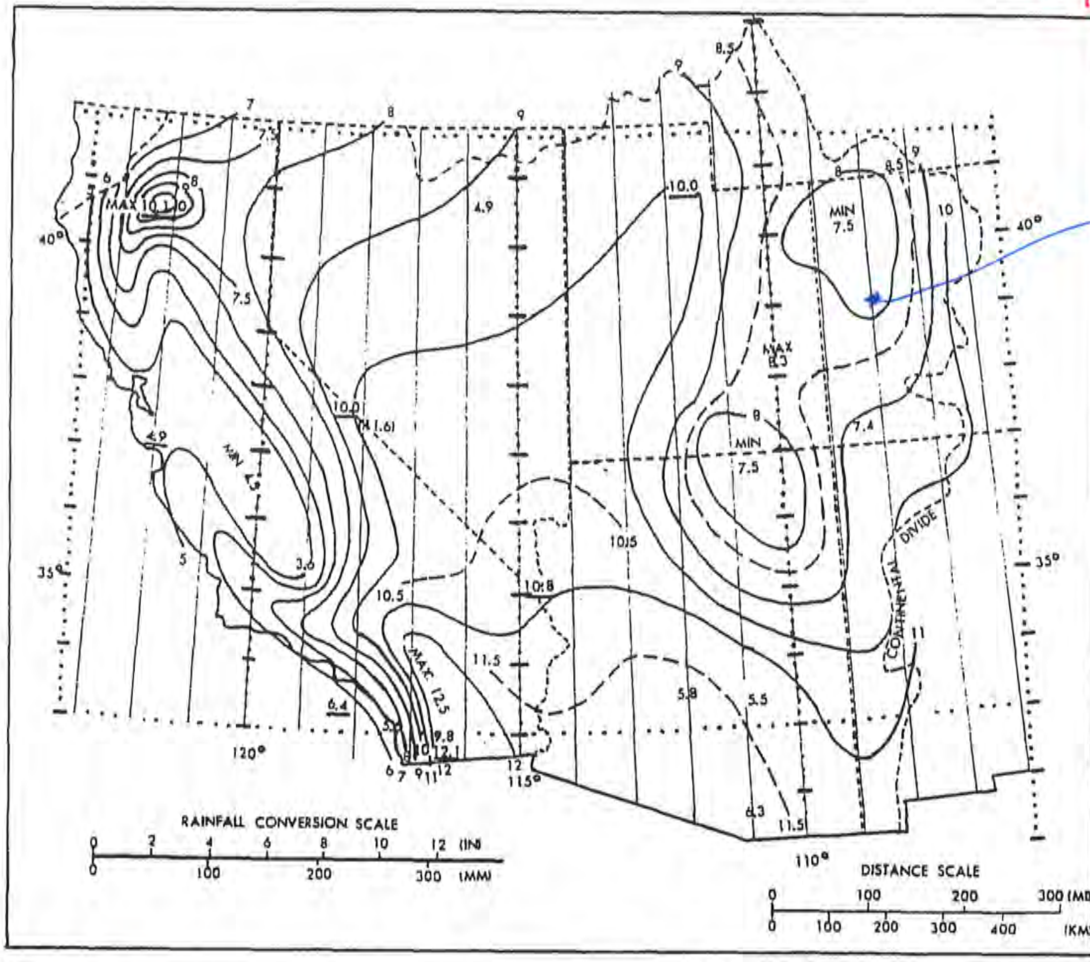
 14/20
10/16/18 EMH




Say 4.9"

*Figure 4.5--Local-storm PMP for 1 mi$^2$ (2.6 km$^2$) 1 hr. Directly applicable for locations between sea level and 5000 ft (1524 m). Elevation adjustment must be applied for locations above 5000 ft.*

events. In contrast to figure 4.4, figure 4.5 maintains a maximum between these two locations. There is no known meteorological basis for a different solution. The analysis suggests that in the northern portion of the region maximum PMP occurs between the Sierra Nevada on the west and the Wasatch range on the east.

A discrete maximum (> 10 inches, 254 mm) occurs at the north end of the Sacramento Valley in northern California because the northward-flowing moist air is increasingly channeled and forced upslope. Support for this PMP center comes from the Newton, Kennett, and Red Bluff storms (fig. 4.1). Although the analysis in this region appears to be an extension of the broad maximum through the center of the Southwestern Region, it does not indicate the direction of moist inflow. The pattern has evolved primarily as a result of attempts to tie plotted maxima into a reasonable picture while considering inflow directions, terrain effects, and moisture potential.

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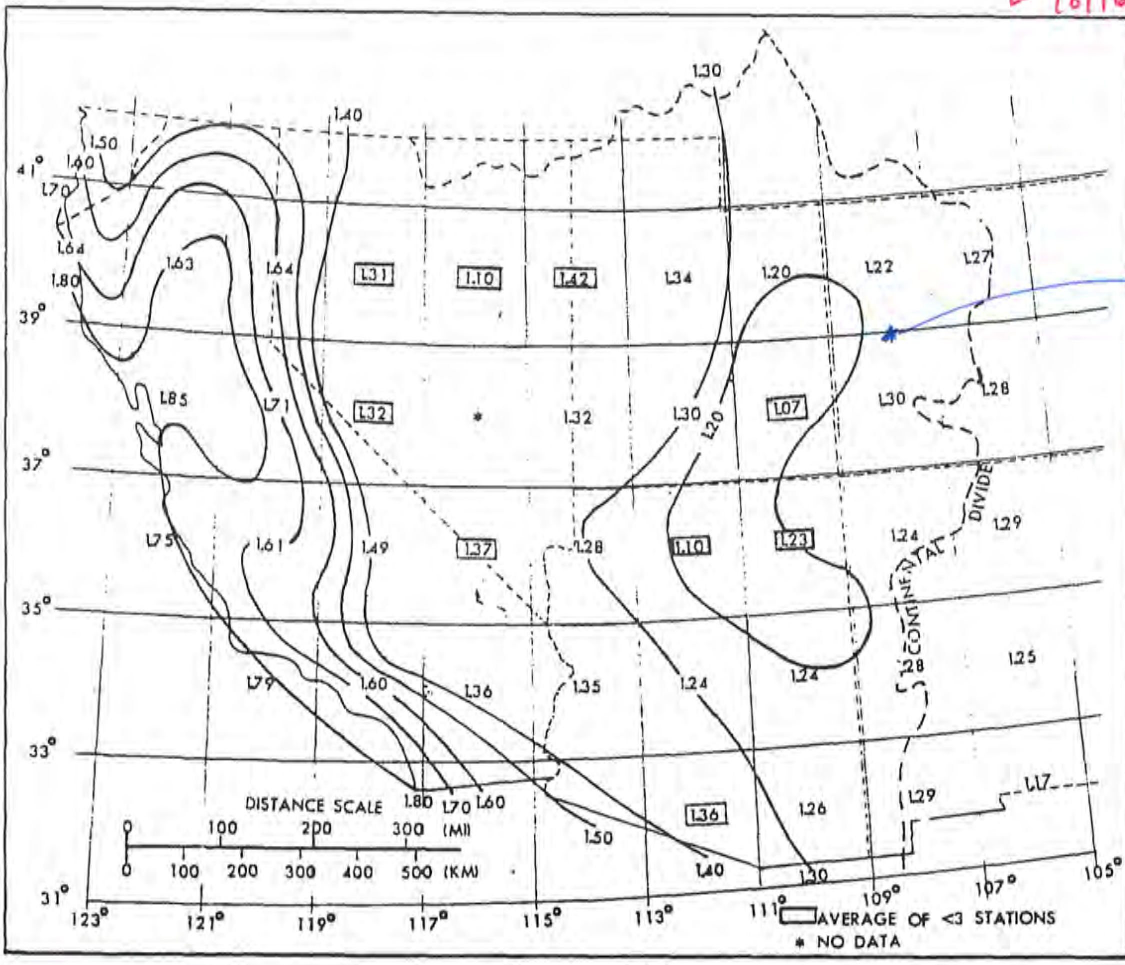
15/20

✓10/16/18 EMH




Average of 1.22 & 1.30 = 1.26 ≈1.3

ok

*Figure 4.7.--Analysis of 6/1-hr ratios of averaged maximum station data (plotted at midpoints of a 2° latitude-longitude grid).*

establish the basic depth-duration curve, then structure a variable set of depth-duration curves to cover the range of 6/1-hr ratios that are needed.

Three sets of data were considered for obtaining a base relation (see table 4.3 for depth-duration data).

a. An average of depth-duration relations from each of 17 greatest 3-hr rains from summer storms (1940-49) in Utah (U. S. Weather Bureau 1951b) and in unpublished tabulations for Nevada and Arizona (1940-63). The 3-hr amounts ranged from 1 to 3 inches (25 to 76 mm) in these events.

b. An average depth-duration relation from 14 of the most extreme short-duration storms listed in Storm Rainfall (U. S. Army, Corps of Engineers 1945- ). These storms come from Eastern and Central States and have 3-hr amounts of 5 to 22 inches (127 to 559 mm).

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ratios than storms with high 3/1-hr ratios. The geographical distribution of 15-min to 1-hr ratios also were inversely correlated with magnitudes of the 6/1-hr ratios of figure 4.7. For example, Los Angeles and San Diego (high 6/1-hr ratios) have low 15-min to 1-hr ratios (approximately 0.60) whereas the 15-min to 1-hr ratios in Arizona and Utah (low 6/1-hr ratios) were generally higher (approximately 0.75).

Depth-duration relations for durations less than 1 hour were then smoothed to provide a family of curves consistent with the relations determined for 1 to 6 hours, as shown in figure 4.3. Adjustment was necessary to some of the curves to provide smoother relations through the common point at 1 hour.

We believe we were justified in reducing the number of the curves shown in figure 4.3 for durations less than 1 hour, letting one curve apply to a range of 6/1-hr ratios. The corresponding curves have been indicated by letter designators, A-D, on figure 4.3. As an example, for any 6-hr amount between 115% and 135% of 1-hr, 1-mi$^2$ (2.6-km$^2$) PMP, the associated values for durations less than 1 hour are obtained from the curve designated as "B".

Table 4.4 lists durational variations in percent of 1-hr PMP for selected 6/1-hr rain ratios. These values were interpolated from figure 4.3.

To determine 6-hr PMP for a basin, use figure 4.3 (or table 4.4) and the geographical distribution of 6/1-hr ratios given in figure 4.7.

Table 4.4.--Durational variation of 1-mi$^2$ (2.6-km$^2$) local-storm PMP in percent of 1-hr PMP (see figure 4.3)

| 6/1-hr | Duration (hr) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ratio | 1/4 | 1/2 | 3/4 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1.1 | 86 | 93 | 97 | 100 | 107 | 109 | 110 | 110 | 110 |
| 1.2 | 74 | 89 | 95 | 100 | 110 | 115 | 118 | 119 | 120 |
| 1.3 | 74 | 89 | 95 | 100 | 114 | 121 | 125 | 128 | 130 |
| 1.4 | 63 | 83 | 93 | 100 | 118 | 126 | 132 | 137 | 140 |
| 1.5 | 63 | 83 | 93 | 100 | 121 | 132 | 140 | 145 | 150 |
| 1.6 | 43 | 70 | 87 | 100 | 124 | 138 | 147 | 154 | 160 |
| 1.8 | 43 | 70 | 87 | 100 | 130 | 149 | 161 | 171 | 180 |
| 2.0 | 43 | 70 | 87 | 100 | 137 | 161 | 175 | 188 | 200 |

## 4.5 Depth-Area Relation

We have thus far developed local-storm PMP for an area of 1 mi$^2$ (2.6 km$^2$). To apply PMP to a basin, we need to determine how 1-mi$^2$ (2.6-km$^2$) PMP should decrease with increasing area. We have adopted depth-area relations based on rainfalls in the Southwest and from consideration of a model thunderstorm.

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10/16/18 EMH

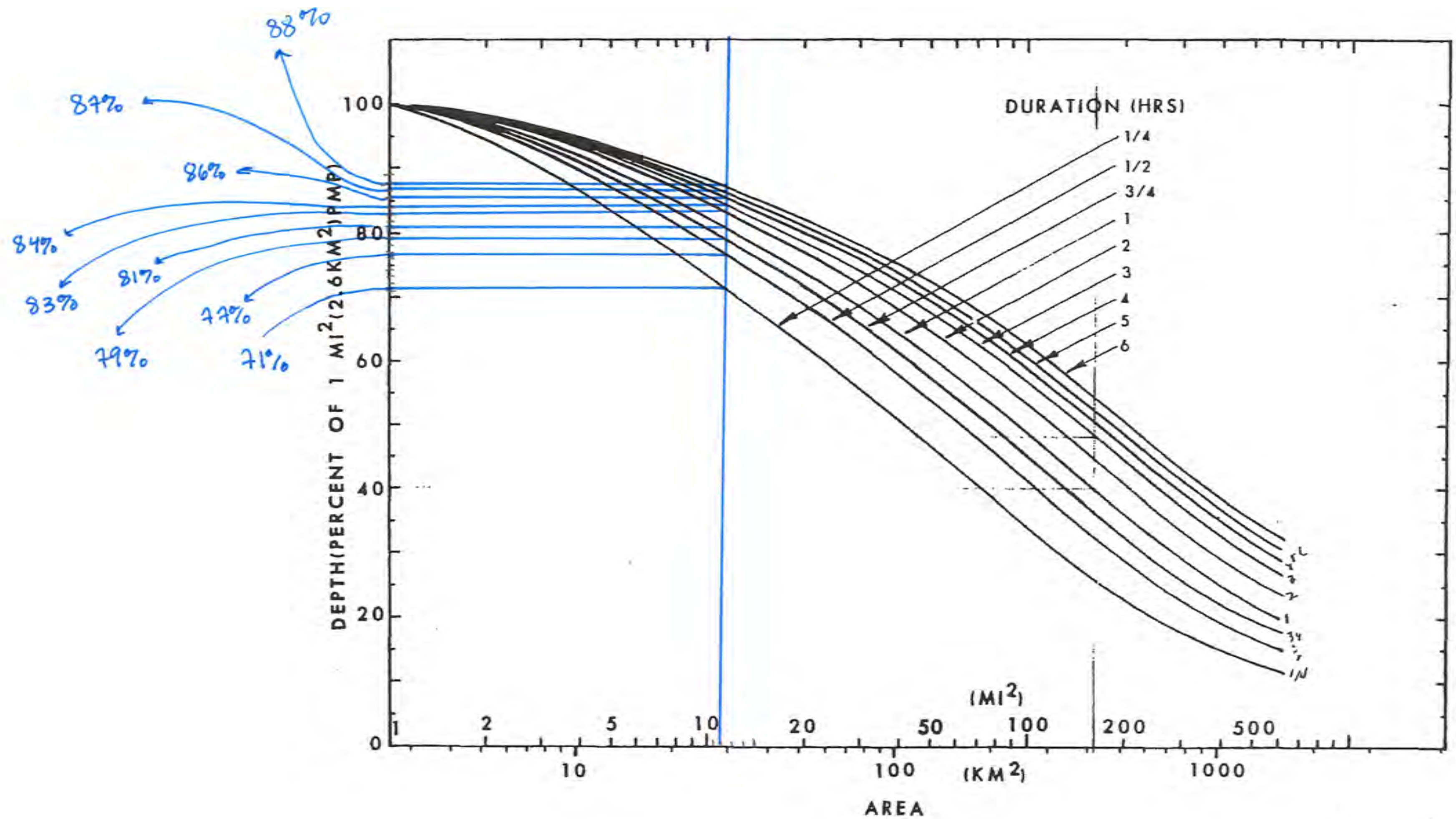


*Figure 4.9.--Adopted depth-area relations for local-storm PMP.*

HMR 49

18/20
10/10/18EMH

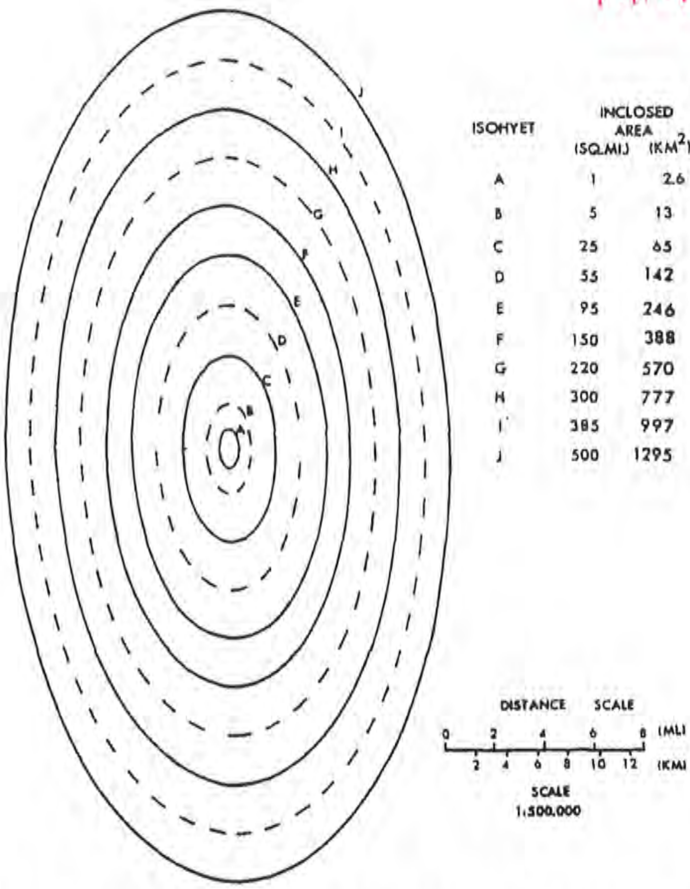


*Figure 4.10.--Idealized local-storm isohyetal pattern.*

storm period. The sequence of hourly incremental PMP for the Southwest 6-hr thunderstorm in accord with this study is presented in column 2 of table 4.7. A small variation from this sequence is given in Engineering Manual 1110-2-1411 (U. S. Army, Corps of Engineers 1965). The latter, listed in column 3 of table 4.7, places greater incremental amounts somewhat more toward the end of the 6-hr storm period. In application, the choice of either of these distributions is left to the user since one may prove to be more critical in a specific case than the other.

Table 4.7.--Time sequence for hourly incremental PMP in 6-hr storm

| | HMR No. 5[1] | EM1110-2-1411[2] |
|---|---|---|
| Increment | Sequence Position | |
| Largest hourly amount | Third | Fourth |
| 2nd largest | Fourth | Third |
| 3rd largest | Second | Fifth |
| 4th largest | Fifth | Second |
| 5th largest | First | Last |
| least | Last | First |

[1] U. S. Weather Bureau 1947.
[2] U. S. Corps of Engineers 1952.

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Also of importance is the sequence of the four 15-min incremental PMP values. We recommend a time distribution, table 4.8, giving the greatest intensity in the first 15-min interval (U.S. Weather Bureau 1947). This is based on data from a broad geographical region. Additional support for this time distribution is found in the reports of specific storms by Keppell (1963) and Osborn and Renard (1969).

Table 4.8.--Time sequence for 15-min incremental PMP within 1 hr.

| Increment | Sequence Position |
|---|---|
| Largest 15-min amount | First |
| 2nd largest | Second |
| 3rd largest | Third |
| least | Last |

## 4.8 Seasonal Distribution

The time of the year when local-storm PMP is most likely is of interest. Guidance was obtained from analysis of the distribution of maximum 1-hr thunderstorm events through the warm season at the recording stations in Utah, Arizona, and in southern California (south of 37°N and east of the Sierra Nevada ridgeline). The period of record used was for 1940-72 with an average record length for the stations considered of 27 years. The month with the one greatest thunderstorm rainfall for the period of record at each station was noted. The totals of these events for each month, by States, are shown in table 4.9.

Table 4.9.--Seasonal distribution of thunderstorm rainfalls.

(The maximum event at each of 108 stations, period of record 1940-72.)

| | Month | | | | | | |
|---|---|---|---|---|---|---|---|
| | M | J | J | A | S | O | No. of Cases |
| Utah | 1 | 5 | 9 | 14 | 5 | | 34 |
| Arizona | | 4 | 16 | 19 | 4 | | 43 |
| S. Calif.* | | 14 | 10 | 7 | | | 31 |
| No. of cases/mo. | 1 | 23 | 35 | 40 | 9 | 0 | |

*South of 37°N and east of Sierra Nevada ridgeline.

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Atlas No. 2; "Precipitation-Frequency Atlas of the Western United States, Vol III - Colorado" (NOAA-2) is generally used in lieu of site specific statistical studies.

e. The State Engineer uses the U. S. Army Corps of Engineers computer model HEC-1 for evaluating the Inflow Design Flood. The synthetic storm data that is entered into the HEC-1 computer program is determined from the "Depth-Duration Values" table as shown below. The data is entered on the "PH Record" or Hypothetical Storm Record.

FIGURE II-3
PRECIPITATION DEPTH-DURATION VALUES FOR HEC-1 "PH" RECORD

| Source | Storm | 5 min | 15 min | 1 hr | 2 hr | 3 hr | 6 hr | 12 hr | 24 hr | 48 hr |
|---|---|---|---|---|---|---|---|---|---|---|
| HMR-55A | GS | A | A | x | I | I | x | I | x | I |
| HMR-55A | LS | B | x | x | x | x | x | N | N | N |
| HMR-49 | GS | * | * | C | C | C | x | x | x | x |
| HMR-49 | LS | B | x | x | x | x | x | N | N | N |
| HMR-51/52 | GS | x | x | x | I | I | I | x | x | x |
| NOAA-2 | ALL | x | x | x | x | x | x | x | x | N |

NOTES: For FIGURE II-3 "Precipitation Depth-Durations Values for HEC-1 "PH" Record.

By using the matrix in the above table and the index below a smooth depth-duration curve may be developed for the storm of interest.

GS: General Storm
LS: Local Storm
x : Precipitation value for this duration can be determined directly from the source publication.
N : Duration of storm not applicable to this series
I : Precipitation value is readily interpolated from a plotted depth-duration curve
A : Precipitation values for these durations computed by : 15 min = 45% of 1 hr; 5 min = 38% of 15 min
B : Precipitation value for this duration is computed by : 5 min = 45% of 15 min
C : Precipitation values for these durations computed by : 1 hr = 25% 6 hr; 2 hr = 48% 6 hr; 3 hr = 66% 6 hr.
* : No current recommendation; HMR-49 Local Storm is more critical for short duration precipitation.



Colorado SEO "Dam Safety Project Review Guide" 3rd Ed. 2000

Objective: Develop final Inflow Design Flood (IDF) precipitation depths.

Assumptions:

1) Use RJH Calc. Package "Hogchute Dam Hydrology - PMP from HMR 49" dated 10/8/18.

2) Use Colorado Office of the State Engineer Rules and Regulations for Dam Safety and Construction.

Results:

| Duration | General Storm PMP Depth (in.) | General Storm with SEO Reductions (in) | Local Storm PMP Depth (in.) | Local Storm w/ SEO Reductions (in.) |
|---|---|---|---|---|
| 5 min | - | - | 1.4 | 1.3 |
| 15 min | - | - | 3.1 | 2.8 |
| 1 hr. | - | - | 4.1 | 3.7 |
| 2 hr. | - | - | 4.9 | 4.4 |
| 3 hr. | 1.9 | 1.3 | 6.9 | 6.2 |
| 6 hr. | 7.7 | ~~3.7~~ 5.4 | - | - |
| 12 hr. | 10.8 | 7.6 | - | - |
| 24 hr. | 14.5 | 10.2 | - | - |
| 48 hr. | 19.2 | 13.4 | - | - |

Analysis:

- Verify hazard classification see pg. 4 from the National Inventory of Dams

↳ High Hazard

- Apply Large, High reduction factors to Local Storm (pg. 2)

↳ 0.9 PMP

- Apply elevation reduction factors to General Storm (pg. 3)

↳ 0.7 PMP

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✓EMH 10/22/18

5.9.1.3.3 New Small, Significant Hazard dams and enlargements shall have spillways capable of passing, as a minimum, the inflow design flood generated by 50 percent of the Extreme Storm Precipitation (ESP), unless an Incremental Damage Analysis (IDA) demonstrates a lesser inflow design flood is applicable.

5.9.1.3.4 New Minor, Significant Hazard plus new Large and Small, Low Hazard dams and enlargements shall have spillways capable of passing, as a minimum, the inflow design flood generated by a 24-hour, 100-year rainstorm event.

5.9.1.3.5 New Minor, Low Hazard dams and new Large, NPH Dams and enlargements shall have spillways capable of passing the inflow design flood generated by a 24-hour, 50-year rainstorm event.

5.9.1.3.6 New Small and Minor NPH dams and enlargements shall have spillways capable of passing the Inflow Design Flood (IDF) generated by a 24-hour, 25 year rainstorm event.

5.9.1.3.7 The minimum size spillway for all High Hazard, Significant Hazard, and Large and Small, Low Hazard jurisdictional size dams for which an IDA shows a smaller spillway is justifiable under Rule 5.9.7.1 shall be capable of passing the inflow design flood generated by a 24-hour, 100-year rainstorm event. For all other jurisdictional size dams, the minimum size spillway shall be capable of passing the IDF generated by the appropriate rainstorm event presented in the above table.

5.9.1.4 Hydrometeorological Report PMP - The Inflow Design Flood (IDF) requirements for determining the spillway capacity may be developed through the use of the most current Probable Maximum Precipitation (PMP) estimates from the Office of Hydrology, National Weather Service, NOAA Hydrometeorological Report Series. The PMP values are normally determined from the appropriate Hydrometeorological Report (HMR). Currently, HMR 52 and 55A are applicable for drainage basin located to the east of the Continental Divide and HMR 49 for drainage basin west of the Continental Divide. The IDF requirements for determining the spillway capacity using the appropriate HMR are summarized in Table 5.2:

**TABLE 5.2**

INFLOW DESIGN FLOOD REQUIREMENTS USING HYDROMETEOROLOGICAL REPORTS (HMR)

| DAM SIZE | HAZARD CLASSIFICATION | | | |
|---|---|---|---|---|
| | High | Significant | Low | NPH |
| Large | 0.90 PMP | 0.68 PMP | 100 YR | 50 YR |
| Small | 0.90 PMP | 0.45 PMP | 100 YR | 25 YR |
| Minor | 0.45 PMP | 100 YR | 50 YR | 25 YR |



SEO Rules & Regulations for Dam Safety & Construction

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EMH 10/22/18

**TABLE 5.3**

HMR PMP INFLOW DESIGN FLOOD REQUIREMENTS
REDUCED FOR ELEVATION

| DAM SIZE | STORM TYPE | ELEVATION | HAZARD CLASSIFICATION | |
|---|---|---|---|---|
| | | | High | Significant |
| Large | General Storm East | 6,000 - 12,000 ft MSL | 0.80 PMP | 0.60 PMP |
| | | Above 12,000 ft MSL | 0.70 PMP | 0.53 PMP |
| | General Storm West | 5,000 - 8,000 ft MSL | 0.80 PMP | 0.60 PMP |
| | | Above 8,000 ft MSL | 0.70 PMP | 0.53 PMP |
| | Local Storm | 10,000 - 11,500 ft MSL | 0.80 PMP | 0.60 PMP |
| | | 11,501 - 13,000 ft MSL | 0.70 PMP | 0.53 PMP |
| | | Above 13,000 ft MSL | 0.60 PMP | 0.45 PMP |
| Small | General Storm East | 6,000 - 12,000 ft MSL | 0.80 PMP | 0.40 PMP |
| | | Above 12,000 ft MSL | 0.70 PMP | 0.35 PMP |
| | General Storm West | 5,000 - 8,000 ft MSL | 0.80 PMP | 0.40 PMP |
| | | Above 8,000 ft MSL | 0.70 PMP | 0.35 PMP |
| | Local Storm | 10,000 - 11,500 ft MSL | 0.80 PMP | 0.40 PMP |
| | | 11,501 - 13,000 ft MSL | 0.70 PMP | 0.35 PMP |
| | | Above 13,000 ft MSL | 0.60 PMP | 0.30 PMP |
| Minor | General Storm East | 6,000 - 12,000 ft MSL | 0.40 PMP | Not Applicable |
| | | Above 12,000 ft MSL | 0.35 PMP | Not Applicable |
| | General Storm West | 5,000 - 8,000 ft MSL | 0.40 PMP | Not Applicable |
| | | Above 8,000 ft MSL | 0.35 PMP | Not Applicable |
| | Local Storm | 10,000 - 11,500 ft MSL | 0.40 PMP | Not Applicable |
| | | 11,501 - 13,000 ft MSL | 0.35 PMP | Not Applicable |
| | | Above 13,000 ft MSL | 0.30 PMP | Not Applicable |

5.9.1.6 Site Specific Hydrometeorologic Analysis - Site Specific Hydrometeorologic Analysis (SSHMA) may be used to determine the appropriate site specific extreme storm precipitation (SSESP) for the determination of the IDF. Site-specific evaluations are subject to approval by the State Engineer. Any procedures developed and approved by the State Engineer shall be used to determine the applicable Extreme Precipitation Event. Snowmelt conditions shall be considered as base flow when appropriate. The percentage reduction of the PMP as shown in Rule 5.9.1.5 are not applicable or allowed in the determination of site specific extreme storm precipitation or PMP values determined by the procedures and analysis provided for in this Rule for all High Hazard dams and Large Significant Hazard dams. The IDF requirement developed through the use of site specific analyses for determining spillway capacity are summarized in Table 5.4:

SEO Rules & Regulations for Dam Safety & Construction

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10/22/18 EMH

| DAMID | Dam Name | Other Dam Names | NID ID | WDID | Physical Status |
|---|---|---|---|---|---|
| 420127 | HOGCHUTE | CARSON LAKE | 88 | | Active |

| Data Transposed 8/13/18 by JNH | |
|---|---|
| DAMID | 420127 |
| Dam Name | HOGCHUTE |
| Other Dam Names | CARSON LAKE |
| NID ID | 88 |
| WDID | |
| Physical Status | Active |
| DIV | 4 |
| WD | 42 |
| County | MESA |
| PM | S |
| Township | 12.0 S |
| Range | 96.0 W |
| Section | 22 |
| Q160 | |
| Q40 | |
| UTM x | 230460.5 |
| UTM y | 4320830.6 |
| Location Accuracy | |
| Latdecdeg | 38.994999 |
| Longdecdeg | -108.112221 |
| Stream | KANNAH CREEK |
| Downstream Town | WHITEWATER |
| Town Distance | 23 |
| Year Completed | 1947 |
| Purposes | S |
| Federal Land | Y |
| Federal Regulations | N |
| Dam Type | RE |
| Dam Length | 620 |
| Dam Height | 53 |
| Crest Elevation | 9,890 |
| Normal Storage | 637 |
| Surface Area | 35 |
| Drainage Area | 6,240 |
| Spillway Capacity | 2,400 |
| Outlet Description | 30 WSP below two 20 hydraulic gates |
| Outlet Capacity | 137 |
| Outlet Inspection | 9/11/2008 |
| Hazard Class | High |

# APPENDIX B.2

## PMP FROM REPS TOOL

RJH CONSULTANTS, INC.

| | | | |
|---|---|---|---|
| Project | 18115 | Page | 1/1 |
| Date | 10/8/18 | By | BJB |
| Client: City of Grand Junction | | | |
| Checked | 10/18/18 | By | MJB |
| Subject: Hogchute Dam Hydrology - PMP from REPS tool | | | |
| Approved | | By | 10/24/18 |

Objective: Determine the general and local depths for the Probable Maximum Precipitation (PMP) storm event for Hogchute Dam.

Assumptions:

1) Use the Regional Extreme Precipitation Study (REPS) trial tool from the Colorado Dam Safety office.

2) Use the previously delineated basin as seen in RJH Calc. Package "Hogchute Dam Hydrology - Basin" dated 7/19/18.

3) Select all temporal patterns to evaluate.

4) Use ArcMap 10.4.1.

Results:

| Duration | General Storm PMP Depth (in.) | Local Storm PMP Depth (in.) |
|---|---|---|
| 1 hr. | 1.2 | 4.64 |
| 2 hr. | – | 4.61 |
| 3 hr. | – | ↓ |
| 4 hr. | – | ↓ |
| 5 hr. | – | ↓ |
| 6 hr. | 5 | 4.61 |
| 12 hr. | 8.1 | 4.64 |
| 24 hr. | 9.3 | 4.64 |
| 48 hr. | 13.8 | – |
| 72 hr. | 14.1 | – |

Analysis:

- Run REPS tool in ArcMap.
- Open the "General_PMP_Basin_Average_12sqmi" table for general storm depths.
- Open the "Local_PMP_Basin_Average_12sqmi" table for local storm depths.
- Map used is found here: "P:\18115 - Hogchute Dam Safety Evaluation\Engineering\GIS\Figures\Hydrology Work Map.mxd"

# APPENDIX C

## PRECIPITATION LOSSES

C.1 HYDRAULIC CONDUCTIVITY

C.2 INITIAL AND CONSTANT LOSSES

# APPENDIX C.1

## HYDRAULIC CONDUCTIVITY

**Required**:

Determine the geometrically-weighted average of the hydraulic conductivity (XKSAT) for the contributing subbasins to Hogchute Dam

**Assumptions:**

1.) Use Colorado SEO "Hydrologic Basin Response Parameter Estimation Guidelines" (HBRPEG) (Sabol, 2008).
2.) Use NRCS Web Soil Survey
3.) Use ESRI ArcMap 10.4.1
4.) RJH calculation package "Hogchute Dam Hydrology – Basin Delineation" dated 12/3/2018

**Analysis:**

- Upper and Lower subbasin shapefiles exported to NRCS Web Soil Survey interface to access soil map data (p.6-11)

- Component soil groups were evaluated for hydrologic properties (p.4-5)

- Soil horizons with the most conservative properties (least porous) were chosen as the defining layer; these representative layers were used in weighted averaging for each constituent map group to calculate an average XKSAT and porosity for each subbasin in general accordance with HBRPEG (Sabol, 2008) (p.12-15)

**Results:**

- Upper ➔ **0.04 in/hr**
- Lower ➔ **0.06 in/hr**

**Hogchute Dam Safety Evaluation - Hydrology**
**Project No. 18115**

RJH Consultants, Inc.
Prepared by: ATMerook 12/3/2018
Checked by: EMH 12/7/18
Approved by: ______

NRCS Web Soil Survey for Hydrologic Soil Groups for the Hogchute Dam drainage basin

| Map unit symbol | Map unit name | Rating | Acres in AOI | XKSAT Value (in/hr)[2] | Area Fraction (acres) | Geom. Weighted Average XKSAT (in/hr) |
|---|---|---|---|---|---|---|
| 101 | Afley, warm-Rock outcrop association, 0 to 12 percent slopes | C | 456.6 | 0.09 | 0.199 | -487.67 |
| 126 | Cowood family-Heterwa complex, 0 to 15 percent slopes | D | 1,477.8 | 0.02 | 0.644 | -2536.91 |
| 127 | Cryaquolls and Borohemists, 0 to 10 percent slopes | C | 263.7 | 0.22 | 0.115 | -173.88 |
| 182 | Rubble land | | 2.5 | 1.20 | 0.001 | 0.20 |
| 203 | Water | | 93 | | 0.041 | |
| **Totals for Area of Interest** | | | **2,293.60** | | 1.000 | |
| **Geometric Weighted Average XKSAT (in/hr)** [3] | | | | | | 0.04 |

Notes:
1. Soil types and areas are from the NRCS Web Soil Survey.
2. XKSAT and Effective Porosity Values calculated using Equation 2 on pg. 53 of HBRPEG
3. XKSAT values from Table 10 of HBRPEG.
4. Geometric Weighted Average XKSAT from Equation 2 on pg. 53 of HBRPEG.

**Hogchute Dam Safety Evaluation - Hydrology**
**Project No. 18115**

RJH Consultants, Inc.
Prepared by: ATMerook 12/5/2018
Checked by: EMH 12/7/18
Approved by: ______

NRCS Web Soil Survey for Hydrologic Soil Groups for the Hogchute Dam drainage basin

| Map unit symbol | Map unit name | Rating | Acres in AOI | XKSAT Value (in/hr)[2] | Area Fraction (acres) | Geom. Weighted Average XKSAT (in/hr) |
|---|---|---|---|---|---|---|
| 101 | Afley, warm-Rock outcrop association, 0 to 12 percent slopes | C | 1076.6 | 0.09 | 0.202 | -1149.85 |
| 105 | Booneville, warm-Doughspon complex, 5 to 15 percent slopes, very stony | C | 205.9 | 0.03 | 0.039 | -307.61 |
| 107 | Boralfs and Borolls, clayey, slumped, 5 to 65 percent slopes | C | 10.5 | 0.10 | 0.002 | -10.50 |
| 126 | Cowood family-Heterwa complex, 0 to 15 percent slopes | D | 1,914.8 | 0.02 | 0.359 | -3287.09 |
| 127 | Cryaquolls and Borohemists, 0 to 10 percent slopes | C | 521.6 | 0.22 | 0.098 | -343.93 |
| 128 | Cryoboralfs, Cryochrepts, and Rubble land, 5 to 65 percent slopes | D | 250.1 | 0.23 | 0.047 | -160.13 |
| 129 | Cryoboralfs, Cryochrepts, and Rubble land, 65 to 99 percent slopes | D | 69.2 | 0.23 | 0.013 | -44.31 |
| 130 | Cryochrepts-Cryoborolls-Rubble land complex, 15 to 90 percent slopes | B | 111.3 | 0.41 | 0.021 | -43.07 |
| 135 | Doughspon, dry-Wesdy complex, 5 to 25 percent slopes | C | 1.3 | 0.02 | 0.000 | -2.30 |
| 151 | Grandmesa-ElkwalowDoughspon complex, 0 to 10 percent slopes | D | 626.2 | 0.09 | 0.117 | -666.48 |
| 164 | Irson-NamelaDoughspon, well drained complex, 0 to 10 percent slopes, extremely stony | D | 119.3 | 0.02 | 0.022 | -192.27 |
| 168 | Namela, moist Bullbasin-Doughspon complex, 0 to 10 percent slopes | C | 271 | 0.12 | 0.051 | -247.35 |
| 170 | Needleton-Scout families complex, 5 to 40 percent slopes | B | 70.6 | 0.25 | 0.013 | -42.51 |
| 182 | Rubble land | | 4.2 | 1.20 | 0.001 | 0.33 |
| 203 | Water | | 77.2 | | 0.014 | |
| **Totals for Area of Interest** | | | **5,329.80** | | 1.000 | |
| **Geometric Weighted Average XKSAT (in/hr)** [3] | | | | | | 0.06 |

Notes:
1. Soil types and areas are from the NRCS Web Soil Survey.
2. XKSAT and Effective Porosity Values calculated using Equation 2 on pg. 53 of HBRPEG
3. XKSAT values from Table 10 of HBRPEG.
4. Geometric Weighted Average XKSAT from Equation 2 on pg. 53 of HBRPEG.

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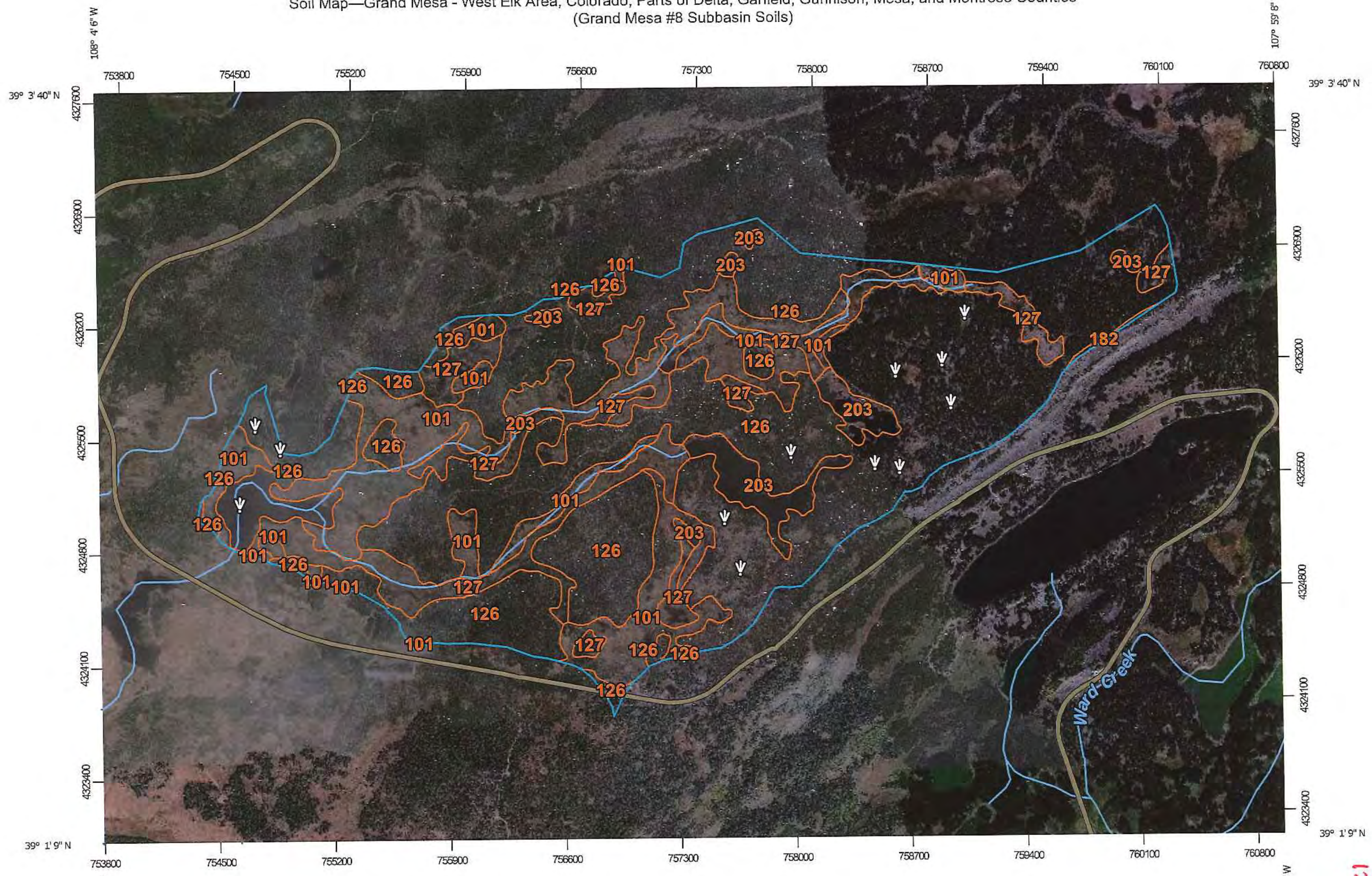
| Map unit symbol | Map unit name | Percent of map unit | Rating | Total Depth (in) | Depth (in) | Cumulative Depth (in) | USDA texture | XKSAT Value $(in/hr)^2$ | Geometric Avg. XKSAT Value $(in/hr)^2$ |
|---|---|---|---|---|---|---|---|---|---|
| 101 | **Afley, warm-Rock outcrop association, 0 to 12 percent slopes** | 75 | | | | | | | **0.09** |
| | Afley, warm | 50 | C | 18 | 7 | 7 | Gravelly loam | 0.25 | -30.10 |
| | | | | | 11 | 18 | Very stony loam | 0.25 | |
| | Rock outcrop | 25 | D | 18 | 18 | 18 | Unweathered bedrock | 0.01 | -50.00 |
| 105 | **Booneville, warm-Doughspon complex, 5 to 15 percent slopes, very stony** | 85 | | | | | | | **0.03** |
| | Booneville | 45 | C | 18 | 5 | 5 | Very stony loam | 0.25 | -62.91 |
| | | | | | 13 | 18 | Very stony clay loam | 0.04 | |
| | Doughspon | 40 | D | 18 | 6 | 6 | Gravelly loam | 0.25 | -64.08 |
| | | | | | 10 | 16 | Cobbly loam | 0.25 | |
| | | | | | 2 | 18 | Very cobbly clay, very cobbly clay loam | 0.025 | |
| 107 | **Boralfs and Borolls, clayey, slumped, 5 to 65 percent slopes** | 90 | | | | | | | **0.10** |
| | Boralfs, clayey, slumped | 45 | C | 18 | 11 | 11 | Gravelly loam | 0.25 | -62.91 |
| | | | | | 7 | 18 | Very cobbly clay loam | 0.04 | |
| | Borolls, clayey, slumped | 45 | C | 18 | 18 | 18 | Loam | 0.25 | -27.09 |
| 126 | **Cowood family-Heterwa complex, 0 to 15 percent slopes** | 85 | | | | | | | **0.02** |
| | Cowood family | 45 | D | 18 | 8 | 8 | Very stony loam | 0.25 | -90.00 |
| | | | | | 9 | 17 | Very stony loam | 0.25 | |
| | | | | | 1 | 18 | Unweathered bedrock | 0.01 | |
| | Heterwa | 40 | C | 18 | 5 | 5 | Cobbly loam | 0.25 | -55.92 |
| | | | | | 13 | 18 | Very gravelly sandy clay loam, very gravelly loa | 0.04 | |
| 127 | **Cryaquolls and Borohemists, 0 to 10 percent slopes** | 80 | | | | | | | **0.22** |
| | Borohemists | 40 | A/D | 18 | 18 | 18 | Peat | 1.2 | 3.17 |
| | Cryaquolls | 40 | C | 18 | 8 | 8 | Sandy loam | 0.4 | -55.92 |
| | | | | | 9 | 17 | Clay loam, sandy clay loam | 0.04 | |
| | | | | | 1 | 18 | Gravelly loam | 0.25 | |
| 128 | **Cryoboralfs, Cryochrepts, and Rubble land, 5 to 65 percent slopes** | 90 | | | | | | | **0.23** |
| | Cryoboralfs | 30 | D | 18 | 7 | 7 | Very stony loam | 0.25 | -41.94 |
| | | | | | 11 | 18 | Very stony loam, very stony clay loam | 0.04 | |
| | Cryochrepts | 30 | B | 18 | 4 | 4 | Extremely stony loam | 0.25 | -18.06 |
| | | | | | 14 | 18 | Extremely stony loam | 0.25 | |
| | Rubble land | 30 | | 18 | 18 | 18 | Fragmental material | 1.2 | 2.38 |
| 129 | **Cryoboralfs, Cryochrepts, and Rubble land, 65 to 99 percent slopes** | 90 | | | | | | | **0.23** |
| | Cryoboralfs | 30 | D | 18 | 7 | 7 | Very stony loam | 0.25 | -41.94 |
| | | | | | 11 | 18 | Very stony loam, very stony clay loam | 0.04 | |
| | Cryochrepts | 30 | B | 18 | 4 | 4 | Extremely stony loam | 0.25 | -18.06 |
| | | | | | 14 | 18 | Extremely stony loam | 0.25 | |
| | Rubble land | 30 | | 18 | 18 | 18 | Fragmental material | 1.2 | 2.38 |
| 130 | **Cryochrepts-Cryoborolls-Rubble land complex, 15 to 90 percent slopes** | 95 | | | | | | | **0.41** |
| | Cryochrepts | 35 | B | 18 | 4 | 4 | Extremely stony loam | 0.25 | -21.07 |
| | | | | | 14 | 18 | Extremely stony loam | 0.25 | |
| | Cryoborolls | 30 | D | 18 | 11 | 11 | Very stony sandy loam | 0.4 | -18.06 |
| | | | | | 7 | 18 | Very stony loam | 0.25 | |
| | Rubble land | 30 | | 18 | 18 | 18 | Fragmental material | 1.2 | 2.38 |
| 135 | **Doughspon, dry-Wesdy complex, 5 to 25 percent slopes** | 85 | | | | | | | **0.02** |
| | Doughspon, dry | 50 | C | 18 | 6 | 6 | Gravelly loam | 0.25 | -80.10 |
| | | | | | 10 | 16 | Cobbly loam | 0.25 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2 | 18 | Very cobbly clay, very cobbly clay loam | 0.025 | |
| | Cryoborolls | 35 | C | 18 | 7 | 7 | Cobbly loam | 0.25 | -70.00 |
| | | | | | 4 | 11 | Very cobbly silt loam | 0.15 | |
| | | | | | 7 | 18 | Very cobbly clay | 0.01 | |
| **151** | **Grandmesa-ElkwalowDoughspon complex, 0 to 10 percent slopes** | 90 | | | | | | | **0.09** |
| | Grandmesa | 35 | D | 18 | 10 | 10 | Loam | 0.25 | -21.07 |
| | | | | | 4 | 14 | Cobbly loam | 0.25 | |
| | | | | | 4 | 18 | Very cobbly loam | 0.25 | |
| | Elkwalow | 30 | C | 18 | 2 | 2 | Loam | 0.25 | -24.72 |
| | | | | | 16 | 18 | Silt loam | 0.15 | |
| | Doughspon | 25 | D | 18 | 6 | 6 | Gravelly loam | 0.25 | -50.00 |
| | | | | | 10 | 16 | Cobbly loam | 0.25 | |
| | | | | | 2 | 18 | Very cobbly clay loam, very cobbly clay | 0.01 | |
| **164** | **Irson-NamelaDoughspon, well drained complex, 0 to 10 percent slopes.** | 90 | | | | | | | **0.02** |
| | Irson | 45 | D | 18 | 13 | 13 | Extremely stony loam | 0.25 | -90.00 |
| | | | | | 5 | 18 | Unweathered bedrock | 0.01 | |
| | Namela | 25 | C | 18 | 4 | 4 | Very cobbly loam | 0.25 | -15.05 |
| | | | | | 14 | 18 | Extremely stony loam | 0.25 | |
| | Doughspon, well drained | 20 | C | 18 | 6 | 6 | Gravelly loam | 0.25 | -40.00 |
| | | | | | 10 | 16 | Cobbly loam | 0.25 | |
| | | | | | 2 | 18 | Very cobbly clay loam, very cobbly clay | 0.01 | |
| **168** | **Namela, moist Bullbasin-Doughspon complex, 0 to 10** | 90 | | | | | | | **0.12** |
| | Namela, moist | 40 | C | 18 | 4 | 4 | Very cobbly loam | 0.25 | -24.08 |
| | | | | | 14 | 18 | Extremely stony loam | 0.25 | |
| | Bullbasin | 30 | C | 18 | 18 | 18 | Loam | 0.25 | -18.06 |
| | Doughspon | 20 | D | 18 | 6 | 6 | Gravelly loam | 0.25 | -40.00 |
| | | | | | 10 | 16 | Cobbly loam | 0.25 | |
| | | | | | 2 | 18 | Very cobbly clay loam, very cobbly clay | 0.01 | |
| **170** | **Needleton-Scout families complex, 5 to 40 percent slopes** | 85 | | | | | | | **0.25** |
| | Nedleton family | 55 | B | 18 | 13 | 13 | Cobbly loam | 0.25 | -33.11 |
| | | | | | 5 | 18 | Very cobbly loam | 0.25 | |
| | Scout family | 30 | A | 18 | 6 | 6 | Gravelly loam | 0.25 | -18.06 |
| | | | | | 5 | 11 | Gravelly sandy loam | 0.4 | |
| | | | | | 5 | 16 | Very gravelly sandy loam | 0.4 | |
| | | | | | 2 | 18 | Very gravelly sandy loam | 0.4 | |
| **182** | **Rubble land** | 80 | | | | | | | **1.20** |
| | Rubble land | 80 | | 18 | 18 | 18 | Fragmental material | 1.2 | |

Soil Map—Grand Mesa - West Elk Area, Colorado, Parts of Delta, Garfield, Gunnison, Mesa, and Montrose Counties
(Grand Mesa #8 Subbasin Soils)




Map Scale: 1:32,700 if printed on A landscape (11" x 8.5") sheet.

N

Meters: 0 450 900 1800 2700

Feet: 0 1500 3000 6000 9000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 12N WGS84

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## MAP LEGEND

**Area of Interest (AOI)**
- Area of Interest (AOI)

**Soils**
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

**Special Point Features**
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

**Water Features**
- Streams and Canals

**Transportation**
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

**Background**
- Aerial Photography

## MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Grand Mesa - West Elk Area, Colorado, Parts of Delta, Garfield, Gunnison, Mesa, and Montrose Counties
Survey Area Data: Version 8, Sep 10, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Dec 31, 2009—Jul 29, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

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# Map Unit Legend

| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
|---|---|---|---|
| 101 | Afley, warm-Rock outcrop association, 0 to 12 percent slopes | 456.6 | 19.9% |
| 126 | Cowood family-Heterwa complex, 0 to 15 percent slopes | 1,477.8 | 64.4% |
| 127 | Cryaquolls and Borohemists, 0 to 10 percent slopes | 263.7 | 11.5% |
| 182 | Rubble land | 2.5 | 0.1% |
| 203 | Water | 93.0 | 4.1% |
| **Totals for Area of Interest** | | **2,293.7** | **100.0%** |

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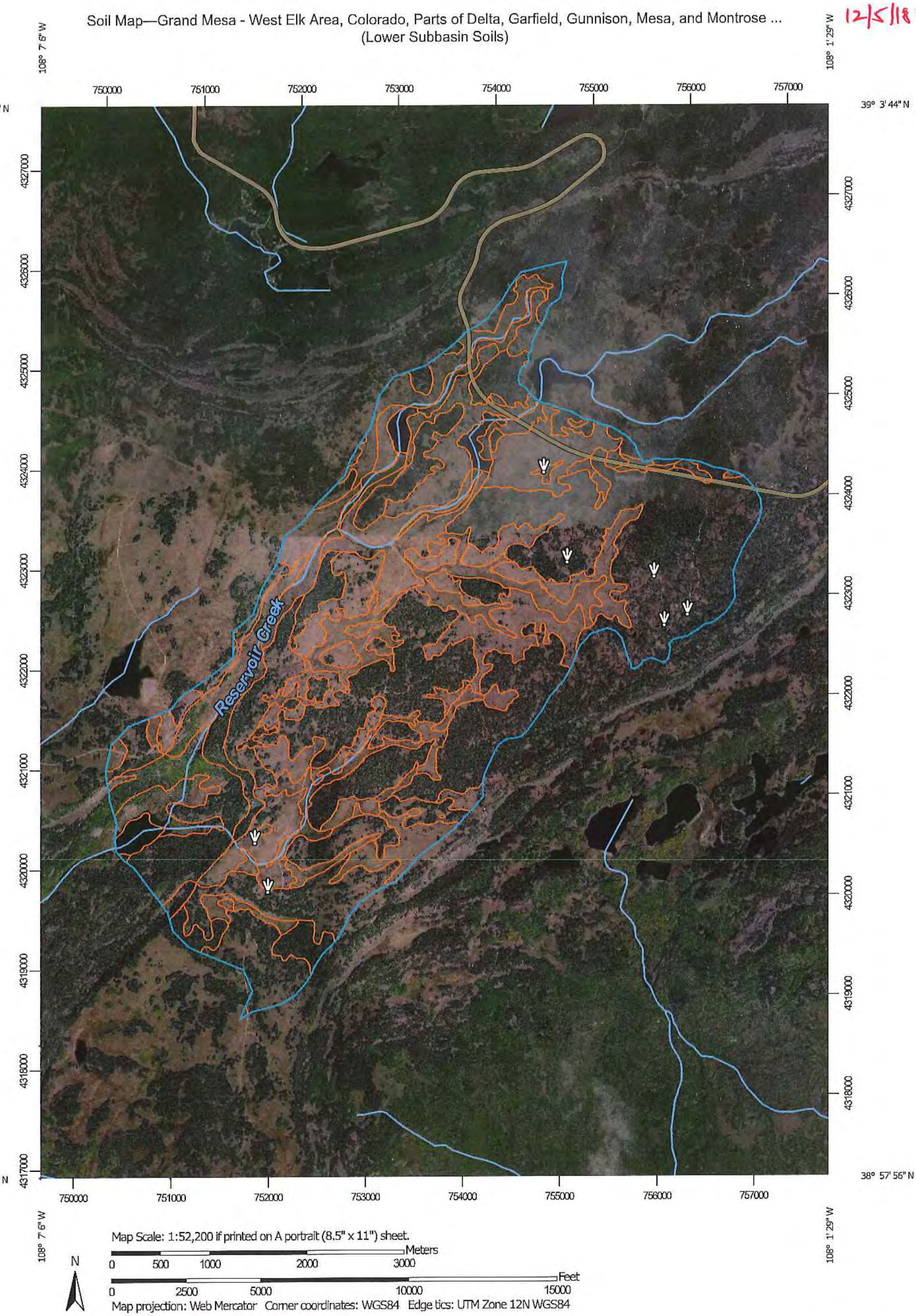
Soil Map—Grand Mesa - West Elk Area, Colorado, Parts of Delta, Garfield, Gunnison, Mesa, and Montrose ...
(Lower Subbasin Soils)



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## MAP LEGEND

**Area of Interest (AOI)**
- Area of Interest (AOI)

**Soils**
- Soil Map Unit Polygons
- Soil Map Unit Lines
- Soil Map Unit Points

**Special Point Features**
- Blowout
- Borrow Pit
- Clay Spot
- Closed Depression
- Gravel Pit
- Gravelly Spot
- Landfill
- Lava Flow
- Marsh or swamp
- Mine or Quarry
- Miscellaneous Water
- Perennial Water
- Rock Outcrop
- Saline Spot
- Sandy Spot
- Severely Eroded Spot
- Sinkhole
- Slide or Slip
- Sodic Spot
- Spoil Area
- Stony Spot
- Very Stony Spot
- Wet Spot
- Other
- Special Line Features

**Water Features**
- Streams and Canals

**Transportation**
- Rails
- Interstate Highways
- US Routes
- Major Roads
- Local Roads

**Background**
- Aerial Photography

## MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:24,000.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service
Web Soil Survey URL:
Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Grand Mesa - West Elk Area, Colorado, Parts of Delta, Garfield, Gunnison, Mesa, and Montrose Counties
Survey Area Data: Version 8, Sep 10, 2018

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Dec 31, 2009—Jul 29, 2017

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

# Map Unit Legend

| Map Unit Symbol | Map Unit Name | Acres in AOI | Percent of AOI |
|---|---|---|---|
| 101 | Afley, warm-Rock outcrop association, 0 to 12 percent slopes | 1,076.7 | 20.2% |
| 105 | Booneville, warm-Doughspon complex, 5 to 15 percent slopes, very stony | 205.9 | 3.9% |
| 107 | Boralfs and Borolls, clayey, slumped, 5 to 65 percent slopes | 10.5 | 0.2% |
| 126 | Cowood family-Heterwa complex, 0 to 15 percent slopes | 1,914.8 | 35.9% |
| 127 | Cryaquolls and Borohemists, 0 to 10 percent slopes | 521.6 | 9.8% |
| 128 | Cryoboralfs, Cryochrepts, and Rubble land, 5 to 65 percent slopes | 250.1 | 4.7% |
| 129 | Cryoboralfs, Cryochrepts, and Rubble land, 65 to 99 percent slopes | 69.2 | 1.3% |
| 130 | Cryochrepts-Cryoborolls-Rubble land complex, 15 to 90 percent slopes | 111.3 | 2.1% |
| 135 | Doughspon, dry-Wesdy complex, 5 to 25 percent slopes | 1.3 | 0.0% |
| 151 | Grandmesa-Elkwalow-Doughspon complex, 0 to 10 percent slopes | 626.2 | 11.7% |
| 164 | Irson-Namela-Doughspon, well drained complex, 0 to 10 percent slopes, extremely stony | 119.3 | 2.2% |
| 168 | Namela, moist-Bullbasin-Doughspon complex, 0 to 10 percent slopes | 271.0 | 5.1% |
| 170 | Needleton-Scout families complex, 5 to 40 percent slopes | 70.6 | 1.3% |
| 182 | Rubble land | 4.2 | 0.1% |
| 203 | Water | 77.2 | 1.4% |
| **Totals for Area of Interest** | | **5,330.0** | **100.0%** |

HBRPEG
(Sutl, 2008)

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capacity and wilting points of typical vegetation. Three conditions are provided for DTHETA; Dry, Normal and Saturated. See page 45 for a discussion of the selection of the DTHETA condition. For Dry and Normal conditions, the value of DTHETA is selected from Figure 4 as a function of the bare ground XKSAT. For Saturated soil, DTHETA is 0.0. The values of XKSAT from Table 10 and corresponding values for PSIF and DTHETA from Figure 4 are used if the best available information is limited to a general soil texture classification of the drainage area.

**Table 10**

**Hydraulic conductivity (XKSAT) based on bare ground soil texture**

| Soil Texture Classification (1) | XKSAT inches/hour (2) |
|---|---|
| loamy sand & sand | 1.20 |
| sandy loam | 0.40 |
| loam | 0.25 |
| silty loam | 0.15 |
| silt | 0.10 |
| sandy clay loam | 0.06 |
| clay loam | 0.04 |
| silty clay loam | 0.04 |
| sandy clay | 0.02 |
| silty clay | 0.02 |
| clay | 0.01 |

HBRPEC
(Sabol, 2008)

To illustrate this process, refer to Figure 6 and Figure 7. Figure 6 is an excerpt from a PDF of the Engineering Properties table created using the NRCS Web Soil Survey web site. Figure 7 is an excerpt from the Component Legend table. Both are from the Soil Survey for Logan County, Colorado. Examining the data supplied for SMU 4, it can be seen that there are two component soils for SMU 4. From Figure 7, Altvan makes up 50% of the SMU, and Eckley 30%. The remaining 20% of the SMU is made up of minor soils, which are ignored for the purposes of estimating an XKSAT value for an SMU.

The Altvan component has a horizon identified for the first 60 inches of the soil profile, which is typical of most NRCS soil surveys. The first layer is 8 inches thick and consists of a soil with a sandy loam texture. Sandy loam is therefore assumed to be the controlling texture, and has a corresponding XKSAT value of 0.4 inches per hour.

The Eckley component has multiple layers within the first 6 inches. The first 3 inches have a sandy loam texture. The next 17 inches have a gravelly sandy clay loam texture. Ignoring the gravelly adjective for now, the corresponding XKSAT value for a sandy clay loam is 0.06 inches per hour. The controlling horizon layer is the sandy clay loam.

2. <u>Estimate the XKSAT Value for the SMU:</u> The estimated XKSAT value for the SMU is derived by area-weighting the XKSAT values for the SMU component soils. The engineer may do this by applying engineering judgment or by mathematically computing a weighted value. The mathematical computation should be done using equation 2. Equation 2 is also used for computing an area-weighted value of bare ground XKSAT for watershed sub-basins.

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HBRPEG (Sabol, 2008)

$$\overline{XKSAT} = a\log\left(\frac{\sum A_i \log XKSAT_i}{A_T}\right) \quad \text{Eqn 2}$$

where:

$\overline{XKSAT}$ = composite bare ground hydraulic conductivity for the SMU (or watershed sub-basin), inches/hour

$XKSAT_i$ = bare ground hydraulic conductivity of the SMU component soil (or SMU within a sub-basin), inches/hour

$A_i$ = component area in % of SMU (or size of SMU sub-area within a sub-basin)

$A_T$ = % of SMU components (or size of the watershed or sub-basin)

When the SMU component percentages do not total 100%, the percentages should be normalized to total 100%. For this example, the area-weighted bare ground XKSAT value for SMU 4 is:

$$SMU\ 4\ \overline{XKSAT} = a\log\left(\frac{\left(\frac{50}{80}\right)\log(0.40) + \left(\frac{30}{80}\right)\log(0.06)}{80/80}\right) = 0.20\ inches/hour$$

3. Update GIS Table: Add a bare ground XKSAT field to the GIS soils polygon coverage and populate it with the computed values for each SMU.

4. Additional Considerations: Many SMUs will have soil textures described with adjectives such as gravelly, very gravelly, fine, cobbly, very cobbly, etc. There is virtually no guidance in the literature regarding how to address these conditions, and where guidance is found, it is conflicting. Until further conclusive research is performed, these adjectives should be ignored when assigning XKSAT values, unless the hydrologist has scientific evidence to support adjustments to the general soil texture.

   Rainfall-runoff parameter values for design should be based on reasonable estimates of watershed conditions that would minimize rainfall losses. The hydrologist should keep this in mind when assigning XKSAT values to SMUs. Using engineering judgment when assigning a weighted XKSAT value for SMUs that have more than

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$$\overline{IA} = \left( \frac{\sum A_i IA_i}{A_T} \right) \qquad \text{Eqn 1}$$

where:

$\overline{IA}$ = composite value of IA, inches

$IA_i$ = IA of each sub-area, inches

$A_i$ = size of IA sub-area

$A_T$ = size of the watershed or sub-basin

Instructions for Soil Map Unit Bare Ground XKSAT:

1. The Determine Controlling Soil Horizon Layer: The first step in estimating XKSAT for each SMU is to determine the controlling soil layer in the horizon of each component soil type. Surface soils that are more than 6 inches thick are generally adequate to contain infiltrated rainfall for inflow design floods in Colorado without deeper soil horizons restricting the infiltration rate. This is because most common soils have porosities that range from about 25 to 35 percent, and therefore 6 inches of soil with a porosity of 30 percent can absorb about 1.8 inches (6 inches times 30 percent) of rainfall infiltration. Accordingly, in estimating the Green and Ampt infiltration parameters in Colorado, for up to and including the 100-year rainfall, the top 6 inches of soil should be considered. If the top 6 inch horizon is uniform soil or nearly uniform, then select the Green and Ampt parameters for that soil texture. If the top 6 inch horizon is layered with different soil textures, then select the horizon with the soil texture that has the lowest corresponding XKSAT value. For less frequent floods including the PMF, examine the soil to a greater depth, at least 12 inches but no more than 18 inches, and use engineering judgment in selecting the controlling horizon. From a practical consideration, since the soil in the horizon beneath the upper most horizon generally extends to depths ranging from 8 to 18 inches or more, the same soil controlling horizon will usually exist for all floods including the PMF. It is not generally warranted to use different controlling soil horizons for different design events unless unusual soil horizons or shallow soil over an impermeable layer exists for large areal extents.

# APPENDIX C.2

## INITIAL AND CONSTANT LOSSES

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| | | | |
|---|---|---|---|
| Project | 18115 | Page | 1/9 |
| Date | 12/10/2018 | By | ATMerook |
| Checked | 12/10/18 | By | EMH |
| Approved | 12/13/18 | By | GOJ |

Client: City of Grand Junction

Subject: Hogchute Dam Hydrology – Initial & Constant Losses

**Required:**

Determine the initial and constant losses for the Hogchute Dam drainage basin for the Probable Maximum Precipitation event.

**Assumptions:**

1.) Use Colorado SEO "Hydrologic Basin Response Parameter Estimation Guidelines" (HBRPEG) (Sabol, 2008).
2.) RJH calculation package "Hogchute Dam Hydrology – Basin Parameters" dated 12/3/2018
3.) RJH calculation package "Hogchute Dam Hydrology – Hydraulic Conductivity" dated 12/3/2018

**Analysis:**

- The Initial and Uniform Loss Method requires estimation of the following components (p.8-9):

  **STRTL** ➔ initial loss (surface retention + initial infiltration)

  - **IA** (Initial Abstraction) ➔ *f* (average basin slope, vegetative cover)

    **= 0.6 in.**

    - Average subbasin slope = 1-5% (see p.4) ok
    - % vegetative cover = 40-80% (assumed via Google Earth aerial images) (p.6) ok

  - **II** (Initial Infiltration) ➔ estimated based on antecedent moisture conditions and XKSAT

    - For Rocky Mountains region, assume area **Saturated** with snowmelt predominating
    - XKSAT = 0.04 in/hr (Grand Mesa #8) and 0.06 in/hr (Grand Mesa #9)

    **= 0.0 in.** (snowmelt conditions conservatively assumed for saturated ground at PMP)

  **CNSTL** ➔ uniform loss rate parameter (vegetation-adjusted XKSAT) (see p.7)

  - Assume vegetation correction factors for 45% and 70% vegetative cover, respectively (p.7)

    - Upper: (1.67)(0.04 in/hr) = 0.0668 in/hr = **0.07 in/hr**
    - Lower: (1.33)(0.06 in/hr) = 0.0798 in/hr = **0.08 in/hr**

**RTIMP** → effective impervious area (p.8)

- Assume water-covered land area from NRCS Web Soil Survey = RTIMP
  - Upper = **1.4%** ✓
  - Lower = **4.1%** ✓

- **Average Slope Determination**

1.) Draw 5-10 polylines from edge of basin to longest flowpath in ArcMap (p.4)
2.) Calculate the % slope of each polyline and determine the average % slope.

- Average basin slope = 1.4%

3.) Compare to flowpath slope:
  - Upper = 1.1%
  - Lower = 3.3%

4.) Select average slope range that best represents the average % slope and basin slope:
  - Range = **1-5%** ✓

- **Results** → see p.3

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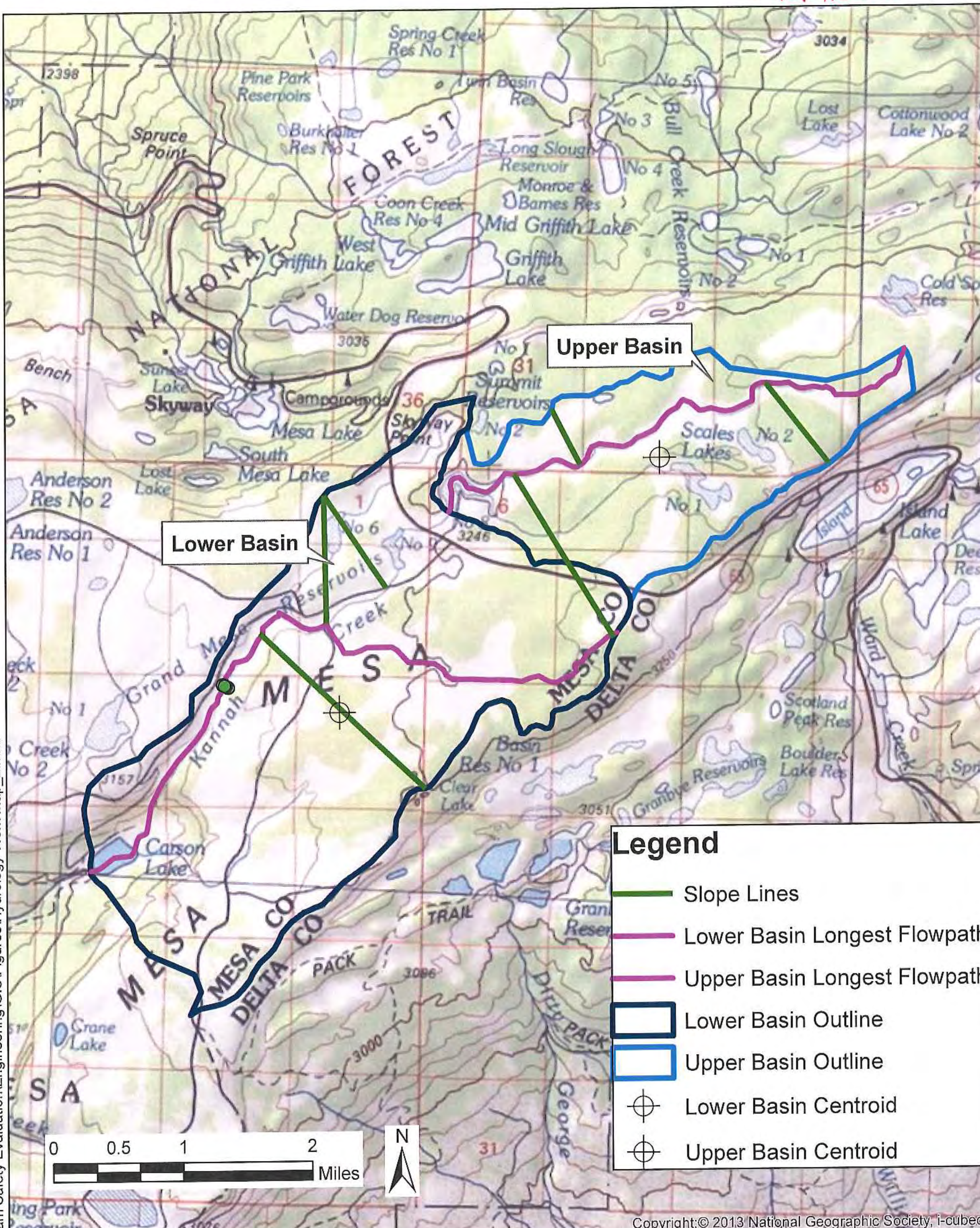
Hogchute Dam Hydrology
Project No. 18115
Prepared by: ATMerook 12/7/18
Checked by: EMH 12/7/18
Approved by: ________

## Losses

| | | | | STRTL | | | CNSTL | RTIMP |
|---|---|---|---|---|---|---|---|---|
| Basin | Average Slope (%)[1] | Bare Ground XKSAT (in/hr) | Vegetation Cover (%)[5] | Initial Abstraction, IA (in)[2] | Initial Infiltration, II (in)[3] | Combined Initial Losses, STRTL (in) | Vegetation Adjusted XKSAT (in/hr)[4] | Percent Impervious (%)[5] |
| Upper | 1.1 | 0.04 | 45 | 0.6 | 0 | 0.6 | 0.07 | 1.4 |
| Lower | 3.3 | 0.06 | 70 | 0.6 | 0 | 0.6 | 0.08 | 4.1 |

Note:

1) Average slope determined in ArcGIS.
2) Initial Abstraction from HBRPEG (CO SEO 2008) Table 8.
3) Initial Infiltration from HBRPEG (CO SEO 2008) Table 12.
4) XKSAT vegetation adustment factors of 1.67 and 1.33 were used for 45% and 70% vegetation cover, respectively,
5) Percent Impervious and vegetation cover estimated from Google Earth.




P:\18115 - Hogchute Dam Safety Evaluation\Engineering\GIS\Figures\Hydrology Work Map_2.mxd

| | | | |
|---|---|---|---|
| **THIS DOCUMENT MUST BE REPRODUCED IN COLOR**<br>**Datum: NAVD 1988** | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION - HYDROLOGY | AVERAGE SLOPE DETERMINATION |
| | | PROJECT NUMBER 18115 | December 2018 **Figure** |

12/5/18 EMH

HBRPEC (Sabol, 2008)

## Table 8

**IA as a function of vegetation cover and average land slope for natural areas**
(to be used with the Green and Ampt infiltration equation for estimating rainfall losses)

**Surface Retention Loss (IA), inches**

| Average Slope (1) | % Vegetation Cover | | | |
|---|---|---|---|---|
| | **0-10% (2)** | **10-40% (3)** | **40-80% (4)** | **80-100% (5)** |
| 0-1% | 0.4 | 0.6 | 0.8 | 1.0 |
| 1-5% | 0.3 | 0.4 | 0.6 | 0.8 |
| 5-10% | 0.2 | 0.3 | 0.4 | 0.6 |
| >10% | 0.1 | 0.2 | 0.3 | 0.4 |

Note: Not to be used in rainfall-runoff modeling with rainfalls more frequent than 100-year.

HBRPEC (Sabol, 2008)

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**Table 12**
**Initial Loss Plus Uniform Loss Rate Parameter Values for Bare Ground**

| Uniform Loss Rate, inches/hour | Initial Infiltration, inches II[1] | | |
|---|---|---|---|
| (1) | Dry (2) | Normal (3) | Saturated (4) |
| 0.30 – 1.20 | 0.6 | 0.5 | 0 |
| 0.15 – 0.30 | 0.5 | 0.3 | 0 |
| 0.05 – 0.15 | 0.5 | 0.3 | 0 |
| 0.00 – 0.05 | 0.4 | 0.2 | 0 |

Note:
1. Selection of II:
   Dry = Non-irrigated lands, such as mountain, hillslope and rangeland.
   Normal = Irrigated lawn, turf, and permanent pasture.
   Saturated = Irrigated agricultural land, or land that can be assumed to have high soil moisture content due to snowmelt.

## Instructions For Computing Initial And Uniform Loss Parameters:

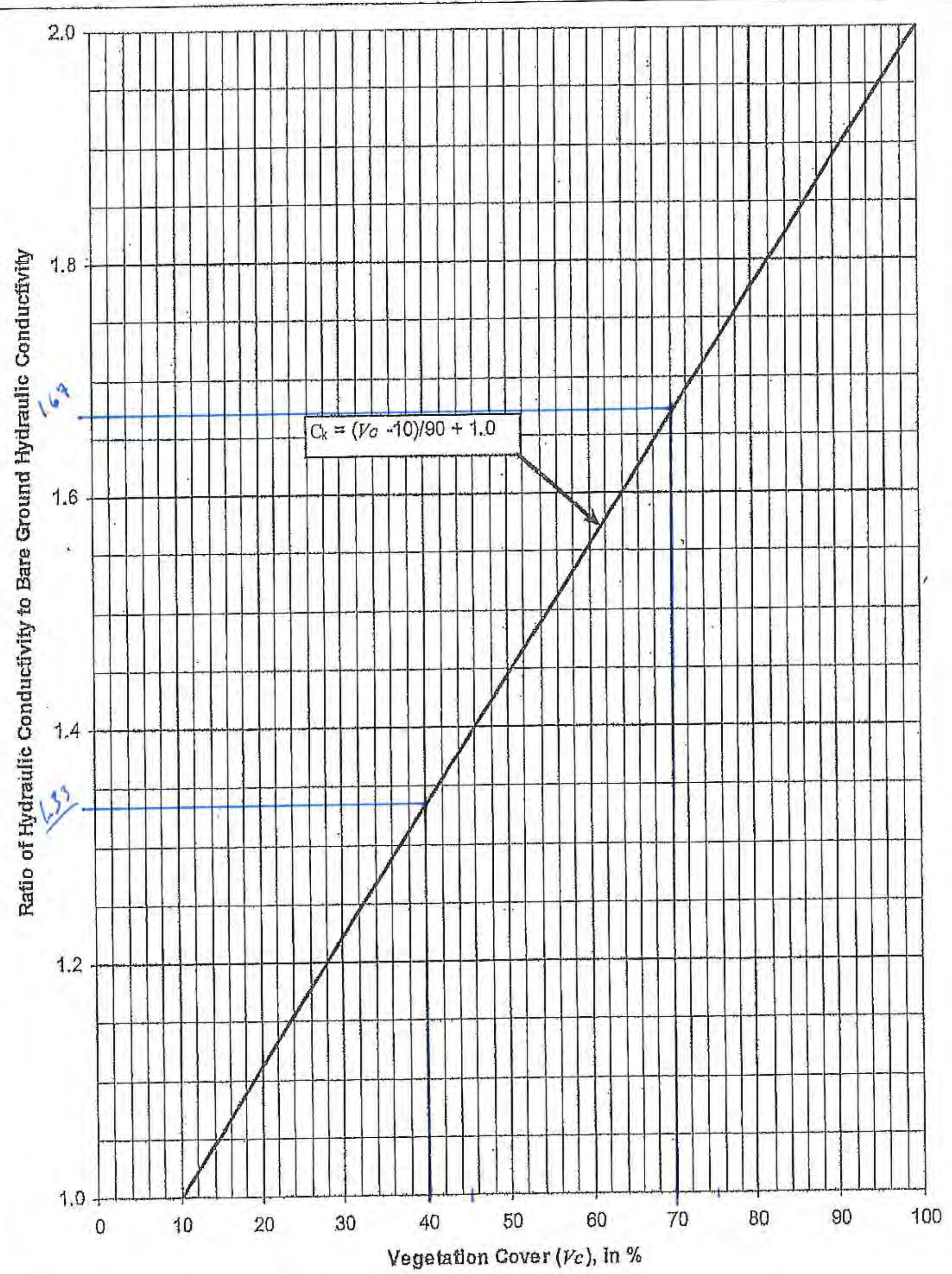
**General:** In general the following steps are used to compute rainfall loss parameters for the Initial Loss and Uniform Loss Rate method. The sets of instructions following these general steps are specific to computing parameter values for each sub-basin.

1. Sub-basin Delineation. Prepare a base map of the drainage area and delineate modeling basins for the concentration points of interest. Delineate sub-basins from each basin so that the sub-basins are as homogeneous as possible in terms of area and/or time of concentration characteristics, and surface characteristics and/or soil type. Delineate large areas of impervious area as separate sub-basins. Create GIS polygon coverages for each basin and sub-basin and calculate the area of each basin and sub-basin.

2. Sub-Area Delineation. Delineate sub-areas for each sub-basin for the purpose of assigning IA and RTIMP estimates. The polygons from NRCS soil surveys delineating SMUs also are sub-areas, and often are used as sub-areas for estimation of IA and RTIMP. Create GIS polygon coverages for each sub-area and calculate the area of each sub-area.

is evaluated on basal area for grass and forbs, and is evaluated on canopy cover for trees and shrubs. Note that this correction can be applied only to soils other than sand and loamy sand.

**Figure 8**
**Effect of Vegetation Cover on Hydraulic Conductivity**
**For All Soil Textures Other Than Sand and Loamy Sand**



HBRPEG (Sabol, 2005) 8

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2. Compute a Composite Value of RTIMP: If there are multiple sub-areas within a sub-basin, calculate an area-weighted value of RTIMP using equation 3.

$$\overline{RTIMP} = \left( \frac{\sum A_i RTIMP_i}{A_T} \right) \quad \text{Eqn 3}$$

where:

$\overline{RTIMP}$ = composite value of RTIMP, inches

$RTIMP_i$ = RTIMP of each sub-area, inches

$A_I$ = size of RTIMP sub-area

$A_T$ = size of the watershed or sub-basin

## Initial Loss And Uniform Loss Rate:

**Introduction:** This is a simplified rainfall loss estimation method that is often used, and generally accepted, for flood hydrology. It is assumed that the rainfall loss process can be simulated as a two-step procedure, as illustrated in Figure 9. The two steps are:

Step 1: All rainfall is lost to runoff until the accumulated rainfall is equal to the initial loss (STRTL).

Step 2: After the initial loss is satisfied, a portion of all future rainfall is lost at a uniform rate (CNSTL). All of the rainfall is lost (runoff does not occur) if the rainfall intensity is less than the uniform loss rate.

The HEC-1 implementation of this method requires input of the three parameters, STRTL, CNSTL, and RTIMP. These guidelines are based on the same presumptions listed in the method description for the Green and Ampt parameters section.

**Applicability:** This method is acceptable for use when modeling very infrequent storms with high amounts of precipitation. It is also an acceptable method for more frequent storms when the dominate soils in the watershed are sand and/or loamy sand. This method should not generally be used for the one percent and more frequent storms.

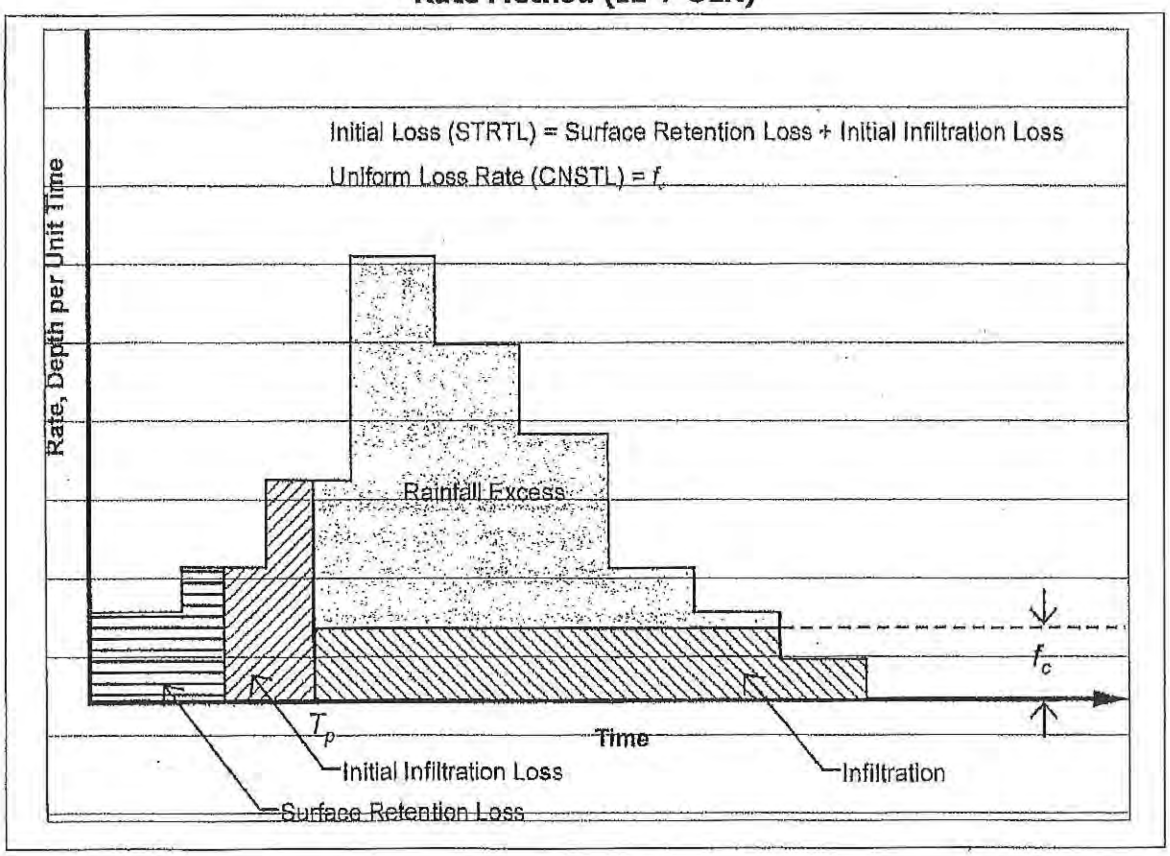
**STRTL:** The initial loss, STRTL, can be assumed to consist of two components, the surface retention loss, IA from the Green and Ampt method, and the initial infiltration, II. After the

IA is satisfied, II includes all other losses that occur until the soil profile is saturated and a stabilized, uniform infiltration condition occurs. Therefore, STRTL is the sum of IA and II. IA can be estimated using Table 8. II can be estimated using Table 12.

**CNSTL:** The uniform loss rate parameter, CNSTL, is equivalent to the Green and Ampt method bare ground XKSAT parameter adjusted for vegetation cover and can be estimated using the procedures for adjusted XKSAT.

**RTIMP:** RTIMP for the Initial Loss and Uniform Loss Rate method is identical to the parameter used with the Green and Ampt method. The procedures defined for estimating RTIMP for the Green and Ampt method should be used for the Initial Loss and Uniform Loss Rate method.

**Figure 9**
**Representation of Rainfall Loss According to the Initial Loss Plus Uniform Loss Rate Method (IL + ULR)**



# APPENDIX D

## LAG TIME

**Required:**

- Calculate the lag time for the contributing subbasin upstream of Hogchute Dam
- Determine the appropriate unit hydrograph for hydrologic modeling

**Assumptions:**

1.) Use Colorado SEO "Hydrologic Basin Response Parameter Estimation Guidelines" (HBRPEG) (Sabol, 2008)
2.) Use RJH calculation package "Hogchute Dam Hydrology – Basin Parameters" dated 12/5/2018
3.) Use USBR Flood Hydrology Manual

**Results:**

- See p.3

**Analysis:**

*Lag Time* (see p.3-6)

$$L_g = 26 \cdot K_n \cdot (LL_{CA}/S^{0.5})^{0.33}$$

Where, $L_g$ = lag time (hr)
$K_n$ == overland roughness parameter [-]
$LL_{CA}/S^{0.5}$ = basin slope factor [-]

$K_n$ values for the local storm were developed using USBR-specific index storms that have similar basin slope factors and vegetation characteristics.

The Upper and Lower Subbasins have basin slope factors of 0.77 and 1.39, respectively.

- Using Tables 4.2 and 4.3 in the USBR Flood Hydrology Manual (p.7-8), $K_n$ values were selected for studied areas with basin slope factors between 0.5 and 10 with similar vegetation (i.e. mixture of native grasses and interspersed forest areas). The similar basins and corresponding Kn values are:

| Basin: | Basin Slope Factor: | $K_n$ |
|---|---|---|
| Coal Creek near Cedar City, UT | 6.6 | 0.050 |
| West Fork San Gabriel at Cogswell Dam, CA | 1.8 | 0.051 |
| Pacoima Wash at Pacoima Dam, CA | 6.8 | 0.049 |
| Santa Anita Creek at San Anita Dam, CA | 0.6 | 0.051 |
| San Antonio Creek at Claremount, CA | 0.6 | 0.055 |

- This range of values was compared to $K_n$ values recommended in the SEO HBRPEG (p.6) which are based on geographic region.

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| | | | | | |
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| Date | 12/5/2018 | By | ATMerook | | |
| Client | City of Grand Junction | Checked | 12/7/18 | By | EMH |
| Subject | Hogchute Dam Lag Tim/Unit Hydrograph | Approved | | By | |

The Hogchute Dam drainage basin is located near the boundary of the Rocky Mountains and Colorado Plateau regions. Basin vegetation consisting of native grasses and pine forests more closely aligns with typical vegetation in the Rocky Mountain region.

Recommended $K_n$ values range from 0.05 to 0.08 for the Rocky Mountain region and 0.04 to 0.06 for the Colorado Plateau region.

Values from the USBR-specific index storms would be at the low end of the Rocky mountain region range, which seems appropriate because forested areas do not predominate the drainage basin and would not be as dense as other forested areas in the Rocky Mountain region.

- Based on this evaluation, a $K_n$ values of **0.05** was selected for the local storm.

Similar USBR-specific index storms could not be identified for the general storm; $K_n$ values recommended in the SEO HBRPEG document range from 0.15 to 0.50 for the Rocky Mountain region and 0.05 to 0.07 for the Colorado Plateau region.

To be consistent with the evaluation and rationale for the local storm $K_n$ selection, a $K_n$ value of **0.15** was selected for the general storm, which would be at the lowest end of the recommended in HBRPEG.

*Unit Hydrograph* (see p.9-10)

Use the Dimensionless S-graph for the Rocky Mountains as the appropriate unit hydrograph for hydrologic modeling.

**Hogchute Dam Safety Evaluation - Hydrology**
**Project No. 18115**

By: ATMerook Date: 12/5/2018
Checked: 12/7/18 Date: EMH
Approved: Date:

| Basin | Region | $L^*L_{ca}/S^{0.5}$ | Thunderstorm-PMP | | General-Storm PMP | |
|---|---|---|---|---|---|---|
| | | | $K_n$ Value | $L_g$ (hours) | $K_n$ Value | $L_g$ (hours) |
| Upper Basin | Rocky Mountains | 0.77 | 0.05 | 1.19 | 0.15 | 3.57 |
| Lower Basin | Rocky Mountains | 1.39 | 0.05 | 1.45 | 0.15 | 4.35 |

| Rocky Mountain | Kn |
|---|---|
| Thunderstorm PMP | 0.05 |
| General Storm PMP | 0.15 |

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The recommended types of synthetic unit hydrographs for use in estimating inflow design floods in Colorado are shown in Table 1. The Clark unit hydrograph is recommended for urban watersheds and smaller (less than 50-square mile) predominantly agricultural watersheds. Dimensionless unit hydrographs and S-graphs are recommended for Rocky Mountain, Great Plains and Colorado Plateau watersheds. The Clark unit hydrograph can be an acceptable alternative for small (less than 10-square mile) watersheds of those types and when verification studies indicate that the Clark unit hydrograph yields more reasonable results than the dimensionless or S-graphs.

**Table 1**

**Selection of synthetic unit hydrographs for use in estimating inflow design floods in Colorado**

| Watershed Type | Dimensionless Unit Hydrograph or S-graph | Clark Unit Hydrograph |
|---|---|---|
| Rocky Mountain | Preferred | Acceptable Alternative |
| Great Plains | Preferred | Acceptable Alternative |
| Colorado Plateau | Preferred | Acceptable Alternative |
| Agricultural | Not Recommended except for agricultural watersheds larger than 50 square miles | Preferred |
| Urban | Not Recommended | Preferred |

## Clark Unit Hydrograph Parameter Estimation

The Clark unit hydrograph is a three parameter method; time of concentration ($T_c$), storage coefficient (R), and the time-area relation. Equations for estimating $T_c$ and R were estimated from an analysis of all relevant watershed data (Sabol, 1987 and 1993), and synthetic time-area relations are available.

**Time of Concentration:** Time of concentration is the travel time, during the corresponding period of most intense rainfall excess, for a floodwave to travel from the hydraulically most distant point in the watershed to the point of interest (concentration point). Three time of concentration ($T_c$) equations are recommended depending on the type of watershed:

Rocky Mountain, Great Plains and Colorado Plateau

$$T_c = 2.4\, A^{.1}\, L^{.25}\, L_{ca}^{.25}\, S^{-.2}$$

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## Dimensionless Unit Hydrographs and Estimation of Lag

A variety of dimensionless unit hydrographs and S-graphs (a form of dimensionless unit hydrograph) are available for use in flood hydrology studies. The U.S. Bureau of Reclamation (USBR) *Flood Hydrology Manual* (Cudworth, 1989) provides a few selected dimensionless unit hydrographs and S-graphs. Those that are recommended for use in Colorado are provided by Cudworth in Table 4-7 and Table 4-8 for the Great Plains (generally east of the Front Range); Table 4-9 and Table 4-10 for general storms in the Rocky Mountains; Table 4-11 and Table 4-12 for high intensity thunderstorms in the Rocky Mountains; Table 4-13 and Table 4-14 for the Colorado Plateau of western Colorado; and Table 4-17 and Table 4-18 for urban watersheds. A more extensive compilation of S-graphs, some of which are applicable for use in Colorado, is provided by Sabol (1987). For the USBR dimensionless unit hydrographs and S-graphs, the single parameter that defines the coordinates of the unit hydrograph is Lag.

**Lag:** The unit hydrograph Lag is estimated by:

$$Lag = 26\, K_n \left( \frac{L L_{ca}}{S^{0.5}} \right)^{0.33}$$

Lag = lag time, in hours

L = distance of longest watercourse, in miles

$L_{ca}$ = distance from point of interest (basin or subbasin outlet) to a point opposite the centroid of the drainage basin (or subbasin), in miles

S = overall slope of L measured from the point of interest to the drainage basin divide, in feet per mile, and

$K_n$ = a lumped parameter representing the resistance to overland flow from the drainage basin incorporating a weighting of the various components of flow resistance along the entire L flow path.

## TABLE 7

## Summary of Unit Hydrographs and Kn Values for Colorado Watersheds

| Watershed Type | Recommended Unit Hydrograph | $K_n$ for Dimensionless Unit Hydrograph | | | |
|---|---|---|---|---|---|
| | | Range | 100-yr[1] | PMF Thunderstorm | PMF General Storm |
| (1) | (2) | (3) | (4) | (5) | (6) |
| Mountains (PMP thunderstorm) | Dimensionless Rocky Mountain Thunderstorm | 0.05-0.08 | NA | 0.05-0.08 | NA |
| Mountains (PMP general storm) | Dimensionless Rocky Mountain General Storm | 0.15-0.30 | NA | NA | 0.15-0.30 |
| Mountains (100-year) | Dimensionless Rocky Mountain Thunderstorm | 0.20-0.30 | 0.20-0.30 | NA | NA |
| Rangelands of western Colorado | Dimensionless Colorado Plateau | 0.04-0.07 | 0.05-0.07 | 0.04-0.06 | 0.05-0.07 |
| Valleys ("Parks") within mountains | Dimensionless Great Plains | 0.03-0.07 | 0.04-0.07 | 0.03-0.06 | 0.04-0.07 |
| Western Colorado, arid Plateau | Dimensionless Colorado Plateau | 0.04-0.07 | 0.05-0.07 | 0.04-0.06 | 0.05-0.07 |
| Plains of Front Range | Dimensionless Great Plains | 0.03-0.07 | 0.04-0.07 | 0.03-0.06 | 0.04-0.07 |
| Agricultural Fields | Clark Unit Hydrograph | NA | NA | NA | NA |
| Urban | Clark Unit Hydrograph | NA | NA | NA | NA |

Notes:
1 – It is assumed that for the 100-year storm the 24-hour hypothetical rainfall distribution is used. That rainfall distribution simulates high intensity thunderstorm rainfall within a long-term general storm.

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Table 4-2.—Unit hydrograph lag data for the Rocky Mountains, New Mexico, Colorado, Utah, Wyoming, Montana, Idaho, and Oregon.

| Index No. | Station and location | Drainage area, mi² | Basin factor, $LL_{ca}/S^{0.5}$ | Lag time, $L_g$, hours | $K_n$ | $C_t$ |
|---|---|---|---|---|---|---|
| 1 | Purgatoire R. at Trinidad, CO | 742.0 | 69.8 | 8.0 | 0.076 | 1.98 |
| 2 | Wood R. nr. Meeteetse, WY | 194.0 | 41.9 | 21.5 | .241 | 6.27 |
| 3 | Grey Bull R. nr. Meeteetse, WY | 681.0 | 68.3 | 34.0 | .324 | 8.42 |
| 4 | San Miguel R. at Naturita, CO | 1080.0 | 174.0 | 34.0 | .238 | 6.19 |
| 5 | Uncompaghre R. at Delta, CO | 1110.0 | 216.0 | 36.0 | .235 | 6.11 |
| 6 | Dry Gulch nr. Estes Park, CO | 2.1 | 0.2 | 0.9 | .059 | 1.53 |
| 7 | Rabbit Gulch nr. Estes Park, CO | 3.4 | 0.2 | 1.0 | .065 | 1.69 |
| 8 | North Fk. Big Thompson R. nr. Glen Haven, CO | 1.3 | 0.1 | 0.7 | .058 | 1.51 |
| 9 | Uintah R. nr. Neola, UT | 181.0 | 59.0 | 32.0 | .324 | 8.42 |
| 10 | South Fk. Payette R. nr. Garden Valley, ID | 779.0 | 123.0 | 30.0 | .236 | 6.14 |
| 11 | Malheur R. nr. Drewsey, OR | 910.0 | 114.0 | 30.0 | .242 | 6.29 |
| 12 | Weiser R. above Craney Cr. nr. Weiser, ID | 1160.0 | 310.0 | 37.0 | .214 | 5.56 |
| 13 | Madison R. nr. Three Forks, MT | 2511.0 | 2060.0 | 50.0 | .155 | 4.03 |
| 14 | Gallatin R. at Logan, MT | 1795.0 | 443.0 | 38.0 | .196 | 5.10 |
| 15 | Surface Cr. at Cedaredge, CO | 43.0 | 11.3 | 11.3 | .195 | 5.07 |
| 16 | South Piney Cr. at Willow Park, WY | 28.9 | 3.8 | 10.5 | .260 | 6.76 |
| 17 | Piney Cr. at Kearney, WY | 106.0 | 29.0 | 16.5 | .209 | 5.43 |
| 18 | Coal Cr. nr. Cedar City, UT | 92.0 | 6.6 | 2.4 | .050 | 1.30 |
| 19 | Sevier R. nr. Hatch, UT | 260.0 | 41.0 | 5.1 | .058 | 1.51 |
| 20 | Sevier R. nr. Kingston, UT | 1110.0 | 469.0 | 11.0 | .056 | 1.46 |
| 21 | Centerville Cr. nr. Centerville, UT | 3.9 | 0.4 | 2.4 | .124 | 3.22 |
| 22 | Parrish Cr. nr. Centerville, UT | 2.0 | 0.3 | 2.2 | .126 | 3.28 |
| 23 | Florida R. nr. Hermosa, CO | 69.4 | 12.5 | 15.5 | .259 | 6.73 |
| 24 | Dolores R. nr. McPhee, CO | 793.0 | 193.0 | 9.0 | .061 | 1.59 |
| 25 | Los Pinos R. nr. Bayfield, CO | 284.0 | 35.0 | 28.5 | .339 | 8.81 |

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Table 4-3.—Unit hydrograph lag data for the Southwest Desert, Great Basin, and Colorado Plateau.

| Index No. | Station and location | Drainage area, mi² | Basin factor, $LL_{ca}/S^{0.5}$ | Lag time, $L_g$, hours | $K_n$ | $C_t$ |
|---|---|---|---|---|---|---|
| 1 | Salt River at Roosevelt, AZ | 4341.0 | 1261.0 | 16.0 | 0.058 | 1.51 |
| 2 | Verde R. above E. Verde and below Jerome, AZ | 3190.0 | 760.0 | 12.0 | .052 | 1.35 |
| 3 | Tonto Cr. above Gun Cr., AZ | 678.0 | 66.3 | 6.5 | .063 | 1.64 |
| 4 | Agua Fria R. nr. Mayor, AZ | 590.0 | 63.2 | 5.4 | .053 | 1.38 |
| 5 | San Gabriel R. at San Gabriel Dam, CA | 162.0 | 14.4 | 3.3 | .053 | 1.38 |
| 6 | West Fk. San Gabriel R. at Cogswell Dam, CA | 40.4 | 1.8 | 1.6 | .051 | 1.33 |
| 7 | Santa Anita Cr. at Santa Anita Dam, CA | 10.8 | 0.6 | 1.1 | .050 | 1.30 |
| 8 | Sand Dimas Cr. at San Dimas Dam, CO | 16.2 | 2.0 | 1.5 | .046 | 1.20 |
| 9 | Eaton Wash at Eaton Wash Dam, CA | 9.5 | 1.3 | 1.3 | .046 | 1.20 |
| 10 | San Antonio Cr. nr. Claremont, CA | 16.9 | 0.6 | 1.2 | .055 | 1.43 |
| 11 | Santa Clara R. nr. Saugus, CA | 355.0 | 48.2 | 5.6 | .060 | 1.56 |
| 12 | Temecula Cr. at Pauba Canyon, CA | 168.0 | 24.1 | 3.7 | .050 | 1.30 |
| 13 | Santa Margarita R. nr. Fallbrook, CA | 645.0 | 99.2 | 7.3 | .062 | 1.61 |
| 14 | Santa Margarita R. at Ysidora, CA | 740.0 | 228.0 | 9.5 | .061 | 1.59 |
| 15 | Live Oak Cr. at Live Oak Dam, CA | 2.3 | 0.2 | 0.8 | .052 | 1.35 |
| 16 | Tujunga Cr. at Big Tujunga Dam, CA | 81.4 | 6.5 | 2.5 | .052 | 1.35 |
| 17 | Murrieta Cr. at Temecula, CA | 220.0 | 28.9 | 4.0 | .051 | 1.33 |
| 18 | Los Angeles R. at Sepulveda Dam, CA | 152.0 | 14.3 | 3.5 | .056 | 1.46 |
| 19 | Pacoima Wash at Pacoima Dam, CA | 27.8 | 6.8 | 2.4 | .049 | 1.27 |
| 20 | East Fullerton Cr. at Fullerton Dam, CA | 3.1 | 0.5 | 0.6 | .029 | 0.75 |
| 21 | San Jose Cr. at Workman Mill Rd. CA | 81.3 | 24.8 | 2.4 | .032 | 0.83 |
| 22 | San Vincente Cr. at Foster, CA | 75.0 | 12.8 | 3.2 | .053 | 1.38 |
| 23 | San Diego R. nr. Santee, CA | 380.0 | 95.4 | 9.2 | .078 | 2.03 |
| 24 | Deep Cr. nr. Hesperia, CA | 137.0 | 28.1 | 2.8 | .036 | 0.94 |
| 25 | Bill Williams R. at Planet, AZ | 4730.0 | 1476.0 | 16.2 | .056 | 1.46 |
| 26 | Gila R. at Conner No. 4 Damsite, AZ | 2840.0 | 1722.0 | 21.5 | .071 | 1.85 |
| 27 | San Francisco R. at Jct. with Blue R., AZ | 2000.0 | 1688.0 | 20.6 | .068 | 1.77 |
| 28 | Blue R., nr. Clifton, AZ | 790.0 | 352.0 | 10.3 | .057 | 1.48 |
| 29 | Moencopi Wash nr. Tuba City, AZ | 2490.0 | 473.0 | 9.2 | .046 | 1.20 |
| 30 | Clear Cr. nr. Winslow, AZ | 607.0 | 570.0 | 11.2 | .053 | 1.38 |
| 31 | Puerco R. nr. Adinana, AZ | 2760.0 | 1225.0 | 15.9 | .058 | 1.51 |
| 32 | Plateau Cr. nr. Cameo, CO | 604.0 | 89.9 | 7.9 | .069 | 1.79 |
| 33 | White R. nr. Watson, UT | 4020.0 | 1473.0 | 15.7 | .054 | 1.40 |
| 34 | Paria R. at Lees Ferry, AZ. | 1570.0 | 296.0 | 10.2 | .060 | 1.56 |
| 35 | New River at Rock Springs, AZ | 67.3 | 16.5 | 3.1 | .047 | 1.22 |
| 36 | New River at New River, AZ | 85.7 | 26.3 | 3.7 | .048 | 1.25 |
| 37 | New R. at Bell Road nr. Phoenix, AZ | 187.0 | 108.0 | 5.3 | .043 | 1.12 |
| 38 | Skunk Cr. nr. Phoenix, AZ | 64.6 | 18.7 | 2.4 | .035 | 0.91 |

USBR Flood Hydrology Manual

9/10
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Table 4-10.—General storm dimensionless S-graph data for the Rocky Mountains.

| Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0.05 | 105 | 52.51 | 205 | 81.06 | 305 | 91.68 | 405 | 96.55 | 505 | 98.82 |
| 10 | .23 | 110 | 54.87 | 210 | 81.83 | 310 | 92.02 | 410 | 96.71 | 510 | 98.89 |
| 15 | .62 | 115 | 57.10 | 215 | 82.56 | 315 | 92.35 | 415 | 96.86 | 515 | 98.96 |
| 20 | 1.20 | 120 | 59.21 | 220 | 83.26 | 320 | 92.67 | 420 | 97.01 | 520 | 99.04 |
| 25 | 2.15 | 125 | 61.20 | 225 | 83.93 | 325 | 92.97 | 425 | 97.15 | 525 | 99.11 |
| 30 | 3.46 | 130 | 63.08 | 230 | 84.57 | 330 | 93.26 | 430 | 97.29 | 530 | 99.19 |
| 35 | 4.97 | 135 | 64.84 | 235 | 85.18 | 335 | 93.55 | 435 | 97.42 | 535 | 99.26 |
| 40 | 6.72 | 140 | 66.50 | 240 | 85.78 | 340 | 93.82 | 440 | 97.54 | 540 | 99.33 |
| 45 | 9.33 | 145 | 68.05 | 245 | 86.35 | 345 | 94.08 | 445 | 97.66 | 545 | 99.39 |
| 50 | 12.74 | 150 | 69.51 | 250 | 86.89 | 350 | 94.33 | 450 | 97.78 | 550 | 99.46 |
| 55 | 16.84 | 155 | 70.88 | 255 | 87.42 | 355 | 94.58 | 455 | 97.89 | 555 | 99.52 |
| 60 | 21.47 | 160 | 72.17 | 260 | 87.92 | 360 | 94.81 | 460 | 98.00 | 560 | 99.58 |
| 65 | 26.17 | 165 | 73.39 | 265 | 88.41 | 365 | 95.03 | 465 | 98.11 | 565 | 99.64 |
| 70 | 30.58 | 170 | 74.53 | 270 | 88.87 | 370 | 95.25 | 470 | 98.21 | 570 | 99.69 |
| 75 | 34.66 | 175 | 75.62 | 275 | 89.32 | 375 | 95.45 | 475 | 98.31 | 575 | 99.75 |
| 80 | 38.32 | 180 | 76.64 | 280 | 89.75 | 380 | 95.65 | 480 | 98.40 | 580 | 99.80 |
| 85 | 41.57 | 185 | 77.61 | 285 | 90.17 | 385 | 95.85 | 485 | 98.49 | 585 | 99.85 |
| 90 | 44.55 | 190 | 78.54 | 290 | 90.57 | 390 | 96.03 | 490 | 98.58 | 590 | 99.90 |
| 95 | 47.35 | 195 | 79.43 | 295 | 90.95 | 395 | 96.21 | 495 | 98.66 | 595 | 99.95 |
| 100 | 50.00 | 200 | 80.26 | 300 | 91.32 | 400 | 96.38 | 500 | 98.74 | 600 | 100.00 |

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Manual

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12/5/18 EMH

Table 4-12.—Thunderstorm dimensionless S-graph data for the Rocky Mountains.

| Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate | Time $t$, in % of $L_g$ | Discharge, % of ultimate |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 0.03 | 105 | 54.43 | 205 | 87.87 | 305 | 95.09 | 405 | 98.11 | 505 | 99.40 |
| 10 | .07 | 110 | 58.48 | 210 | 88.44 | 310 | 95.31 | 410 | 98.21 | 510 | 99.44 |
| 15 | .14 | 115 | 62.14 | 215 | 88.97 | 315 | 95.52 | 415 | 98.30 | 515 | 99.48 |
| 20 | .24 | 120 | 65.42 | 220 | 89.47 | 320 | 95.72 | 420 | 98.38 | 520 | 99.52 |
| 25 | .40 | 125 | 68.32 | 225 | 89.95 | 325 | 95.92 | 425 | 98.46 | 525 | 99.55 |
| 30 | .70 | 130 | 70.83 | 230 | 90.39 | 330 | 96.10 | 430 | 98.54 | 530 | 99.58 |
| 35 | 1.39 | 135 | 72.98 | 235 | 90.81 | 335 | 96.28 | 435 | 98.62 | 535 | 99.62 |
| 40 | 2.57 | 140 | 74.86 | 240 | 91.22 | 340 | 96.45 | 440 | 98.69 | 540 | 99.65 |
| 45 | 4.21 | 145 | 76.53 | 245 | 91.60 | 345 | 96.61 | 445 | 98.76 | 545 | 99.68 |
| 50 | 6.31 | 150 | 78.02 | 250 | 91.96 | 350 | 96.77 | 450 | 98.82 | 550 | 99.71 |
| 55 | 8.86 | 155 | 79.35 | 255 | 92.31 | 355 | 96.92 | 455 | 98.89 | 555 | 99.73 |
| 60 | 11.88 | 160 | 80.55 | 260 | 92.64 | 360 | 97.06 | 460 | 98.95 | 560 | 99.76 |
| 65 | 15.39 | 165 | 81.65 | 265 | 92.96 | 365 | 97.20 | 465 | 99.01 | 565 | 99.78 |
| 70 | 19.41 | 170 | 82.65 | 270 | 93.27 | 370 | 97.33 | 470 | 99.06 | 570 | 99.82 |
| 75 | 23.92 | 175 | 83.57 | 275 | 93.57 | 375 | 97.46 | 475 | 99.12 | 575 | 99.85 |
| 80 | 28.93 | 180 | 84.44 | 280 | 93.85 | 380 | 97.58 | 480 | 99.17 | 580 | 99.88 |
| 85 | 34.43 | 185 | 85.22 | 285 | 94.12 | 385 | 97.69 | 485 | 99.22 | 585 | 99.91 |
| 90 | 39.99 | 190 | 85.95 | 290 | 94.38 | 390 | 97.81 | 490 | 99.27 | 590 | 99.94 |
| 95 | 45.18 | 195 | 86.64 | 295 | 94.63 | 395 | 97.91 | 495 | 99.31 | 595 | 99.97 |
| 100 | 50.00 | 200 | 87.27 | 300 | 94.86 | 400 | 98.01 | 500 | 99.36 | 600 | 100.00 |

USBR Flood Hydrology Manual

# APPENDIX E

# RESERVOIR ROUTING PARAMETERS

**Required:**

Develop elevation-capacity relationships and spillway rating curves as HEC-HMS input for Grand Mesa Reservoirs #8 and #9 and Hogchute Dam/Carson Lake.

**References:**

1.) ESRI ArcMap 10.4.1
2.) EM 1110-2-4000 (USACE, 1959) for prismoid method volume calculations (p.3)
3.) Autodesk Civil 3D 2019
4.) Grand Mesa #8 Rehabilitation As-Built drawings by Western Engineers, Inc. dated 9/25/1986 (p.4)
5.) Grand Mesa #9 Dam Data Summary Report sent by Jackie Blumberg (DNR) to Garrett Jackson on 11/27/2018 (p.7)
6.) Mesa County "Aerial Imagery, Elevation, and GIS Download" online interface for 2-ft contours in project area based on LiDAR cloud data (p.8,10a)
7.) City of Grand Junction – Improvements to Water Supply System – Hogchute Reservoir – Vicinity Map and General Plan dated May 1947 (p.15-16)
8.) Open Channel Hydraulics (2nd Ed.) (Sturm, 2010) (p.10b)
9.) "Broad-Crested Weir Coefficients" from Brater and King (1976) (p.11)

**Results:**

| | Grand Mesa #8 | Grand Mesa #9 | Hogchute/Carson Lake |
|---|---|---|---|
| Elevation-Capacity | p.6 | p.10a | p.12 |
| Spillway Discharge | p.5 | N/A | p.13 |

**Analysis:**

- Grand Mesa #8
    - Using Reference #4, the elevation-capacity and spillway rating curve approximation equations were taken directly from the as-built drawings (see. p.4-6)
- Grand Mesa #9
    - Using References #5 and #6, dam and spillway crest elevation information were used in conjunction with published terrain data to define simplified elevation-capacity relationships (p.7-8,10a)
    - The reported dam crest elevation did not coincide directly with the equivalent contour elevation from Mesa County LiDAR-based contour.
        - Reported dam crest elevation matched by observation with the LiDAR terrain contour that represented the dam crest location and used as datum to develop elevation-capacity relationship (see p.7-8,10a)

- Using reported maximum spillway capacity from References #5, the standard weir equation from Reference #8 was employed to approximate the spillway discharge for Grand Mesa #9 (p.10a-11)

$$Q = CLH_e^{1.5} \quad \text{(p.10)}$$

Where,
Q = discharge (cfs)
L = weir length (ft) (from construction drawing and aerial images) (p.9)
$H_e$ = head on crest (ft)
C = weir coefficient (assume 2.65 from Reference #9) (p.11)

- C= 2.65 and L=15ft were used to calculate broad-crested weir discharge in HEC-HMS model internally (p.10a-11) ok

- Hogchute Dam/Carson Lake

  - Using Reference #7-9, published elevation-capacity and spillway discharge information was previously determined to encompass total discharge from both spillway and dam overtopping (p.15-16) ➔ **see results on p.13-15**

Reference #2 - USACE (1989)

12/5/18 EMH

APPENDIX I

RESERVOIR CAPACITY AND STORAGE DEPLETION COMPUTATIONS

I-1. Introduction. The most commonly used method for calculating volume of sediment deposits is by subtracting the resurvey capacity from the original capacity. Heinemann and Rausch [28] stated that the sediment deposits may change in average density because of compaction between successive surveys and could possible give erroneous sedimentation rates (usually in weight/time) if the differences in successive reservoir capacities is used and adjustments are not made to the density. This problem is eliminated if the average density of the deposits for the time period is known.

I-2. Contour Area Methods. The contour area methods are based upon the assumption that the area encompassed by a contour line and the contour interval can adequately represent the volume between any successive contour elevations. The smaller the contour interval the more accurate is the method. Experience has shown that 2-ft contour intervals are adequate for most volume computations. There are four contour area methods: Stage-area, modified prismoidal, average contour area, and Simpson's rule.

a. Stage-Area Method. This method requires an accurate stage-area curve. The stage-area curve is developed by planimetering the area inside a contour line and plotting it against the contour elevation as shown in Figure I-1. Reservoir volume is calculated by integrating the area between this "contour-area curve" and the y-axis as indicated by the shaded area of Figure I-1 [2].

b. Modified Prismoidal Method. This method is based upon an averaging of the areas of two successive contour lines and a geometric mean area all multiplied by the contour interval to obtain the volume between the contour elevations. Figure I-2 shows the concept for this method [2]. It is expressed mathematical as

$$V = ( L / 3)*(A + SQRT(A*B) + B) \qquad (I-1)$$

where

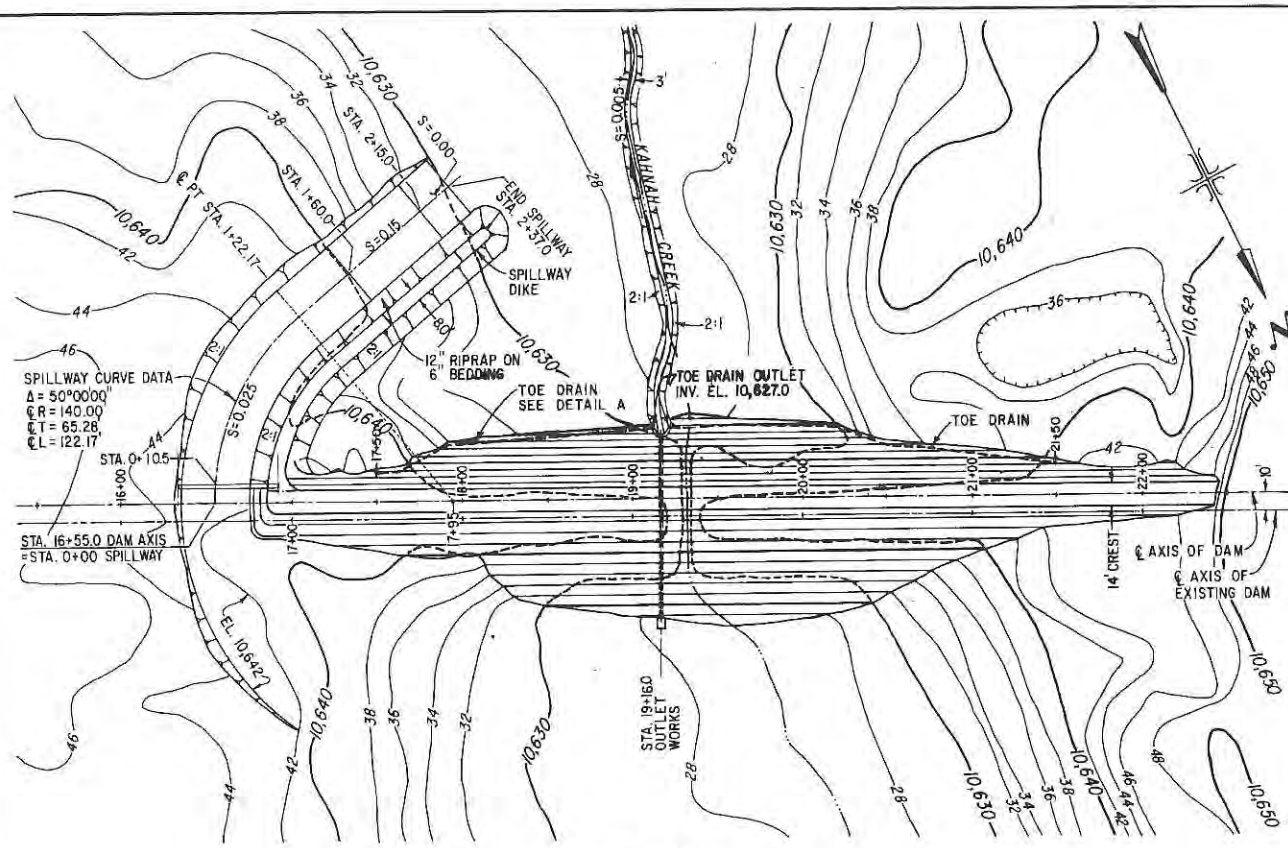
V = Volume between two contour elevations
L = Contour interval
A = Area of lower contour
B = Area of upper contour

c. Average Contour Area Method. This method uses the averaging of two contour areas multiplied by the contour interval and is represented by the following equation. The variables are the same as in the modified prismoidal method.

$$V = (L/2)(A + B) \qquad (I-2)$$

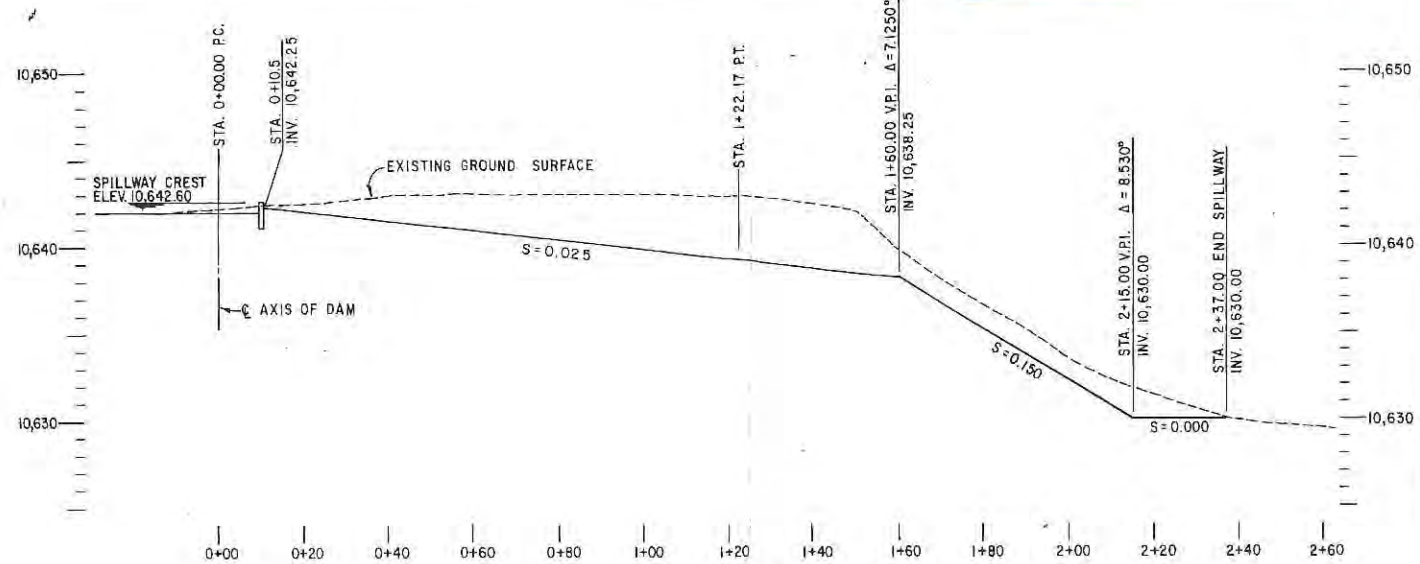
d. Simpson's Rule. This method requires the contour interval to be constant if using contour-area data. If cross section-area data is used, the cross sections must be parallel and evenly spaced. Both require an even number of segments; therefore, if there is an odd number of segments, another

Reloc #4 12/7/18 EMH

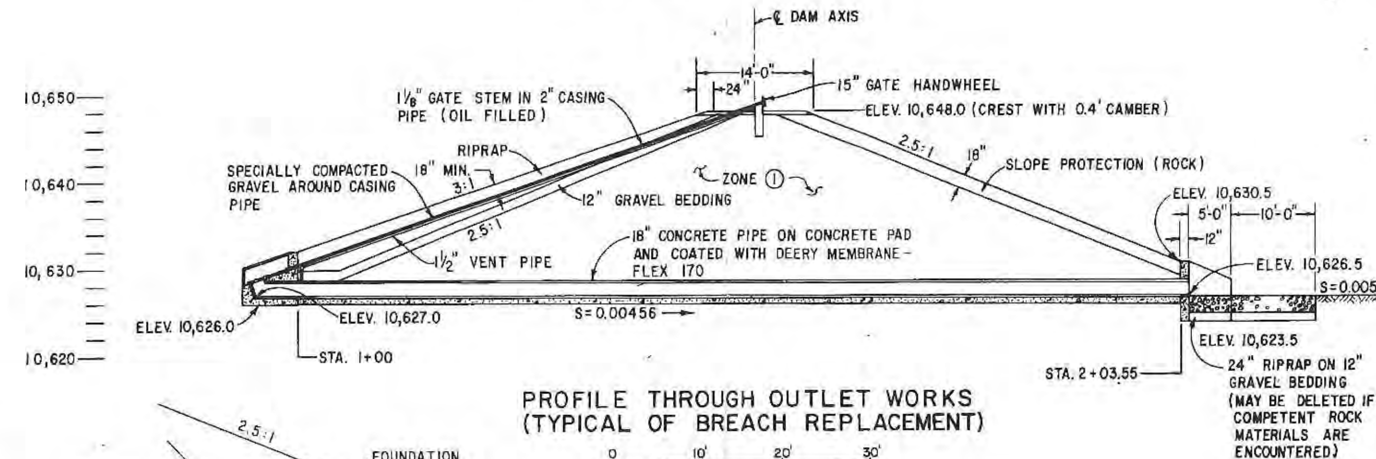



## PLAN

SCALE IN FEET
CONTOUR INTERVAL 2 FEET

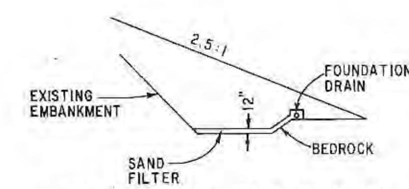



## SPILLWAY PROFILE ALONG CENTERLINE



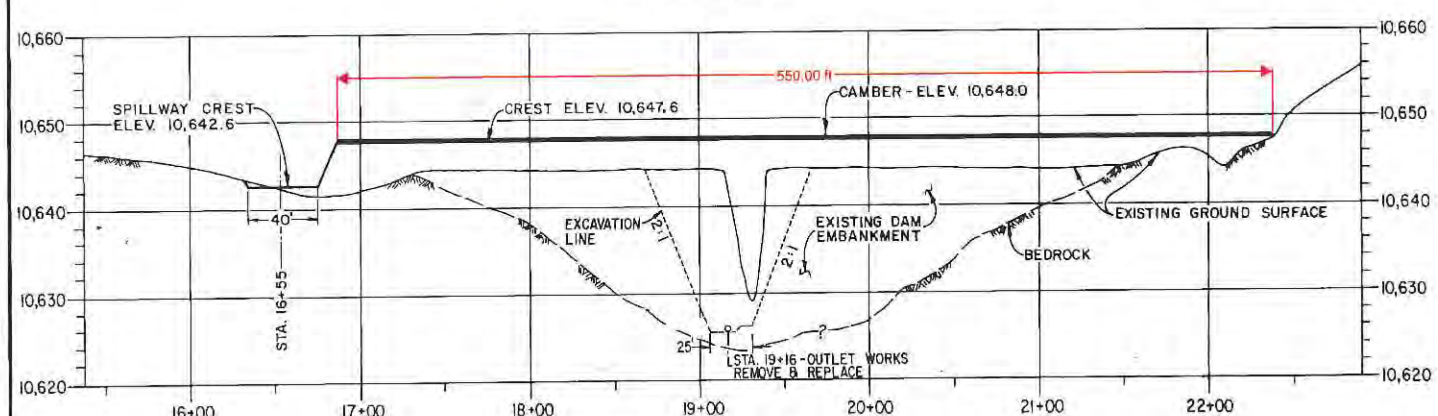

## PROFILE THROUGH OUTLET WORKS (TYPICAL OF BREACH REPLACEMENT)

SCALE IN FEET

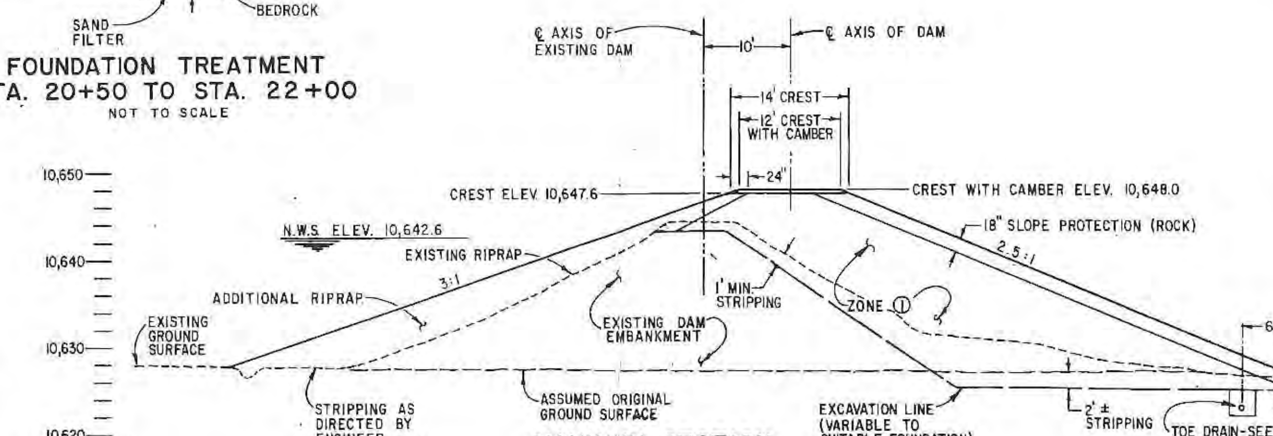



## FOUNDATION TREATMENT STA. 20+50 TO STA. 22+00

NOT TO SCALE

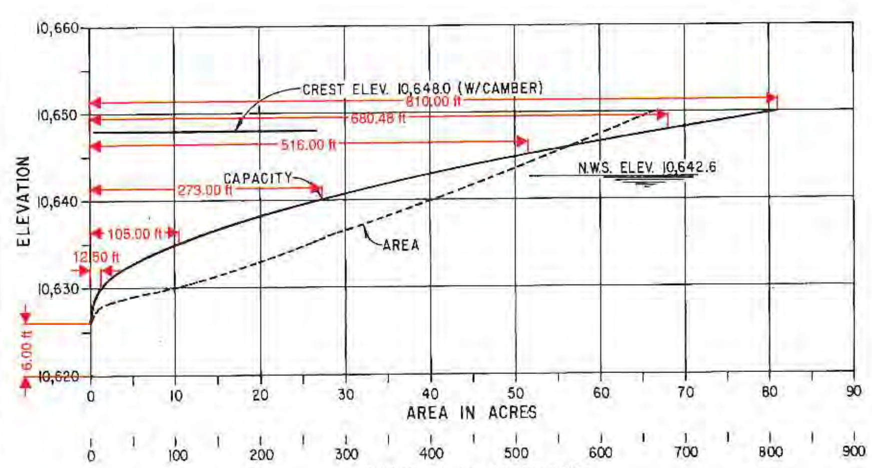



## PROFILE ALONG DAM AXIS

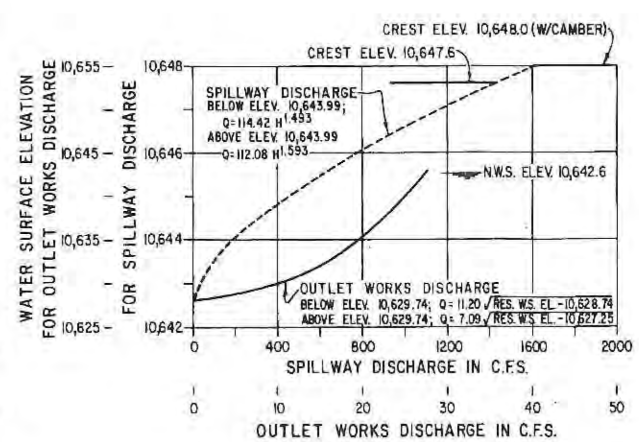



## MAXIMUM SECTION

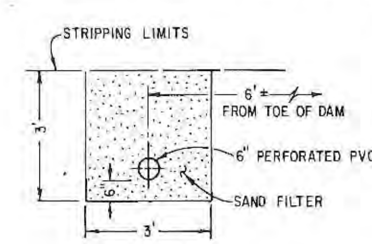
SCALE IN FEET




## AREA-CAPACITY CURVE




## DISCHARGE CURVE




## DETAIL A

SCALE IN FEET

C-1646

AS-BUILT

| NO. | DATE | REVISION-DESCRIPTION | BY |
|---|---|---|---|
| 2 | 9/25/86 | AS-BUILT | GLL |
| 1 | 9/9/85 | AGENCY REVIEW | DLH |

SEAL

WESTERN ENGINEERS, INC. CONSULTING ENGINEERS/LAND SURVEYORS

GRAND MESA RESERVOIR COMPANY
WHITEWATER, COLORADO 81527

GRAND MESA NO. 8 DAM REHABILITATION
MESA COUNTY, COLORADO

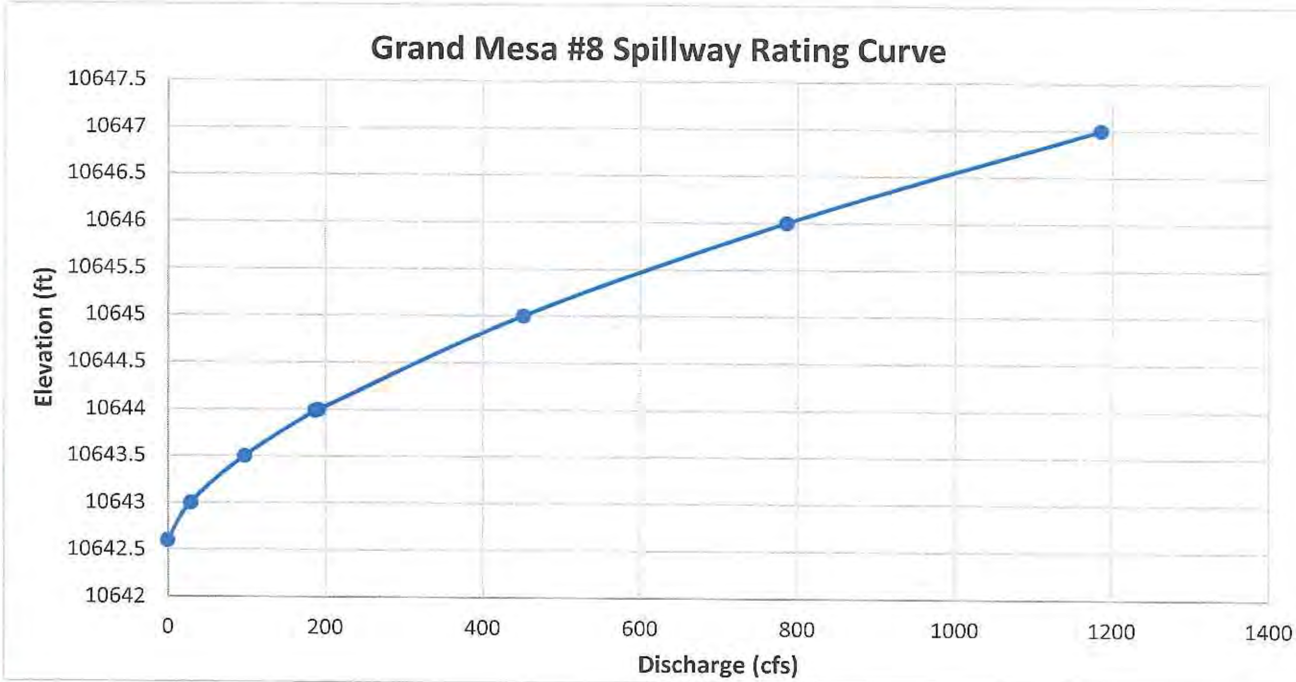
GENERAL PLAN AND SECTIONS

| DESIGN | T.D. / F.L.W. | DRAWN | R.W.Q. | SHEET |
|---|---|---|---|---|
| CHECKED | T.D. / F.L.W. | APPROVED | T.D. / F.L.W. | 3 OF 5 |
| DATE | 5/15/85 | | | |

By: ATMerook Date: 12/5/2018
Checked: EMH Date: 12/7/18
Approved: Date:

Spillway Crest ELE 10642.6

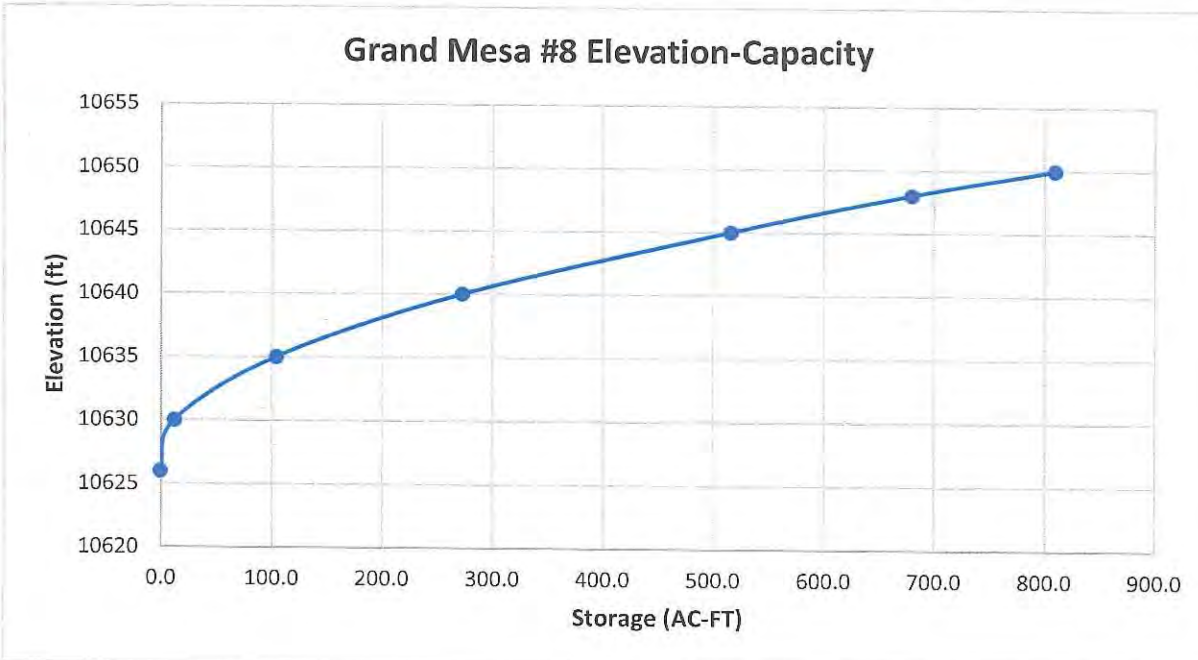
| Elevation FT | Head FT | Discharge CFS |
|---|---|---|
| 10642.6 | 0 | 0 |
| 10643 | 0.4 | 29 |
| 10643.5 | 0.9 | 98 |
| 10643.99 | 1.39 | 187 |
| 10644 | 1.4 | 192 |
| 10645 | 2.4 | 452 |
| 10646 | 3.4 | 787 |
| 10647 | 4.4 | 1187 |
| 10648 | 5.4 | 1645 |
| 10649 | 6.4 | 2157 |
| 10650 | 7.4 | 2718 |
| 10651 | 8.4 | 3326 |
| 10652 | 9.4 | 3979 |
| 10653 | 10.4 | 4674 |
| 10654 | 11.4 | 5410 |
| 10655 | 12.4 | 6185 |




5

By: ATMerook Date: 12/4/2018
Checked: EMH Date: 12/7/18
Approved: ______ Date: ______

| Elevation FT | Storage AC-FT |
|---|---|
| 10626 | 0.0 |
| 10630 | 12.5 |
| 10635 | 105.0 |
| 10640 | 273.0 |
| 10645 | 516.0 |
| 10648 | 680.5 |
| 10650 | 810.0 |



✓12/7/18 EMH7

# Dam name: GRAND MESA #9

Reference #5

**DWR Dam ID: 420123**

*AKA names:* TERNAHAN
*Former name:*
*Hazard Class:* **Low**
*Abandonment Code:*

*National Inventory ID:* 00828
*DWR Administrative ID:* 4203617
*US Forest ID:* 4020058

## Location Information

*Division* 4 *Water District* 42 *County:* MESA *Topomap Number:* 44P
*UTM Coordinates (NAD83) Northing (utm_y):* 4324583.4 *Easting (utm_x):* 234489.7
*Latitude/Longitude (decimal degrees):* 39.029999 *Longitude* -108.06722
*Section:* 1 *Township:* 12 S *Range:* 96 W *Principal Meridian:* Sixth
*Stream:* KAHNAH CREEK *Stream Code:* N *DWR Adminstrative Stream ID:* 3
*Nearest downstream town:* GRAND JUNCTION *Distance (miles):* 23

## Engineering Information

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Year of Completion:* | 1904 | *Designer:* | | | | *Private dam on Federal Lands?* | Y |
| *Purposes:* | I | *Year modified:* | | | | *Regulated by Federal Agency?* | N |
| *Dam type:* | RE | *Dam length (ft):* | 600 | *Crest width (ft):* | 8 | *Crest Elevation (ft):* | 10616 |
| *Core:* | HEZ | *Dam height (ft):* | 15 | *Structural height (ft):* | 0 | *Hydraulic height (ft):* | 0 |
| *Foundation:* | RSK | *Dam volume (cy):* | 14667 | | | | |
| *Normal Storage (AF):* | 153 | *Max. Storage (AF):* | 268 | *Drainage Basin (AC):* | 2880 | *Surface Area (AC):* | 23 |

*Remarks:*
*Last safety inspection:* 7 /1 /2013 *Inspected by:* GOJ *Agency responsible for regulating structure:* DWR
*Hydrology Study?* ☐ *Study date:*
*Notes:*

## Spillway Information

| | | | | | |
|---|---|---|---|---|---|
| *Width (ft):* | 15 | *Side slope:* | 0 | *Type:* | |
| *Freeboard (ft):* | 5 | *Capacity (cfs):* | 0 | *Code:* | |
| *Width (ft):* | 10 | *Side slope:* | 0 | *Type:* | |
| *Freeboard (ft):* | 2 | *Capacity (cfs):* | 0 | *Code:* | |
| *Width (ft):* | 0 | *Side slope:* | 0 | *Type:* | |
| *Freeboard (ft):* | 0 | *Capacity (cfs):* | 0 | *Code:* | |

PRIMARY VISIBLE FROM AERIEL IMAGERY

For reported $L = 15$ ft + $Q = CLH_c^{1.5}$,

$$C = \frac{(186\ ft^3/s)}{(15\ ft)(3.0\ ft)^{1.5}} = 2.39$$

↳ $C \geq 2.65$ from literature;
ignore $Q_p = 186$ cfs → use $C = 2.65$

*Total Spillway Capacity (cfs):* 186

## Outlet Information

*Outlet Description:* 12" CONC. Lined w/CIPP 2003.
*Outlet Gates:* U;S *Outlet capacity (cfs):* 12 *Last outlet inspection* 12/7 /2005
*Emergency Action Plan on file?* Y *Latest EAP Date* 11/27/2018 *Corps of Engineer's Phase 1 inspection?* N

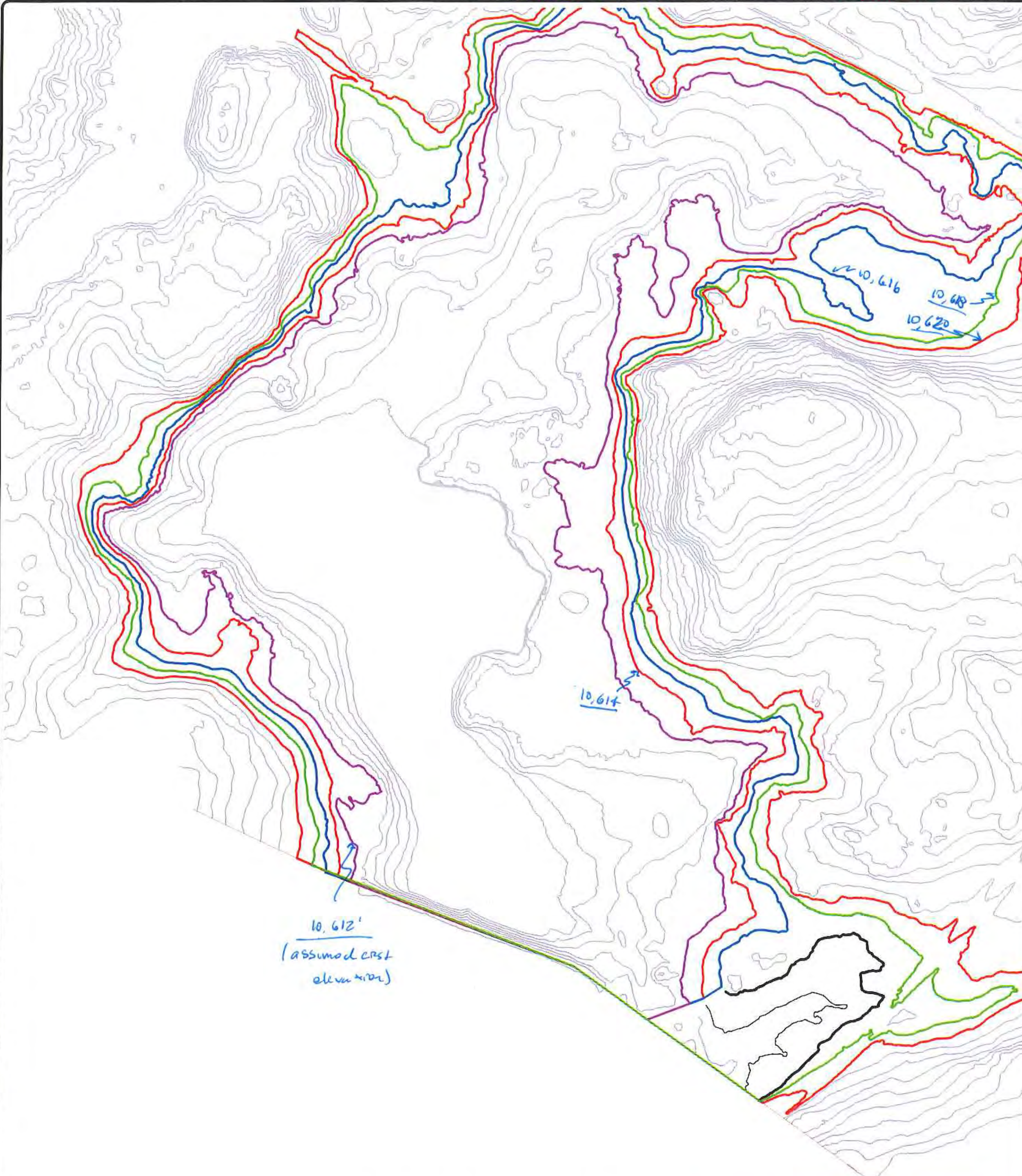
## Restrictions

## Contact Information

*Name:* **GRAND MESA RESERVOIR CO.**
*Relationship:* **Private Owner**
*Address:* 4614 HWY. 50
*City/St/Zip:* WHITEWATER CO 81527-0000
*Contact:* MIKE BRADBURY, PRESIDENT
☑ *Primary owner* ☐ *Primary contact*
*Phone:* (970) 241-3933X
*Cell phone:* *Pager:*
*E-mail:* MIKEANDROBINXIH@CENTURYLINK.

*Name:* **CITY OF GRAND JUNCTION**
*Relationship:* **Local Government**
*Address:* 333 WEST AVENUE
*City/St/Zip:* GRAND JUNCTION CO 81501-0000
*Contact:* LEE COOPER
☐ *Primary owner* ☑ *Primary contact*
*Phone:* (970) 256-4155X
*Cell phone:* (970) 589-4985X *Pager:*
*E-mail:* LEEC@GJCITY.ORG

Reference #6 12/7/18 EMH




0 150 300 600
SCALE IN FEET

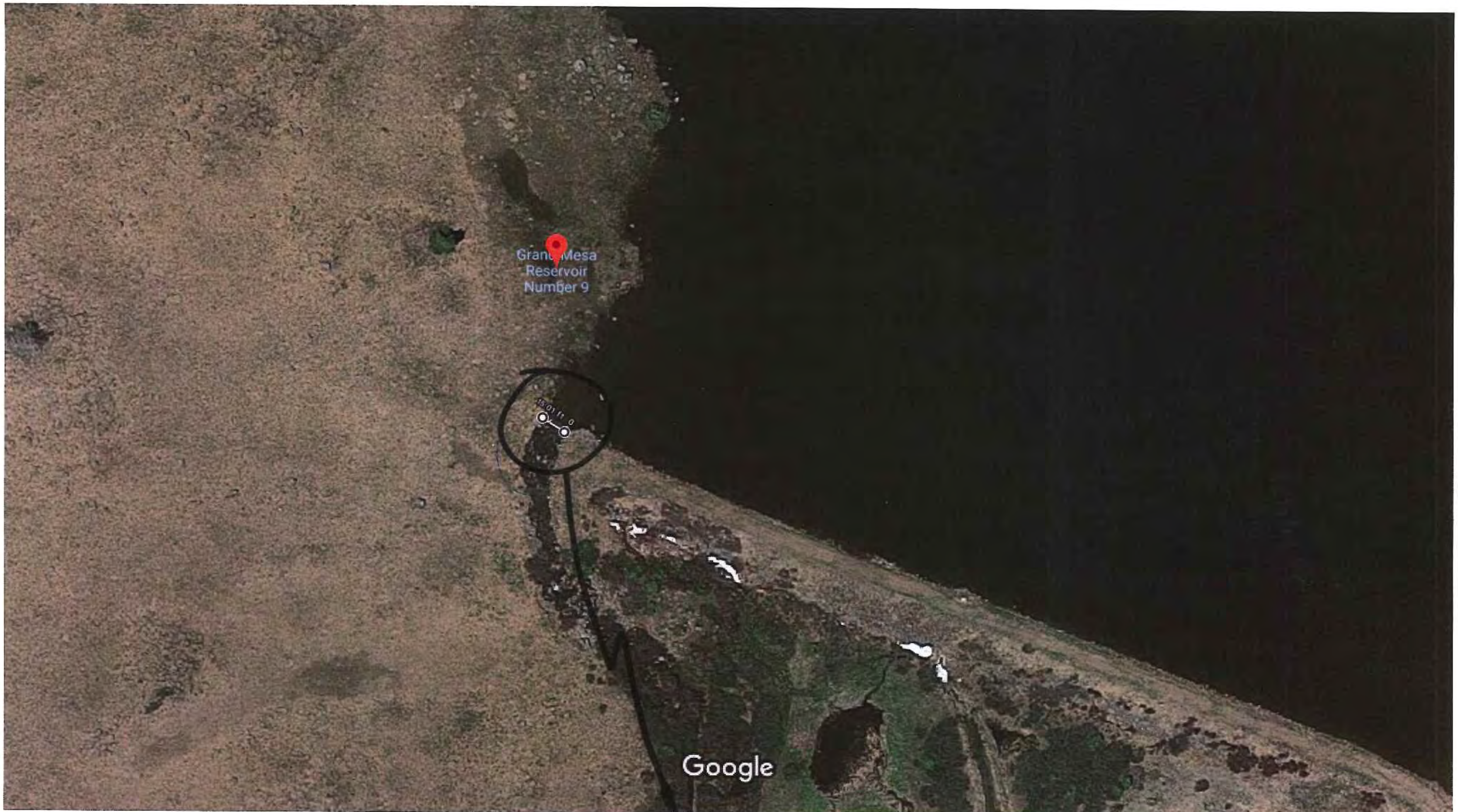
PRELIMINARY
NOT FOR CONSTRUCTION

RJH CONSULTANTS, INC.

| | |
|---|---|
| HOGCHUTE DAM SAFETY EVALUATION | GRAND MESA #9 ELEVATION-CAPACITY |
| PROJECT NO. 18115 | November 2018 **Figure** |

P:\18115 – HOGCHUTE DAM SAFETY EVALUATION\CAD\WORKING\GRAND MESA #9 ELEVATION-CAPACITY.DWG 12/10/2018 8:00 AM

Google Maps Grand Mesa Reservoir Number 9



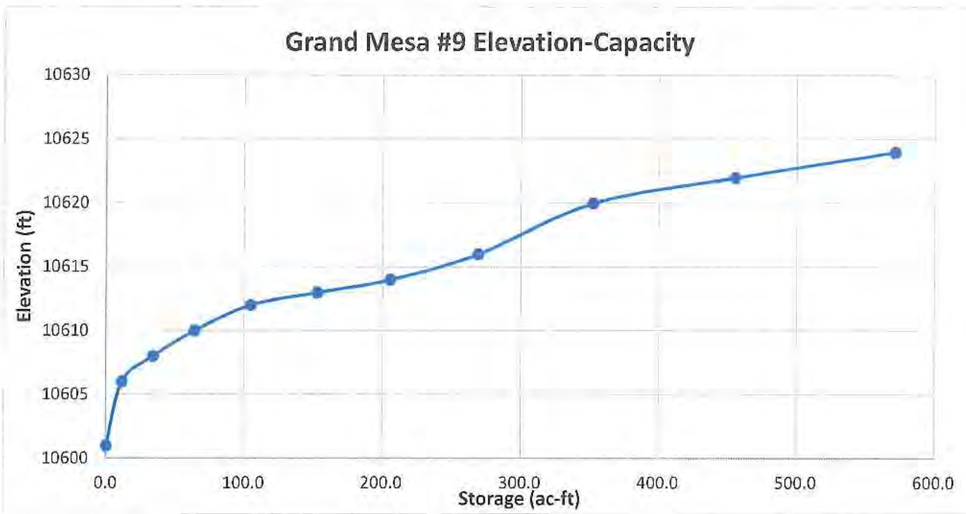

Imagery ©2018 Google, Map data ©2018 Google 50 ft

Spillway length ≈ 15 ft (verified in Google Earth)

✓ 12/7/18 EMH 9

By: ATMerook Date: 12/6/2018
Checked: EMH Date: 12/11/18
Approved: Date:

| H | REPORTED Elevation | LiDAR Elevation | Area | Area | INCREMENTAL Storage | CUMULATIVE Storage | Source: |
|---|---|---|---|---|---|---|---|
| FT | FT | FT | SQ FT | AC | AC-FT | AC-FT | |
| 0 | 10601 | - | 115000 | 2.6 | 0 | 0.0 | ASSUMED |
| 5 | 10606 | 10602 | 419436 | 9.6 | 11.5 | 11.5 | LiDAR-BASED CONTOURS |
| 7 | 10608 | 10604 | 559345 | 12.8 | 22.4 | 33.9 | LiDAR-BASED CONTOURS |
| 9 | 10610 | 10606 | 766925 | 17.6 | 30.3 | 64.2 | LiDAR-BASED CONTOURS |
| 11 | 10612 | 10608 | 1003301 | 23.0 | 40.5 | 104.7 | LiDAR-BASED CONTOURS |
| 12 | 10613 | - | 1100000 | 25.3 | 48.3 | 153.0 | DAM DATA SHEET |
| 13 | 10614 | 10610 | 1202555 | 27.6 | 52.8 | 205.8 | LiDAR-BASED CONTOURS |
| 15 | 10616 | 10612 | 1596653 | 36.7 | 63.1 | 269.0 | DAM DATA SHEET |
| 19 | 10620 | 10616 | 2048236 | 47.0 | 83.5 | 352.4 | LiDAR-BASED CONTOURS |
| 21 | 10622 | 10618 | 2427445 | 55.7 | 102.6 | 455.0 | LiDAR-BASED CONTOURS |
| 23 | 10624 | 10620 | 2630626 | 60.4 | 116.1 | 571.1 | LiDAR-BASED CONTOURS |



ge flood discharges safely from a
ignificant elevation changes and
e shape shown in Figure 6.1 is
e coming off a ventilated, sharp-
ntain pressure on the face of the
itation pressure.
ping the head-discharge relation-
ock relationship for the discharge
ly in Chapter 2 as Equation 2.42.
erm involving $H/P$ becomes small
alue of 0.611; however, this value
ed weir as shown in Figure 6.1. If
head, $H$, which is measured rela-
because $H = 0.89H'$, as shown in
$/(LH^{3/2})$ has an equivalent value of
h spillway.
ach velocity and the vertical con-
onal geometric parameter given by
the spillway crest relative to the
ue of the discharge coefficient is
*design head*, $H_d$, because the pres-
heric pressure associated with the
ead becomes larger than the design
become less than atmospheric and
e larger than atmospheric for heads
e risk of cavitation at heads higher
ischarge coefficients because of the
other words, the spillway becomes
rge for the same head with a larger

ete spillway crest
ıg to the underside of
f sharp-crested weir

ir.

P. Prob #8 - Sturm (2010)



10/10 ✓ 12/5/18 EMH

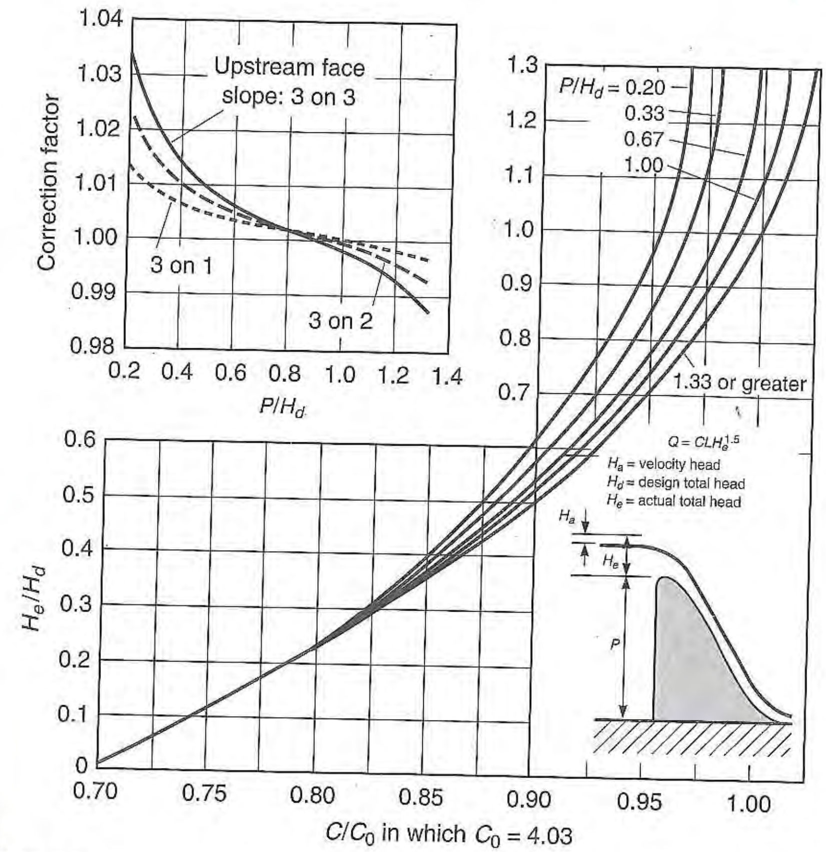



**FIGURE 6.2**
Discharge coefficient for the WES standard spillway shape (Chow 1959). (*Source: Used with permission of Chow estate.*)

value of the discharge coefficient. The spillway discharge coefficient is given in Figure 6.2 for the standard WES (Waterways Experiment Station) overflow spillway in terms of the influence of the spillway height relative to the design head, $P/H_d$, and the effect of heads other than the design head as indicated by $H_e/H_d$, in which $H_d$ is the design total head and $H_e$ is the actual total head on the spillway crest, including the approach velocity head. The discharge coefficient, $C$, with $Q$ in cubic feet per second and both $L$ and $H_e$ in feet is defined by

$$C = \frac{Q}{LH_e^{1.5}} \tag{6.1}$$

in which $L$ is the net effective crest length. In analogy with the sharp-crested weir equation in Chapter 2, the dimensionless coefficient of discharge, $C_d = C/[(2/3)(2g)^{1/2}]$. If C is in English units (*EN*) as in this section on spillways with head in ft and discharge in cfs, then $C_d = 0.187C$ so that $C$ varying from 3.0 to 4.0 corresponds to $C_d$ = 0.56–0.75. The inset in Figure 6.2 shows that a sloping upstream face, which can be used to prevent a separation eddy that might occur on

Release #9

11

12/5/18 EMH

# Broad-Crested Weir Coefficients

**Broad-Crested Weir Coefficient C Values As A Function Of Weir Crest Breadth And Head**

| Measured Head, H[1] | Breadth Of The Crest Of Weir (m) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (mm) | 0.15 | 0.23 | 0.3 | 0.45 | 0.60 | 0.75 | 0.90 | 1.20 | 1.50 | 3.00 | 4.50 |
| 60 | 2.80 | 2.75 | 2.69 | 2.62 | 2.54 | 2.48 | 2.44 | 2.38 | 2.34 | 2.49 | 2.68 |
| 120 | 2.92 | 2.80 | 2.72 | 2.64 | 2.61 | 2.60 | 2.58 | 2.54 | 2.50 | 2.56 | 2.70 |
| 180 | 3.08 | 2.89 | 2.75 | 2.64 | 2.61 | 2.60 | 2.68 | 2.69 | 2.70 | 2.70 | 2.70 |
| 240 | 3.30 | 3.04 | 2.85 | 2.68 | 2.60 | 2.60 | 2.67 | 2.68 | 2.68 | 2.69 | 2.64 |
| 300 | 3.32 | 3.14 | 2.98 | 2.75 | 2.66 | 2.64 | 2.65 | 2.67 | 2.68 | 2.68 | 2.63 |
| 360 | 3.32 | 3.20 | 3.08 | 2.86 | 2.70 | 2.65 | 2.64 | 2.67 | 2.66 | 2.69 | 2.64 |
| 420 | 3.32 | 3.26 | 3.20 | 2.92 | 2.77 | 2.68 | 2.64 | 2.65 | 2.65 | 2.67 | 2.64 |
| 480 | 3.32 | 3.29 | 3.28 | 3.07 | 2.89 | 2.75 | 2.68 | 2.66 | 2.65 | 2.64 | 2.63 |
| 240 | 3.32 | 3.32 | 3.31 | 3.07 | 2.88 | 2.74 | 2.68 | 2.66 | 2.65 | 2.64 | 2.63 |
| 600 | 3.32 | 3.31 | 3.30 | 3.03 | 2.85 | 2.76 | 2.27 | 2.68 | 2.65 | 2.64 | 2.63 |
| 750 | 3.32 | 3.32 | 3.31 | 3.28 | 3.07 | 2.89 | 2.81 | 2.72 | 2.67 | 2.64 | 2.63 |
| 900 | 3.32 | 3.32 | 3.32 | 3.32 | 3.20 | 3.05 | 2.92 | 2.73 | 2.66 | 2.64 | 2.63 |
| 1,050 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.19 | 2.97 | 2.76 | 2.68 | 2.64 | 2.63 |
| 1,200 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.07 | 2.79 | 2.70 | 2.64 | 2.63 |
| 1,350 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 2.88 | 2.74 | 2.64 | 2.63 |
| 1,500 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.07 | 2.79 | 2.64 | 2.63 |
| 1,650 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 2.88 | 2.64 | 2.63 |

8.00 ft → C = 2.65

| Measured Head, H[1] | Breadth Of The Crest Of Weir (ft) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| (ft) | 0.50 | 0.75 | 1.00 | 1.50 | 2.00 | 2.50 | 3.00 | 4.00 | 5.00 | 10.00 | 15.00 |
| 0.2 | 2.80 | 2.75 | 2.69 | 2.62 | 2.54 | 2.48 | 2.44 | 2.38 | 2.34 | 2.49 | 2.68 |
| 0.4 | 2.92 | 2.80 | 2.72 | 2.64 | 2.61 | 2.60 | 2.58 | 2.54 | 2.50 | 2.56 | 2.70 |
| 0.6 | 3.08 | 2.89 | 2.75 | 2.64 | 2.61 | 2.60 | 2.68 | 2.69 | 2.70 | 2.70 | 2.70 |
| 0.8 | 3.30 | 3.04 | 2.85 | 2.68 | 2.60 | 2.60 | 2.67 | 2.68 | 2.68 | 2.69 | 2.64 |
| 1.0 | 3.32 | 3.14 | 2.98 | 2.75 | 2.66 | 2.64 | 2.65 | 2.67 | 2.68 | 2.68 | 2.63 |
| 1.2 | 3.32 | 3.20 | 3.08 | 2.86 | 2.70 | 2.65 | 2.64 | 2.67 | 2.66 | 2.69 | 2.64 |
| 1.4 | 3.32 | 3.26 | 3.20 | 2.92 | 2.77 | 2.68 | 2.64 | 2.65 | 2.65 | 2.67 | 2.64 |
| 1.6 | 3.32 | 3.29 | 3.28 | 3.07 | 2.89 | 2.75 | 2.68 | 2.66 | 2.65 | 2.64 | 2.63 |
| 1.8 | 3.32 | 3.32 | 3.31 | 3.07 | 2.88 | 2.74 | 2.68 | 2.66 | 2.65 | 2.64 | 2.63 |
| 2.0 | 3.32 | 3.31 | 3.30 | 3.03 | 2.85 | 2.76 | 2.27 | 2.68 | 2.65 | 2.64 | 2.63 |
| 2.5 | 3.32 | 3.32 | 3.31 | 3.28 | 3.07 | 2.89 | 2.81 | 2.72 | 2.67 | 2.64 | 2.63 |
| 3.0 | 3.32 | 3.32 | 3.32 | 3.32 | 3.20 | 3.05 | 2.92 | 2.73 | 2.66 | 2.64 | 2.63 |
| 3.5 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.19 | 2.97 | 2.76 | 2.68 | 2.64 | 2.63 |
| 4.0 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.07 | 2.79 | 2.70 | 2.64 | 2.63 |
| 4.5 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 2.88 | 2.74 | 2.64 | 2.63 |
| 5.0 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.07 | 2.79 | 2.64 | 2.63 |
| 5.5 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 3.32 | 2.88 | 2.64 | 2.63 |

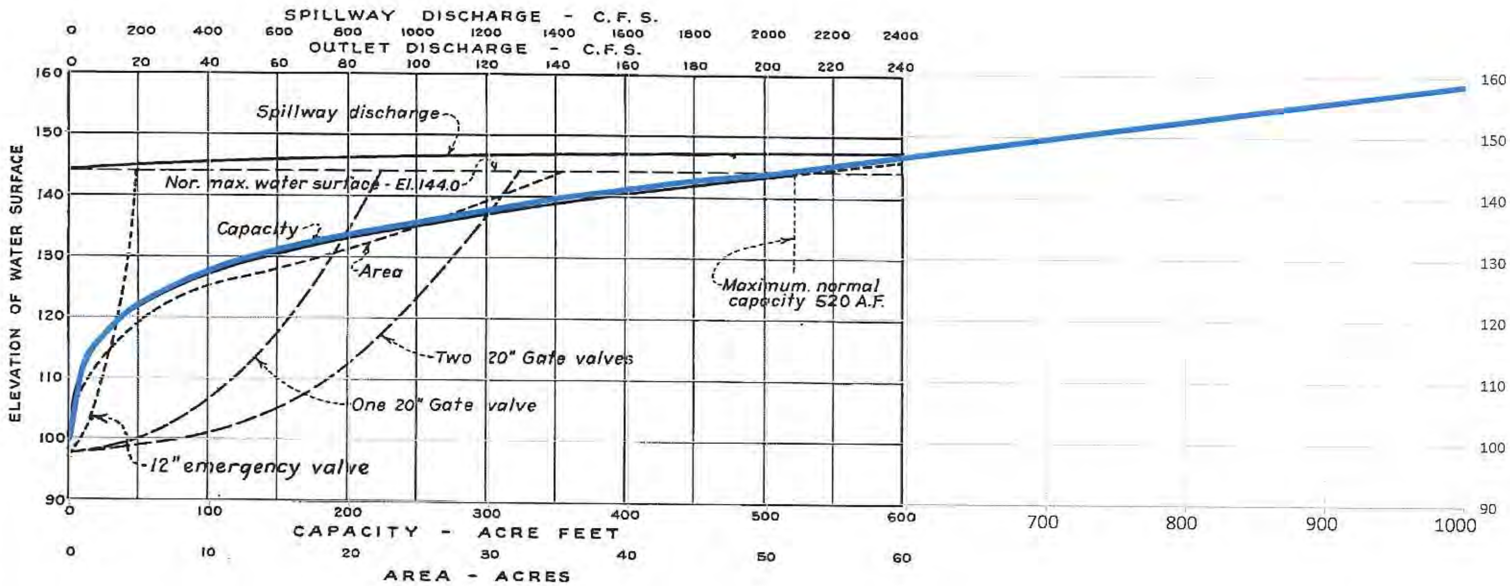
[1]Measured at least 2.5H upstream of the weir.

Reference: Brater and King (1976).

RJH Consultants, Inc.
Hogchute Dam Hydrology
Project No. 18115
Prepared by: B. Bender 10/26/18
Checked by: EMH 11/5/18
Approved by: ______

| Elevation (ft) | Storage (ac-ft) |
|---|---|
| 100 | 0 |
| 112 | 10 |
| 117 | 25 |
| 122 | 50 |
| 127.5 | 100 |
| 131 | 150 |
| 133.5 | 200 |
| 135.5 | 250 |
| 137.5 | 300 |
| 139.5 | 350 |
| 141 | 400 |
| 142.5 | 450 |
| 143.5 | 500 |
| 144 | 517 |
| 145 | 550 |
| 146.5 | 600 |
| 148 | 650 |
| 149.5 | 700 |
| 151 | 750 |
| 152.5 | 800 |
| 154 | 850 |
| 155.5 | 900 |
| 157 | 950 |
| 158.5 | 1000 |

Hogchute Dam



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RJH Consultants, Inc.
Hogchute Dam Hydrology
Project No. 18115
Prepared by: B. Bender 10/26/18
Checked by: EMH 11/5/18
Approved by: ______

Hogchute Dam

**Dam Overtopping:**
Weir Length: 620 ft (see pg. 17)
Discharge Coefficient: 2.65

**Spillway Overtopping:**
Weir Length: 151 ft (average)
Discharge Coefficient: 2.65

Top length: 160 ft (see pg. 17)
Bottom length: 142 ft

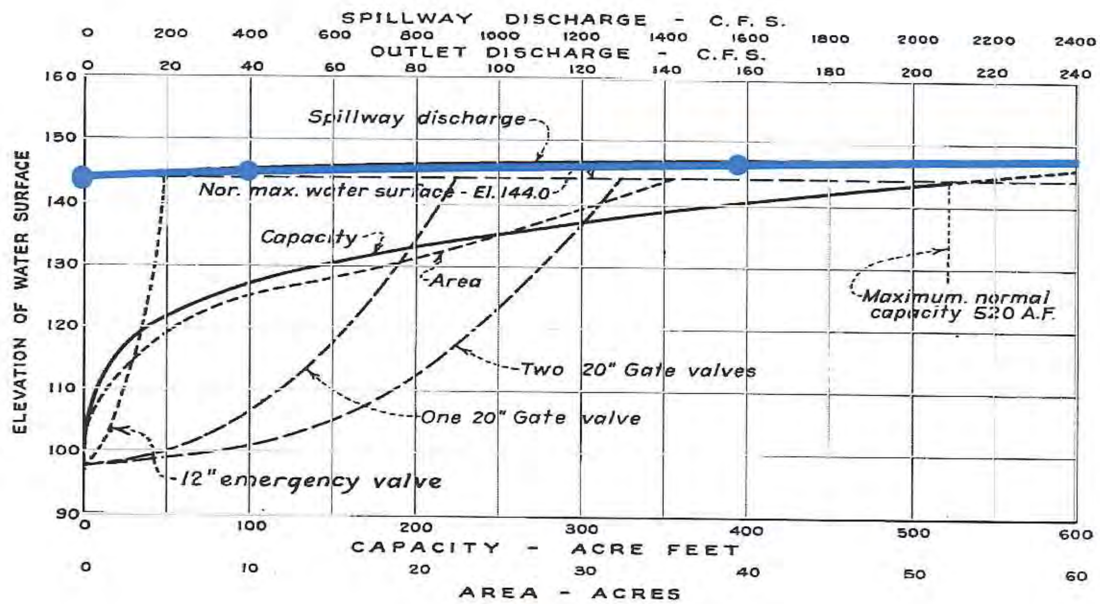
| | Elevation (ft) | Storage (ac-ft) | Spillway Discharge (cfs) | Dam OT Discharge (cfs) | Total Discharge (cfs) |
|---|---|---|---|---|---|
| | 100 | 0 | 0 | 0 | 0 |
| | 112 | 10 | 0 | 0 | 0 |
| | 117 | 25 | 0 | 0 | 0 |
| | 122 | 50 | 0 | 0 | 0 |
| | 127.5 | 100 | 0 | 0 | 0 |
| | 131 | 150 | 0 | 0 | 0 |
| | 133.5 | 200 | 0 | 0 | 0 |
| | 135.5 | 250 | 0 | 0 | 0 |
| | 137.5 | 300 | 0 | 0 | 0 |
| | 139.5 | 350 | 0 | 0 | 0 |
| | 141 | 400 | 0 | 0 | 0 |
| | 142.5 | 450 | 0 | 0 | 0 |
| | 143.5 | 500 | 0 | 0 | 0 |
| Spillway Crest | 144 | 517 | 0 | 0 | 0 |
| | 145 | 550 | 400 | 0 | 400 |
| | 146.5 | 600 | 1582 | 0 | 1581.732 |
| | 148 | 650 | 3201 | 0 | 3201.2 |
| | 149.5 | 700 | 5161 | 0 | 5161.392 |
| Dam Crest | 151 | 750 | 7411 | 0 | 7410.882 |
| | 152.5 | 800 | 9916 | 3,018 | 12,935 |
| | 154 | 850 | 12654 | 8,537 | 21,191 |
| | 155.5 | 900 | 15605 | 15,684 | 31,289 |
| | 157 | 950 | 18756 | 24,147 | 42,903 |
| | 158.5 | 1000 | 22094 | 33,747 | 55,841 |

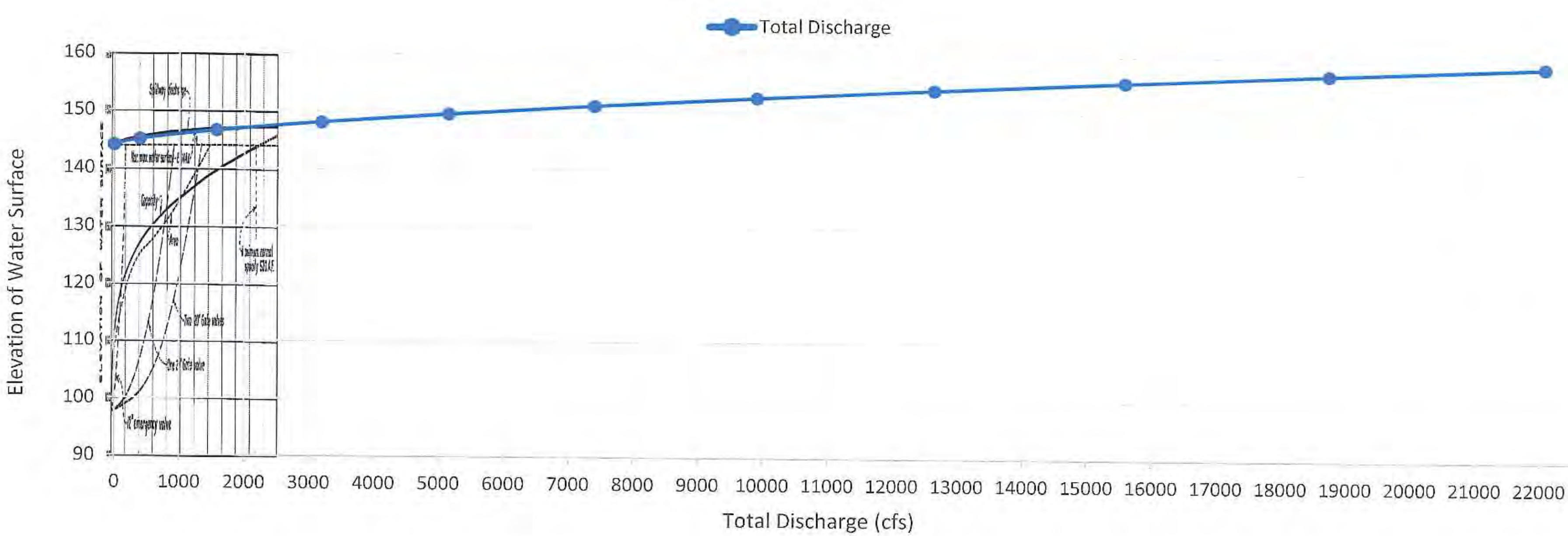


11/5/18 EMH

11/5/18 EMH 14

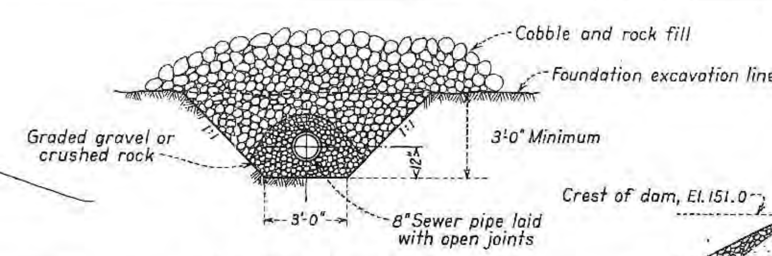
# HOGCHUTE DAM



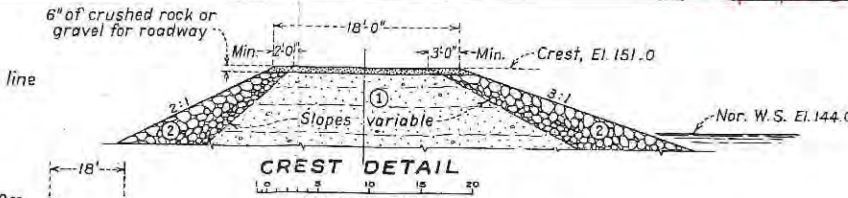




P:\18115 - Hogchute Dam Safety Evaluation\Engineering\Task 1 Hydrology\HEC-HMS\Storage-Discharge-Area

10/30/18 EWH 16

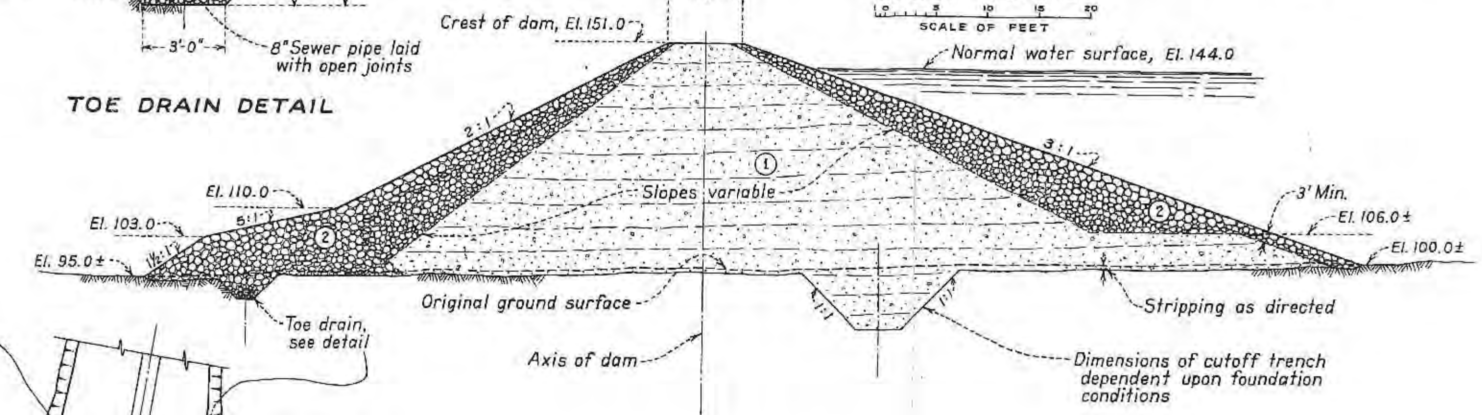



TOE DRAIN DETAIL



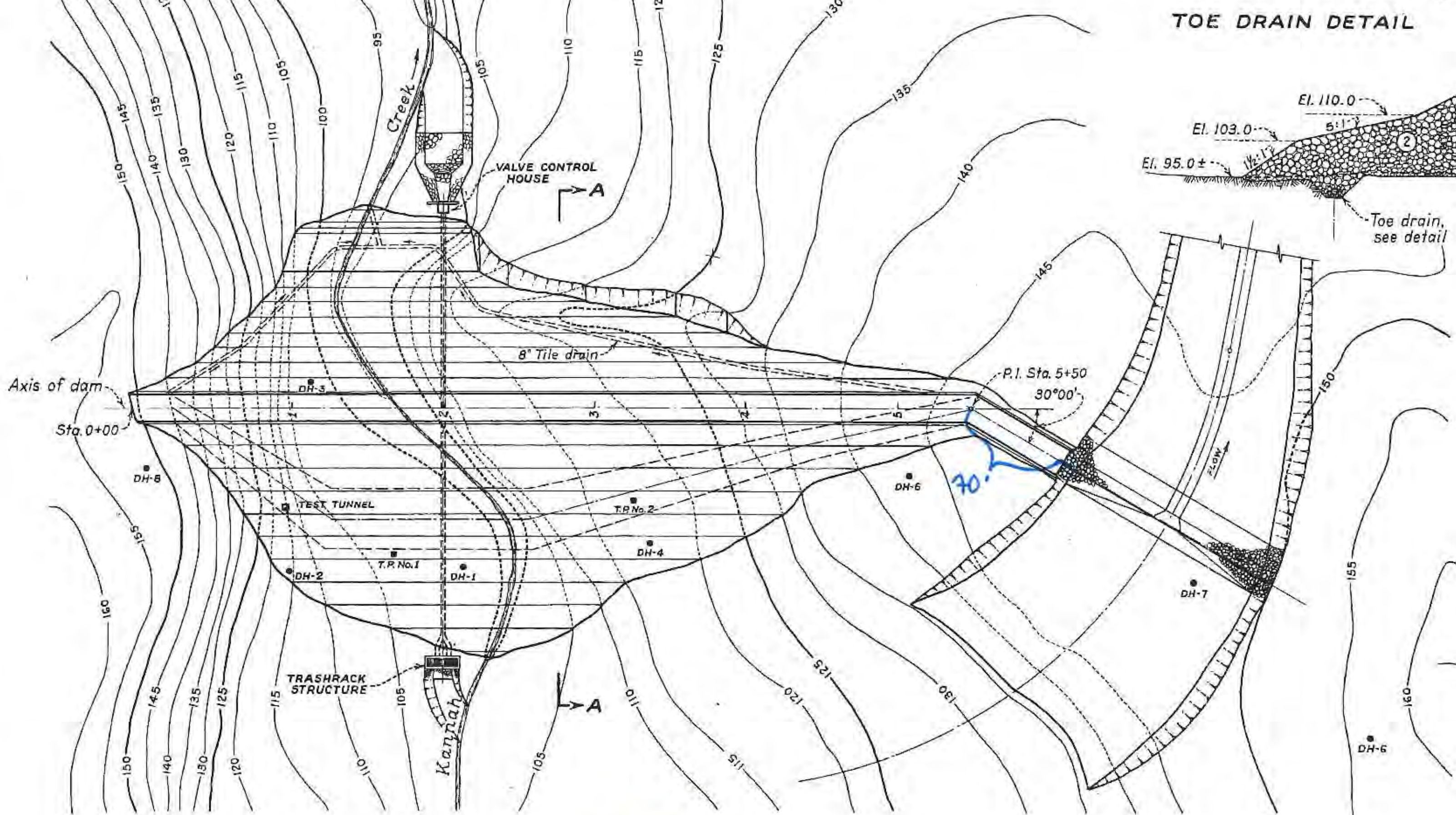

CREST DETAIL

SCALE OF FEET



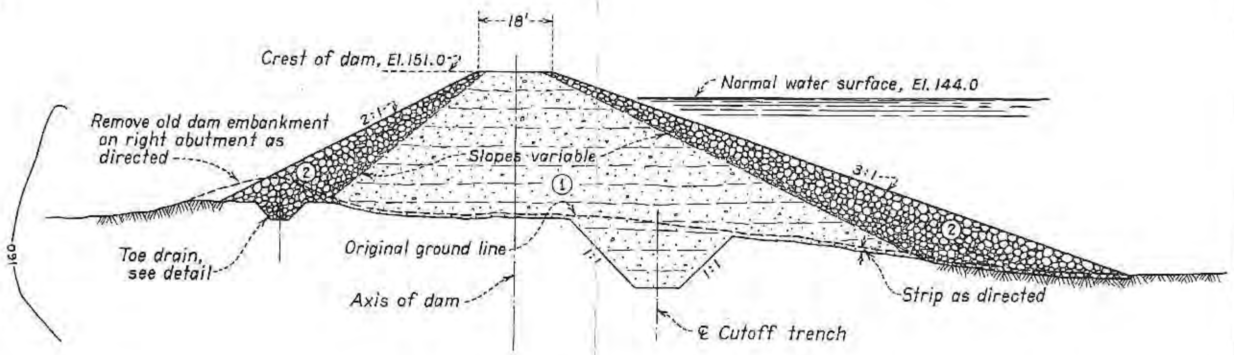

MAXIMUM SECTION

SCALE OF FEET




PLAN

SCALE OF FEET



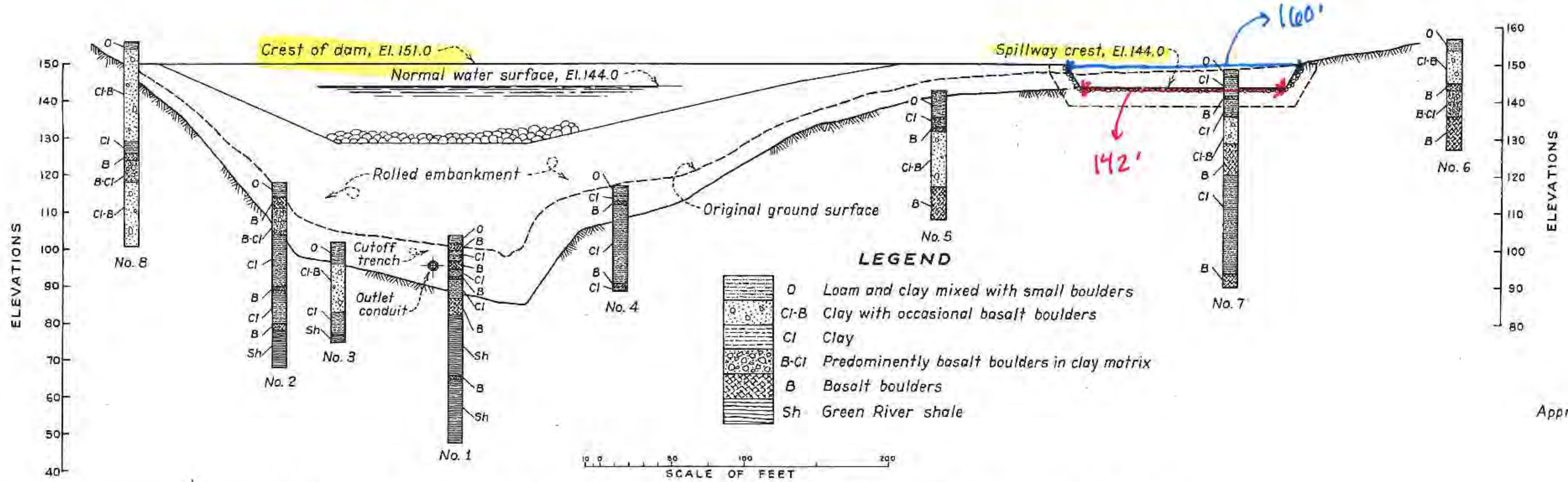

SECTION A-A

## EMBANKMENT NOTES

① Impervious fill of clay or clay, sand and gravel graded with coarser material on outer slopes and compacted in 6" layers.
② Cobble and rock fill graded with coarser material on outer slopes.

## NOTES

All elevations refer to an assumed datum
Final location of outlet works and appurtenant structures are dependent on foundation conditions encountered.




## LEGEND

| | |
|---|---|
| O | Loam and clay mixed with small boulders |
| Cl-B | Clay with occasional basalt boulders |
| Cl | Clay |
| B-Cl | Predominently basalt boulders in clay matrix |
| B | Basalt boulders |
| Sh | Green River shale |

SCALE OF FEET

PROFILE ON ℄ OF CUTOFF TRENCH AND SPILLWAY - LOG OF DRILL HOLES

Approved on the 24 day of May 1947
By M. C. Hinderlider STATE ENGINEER
By ........ DEPUTY

CITY OF GRAND JUNCTION
R.J. TIPTON AND ASSOCIATES INC., ENGINEERS
DENVER, COLORADO
IMPROVEMENTS TO WATER SUPPLY SYSTEM
HOGCHUTE RESERVOIR
PLAN, PROFILE AND SECTIONS

DRAWN N.L.L. APPROVED R.J. TIPTON AND ASSOCIATES INC.
TRACED L.W.M. APPROVED DIRECTOR OF PUBLIC WORKS AND PLANNING
CHECKED N.L.L. APPROVED CITY MANAGER

DENVER, COLORADO MAY 1947 705-31

C-454

# APPENDIX F

# DAM BREACH PARAMETERS

| | | | |
|---|---|---|---|
| Project | 18115 | Page | 1/7 |
| Date | 12/10/2018 | By | ATMerook |
| Checked | 12/10/18 | By | EMH |
| Approved | 12/13/18 | By | GOJ |

RJH CONSULTANTS, INC.

Client: City of Grand Junction

Subject: Hogchute Dam Hydrology – Dam Breach Parameters

**Required:**

Determine the dam breach parameters appropriate for Grand Mesa Dams #8 and #9 for input in HEC-HMS model.

**References:**

1.) Colorado SEO "Guidelines for Dam Breach Analysis" dated 2/10/2010
2.) RJH calculation package "Hogchute Dam Hydrology – El-Cap and Spillway Rating Curves" dated 12/4/2018

**Analysis:**

- Using References #1 and #2, Grand Mesa #8 and #9 both exceed 100 ac-ft (645 ac-ft and 153 ac-ft, respectively) but do not exceed 4000 ac-ft ➔ both are classified as **Small Dams** (p.2) ✓

- Storage Intensity (SI) = $V_w/H_w$
  Where $V_w$ = reservoir volume corresponding with $H_w$ (ac-ft)
  $H_w$ = Maximum water depth behind breach (ft)

  - Grand Mesa #8 ➔ (645 ac-ft)/(20ft) = 32.3 ac. ➔ **High rating** ✓
  - Grand Mesa #9 ➔ (268 ac-ft)/(15ft) = 17.9 ac. ➔ **Medium rating** ✓

- For both Medium and High rating, the Froehlich (2008) method is preferred in general accordance with Reference #1 (p.3). ok

  - The Froehlich (2008) method does no differentiate between embankment type; an overtopping failure is assumed for modeling scenarios (p.4)

- From Reference #2, geometric properties of the dam breach are input into the SEO-provided spreadsheets with a conservative assumption of a full breach reaching existing ground. (p.7).

- See results for both Grand Mesa #8 and #9 on p.5-6.

## 2.1 Colorado Dam Breach Analysis Requirements

Requirements for dam breach analyses are contained in the State of Colorado Rules and Regulations for Dam Safety and Dam Construction (Rules). Specifically, the applicable rules are: Rule 4 – Definitions, Rule 5.4.1 – Hazard Classification Report, and Rule 16.1.5 – Inundation Mapping. For clarity, pertinent sections of the Rules are contained below.

**Rule 4 - Definitions**

4.2.5 "**Dam**" means a man-made barrier, together with appurtenant structures, constructed above the natural surface of the ground for the purpose of impounding water. Flood control and storm runoff detention dams are included.

4.2.5.1 "**Jurisdictional Size Dam**" is a dam creating a reservoir with a capacity of more than 100 acre-feet, or creates a reservoir with a surface area in excess of 20 acres at the high-water line, or exceeds 10 feet in height measured vertically from the elevation of the lowest point of the natural surface of the ground where that point occurs along the longitudinal centerline of the dam up to the crest of the emergency spillway of the dam. For reservoirs created by excavation, or where the invert of the outlet conduit is placed below the surface of the natural ground at its lowest point beneath the dam, the jurisdictional height shall be measured from the invert of the outlet at the longitudinal centerline of the embankment or from the bottom of the excavation at the longitudinal centerline of the dam, which ever is greatest. Jurisdictional height is defined in Rule 4.2.19. The State Engineer shall have final authority over determination of the jurisdictional height of the dam.

4.2.5.2 "**Non-jurisdictional Size Dam**" is a dam creating a reservoir with a capacity of 100 acre-feet or less and a surface area of 20 acres or less and with a height measured as defined in Rules 4.2.5.1 and 4.2.19 of 10 feet or less. Non-jurisdictional size dams are regulated and subject to the authority of the State Engineer consistent with sections 37-87-102 and 37-87-105 C.R.S.

4.2.5.3 "**Minor Dam**" is a jurisdictional size dam that does not exceed 20 feet in jurisdictional height and/or 100 acre feet in capacity (see Figure 1).

4.2.5.4 "**Small Dam**" is a dam with a jurisdictional height greater than 20 feet but less than or equal to 50 feet and/or a reservoir capacity greater than 100 acre-feet, but less than 4,000 acre-feet (see Figure 1).

4.2.5.5 "**Large Dam**" is a dam greater than 50 feet in jurisdictional height, and/or greater than 4,000 acre-feet in capacity (see Figure 1).

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$H_w \approx 20$ ft

Erosion rate (ER) guidelines of $1 < ER/H_w < 21$, where $ER=B_{avg}/T_f$, can be used as check of the methods and the parameters adjusted accordingly. Table 3 summarizes the generally appropriate empirical methods for varying dam sizes and storage intensities. This is only a guide and engineering judgment is needed on a case-by-case basis considering the $ER/H_w$ and $B_{avg}/H_b$ guidelines mentioned above.

$V_w = 685$ AF

$V_w/H_w \approx 34$

**Table 3 - Guide of Appropriate Empirical Methods for Various Dam Sizes and Storage-Intensities**

| **Dam Size** | **Storage Intensity *(SI)* = $V_w/H_w$** | | |
|---|---|---|---|
| | **Low** ($SI < 5$) | **Medium** ($5 < SI < 20$) | **High** ($SI > 20$) |
| Minor | *MacDonald & Langridge-Monopolis with Washington State failure time. Froehlich for Overtopping. | *MacDonald & Langridge-Monopolis with Washington State failure time. Froehlich for Overtopping. | *MacDonald & Langridge-Monopolis with Washington State failure time. Froehlich for Overtopping. |
| Small | *MacDonald & Langridge-Monopolis with Washington State failure time and possibly Froehlich (case-by-case). Froehlich for Overtopping. | Froehlich and possibly *MacDonald & Langridge-Monopolis with Washington State failure time (case-by-case). | Froehlich for geometry and failure time. |
| Large | Froehlich. The side slopes may need to be adjusted to yield a reasonable bottom width. | Froehlich and possibly *MacDonald & Langridge-Monopolis with Washington State failure time (case-by-case). | Froehlich and possibly *MacDonald & Langridge-Monopolis with Washington State failure time (case-by-case). |
| Comments | Parameters likely need to be adjusted with judgment on a case-by-case basis – may need to be modeled as piping hole for Small and Minor dams. | Both Froehlich and *MacDonald & Langridge-Monopolis seem to work for Small and Large dams in the middle range of SI. Engineering judgment is needed on a case-by-case basis. | It is important to look at valley and dam constraints as the computed parameters may exceed the valley width and/or dam length. |
| References | Froehlich (2008)<br>MacDonald & Langridge-Monopolis (1984)<br>Washington State (2007) | | |
| * Where the MacDonald & Langridge-Monopolis Method is referenced as a recommendation, this only applies for embankments constructed of cohesive materials. The Washington State Method is preferred for cohesionless earthen embankments. | | | |

#### 7.1.1.1 Piping Failure Considerations with Empirical Methods

For Small and Minor dams with low storage intensities (SI less than 5) that are built with cohesive soils, it is possible that a piping failure could occur and drain the reservoir without fully breaching the dam (i.e. collapsing the crest). This situation is evident when the MacDonald & Langridge-Monopolis and Washington State empirical method for establishing the breach parameters shows that the volume eroded ($V_{er}$) results in a corresponding $B_{avg}/H_b$ of less than about 0.5. This phenomenon is common for Small dams with a volume less than 100 AF and SI less than about 2.5, and Minor dams when SI is less than about 1.5. When this occurs, it is possible to calculate the maximum piping-hole size (assumed to be square) from the volume of embankment eroded. This piping-only failure mode does not apply to dams

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12/5/18 EMH



**Table 2 – Summary of Recommended Empirical Equations (English Units)**

| Breach Parameters | MacDonald & Langridge-Monopolis (1984) | Washington (2007) | Froehlich (2008) |
|---|---|---|---|
| **Volume Eroded** $V_{er}$ **(yd³)** | $V_{er} = 3.264BFF^{0.77}$ (best fit all data) | $V_{er} = 3.75BFF^{0.77}$ (cohesionless dams) | |
| | $V_{er} = 0.714BFF^{0.852}$ (rockfill) | $V_{er} = 2.5BFF^{0.77}$ (cohesive dams) | |
| **Average Breach Width** $B_{avg}$ **(ft)** | $B_{avg} = \frac{V_{er}}{(H_b \times W_{avg})}$ | | $B_{avg} = 8.239K_oV_w^{0.32}H_b^{0.04}$ <br> $K_o$=1.0 for piping <br> $K_o$=1.3 for overtopping |
| **Breach Side slopes** $Z_b$ **(H:V)** | 2.0:1 | | 0.7:1 - piping <br> 1.0:1 - overtopping |
| **Breach Development Time** $T_f$ **(hr)** | $T_f = 0.016V_{er}^{0.364}$ | $T_f = 0.02V_{er}^{0.36}$ (cohesionless) | $T_f = 3.664\sqrt{\frac{V_w}{gH_b^2}}$ |
| | | $T_f = 0.036V_{er}^{0.36}$ (cohesive) | |

**Suggested Methods to Validate the Parameters Calculated using Empirical Methods:**

On a case by case basis, judgment is needed with the predicted parameters calculated using the recommended methods presented here. There are a few general tools used to validate the predicted parameters:

1. An estimate of linear erosion rate can be used to check the validity of the failure time. Linear erosion rate (ER) is defined as the $B_{avg}/T_f$. Von Thun and Gillette (1990) suggests the minimum allowable erosion rate related to the height of the water above the breach bottom, can be empirically defined as $4H_w$ and the maximum erosion rate related to the water depth is $200 + 4H_w$. However, the data set used to develop the empirical parameters suggest a minimum ER of $1.6H_w$. **If the $T_f$, $B_{avg}$, and $H_w$ computed by the empirical methods listed above produces an $ER/H_w$ much less than 1.6, then either the $T_f$ is too long or $B_{avg}$ is too small** and adjustments are needed or a different method selected. Likewise, the maximum $ER/H_w$ in the data set was only 21, which is considerably less than upper limit defined by Von Thun and Gillette (1990) (greater than 200). The average $ER/H_w$ computed from the database was 6.7. **Therefore, if the $ER/H_w$ ratio is greater than 21, then the parameters are considered suspect.**

2. Von Thun and Gillette (1990) suggests that $B_{avg}/H_w$ cannot be less than 2.5. However, the data set, especially for piping, shows $B_{avg}/H_w$ less than 2.5 in many instances. In fact, it is near 1.0 in several cases and less than 1.0 in a few instances. The minimum $B_{avg}/H_w$ for the data set was 0.6 and the minimum $B_{avg}/H_b$ was 0.5. This ratio is highly dependent on storage-intensity ($SI = V_w/H_w$) and with a relatively small reservoir volume relative to the dam height (low storage intensity), the reservoir evacuates quickly and does not allow for the breach to widen. Piping failure of a dam with a very low storage-intensity may evacuate the reservoir through the piping hole without a full rectangular or trapezoidal breach forming. Paquir, et.al, (post 1995) suggested that the piping hole width has to reach 2/3 of the dam height above the bottom of the pipe before the roof of the piping hole collapses

# ESTIMATION OF DAM BREACH PARAMETERS
# USING THE FROEHLICH 2008 METHOD

**PROJECT:** GRAND MESA DAM #8

**BREACH INPUT PARAMETERS:**

| | | |
|---|---|---|
| Select Failure Mode From Drop-Down Menu: | OVERTOPPING | |
| Height of water over base elevation of breach ($H_w$) = | 20.0 | Feet |
| Volume of water in the reservoir at the time of failure ($V_w$) = | 685.0 | Acre-Feet |
| Reservoir Surface Area at Hw ($A_s$) = | 61.0 | Acres |
| Height of breach ($H_b$) = | 20.0 | Feet |
| Failure Mode Factor ($K_o$) = | 1.3 | |
| Breach Side-Slope Ratio ($Z_b$) = | 1 | Z(H):1(V) |
| Dam Size Class: | Small | Assumes Full Reservoir At Time of Breach. |

**CALCULATED BREACH CHARACTERISTICS:**

| | | |
|---|---|---|
| Average Breach Width ($B_{avg}$) = | 97.6 | Feet |
| Bottom Width of Breach ($B_b$) = | 77.6 | Feet |
| Breach Formation Time ($T_f$) = | 0.84 | Hours |
| Storage Intensity (SI) = | 34.3 | Acre Feet/Foot |
| Predicted Peak Flow ($Q_p$) = | 13578 | Cubic Feet per Second |

**RESULTS CHECK:**

| | | |
|---|---|---|
| Average Breach Width Divided by Height of Breach ($B_{avg}/H_b$) = | 4.88 | If ($B_{avg}/H_b$) > 0.6, Full Breach Devlopment is Anticipated |
| Erosion Rate (ER), Calculated as ($B_{avg}/T_f$) = | 115.5 | |
| Erosion Rate Divided by Height of Water Over Base of Breach ($ER/H_w$) = | 5.8 | If 1.6 < ($ER/H_w$) < 21, Erosion Rate is Assumed Reasonable |

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# ESTIMATION OF DAM BREACH PARAMETERS
## USING THE FROEHLICH 2008 METHOD

**PROJECT:** GRAND MESA DAM #9

**BREACH INPUT PARAMETERS:**

| | | |
|---|---|---|
| Select Failure Mode From Drop-Down Menu: | OVERTOPPING | |
| Height of water over base elevation of breach ($H_w$) = | 15.1 | Feet |
| Volume of water in the reservoir at the time of failure ($V_w$) = | 268.0 | Acre-Feet |
| Reservoir Surface Area at Hw ($A_s$) = | 36.0 | Acres |
| Height of breach ($H_b$) = | 15.0 | Feet |
| Failure Mode Factor ($K_o$) = | 1.3 | |
| Breach Side-Slope Ratio ($Z_b$) = | 1 | Z(H):1(V) |
| Dam Size Class: | Small | Assumes Full Reservoir At Time of Breach. |

**CALCULATED BREACH CHARACTERISTICS:**

| | | |
|---|---|---|
| Average Breach Width ($B_{avg}$) = | 71.4 | Feet |
| Bottom Width of Breach ($B_b$) = | 56.4 | Feet |
| Breach Formation Time ($T_f$) = | 0.70 | Hours |
| Storage Intensity (SI) = | 17.7 | Acre Feet/Foot |
| Predicted Peak Flow ($Q_p$) = | 6945 | Cubic Feet per Second |

**RESULTS CHECK:**

| | | |
|---|---|---|
| Average Breach Width Divided by Height of Breach ($B_{avg}/H_b$) = | 4.76 | If ($B_{avg}/H_b$) > 0.6, Full Breach Devlopment is Anticipated |
| Erosion Rate (ER), Calculated as ($B_{avg}/T_f$) = | 101.4 | |
| Erosion Rate Divided by Height of Water Over Base of Breach ($ER/H_w$) = | 6.7 | If 1.6 < ($ER/H_w$) < 21, Erosion Rate is Assumed Reasonable |



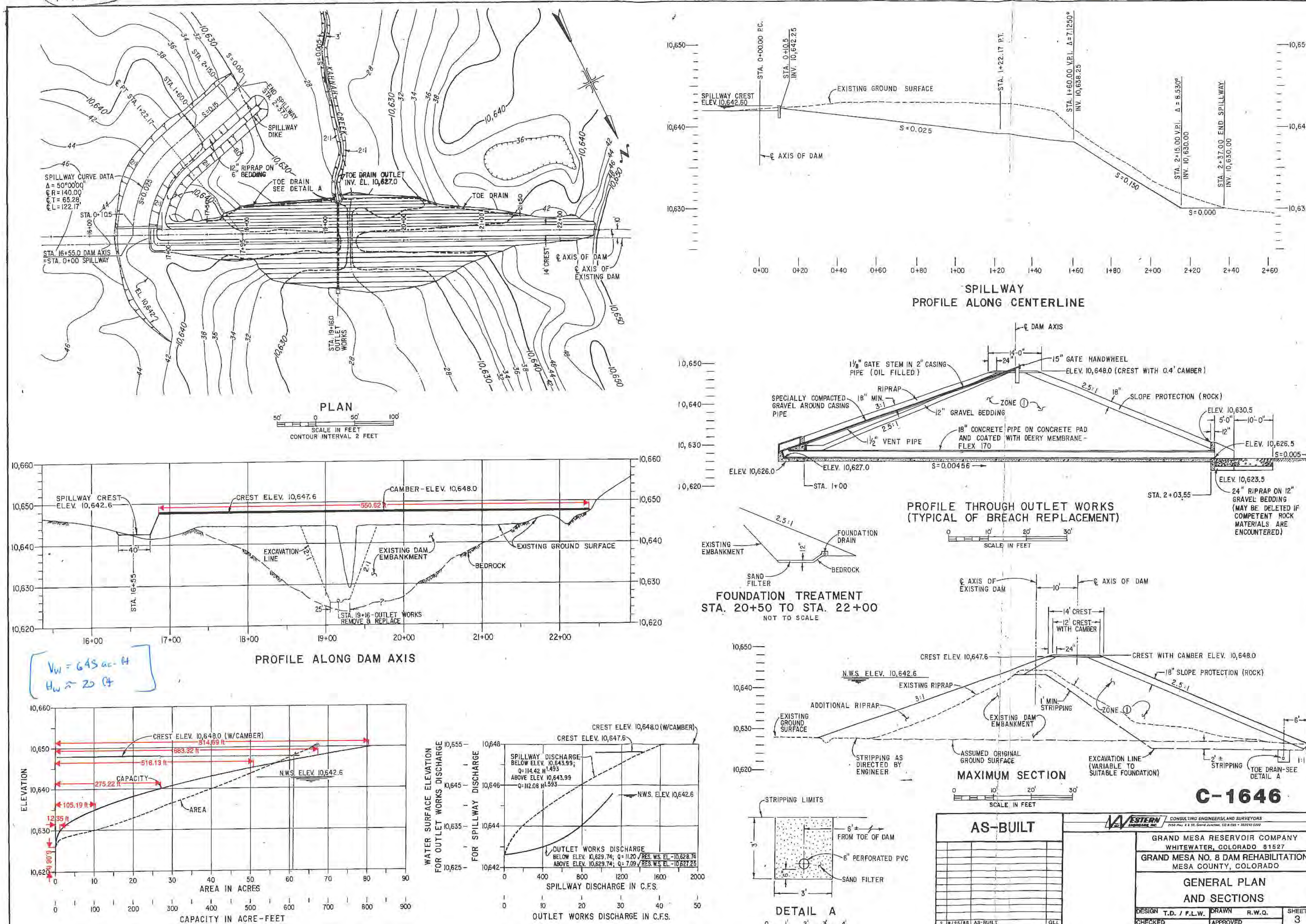
12/5/18 EMH

6

Farthen

Replace #2

12/5/18 EMH



# APPENDIX G

## CHANNEL ROUTING PARAMETERS

RJH CONSULTANTS, INC.

| | | | | | |
|---|---|---|---|---|---|
| | | Project | 18115 | Page | 1/5 |
| | | Date | 12/4/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/7/18 | By | EMH |
| Subject | Hogchute Dam Hydrology-Muskingum-Cunge XS and Manning's *n* | Approved | 12/13/18 | By | GOJ |

**Required**:

- Develop 8-point cross section for HEC-HMS reach and determine average reach (channel) slope.
- Determine associated roughness coefficients for channel and overbank areas.

**Assumptions**:

1.) Use ArcMap 10.4.2
2.) Use 2-ft contours from LiDAR point cloud in project area from Mesa County website
3.) Cross-section location selected such that the resulting 8-point cross-section is representative of most of the channel
4.) Channel slope = (Max. Elevation – Min. Elevation)/Reach Length
5.) Use V.T. Chow Open Channel Hydraulics (1959) Table 5-6 Values of the Roughness Coefficient *n* (p. 4 )

**Analysis:**

*Muskingum-Cunge Cross-Section*

- Cross-section location shown on p. 2
- 8-point cross-section stationing and elevation shown on p. 3
- Max./Min. elevations and length calculated in ArcMap 10.4.2

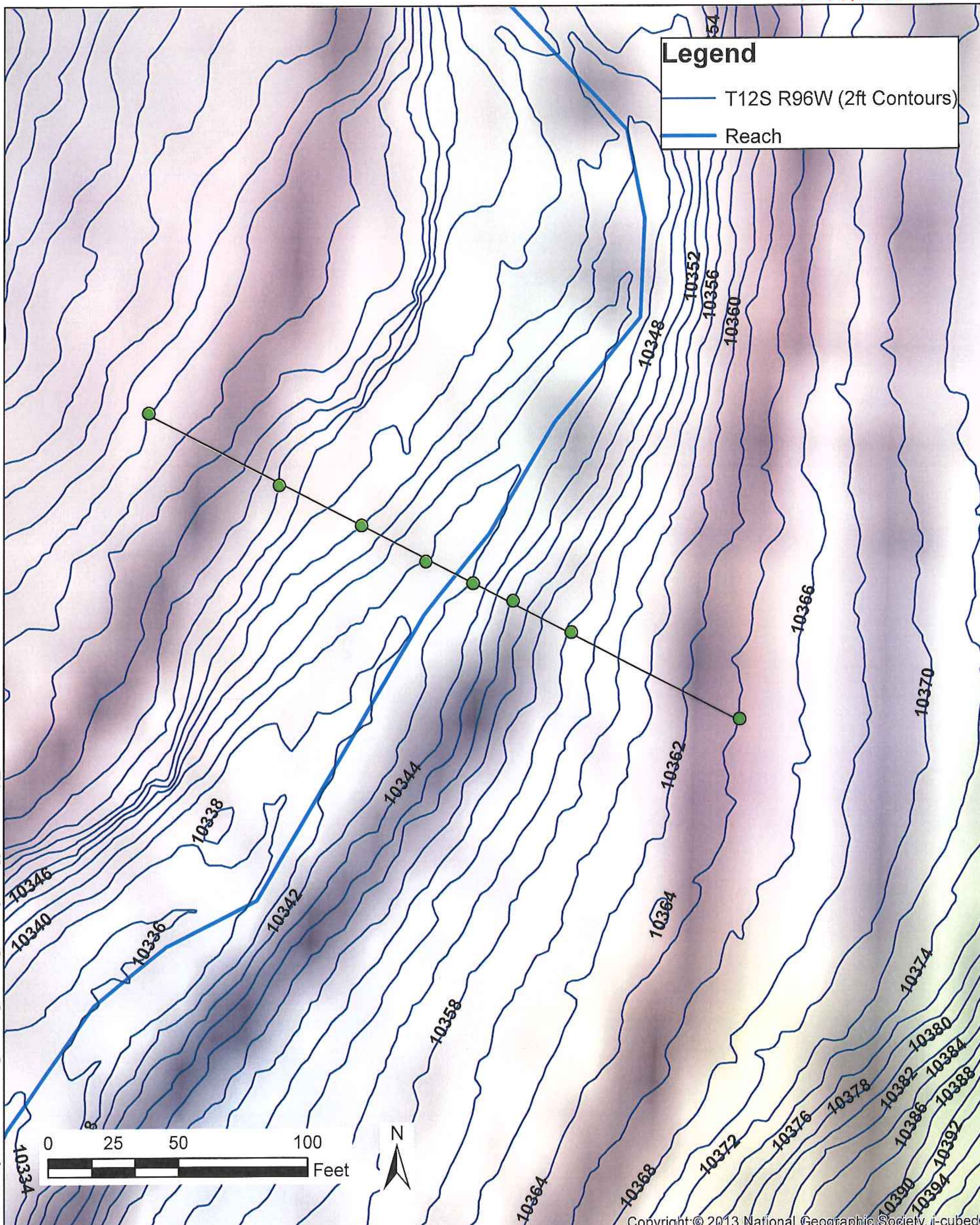
*Channel Roughness*

Using Chow (1959) (p. 4 )

| D. Natural Streams | Min. | Normal | Max. |
|---|---|---|---|
| D.2. Flood Plains | | | |
| C. Brush | | | |
| 3. Light brush and trees, summer | 0.04 | 0.06 | 0.08 |
| D. Tree | | | |
| 4. Heavy stand of timber, a few down trees, little undergrowth, flood storage below branches. | 0.08 | 0.10 | 0.12 |

For simplified Muskingum-Cunge cross section selection for reach characterization, select ***n* = 0.06** for the assumed roughness coefficient as the reach is predominantly brush and light trees with only heavy stand in the length closest to Carson Lake. (p. 5-8) ok

12/7/18 EMH ✓ 2




P:\18115 - Hogchute Dam Safety Evaluation\Engineering\GIS\Figures\Hydrology Work Map_2.mxd

| | | | |
|---|---|---|---|
| **THIS DOCUMENT MUST BE REPRODUCED IN COLOR**<br>**Datum: NAVD 1988** | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION - HYDROLOGY | MUSKINGUM-CUNGE CROSS SECTION |
| | | PROJECT NUMBER 18115 | November 2018 **Figure** |

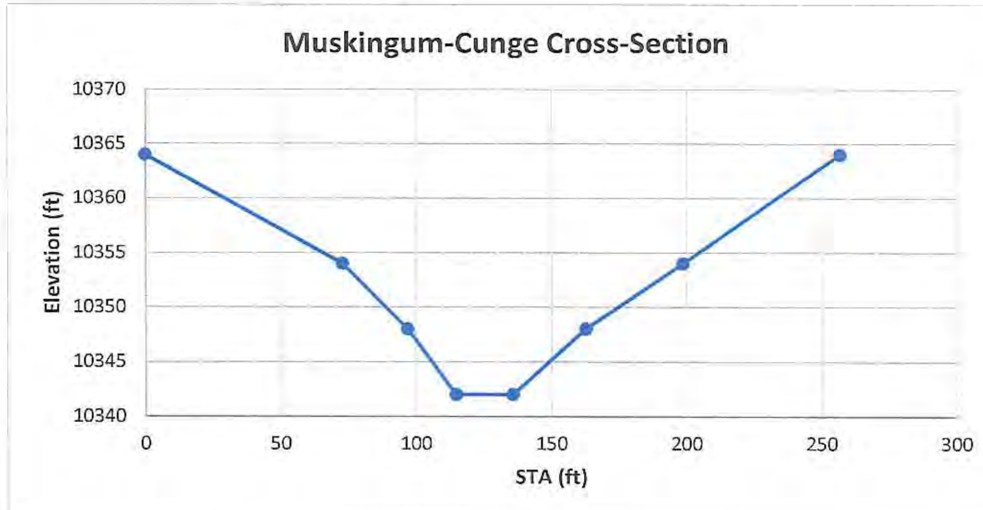
| | | | |
|---|---|---|---|
| By: | ATMerook | Date: | 12/5/2018 |
| Checked: | EMIT | Date: | 12/7/18 |
| Approved: | | Date: | |

Notes:

1. Reach defined as channel carrying flow from Grand Mesa Reservoir #9 to Carson Lake with no contribution from Lower subbasin.
2. Cross-section is generally representative of the entire reach length.
3. Elevation based on 2-ft contours downloaded from Mesa County website generated from LiDAR data.

| POINT | INCR. DIST. *FT* | STA *FT* | ELE *FT* |
|---|---|---|---|
| 1 | 0 | 0 | 10364 |
| 2 | 73 | 73 | 10354 |
| 3 | 24 | 97 | 10348 |
| 4 | 18 | 115 | 10342 |
| 5 | 21 | 136 | 10342 |
| 6 | 27 | 163 | 10348 |
| 7 | 36 | 199 | 10354 |
| 8 | 58 | 257 | 10364 |

| | |
|---|---|
| Max. Elevation (ft) | 10601 |
| Min. Elevation (ft) | 9990 |
| Length (ft) | 15165 |
| Slope (ft/ft) | 0.040 |



V.T. Chow Open Channel Hydraulics (1959)

4

12/5/18 EMH



TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT $n$ (*continued*)

| Type of channel and description | Minimum | Normal | Maximum |
|---|---|---|---|
| *b*. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages | | | |
| 1. Bottom: gravels, cobbles, and few boulders | 0.030 | 0.040 | 0.050 |
| 2. Bottom: cobbles with large boulders | 0.040 | 0.050 | 0.070 |
| D-2. Flood plains | | | |
| *a*. Pasture, no brush | | | |
| 1. Short grass | 0.025 | 0.030 | 0.035 |
| 2. High grass | 0.030 | 0.035 | 0.050 |
| *b*. Cultivated areas | | | |
| 1. No crop | 0.020 | 0.030 | 0.040 |
| 2. Mature row crops | 0.025 | 0.035 | 0.045 |
| 3. Mature field crops | 0.030 | 0.040 | 0.050 |
| *c*. Brush | | | |
| 1. Scattered brush, heavy weeds | 0.035 | 0.050 | 0.070 |
| 2. Light brush and trees, in winter | 0.035 | 0.050 | 0.060 |
| 3. Light brush and trees, in summer | 0.040 | 0.060 | 0.080 |
| 4. Medium to dense brush, in winter | 0.045 | 0.070 | 0.110 |
| 5. Medium to dense brush, in summer | 0.070 | 0.100 | 0.160 |
| *d*. Trees | | | |
| 1. Dense willows, summer, straight | 0.110 | 0.150 | 0.200 |
| 2. Cleared land with tree stumps, no sprouts | 0.030 | 0.040 | 0.050 |
| 3. Same as above, but with heavy growth of sprouts | 0.050 | 0.060 | 0.080 |
| 4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches | 0.080 | 0.100 | 0.120 |
| 5. Same as above, but with flood stage reaching branches | 0.100 | 0.120 | 0.160 |
| D-3. Major streams (top width at flood stage >100 ft). The $n$ value is less than that for minor streams of similar description, because banks offer less effective resistance. | | | |
| *a*. Regular section with no boulders or brush | 0.025 | ..... | 0.060 |
| *b*. Irregular and rough section | 0.035 | ..... | 0.100 |

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| | | | | | |
|---|---|---|---|---|---|
| | | Project | 18115 | Page | 5/5 |
| | | Date | 12/5/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/7/18 | By | EMH |
| Subject | Hogchute Dam Hydrology-Muskingum-Cunge XS and Manning's *n* | Approved | | By | |

Reach Overview:


- **Figure 1**. Reach spans from Grand Mesa #9 down to Carson Lake predominantly along Kannah Creek

Reach Description:

- The reach is bordered on both sides by brush grasses for most of its length.
- Approximately 2/3rds along reach, trees encroach on the floodplain and channel on the south side
- The final ~3500ft before terminating at Carson Lake are relatively heavily forested in the floodplain and overbank areas
- Typical Manning's $n$ = **0.06**

# APPENDIX H

# HEC-HMS MODEL INPUT AND OUTPUT

RJH CONSULTANTS, INC.

| | | | | | |
|---|---|---|---|---|---|
| | | Project | 18115 | Page | 1 |
| | | Date | 12/11/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/11/18 | By | EMH |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | 12/13/18 | By | GOJ |

**Required:**

Develop a HEC-HMS model for Hogchute Dam contributing subbasins using PMP depths from HMR 49 and the CO-NM REPS PMP Tool.

**References:**

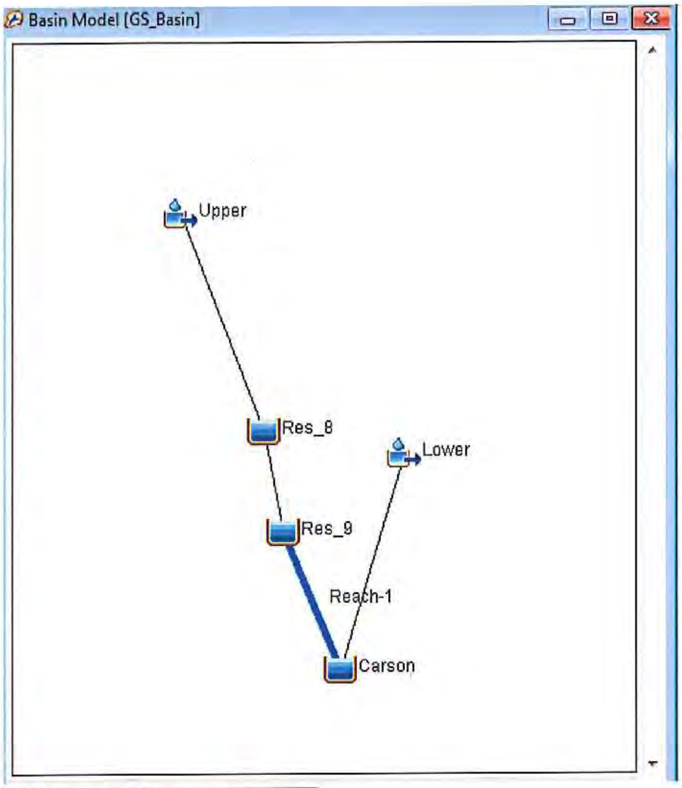
1.) RJH calculation package "Hogchute Dam Hydrology – Basin Parameters" dated 12/3/2018
2.) RJH calculation package "Hogchute Dam Hydrology – Lag Time and Unit Hydrograph" dated 12/3/2018
3.) RJH calculation package "Hogchute Dam Hydrology – PMP Initial and Constant Losses" dated 12/4/2018
4.) RJH calculation package "Hogchute Dam Hydrology – IDF Depth" dated 10/19/2018
5.) RJH calculation package "Hogchute Dam Hydrology – PMP from REPS Tool" dated 10/8/2018
6.) RJH calculation package "Hogchute Dam Hydrology – El-Cap and Spillway Rating Curves" dated 12/4/2018
7.) RJH calculation package "Hogchute Dam Hydrology – Dam Breach Parameters" dated 12/4/2018
8.) RJH calculation package "Hogchute Dam Hydrology – Muskingum-Cunge Channel Routing and Manning's *n*" dated 12/4/2018
9.) Topographic survey data from Mesa County at Hogchute Dam (p.17-18)

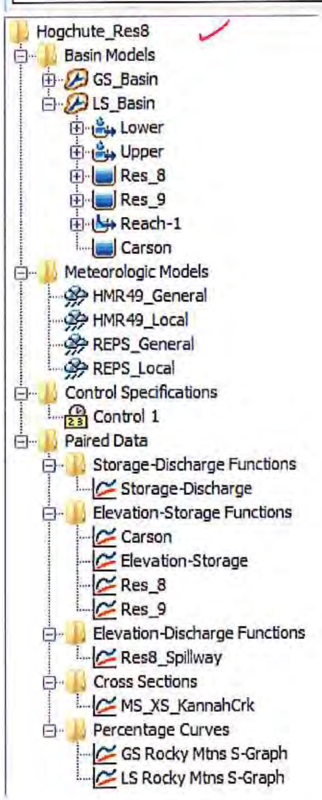
**Results:**

- See p.13 for HMR49 General Storm Results
    - Peak elevation does not overtop Hogchute Dam: 9902' – 9900.8' = **1.2' freeboard** ✓
- See p.14 for HMR49 Local Storm Results
    - Peak elevation overtops Hogchute Dam: 9905.6' – 9902' = **3.6' overtopping** ✓
- See p.15 for REPS General Storm Results
    - Peak elevation does not overtop Hogchute Dam: 9902' – 9901.3' = **0.7' of freeboard** ✓
- See p.16 for REPS Local Storm Results
    - Peak elevation overtops Hogchute Dam: 9906.9' – 9902' = **4.9' overtopping** ✓

| | | | | | |
|---|---|---|---|---|---|
| | | Project | 18115 | Page | 2 |
| | | Date | 12/11/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/12/18 | By | EMH |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | | By | |

**Model Setup:**




- Model setup is similar for both General and Local PMF evaluations

**Basin Model:**

- Element setup and Loss information same for both General and Local Storms. Transform information dependent on the chosen S-graph.

Upper Subbasin (*Upper*):

Subbasin | Loss | Transform | Options

| | |
|---|---|
| **Basin Name:** | **GS_Basin** |
| **Element Name:** | **Upper** |
| Description: | |
| Downstream: | Res_8 |
| *Area (MI2) | 3.58 |
| Latitude Degrees: | |
| Latitude Minutes: | |
| Latitude Seconds: | |
| Longitude Degrees: | |
| Longitude Minutes: | |
| Longitude Seconds: | |
| Canopy Method: | --None-- |
| Surface Method: | --None-- |
| Loss Method: | Initial and Constant |
| Transform Method: | User-Specified S-Graph |
| Baseflow Method: | --None-- |

Loss:

Subbasin | Loss | Transform | Options

| | |
|---|---|
| **Basin Name:** | **GS_Basin** |
| **Element Name:** | **Upper** |
| *Initial Loss (IN) | 0.6 |
| *Constant Rate (IN/HR) | 0.07 |
| *Impervious (%) | 1.4 |

Transform (General):

Subbasin | Loss | Transform | Options

| | |
|---|---|
| **Basin Name:** | **GS_Basin** |
| **Element Name:** | **Upper** |
| *S-Graph: | GS Rocky Mtns S-Graph |
| Method: | Standard |
| *Lag Time (HR) | 3.57 |

Transform (Local):

Subbasin | Loss | Transform | Options

| | |
|---|---|
| **Basin Name:** | **LS_Basin** |
| **Element Name:** | **Upper** |
| *S-Graph: | LS Rocky Mtns S-Graph |
| Method: | Standard |
| *Lag Time (HR) | 1.19 |

## Grand Mesa #8 Reservoir (*Res_8*):

Reservoir | Options

**Basin Name:** LS_Basin
**Element Name:** Res_8

| | |
|---|---|
| Description: | |
| Downstream: | Res_9 |
| Method: | Outflow Structures |
| Storage Method: | Elevation-Storage |
| *Elev-Stor Function: | Res_8 |
| Initial Condition: | Elevation |
| *Initial Elevation (FT) | 10642.6 ✓ |
| Main Tailwater: | Assume None |
| Auxiliary: | --None-- |
| Time Step Method: | Automatic Adaption |
| Outlets: | 0 |
| Spillways: | 1 |
| Dam Tops: | 1 |
| Pumps: | 0 |
| Dam Break: | Yes |
| Dam Seepage: | No |
| Release: | No |
| Evaporation: | No |

## Spillway:

Reservoir | Spillway 1 | Options ✓

**Basin Name:** LS_Basin
**Element Name:** Res_8

| | |
|---|---|
| Method: | Specified Spillway |
| Direction: | Main |
| *Rating Curve: | Res8_Spillway |

## Dam Top:

Reservoir | Dam Top 1 | Options

**Basin Name:** LS_Basin
**Element Name:** Res_8

| | |
|---|---|
| Method: | Level Overflow |
| Direction: | Main |
| *Elevation (FT) | 10647.6 ✓ |
| *Length (FT) | 550.6 ✓ |
| *Coefficient (FT^0.5/S) | 2.63 ✓ |

## Dam Break:

Reservoir | Dam Break | Options

**Basin Name:** LS_Basin
**Element Name:** Res_8

| | |
|---|---|
| Method: | Overtop Breach |
| Direction: | Main |
| *Top Elevation (FT) | 10648 ✓ |
| *Bottom Elevation (FT) | 10628 ✓ |
| *Bottom Width (FT) | 77.6 ✓ |
| *Left Slope (xH:1V) | 1 ✓ |
| *Right Slope (xH:1V) | 1 ✓ |
| *Development Time (HR) | 0.84 ✓ |
| Trigger Method: | Elevation |
| *Trigger Elevation (FT) | 10648 ✓ |
| Progression Method: | Linear |

Grand Mesa #9 Reservoir (*Res_9*):

Reservoir | Dam Break | Options

**Basin Name: GS_Basin**
**Element Name: Res_9**

| | |
|---|---|
| Description: | |
| Downstream: | Reach-1 |
| Method: | Outflow Structures |
| Storage Method: | Elevation-Storage |
| *Elev-Stor Function: | Res_9 |
| Initial Condition: | Elevation |
| *Initial Elevation (FT) | 10613 |
| Main Tailwater: | Assume None |
| Auxiliary: | --None-- |
| Time Step Method: | Automatic Adaption |
| Outlets: | 0 |
| Spillways: | 1 |
| Dam Tops: | 1 |
| Pumps: | 0 |
| Dam Break: | Yes |

Spillway:

Reservoir | Spillway 1 | Options

**Basin Name: GS_Basin**
**Element Name: Res_9**

| | |
|---|---|
| Method: | Broad-Crested Spillway |
| Direction: | Main |
| *Elevation (FT) | 10613 |
| *Length (FT) | 15 |
| *Coefficient (FT^0.5/S) | 2.65 |
| Gates: | 0 |

Dam Top:

Reservoir | Dam Top 1 | Options

**Basin Name: GS_Basin**
**Element Name: Res_9**

| | |
|---|---|
| Method: | Level Overflow |
| Direction: | Main |
| *Elevation (FT) | 10616 |
| *Length (FT) | 600 |
| *Coefficient (FT^0.5/S) | 2.65 |

Dam Break:

Reservoir | Dam Break | Options

**Basin Name: GS_Basin**
**Element Name: Res_9**

| | |
|---|---|
| Method: | Overtop Breach |
| Direction: | Main |
| *Top Elevation (FT) | 10616 |
| *Bottom Elevation (FT) | 10601 |
| *Bottom Width (FT) | 56.4 |
| *Left Slope (xH:1V) | 1 |
| *Right Slope (xH:1V) | 1 |
| *Development Time (HR) | 0.7 |
| Trigger Method: | Elevation |
| *Trigger Elevation (FT) | 10616 |
| Progression Method: | Linear |

Reach 1 (*Reach-1*):

Reach | Routing | Options

**Basin Name: GS_Basin**
**Element Name: Reach-1**

| | |
|---|---|
| Time Step Method: | Automatic Fixed Interval |
| *Length (FT) | 15165 ✓ |
| *Slope (FT/FT) | 0.0435 ✓ |
| *Manning's n: | 0.06 ✓ |
| Invert (FT) | |
| Shape: | Eight Point |
| *Left Manning's n: | 0.06 ✓ |
| *Right Manning's n: | 0.06 ✓ |
| *Cross Section: | MS_XS_KannahCrk |

Lower Subbasin (*Lower*):

Subbasin | Loss | Transform | Options

**Basin Name: GS_Basin**
**Element Name: Lower**

| | |
|---|---|
| Description: | |
| Downstream: | Carson |
| *Area (MI2) | 8.33 ✓ |
| Latitude Degrees: | |
| Latitude Minutes: | |
| Latitude Seconds: | |
| Longitude Degrees: | |
| Longitude Minutes: | |
| Longitude Seconds: | |
| Canopy Method: | --None-- |
| Surface Method: | --None-- |
| Loss Method: | Initial and Constant |
| Transform Method: | User-Specified S-Graph |
| Baseflow Method: | --None-- |

Loss:

Subbasin | Loss | Transform | Options

**Basin Name: GS_Basin**
**Element Name: Lower**

| | |
|---|---|
| *Initial Loss (IN) | 0.6 ✓ |
| *Constant Rate (IN/HR) | 0.08 ✓ |
| *Impervious (%) | 4.1 ✓ |

Transform (General):

Subbasin | Loss | Transform | Options

**Basin Name: GS_Basin**
**Element Name: Lower**

| | |
|---|---|
| *S-Graph: | GS Rocky Mtns S-Graph |
| Method: | Standard |
| *Lag Time (HR) | 4.35 ✓ |

Transform (Local):

Subbasin | Loss | Transform | Options

**Basin Name: LS_Basin**
**Element Name: Lower**

| | |
|---|---|
| *S-Graph: | LS Rocky Mtns S-Graph |
| Method: | Standard |
| *Lag Time (HR) | 1.45 ✓ |

Carson Lake (*Carson*):

Reservoir | Options

**Basin Name: GS_Basin**
**Element Name: Carson**

| | |
|---|---|
| Description: | |
| Downstream: | --None-- |
| Method: | Outflow Curve |
| Storage Method: | Elevation-Storage-Discharge |
| *Stor-Dis Function: | Storage-Discharge |
| *Elev-Stor Function: | Carson |
| Primary: | Storage-Discharge |
| Initial Condition: | Elevation |
| *Initial Elevation (FT) | 9895 |

## Meteorological Models:

General PMF (HMR49):

Frequency Storm

**Met Name: HMR49_General**

| | |
|---|---|
| Probability: | Other |
| Input Type: | Partial Duration |
| Output Type: | Annual Duration |
| Intensity Duration: | 1 Hour |
| Storm Duration: | 4 Days |
| Intensity Position: | 50 Percent |
| Storm Area (MI2) | 0.01 |
| Curve: | Uniform For All Subbasins |

| Duration | Partial-Duration Depth (IN) |
|---|---|
| 5 Minutes | |
| 15 Minutes | |
| 1 Hour | 1.3000 |
| 2 Hours | 2.6000 |
| 3 Hours | 3.6000 |
| 6 Hours | 5.4000 |
| 12 Hours | 7.6000 |
| 1 Day | 10.200 |
| 2 Days | 13.400 |
| 4 Days | 15.000 |

Local PMF (HMR49):

Frequency Storm

**Met Name: HMR49_Local**

| | |
|---|---|
| Probability: | Other |
| Input Type: | Partial Duration |
| Output Type: | Annual Duration |
| Intensity Duration: | 5 Minutes |
| Storm Duration: | 6 Hours |
| Intensity Position: | 50 Percent |
| Storm Area (MI2) | 0.01 |
| Curve: | Uniform For All Subbasins |

| Duration | Partial-Duration Depth (IN) |
|---|---|
| 5 Minutes | 1.3000 |
| 15 Minutes | 2.8000 |
| 1 Hour | 4.4000 |
| 2 Hours | 5.0000 |
| 3 Hours | 5.5000 |
| 6 Hours | 6.2000 |

General PMF (REPS PMP Tool):

Frequency Storm

**Met Name: REPS_General**

| | |
|---|---|
| Probability: | Other |
| Input Type: | Partial Duration |
| Output Type: | Annual Duration |
| Intensity Duration: | 1 Hour |
| Storm Duration: | 4 Days |
| Intensity Position: | 50 Percent |
| Storm Area (MI2) | 0.01 |
| Curve: | Uniform For All Subbasins |

| Duration | Partial-Duration Depth (IN) |
|---|---|
| 5 Minutes | |
| 15 Minutes | |
| 1 Hour | 1.2000 |
| 2 Hours | 2.0000 |
| 3 Hours | 2.9000 |
| 6 Hours | 5.0000 |
| 12 Hours | 8.1000 |
| 1 Day | 9.3000 |
| 2 Days | 13.800 |
| 4 Days | 14.100 |

Local PMF (REPS PMP Tool):

Frequency Storm

**Met Name: REPS_Local**

| | |
|---|---|
| Probability: | Other |
| Input Type: | Partial Duration |
| Output Type: | Annual Duration |
| Intensity Duration: | 5 Minutes |
| Storm Duration: | 1 Day |
| Intensity Position: | 50 Percent |
| Storm Area (MI2) | 0.01 |
| Curve: | Uniform For All Subbasins |

| Duration | Partial-Duration Depth (IN) |
|---|---|
| 5 Minutes | 0.70000 |
| 15 Minutes | 1.8100 |
| 1 Hour | 4.6400 |
| 2 Hours | 7.6100 |
| 3 Hours | 7.6100 |
| 6 Hours | 7.6100 |
| 12 Hours | 7.6400 |
| 1 Day | 7.6400 |

| | | | | | |
|---|---|---|---|---|---|
| RJH CONSULTANTS, INC. | | Project | 18115 | Page | 9 |
| | | Date | 12/11/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/11/18 | By | EM17 |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | | By | |

**Control Specifications:**

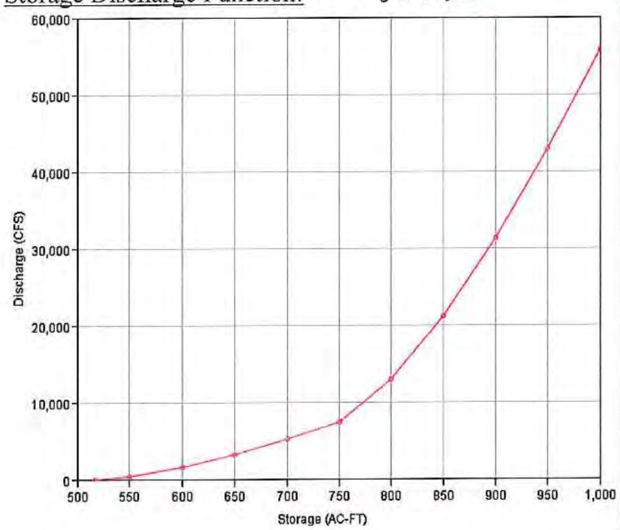
Control 1:

Control Specifications

Name: Control 1
Description:
*Start Date (ddMMMYYYY) 01Jan2000
*Start Time (HH:mm) 00:00
*End Date (ddMMMYYYY) 08Jan2000
*End Time (HH:mm) 00:00
Time Interval: 1 Minute

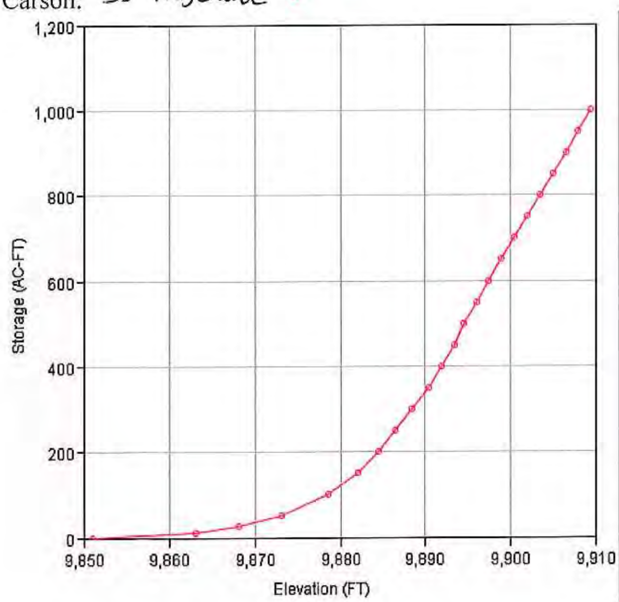
**Paired Data:**

Storage Discharge Function: → Hogchute ✓



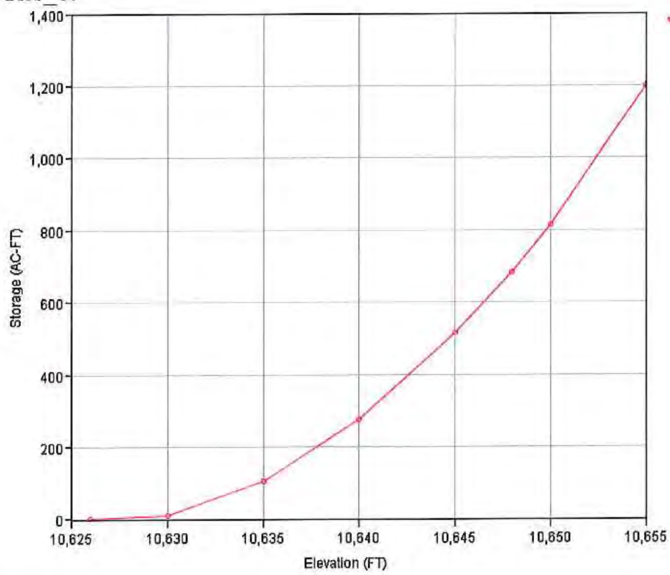

Elevation-Storage Functions:

Carson: → Hogchute ✓

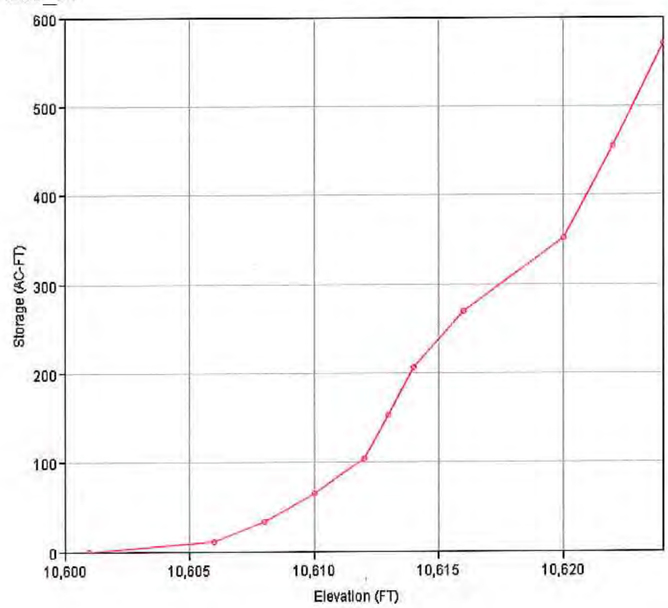


| | | | | |
|---|---|---|---|---|
| CONSULTANTS, INC. | | Project 18115 | Page | 16 |
| | | Date 12/11/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked 12/11/18 | By | EMH |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | By | |

Res_8:



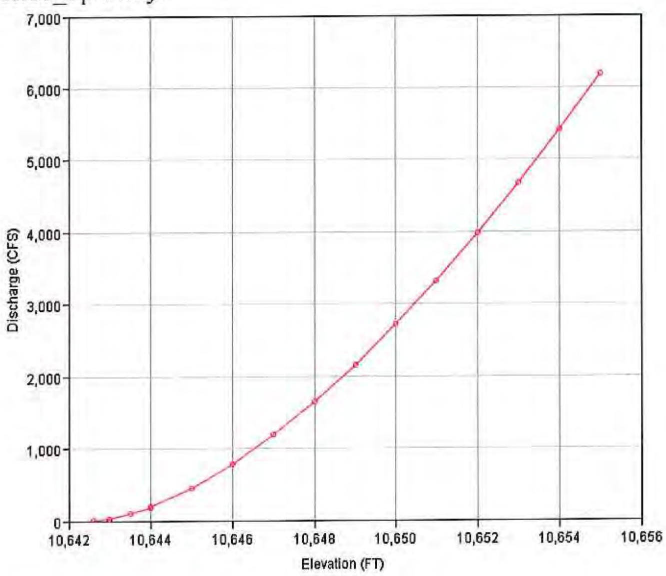

Res_9:



| | | | | | |
|---|---|---|---|---|---|
| | | Project | 18115 | Page | 11 |
| | | Date | 12/11/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/11/18 | By | EMH |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | | By | |

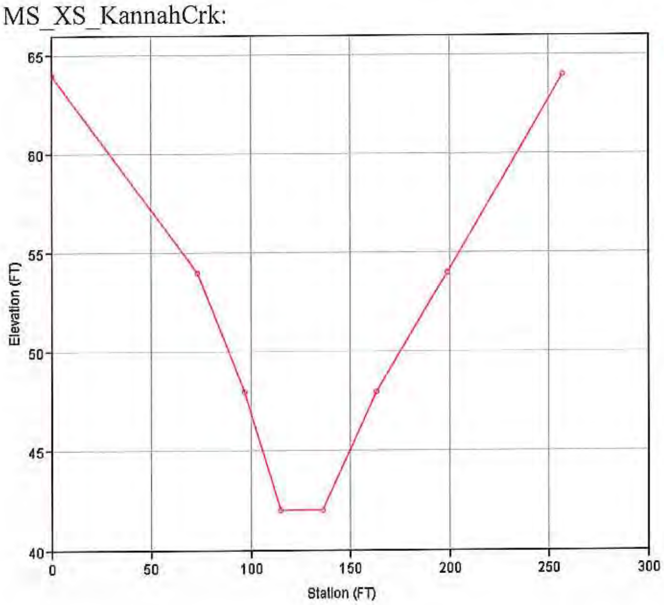
Elevation-Discharge Functions:

Res8_Spillway:




Cross Sections:

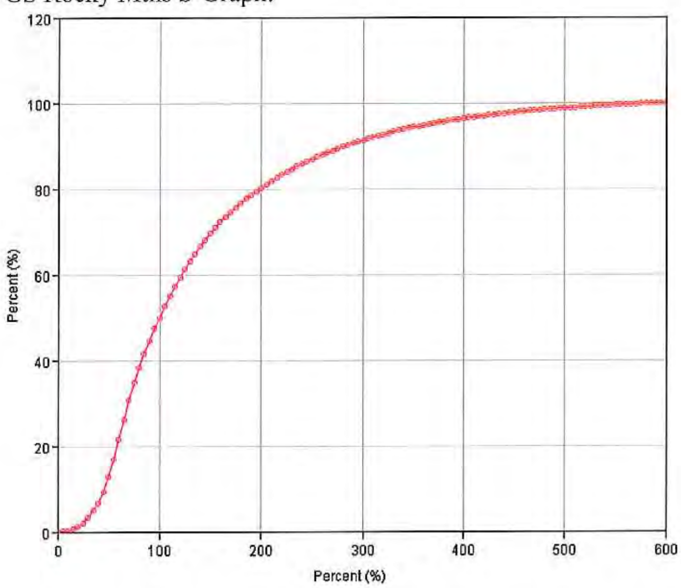
MS_XS_KannahCrk:



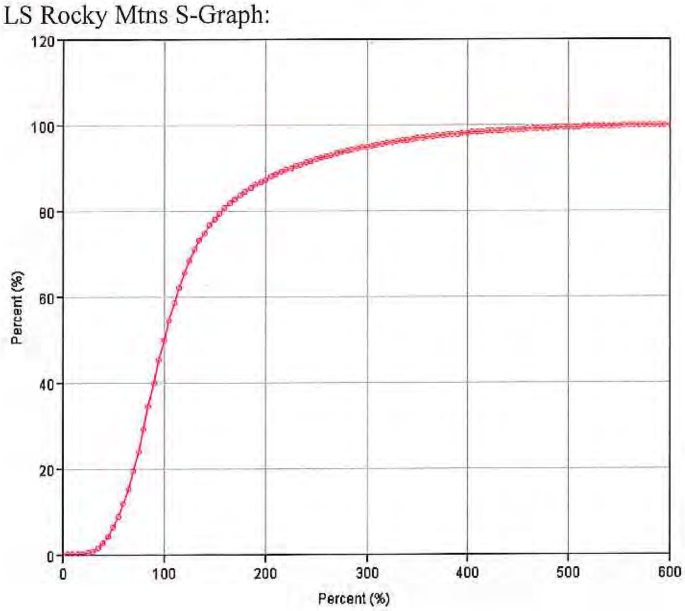
| | | | | | |
|---|---|---|---|---|---|
| | | Project | 18115 | Page | 12 |
| | | Date | 12/11/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/11/18 | By | EMH |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | | By | |

Percentage Curves:

GS Rocky Mtns S-Graph:



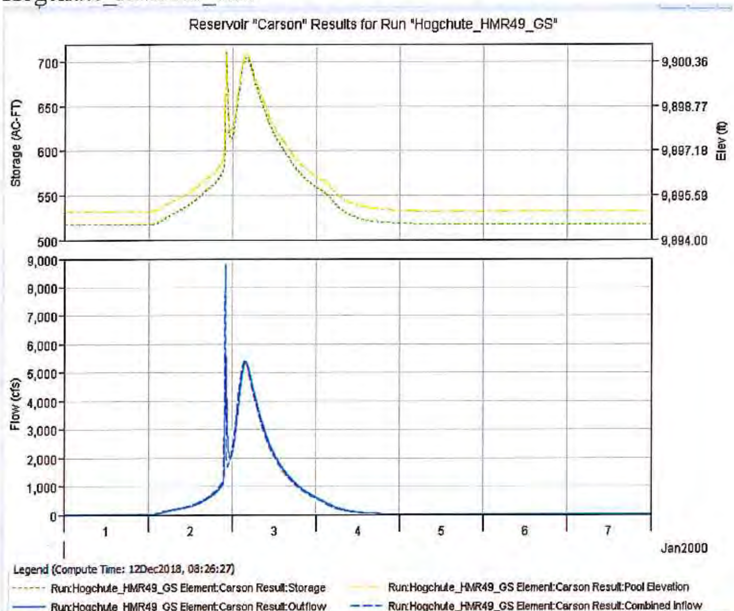

LS Rocky Mtns S-Graph:



| | | | | | |
|---|---|---|---|---|---|
| RJH CONSULTANTS, INC. | | Project | 18115 | Page | 13 |
| | | Date | 12/11/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/11/18 | By | EMH |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | | By | |

**Results:**

Hogchute_HMR49_GS:




Summary Results for Reservoir "Carson"

Project: Hogchute_Res8 Simulation Run: Hogchute_HMR49_GS
Reservoir: Carson

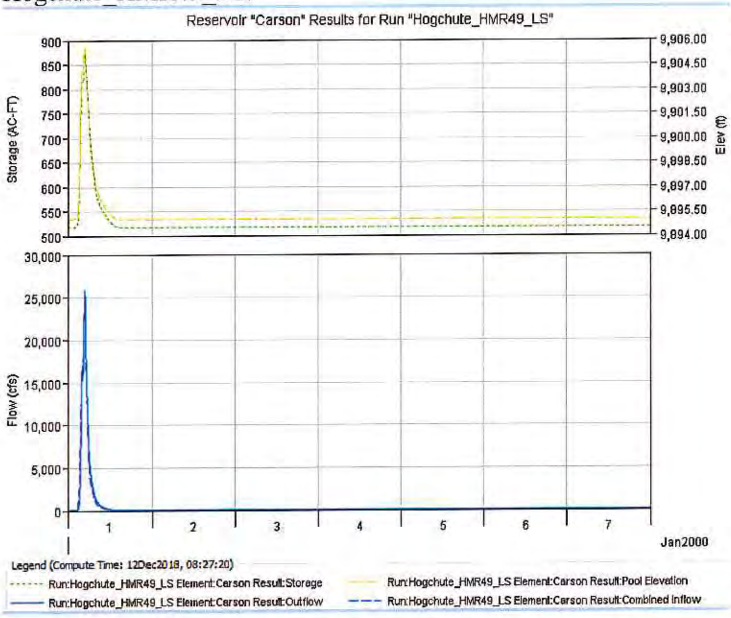
| | | | |
|---|---|---|---|
| Start of Run: | 01Jan2000, 00:00 | Basin Model: | GS_Basin |
| End of Run: | 08Jan2000, 00:00 | Meteorologic Model: | HMR49_General |
| Compute Time: | 12Dec2018, 08:26:27 | Control Specifications: | Control 1 |

Volume Units: IN ◉ AC-FT

Computed Results

| | | | |
|---|---|---|---|
| Peak Inflow: | 8793.3 (CFS) | Date/Time of Peak Inflow: | 02Jan2000, 22:02 |
| Peak Discharge: | 5578.1 (CFS) | Date/Time of Peak Discharge: | 02Jan2000, 22:12 |
| Inflow Volume: | 6429.5 (AC-FT) | Peak Storage: | 709.3 (AC-FT) |
| Discharge Volume: | 6429.5 (AC-FT) | Peak Elevation: | 9900.8 (FT) |

Hogchute_HMR49_LS:




Project: Hogchute_Res8 Simulation Run: Hogchute_HMR49_LS
Reservoir: Carson

| | | | |
|---|---|---|---|
| Start of Run: | 01Jan2000, 00:00 | Basin Model: | LS_Basin |
| End of Run: | 08Jan2000, 00:00 | Meteorologic Model: | HMR49_Local |
| Compute Time: | 12Dec2018, 08:27:20 | Control Specifications: | Control 1 |

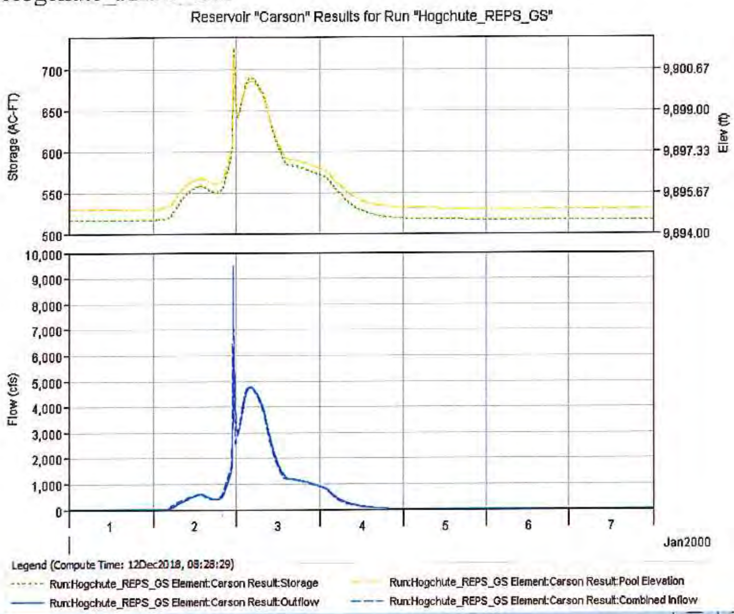
Volume Units: IN AC-FT

Computed Results

| | | | |
|---|---|---|---|
| Peak Inflow: | 25781.6 (CFS) | Date/Time of Peak Inflow: | 01Jan2000, 05:00 |
| Peak Discharge: | 25407.6 (CFS) | Date/Time of Peak Discharge: | 01Jan2000, 05:03 |
| Inflow Volume: | 3927.7 (AC-FT) | Peak Storage: | 870.9 (AC-FT) |
| Discharge Volume: | 3927.7 (AC-FT) | Peak Elevation: | 9905.6 (FT) |

| | | | | | |
|---|---|---|---|---|---|
| RJH CONSULTANTS, INC. | | Project | 18115 | Page | 15 |
| | | Date | 12/11/2018 | By | ATMerook |
| Client | City of Grand Junction | Checked | 12/11/18 | By | EMH |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | | By | |

Hogchute_REPS_GS:




Project: Hogchute_Res8 Simulation Run: Hogchute_REPS_GS
Reservoir: Carson

| | | | |
|---|---|---|---|
| Start of Run: | 01Jan2000, 00:00 | Basin Model: | GS_Basin |
| End of Run: | 08Jan2000, 00:00 | Meteorologic Model: | REPS_General |
| Compute Time: | 12Dec2018, 08:28:29 | Control Specifications: | Control 1 |

Volume Units: IN AC-FT

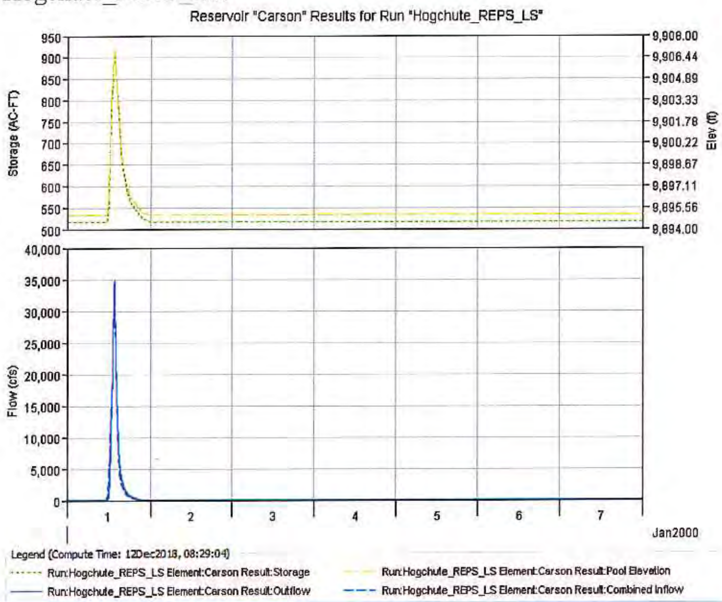
Computed Results

| | | | |
|---|---|---|---|
| Peak Inflow: | 9456.2 (CFS) | Date/Time of Peak Inflow: | 02Jan2000, 23:13 |
| Peak Discharge: | 6358.0 (CFS) | Date/Time of Peak Discharge: | 02Jan2000, 23:23 |
| Inflow Volume: | 10.24 (IN) | Peak Storage: | 726.6 (AC-FT) |
| Discharge Volume: | 10.24 (IN) | Peak Elevation: | 9901.3 (FT) |

RJH CONSULTANTS, INC.

| | | | | | |
|---|---|---|---|---|---|
| Client | City of Grand Junction | Project | 18115 | Page | 16 |
| | | Date | 12/11/2018 | By | ATMerook |
| | | Checked | 12/11/18 | By | EMH |
| Subject | Hogchute Dam Hydrology: HEC-HMS Model | Approved | | By | |

Hogchute_REPS_LS:




Project: Hogchute_Res8   Simulation Run: Hogchute_REPS_LS
Reservoir: Carson

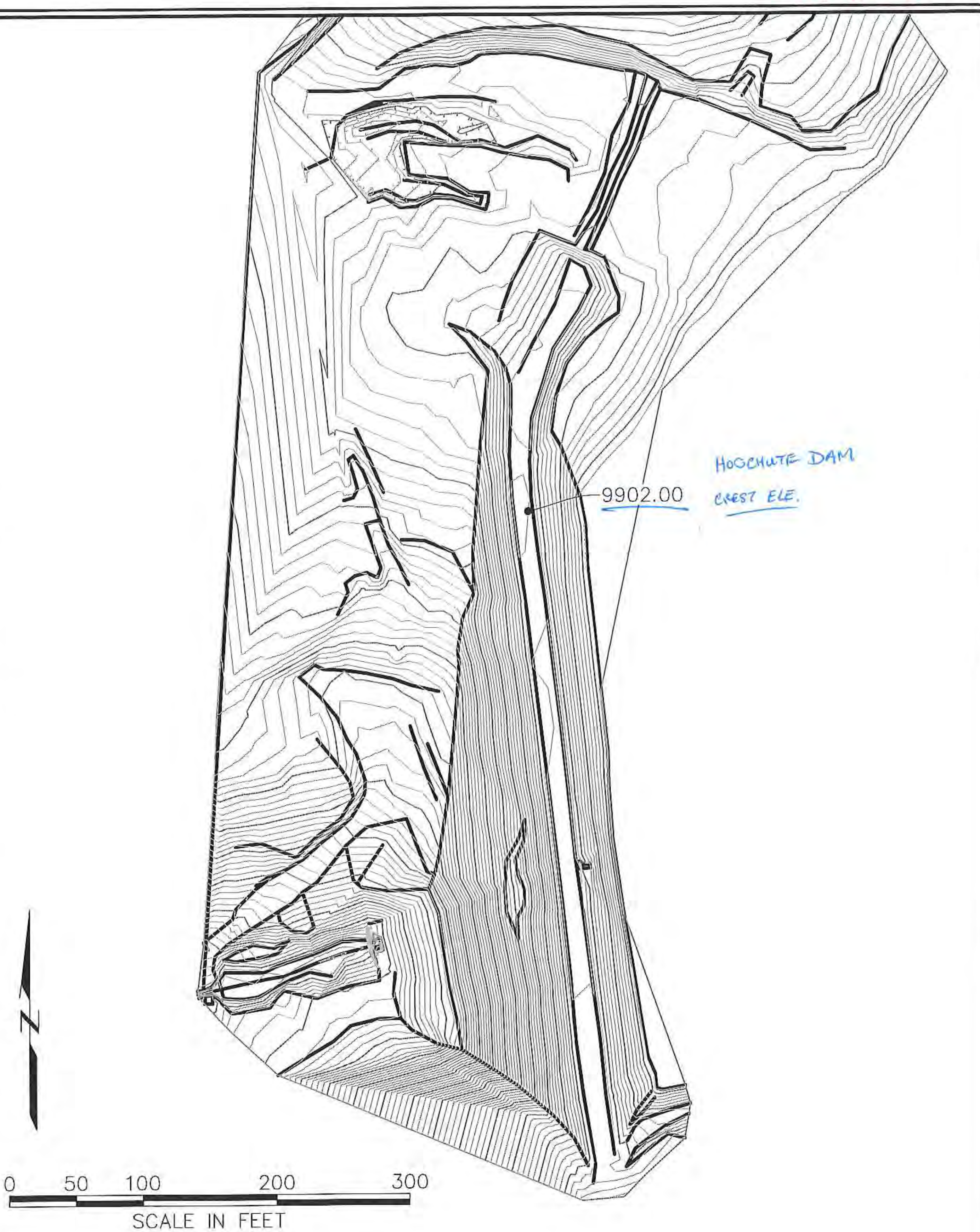
| | | | |
|---|---|---|---|
| Start of Run: | 01Jan2000, 00:00 | Basin Model: | LS_Basin |
| End of Run: | 08Jan2000, 00:00 | Meteorologic Model: | REPS_Local |
| Compute Time: | 12Dec2018, 08:29:04 | Control Specifications: | Control 1 |

Volume Units: ◯ IN ◉ AC-FT

Computed Results

| | | | |
|---|---|---|---|
| Peak Inflow: | 35097.2 (CFS) | Date/Time of Peak Inflow: | 01Jan2000, 13:51 |
| Peak Discharge: | 34628.9 (CFS) | Date/Time of Peak Discharge: | 01Jan2000, 13:54 |
| Inflow Volume: | 4937.4 (AC-FT) | Peak Storage: | 914.4 (AC-FT) |
| Discharge Volume: | 4937.4 (AC-FT) | Peak Elevation: | 9906.9 (FT) |

✓ 12/11/18 EMH 17




P:\18115 - HOGCHUTE DAM SAFETY EVALUATION\CAD\SURVEY\18115_20181211_EXITINGHOGCHUTESURVEY.DWG 12/11/2018 12:33 PM

| | | |
|---|---|---|
| RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION | EXISTING TOPO CREST EL. 9902.0 |
| | PROJECT NO. 18115 | December 2018 **Figure** |

| | | | |
|---|---|---|---|
| **By:** | ATMerook | **Date:** | 12/11/2018 |
| **Checked:** | BMH | **Date:** | 12/11/18 |
| **Approved:** | | **Date:** | |

| **Gage Ele.**[(1)] *FT* | **Absolute Ele.**[(2)] *FT* | **Storage** *AC-FT* |
|---|---|---|
| 100 | 9851 | 0 |
| 112 | 9863 | 10 |
| 117 | 9868 | 25 |
| 122 | 9873 | 50 |
| 127.5 | 9878.5 | 100 |
| 131 | 9882 | 150 |
| 133.5 | 9884.5 | 200 |
| 135.5 | 9886.5 | 250 |
| 137.5 | 9888.5 | 300 |
| 139.5 | 9890.5 | 350 |
| 141 | 9892 | 400 |
| 142.5 | 9893.5 | 450 |
| 143.5 | 9894.5 | 500 |
| 145 | 9896 | 550 |
| 146.5 | 9897.5 | 600 |
| 148 | 9899 | 650 |
| 149.5 | 9900.5 | 700 |
| 151 | 9902 | 750 |
| 152.5 | 9903.5 | 800 |
| 154 | 9905 | 850 |
| 155.5 | 9906.5 | 900 |
| 157 | 9908 | 950 |
| 158.5 | 9909.5 | 1000 |

**Notes:**

**1** Gage elevation from construction drawings in Reference #6.

**2** Correlation between gage and absolute elevation use Mesa County topographic survey data to define the dam crest elevation as 9902.0 from Reference #10.

# APPENDIX D

# GEOTECHNICAL DATA REPORT

CONSULTANTS, INC.

*GEOTECHNICAL AND*
*WATER RESOURCES ENGINEERING*

# GEOTECHNICAL DATA REPORT

## HOGCHUTE DAM (AKA CARSON LAKE)
## DAM ID 420127
### MESA COUNTY, COLORADO

Submitted to
**City of Grand Junction**
250 North 5th Street
Grand Junction, CO 81501

Submitted by
**RJH Consultants, Inc.**
9800 Mt. Pyramid Court, Suite 330
Englewood, Colorado 80112
303-225-4611
www.rjh-consultants.com

January 2019
Project 181155

COLORADO REGISTERED
GARRETT O. JACKSON
1/4/19
29302
PROFESSIONAL ENGINEER

Garrett O. Jackson, P.E.
Project Manager

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## LIST OF TABLES



## LIST OF FIGURES



## APPENDICES

# SECTION 1 - INTRODUCTION

## 1.1 Objective and Purpose

The City of Grand Junction (City) retained RJH Consultants, Inc. (RJH) to provide engineering services for the Hogchute Dam Safety Evaluation Project (Project). The purpose of this Geotechnical Data Report (Report) is to present data collected by RJH to support engineering evaluations of potential dam safety issues that have been identified by the Colorado Office of the State Engineer (SEO) as part of a Comprehensive Dam Safety Evaluation (CDSE). The engineering evaluations are presented in a separate dam safety evaluation report.

## 1.2 Background

Hogchute Dam (DAMID 420127) is located in Mesa County, Colorado, approximately 22 miles east-southeast of Grand Junction (Site). The dam is a 56-foot-high earth structure that impounds Carson Lake on Kannah Creek at an elevation (El.) of about 9,900 feet in the Grand Mesa National Forest. The reservoir provides water storage for domestic use, irrigation, and fishing recreation. A Site vicinity map is shown on Figure 1.1.

Based on design records, the dam was constructed in 1947, with a low-permeability earthen core protected by upstream and downstream rock shells of gravels, cobbles, and boulders. The embankment was designed to have an 18-foot-wide crest, 3 horizontal to 1 vertical (H:V) upstream slope, and 2H:1V downstream slope. A plan of the dam is shown on Figure 1.2. The outlet works consists of two 20-inch welded steel pipes with hydraulic slide gates at the upstream toe of the dam. The 20-inch pipes converge within the dam into a single 30-inch conduit that discharges into a rock-lined basin at the downstream toe of the dam. There appears to also be a 12-inch outlet gate installed on a 12-inch pipe between the two 20-inch conduits, but the configuration and use of this gate are not clear. The unlined emergency spillway is located at the north (right) end of the dam.

In 1988, the City relocated the outlet control structure from the downstream toe to the crest of the dam. At about the same time, the City extended the 8-inch toe drain discharge pipe into the outlet discharge basin. The work to move the outlet controls and extend the toe drain discharge is described in a 1988 letter, which also includes some photographs of the toe drain work. There are no other construction records for the dam. The City has a four-sheet plan set, dated 1947, that appears to show the original design.

In 2015, the SEO changed the dam's hazard classification to high hazard, based on inundation mapping performed by the City to assess the impacts of a potential dam failure on downstream development that had occurred since construction of the dam. Several SEO dam safety inspection reports over the years have mentioned concerns for undocumented seepage (not collected and not monitored), the absence of any filtering of the embankment core material, apparently broken outlet gate air vents, and the deteriorated condition of the spillway.

In 2017, the SEO performed a CDSE to assess the overall safety of the dam and provide the City with guidance in planning needed dam improvements.

## 1.3 RJH Scope of Work

RJH performed the following for the data collection phase of the Project:

- Reviewed documents provided by City and SEO.
- Prepared a base topographic map of the Site based on survey data provided by the City.
- Prepared for fieldwork, which included preparing a Project-specific Health and Safety Plan (HASP), coordinating utility clearances, and developing a Drilling and Site Investigation Plan for SEO review and approval.
- Drilled, sampled, and logged seven borings. Six borings were completed as open-standpipe monitoring wells and one boring was backfilled with cement-bentonite grout.
- Surveyed the locations of RJH's borings and monitoring wells using a handheld Global Positioning System (GPS).
- Prepared Daily Site Reports to document field activities.
- Performed quality assurance review of collected samples and field logs by a senior engineer.
- Performed laboratory tests on representative samples from the borings.
- Prepared final boring logs based on the field logs, quality assurance review, and laboratory test results.
- Prepared this Report.

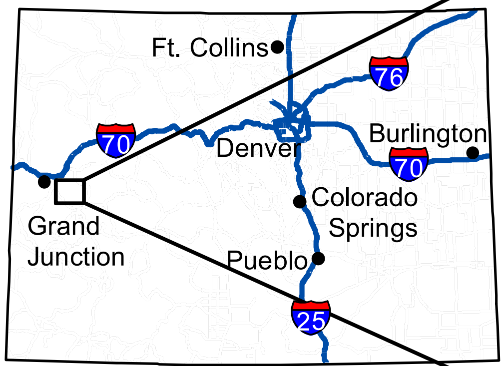
## 1.4 Authorization

This work was performed in general accordance with the terms and conditions of the Professional Services Contract RFP-4519-18-DH between the City and RJH, dated June 26, 2018 and a Contract Modification Request, dated September 12, 2018. Drilling was performed in general conformance with the Drilling and Site Investigation Plan approved by the SEO on July 16, 2018 and Addendum approved with contingencies by the SEO on August 28, 2018.

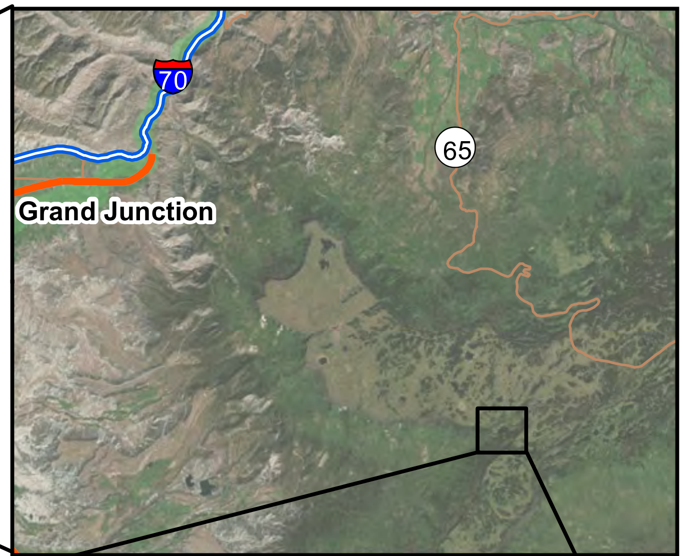
## 1.5 Project Personnel

The following personnel from RJH are responsible for the work contained in this Report:

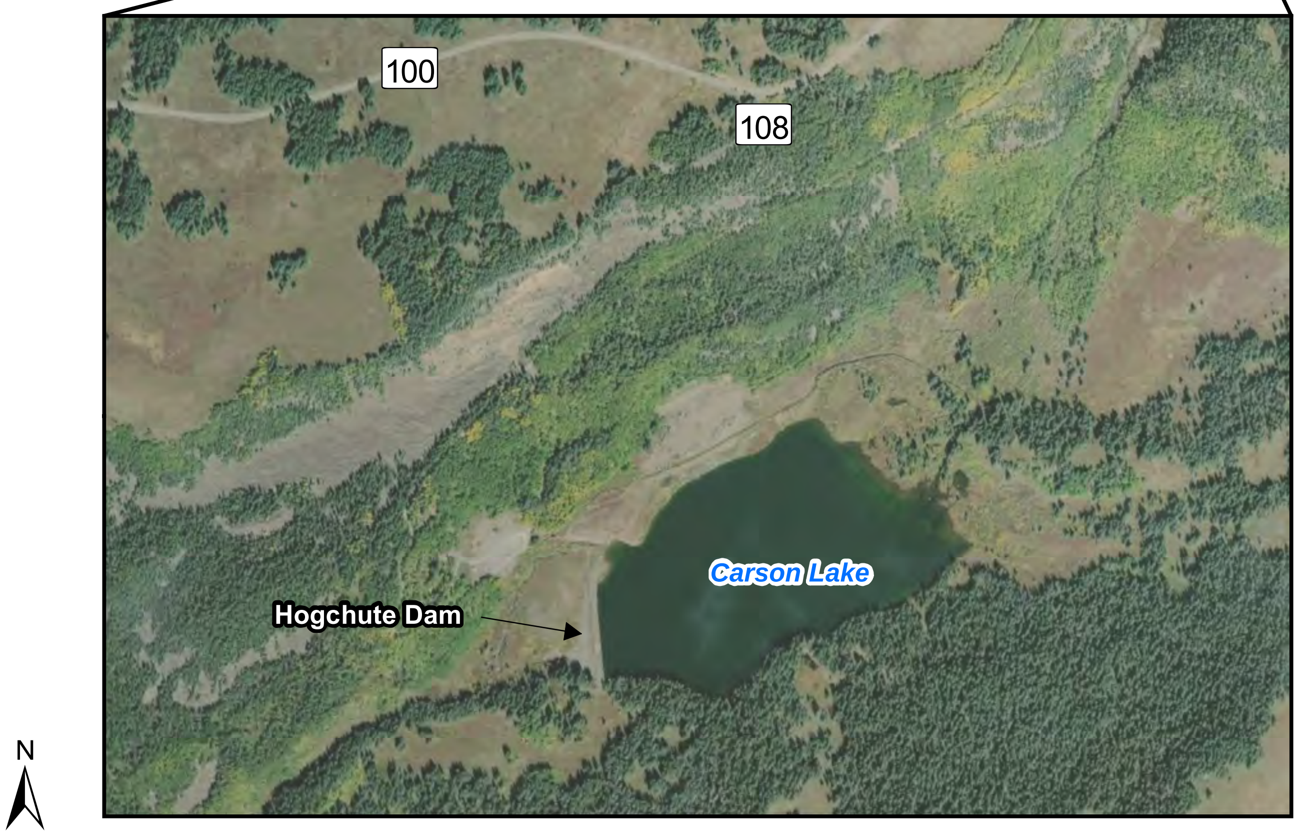
| | |
|---|---|
| Project Manager: | Garrett Jackson, P.E. |
| Staff Geological Engineer: | Jacquelyn Hagbery, E.I. |
| Technical Review: | Robert Huzjak, P.E. |




**PROJECT VICINITY MAP**
**(NOT TO SCALE)**




**PROJECT LOCATION MAP**
**(NOT TO SCALE)**




**SITE LOCATION MAP**
**(NOT TO SCALE)**

| | | | |
|---|---|---|---|
| City of Grand Junction Colorado | RJH Consultants, Inc. | HOGCHUTE DAM<br>SAFETY EVALUATION<br>GEOTECHNICAL DATA REPORT | SITE VICINITY<br>MAP |
| | | PROJECT NO. 18115 | January 2019 **Figure 1.1** |

P:\18115 - Hogchute Dam Safety Evaluation\Engineering\GIS\Geotech\Geotech_Data_Report\Site Vicinity Map.mxd


LEGEND

- MONITORING WELL
- BORING BACKFILLED WITH CEMENT–BENTONITE GROUT

NOTES:

1. AERIAL IMAGERY WAS OBTAINED FROM MICROSOFT BING, IMAGERY DATE UNKNOWN.
2. GROUND SURFACE TOPOGRAPHY DATA PROVIDED BY CITY OF GRAND JUNCTION, CO. HORIZONTAL DATUM IS NAD83 AND VERTICAL DATUM IS NAVD88.
3. LOCATIONS OF MONITORING WELLS AND BORINGS WERE OBTAINED FROM HANDHELD GPS UNIT AND HAVE NOT BEEN SURVEYED.

0 50 100 200 300

SCALE IN FEET

REPRODUCE IN COLOR

| CITY OF Grand Junction COLORADO | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | DAM PLAN |
|---|---|---|---|
| | | PROJECT NO. 18115 | January 2019 **Figure 1.2** |

P:\18115 – HOGCHUTE DAM SAFETY EVALUATION\CAD\FIGURES\MONITORING WELLS\MONITORING WELLS.DWG 12/21/2018 11:28 AM

# SECTION 2 - SITE INVESTIGATION

## 2.1 General

The Site investigation was performed in two phases, from July 23 to July 28, 2018 and from September 17 to September 22, 2018. The Site investigation generally consisted of the following activities:

- Surveying with handheld GPS.
- Drilling, sampling, and logging borings.
- Preparing Daily Site Reports.
- Performing permeability tests in embankment fill and colluvium.
- Installing monitoring wells.
- Measuring groundwater levels.

## 2.2 Surveying

The City performed Project-specific topographic surveying in winter 2017. Topographic surveying of the dam and spillway was performed using conventional (i.e., field) survey equipment. RJH prepared a base topographic map for the Project based on the collected survey data. Based on the topographic data, the dam crest is at approximately El. 9902. The crest width of the embankment is between 14 and 18 feet, the upstream slope of the embankment is inclined at approximately 2.5H:1V to 3H:1V, and the downstream slope is inclined at approximately 2H:1V. Based on survey data and design documents, the maximum normal water level (NWL) is at approximately El. 9895. The horizontal coordinate system used for the Project is Mesa County Local Coordinate System Grand Mesa Area (GMA) with an offset because the surveyed area is beyond the limits of GMA. Therefore, the horizontal coordinates are spatially correct with respect to other points in the survey, but are not related to other global coordinate systems. The horizontal datum is NAD83 and vertical datum is NAVD88.

The borings were surveyed by RJH using a handheld GPS. The horizontal coordinates are in WGS84 and the datum is NAD83. The boring elevations were estimated based on the topographic data provided by the City. The City plans to survey the borings in spring 2019 when the Site can be accessed as weather and ground conditions allow.

## 2.3 Borings

Seven borings were drilled for the Project. The horizontal coordinates and ground surface elevations at the boring locations are provided in Table 2.1. The boring locations are shown on Figure 1.2. Boring logs are provided in Appendix B.

**TABLE 2.1**
**SUMMARY OF BORINGS**

| Boring ID | Latitude[(1)] (deg) | Longitude[(1)] (deg) | Ground Surface Elevation[(2)] (ft) | Total Depth[(3)] of Boring (ft) | Boring Completion |
|---|---|---|---|---|---|
| Dam Crest | | | | | |
| B-101(P) | 38.995296 | -108.109759 | 9902.2 | 77.5 | 1.5-inch Monitoring Well |
| B-102A(P) | 38.995677 | -108.109800 | 9902.1 | 48.0 | 2-inch Monitoring Well |
| B-102B | 38.995667 | -108.109796 | 9902.1 | 5.0 | Cement-Bentonite Grout |
| B-103(P) | 38.996095 | -108.109881 | 9901.8 | 30.0 | 2-inch Monitoring Well |
| Dam Downstream Toe | | | | | |
| B-104(P) | 38.995285 | -108.110292 | 9846.1 | 33.0 | 2-inch Monitoring Well |
| B-105A(P) | 38.995632 | -108.110160 | 9865.7 | 73.5 | 2-inch Monitoring Well |
| B-105B(P) | 38.995681 | -108.110127 | 9866.9 | 12.6 | 2-inch Monitoring Well |

Notes:
1. Boring locations were surveyed by RJH with a handheld GPS. Horizontal coordinate system is WGS84 and datum is NAD83.
2. Elevation was estimated from the topographic survey data. Vertical datum is NAVD88.
3. Depth measured along boring axis. All borings were vertical.

RJH retained HRL Compliance Solutions, Inc. (HRL) of Grand Junction, Colorado to provide drilling equipment and services. Borings were drilled using a track-mounted CME 55LC drill rig with an automatic hammer.

Vertical borings in the dam crest were advanced from the ground surface using 7.75-inch outside-diameter (O.D.) (4.25-inch inside-diameter (I.D.)) hollow-stem augers. During auger advancement, sampling was generally performed at 2.5-foot intervals but sampling ranged from continuously to 8-foot intervals, depending on the presence of cobbles and boulders. Auger refusal was encountered in all dam crest borings and in our opinion was caused by cobbles and boulders in the subsurface. Based on the presence of cobbles and boulders in the crest borings, the drillers switched to a Symmetrix drive casing advancer, an air-hammer drilling method, for the dam downstream toe borings. The Symmetrix drive casing advancer was 5.375-inch O.D. (5.0-inch I.D.) and had continuous casing advancement. During casing advancement, sampling was generally performed at 2.5-foot intervals but ranged from continuously to 5-foot intervals based on casing limitations at greater depths. The air compressor used for the Symmetrix drive casing advancer was set at the "low" pressure setting and air pressure measured at the air compressor ranged from 110 to 120 pounds per square inch (psi) during drilling.

The following sampler types were used during auger and Symmetrix drive casing advancer drilling:

- 1.375-inch I.D. (2.0-inch O.D.) standard split-spoon sampler (ASTM D1586). These sample locations are denoted with the prefix "S- "on the boring logs.
- 2.4-inch I.D. (2.5-inch O.D.) thin walled (Shelby) tube sampler (ASTM D1587). These sample locations are denoted with the prefix "U- "on the boring logs.
- 2.0-inch I.D. (2.5-inch O.D.) thick-walled, ring-lined (California) sampler (ASTM D3550). These sample locations are denoted with the prefix "CA- "on the boring logs.
- Bulk samples of cuttings were collected during auger advancement.

The ability to sample coarse particles was limited by the sampler sizes and sampling techniques; the collected samples likely underestimate the percentages of gravels, cobbles, or boulders within the embankment and colluvium.

A standard penetration test (SPT) was performed in general accordance with ASTM D1586 at the location of each split-spoon sample. At each SPT location, RJH obtained a "standard penetration resistance" or SPT N-value. The SPT N-value equals the number of blows that are required from a 140-pound hammer dropped 30 inches to drive a standard split-spoon sampler from 6 to 18 inches. At some locations, the SPT sampler encountered refusal (50 blows for less than 6 inches of penetration) prior to advancing 18 inches; therefore, SPT N-values and the associated samples could not be obtained at these locations. At some locations, more material was recovered than the penetration depth, likely because of either sampler seating blows or slough from the boring sides. Blow counts were also recorded at the location of California samples; these blow counts do not correlate directly to N-values, but provide a general indication of the consistency of the sampled material. The SPT N-values and blow counts presented in this Report were not adjusted to account for overburden pressures, hammer energy, etc. SPT and California sampler blow counts were likely influenced by the prevalence of larger gravel or cobbles.

Bedrock was not encountered in any of the borings.

At B-103(P), the initial boring location was terminated about 3 feet deep because of a boulder obstruction. This initial boring was backfilled with cuttings and the boring was re-drilled about 3 feet to the south. The surveyed coordinates presented in Table 2.1 correspond to the location of the re-drilled boring and the completed monitoring well.

Boring B-102B was terminated about 5 feet deep because of a boulder obstruction and was backfilled with cement-bentonite grout. Water from Carson Lake was used as the drilling fluid for mixing grout. The remaining borings were completed as open-standpipe monitoring wells as described in Section 2.7.

## 2.4 Daily Site Reports

RJH documented Site field activities in Daily Site Reports. Daily Site Reports are presented in Appendix D.

## 2.5 Logging and Sampling Procedures

RJH observed drilling procedures, recorded relevant drilling information, photographed and visually classified soil samples, and prepared a field log of each boring. In the field, soil samples were classified in general accordance with ASTM D2488 (visual-manual method), except for cuttings, where constituent percentages were estimated for the entire recovered sample, not just the fraction finer than 3 inches.

Recovered split-spoon samples were placed in sealed plastic bags to help preserve the natural moisture content of the material. Samples recovered from California samplers were generally capped and sealed with vinyl tape unless insufficient material was recovered and these samples were placed in sealed plastic bags to help preserve the natural moisture content. One successful Shelby tube sample was capped and sealed with vinyl tape. Bulk samples collected from auger cuttings were placed in either sealed plastic bags or canvas sample bags.

RJH prepared final boring logs based on field and laboratory classifications, quality assurance office review of samples, and indirect observations (i.e., drill chatter, drill resistance, etc.) as appropriate. Between recovered samples, the lithology presented on the boring logs is interpreted. Explanations of the soil descriptors used on the boring logs are presented in Appendix A. Boring logs are presented in Appendix B. Photographs of soil samples are presented in Appendix C.

## 2.6 Permeability Testing in Soil

RJH performed 13 tests to evaluate the hydraulic conductivity characteristics in the embankment fill and colluvium. In-situ permeability testing consisted of rising head and falling head tests over test intervals ranging between 0 and 21.0 feet in length. Testing was generally performed as follows:

Rising Head Test: Eleven rising head tests were performed in borings during drilling and in completed wells. Four tests were performed in borings during Symmetrix drilling; the casing was either raised from the bottom of the hole to expose the test interval or remained at the bottom of the hole. The test was conducted by measuring natural recovery of groundwater, because groundwater was removed from the hole during drilling by the use of an air compressor. No rising head tests were performed during auger drilling. The remaining seven tests were performed in wells; either a hand bailer or submersible pump was used to remove water from the well casing. The water level in the well was then measured over time as it recovered to near its original level. Hydraulic conductivity of the test interval was estimated from the field data using techniques published by Lambe and Whitman (1969) and equations by Hvorslev (1951) for all test configurations.

Falling Head Test: Two falling head tests were performed during auger drilling. Augers remained at the bottom of the hole and the vertical hydraulic conductivity was measured during testing. The augers were filled with water and then the water level within the augers was measured over time as it declined. Hole depths were measured again following the tests to confirm that hole collapse did not occur during testing. Hydraulic conductivity of the test interval was estimated from the field data using techniques published by Lambe and Whitman (1969) and equations by Hvorslev (1951) for both test configurations.

In-situ hydraulic conductivity test results are summarized in Table 2.2 and calculations are presented in Appendix E.

**TABLE 2.2**
**SOIL HYDRAULIC CONDUCTIVITY TEST RESULTS**

| Boring ID | Test | Test Performed | Depth Interval (ft)[1] | Test Type | Hydraulic Conductivity (cm/s)[2] | USCS Soil Classification |
|---|---|---|---|---|---|---|
| **Dam Embankment Fill** | | | | | | |
| B-102A(P) | K-1 | During drilling | 46.5 to 46.5 | Falling Head[3] | $1.2x10^{-4}$ | GP-GC |
| B-102A(P) | K-2 | In well | 36.5 to 48.0 | Rising Head[4] | $2.7x10^{-6}$ | GC, GP-GC, SC |
| B-102A(P) | K-3 | In well | 36.5 to 48.0 | Rising Head[4] | $8.0x10^{-6}$ | GC, GP-GC, SC |
| **Colluvium** | | | | | | |
| B-101(P) | K-1 | In well | 53.0 to 74.0 | Rising Head[4] | $4.0x10^{-6}$ | Mostly CL, SP-SC |
| B-101(P) | K-2 | In well | 53.0 to 74.0 | Rising Head[4] | $5.3x10^{-6}$ | Mostly CL, SP-SC |
| B-103(P) | K-1 | During drilling | 30.0 to 30.0 | Falling Head[3] | $1.6x10^{-3}$ | SC |
| B-104(P) | K-1 | During drilling | 26.0 to 27.0 | Rising Head[4] | $2.0x10^{-4}$ | SC |
| B-104(P) | K-2 | In well | 8.9 to 14.5 | Rising Head[4] | $7.9x10^{-5}$ | CL |
| B-105A(P) | K-1 | During drilling | 21.0 to 22.0 | Rising Head[4] | $1.4x10^{-4}$ | CL |
| B-105A(P) | K-2 | During drilling | 52.0 to 52.0 | Rising Head[3] | $1.1x10^{-3}$ | SC |
| B-105A(P) | K-3 | In well | 53.0 to 73.5 | Rising Head[4] | $1.0x10^{-4}$ | CL, SC |
| B-105B(P) | K-1 | During drilling | 12.6 to 12.6 | Rising Head[3] | $7.1x10^{-3}$ | CL |
| B-105B(P) | K-2 | In well | 8.6 to 12.6 | Rising Head[4] | $3.4x10^{-4}$ | CL, SC |

Notes:
1. Depth below the ground surface, measured along the orientation of the boring.
2. Geometric mean of hydraulic conductivity was calculated.
3. Tested vertical hydraulic conductivity.
4. Tested horizontal hydraulic conductivity

While drilling B-105A(P), water pressure generated by the Symmetrix drilling method caused water and air to be expelled at the ground surface between the casing and the boring wall. Rising head test B-105A(P), K-2 was performed to measure recovery of the groundwater and resolution of expelled water. The water and air expulsion ceased after approximately 33 minutes into the test, and the test was stopped after about 67 minutes once the groundwater level approached static conditions similar to rising head test B-105A(P), K-1. The results for test B-105A(P) K-2 presented in Table 2.2 are for the first 15 minutes of the test.

## 2.7 Monitoring Wells

### *2.7.1 Monitoring Well Installation*

Open-standpipe monitoring wells were installed in all borings, except B-102B. The locations of the monitoring wells are shown on Figure 1.2. B-101(P) measures groundwater levels in colluvium beneath the dam, B-102A(P) and B-103(P) measure groundwater levels in the embankment fill, and B-104(P), B-105A(P), and B-105B(P) measure groundwater levels in colluvium at the downstream toe of the dam. Information about construction of the monitoring wells is discussed below and shown on Figures 2.1 through 2.6.

All monitoring wells were installed following completion of the boring using conventional techniques, which generally consist of slowly introducing sand or gravel pack and boring sealing materials (bentonite chips or pellets and cement-bentonite grout) into the annular space between the boring wall and PVC pipe while simultaneously withdrawing either hollow-stem augers or casing from the ground.

Monitoring wells B-101(P), B-102A(P), and B-103(P) were constructed using solid and slotted PVC pipe and 10/20 silica sand pack. Well casings consisted of 2-inch Schedule 40 PVC pipe, except for B-101(P) which consisted of 1.5-inch Schedule 40 PVC pipe.

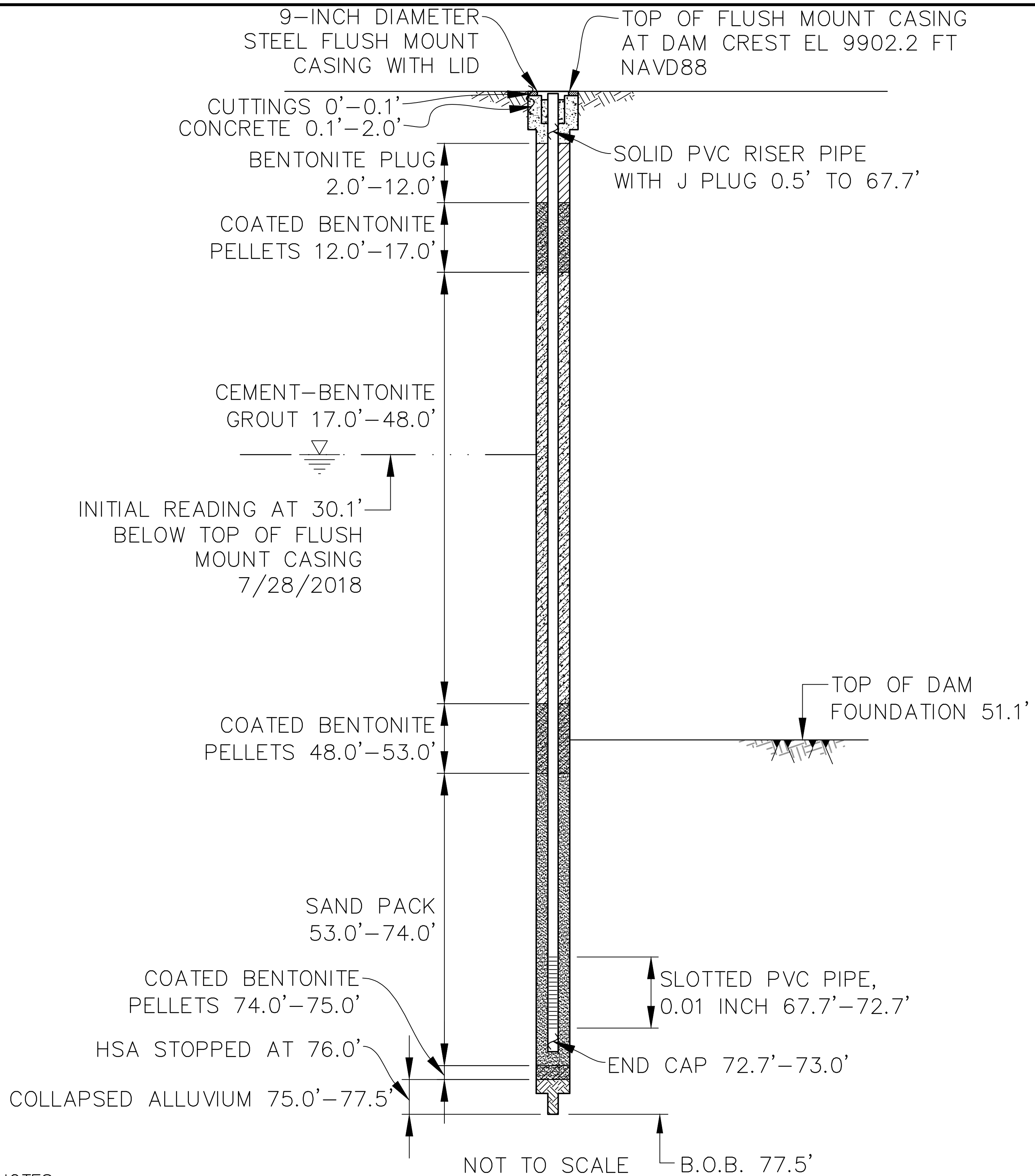
Monitoring wells B-104(P), B-105A(P), and B-105B(P) were constructed using solid PVC pipe, a pre-packed well screen, and minus ¼-inch gravel pack. The pre-packed well screen consisted of slotted PVC well screen surrounded by stainless steel mesh, which encapsulates 20/40 sized well sand between the PVC pipe exterior and the mesh interior. The pre-packed well screen was 2.0-inches I.D. and 2.8-inches O.D. Schedule 40 PVC pipe.

After installation, all monitoring wells were developed to remove groundwater and drilling water from the well and sand or gravel pack. The monitoring wells were developed by surging, bailing, and pumping water from the wells with a submersible pump until either no additional water could be removed or the water was clear.

### *2.7.2 Monitoring Well Readings*

Monitoring wells were measured during the fieldwork. Groundwater level measurements were obtained by RJH while onsite. The City and the SEO also obtained groundwater level measurements. Measured groundwater levels obtained by RJH, the City, and the SEO are presented on Figure 2.7. Data are provided in Appendix F.

The groundwater level measured in B-101(P) on August 23, 2018 and September 6, 2018, do not appear to follow the trend of B-102A(P) or the general trend of decreasing reservoir level. These well measurements may have been improperly recorded.




NOTES:

1. MONITORING WELL INSTALLED 7/28/2018 WITH 7.75–INCH O.D. HOLLOW STEM AUGERS.
2. LOCATION: LAT 38.995296, LONG –108.109759 DEGREES WGS84. BASED ON HANDHELD GPS.
3. TWO 9/16–INCH BOLTS SECURE SURFACE MOUNT CASING.
4. PVC RISER PIPE 1.5 INCHES I.D. 1.9 INCHES O.D. SCH 40. SAND PACK SIZE 10/20.
5. ANNULAR BACKFILL FROM 76.0 FEET TO BOTTOM OF BORING IS ALLUVIUM THAT COLLAPSED INTO BORING AS HOLLOW STEM AUGERS WERE WITHDRAWN.
6. WELL DEVELOPED WITH HAND BAILER 7/28/2018 AND SUBMERSIBLE PUMP 9/18/2018.

| | | | |
|---|---|---|---|
| City of Grand Junction Colorado | RJH Consultants, Inc. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | MONITORING WELL INSTALLATION B-101(P) |
| | | PROJECT NO. 18115 | January 2019 **Figure 2.1** |

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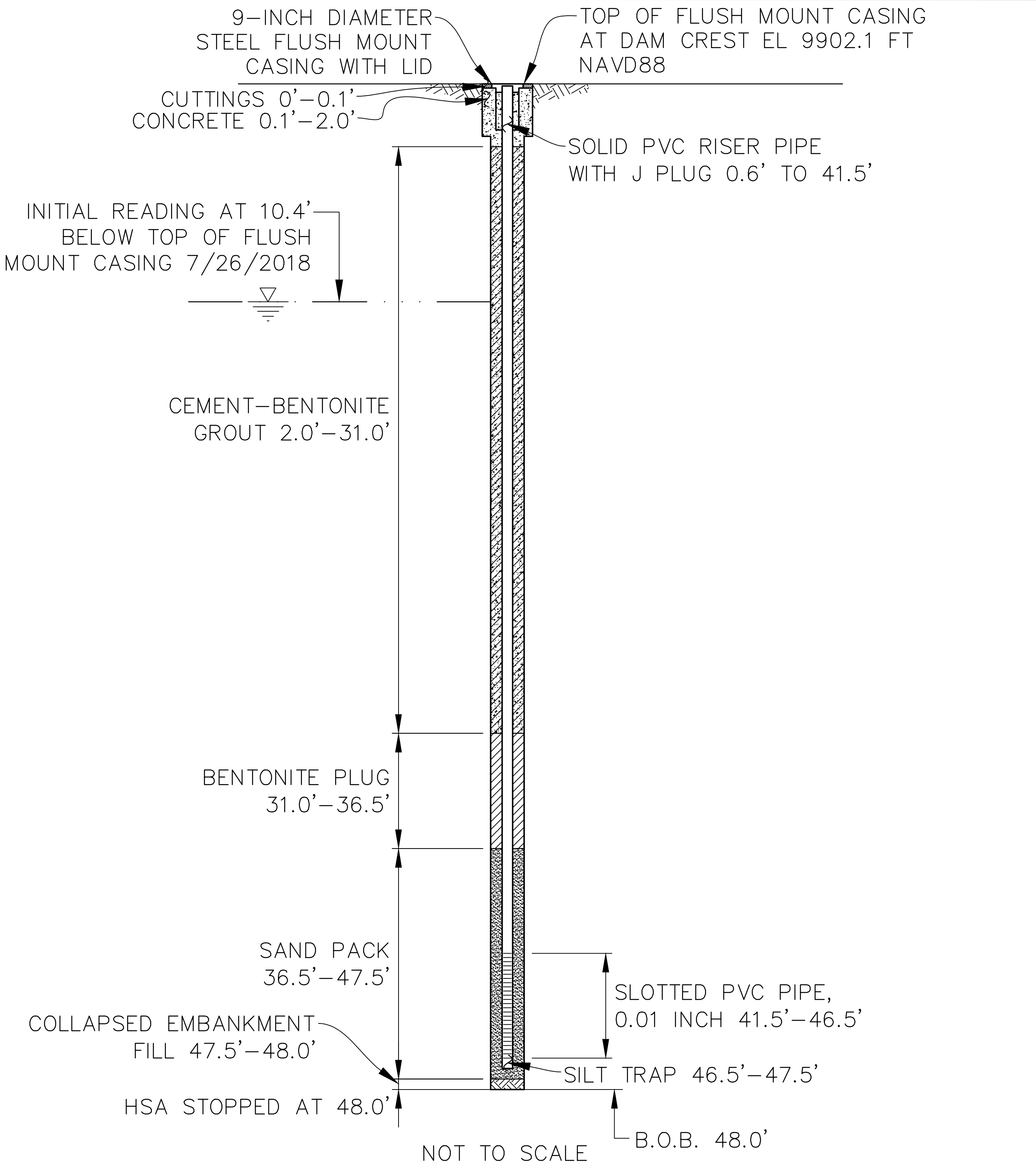
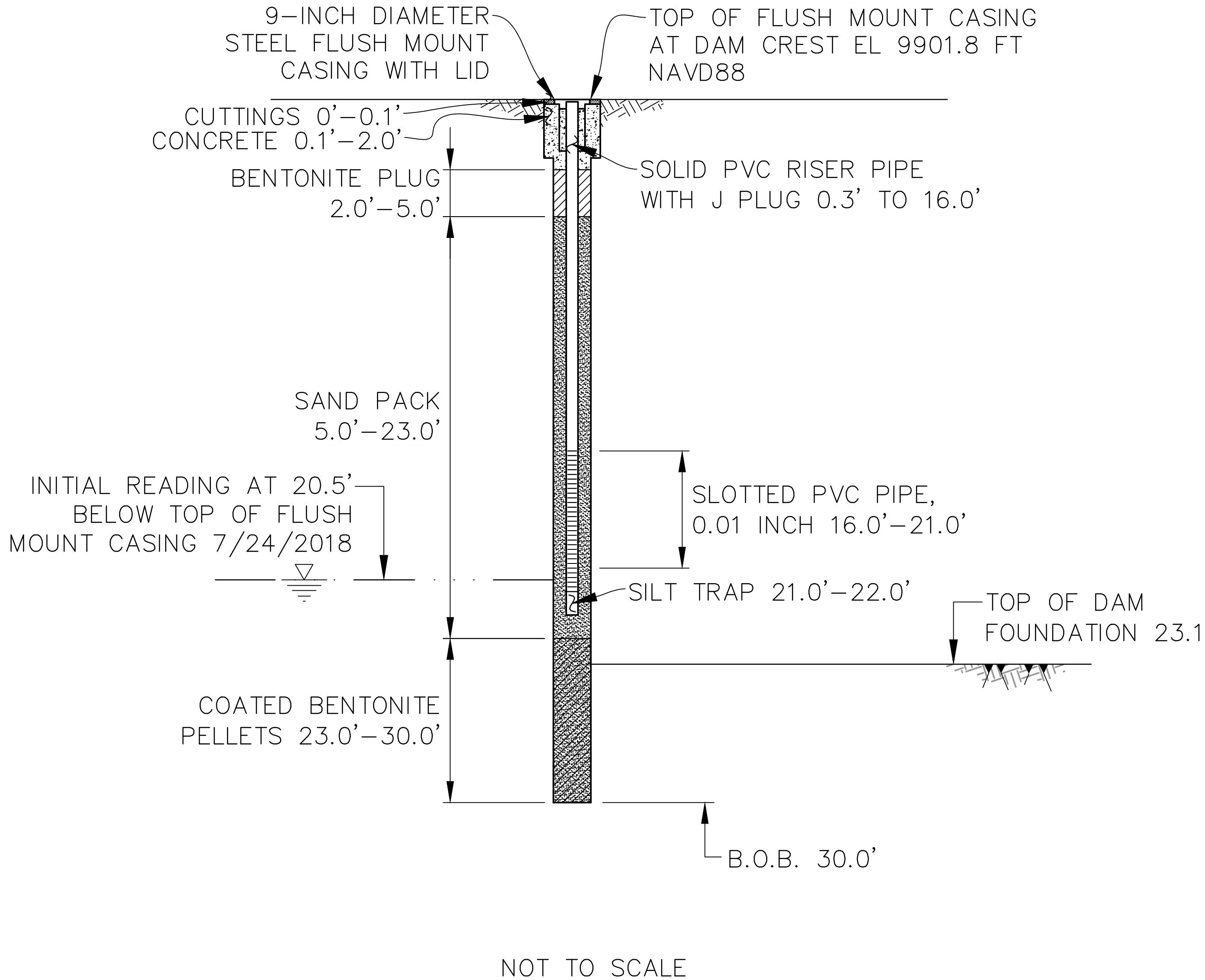



NOTES:

1. MONITORING WELL INSTALLED 7/26/2018 WITH 7.75-INCH O.D. HOLLOW STEM AUGERS.
2. LOCATION: LAT 38.995677, LONG -108.109800 DEGREES WGS84. BASED ON HANDHELD GPS.
3. TWO 9/16-INCH BOLTS SECURE SURFACE MOUNT CASING.
4. PVC RISER PIPE 2.0 INCHES I.D. 2-3/8 INCHES O.D. SCH 40. SAND PACK SIZE 10/20.
5. ANNULAR BACKFILL FROM 47.5 FEET TO BOTTOM OF BORING IS EMBANKMENT FILL THAT COLLAPSED INTO BORING AS HOLLOW STEM AUGERS WERE WITHDRAWN.
6. WELL DEVELOPED WITH SURGE BLOCK AND SUBMERSIBLE PUMP 7/26/2018.

| | | | |
|---|---|---|---|
| CITY OF Grand Junction COLORADO | RJH CONSULTANTS, INC. | HOGCHUTE DAM<br>SAFETY EVALUATION<br>GEOTECHNICAL DATA REPORT | MONITORING WELL<br>INSTALLATION B-102A(P) |
| | | PROJECT NO. 18115 | January 2019 **Figure 2.2** |




NOTES:

1. MONITORING WELL INSTALLED 7/24/2018 WITH 7.75–INCH O.D. HOLLOW STEM AUGERS.
2. LOCATION: LAT 38.996095, LONG –108.109881 DEGREES WGS84. BASED ON HANDHELD GPS.
3. TWO 9/16–INCH BOLTS SECURE SURFACE MOUNT CASING.
4. PVC RISER PIPE 2.0 INCHES I.D. 2–3/8 INCHES O.D. SCH 40. SAND PACK SIZE 10/20.
5. WELL DEVELOPED WITH SURGE BLOCK AND SUBMERSIBLE PUMP 7/24/2018.

| | | | |
|---|---|---|---|
| CITY OF Grand Junction COLORADO | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | MONITORING WELL INSTALLATION B-103(P) |
| | | PROJECT NO. 18115 | January 2019 **Figure 2.3** |

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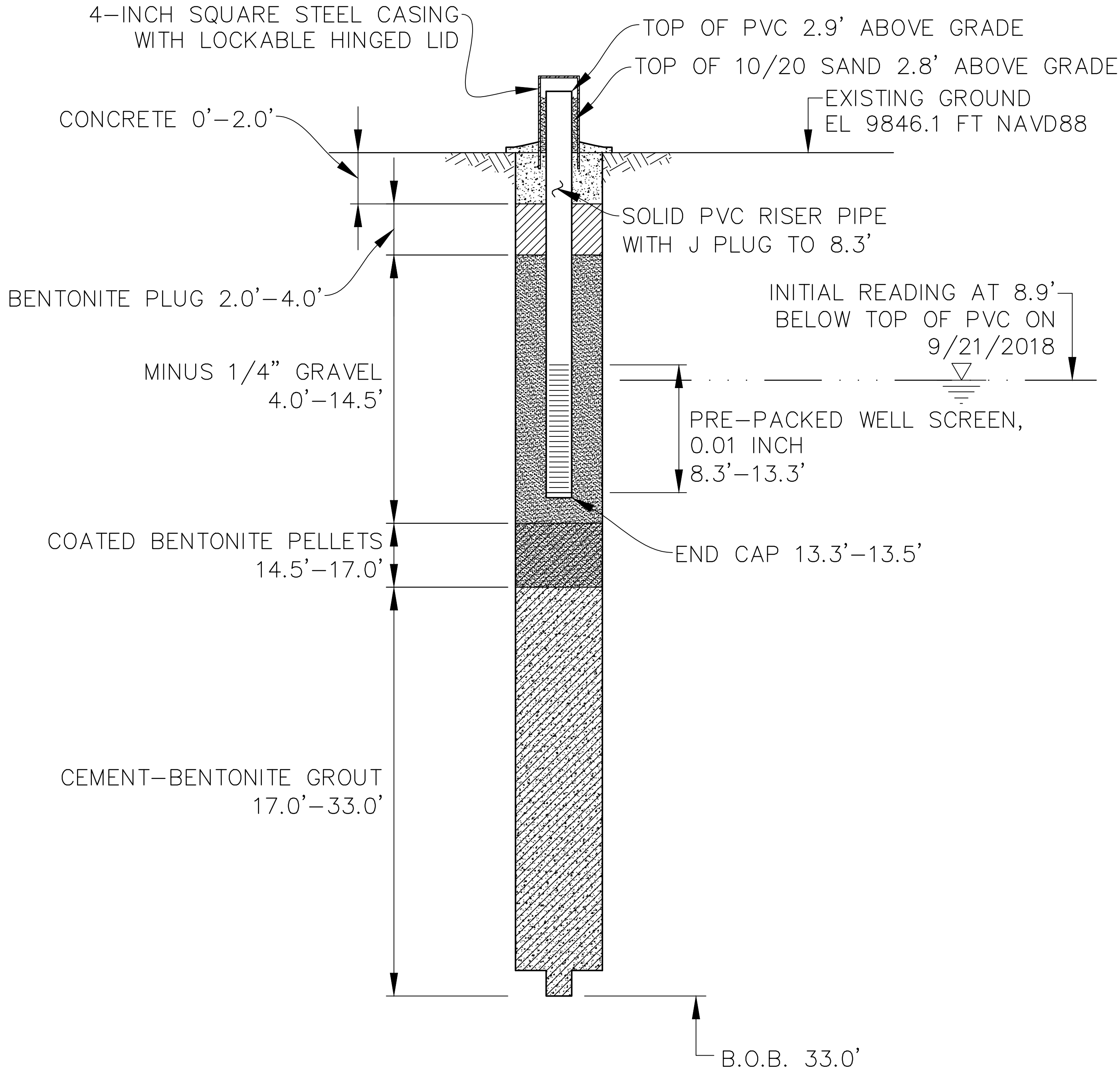


NOT TO SCALE

NOTES:

1. MONITORING WELL INSTALLED 9/21/2018 WITH 5-3/8 INCHES O.D. SYMMETRIX DRIVE CASING ADVANCER.
2. LOCATION: LAT 38.995285, LONG -108.110292 DEGREES WGS84. BASED ON HANDHELD GPS.
3. PVC RISER PIPE 2.0 INCHES I.D. 2-3/8 INCHES O.D. SCHEDULE 40.
4. PRE-PACKED WELL SCREEN 2.0 INCHES I.D. 2.8 INCHES O.D. PVC SCHEDULE 40. SAND PACK SIZE 20/40.
5. WELL DEVELOPED WITH SURGE BLOCK AND SUBMERSIBLE PUMP 9/21/2018.

| | | | |
|---|---|---|---|
| City of Grand Junction Colorado | RJH CONSULTANTS, INC. | HOGCHUTE DAM<br>SAFETY EVALUATION<br>GEOTECHNICAL DATA REPORT | MONITORING WELL<br>INSTALLATION B-104(P) |
| | | PROJECT NO. 18115 | January 2019 **Figure 2.4** |

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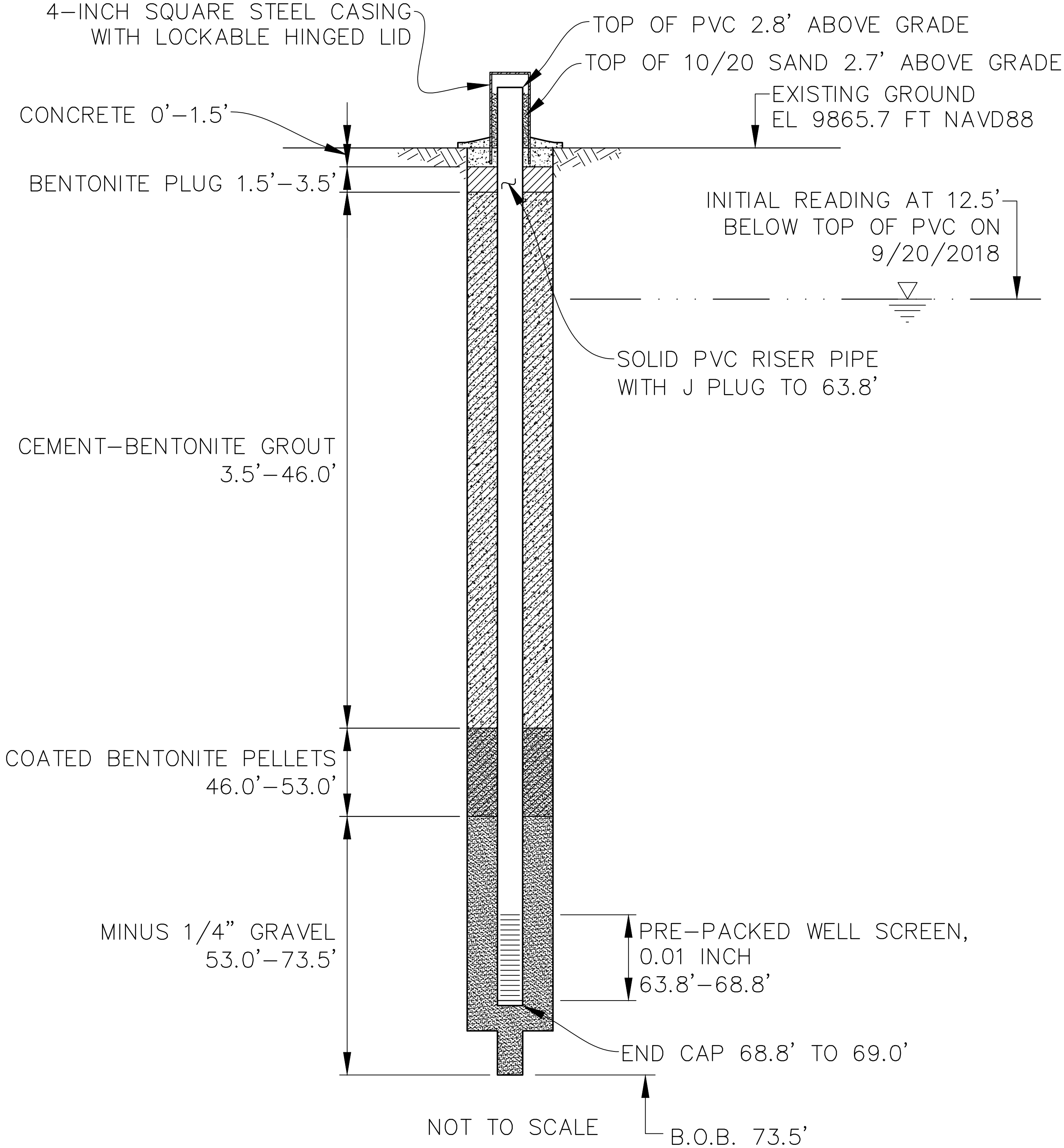


NOTES:

1. MONITORING WELL INSTALLED 9/20/2018 WITH 5-3/8 INCHES O.D. SYMMETRIX DRIVE CASING ADVANCER.
2. LOCATION: LAT 38.995632, LONG -108.110160 DEGREES WGS84. BASED ON HANDHELD GPS.
3. PVC RISER PIPE 2.0 INCHES I.D. 2-3/8 INCHES O.D. SCHEDULE 40.
4. PRE-PACKED WELL SCREEN 2.0 INCHES I.D. 2.8 INCHES O.D. PVC SCHEDULE 40. SAND PACK SIZE 20/40.
5. WELL DEVELOPED WITH SURGE BLOCK AND SUBMERSIBLE PUMP 9/20/2018.

| | | | |
|---|---|---|---|
| City of Grand Junction Colorado | RJH Consultants, Inc. | HOGCHUTE DAM<br>SAFETY EVALUATION<br>GEOTECHNICAL DATA REPORT | MONITORING WELL<br>INSTALLATION B-105A(P) |
| | | PROJECT NO. 18115 | January 2019 **Figure 2.5** |

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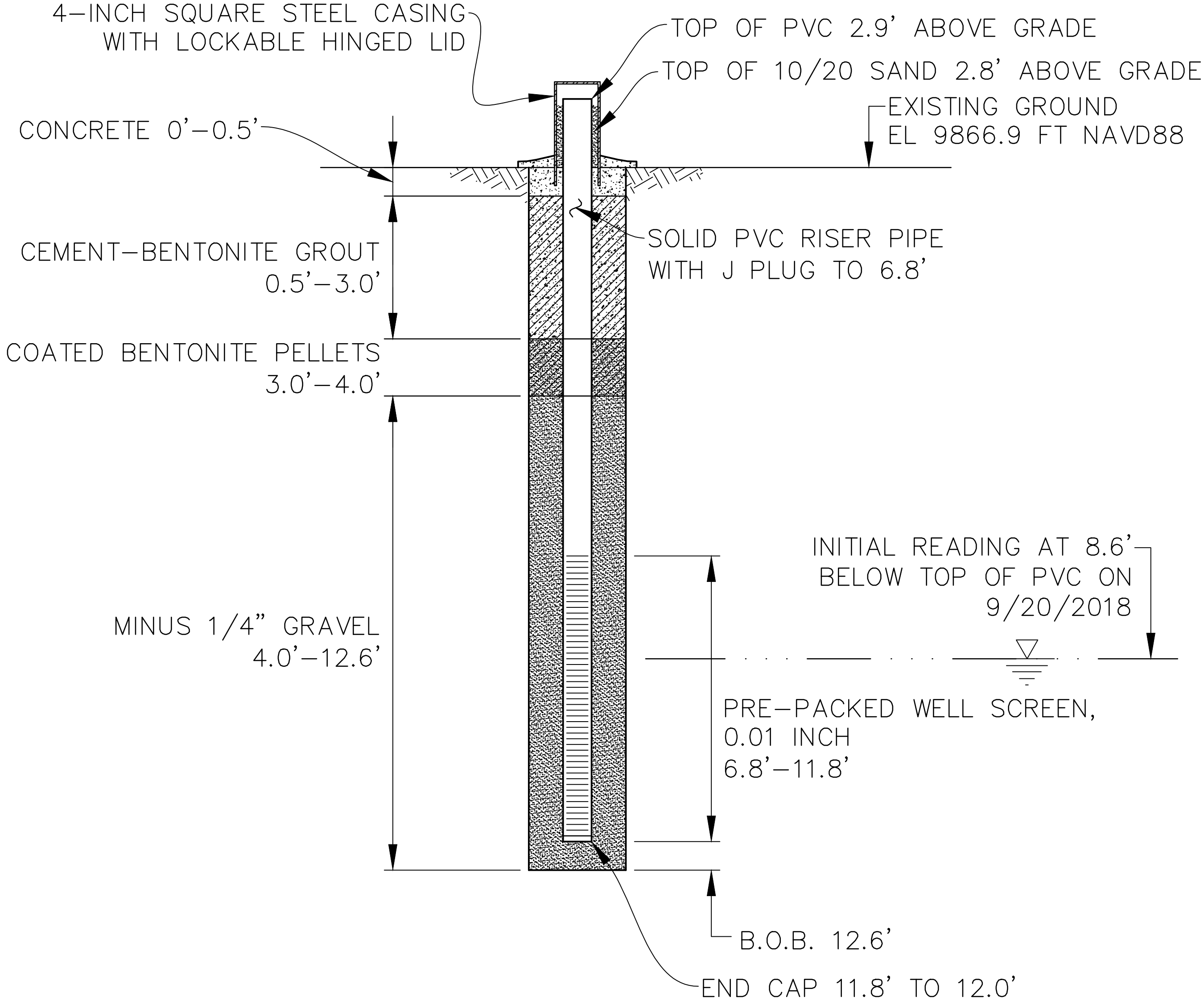


NOT TO SCALE

NOTES:

1. MONITORING WELL INSTALLED 9/20/2018 WITH 5-3/8 INCHES O.D. SYMMETRIX DRIVE CASING ADVANCER.
2. LOCATION: LAT 38.995681, LONG -108.110127 DEGREES WGS84. BASED ON HANDHELD GPS.
3. PVC RISER PIPE 2.0 INCHES I.D. 2-3/8 INCHES O.D. SCHEDULE 40.
4. PRE-PACKED WELL SCREEN 2.0 INCHES I.D. 2.8 INCHES O.D. PVC SCHEDULE 40. SAND PACK SIZE 20/40.
5. WELL DEVELOPED WITH SURGE BLOCK AND SUBMERSIBLE PUMP 9/20/2018.

| CITY OF Grand Junction COLORADO | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | MONITORING WELL INSTALLATION B-105B(P) |
|---|---|---|---|
| | | PROJECT NO. 18115 | January 2019 **Figure 2.6** |

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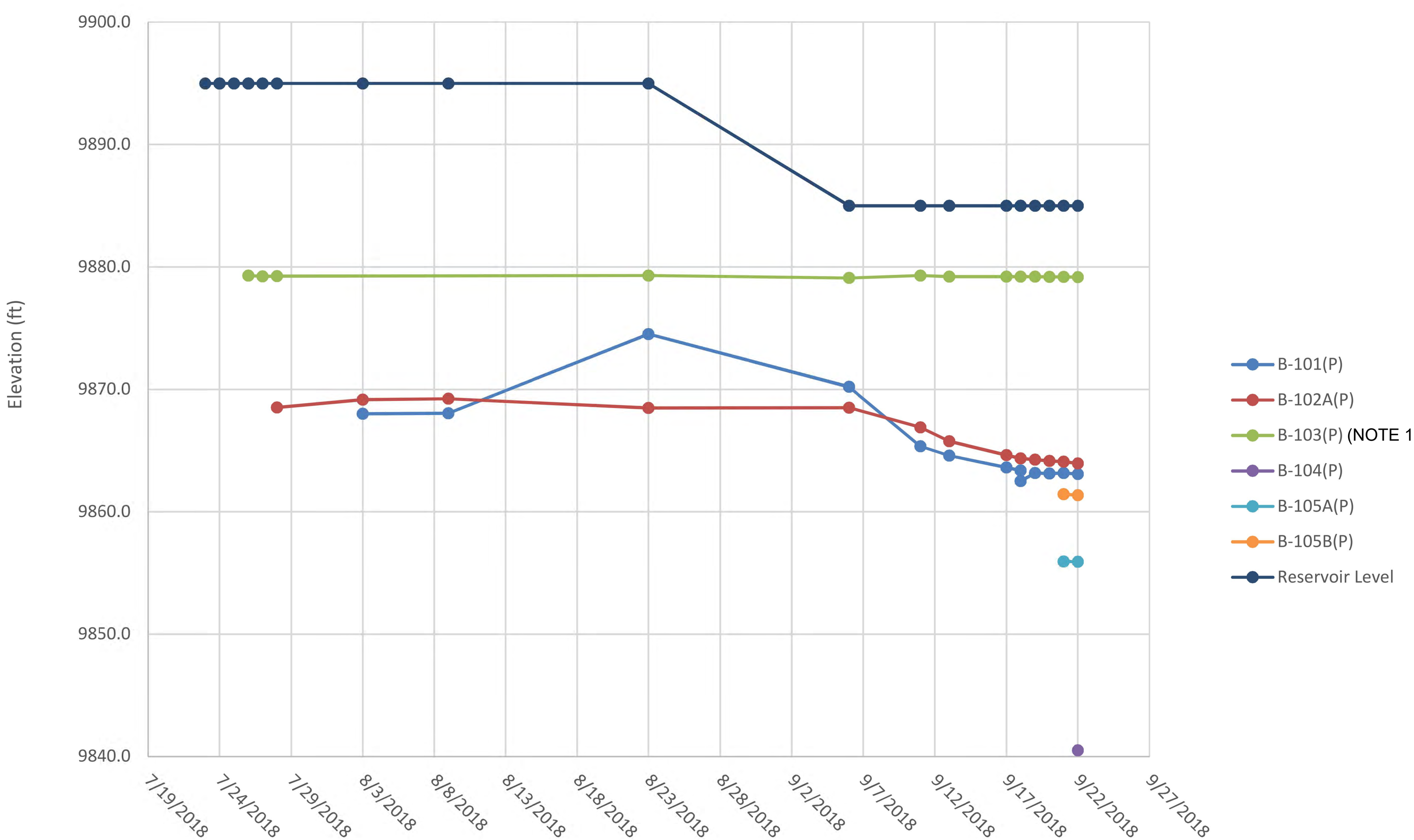


NOTE:

1. MEASUREMENTS FOR B–103(P) ARE THE BOTTOM OF THE DRY WELL AND DO NOT REPRESENT THE GROUNDWATER LEVEL

REPRODUCE IN COLOR

| | | | |
|---|---|---|---|
| CITY OF Grand Junction COLORADO | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | FIELD INVESTIGATION MONITORING WELL DATA |
| | | PROJECT NO. 18115 | January 2019 **Figure 2.7** |

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# SECTION 3 - LABORATORY TESTING

Laboratory tests were performed on representative samples of soil collected from the borings. RJH retained Advanced Terra Testing of Lakewood, Colorado to perform the laboratory testing. The tests consisted of:

Index Tests:

- Three moisture content and density tests (ASTM D2216 and D7263).
- Five Atterberg limit tests (ASTM D4318).
- Four grain-size analyses (ASTM D6913).
- Two grain-size analyses with hydrometer (ASTM D6913 and D7928).
- Three percent minus #200 analyses (ASTM D1140).
- Three standard Proctor compaction tests (ASTM D698).
- One one-dimensional consolidation test (ASTM D2435).
- Three corrosion suite tests (ASTM C1580, D4972, D1411, and G187).
- Two pinhole dispersion tests (ASTM D4647 Method A).

Permeability Tests:

- Three back pressure permeability tests, flow pump method (ASTM D5084 Method D).

Strength Tests:

- One series of three consolidated undrained triaxial compression tests (ASTM D4767).
- One unconfined compressive strength test (ASTM D2166).

The unconfined compressive strength tests could not be performed on two samples because gravel prevented the samples from remaining intact during extrusion. Similar material recovery issues may have influenced other laboratory results.

Laboratory index test results are summarized in Table 3.1. Laboratory permeability and strength test results are summarized in Table 3.2. Strength test results are shown on Figures 3.1 and 3.2. Laboratory test sheets are provided in Appendix G.

# TABLE 3.1
## SUMMARY OF INDEX LABORATORY TEST RESULTS

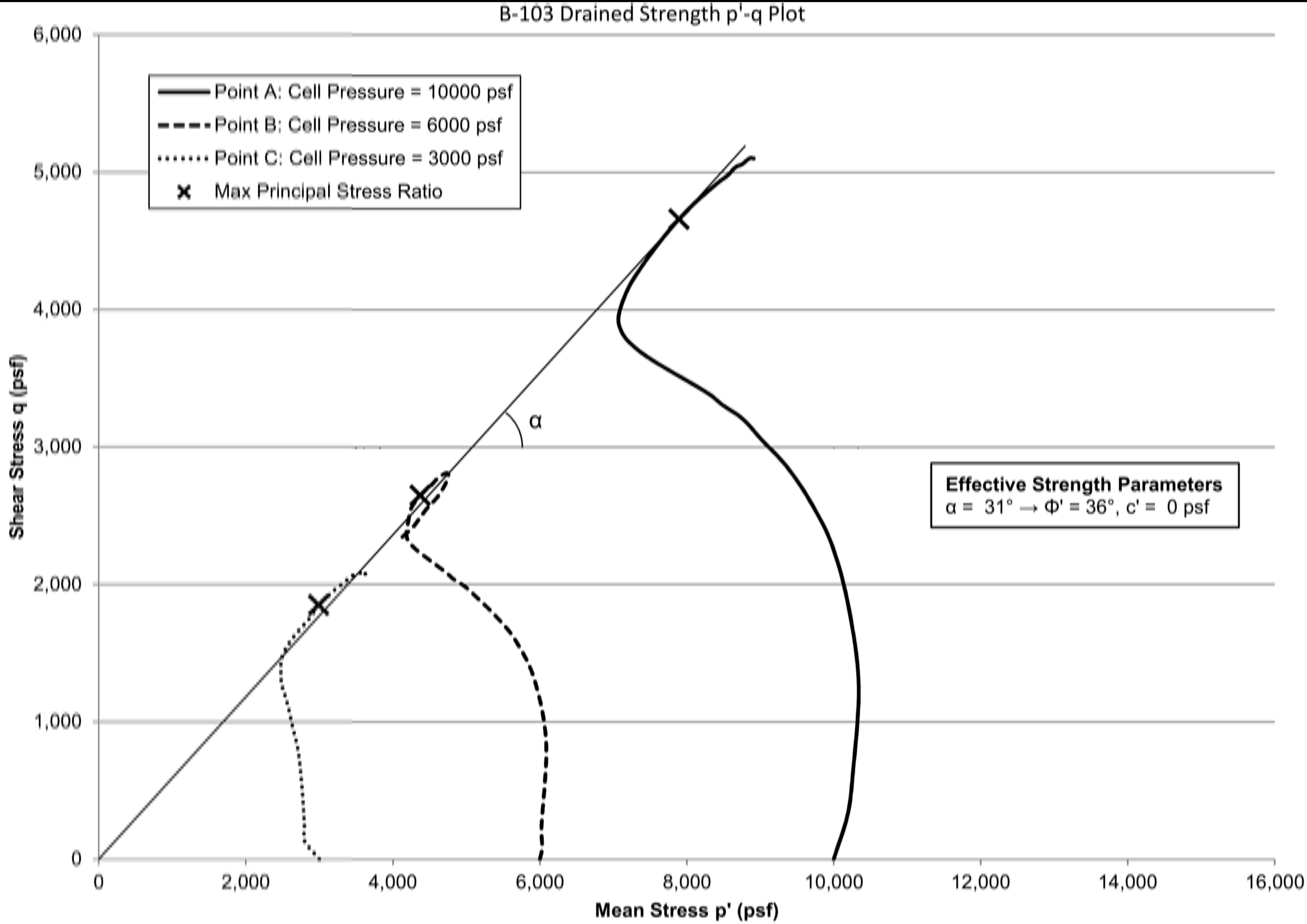
| Boring | Sample ID | Depth (ft) | Moisture Content (%) | Dry Density (pcf) | Liquid Limit, LL | Plasticity Index, PI | Percent Gravel (3" to #4) | Percent Sand (#4 to #200) | Percent Fines (< #200) | Optimum Moisture Content (%) | Maximum Dry Unit Weight (pcf) | Coefficient of Compression, Cc | Coefficient of Re-Compression, Cr | Preconsolidation Stress (psf) | Sulfate Concentration (ppm) | Chloride Concentration (ppm) | pH | Minimum Resistivity (Ω*cm) | Sulfide Concentration (ppm) | Pinhole Dispersion Test Results |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Dam Embankment Fill** | | | | | | | | | | | | | | | | | | | | |
| B-101(P) | Bu-6 | 15.0 to 25.0 | | | | | | | | 10.4(1) | 131.1(1) | | | | | | | | | |
| B-101(P) | Bu-13 | 25.0 to 40.0 | | | 28 | 11 | 25.5 | 28.6 | 45.9 | | | | | | | | | | | |
| B-101(P) | CA-11 | 30.0 to 31.0 | 14.3 | 109.6 | | | | | | | | | | | | | | | | ND1(2)(3) |
| B-101(P) | CA-16 | 42.5 to 43.5 | | | | | 30.1 | 30.6 | 39.3 | | | | | | | | | | | |
| B-101(P) | Bu-15 | 45.0 to 50.0 | | | | | | | | | | | | | 23 | 38.5 | 6.8 | 2,400 | 0.104 | |
| B-101(P) | S-19 | 50.6 to 51.5 | | | | | | | | | | | | | 107 | 144 | 7.3 | 2,600 | 0.184 | |
| B-102A(P) | Bu-10 | 18.0 to 41.5 | | | 28 | 11 | 24.3 | 29.1 | 46.6 | | | | | | | | | | | |
| B-102A(P) | CA-14 | 29.0 to 30.0 | | | | | 57.0 | 21.1 | 21.9 | | | | | | | | | | | |
| B-102A(P) | CA-20 | 44.0 to 45.0 | 25.4 | 95.6 | | | | | | | | | | | 5 | 108 | 7.4 | 1,540 | 0.01 | |
| B-103(P) | Bu-11 | 10.0 to 17.5 | | | 27 | 11 | 23.9 | 33.1 | 43.0 | 10.3(1) | 131.3(1) | | | | | | | | | |
| B-103(P) | CA-8 | 15.0 to 16.0 | 10.8 | 105.1 | | | 46.0 | 21.4 | 32.6 | | | | | | | | | | | ND1(2)(4) |
| **Colluvium** | | | | | | | | | | | | | | | | | | | | |
| B-101(P) | Bu-20 | 51.0 to 65.0 | | | 27 | 12 | 19.8 | 26.2 | 54.0 | 12.1(1) | 126.9(1) | | | | | | | | | |
| B-103(P) | U-14 | 27.5 to 29.9 | 25.1(5) | 101.6(5) | | | 24.8 | 43.9 | 31.3 | | | 0.224 | 0.011 | 6,780 | | | | | | |
| B-104(P) | CA-9 | 32.0 to 33.0 | 19.7 | 111.8 | 32 | 13 | 33.4 | 8.5 | 58.1 | | | | | | | | | | | |

Notes:
1. Results in this table are presented with oversized particle corrections. Tests were performed using standard energy (ASTM D698) and the maximum particle size included in the test was ¾ inch. The percentage of oversized material exceeded the recommendations of ASTM D698.
2. ND1 corresponds to nondispersive clays with very slight to no colloidal erosion under 15 inches to 40 inches of head.
3. Specimen remolded to a dry unit weight of 110 pounds per cubic foot (pcf) and a water content of 17 percent.
4. Specimen remolded to a dry unit weight of 106 pcf and a water content of 14 percent.
5. Average of tests from three triaxial shear test specimens.

# TABLE 3.2
# SUMMARY OF PERMEABILITY AND STRENGH LABORATORY TEST RESULTS

| Boring | Sample ID | Depth (ft) | Permeability (cm/s) | Effective Strength | | Total Strength | | Unconfined Compressive Strength (psf) |
|---|---|---|---|---|---|---|---|---|
| | | | | $\phi'$ (deg.) | c' (psf) | $\phi_T$ (deg.) | $c_T$ (psf) | |
| **Colluvium** | | | | | | | | |
| B-103(P) | U-14 | 27.5 to 29.9 | $1.7x10^{-5(1)}$<br>$3.1x10^{-3(2)}$<br>$3.4x10^{-5(3)}$ | 36(4,5) | 0(4,5) | 22(4,5) | 640(4,5) | |
| B-104(P) | CA-9 | 32.0 to 33.0 | | | | | | 958 |

Notes:
1. Permeability test performed at the consolidated undrained triaxial compression test pressure of 10,000 pounds per square foot (psf).
2. Permeability test performed at the consolidated undrained triaxial compression test pressure of 6,000 psf.
3. Permeability test performed at the consolidated undrained triaxial compression test pressure of 3,000 psf.
4. Consolidated undrained triaxial compression test performed in general accordance with ASTM D4767 with confining pressures of 3,000; 6,000; and 10,000 psf.
5. Based on maximum principal stress ratio.




CITY OF Grand Junction COLORADO

RJH CONSULTANTS, INC.

HOGCHUTE DAM
SAFETY EVALUATION
GEOTECHNICAL DATA REPORT

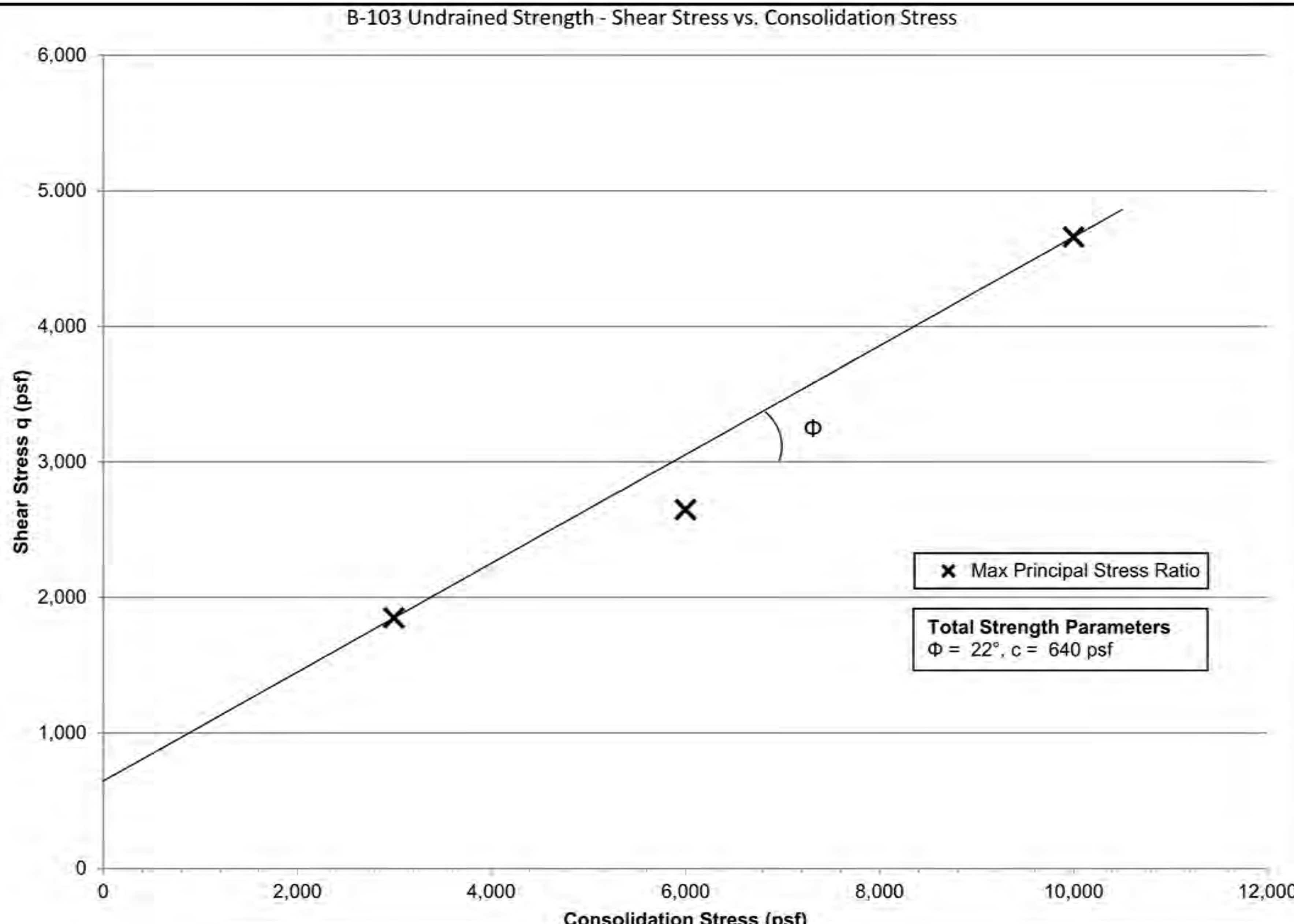
COLLUVIUM
DRAINED STRENGTH

PROJECT NO. 18115

January 2019

**Figure 3.1**

P:\18115 – HOGCHUTE DAM SAFETY EVALUATION\CAD\FIGURES\MONITORING WELLS\FOUNDATION.DWG 1/2/2019 11:25 AM




Grand Junction

RJH CONSULTANTS, INC.

HOGCHUTE DAM
SAFETY EVALUATION
GEOTECHNICAL DATA REPORT

PROJECT NO. 18115

COLLUVIUM
UNDRAINED STRENGTH

January 2019

**Figure 3.2**

# SECTION 4 - SITE AND SUBSURFACE CONDITIONS

## 4.1 General Geology

According to published maps (Ellis and Gabaldo, 1989), the Site is located in the southwest portion of the Piceance Basin on the Grand Mesa. The Piceance Basin is a Late Cretaceous to early Tertiary-age (56 to 100 million years old) feature with a series of Laramide uplifts defining the boundaries of the structural basin. The Grand Mesa is capped by resistant basalt flows. Geologic units at the Site consist of Quaternary-age (less than 2.6 million years old) colluvium overlying Tertiary-age (Eocene, 33.9 to 56 million years old) Green River Formation bedrock. Other geologic units in the nearby area surrounding the Site consist of Quaternary-age terrace gravel and till, and Tertiary-age basalt and Wasatch Formation. The published geology at the Site and nearby surrounding area is shown on Figure 4.1.

Published maps do not show faults in the Site vicinity; however, the southern edge of the Grand Mesa is defined by an escarpment above the flat-lying valley below. The Site is located near the top of the escarpment.

## 4.2 Site Geology

The Site is generally covered by native vegetation that would be typical of a wet, high-altitude environment. Evidence of possible reservoir seepage downstream of the dam included a small area of inactive seeps near shrubs on the hillside to the right of the outlet works and water flowing under the downstream rock shell toe and discharging from a drain to the right of the outlet works. No evidence of active seepage was observed near the shrubs during our work. Seepage from the drain appeared to be flowing clear at the time of our work and at a rate of approximately 4 to 5 gallons per minute (gpm).

The geologic Site conditions observed by RJH generally agreed with the published geologic mapping. The Site generally consists of colluvial deposits with basalt outcrops forming cliffs to the west, north, and east. Bedrock was not encountered in any of the borings.

## 4.3 Subsurface Conditions

### *4.3.1 General Subsurface Profile*

The subsurface units encountered in the borings were embankment fill and colluvium. Bedrock was not encountered in any of the borings. Borings at the dam's downstream toe did not encounter embankment fill.

The following sections describe the properties of the encountered materials. Subsurface sections are shown on Figures 4.2 through 4.5.

### *4.3.2 Embankment Fill*

Embankment fill was encountered at the ground surface in B-101(P), B-102A(P), B-102B, and B-103(P). Embankment fill extended to depths of 51.1 feet and 23.1 feet in B-101(P) and B-103(P), respectively, and was underlain by colluvial deposits in both borings. Borings B-102A(P) and B-102B encountered refusal at 48.0 feet and 5.0 feet, respectively, and did not extend into the colluvium beneath the dam.

Approximately the first foot of embankment fill was crushed gravel road base. In order of prevalence, the remaining embankment fill consisted of clayey sand with gravel (SC), clayey gravel with sand (GC), clayey sand (SC), and poorly graded gravel with clay and sand (GP-GC). Embankment fill contained 15 to 80 percent fine to coarse grained gravel, 15 to 65 percent fine to coarse grained sand, 5 to 47 percent low to medium plasticity fines, and less than 5 percent cobbles. The maximum recovered particle size was 4 inches. The composition and maximum particle size observed in the recovered samples were influenced by the size of the samplers; difficult drilling and sampling conditions were encountered that are likely indicative of larger cobbles or boulders within the embankment fill.

Embankment fill was generally moist above the water table and moist to wet below the water table. Drive sampler refusal (50 blows for less than 6 inches) was encountered at six locations after advancing the sampler 0.1 to 0.3 foot. At 28 other sample locations, uncorrected SPT N-values ranged from 16 to 54 and averaged 35. In our opinion, the SPT results were likely influenced by larger gravel or cobbles within the embankment fill and are not reliable to correlate with material density; however, apparent density based on SPT values is reported on the boring logs.

Three in-situ permeability tests were performed in the embankment fill in B-102A(P). The calculated vertical hydraulic conductivity was 1.2 x $10^{-4}$ centimeters per second (cm/s) and the calculated horizontal hydraulic conductivity values ranged from 8.0 x $10^{-6}$ to 2.7 x $10^{-6}$ cm/s.

As discussed above, observations during drilling and sampling indicate the presence of significant fractions of large materials, including gravels, cobbles, and boulders in the embankment fill. The results of the field tests were likely influenced by the presence of these larger materials.

Laboratory index property tests were performed on eleven samples of embankment fill material from B-101(P), B-102A(P), and B-103(P), ranging in depth from 10.0 to 51.5 feet. Some of the results are summarized as follows:

- The natural moisture content ranged from 10.8 to 25.4 percent and averaged 16.8 percent.
- The natural dry density ranged from 95.6 to 109.6 pcf and averaged 103.4 pcf.
- The liquid limit was either 27 or 28 and the plasticity index was 11 for all samples.
- Two standard Proctor tests were performed, and the results were very similar between the two samples. The maximum dry density for sample B-103(P), Bu-11 was 131.3 pcf at optimum moisture of 10.3 percent. The maximum dry density for sample B-101(P), Bu-6 was 131.3 pcf at optimum moisture of 10.4 percent.
- Three samples from B-101(P) and B-102A(P) had a suite of corrosion tests performed. The three samples were taken at depths near the approximated depth of the outlet works conduit, ranging from 44.0 to 51.5 feet. See Table 3.1 for corrosion test results.
- Embankment fill materials were classified as nondispersive.

### 4.3.3 Colluvium (Qc)

Colluvium was encountered at the ground surface in B-104(P), B-105A(P), and B-105B(P), and extended to the final boring depths of 33.0, 73.5, and 12.6 feet, respectively. Colluvium was encountered beneath embankment fill and within B-101(P) and B-103(P) at approximately 51.1 and 23.1 feet, respectively, and extended to the final boring depths of 77.5 and 30.0 feet, respectively.

In order of prevalence, colluvium consisted of sandy lean clay with gravel (CL), clayey sand with gravel (SC), gravelly lean clay with sand (CL), lean clay with sand (CL), lean clay (CL), sandy lean clay (CL), poorly graded gravel with silt and sand (GP-GM), lean clay with gravel (CL), and poorly graded sand with clay and gravel (SP-SC). Colluvium contained 5 to 100 percent nonplastic to highly plastic fines, fines were mostly low to medium plasticity, 0 to 80 percent fine to coarse grained sand, and 0 to 75 percent fine to coarse grained gravel. The maximum recovered particle size was 2.0 inches. Chlorite deposits were present in colluvium from depths of 25.3 to 30.3 feet in B-104(P). The composition and maximum particle size observed in the recovered samples were influenced by the size of the samplers; difficult sampling conditions were encountered that are likely indicative of larger gravels, cobbles, or boulders within the colluvium. The colluvium is anticipated to be a heterogeneous material based on its formation from talus deposit, landslide, earthflow, and soil creep processes (Ellis and Gabaldo, 1989).

Colluvium was generally dry to moist above the water table and moist to wet below the water table. Drive samplers encountered refusal (50 blows for less than 6 inches) at nine locations after advancing the sampler 0.2 to 0.4 foot. At 20 other sample locations, uncorrected SPT N-values ranged from 5 to 76 and averaged 33. In our opinion, the SPT results were likely influenced by larger gravel, cobbles, or boulders within the colluvium and are not reliable to correlate with material density; however, apparent density based on SPT values is reported on the boring logs.

Ten in-situ permeability tests were performed in the colluvium; the calculated vertical hydraulic conductivity values ranged from 7.1 x $10^{-3}$ to 1.1 x $10^{-3}$ cm/s and the calculated horizontal hydraulic conductivity values ranged from 3.4 x $10^{-4}$ to 4.0 x $10^{-6}$ cm/s.

As discussed above, observations during drilling and sampling indicate the presence of significant fractions of large materials, including gravels, cobbles, and boulders in the colluvium. The results of the field tests were likely influenced by the presence of these larger materials.

Laboratory index, permeability, and strength tests were performed on three samples of colluvium from B-101(P), B-103(P), and B-104(P). Some of the results are summarized as follows:

- The natural moisture content ranged from 19.7 percent to 25.1 percent.
- The natural dry density ranged from 101.6 pcf to 111.8 pcf.
- The liquid limit was either 27 or 32 and the plasticity index was 12 or 13.

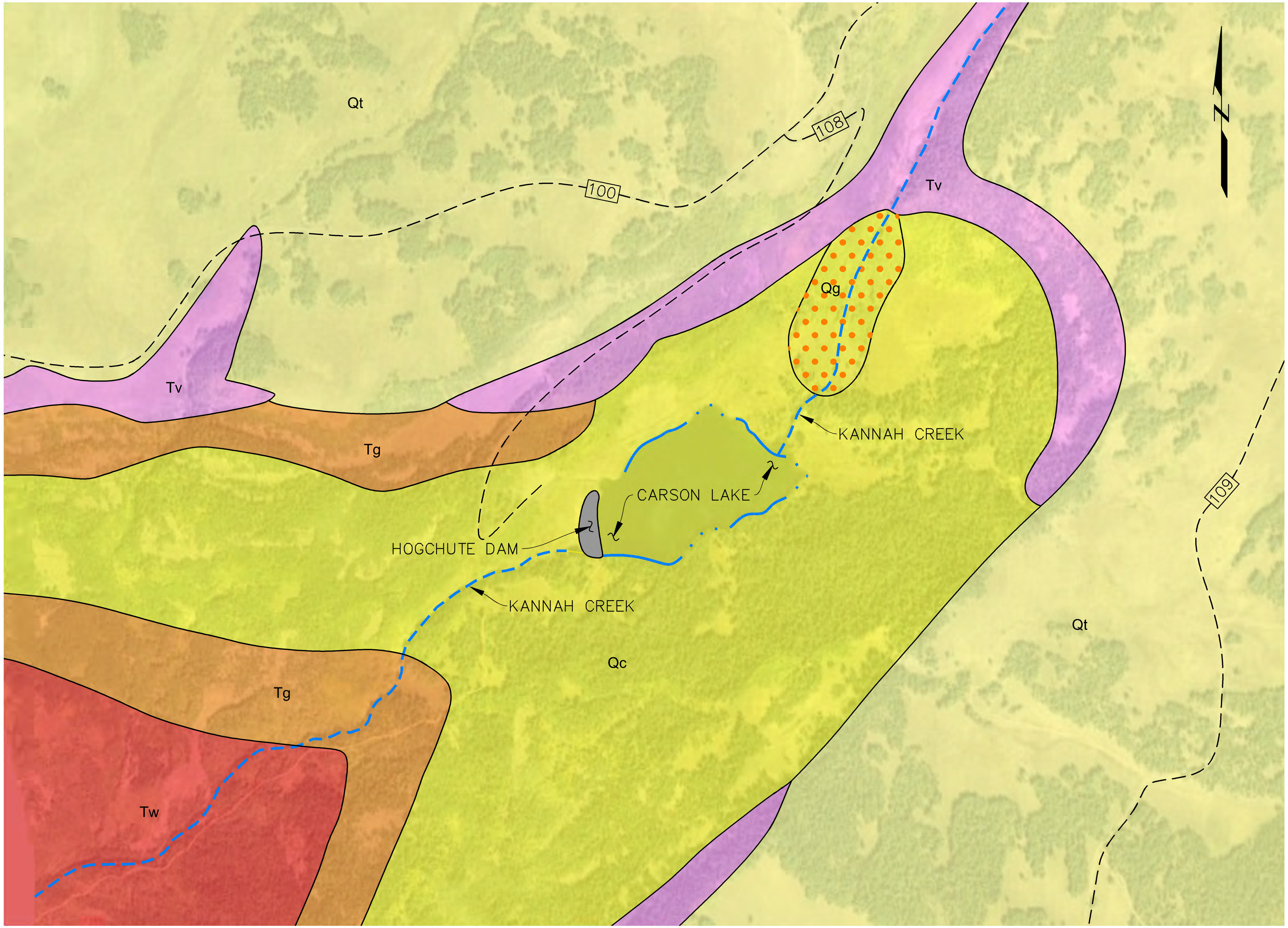
- One standard Proctor test was performed. The maximum dry density for sample B-101(P), Bu-20 was 126.9 pcf at optimum moisture of 12.1 percent.
- Consolidated-undrained triaxial tests and permeability tests were performed on one sample at compression test pressures of 3,000, 6,000, and 10,000 pounds per square foot (psf). The effective strength parameters were phi' of 36 degrees and c' of zero psf. The total strength parameters were phi of 22 degrees and cohesion of 640 psf. The triaxial data are based on the maximum principal stress ratio.
- The permeability results at 3,000, 6,000, and 10,000 psf compression test pressures were 3.4 x $10^{-5}$, 3.1 x $10^{-3}$, and 1.7 x $10^{-5}$ cm/s, respectively.
- See Table 3.1 for results of the one-dimensional compression test and see Table 3.2 for results on the unconfined compressive strength test.

### 4.3.4 Groundwater

Three monitoring wells are located along the crest of the dam (B-101(P), B-102A(P), and B-103(P)). The static water level was recorded in B-101(P) and B-102A(P) at about El. 9868.0 and El. 9869.2, respectively on August 9, 2018, when the reservoir was full at El. 9895. The water level in both wells dropped about 5 feet with a 10-foot decrease in reservoir elevation (to about El. 9885 on September 22, 2018). It is our opinion that the readings for B-101(P) taken on August 23, 2018 and September 6, 2018 were likely recorded in error because they do not appear to follow the trend of B-102A(P) or the general trend of decreasing reservoir level, and do not represent the water level during that period. No water was measured in B-103(P) when the reservoir was full or when the reservoir was lowered 10 feet. The measurements for B-103(P) on Figure 2.7 are the bottom of the dry well; it is likely that groundwater is lower than the B-103(P) screened interval.

Three monitoring wells are located in colluvium downstream of the dam (B-104(P), B-105A(P), and B-105B(P)). The water level at the downstream toe of the dam in B-105A(P) and B-105(B) was at El. 9855.9 and El. 9861.4, respectively, on September 22, 2018 when the reservoir was at El. 9885 feet (about 10 feet below the spillway level). The water level in B-104(P), which is about 45 feet downstream from the embankment toe on the left side of the outlet works, was at El. 9840.5 on September 22, 2018 when the reservoir was at El. 9885.

The drilling operations did not appear to affect the observed flow at the drain near the outlet works or the seeps near shrubs on the hillside. The seepage at the outlet works remained clear prior to, during, and following drilling activities and the seepage rate remained between approximately 4 and 5 gpm.




N

LEGEND:

| | | |
|---|---|---|
| | | EMBANKMENT FILL |
| | Qg | TERRACE GRAVEL |
| | Qc | COLLUVIUM |
| | Qt | UNDIFFERENTIATED TILL |
| | Tv | BASALT |
| | Tg | GREEN RIVER FORMATION |
| | Tw | WASATCH FORMATION |
| | | CREEK |
| | | U.S. FOREST SERVICE ROAD |
| | | BODY OF WATER |

NOTES:

1. AERIAL IMAGERY WAS OBTAINED FROM MICROSOFT BING, IMAGERY DATE UNKNOWN.
2. MAPPED UNITS ARE APPROXIMATE AND BASED ON INFORMATION FROM A PUBLISHED U.S. GEOLOGICAL SURVEY MAP (ELLIS AND GABALDO, 1989). MAPPED UNITS ARE SHOWN ON THIS FIGURE FOR COMPLETENESS AND MAY NOT HAVE BEEN ENCOUNTERED DURING FIELD WORK PERFORMED BY RJH. NOT ALL UNITS SHOWN IMPACT THIS PROJECT AND THEREFORE ARE NOT DESCRIBED IN THE REPORT TEXT.
3. APPROXIMATE LOCATIONS OF U.S. FOREST SERVICE ROADS, HOGCHUTE DAM, AND CARSON LAKE DEVELOPED USING MICROSOFT BING AERIAL IMAGERY.

REPRODUCE IN COLOR

0 500 1000 2000 3000

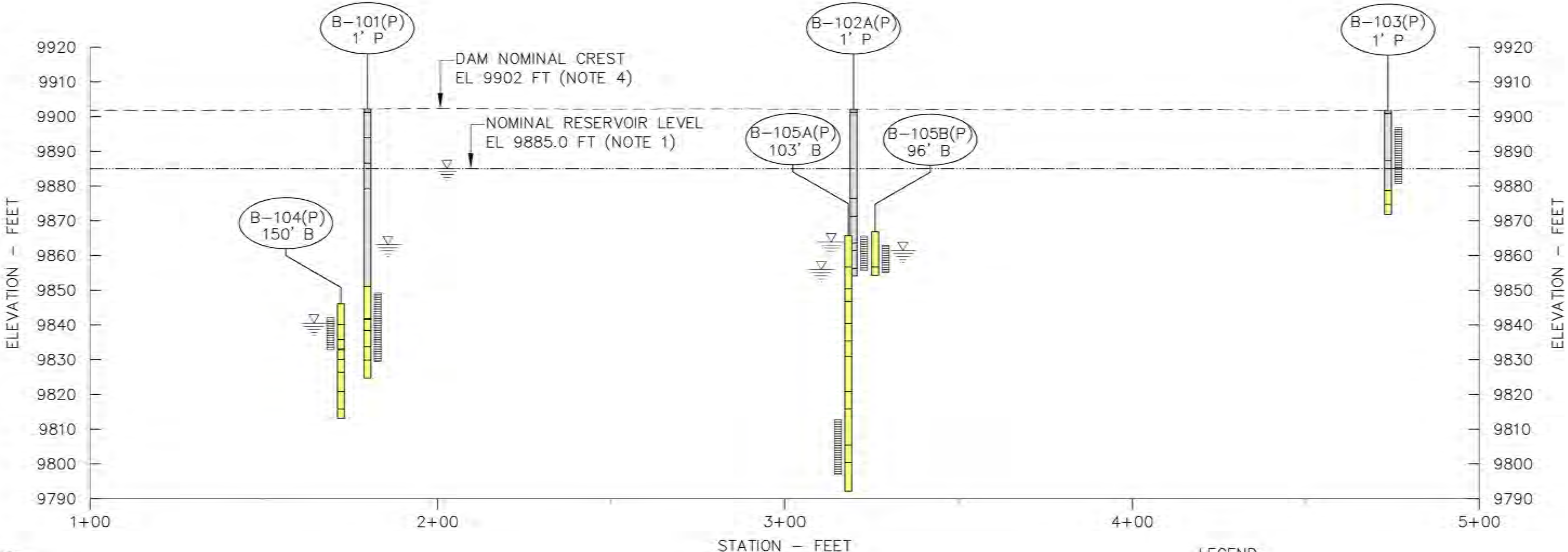
SCALE IN FEET

CITY OF Grand Junction COLORADO

RJH CONSULTANTS, INC.

| | | |
|---|---|---|
| HOGCHUTE DAM<br>SAFETY EVALUATION<br>GEOTECHNICAL DATA REPORT | PUBLISHED SITE GEOLOGY | |
| PROJECT NO. 18115 | January 2019 | **Figure 4.1** |

P:\18115 - HOGCHUTE DAM SAFETY EVALUATION\CAD\FIGURES\MONITORING WELLS\GEO MAP.DWG 1/2/2019 11:53 AM




## PROFILE

0 15 30 60 90

SCALE IN FEET

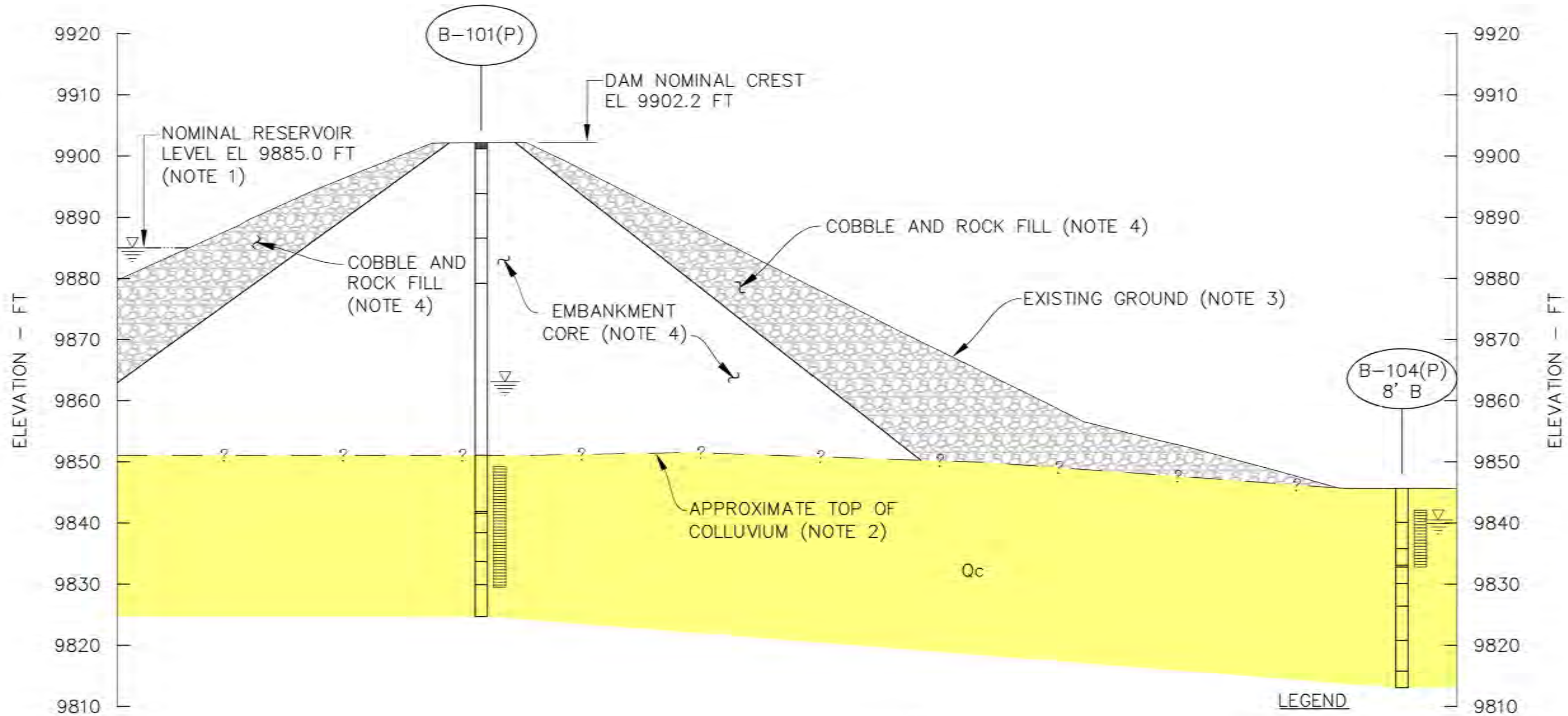
NOTES:

1. NOMINAL RESERVOIR LEVEL DURING FINAL GROUNDWATER LEVEL MEASUREMENT ON 9/22/2018.
2. B-103(P) WELL WAS DRY AT FINAL GROUNDWATER LEVEL MEASUREMENT.
3. ALL GEOLOGICAL CONTACTS ARE APPROXIMATE AND NOT ALL INFORMATION IS SHOWN. BORING LOGS SHOWN GENERALIZE SUBSURFACE CONDITIONS AND ARE NOT INTENDED TO BE A COMPLETE OR ACCURATE DEPICTION OF THE SUBSURFACE CONDITIONS. COMPLETE BORING LOGS ARE PROVIDED IN APPENDIX B.
4. GROUND SURFACE TOPOGRAPHY DATA PROVIDED BY CITY OF GRAND JUNCTION, CO. HORIZONTAL DATUM IS NAD83 AND VERTICAL DATUM IS NAVD88.
5. GEOMETRY OF EMBANKMENT ZONES, OUTLET WORKS, TOE DRAIN, AND CUTOFF TRENCH NOT SHOWN.
6. BORING B-102B NOT SHOWN BECAUSE DRILLED STRATIGRAPHIC UNITS ARE THE SAME AS B-102A(P).

LEGEND

- ROAD BASE
- EMBANKMENT FILL
- Qc COLLUVIUM
- MONITORING WELL SENSING ZONE
- GROUNDWATER LEVEL MEASURED FROM MONITORING WELL ON 9/22/2018
- B-101(P) — MONITORING WELL NAME
- 1' P — DISTANCE PROJECTED (P) OR BEYOND (B) SECTION LOCATION

| City of Grand Junction Colorado | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | DAM PROFILE |
|---|---|---|---|
| | | PROJECT NO. 18115 | January 2019 **Figure 4.2** |




SECTION A 1.2

0 10 20 40 60
SCALE IN FEET

NOTES:

1. NOMINAL RESERVOIR LEVEL DURING FINAL GROUNDWATER LEVEL MEASUREMENT ON 9/22/2018.
2. ALL GEOLOGICAL CONTACTS ARE APPROXIMATE AND NOT ALL INFORMATION IS SHOWN. BORING LOGS SHOWN GENERALIZE SUBSURFACE CONDITIONS AND ARE NOT INTENDED TO BE A COMPLETE OR ACCURATE DEPICTION OF THE SUBSURFACE CONDITIONS. COMPLETE BORING LOGS ARE PROVIDED IN APPENDIX B.
3. GROUND SURFACE TOPOGRAPHY DATA PROVIDED BY CITY OF GRAND JUNCTION, CO. HORIZONTAL DATUM IS NAD83 AND VERTICAL DATUM IS NAVD88.
4. GEOMETRY OF EMBANKMENT ZONES WAS APPROXIMATED USING DATA FROM DESIGN DRAWINGS. OUTLET WORKS, TOE DRAIN, AND CUTOFF TRENCH NOT SHOWN.

LEGEND

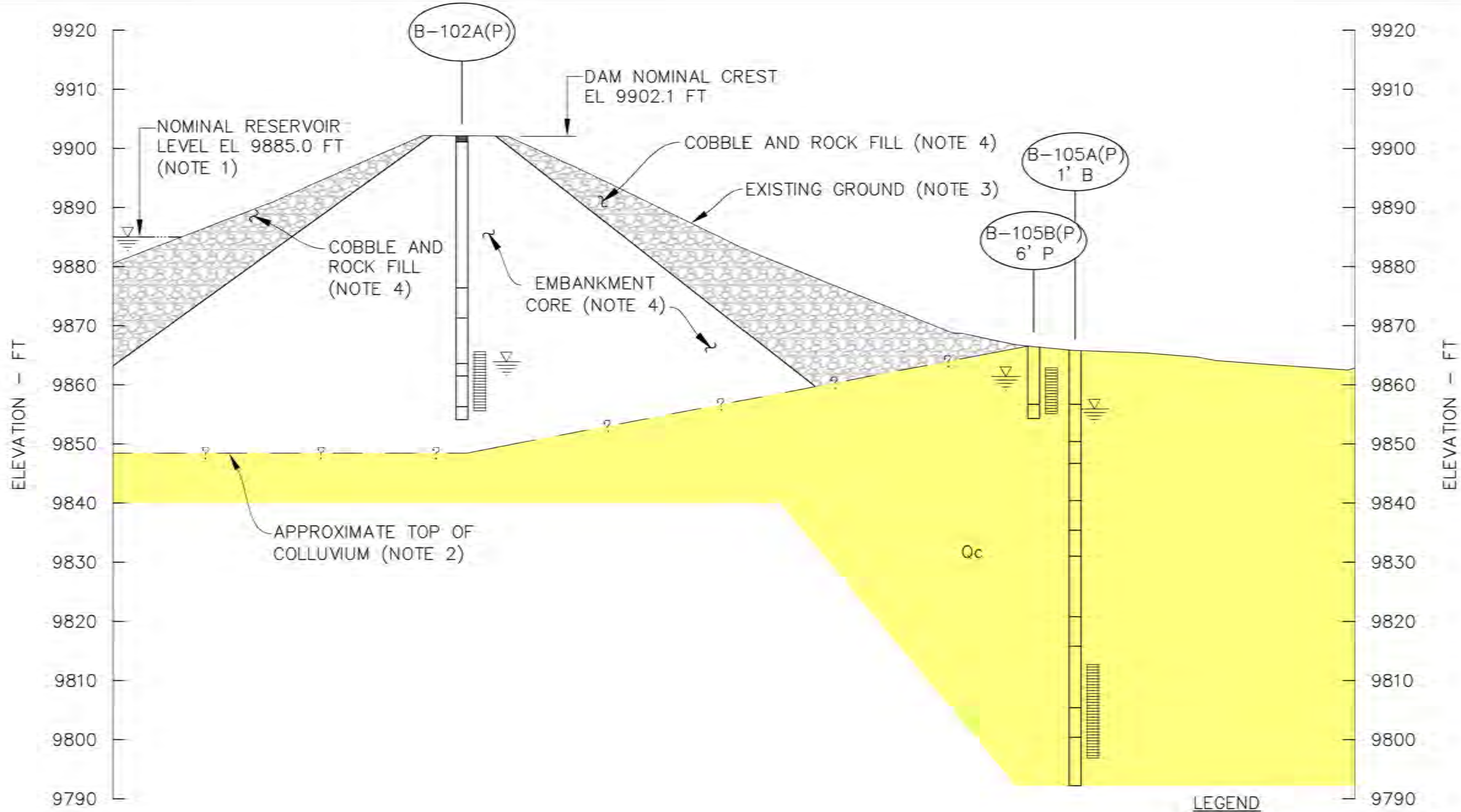
- ROAD BASE
- EMBANKMENT FILL
- Qc COLLUVIUM
- MONITORING WELL SENSING ZONE
- GROUNDWATER LEVEL MEASURED FROM MONITORING WELL ON 9/22/2018
- B-101(P) 1' P — MONITORING WELL NAME; DISTANCE PROJECTED (P) OR BEYOND (B) SECTION LOCATION

City of Grand Junction Colorado | RJH Consultants, Inc.

HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT

DAM SECTION A SOUTH

PROJECT NO. 18115 | January 2019 | **Figure 4.3**




NOTES:

1. NOMINAL RESERVOIR LEVEL DURING FINAL GROUNDWATER LEVEL MEASUREMENT ON 9/22/2018.
2. ALL GEOLOGICAL CONTACTS ARE APPROXIMATE AND NOT ALL INFORMATION IS SHOWN. BORING LOGS SHOWN GENERALIZE SUBSURFACE CONDITIONS AND ARE NOT INTENDED TO BE A COMPLETE OR ACCURATE DEPICTION OF THE SUBSURFACE CONDITIONS. COMPLETE BORING LOGS ARE PROVIDED IN APPENDIX B.
3. GROUND SURFACE TOPOGRAPHY DATA PROVIDED BY CITY OF GRAND JUNCTION, CO. HORIZONTAL DATUM IS NAD83 AND VERTICAL DATUM IS NAVD88.
4. GEOMETRY OF EMBANKMENT ZONES WAS APPROXIMATED USING DATA FROM DESIGN DRAWINGS. OUTLET WORKS, TOE DRAIN, AND CUTOFF TRENCH NOT SHOWN.
5. BORING B-102B NOT SHOWN BECAUSE DRILLED STRATIGRAPHIC UNITS ARE THE SAME AS B-102A(P). BORING B-102B TERMINATED SHALLOW ON A ROCK.

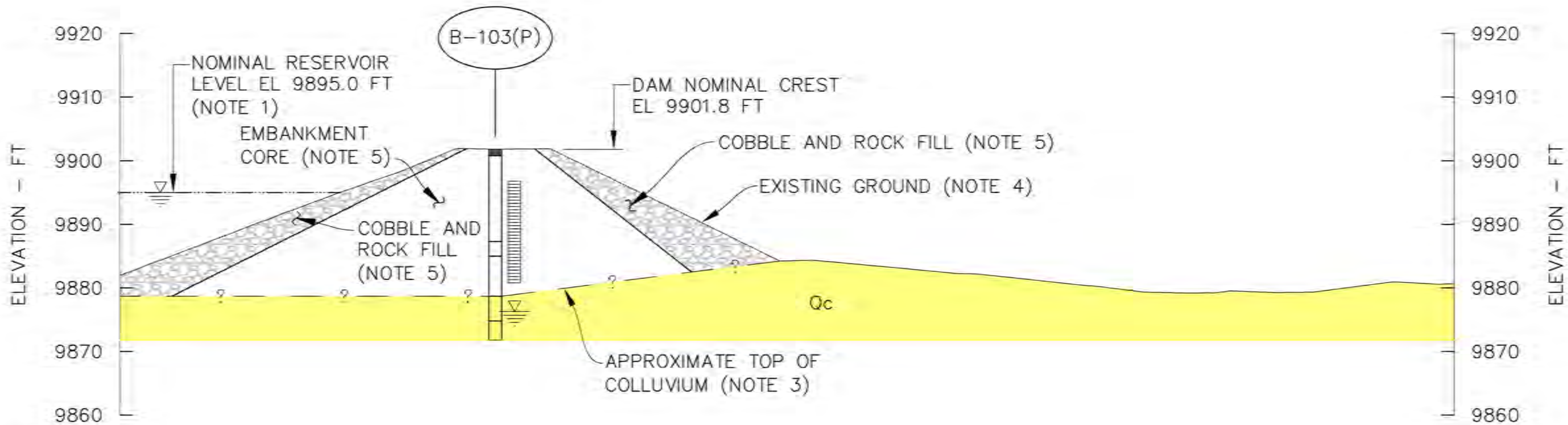
SECTION B / 1.2

0 10 20 40 60
SCALE IN FEET

LEGEND

- ROAD BASE
- EMBANKMENT FILL
- Qc COLLUVIUM
- MONITORING WELL SENSING ZONE
- GROUNDWATER LEVEL MEASURED FROM MONITORING WELL ON 9/22/2018
- B-101(P) — MONITORING WELL NAME
- 1' P — DISTANCE PROJECTED (P) OR BEYOND (B) SECTION LOCATION

| City of Grand Junction Colorado | RJH CONSULTANTS, INC. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | DAM SECTION B MIDDLE |
|---|---|---|---|
| | | PROJECT NO. 18115 | January 2019 Figure 4.4 |




SECTION C 1.2

0 10 20 40 60
SCALE IN FEET

NOTES:

1. NOMINAL RESERVOIR LEVEL DURING DRILLING ON 7/23/2018.
2. B-103(P) WELL WAS DRY DURING FINAL GROUNDWATER LEVEL MEASUREMENT FROM WELL ON 9/22/2018. GROUNDWATER LEVEL SHOWN WAS MEASURED DURING DRILLING ON 7/23/2018.
3. ALL GEOLOGICAL CONTACTS ARE APPROXIMATE AND NOT ALL INFORMATION IS SHOWN. BORING LOGS SHOWN GENERALIZE SUBSURFACE CONDITIONS AND ARE NOT INTENDED TO BE A COMPLETE OR ACCURATE DEPICTION OF THE SUBSURFACE CONDITIONS. COMPLETE BORING LOGS ARE PROVIDED IN APPENDIX B.
4. GROUND SURFACE TOPOGRAPHY DATA PROVIDED BY CITY OF GRAND JUNCTION, CO. HORIZONTAL DATUM IS NAD83 AND VERTICAL DATUM IS NAVD88.
5. GEOMETRY OF EMBANKMENT ZONES WAS APPROXIMATED USING DATA FROM DESIGN DRAWINGS. OUTLET WORKS, TOE DRAIN, AND CUTOFF TRENCH NOT SHOWN.

LEGEND

- ROAD BASE
- EMBANKMENT FILL
- Qc COLLUVIUM
- MONITORING WELL SENSING ZONE
- GROUNDWATER LEVEL MEASURED FROM MONITORING WELL ON 7/23/2018
- B-101(P) MONITORING WELL NAME

| City of Grand Junction Colorado | RJH Consultants, Inc. | HOGCHUTE DAM SAFETY EVALUATION GEOTECHNICAL DATA REPORT | DAM SECTION C NORTH |
|---|---|---|---|
| | | PROJECT NO. 18115 | January 2019 **Figure 4.5** |

P:\18115 - HOGCHUTE DAM SAFETY EVALUATION\CAD\FIGURES\MONITORING WELLS\MONITORING WELLS.DWG 1/2/2019 3:02 PM

# SECTION 5 - LIMITATIONS

This Report has been prepared for the exclusive use of RJH, the City of Grand Junction, and the SEO to support evaluation of potential dam safety issues at Hogchute Dam. RJH is not responsible for technical interpretations of this data by others. RJH has endeavored to conduct our professional services for this Project in a manner consistent with a level of care and skill ordinarily exercised by members of the engineering profession currently practicing in Colorado under similar conditions as this Project. RJH makes no other warranty, expressed or implied.

The methods used in this study indicate subsurface conditions only at the specific locations where samples were obtained, only at the time they were obtained, and only to the depths penetrated. Samples cannot be relied on to accurately reflect variations in subsurface conditions that may exist between sampling locations.

# SECTION 6 - REFERENCES

Ellis, M.S. and Gabaldo, V. (1989). *Geologic Map and Cross Sections of Parts of the Grand Junction and Delta 30' x 60' Quadrangles, West-Central Colorado.* U.S. Geological Survey Coal Investigations Map C-124.

Hvorslev, M.J. (1951). *Time Lag and Soil Permeabilities in Groundwater Observations.* U.S. Army Corps of Engineers Waterways Experiment Station Bulletin 36.

Lambe, T.W. and Whitman, R.V. (1969). *Soil Mechanics.* John Wiley & Sons, New York.

# APPENDIX A

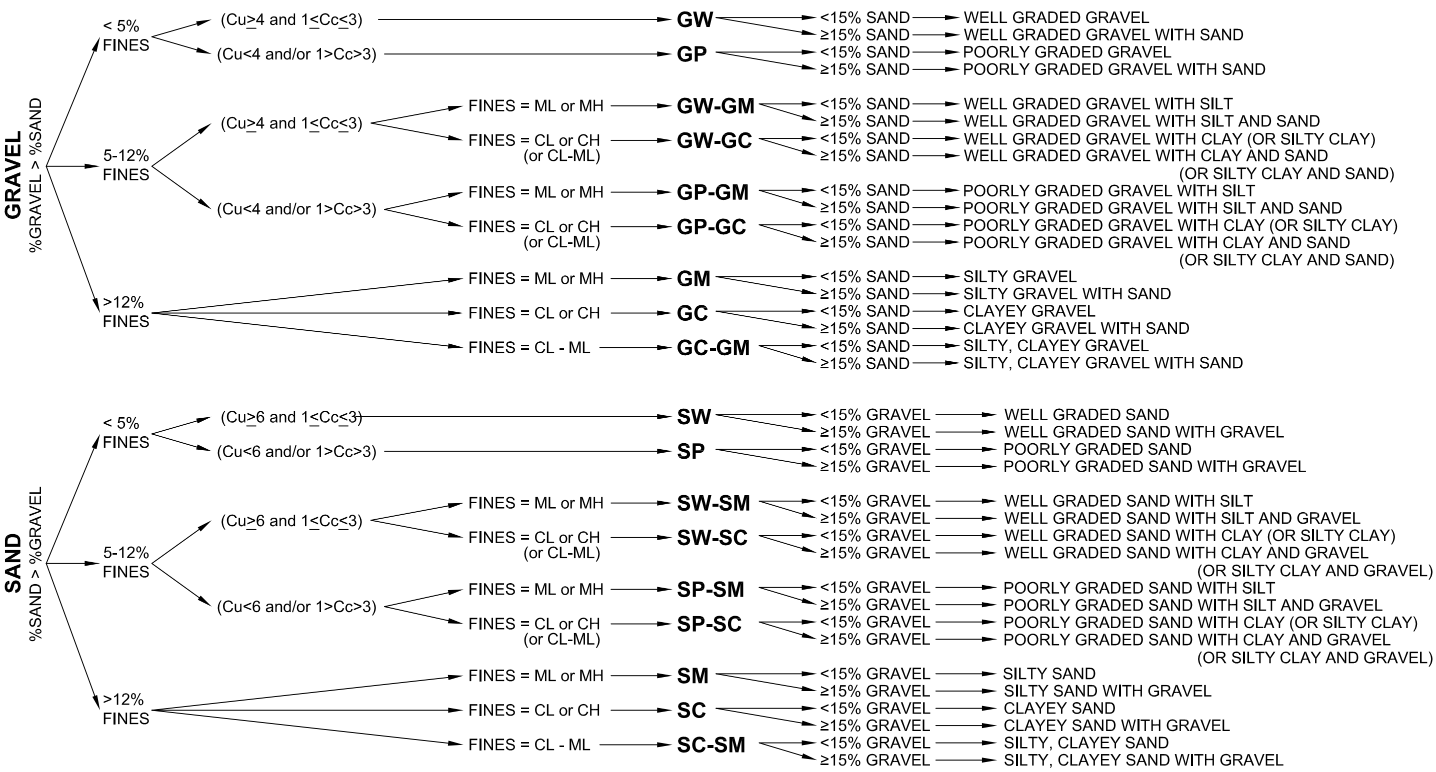
## SOIL DESCRIPTORS

# ABBREVIATIONS

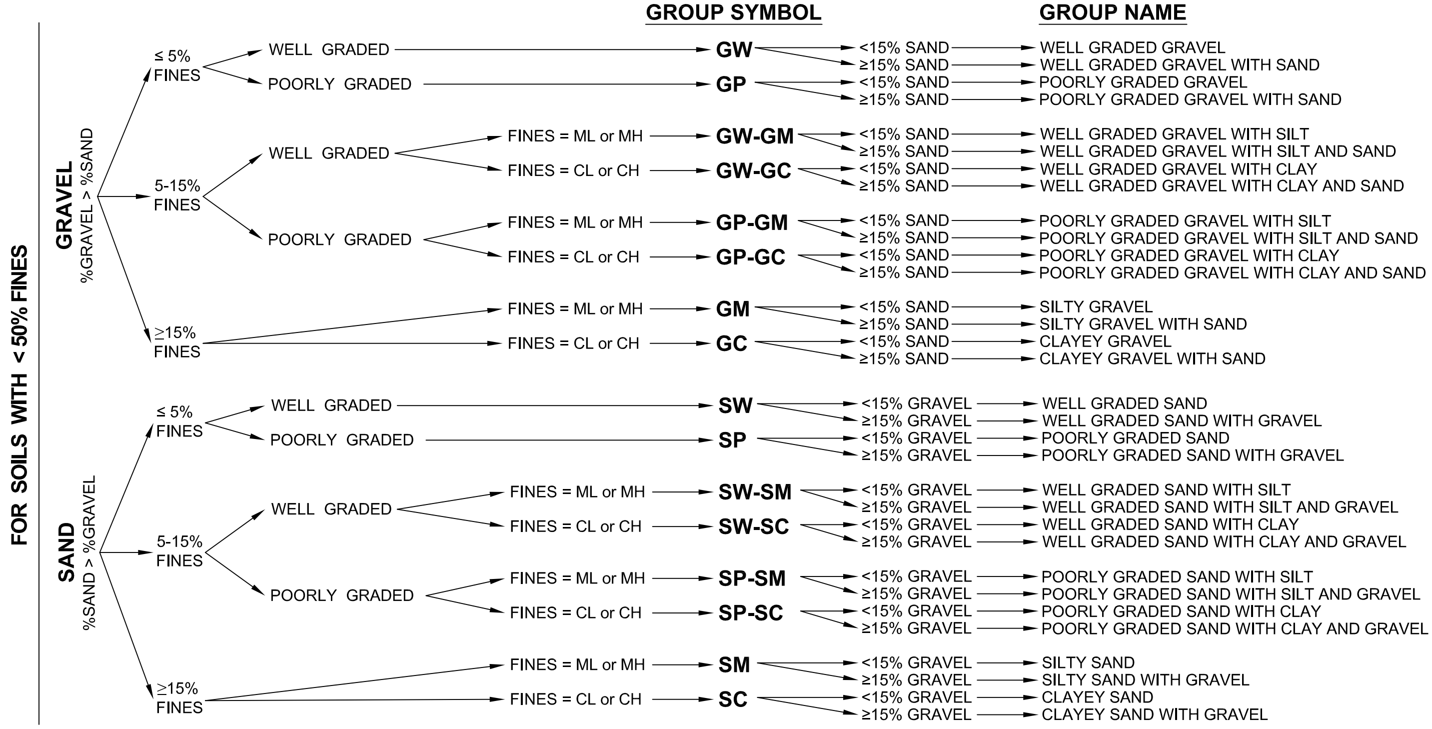
| | |
|---|---|
| Bu | Bulk sample |
| CA | 2.0-inch I.D. ring-lined split barrel California sample |
| DM | 2.5-inch I.D. ring-lined split barrel Dames and Moore (modified California) sample |
| RQD | Rock Quality Designation |
| S | 1.375-inch I.D. standard split-spoon sample (unlined) |
| U | Shelby Tube sample |

# COARSE GRAINED SOILS
# (< 50% FINES)

### A) FLOWCHART APPLIED TO LABORATORY TESTED SOIL SAMPLES.
### ADAPTED FROM ASTM D 2487 *CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES (USCS)*.

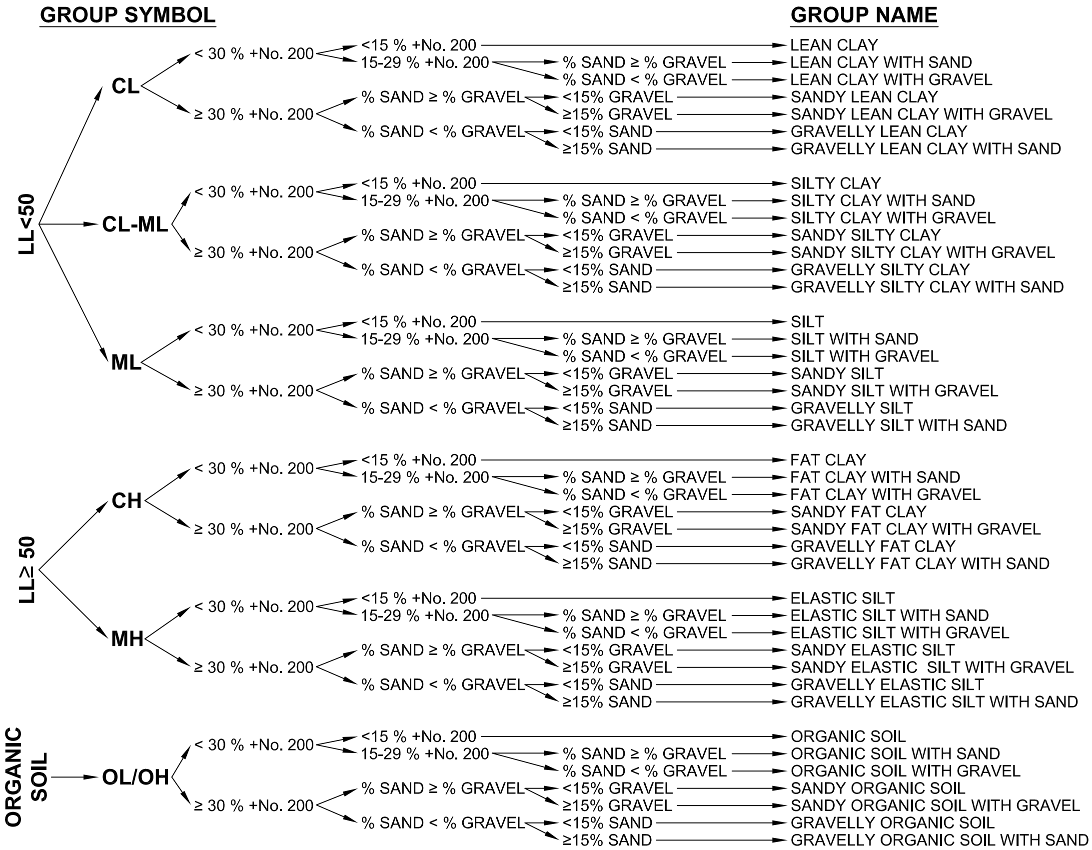



### B) FLOWCHART APPLIED TO FIELD CLASSIFIED SOIL SAMPLES.
### ADAPTED FROM ASTM D 2488 *DESCRIPTION AND IDENTIFICATION OF SOILS (VISUAL-MANUAL PROCEDURE)*.

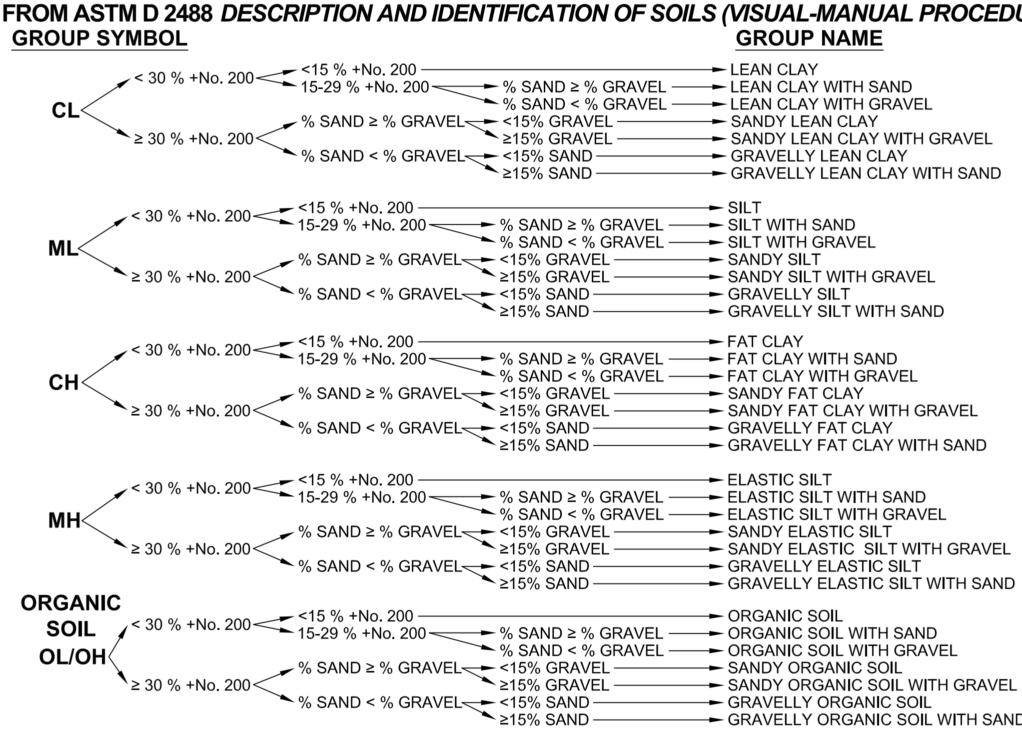


# FINE GRAINED SOILS
# (≥ 50% FINES)

### A) FLOWCHART APPLIED TO LABORATORY TESTED SOIL SAMPLES.
### ADAPTED FROM ASTM D 2487 *CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES (USCS)*.




### B) FLOWCHART APPLIED TO FIELD CLASSIFIED SOIL SAMPLES.
### ADAPTED FROM ASTM D 2488 *DESCRIPTION AND IDENTIFICATION OF SOILS (VISUAL-MANUAL PROCEDURE)*.

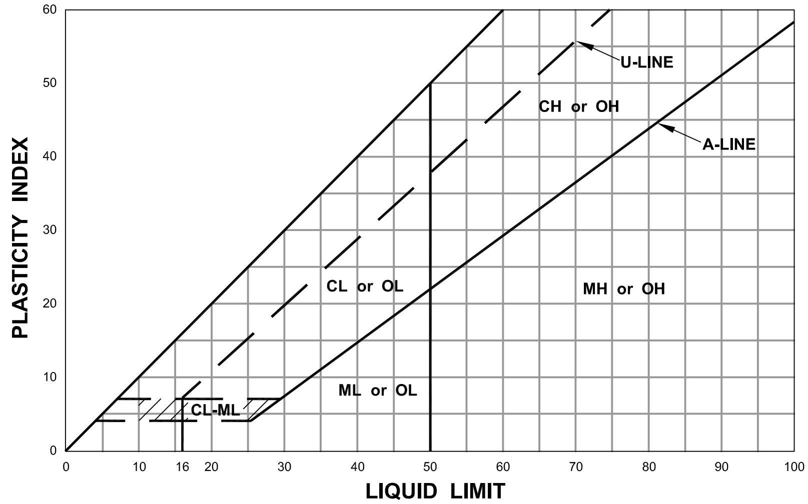



**NOTE:**

1. **THE PLASTICITY CHART ON THE FOLLOWING PAGE WAS USED TO IDENTIFY THE GROUP SYMBOL FOR FLOWCHART A.**
   **A COMBINATION OF THE VISUAL MANUAL CRITERIA ON THE FOLLOWING PAGE WERE USED TO IDENTIFY THE GROUP SYMBOL FOR FLOWCHART B.**

# SOIL PLASTICITY CHARACTERISTICS

## PLASTICITY CHART




**A) IDENTIFICATION OF FINES GROUP SYMBOL FROM LABORATORY TESTS.**
**REPRODUCED FROM ASTM D 2487 *CLASSIFICATION OF SOILS FOR ENGINEERING PURPOSES (USCS)*.**

**B) IDENTIFICATION OF FINES GROUP SYMBOL FROM VISUAL-MANUAL CRITERIA.**
**REPRODUCED FROM ASTM D 2488 *DESCRIPTION AND IDENTIFICATION OF SOILS (VISUAL-MANUAL PROCEDURE).***

| DRY STRENGTH | |
|---|---|
| DESCRIPTION | CRITERIA |
| NONE | CRUMBLES TO POWDER WHILE HANDLING. |
| LOW | CRUMBLES TO POWDER WITH SOME FINGER PRESSURE. |
| MEDIUM | BREAKS INTO PIECES OR CRUMBLES WITH CONSIDERABLE FINGER PRESSURE. |
| HIGH | CANNOT BE BROKEN WITH FINGER PRESSURE. BREAKS INTO PIECES BETWEEN THUMB AND HARD SURFACE. |
| VERY HIGH | CANNOT BE BROKEN BETWEEN THUMB AND HARD SURFACE. |

| DILATANCY (RESISTANCE TO SHAKING) | |
|---|---|
| DESCRIPTION | CRITERIA |
| NONE | NO VISIBLE CHANGE IN SPECIMEN. |
| SLOW | WATER APPEARS SLOWLY ON THE SURFACE OF THE SPECIMEN DURING SHAKING AND DOES NOT DISAPPEAR OR DISAPPEARS SLOWLY UPON SQUEEZING. |
| RAPID | WATER APPEARS QUICKLY ON THE SURFACE OF THE SPECIMEN DURING SHAKING AND DISAPPEARS QUICKLY UPON SQUEEZING. |

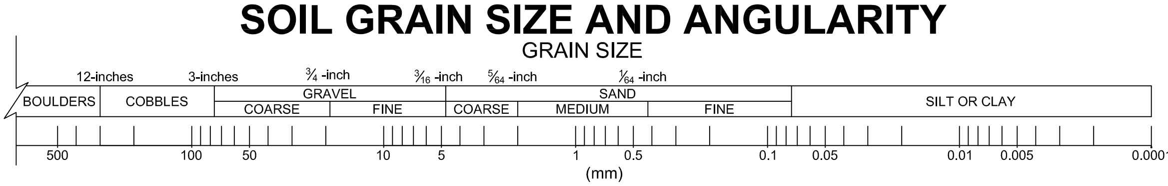
| TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT) | |
|---|---|
| DESCRIPTION | CRITERIA |
| LOW | ONLY SLIGHT PRESSURE IS REQUIRED TO ROLL THE THREAD. THREAD AND LUMP ARE WEAK AND SOFT. |
| MEDIUM | MEDIUM PRESSURE IS REQUIRED TO ROLL THE THREAD. THREAD AND LUMP HAVE MEDIUM STIFFNESS. |
| HIGH | CONSIDERABLE EFFORT IS REQUIRED TO ROLL THE THREAD. THREAD AND LUMP HAVE HIGH STIFFNESS. |

| PLASTICITY | |
|---|---|
| DESCRIPTION | CRITERIA FOR A ⅛-INCH (3 mm) THREAD. |
| NON-PLASTIC | THREAD CANNOT BE ROLLED. |
| LOW | THREAD CAN BARELY BE ROLLED AND THE LUMP CANNOT BE FORMED WHEN DRIER THAN THE PLASTIC LIMIT. |
| MEDIUM | THREAD IS EASY TO ROLL AND NOT MUCH TIME IS REQUIRED TO REACH THE PLASTIC LIMIT. THE THREAD CANNOT BE RE-ROLLED SEVERAL TIMES AFTER REACHING THE PLASTIC LIMIT. THE LUMP CRUMBLES WHEN DRIER THAN THE PLASTIC LIMIT. |
| HIGH | IT TAKES CONSIDERABLE TIME ROLLING AND KNEADING TO REACH THE PLASTIC LIMIT. THE THREAD CAN BE RE-ROLLED SEVERAL TIMES AFTER REACHING THE PLASTIC LIMIT. THE LUMP CAN BE FORMED WITHOUT CRUMBLING WHEN DRIER THAN THE PLASTIC LIMIT. |

| SYMBOL | DRY STRENGTH | DILATANCY | TOUGHNESS AND PLASTICITY | PLASTICITY |
|---|---|---|---|---|
| ML | NONE - LOW | SLOW - RAPID | LOW | LOW TO NON-PLASTIC |
| CL | MEDIUM - HIGH | NONE - SLOW | MEDIUM | LOW TO MEDIUM |
| MH | LOW - MEDIUM | NONE - SLOW | LOW TO MEDIUM | LOW TO MEDIUM |
| CH | HIGH - VERY HIGH | NONE | HIGH | HIGH |

# SOIL GRAIN SIZE AND ANGULARITY

## GRAIN SIZE




## PARTICLE ANGULARITY

ROUNDED SUBROUNDED SUBANGULAR ANGULAR

## TABLE 1.1
## CRITERIA FOR DESCRIBING SOIL STRUCTURE[1]

| Description | Criteria |
|---|---|
| Stratified | Alternating layers of varying material or color with layers greater than or equal to 1/4 inch thick (6 mm) |
| Laminated | Alternating layers of varying material or color with layers less than 1/4 inch thick (6 mm) |
| Fissured | Breaks along definite plates of fracture with little resistance to fracturing |
| Slickensided | Fracture planes appear polished or glossy, sometimes striated |
| Blocky | Cohesive soil that can be broken down into small angular lumps which resist further breakdown |
| Lensed | Inclusion of small pockets of different soils, such as small lenses of sand scattered through a mass of clay |
| Homogeneous | Same color and appearance throughout |

Note:
1. Modified from ASTM D 2488 *Description and Identification of Soils (Visual-Manual Procedure)* and differ from the U.S. Bureau of Reclamation *Engineering Geology Field Manual* (2001).

## TABLE 1.2
## RELATIVE DENSITY OF SANDS ACCORDING TO RESULTS OF STANDARD PENETRATION TEST[1]

| Number of Blows N | Relative Density |
|---|---|
| 0-4 | Very Loose |
| 5-10 | Loose |
| 11-30 | Medium |
| 31-50 | Dense |
| Over 50 | Very Dense |

Note:
1. Modified from Terzaghi, Peck, and Mesri (1996).

## TABLE 1.3
## GUIDE FOR STIFFNESS OF FINE-GRAINED SOILS[1]

| Description | Criteria | Estimated Unconfined Compressive Strength (TSF) |
|---|---|---|
| Very Soft | Extrudes between fingers when squeezed | <0.25 |
| Soft | Molded by light finger pressure | 0.25-0.50 |
| Medium | Molded by strong finger pressure | 0.50-1.00 |
| Stiff | Readily indented by thumb or penetrated with great effort | 1.00-2.00 |
| Very Stiff | Readily indented by thumbnail | 2.00-4.00 |
| Hard | Indented with difficulty by thumbnail | >4.00 |

Note:
1. Reproduced from NAVFAC (1986).

## TABLE 1.4
## CRITERIA FOR DESCRIBING SOIL MOISTURE CONDITION(1)

| Description | Criteria |
|---|---|
| Dry | Absence of moisture, dusty, dry to the touch |
| Moist | Damp but no visible water |
| Wet | Visible free water, usually soil is below the water table |

Note:
1. Reproduced from ASTM 2488 *Description and Identification of Soils (Visual-Manual Procedure)*.

## TABLE 1.5
## CRITERIA FOR DESCRIBING SOIL CEMENTATION(1)(2)

| Description | Criteria |
|---|---|
| Weak | Crumbles or breaks with handling or little finger pressure |
| Moderate | Crumbles or breaks with considerable finger pressure |
| Strong | Will not crumble or break with finger pressure |

Notes:
1. Reproduced from ASTM 2488 *Description and Identification of Soils (Visual-Manual Procedure)*.
2. The absence of cementation was not recorded on boring logs.

## TABLE 1.6
## CRITERIA FOR DESCRIBING SOIL REACTION WITH HCL(1)

| Description | Criteria |
|---|---|
| None(2) | No visible reaction |
| Weak | Some reaction, with bubbles forming slowly |
| Strong | Violent reaction, with bubbles forming immediately |

Notes:
1. Reproduced from ASTM 2488 Description and Identification of Soils (Visual-Manual Procedure).
2. The absence of a reaction was not recorded on boring logs.

ASTM D 2487 (2011). *Standard Classification of Soils for Engineering Purposes (USCS)*. June.

ASTM D 2488 (2009). *Standard Practice for Description and Identification of Soils (Visual-Manual Method*). July.

Bates, Robert C. and Jackson, Julia A. (1984). *Dictionary of Geologic Terms,* 3rd Edition.

Hunt, Roy E. (Hunt) (2005). *Geotechnical Investigation Handbook*.

Naval Facilities Engineering Command (NAVFAC) (1986). *Soil Mechanics Design Manual 7.01 (DM-7.01)*. September.

Terzaghi, Karl, Peck, Ralph B., and Mesri, Gholamreza. (Terzaghi, Peck, and Mesri). (1996). *Soil Mechanics in Engineering Practice*.

U.S. Bureau of Reclamation (USBR) (2001). *Engineering Geology Field Manual*.

# APPENDIX B

## BORING LOGS

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995296, Long: -108.109759 deg
Ground El: 9902.2 ft  Total Depth: 77.5 ft
Groundwater El: 9878.0 ft  On Date: 07-26-2018

Start Date: 07-25-2018  End Date: 07-28-2018
Driller: HRL Compliance - Jose  Logged By: JNH
Bedrock Depth: Not encountered  Checked By: ERS
Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

Borehole ID: **B-101(P)**
Sheet 1 of 4

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|
| | 0.0 | | | | | | 0.0 to 1.0 ft: Road Base; [--] |
| 9901.2 | 1.0 | | | | | Grinding and minor rig rocking from 1.0 to 14.0 feet. Sample Bu-1 collected from 2.0 to 10.0 feet. | Bu-1, S-2: Clayey Gravel with Sand Mostly gravel, fine to coarse grained, subangular to subrounded; 20-35% fines, medium plasticity; 15-30% sand, fine to coarse grained, subangular to subrounded; less than 5% cobbles; maximum particle size = 4 inches; dense; moist; dark brown; (GC); [Fill] |
| | 5.0 | S - 2 | 7/13/21 | 1.5 | 1.6 | | 5.0 to 6.5 ft: 20-35% sand; 15-30% fines; |
| 9893.9 | 8.3 | | | | | | S-3, S-4, U-5: Clayey Sand with Gravel Mostly sand, fine to coarse grained, subangular to subrounded; 20-35% fines, medium plasticity; 15-25% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.75 inches; medium dense; moist; dark brown; (SC); [Fill] |
| | 10.0 | S - 3 | 5/10/12 | 1.5 | 1.6 | | |
| | 12.5 | S - 4 | 7/11/10 | 1.5 | 1.9 | | |
| | 14.0 | | | | | Smooth augering from 14.0 to 16.0 feet. | |
| | 15.0 | U - 5 | | 0.6 | | U-5 disturbed, gravel/cobble damaged sampler. | |
| 9886.6 | 15.6 | | | | | Sample Bu-6 collected from 15.0 to 25.0 feet. Grinding and minor rig rocking from 16.0 to 36.5 feet. | Bu-6, S-7, CA-8: Clayey Gravel with Sand Mostly gravel, fine to coarse grained, subangular to subrounded; 20-30% sand, fine to coarse grained, subangular to subrounded; 15-30% fines, medium plasticity; maximum particle size = 2.25 inches; dense; moist; dark brown; (GC); [Fill] |
| | 17.5 | S - 7 | 11/15/20 | 1.5 | 0.6 | | |
| | 20 | | | | | | |

Continued on next sheet

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the dam foundation.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995296, Long: -108.109759 deg
Ground El: 9902.2 ft    Total Depth: 77.5 ft
Groundwater El: 9878.0 ft    On Date: 07-26-2018

Start Date: 07-25-2018    End Date: 07-28-2018
Driller: HRL Compliance - Jose    Logged By: JNH
Bedrock Depth: Not encountered    Checked By: ERS

Borehole ID: **B-101(P)**
Sheet 2 of 4

Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | 20–21 | CA - 8 | 35/40 | 1.0 | 1.0 | CA-8 disturbed by gravel/ cobble. | | |
| 9879.2 | 23 | | | | | | | S-9, S-10, CA-11, S-12, Bu-13, S-14, Bu-15, CA-16, U-17, S-18, S-19: Clayey Sand with Gravel<br>Mostly sand, fine to coarse grained, subangular to subrounded; 20-45% fines, medium plasticity; 20-35% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.5 inches; medium dense to dense; moist to wet; dark brown; (SC);<br>[Fill] |
| | 24 | | | | | Groundwater encountered at 24.2 feet during drilling on 7/26/2018. | | |
| | 25–26.5 | S - 9 | 8/13/18 | 1.5 | 1.6 | Sample Bu-13 collected from 25.0 to 40.0 feet. | | |
| | 27.5–29 | S - 10 | 9/10/23 | 1.5 | 1.5 | | | |
| | 30–31 | CA - 11 | 10/15 | 1.0 | 1.0 | | | 30.0 to 31.0 ft: PP = 4 tsf; |
| | 34 | | | | | Cuttings and samples are moist, no longer wet, from 34.0 to 55.3 feet. Potential perched water table at 24.2 feet. | | |
| | 35–36.5 | S - 12 | 30/21/17 | 1.5 | 1.5 | | | 35.0 to 36.5 ft: 15-30% fines; |
| | 36.5 | | | | | Grinding with occasional periods of smooth augering from 36.5 to 64.5 feet. | | |
| | 38.3 | | | | | Groundwater encountered at 38.3 feet on 7/27/2018 a.m. after drilling to 75.0 feet the previous day. | | |
| | 40 | | | | | | | |

Continued on next sheet

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the dam foundation.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995296, Long: -108.109759 deg
Ground El: 9902.2 ft    Total Depth: 77.5 ft
Groundwater El: 9878.0 ft    On Date: 07-26-2018

Start Date: 07-25-2018    End Date: 07-28-2018
Driller: HRL Compliance - Jose    Logged By: JNH
Bedrock Depth: Not encountered    Checked By: ERS
Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

Borehole ID: **B-101(P)**


| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|
| | 41 | S - 14 | 6/10/25 | 1.5 | 1.6 | | |
| | 42 | | | | | | |
| | 43 | CA - 16 | 13/28 | 1.0 | 1.0 | | *42.5 to 43.5 ft: PP = 4.5 tsf;* |
| | 44 | | | | | | |
| | 45 | U - 17 | | 0.3 | 0.3 | U-17 disturbed, gravel/cobble damaged sampler. | |
| | 46 | S - 18 | 9/17/20 | 1.5 | 1.7 | Sample Bu-15 collected from 45.0 to 50.0 feet. | |
| | 47 | | | | | | |
| | 48 | | | | | | |
| | 49 | | | | | | |
| | 50 | | | | | | |
| 9851.1 | 51 | S - 19 | 11/23/20 | 1.5 | 1.6 | Bottom of embankment fill at approximately 51.1 feet. | S-19, Bu-20, U-21, S-22: Sandy Lean Clay with Gravel Mostly fines, low to medium plasticity; 20-35% sand, fine to coarse grained, subangular to subrounded; 15-25% gravel, fine to coarse grained; maximum particle size = 2 inches; soft to medium stiff; moist; brown-gray; gravel composed of mostly basalt; (CL); [Colluvium] |
| | 52 | | | | | Sample Bu-20 collected from 51.0 to 65.0 feet. | |
| | 53 | | | | | | |
| | 54 | | | | | | |
| | 55 | U - 21 | | 0.3 | 0.3 | U-21 disturbed, gravel/cobble damaged sampler. | |
| | 56 | | | | | Groundwater encountered at 55.3 feet during drilling on 7/26/2018. | |
| | 57 | | | | | | |
| | 58 | | | | | | |
| | 59 | | | | | | |
| | 60 | | | | | | |

Continued on next sheet

Notes: Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the dam foundation.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995296, Long: -108.109759 deg
Ground El: 9902.2 ft Total Depth: 77.5 ft
Groundwater El: 9878.0 ft On Date: 07-26-2018

Start Date: 07-25-2018 End Date: 07-28-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS
Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

Borehole ID: **B-101(P)**


| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|
| 9841.9 | | | | | | | |
| 9841.6 | 61 | S - 22 | 8/23/31 | 1.5 | 1.5 | | S-22: Poorly Graded Sand with Clay and Gravel<br>Mostly sand, fine to coarse grained, subangular to subrounded; 15-30% gravel, fine grained, subangular to subrounded; 5-15% fines, low to medium plasticity; maximum particle size = 0.5 inches; very dense; wet; dark brown-black; (SP-SC);<br>[Colluvium]<br>S-22: Sandy Lean Clay with Gravel<br>Mostly fines, medium plasticity; 20-35% gravel, fine to coarse grained, subangular to subrounded; 15-25% sand, fine to coarse grained, subangular to subrounded; maximum particle size = 1.75 inches; soft to medium stiff; moist; brown-gray; (CL);<br>[Colluvium] |
| 9838.4 | 64 | | | | | Grinding and minor rig rocking from 64.5 to 76.5 feet.<br>Sample Bu-23 collected from 66.0 to 67.0 feet. | Bu-23: Lean Clay with Sand<br>Mostly fines, medium plasticity; 5-15% sand, fine to coarse grained, subangular to subrounded; less than 5% gravel, fine grained; maximum particle size = 0.2 inches; very soft; wet; brown-gray; (CL);<br>[Colluvium] |
| 9833.7 | 68 | | | | | | S-24: Lean Clay<br>Mostly fines, medium plasticity; 5-15% sand, fine to coarse grained, subangular to subrounded; soft to medium stiff; moist to wet; dark brown-gray; (CL);<br>[Colluvium] |
| | 70 | S - 24 | 4/14/18 | 1.5 | 1.5 | | |
| 9829.9 | 72 | | | | | | S-25, S-26: Sandy Lean Clay<br>Mostly fines, medium plasticity; 10-25% sand, fine to coarse grained, subangular to subrounded; 5-15% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.5 inches; medium stiff; moist; dark brown-gray; (CL);<br>[Colluvium] |
| | 73 | S - 25 | 10/41/35 | 1.5 | 1.6 | | |
| | 76 | S - 26 | 11/32/50 for 5 inches | 1.4 | 1.5 | Auger encountered refusal at 76.5 feet. | |
| 9824.7 | 77.5 | | | | | Bottom of boring at 77.5 feet. | End of boring log at 77.50 ft |

Depth scale: 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the dam foundation.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995677, Long: -108.109800 deg
Ground El: 9902.1 ft Total Depth: 48.0 ft
Groundwater El: 9860.6 ft On Date: 07-24-2018

Start Date: 07-24-2018 End Date: 07-26-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS

Borehole ID: **B-102A(P)**


Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 0.0 to 1.0 ft: Road Base; [--] |
| 9901.1 | 1 | | | | | Continuous grinding and occasional rig rocking from 0.5 to 6.0 feet. | | Bu-1, S-2, S-3, S-4, S-5, S-6, S-7, S-8, CA-9, Bu-10, S-11, S-12: Clayey Gravel with Sand Mostly gravel, fine to coarse grained, subangular to subrounded; 20-35% sand, fine to coarse grained, subangular to subrounded; 20-30% fines, medium plasticity; maximum particle size = 3 inches; medium dense; moist; dark brown; (GC); [Fill] |
| | 2 | S - 2 | 4/7/9 | 1.5 | 1.1 | Sample Bu-1 collected from 2.0 to 18.0 feet. | | |
| | 3 | | | | | | | |
| | 4 | S - 3 | 16/7/30 | 1.5 | 1.5 | | | *4.0 to 5.5 ft: dense;* |
| | 5 | | | | | | | |
| | 6 | | | | | Smooth augering from 6.0 to 7.5 feet. | | |
| | 7 | S - 4 | 11/15/14 | 1.5 | 1.1 | Continuous grinding from 7.5 to 11.0 feet. | | |
| | 8 | | | | | | | |
| | 9 | | | | | | | |
| | 10 | S - 5 | 7/9/11 | 1.5 | 1.5 | | | |
| | 11 | | | | | Smooth augering from 11.0 to 14.0 feet. | | |
| | 12 | S - 6 | 9/8/10 | 1.5 | 1.7 | | | |
| | 13 | | | | | | | |
| | 14 | | | | | Grinding from 14.0 to 16.0 feet. | | |
| | 15 | S - 7 | 7/10/15 | 1.5 | 1.5 | | | |
| | 16 | | | | | Smooth augering from 16.0 to 17.5 feet. | | *16.5 to 18.0 ft: very dense;* |
| | 17 | S - 8 | 8/21/33 | 1.5 | 0.8 | Continuous grinding and occasional rig rocking from 17.5 to 21.0 feet. | | |
| | 18 | | | | | Sample Bu-10 collected from 18.0 to 41.5 feet. | | *18.0 to 23.0 ft: 20-49% fines, low to medium plasticity;* |
| | 19 | CA - 9 | 34/50 for 2 inches | 0.7 | 0.5 | CA-9 disturbed by gravel/ cobble. | | |
| | 20 | | | | | | | |

Continued on next sheet

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the embankment.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995677, Long: -108.109800 deg
Ground El: 9902.1 ft Total Depth: 48.0 ft
Groundwater El: 9860.6 ft On Date: 07-24-2018

Start Date: 07-24-2018 End Date: 07-26-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS
Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

Borehole ID: **B-102A(P)**


| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|
| | 21 | | | | | Smooth augering from 21.0 to 22.0 feet. | |
| | 22 | S - 11 | 12/19/30 | 1.5 | 1.5 | Continuous grinding and minor rig rocking from 22.0 to 26.0 feet. | *21.5 to 23.0 ft: dense;* |
| | 23 | | | | | | |
| | 24 | S - 12 | 26/50 for 3 inches | 0.8 | 0.8 | | *24.0 to 24.8 ft: very dense; brown-gray;* |
| | 25 | | | | | | |
| 9876.4 | 26 | | | | | Smooth augering from 26.0 to 27.0 feet. | S-13, CA-14: Clayey Sand<br>Mostly sand, fine to coarse grained, subangular to subrounded; 20-30% fines, medium plasticity; 15-25% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1 inch; dense; moist; dark brown; (SC);<br>[Fill] |
| | 27 | S - 13 | 10/19/21 | 1.5 | 1.1 | Minor grinding from 27.0 to 30.0 feet. | |
| | 28 | | | | | | |
| | 29 | CA - 14 | 59/60 | 1.0 | 1.0 | | *29.0 to 30.0 ft: PP = 2.75 tsf;* |
| | 30 | | | | | Smooth augering from 30.0 to 33.0 feet. | |
| 9871.3 | 31 | | | | | | S-15, S-16, S-17: Clayey Gravel with Sand<br>Mostly gravel, fine to coarse grained, subangular to subrounded; 20-35% sand, fine to coarse grained, subangular to subrounded; 20-30% fines, medium plasticity; maximum particle size = 1.25 inches; dense; moist; dark brown; (GC);<br>[Fill] |
| | 32 | S - 15 | 13/16/15 | 1.5 | 1.7 | | |
| | 33 | | | | | Continuous grinding and minor rig rocking from 33.0 to 48.0 feet. | |
| | 34 | S - 16 | 13/21/28 | 1.5 | 1.0 | | |
| | 35 | | | | | | |
| | 36 | | | | | | |
| | 37 | S - 17 | 7/14/21 | 1.5 | 1.6 | | |
| | 38 | | | | | | |
| 9863.6 | 39 | S - 18 | 52/50 for 4 inches | 0.8 | 0.6 | Shelby tube attempt had no recovery, gravel/cobble damaged sampler. Drove split spoon at same depth. | S-18: Poorly Graded Gravel with Clay and Sand<br>Mostly gravel, fine to coarse grained, subangular to subrounded; 15-25% sand, fine to coarse grained, subangular to subrounded; 5-15% fines, medium plasticity; maximum particle size = 1.5 inches; very dense; moist; |
| | 40 | | | | | | |

Continued on next sheet

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the embankment.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995677, Long: -108.109800 deg
Ground El: 9902.1 ft Total Depth: 48.0 ft
Groundwater El: 9860.6 ft On Date: 07-24-2018

Start Date: 07-24-2018 End Date: 07-26-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS
Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

Borehole ID:
**B-102A(P)**


| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | brown-gray; (GP-GC); [Fill] |
| 9861.5 | 41 | | | | | | | S-19, CA-20: Clayey Sand Mostly sand, fine to coarse grained, subangular to subrounded; 25-40% fines, medium plasticity; 20-35% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 3 inches; medium dense; wet; dark brown; (SC); [Fill] |
| | 42 | S - 19 | 12/10/11 | 1.5 | 0.3 | Groundwater encountered at 41.5 feet during drilling on 7/24/2018. | | |
| | 43 | | | | | | | |
| | 44 | CA - 20 | 15/22 | 1.0 | 1.2 | | | *44.0 to 45.0 ft: PP = 3.5 tsf;* |
| | 45 | | | | | | | |
| 9856.3 | 46 | | | | | | | S-21: Poorly Graded Gravel with Clay and Sand Mostly gravel, fine to coarse grained, subangular to subrounded; 15-30% sand, fine to coarse grained, angular to subrounded; 5-15% fines, medium plasticity; maximum particle size = 1 inch; very dense; wet; black; gravels composed of mostly basalt; (GP-GC); [Fill] |
| | 47 | S - 21 | 50 for 3 inches | 0.3 | 0.3 | | | |
| 9854.1 | 48 | | | | | Augers encountered refusal at 48.0 feet. Bottom of boring at 48.0 feet. | | End of boring log at 48.00 ft |
| | 49 | | | | | | | |
| | 50 | | | | | | | |
| | 51 | | | | | | | |
| | 52 | | | | | | | |
| | 53 | | | | | | | |
| | 54 | | | | | | | |
| | 55 | | | | | | | |
| | 56 | | | | | | | |
| | 57 | | | | | | | |
| | 58 | | | | | | | |
| | 59 | | | | | | | |
| | 60 | | | | | | | |

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the embankment.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995667, Long: -108.109796 deg
Ground El: 9902.1 ft  Total Depth: 5.0 ft
Groundwater El: Not Encountered  On Date: 07-26-2018

Start Date: 07-25-2018  End Date: 07-26-2018
Driller: HRL Compliance - Jose  Logged By: JNH
Bedrock Depth: Not encountered  Checked By: ERS

Borehole ID: **B-102B**
Sheet 1 of 1

Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | 0.0 to 1.0 ft: Road Base; [--] |
| 9901.1 | 1 | | | | | Continuous grinding and rig rocking. | | Bu-1: Clayey Gravel with Sand Mostly gravel, fine to coarse grained, subangular to subrounded; 20-35% fines, medium plasticity; 15-30% sand, fine to coarse grained, subangular to subrounded; less than 5% cobbles; maximum particle size = 4 inches; moist; dark brown; (GC); [Fill] |
| | 2 | | | | | Sample Bu-1 collected from 2.0 to 5.0 feet. | | |
| | 3 | | | | | | | |
| | 4 | | | | | Auger encountered refusal at 5.0 feet. | | |
| 9897.1 | 5 | | | | | Bottom of boring at 5.0 feet. | | End of boring log at 5.00 ft |
| | 6 | | | | | | | |
| | 7 | | | | | | | |
| | 8 | | | | | | | |
| | 9 | | | | | | | |
| | 10 | | | | | | | |
| | 11 | | | | | | | |
| | 12 | | | | | | | |
| | 13 | | | | | | | |
| | 14 | | | | | | | |
| | 15 | | | | | | | |
| | 16 | | | | | | | |
| | 17 | | | | | | | |
| | 18 | | | | | | | |
| | 19 | | | | | | | |
| | 20 | | | | | | | |

Notes  Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was backfilled with cement-bentonite grout.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.996095, Long: -108.109881 deg
Ground El: 9901.8 ft  Total Depth: 30.0 ft
Groundwater El: 9876.3 ft  On Date: 07-23-2018

Start Date: 07-23-2018  End Date: 07-24-2018
Driller: HRL Compliance - Jose  Logged By: JNH
Bedrock Depth: Not encountered  Checked By: ERS

Borehole ID: **B-103(P)**


Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | 0.0 to 1.0 ft: Road Base; [--] |
| 9900.8 | 1 | S - 2 | 8/19/34 | 1.5 | 1.0 | Sample Bu-1 collected from 1.0 to 7.5 feet. Grinding, minor rig rocking. | | Bu-1, S-2, S-3, S-4, S-5, S-6, S-7: Clayey Sand with Gravel Mostly sand, fine to coarse grained, subangular to subrounded; 30-45% fines, medium plasticity; 20-35% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.5 inches; dense to very dense; moist; dark brown; (SC); [Fill] |
| | 2–3 | | | | | Augers encountered refusal at 3.0 feet. Backfilled hole with cuttings, moved 3 feet south and continued augering. | | |
| | 3.5 | S - 3 | 29/24/50 for 1 inch | 1.1 | 0.5 | At 3.5 feet, changed to conical auger bit to help reduce grinding. | | |
| | 5 | S - 4 | 5/15/31 | 1.5 | 1.4 | Minor grinding from 5.0 to 23.1 feet. | | |
| | 7.5 | S - 5 | 22/10/22 | 1.5 | 1.5 | | | *7.5 to 9.0 ft: occasional strong reaction with HCl;* |
| | 10 | S - 6 | 19/14/30 | 1.5 | 1.5 | Sample Bu-11 collected from 10.0 to 17.5 feet. | | |
| | 12.5 | S - 7 | 11/13/29 | 1.5 | 1.5 | | | |
| 9887.3 | 14.5 | | | | | | | CA-8: Clayey Gravel with Sand Mostly gravel, fine to coarse grained, subangular to subrounded; 30-40% fines, medium plasticity; 15-25% sand, fine to coarse grained, subangular to subrounded; maximum particle size = 1.5 inches; moist; dark brown; PP = 1.5 tsf; (GC); [Fill] |
| | 15 | CA - 8 | 15/17 | 1.0 | 1.0 | | | |
| 9885.0 | 16.8 | | | | | | | CA-9, S-10, Bu-11, S-12: Clayey Sand with Gravel Mostly sand, fine to coarse grained, subangular to subrounded; 30-45% fines, medium plasticity; 20-35% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.75 inches; dense to very dense; moist; dark brown; (SC); [Fill] |
| | 17.5 | CA - 9 | 22/22 | 1.0 | 1.0 | | | *17.5 to 18.5 ft: 15-35% fines; PP = 1 tsf;* |
| | 20 | | | | | | | |

Continued on next sheet

Notes: Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the embankment.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.996095, Long: -108.109881 deg
Ground El: 9901.8 ft Total Depth: 30.0 ft
Groundwater El: 9876.3 ft On Date: 07-23-2018

Start Date: 07-23-2018 End Date: 07-24-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS
Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 4-1/4" ID, 7-3/4" OD Hollow Stem Auger (HSA)

Borehole ID:
**B-103(P)**


| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | 21–22 | S - 10 | 12/18/50 for 3 inches | 1.3 | 1.3 | | | |
| 9878.7 | 23–24 | S - 12 | 8/4/9 | 1.5 | 1.5 | Bottom of embankment fill at approximately 23.1 feet. Smooth augering from 23.1 to 30.0 feet. | | S-12, S-13: Gravelly Lean Clay with Sand Mostly fines, medium plasticity; 15-30% gravel, fine to coarse grained, subangular to subrounded; 15-25% sand, fine to coarse grained, subangular to subrounded; maximum particle size = 1 inch; soft; moist to wet; brown; (CL); [Colluvium] |
| | 25–26 | S - 13 | 2/4/4 | 1.5 | 1.3 | Groundwater encountered at 25.5 feet during drilling on 7/23/2018. | | |
| 9874.8 | 27–29 | U - 14 | | 2.1 | 2.1 | | | U-14: Clayey Sand with Gravel Mostly sand, fine to coarse grained, subangular to subrounded; 25-35% fines, medium plasticity; 20-30% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1 inch; moist; brown; (SC); [Colluvium] |
| 9871.8 | 30 | | | | | Bottom of boring at 30.0 feet. | | End of boring log at 30.00 ft |

Depth scale: 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well in the embankment.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995285, Long: -108.110292 deg
Ground El: 9846.1 ft Total Depth: 33.0 ft
Groundwater El: 9835.7 ft On Date: 09-20-2018

Start Date: 09-19-2018 End Date: 09-21-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS

Borehole ID: **B-104(P)**


Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 5" ID, 5-3/8" OD Symmetrix Drive Casing Advancer

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | Continuous slow, smooth drilling; dust from cobbles/ boulders from 0 to 6.0 feet. | | S-1: Poorly Graded Gravel with Silt and Sand Mostly gravel, fine to coarse grained, subangular to subrounded; 20-35% sand, fine to coarse grained, subangular to subrounded; 5-15% fines, nonplastic; maximum particle size = 1.25 inches; dense; dry; black; gravel composed of mostly basalt; (GP-GM); [Colluvium] |
| | 4.5 | S - 1 | 7/15/18 | 1.5 | 0.3 | | | |
| 9840.1 | 6 | | | | | At 6.0 feet, driller said material feels like clay. Continuous slow, smooth drilling from 6.0 to 33.0 feet. | | S-2: Sandy Lean Clay with Gravel Mostly fines, low plasticity; 20-35% sand, fine to coarse grained, subangular to subrounded; 15-30% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.5 inches; medium stiff; moist; brown; (CL); [Colluvium] |
| | 7.5 | S - 2 | 4/7/9 | 1.5 | 1.5 | | | |
| 9835.8 | 10.3 | | | | | Groundwater encountered at 10.4 feet during drilling on 9/20/2018. | | U-3: Lean Clay with Sand Mostly fines, medium to high plasticity; 5-15% sand, fine to coarse grained, subangular to subrounded; 5-10% gravel, fine grained, subangular to subrounded; maximum particle size = 0.75 inches; stiff; moist; dark gray; (CL); [Colluvium] |
| | 12 | U - 3 | | 1.0 | 1.0 | U-3 disturbed, cobble/boulder damaged sampler. | | |
| 9833.1 | 13 | S - 4 | 50 for 3 inches | 0.3 | 0.3 | | | S-4: Gravelly Lean Clay with Sand Mostly fines, medium plasticity; 20-35% gravel, fine to coarse grained, subangular to subrounded; 15-25% sand, fine to coarse grained, subangular to subrounded; maximum particle size = 1.5 inches; medium stiff; moist; dark gray; (CL); [Colluvium] |
| 9832.8 | 13.5 | S - 5 | 17/28/24 | 1.5 | 1.9 | Driller said material feels like gravel from 13.3 to 16.0 feet. | | S-5: Sandy Lean Clay with Gravel Mostly fines, low plasticity; 20-35% sand, fine to coarse grained, subangular to subrounded; 15-30% gravel, fine to coarse grained, subangular to rounded; maximum particle size = 1.25 inches; stiff; moist; brown; (CL); [Colluvium] |
| 9830.1 | 16 | | | | | | | S-6: Gravelly Lean Clay with Sand Mostly fines, medium plasticity; 20-35% gravel, fine to coarse grained, subangular to subrounded; 15-25% sand, fine to coarse grained, subangular to subrounded; maximum particle size = 1.5 inches; soft; wet; brown to gray; (CL); [Colluvium] |
| | 17 | S - 6 | 50 for 4 inches | 0.3 | 0.3 | | | |
| 9826.4 | 19.7 | | | | | | | S-7: Lean Clay with Gravel |
| | 20 | | | | | | | |

Continued on next sheet

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well at the dam toe.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995285, Long: -108.110292 deg
Ground El: 9846.1 ft Total Depth: 33.0 ft
Groundwater El: 9835.7 ft On Date: 09-20-2018

Start Date: 09-19-2018 End Date: 09-21-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS

Borehole ID: **B-104(P)**


Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 5" ID, 5-3/8" OD Symmetrix Drive Casing Advancer

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|
| | 20.0–25.3 | | | | | | Mostly fines, low plasticity; 10-15% gravel, fine to coarse grained, subangular to subrounded; 5-10% sand, fine to coarse grained, subangular to subrounded; maximum particle size = 1 inch; very stiff; moist; brown; occasional weak reaction to HCl; (CL); [Colluvium] |
| | 22.0–23.5 | S - 7 | 12/14/17 | 1.5 | 1.5 | | |
| 9820.8 | 25.3–30.3 | | | | | | S-8: Sandy Lean Clay with Gravel Mostly fines, low plasticity; 20-35% sand, fine to coarse grained, subangular to subrounded; 15-30% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1 inch; very stiff; moist; brown; chlorite deposits throughout; (SC); [Colluvium] |
| | 27.0–28.5 | S - 8 | 20/17/15 | 1.5 | 1.5 | Unable to perform Shelby tube because of gravel/cobbles. | |
| 9815.8 | 30.3–33.0 | | | | | | CA-9: Gravelly Lean Clay Mostly fines, low to medium plasticity; 30-40% gravel, fine to coarse grained, subangular to subrounded; 5-10% sand, fine to coarse grained, subangular to subrounded; maximum particle size = 1.25 inches; stiff to very stiff; moist; brown; PP = 1.75 tsf; (CL); [Colluvium] |
| | 32.0–33.0 | CA - 9 | 9/13 | 1.0 | 1.3 | Unable to perform Shelby tube because of gravel/cobbles. | |
| 9813.1 | 33.0 | | | | | Bottom of boring at 33.0 feet. | End of boring log at 33.00 ft |

Notes: Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well at the dam toe.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

| | |
|---|---|
| Project name: Hogchute Dam Safety Evaluation | Start Date: 09-17-2018 |
| Project No: 18115 | End Date: 09-20-2018 |
| Boring Location: Lat: 38.995632, Long: -108.110160 deg | Driller: HRL Compliance - Jose |
| Ground El: 9865.7 ft | Logged By: JNH |
| Total Depth: 73.5 ft | Bedrock Depth: Not encountered |
| Groundwater El: 9860.9 ft | Checked By: ERS |
| On Date: 09-17-2018 | Borehole ID: **B-105A(P)** |
| Drilling Rig: CME 55LC Track Mounted Rig |  |
| Equipment: 5" ID, 5-3/8" OD Symmetrix Drive Casing Advancer | |

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|
| | 0 | | | | | Sample Bu-1 collected from 0 to 12.0 feet. Continuous slow, smooth drilling. Dust from large boulder while drilling, approximately 1 foot in diameter per driller. | Bu-1, S-2, S-3, S-4,: Clayey Sand with Gravel Mostly sand, fine to coarse grained, subangular to subrounded; 20-35% gravel, fine to coarse grained, subangular to subrounded; 15-30% fines, medium plasticity; maximum particle size = 1.5 inches; medium dense; moist; brown; occasional strong reaction with HCl; (SC); [Colluvium] |
| | 2.0 | S - 2 | 11/8/7 | 1.5 | 0.5 | | |
| | 4.5 | S - 3 | 3/2/4 | 1.5 | 1.5 | Groundwater encountered at 4.8 feet during drilling on 9/17/2018. | *4.5 to 6.0 ft: 15-25% gravel; 25-40% fines; loose; wet;* |
| | 7.0 | S - 4 | 50 for 5 inches | 0.9 | 0.7 | | *7.0 to 7.9 ft: 20-35% fines; very dense; moist to wet;* |
| | 8 | | | | | Dust from large boulder while drilling, approximately 1 foot in diameter per driller. | |
| 9856.7 | 9.0 | | | | | Groundwater encountered at 9.2 feet on 9/18/2018 a.m. after drilling to 27.0 feet the previous day. | S-5, S-6: Sandy Lean Clay with Gravel Mostly fines, low plasticity; 15-30% sand, fine to coarse grained, subangular to subrounded; 15-25% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 0.75 inches; very soft to soft; moist to wet; brown; (CL); [Colluvium] |
| | 10.0 | S - 5 | 2/3/3 | 1.5 | 1.8 | | |
| | 12.0 | S - 6 | 2/3/2 | 1.5 | 1.3 | | |
| | 13.5 | | | | | Sampling interval changed to about every 5 feet. | |
| 9850.4 | 15.3 | | | | | | S-7: Lean Clay with Sand Mostly fines, low to medium plasticity; 5-15% sand, fine to medium grained, subangular to subrounded; less than 10% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.25 inches; soft; moist to wet; brown; (CL); [Colluvium] |
| | 17.0 | S - 7 | 4/4/6 | 1.5 | 1.7 | | |
| 9846.7 | 19.0 | | | | | Driller said material changed to clay with more gravel or a stiffer clay. | S-8: Lean Clay Mostly fines, low to medium plasticity; less than 10% sand, fine to medium grained, subangular to subrounded; medium |
| | 20 | | | | | | |

Continued on next sheet

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well at the dam toe.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995632, Long: -108.110160 deg
Ground El: 9865.7 ft Total Depth: 73.5 ft
Groundwater El: 9860.9 ft On Date: 09-17-2018

Start Date: 09-17-2018 End Date: 09-20-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS
Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 5" ID, 5-3/8" OD Symmetrix Drive Casing Advancer

Borehole ID: **B-105A(P)**


| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | 21 | | | | | | | stiff; moist to wet; brown; (CL); [Colluvium] |
| | 22–23 | S - 8 | 8/13/15 | 1.5 | 1.8 | | | |
| 9840.4 | 25 | | | | | Very slow drilling and increased basalt gravel in cuttings from 25.5 to 34.0 feet. | | S-9: Sandy Lean Clay with Gravel<br>Mostly fines, low plasticity; 15-30% sand, fine to coarse grained, subangular to subrounded; 15-25% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.25 inches; medium stiff to stiff; moist; (CL); [Colluvium] |
| | 27–28 | S - 9 | 12/15/42 | 1.5 | 1.5 | | | |
| 9835.4 | 30 | | | | | | | S-10: Sandy Lean Clay<br>Mostly fines, low plasticity; 15-30% sand, fine to coarse grained, subangular to subrounded; 5-15% gravel, fine grained, subangular to subrounded; maximum particle size = 0.75 inches; medium stiff to stiff; moist; brown; (CL); [Colluvium] |
| | 32 | S - 10 | 50 for 4 inches | 0.3 | 0.4 | | | |
| 9831.0 | 34.5 | | | | | | | S-11, CA-12: Sandy Lean Clay with Gravel<br>Mostly fines, low plasticity; 15-30% sand, fine to coarse grained, subangular to subrounded; 15-25% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.5 inches; medium stiff; moist; brown; (CL); [Colluvium] |
| | 37–38 | S - 11 | 25/34/31 | 1.5 | 1.8 | | | |
| | 40 | | | | | | | |

Continued on next sheet

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well at the dam toe.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995632, Long: -108.110160 deg
Ground El: 9865.7 ft Total Depth: 73.5 ft
Groundwater El: 9860.9 ft On Date: 09-17-2018

Start Date: 09-17-2018 End Date: 09-20-2018
Driller: HRL Compliance - Jose Logged By: JNH
Bedrock Depth: Not encountered Checked By: ERS

Borehole ID: **B-105A(P)**


Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 5" ID, 5-3/8" OD Symmetrix Drive Casing Advancer

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | 41 | | | | | | | |
| | 42 | CA - 12 | 50/50 for 3 inches | 0.8 | 0.8 | | | *42.0 to 42.8 ft: PP = 2.75 tsf;* |
| | 43 | | | | | | | |
| | 44 | | | | | | | |
| 9820.8 | 45 | | | | | | | CA-13: Gravelly Lean Clay with Sand<br>Mostly fines, low to medium plasticity; 20-35% gravel, fine to coarse grained, subangular to rounded; 15-25% sand, fine to coarse grained, subangular to subrounded; maximum particle size = 2 inches; medium stiff to stiff; moist; brown; (CL);<br>[Colluvium] |
| | 46 | | | | | | | |
| | 47 | CA - 13 | 28/50 for 2 inches | 0.7 | 0.7 | CA-13 disturbed, sampler bouncing on cobble/boulder. | | |
| | 48 | | | | | | | |
| | 49 | | | | | Driller said encountered pea gravel at 49.0 feet. | | |
| 9815.8 | 50 | | | | | | | S-14, S-15: Clayey Sand with Gravel<br>Mostly sand, fine to coarse grained, subangular to subrounded; 25-40% fines, low to medium plasticity; 20-35% gravel, fine to coarse grained, subangular to rounded; maximum particle size = 1.5 inches; very dense; moist to wet; brown; (SC);<br>[Colluvium] |
| | 51 | | | | | | | |
| | 52 | S - 14 | 10/50 for 5 inches | 0.9 | 0.4 | Pressurized water coming out between casing and boring annulus at surface on 9/18/2018 after drilling to 52.0 feet. Resolved and continued drilling approximately 1 hour later. | | |
| | 53 | | | | | | | |
| | 54 | | | | | | | |
| | 55 | | | | | | | |
| | 56 | | | | | | | |
| | 57 | S - 15 | 31/27/39 | 1.5 | 0.5 | | | *57.0 to 58.5 ft: 20-35% fines; 15-25% gravel, subangular to subrounded;* |
| | 58 | | | | | | | |
| | 59 | | | | | | | |
| | 60 | | | | | | | |

Continued on next sheet

Notes Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well at the dam toe.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995632, Long: -108.110160 deg
Ground El: 9865.7 ft  Total Depth: 73.5 ft
Groundwater El: 9860.9 ft  On Date: 09-17-2018

Start Date: 09-17-2018  End Date: 09-20-2018
Driller: HRL Compliance - Jose  Logged By: JNH
Bedrock Depth: Not encountered  Checked By: ERS

Borehole ID: **B-105A(P)**
Sheet 4 of 4

Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 5" ID, 5-3/8" OD Symmetrix Drive Casing Advancer

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| 9805.4 | 60.3 | | | | | | | CA-16: Sandy Lean Clay with Gravel<br>Mostly fines, low plasticity; 15-30% sand, fine to coarse grained, subangular to subrounded; 15-25% gravel, fine to coarse grained, subangular to subrounded; maximum particle size = 1.25 inches; medium stiff; moist to wet; brown; (CL);<br>[Colluvium]<br>*62.0 to 63.5 ft: PP = 4.5 tsf;* |
| | 62.0–63.5 | CA - 16 | 20/13/19 | 1.5 | 1.5 | CA-16 sample rings collected from 62.5 to 63.5 feet. | | |
| 9800.4 | 65.3 | | | | | | | S-17, S-18: Clayey Sand with Gravel<br>Mostly sand, fine to coarse grained, subangular to subrounded; 20-35% gravel, fine to coarse grained, subangular to subrounded; 15-25% fines, low to medium plasticity; maximum particle size = 1.5 inches; very dense; moist to wet; brown; (SC);<br>[Colluvium] |
| | 67.0–67.2 | S - 17 | 50 for 2 inches | 0.2 | 0.2 | | | |
| | 72.0–73.5 | S - 18 | 12/22/33 | 1.5 | 1.5 | | | *72.0 to 73.5 ft: 25-35% fines;* |
| 9792.2 | 73.5 | | | | | Bottom of boring at 73.5 feet. | | End of boring log at 73.50 ft |

Notes: Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well at the dam toe.

RJH CONSULTANTS, INC.

# LOG OF SOIL BORING

Project name: Hogchute Dam Safety Evaluation
Project No: 18115
Boring Location: Lat: 38.995681, Long: -108.110127 deg
Ground El: 9866.9 ft    Total Depth: 12.6 ft
Groundwater El: 9858.7 ft    On Date: 09-19-2018

Start Date: 09-19-2018    End Date: 09-20-2018
Driller: HRL Compliance - Jose    Logged By: JNH
Bedrock Depth: Not encountered    Checked By: ERS

Borehole ID: **B-105B(P)**
Sheet 1 of 1

Drilling Rig: CME 55LC Track Mounted Rig
Equipment: 5" ID, 5-3/8" OD Symmetrix Drive Casing Advancer

| Elevation | Depth (ft) | Type - No | Blows per 6 inch | Penetration (ft) | Recovery (ft) | Remarks | Graphic Lithology | Description and Classification of Materials |
|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | Continuous slow, smooth drilling from 0 to 12.6 feet. | | 0.0 to 12.6 ft:<br>No Sampling. Refer to B-105A(P) for lithology.;<br>[Colluvium] |
| | 8 | | | | | Groundwater encountered at 8.2 feet during drilling on 9/19/2018. | | |
| 9854.3 | 12.6 | | | | | Bottom of boring at 12.6 feet. | | End of boring log at 12.60 ft |

Depth scale: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20

Notes    Contacts are approximate and lithology between recovered samples is interpreted. Material descriptions are based on recovered samples, cuttings, and surface observations. Density descriptions are based on blow counts. Large particles may have influenced blow counts and sample recovery. Boring was completed as a monitoring well at the dam toe.

RJH CONSULTANTS, INC.

# APPENDIX C

## SAMPLE PHOTOGRAPHS

B-101(P)

Photograph 1: B-101(P); S-2 from 5.0 to 6.5 feet. Clayey Gravel with Sand [Fill].

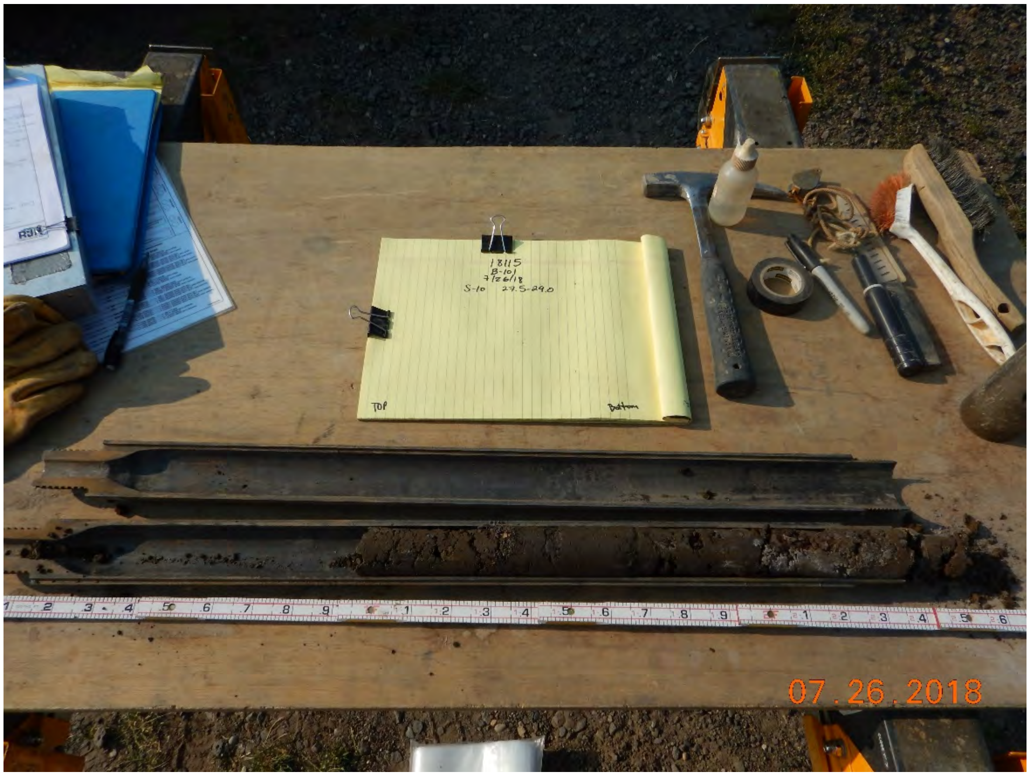
Photograph 2: B-101(P); S-3 from 10.0 to 11.5 feet. Clayey Sand with Gravel [Fill].


Photograph 3: B-101(P); S-3 from 12.5 to 14.0 feet.  Clayey Sand with Gravel [Fill].


Photograph 4: B-101(P); U-5 from 15.0 to 15.6 feet.  Disturbed.  Clayey Sand with Gravel [Fill].

Photograph 5: B-101(P); S-7 from 17.5 to 19.0 feet. Clayey Sand with Gravel [Fill].

Photograph 6: B-101(P); S-9 from 25.0 to 26.5 feet. Clayey Sand with Gravel [Fill].




Photograph 7: B-101(P); S-10 from 27.5 to 29.0 feet. Clayey Sand with Gravel [Fill].


Photograph 8: B-101(P); S-12 from 35.0 to 36.5 feet. Clayey Sand with Gravel [Fill].


Photograph 9: B-101(P); S-14 from 40.0 to 41.5 feet. Clayey Sand with Gravel [Fill].


Photograph 10: B-101(P); S-18 from 45.0 to 46.5 feet. Clayey Sand with Gravel [Fill].


Photograph 11: B-101(P); S-19 from 50.0 to 51.5 feet. Clayey Sand with Gravel [Fill]. Sandy Lean Clay with Gravel [Alluvium/Colluvium].


Photograph 12: B-101(P); S-22 from 60.0 to 61.5 feet. Sandy Lean Clay with Gravel and Poorly Graded Sand with Clay and Gravel [Alluvium/Colluvium].

Photograph 13: B-101(P); S-24 from 70.0 to 71.5 feet. Lean Clay [Alluvium/Colluvium].

Photograph 14: B-101(P); S-25 from 73.0 to 74.5 feet. Sandy Lean Clay [Alluvium/Colluvium].

Photograph 15: B-101(P); S-26 from 76.0 to 77.5 feet. Sandy Lean Clay [Alluvium/Colluvium].

B-102A(P)


Photograph 16: B-102A(P); S-2 from 1.5 to 3.0 feet. Clayey Gravel with Sand [Fill].


Photograph 17: B-102A(P); S-3 from 4.0 to 5.5 feet. Clayey Gravel with Sand [Fill].

Photograph 18: B-102A(P); S-4 from 6.5 to 8.0 feet. Clayey Gravel with Sand [Fill].

Photograph 19: B-102A(P); S-5 from 9.0 to 10.5 feet. Clayey Gravel with Sand [Fill].

Photograph 20: B-102A(P); S-6 from 11.5 to 13.0 feet. Clayey Gravel with Sand [Fill].

Photograph 21: B-102A(P); S-7 from 14.0 to 15.5 feet. Clayey Gravel with Sand [Fill].


Photograph 22: B-102A(P); S-8 from 16.5 to 18.0 feet. Clayey Gravel with Sand [Fill].


Photograph 23: B-102A(P); S-11 from 21.5 to 23.0 feet. Clayey Gravel with Sand [Fill].

Photograph 24: B-102A(P); S-12 from 24.0 to 24.8 feet. Clayey Gravel with Sand [Fill].

Photograph 25: B-102A(P); S-13 from 26.5 to 28.0 feet. Clayey Sand with Gravel [Fill].


Photograph 26: B-102A(P); S-15 from 31.5 to 33.0 feet. Clayey Gravel with Sand [Fill].


Photograph 27: B-102A(P); S-16 from 34.0 to 35.5 feet. Clayey Gravel with Sand [Fill].


Photograph 28: B-102A(P); S-17 from 36.5 to 38.0 feet. Clayey Gravel with Sand [Fill].


Photograph 29: B-102A(P); S-18 from 39.0 to 39.8 feet. Poorly Graded Gravel with Clay and Sand [Fill].


Photograph 30: B-102A(P); S-19 from 41.5 to 43.0 feet.  Clayey Sand with Gravel [Fill].


Photograph 31: B-102A(P); S-21 from 46.5 to 46.8 feet.  Poorly Graded Gravel with Clay and Sand [Fill].

B-103(P)


Photograph 32: B-103(P); S-2 from 1.0 to 2.5 feet. Clayey Sand with Gravel [Fill].


Photograph 33: B-103(P); S-3 from 3.5 to 4.6 feet. Clayey Gravel with Sand [Fill].

Photograph 34: B-103(P); S-4 from 5.0 to 6.5 feet. Clayey Sand with Gravel [Fill].

Photograph 35: B-103(P); S-5 from 7.5 to 9.0 feet. Clayey Sand with Gravel [Fill].


Photograph 36: B-103(P); S-6 from 10.0 to 11.5 feet. Clayey Sand with Gravel [Fill].


Photograph 37: B-103(P); S-7 from 12.5 to 14.0 feet. Clayey Sand with Gravel [Fill].


Photograph 38: B-103(P); S-10 from 21.0 to 22.3 feet. Clayey Sand with Gravel [Fill].


Photograph 39: B-103(P); S-12 from 22.5 to 24.0 feet. Clayey Sand with Gravel [Fill]. Gravelly Lean Clay with Sand [Alluvium/Colluvium].

Photograph 40: B-103(P); S-13 from 25.0 to 26.5 feet. Gravelly Lean Clay with Sand [Alluvium/Colluvium].

B-104(P)

Photograph 41: B-104(P); S-1 from 4.0 to 5.5 feet. Basalt [Alluvium/Colluvium].

Photograph 42: B-104(P); S-2 from 4.0 to 5.5 feet. Sandy Lean Clay with Gravel [Alluvium/Colluvium].


Photograph 43: B-104(P); S-4 from 13.0 to 13.3 feet. Gravelly Lean Clay with Sand [Alluvium/Colluvium].


Photograph 44: B-104(P); S-5 from 13.4 to 14.9 feet. Sandy Lean Clay with Gravel [Alluvium/Colluvium].

Photograph 45: B-104(P); S-6 from 17.0 to 17.3 feet. Gravelly Lean Clay with Sand [Alluvium/Colluvium].

Photograph 46: B-104(P); S-7 from 22.0 to 23.5 feet. Lean Clay with Gravel [Alluvium/Colluvium].


Photograph 47: B-104(P); S-8 from 27.0 to 28.5 feet. Sandy Silt with Gravel [Alluvium/Colluvium].

B-105A(P)

Photograph 48: B-105A(P); S-2 from 2.0 to 3.5 feet. Clayey Sand with Gravel [Alluvium/Colluvium].

Photograph 49: B-105A(P); S-3 from 4.5 to 6.0 feet. Clayey Sand with Gravel [Alluvium/Colluvium].


Photograph 50: B-105A(P); S-4 from 7.0 to 7.9 feet. Clayey Sand with Gravel [Alluvium/Colluvium].


Photograph 51: B-105A(P); S-5 from 10.0 to 11.5 feet. Sandy Lean Clay with Gravel [Alluvium/Colluvium].

Photograph 52: B-105A(P); S-6 from 12.0 to 13.5 feet.  Sandy Lean Clay with Gravel [Alluvium/Colluvium].

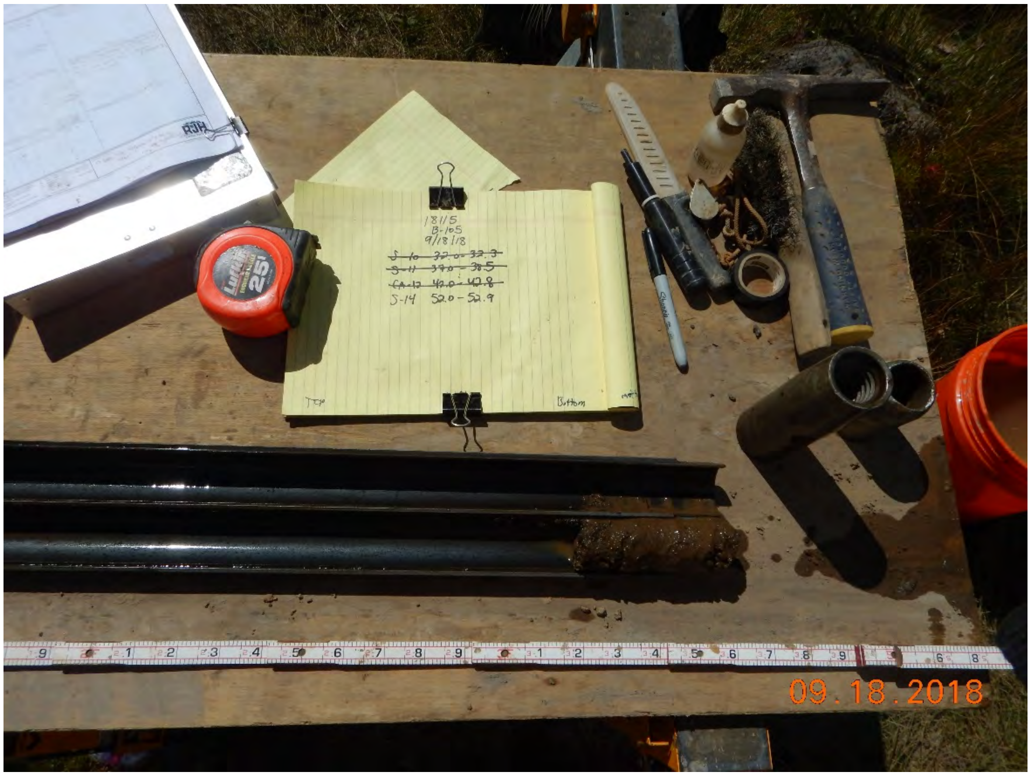
Photograph 53: B-105A(P); S-7 from 17.0 to 18.5 feet.  Lean Clay with Sand [Alluvium/Colluvium].


Photograph 54: B-105A(P); S-8 from 22.0 to 23.5 feet. Lean Clay [Alluvium/Colluvium].


Photograph 55: B-105A(P); S-9 from 27.0 to 28.5 feet. Sandy Lean Clay with Gravel [Alluvium/Colluvium].


Photograph 56: B-105A(P); S-10 from 32.0 to 32.3 feet.  Sandy Lean Clay [Alluvium/Colluvium].


Photograph 57: B-105A(P); S-11 from 37.0 to 38.5 feet.  Sandy Lean Clay with Gravel [Alluvium/Colluvium].




Photograph 58: B-105A(P); S-14 from 52.0 to 52.9 feet. Clayey Sand with Gravel [Alluvium/Colluvium].


Photograph 59: B-105A(P); S-15 from 57.0 to 58.5 feet. Clayey Sand with Gravel [Alluvium/Colluvium].


Photograph 60: B-105A(P); S-17 from 67.0 to 67.2 feet. Clayey Sand with Gravel [Alluvium/Colluvium].


Photograph 61: B-105A(P); S-18 from 72.0 to 73.5 feet. Clayey Sand with Gravel [Alluvium/Colluvium].

# APPENDIX D

## DAILY SITE REPORTS

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project**
**Task 1002 Geotechnical Investigation**

**Report No.: 001-JNH**
**Date: Monday, July 23, 2018**


**Prepared By:** JNH
**Weather:** low 80's, mostly sunny, light-moderate breeze
**Boring(s):** B-103(P)

**People on Site (arrival/departure time)**

- RJH:
    - JNH (09:45/19:00)
    - GOJ (09:45/17:10)
- HRL:
    - Jose Suarez & Devin Lucero (10:00/18:55)
    - Mark Mumby (10:00/12:05)
- Colorado SEO: Jackie Blumberg (on-site upon RJH arrival/15:50)
- U.S. Forest Service: name unknown, 1 person (11:45)

**Equipment on Site**

*Mobile*
- RJH T3
- GJ Chevy Silverado
- HRL Chevy 2500HD
- HRL Dodge 3500
- SEO Ford F-150
- USFS full-size pick-up truck

*At Site Parking Lot Overnight*
- HRL semi-truck and trailer
- HRL support trailer & materials

*At Drill Site Overnight*
- CME 55LC track mounted drill rig

**Material Used**

- 2 buckets coated pellets (5 gallon)
- 2 bags of medium bentonite chips (50# bag)
- 15 bags of 10/20 sand (50# bag)
- 1 J plug
- 10 ft slotted 2" PVC (40) pipe
- (2) 10 ft riser 2" PVC (40) pipe
- 1 slip cap

## Drilling Progress Summary

- HRL mobilized the drill rig and drilling support equipment to the Site.
- Boring B-103 was drilled via HSA to a depth of 30.0 feet. Drillers changed the drill bit to a conical drill bit at 3.5 feet to aid with progressing through gravel and cobbles in the embankment fill.
- A falling head permeability test was completed in the foundation material, below groundwater, at the bottom of the boring.
- The drillers began the monitoring well installation and completed the backfill materials to about 2.0 feet. Tomorrow, concrete will be used to complete the backfill material and a surface mount casing placed in concrete.
- The drillers positioned the drill rig over the boring so as to cover the partially completed monitoring well. A J plug is set in the PVC to prevent debris from entering the monitoring well.

## Seepage Observations

- Seepage near outlet works at toe appeared to have little to no flow prior to and post drilling activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to and post drilling activities.

## Plan for Next Work Day

- JNH and drillers to meet at Site at 07:00.
- Mark to deliver concrete and packer. Complete monitoring well installation at B-103.
- Begin the next boring, B-102, and drill via HSA until advanced 2-3 feet into bedrock. Once in bedrock, switch to HQ wireline coring.
- If time and site conditions allow, install two nested piezometers at B-102; one into bedrock (denoted as B-102A(P)) and one into the embankment fill (denoted as B-102B(P)).

## Site Coordination Activities

- A USFS personnel (Cliff) opened the locked gate so the field crew could transport equipment onto the crest. The gate lock is “dummy locked” for overnight so the field crew can access equipment tomorrow. Either the USFS or the City of Grand Junction will provide the field crew a key to the gate; until this occurs, the field crew will continue to “dummy lock” the gate for overnight.
- Several hikers and fishermen walked past the drill rig on the dam crest during the day with no incidents. Cliff will contact Jon Hare (USFS) about placing signage to close the

dam crest to the public during drilling operations. GJ also left a phone message for Jon about closing the dam crest.

## Photographs

*Boring B-103:*


Figure 1. Dam crest and B-103 prior to drilling activities, looking south.


Figure 2. B-103 equipment set-up, looking southeast.


Figure 3. B-103 at the end of day, looking southeast. Drill rig parked over monitoring well.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 002-JNH**
**Task 1002 Geotechnical Investigation** **Date: Tuesday, July 24, 2018**


**Prepared By:** JNH
**Weather:** upper 70's, mostly sunny, clouds and breeze increase throughout day
**Boring(s):** B-102A(P) & B-103(P)

## People on Site (arrival/departure time)

- RJH: JNH (06:50/19:45)
- HRL:
  - Jose Suarez & Devin Lucero (07:00/19:40)
  - Mark Mumby (12:20/13:25)
- City of Grand Junction: Lee Cooper (09:50/10:20)
- Colorado SEO: Jason Ward (12:40/13:10)

## Equipment on Site

*Mobile*
- RJH T3
- HRL Chevy 2500HD
- HRL Dodge 3500
- City of Grand Junction full-size pick-up truck
- SEO Chevy Trailblazer

*At Site Parking Lot Overnight*
- HRL semi-truck and trailer
- HRL support trailer & materials

*At Drill Site Overnight*
- CME 55LC track mounted drill rig

## Material Used

*B-102A(P)*
- 2 bags of 10/20 sand (50# bag)
- 1 J plug
- 10 ft slotted 2" PVC (40) pipe
- (4) 10 ft riser 2" PVC (40) pipe
- 1 slip cap

*B-103(P)*
- 1 bag concrete
- (1) 9-inch flush mount casing

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 002-JNH**
**Task 1002 Geotechnical Investigation** **Date: Tuesday, July 24, 2018**


## Drilling Progress Summary

- Boring B-102 was drilled via HSA until augers hit refusal at 48.0 feet in the embankment fill. At 46.5 feet, drilling progressed 1.5 feet in 45 to 60 minutes to reach auger refusal depth of 48.0 feet. Numerous gravel and cobbles were encountered throughout drilling and prevented further advancement of the boring.
- A falling head permeability test was completed in the embankment fill, below groundwater and prior to auger refusal.
- Monitoring well, denoted as B-102A(P), was installed at about 48 feet within the embankment fill.
- The drillers began the monitoring well installation at B-102A(P) and completed the backfill materials to about 44.0 feet.
- The drillers attached the auger casing rod to the augers in boring B-102A(P) to cover and protect the integrity of the monitoring well for overnight.
- The drillers completed monitoring well B-103(P) by backfilling the remaining 2.0 feet with concrete and installing the surface mount casing.
- JNH developed B-103(P) using the surge block and submersible pump.

## Seepage Observations

- Seepage behind the outlet works at toe appeared to have little to no flow prior to, during, and post drilling activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. This amount of seepage was also observed yesterday with no changes throughout the day today.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to, during, and post drilling activities.
- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- JNH and drillers to meet at Site at 07:30.
- Mark to deliver additional cement and sand.
- Complete the monitoring well installation at B-102A(P).
- Attempt to drill B-102B via HSA about 5-8 feet south of B-102A location.
    - o If difficulties advancing boring, JNH will contact GJ. GJ may advise field crew to backfill the boring with cement bentonite grout and proceed to drilling the toe borings.
    - o If drilling advancement successful, drill via HSA until advanced 2-3 feet into bedrock. Once in bedrock, switch to HQ wireline coring. If time and site conditions allow, install monitoring well within bedrock.

## Site Coordination Activities

- Representatives from the City of Grand Junction and Colorado SEO were temporarily on-site to meet the field crew, observe and discuss drilling progress, and make other on-site observations.
- GJ provided a lock to secure the USFS gate for the remainder of the week. JNH will remove the lock upon completion of site activities.
- For public safety, JNH will place flags on the crest between the parking lot and the drilling equipment and project vehicles.

## Non-RJH Activities

- About 8-10 hikers and fishermen on-site throughout the day, but not near the crest or drilling equipment.

**Photographs**

*Boring B-102A:*


Figure 1. Dam crest and B-102A prior to drilling activities, looking south. Green "X" in photo indicates boring location.


Figure 2. B-102A equipment set-up, looking southeast.


Figure 3. B-102A at the end of day, looking southeast. Auger casing rod is attached to in-place augers.

*Boring B-103:*


Figure 1. Monitoring well at B-103 covered with bucket while awaiting concrete backfill and well completion. Looking north.


Figure 2. Completed monitoring well installation at B-103, looking north.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project**
**Task 1002 Geotechnical Investigation**

**Report No.: 003-JNH**
**Date: Wednesday, July 25, 2018**


**Prepared By:** JNH
**Weather:** mid 70's, partly sunny and moderate breeze
**Boring(s):** B-102A(P), B-102B, B-101

## People on Site (arrival/departure time)

- RJH: JNH (07:20/18:30)
- HRL:
  - Jose Suarez & Devin Lucero (07:20/18:30)
  - Mark Mumby (08:50/11:55)
- City of Grand Junction: Slade & Jerry(?) (10:30/10:50)

## Equipment on Site

*Mobile*
- RJH T3
- HRL Chevy 2500HD
- HRL Dodge 3500
- City of Grand Junction full-size pick-up truck

*At Site Parking Lot Overnight*
- HRL semi-truck and trailer
- HRL support trailer & materials

*At Drill Site Overnight (at B-101)*
- CME 55LC track mounted drill rig

## Material Used

*B-102A(P)*
- 4 bags of 10/20 sand (50# bag)
- 4 buckets of coated bentonite pellets
- 5 bags of Portland cement (47# bag)
- ½ bag high yield bentonite powder (50# bag)

*B-102B(P)*
- 2 bags of Portland cement (47# bag)
- ¼ bag high yield bentonite powder (50# bag)

*B-101*
- None

**Drilling Progress Summary**

- The drillers continued to work on the B-102A(P) monitoring well installation. The sand pack was having difficulty settling on the bottom of the boring due to the presence of turbid water inside the boring. Mark was able to help the drillers troubleshoot the problem by pumping the fluid out of the boring and adding clean water to the boring; this allowed for the sand to settle and pack properly at the bottom of the boring.
- Cement bentonite grout was placed in B-102A(P) via tremie pipe and hose. The grout needs to set overnight and the monitoring well was covered with a bucket at the end of the day.
- Boring B-102B was attempted about 8 feet south of B-102A(P) and drilled via HSA until auger refusal at about 5 feet. It took 45 minutes to advance the boring 5 feet and continuous auger grinding and rig rocking were observed. Numerous gravel and cobbles were encountered during drilling and prevented further advancement of the boring.
- B-102B was backfilled with cement bentonite grout. The grout needs to set overnight and the boring was covered with a basalt boulder at the end of the day.
- Boring B-101 was drilled via HSA. Gravel and cobbles are present in the embankment fill; however, the augers are advancing at a rate of about 5 feet in 30 minutes, including taking samples. Today, attempts to sample with the California sampler and the Shelby tube have failed due to the presence of gravel and cobbles. The depth of the boring was at 25.0 feet at the end of the day.
- The drillers attached the auger casing rod to the augers in B-101 to cover and protect the integrity of the boring for overnight.

**Seepage Observations**

- Seepage behind the outlet works right headwall at toe appeared to have little flow prior to, during, and post drilling activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. JNH approximated the seepage rate using a 5-gallon bucket at about 4.3 gpm. No changes in the seepage rate or clarity of water were observed prior to, during, and post drilling activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to, during, and post drilling activities.
- No other signs of seepage or abnormalities were observed.

**Plan for Next Work Day**

- JNH and drillers to meet at Site at 07:30.
- Mark to deliver additional cement.

- Complete the monitoring well installation at B-102A(P) by placing concrete and the surface mount casing.
- Complete the backfilling of B-102B and cover with cuttings.
- Continue to drill B-101 via HSA.
  - o If drilling advancement successful, drill via HSA until advanced 2-3 feet into bedrock. Once in bedrock, switch to HQ wireline coring. If time and site conditions allow, install nested piezometers (one in bedrock and one in embankment).
  - o If difficulties advancing boring, either install a monitoring well below the phreatic surface or, if groundwater not encountered prior to auger refusal, backfill boring with cement bentonite grout.

## Site Coordination Activities

- Representatives from the City of Grand Junction were temporarily on-site to deliver materials to place flagging on the crest between the parking lot and the drilling equipment and project vehicles. JNH placed two orange cones and strung caution tape between the cones, across the crest. The representatives said to leave the material near the gate building on the crest at the end of drilling activities.

## Non-RJH Activities

- About 20 hikers and fishermen on-site throughout the day. In the morning, a group of about 8 hikers walked around the drilling equipment along the crest but remained a safe distance from equipment.
- City of Grand Junction on-site with full-size pick-up truck and backhoe. Slade said the City is removing a beaver dam on the right side of the reservoir; a backhoe is being used to remove the debris. The beaver dam has diverted water flow into the reservoir, thus resulting in the spillway overtopping. Once the beaver dam is removed, the reservoir level should return to below or at the spillway crest.

## Photographs

*Borings B-102A and B-102B:*


Figure 1. B-102A at start of day, looking southeast.


Figure 2. B-102A equipment set-up during grouting, looking southeast.


Figure 3. B-102B prior to drilling activity, boring area circled in red and indicated with green "X." Augers in foreground are in B-102A during coated pellet curing time. Looking south.


Figure 4. B-102A and B-102B at the end of day, looking north. B-102A is in background covered with a white bucket, circled in red. B-102B is in foreground covered with a basalt boulder, indicated by red arrow.

*Boring B-101:*


Figure 5. B-101 prior to drilling activities, indicated by green "X." Looking south.


Figure 6. B-101 equipment set-up during drilling, looking south.


Figure 7. B-101 at the end of day, looking south.

*Other Photos:*


Figure 8. Cones and caution tape across crest at north end (nearest parking lot), looking south.


Figure 9. Crest at the end of day, looking south. Cones and caution tape across crest are indicated with red arrows.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 004-JNH**
**Task 1002 Geotechnical Investigation** **Date: Thursday, July 26, 2018**


**Prepared By:** JNH
**Weather:** mid 70's, mostly sunny with moderate breeze in afternoon
**Boring(s):** B-102A(P), B-102B, B-101

## People on Site (arrival/departure time)

- RJH:
  - JNH (07:30/18:55)
  - GOJ (11:20/12:05)
- HRL:
  - Jose Suarez & Devin Lucero (07:30/18:55)
  - Chris (07:30/08:00)

## Equipment on Site

*Mobile*
- RJH T3
- GJ Chevy Silverado
- HRL Chevy 2500HD
- HRL Dodge 3500

*At Site Parking Lot Overnight*
- HRL semi-truck and trailer
- HRL support trailer & materials

*At Drill Site Overnight (at B-101)*
- CME 55LC track mounted drill rig

## Material Used

*B-102A(P)*
- 2 bags of concrete (50# bag)
- 9-inch surface mount casing

*B-102B(P)*
- None

*B-101*
- None

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 004-JNH**
**Task 1002 Geotechnical Investigation** **Date: Thursday, July 26, 2018**


**Drilling Progress Summary**

- Chris (HRL) dropped off additional bags of Portland cement and buckets of coated pellets.
- The drillers completed the monitoring well installation at B-102A(P) by placing concrete and installing the surface mount casing.
- JNH developed B-102A(P) using the surge block and submersible pump. A rising head permeability test was also completed.
- The backfill of B-102B was completed by covering the cement bentonite grout with 0.3 feet of cuttings to create a level surface with the crest.
- Drilling B-101 was continued via HSA. Prior to start of drilling for the day, groundwater was measured in the boring to about 24.2 feet below ground surface (bgs). The cuttings appeared wet to about 34 feet bgs; however, the samples within the interval from 25 to 31 feet were moist. Deeper than 34 feet the cuttings and samples were moist.
- The contact between the embankment and natural ground occurred at about 50.6 feet bgs. The contact appeared as a distinct change in color and increasing clay content (from a generally clayey sand with gravel in the embankment to a sandy lean clay with gravel in the foundation).
- Groundwater was encountered at about 55.3 feet bgs.
- Today, attempts to sample with the California sampler were successful but attempts with the Shelby tube have failed due to the presence of gravel and cobbles.
- Numerous cobbles were encountered throughout drilling resulting in slow boring advancement. At the beginning of the day, the augers were advancing at a rate of about 5 feet in 25 to 30 minutes. Near the middle to end of the day, the augers were advancing about 5 feet in 45 minutes with intermittent auger grinding.
- The depth of the boring was at 75.0 feet at the end of the day and bedrock was not encountered.
- The drillers attached the auger casing rod to the augers in B-101 to cover and protect the integrity of the boring for overnight.

**Seepage Observations**

- Seepage behind the outlet works right headwall at toe appeared to have little flow prior to, during, and post drilling activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. JNH approximated the seepage rate using a 5-gallon bucket at about 4.3 gpm. No changes in the seepage rate or clarity of water were observed prior to, during, and post drilling activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to, during, and post drilling activities.

- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- JNH and drillers to meet at Site at 07:30.
- Mark to deliver additional 5-10 feet of augers and core boxes.
- Continue to drill B-101 via HSA until auger refusal, socketed into bedrock, or if augers reach maximum depth as identified by HRL.
    - If bedrock is encountered, drill via HSA until augers advanced 2-3 feet into bedrock only if the end auger depth is less than the maximum identified by HRL. Once in bedrock, switch to HQ wireline coring. If time and site conditions allow, install piezometer into bedrock only, since groundwater was encountered in the embankment foundation.
    - If difficulties advancing boring, install a monitoring well within the foundation material.

## Site Coordination Activities

- None

## Non-RJH Activities

- About 25-30 hikers and fishermen on-site throughout the day. A group of 3 hikers walked around the drilling equipment along the crest but remained a safe distance from equipment.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 004-JNH**
**Task 1002 Geotechnical Investigation** **Date: Thursday, July 26, 2018**


**Photographs**
*Borings B-102A and B-102B:*


Figure 1. B-102A and B-102B at start of day, looking south. B-102A in the foreground is covered by a white bucket, circled in red. B-102B in the background is covered by a basalt boulder, indicated by red arrow.


Figure 2. B-102A and B-102B at completion, looking south. B-102A in the foreground is circled in red. B-102B in the background is indicated by red arrow.


Figure 3. B-102B at completion, circled in red. Looking south.

*Boring B-101:*


Figure 4. B-101 at start of day, looking south.


Figure 5. B-101 equipment set-up during drilling, looking southeast.


Figure 6. B-101 at the end of day, looking southeast.

*Other Photos:*


Figure 7. Crest at the end of day, looking south. Cones and caution tape across crest are indicated with red arrows.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 005-JNH**
**Task 1002 Geotechnical Investigation** **Date: Friday, July 27, 2018**


**Prepared By:** JNH
**Weather:** high mid 70's, mostly sunny with increasing clouds and thunderstorm in the evening. Drilling was stopped and Site evening clean-up was occurring when first signs of thunder began.
**Boring(s):** B-101

## People on Site (arrival/departure time)

- RJH: JNH (07:20/19:20)
- HRL:
  - Jose Suarez & Devin Lucero (07:20/19:20)
  - Mark Mumby (08:30/19:15)

## Equipment on Site

*Mobile*
- RJH T3
- HRL Chevy 2500HD
- HRL Dodge 3500

*At Site Parking Lot Overnight*
- HRL semi-truck and trailer
- HRL support trailer & materials

*At Drill Site Overnight (at B-101)*
- CME 55LC track mounted drill rig

## Material Used

*B-101*
- 10 bags of 10/20 sand (50# bag)
- 4 buckets of coated bentonite pellets
- 3 bags of Portland cement (92.6# bag) (so about 6 bags of 47# cement)
- 1 bag high yield bentonite powder (50# bag)
- (1) 5 ft slotted 1.5" PVC (40) pipe
- (7) 10 ft riser 1.5" PVC (40) pipe
- (16) 5 ft tremie 1" PVC (40) pipe
- 1 PVC elbow
- 1 end cap

## Drilling Progress Summary

- Drilling B-101 was continued via HSA. Prior to start of drilling for the day, groundwater was measured in the boring to about 38.3 feet below ground surface (bgs). The augers hit refusal at 76.0 feet. At 75.0 feet, drilling progressed 1.0 foot in 30 to 40 minutes with continuous auger grinding and rig rocking to reach auger refusal depth of 76.0 feet. A split spoon sample was taken from 76.0 to 77.5 feet and recovered a sandy lean clay with basalt gravel. Bedrock was not encountered in B-101.
- The drillers installed monitoring well B-101(P) at about 73.0 feet within the foundation. Backfill materials were completed to about 12.0 feet.
- During monitoring well installation, a nested piezometer was considered at B-101, with one piezometer within the foundation and one within the embankment; however, due to well installation challenges, time constraints, driller's Department of Transportation (DOT) hour restrictions, and other non-project constraints, only one piezometer was installed within the foundation.
- During the initial phase of the monitoring well installation, the sand pack was having difficulty settling on the bottom of the boring, similar to conditions encountered during the installation of B-102A(P). Mark was on-site to help the drillers troubleshoot the well installation. After discussions with RJH management, additional water was poured down the hole to counteract an upward gradient from a confined groundwater source. The additional water head allowed for the sand to settle and pack properly at the bottom of the boring.
- Cement bentonite grout was placed in B-101(P) via tremie pipe to about 12.0 feet. The grout needs to set overnight and the monitoring well was covered for overnight.

## Seepage Observations

- Seepage behind the outlet works right headwall at toe appeared to have little flow prior to, during, and post drilling activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. JNH approximated the seepage rate using a 5-gallon bucket at about 4.3 gpm. No changes in the seepage rate or clarity of water were observed prior to, during, and post drilling activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to, during, and post drilling activities.
- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- JNH and drillers to meet at Site at 07:30.
- Complete the monitoring well installation at B-101(P) by placing bentonite chips, concrete, and the surface mount casing. Place cuttings around monitoring well to cover concrete.
- Demobilize equipment from site. Preferably, this will occur prior to persons from the Grand Mesa Ultra running race being on-site. However, if runners are present, equipment travel will attempt to be coordinated so as to move equipment while runners are not on the crest.
- JNH to store City of Grand Junction cones and caution tape at the gate structure building and to relock the gate with the USFS lock.

## Site Coordination Activities

- None

## Non-RJH Activities

- About 15-20 hikers and fishermen on-site throughout the day. Two hikers walked around the drilling equipment along the crest but remained a safe distance from equipment.
- A person from the Grand Mesa Ultra running race was on-site placing flags along the crest. The man said that there is a trail running race taking place tomorrow, Saturday 7/28/18, and the route travels across the crest of Hogchute Dam. The man indicated that the runners will be at the crest starting around 14:00.

## Photographs

*Boring B-101:*

Figure 1. B-101 at start of day, looking southeast.

Figure 2. B-101 equipment set-up during grouting, looking southeast.

Figure 3. B-101 at end of day, looking southeast.

*Other Photos:*

Figure 4. Cones and caution tape across crest at north end (nearest parking lot) at end of day, looking south.


Figure 5. Flag placed on crest for trail running race that occurs Saturday 7/28/18, looking north. Flag circled in red. Monitoring well in photo is B-102A(P).


Figure 6. Flag placed on roadway between parking lot and crest for trail running race.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 006-JNH**
**Task 1002 Geotechnical Investigation** **Date: Saturday, July 28, 2018**


**Prepared By:** JNH
**Weather:** high low-mid 60's, clouds increasing to overcast with intermittent rain and few lightning and thunder. Drilling equipment was demobilized off the crest prior to lightning.
**Boring(s):** B-101

## People on Site (arrival/departure time)

- RJH: JNH (07:20/10:30)
- HRL:
  - Jose Suarez & Devin Lucero (07:30/10:05)
  - Mark Mumby (08:25/10:05)

## Equipment on Site

*Mobile*
- RJH T3
- HRL Chevy 2500HD
- HRL Dodge 3500

*Demobilized*
- HRL semi-truck and trailer
- HRL support trailer & materials
- CME 55LC track mounted drill rig

## Material Used

*B-101*
- 2 buckets of coated bentonite pellets
- 5 bags of medium bentonite chips (50# bag)
- 2 bags of concrete (50# bag)
- 9-inch surface mount casing

## Drilling Progress Summary

- No drilling occurred today.
- Prior to continuing the monitoring well installation at B-101 for the day, groundwater was measured in the well to about 30.55 feet below ground surface (bgs).
- The drillers completed the monitoring well installation at B-101(P).
- The drillers demobilized the drill rig and equipment off of the crest. Mark was on-site to assist the drillers with demobilization. The drillers completed site clean-up while JNH

developed well B-101(P) with the 1-inch hand bailer and performed a rising head permeability test.
- No 1.5-inch slip cap or J-plug was on-site. The well at B-101(P) was covered with duct tape to protect the well from debris. Mark said that he would return to the site next week (of 7/30/18) and install a cap for the well; JNH requested that Mark install a J-plug. Mark to notify JNH when he returns to the site to cover the well at B-101(P).
- JNH placed the City of Grand Junction cones and tape surrounding B-101(P) in an attempt to prevent the trail runners or other public on the crest from stepping into the concrete that was placed today. Plenty of space remains for public to safely access the crest on either side of the monitoring well.
- JNH secured the USFS gate with the USFS lock and removed RJH's lock.
- The drillers and all equipment and material were demobilized from the Site prior to any trail runners being present.

## Seepage Observations

- Seepage behind the outlet works right headwall at toe appeared to have little flow prior to and post daily activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. JNH approximated the seepage rate using a 5-gallon bucket at about 4.3 gpm. No changes in the seepage rate or clarity of water were observed prior to and post daily activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to and post daily activities.
- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- Drilling for this phase of the geotechnical investigation is complete.
- Mark to notify JNH when he returns to the site next week to place the J-plug in B-101(P).

## Site Coordination Activities

- None

## Non-RJH Activities

- About 15-20 fishermen and trail running race spectators were on-site throughout the morning.

**Photographs**

*Boring B-101:*


Figure 1. B-101 at start of day, looking southeast.


Figure 2. Duct tape covering well opening at B-101.


Figure 3. B-101 at end of day, looking north. Cones and caution tape placed either side of monitoring well surface mount casing.


Figure 4. Crest and B-101 at end of day, looking south. B-101 location circled in red.

*Other Photos:*


Figure 5. Crest at the beginning of day, looking south.


Figure 6. Crest at the end of day, looking south.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 007-JNH**
**Task 1002 Geotechnical Investigation** **Date: Monday, September 17, 2018**


**Prepared By:** JNH
**Weather:** high low 70's, mostly sunny, light to moderate breeze
**Boring(s):** B-105

## People on Site (arrival/departure time)

- RJH:
    - JNH (08:45/17:45)
    - GOJ (12:50/17:10)
- HRL:
    - Jose Suarez & Devin Lucero (09:15/17:35)
    - Mark Mumby (09:15/11:45)
    - Chris (09:15/09:35 and 16:25/16:35)
- SEO: Jackie Blumberg (12:15/16:30)
- Girardis Towing (09:15/09:25)

## Equipment on Site

*Mobile*
- RJH T3
- GOJ Chevy Silverado
- HRL Chevy 2500HD
- HRL Dodge 3500
- HRL Dodge diesel pickup truck and trailer
- SEO Ford F-150
- Girardis semi-truck and trailer

*At Site Parking Lot Overnight*
- HRL support trailer & materials

*At Drill Site Overnight (B-105)*
- CME 55LC track mounted drill rig
- Sullair 375HH trailer mounted air compressor
- New Holland C185 track mounted skid steer

## Material

*At Site Parking Lot*
- About 4 cubic yards (CY) of C-33 fine aggregate sand
- About 4 CY of Chat/minus ¼ inch gravel

*Used (B-105)*

- About 2 CY each of fine aggregate sand and Chat/minus ¼ inch gravel staged near B-105

## Carson Lake Water Level

- About 10 feet below the spillway crest

## Drilling Progress Summary

- JNH recorded groundwater levels in B-101(P), B-102A(P), and B-103(P) prior to the start of drilling activities. B-102A(P) was pumped dry with the submersible pump and a rising head permeability test was performed.
- HRL mobilized the drill rig and drilling support equipment to the Site. HRL stated that Whitewater delivered the C-33 fine aggregate and Chat/minus ¼ inch gravel to the Site parking lot Friday 9/14/18.
- The keyed lock to the USFS gate was cut to allow equipment access. GOJ to coordinate lock replacement with the City and USFS.
- HRL mobilized about 2 CY each of the fine aggregate sand and ¼ inch gravel emergency supplies to near B-105.
- Boring B-105 was drilled via drive casing advancer methods, specifically Symmetrix, to a depth of 27.0 feet. A representative from the SEO was onsite during drilling. Smooth drilling advanced through clay, gravel, cobbles, and a few boulders. The air compressor was kept at the “low pressure” setting throughout drilling.
- Groundwater was encountered at about 4.8 feet and the depth of water in the boring varied throughout drilling. The groundwater was under positive pressure and as a result, a rising head permeability test was completed at 21.0 to 22.0 feet in lean clay material.
- A split spoon sample was taken from about 27.0 to 28.5 at the end of the day and bedrock was not encountered.
- The drillers attached the drive casing head in B-105 to cover and protect the integrity of the boring for overnight.
- RJH placed a keyed lock to secure the USFS gate for overnight.

## Seepage Observations

- Seepage behind the outlet works right headwall at toe appeared to have typical low flow prior to and post daily activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. JNH approximated the seepage rate using a 5-gallon bucket at about 5 gpm. No changes in the seepage rate or clarity of water were observed prior to and post daily activities.

- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to and post daily activities.
- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- JNH to use the 1.5-inch submersible pump on B-101(P) and perform a rising head permeability test.
- JNH to meet drillers at Site at 07:30.
- Continue to drill B-105 via drive casing advancer until bedrock is encountered or a depth of about 75 feet is reached; HRL identified about 75 feet as the maximum allowable depth.
    - If bedrock is encountered, drill via drive casing advancer until advanced 2-3 feet into bedrock, only if the end casing depth is less than the maximum identified by HRL. Once in bedrock, switch to HQ wireline coring and perform packer tests.
- If time and site conditions allow, install piezometer in colluvium/alluvium.

## Site Coordination Activities

- None

## Non-RJH Activities

- About 15-25 fishermen and campers were on-site throughout the day; no public were near equipment at dam toe.

## Photographs

*Boring B-105:*


Figure 1. B-105 (circled in red) prior to drilling, looking southeast.


Figure 2. B-105 equipment set-up prior to drilling, taken from crest looking west.


Figure 3. B-105 equipment set-up during drilling, looking south.


Figure 4. B-105 at the end of day, looking southeast.

*Other Photos:*


Figure 5. Carson lake water level prior to drilling activities, looking southwest. Water level is about 10 feet below normal maximum. Normal maximum marked with red arrow.


Figure 6. Emergency stockpiles of sand and gravel stationed at the Site parking lot, looking east.


Figure 7. Symmetrix drive casing advancer bit. Camera case is 6-inches long for scale.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 008-JNH**
**Task 1002 Geotechnical Investigation** **Date: Tuesday, September 18, 2018**


**Prepared By:** JNH
**Weather:** high low-mid 70's, mostly sunny, light to moderate breeze
**Boring(s):** B-105A

## People on Site (arrival/departure time)

- RJH: JNH (06:40/17:40)
- HRL: Jose Suarez & Devin Lucero (07:25/17:25)
- SEO: Jason Ward (09:05/15:00)

## Equipment on Site

*Mobile*
- RJH T3
- HRL Chevy 2500HD
- SEO – vehicle unknown

*At Site Parking Lot Overnight*
- HRL support trailer & materials

*At Drill Site Overnight (B-105A)*
- CME 55LC track mounted drill rig
- Sullair 375HH trailer mounted air compressor
- New Holland C185 track mounted skid steer

## Material

*At Site Parking Lot*
- About 4 cubic yards (CY) of C-33 fine aggregate sand
- About 4 CY of Chat/minus ¼ inch gravel

*Used (B-105A)*
- About 2 CY each of fine aggregate sand and Chat/minus ¼ inch gravel staged near B-105
- RJH provided:
    - End Cap
    - 5 ft prepacked well screen 2" PVC (40) pipe
- HRL provided:
    - (7) 10 ft riser 2" PVC (40) pipe
    - 3 buckets of bentonite coated pellets

## Carson Lake Water Level

- About 10 feet below the spillway crest

## Drilling Progress Summary

- JNH pumped B-101(P) with the 1.5-inch submersible pump and performed a rising head permeability test prior to the start of drilling activities.
- Drilling B-105A was continued via drive casing advancer methods. Prior to start of drilling for the day, groundwater was measured in the boring to about 9.2 feet below ground surface (bgs). A representative from the SEO was onsite during almost the entire drilling process.
- Slow and smooth drilling advanced through clay, gravel, cobbles, and boulders. The air compressor was kept at the "low pressure" setting throughout drilling.
- The depth of groundwater in the boring varied throughout drilling. The groundwater was under positive pressure and water releasing (i.e. bubbling) at the surface was observed when the boring bottom was at about 52.0 feet. The water was releasing between the casing and the boring wall. Drilling was stopped to observed if conditions changed or recovered. A rising head permeability test (K-2) was performed and data was recorded for 67 minutes. The water release at the surface stopped after about 30 minutes of no drilling activity. At about 65 minutes, the water level and water rebound rate was similar to the water depth and rate of water rebound observed in the rising head permeability test (K-1) performed yesterday, 9/17/18.
- After discussions among the field crew, it appeared likely that no damage was caused from today's drilling activities. RJH decided to continue drilling based on the following observations:
    - The water release stopped.
    - The ring bit provided about 3/8-inch total annulus around the casing and boring wall and is the source of space for air and water to travel to the surface.
    - The water rebound rate was observed to be approximately the same as observed during K-1 at a similar water depth.
- The depth of the boring was at a maximum allowable depth of 72.0 feet at the end of the day and bedrock was not encountered. No additional water releases at the surface were observed.
- A split spoon sample was taken from about 72.0 to 73.5 at the end of the day and bedrock was not encountered.
- The drillers began the monitoring well installation at B-105A(P) and completed the backfill materials to about 48.0 feet. Chat/minus ¼ inch gravel was used as the permeable backfill around the prepacked well screen and was placed downhole. Bentonite coated pellets were placed to 48.0 feet and allowed to set overnight.
- The drillers attached the drive casing head in B-105A(P) to cover and protect the integrity of the boring and monitoring well for overnight.

## Seepage Observations

- Seepage behind the outlet works right headwall at toe appeared to have typical low flow prior to, during, and post daily activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. No changes in the seepage rate or clarity of water were observed prior to, during, and post daily activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to, during, and post daily activities.
- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- JNH to meet drillers at Site at 07:30.
- Continue to install monitoring well B-105A(P).
- Move drill rig about 10 feet in any feasible direction and begin drilling B-105B.
- Install monitoring well B-105B at about 10-12 feet to capture non-high-pressure phreatic surface. No sampling necessary at B-105B.
- If time and site conditions allow, begin to move equipment and material to B-104.

## Site Coordination Activities

- JNH and Jason Ward discussed the SEO's verbal approval to continuing drilling the remaining monitoring wells along the dam toe. RJH to send summary email to Project partners and SEO regarding approval to continue drilling remaining borings; GOJ to perform this task after tomorrow's activities.

## Non-RJH Activities

- About 15-25 fishermen, hunters, and campers were on-site throughout the day; no public were near equipment at dam toe.

*City of Grand Junction (City)*

- People on Site: 1 man
- Equipment on Site: City pickup truck
- One man from the City was observed onsite on the dam crest appearing to take monitoring well measurements of the crest wells. The water level he measured in B-101(P) will likely be still rebounding from RJH pumping that well and performing a rising head permeability test earlier today.

**<u>Photographs</u>**
*Boring B-105A:*


Figure 1. B-105A at start of day, looking west.


Figure 2. B-105A at start of day, looking south.


Figure 3. B-105A equipment set-up during drilling, looking south.


Figure 4. B-105A at the end of day, looking southeast.


Figure 5. B-105A at the end of day, looking west.

*Other Photos:*


Figure 6. Area where water release was occurring at the surface, circled in red. Drilling stopped.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 009-JNH**
**Task 1002 Geotechnical Investigation** **Date: Wednesday, September 19, 2018**


**Prepared By:** JNH
**Weather:** high mid 60's but mostly mid 50's, partly cloudy to overcast, occasional light rain, light to moderate breeze
**Boring(s):** B-105A, B-105B, B-104

**People on Site (arrival/departure time)**

- RJH:
  - JNH (06:55/17:30)
  - GOJ (13:15/14:40)
- HRL:
  - Jose Suarez & Devin Lucero (07:20/17:30)
  - Mark Mumby (10:50/11:15)

**Equipment on Site**

*Mobile*
- RJH T3
- GOJ Chevy Silverado
- HRL Chevy 2500HD
- HRL Dodge 3500

*At Site Parking Lot Overnight*
- HRL support trailer & materials

*At Drill Site Overnight*
- *At B-104*
  - CME 55LC track mounted drill rig

- *Right of Outlet Works*
  - Sullair 375HH trailer mounted air compressor
  - New Holland C185 track mounted skid steer

**Material**

*At Site Parking Lot*
- About 4 cubic yards (CY) of C-33 fine aggregate sand
- About 3 CY of Chat/minus ¼ inch gravel

*Used*
*B-105A(P)*
- 7 bags of Portland cement (47# bag)

- ½ bag high yield bentonite powder (50# bag)
- J plug

*B-105B(P)*

- RJH provided:
    - End cap
    - 5 ft prepacked well screen 2" PVC (40) pipe
- HRL provided:
    - (1) 10 ft riser 2" PVC (40) pipe
    - 1 bucket of bentonite coated pellets
    - 1 bag of Portland cement (47# bag)
    - ¼ bag high yield bentonite powder (50# bag)
    - J plug

*B-104*

- About 2 CY of fine aggregate sand and Chat/minus ¼ inch gravel moved from near B-105 to near B-104
- Additional about 1 CY Chat/minus ¼ inch gravel moved from Site parking lot to near B-104

**<u>Carson Lake Water Level</u>**

- About 10 feet below the spillway crest

**<u>Drilling Progress Summary</u>**

- JNH measured water levels in B-101(P), B-102A(P), and B-103(P) prior to the start of daily activities.
- Groundwater was measured in boring B-105A at about 9.1 feet bgs prior to daily activities.
- The drillers continued to work on the B-105A(P) monitoring well installation. Cement bentonite grout was placed via tremie pipe; the grout needs to set overnight.
- Boring B-105B was drilled about 9.5 feet north of B-105A via drive casing advancer methods to a total depth of about 12.6 feet. Smooth drilling advanced through clay, gravel, cobbles, and a few boulders at the surface. The air compressor was kept at the "low pressure" setting throughout drilling. No sampling was taken at B-105B due to the proximity to B-105A.
- No groundwater was observed in boring B-105B during drilling; however, water was heard entering the boring at a depth of about 12.6 feet and a rising head permeability test was performed. Groundwater raised to about 8.2 feet bgs.
- The drillers began the monitoring well installation at B-105B(P) and completed the backfill materials to about 2 feet. Chat/minus ¼ inch gravel was used as the

permeable backfill around the prepacked well screen and was placed downhole. Bentonite coated pellets were placed to 3 feet and allowed to set for about 1.5 hours. Cement bentonite grout was placed downhole; the grout needs to set overnight.

- The drillers mobilized equipment and material to B-104. Stockpiles of sand and gravel were moved from near B-105 to near B-104. Additional gravel was moved from the Site parking lot to near B-104. The remaining sand and gravel near B-105 was smoothed with rakes and shovels.
- Boring B-104 was drilled via drive casing advancer methods to a depth of about 12.0 feet. Slow and smooth drilling advanced through clay, gravel, cobbles, and boulders; numerous boulders were encountered from about 0 to 6 feet. The air compressor was kept at the “low pressure” setting throughout drilling.
- Groundwater was not encountered during drilling but samples were moist after about 7 feet.
- A Shelby tube was attempted at 12.0 feet but encountered a cobble at 13.0 feet which disturbed the sample. A split spoon sample was taken at about 13.0 feet but only advanced 0.3 feet due to a cobble. Bedrock was not encountered.
- The drillers attached the drive casing head in B-104 to cover and protect the integrity of the boring for overnight.

## Seepage Observations

- Seepage behind the outlet works right headwall at toe appeared to have typical low flow prior to and post daily activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. No changes in the seepage rate or clarity of water were observed prior to and post daily activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to and post daily activities.
- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- JNH to meet drillers at Site at 07:30.
- Continue installation of monitoring wells B-105A(P) and B-105B(P).
- Continue to drill B-104 via drive casing advancer until bedrock is encountered or a depth of about 35 feet is reached.
    - o If bedrock is encountered, drill via drive casing advancer until advanced 2-3 feet into bedrock. Once in bedrock, switch to HQ wireline coring, core about 10 feet into bedrock, and perform packer tests.
- Begin monitoring well B-104(P) installation. Install monitoring well in colluvium/alluvium.

# DAILY SITE REPORT



**Site Coordination Activities**

- None

**Non-RJH Activities**

- About 10-15 fishermen, hunters, and campers were on-site throughout the day; no public were near equipment at dam toe.

**<u>Photographs</u>**

*Boring B-105A:*


Figure 1. B-105A at start of day, looking southeast.


Figure 2. B-105A during monitoring well installation, looking south.

*Boring B-105B:*


Figure 3. B-105B prior to drilling, looking south.

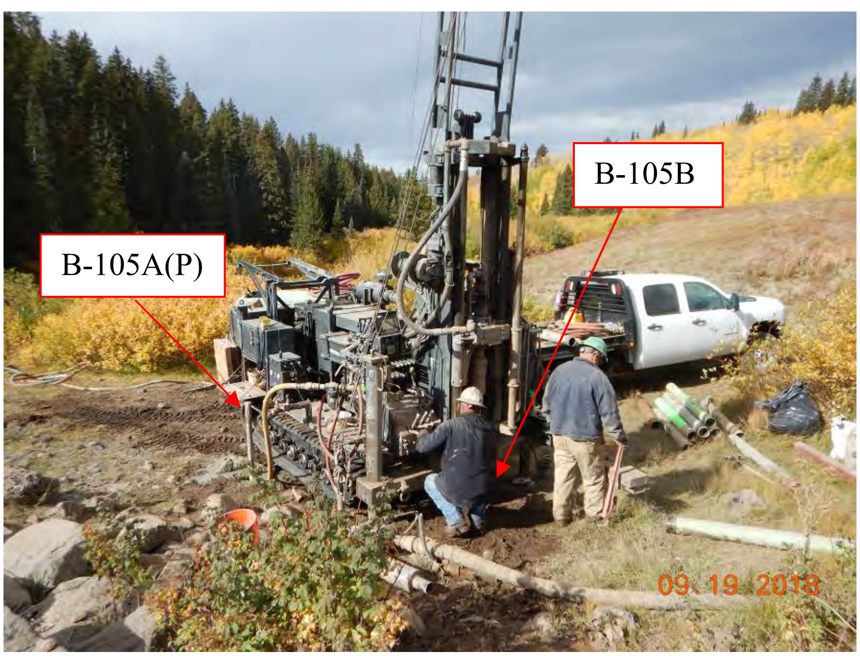



Figure 4. B-105B equipment set-up during drilling, looking west. B-105A(P) riser pipe on left in photo.

Figure 5. B-105B equipment set-up during drilling, looking south.

*B-105A(P) and B-105B(P):*

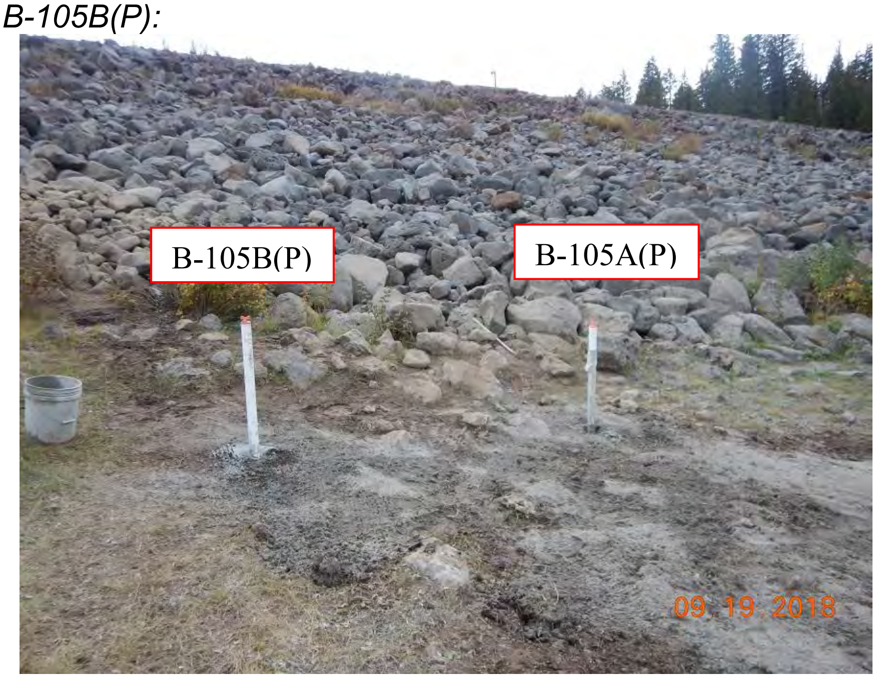


Figure 6. Riser pipes to B-105A(P) on right and B-105B(P) on left in photo at the end of day, looking southeast.

*Boring B-104:*


Figure 7. B-104 prior to drilling, looking south.


Figure 8. B-104 equipment set-up prior to drilling, looking southeast. Air compressor is right of outlet works and drill rig and skid steer are left of outlet works.


Figure 9. B-104 equipment set-up during drilling, looking east.


Figure 10. Sand and gravel stockpiles near B-104, looking west.


Figure 11. B-104 at the end of day, looking south.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 010-JNH**
**Task 1002 Geotechnical Investigation** **Date: Thursday, September 20, 2018**


**Prepared By:** JNH
**Weather:** high about 60°, sunny, light to moderate breeze
**Boring(s):** B-105A, B-105B, B-104

**People on Site (arrival/departure time)**

- RJH: JNH (07:00/16:50)
- HRL:
  - Jose Suarez & Devin Lucero (07:25/15:15)
  - Chris (Prior to RJH arrival on Site/07:10)
- SEO: Jackie Blumberg (08:25/13:20)

**Equipment on Site**

*Mobile*
- RJH T3
- HRL Chevy 2500HD
- HRL Toyota Tacoma
- SEO Ford F150

*At Site Parking Lot Overnight*
- HRL support trailer & materials
- Sullair 375HH trailer mounted air compressor

*At Drill Site Overnight*
- *At B-104*
  - CME 55LC track mounted drill rig

- *Right of Outlet Works*
  - New Holland C185 track mounted skid steer

**Material**

*At Site Parking Lot*
- About 4 cubic yards (CY) of C-33 fine aggregate sand
- About 3 CY of Chat/minus ¼ inch gravel

*Used*
*B-105A(P)*
- 1 bag medium bentonite chips (50# bag)
- ½ bag of concrete (50# bag)

- ½ bag 10/20 sand (50# bag)
- 5 ft steel riser casing, 4 in x 4 in square

*B-105B(P)*

- ½ bag of concrete (50# bag)
- ½ bag 10/20 sand (50# bag)
- 5 ft steel riser casing, 4 in x 4 in square

*B-104*

- About 2 CY of fine aggregate sand and about 3 CY Chat/minus ¼ inch gravel staged near B-104
- 2 bags of Portland cement (47# bag)
- ¼ bag high yield bentonite powder (50# bag)

**Carson Lake Water Level**

- About 10 feet below the spillway crest

**Drilling Progress Summary**

- JNH measured water levels in B-101(P), B-102A(P), and B-103(P) prior to the start of daily activities.
- The installation of monitoring wells B-105A(P) and B-105B(P) were completed by adding concrete and setting steel riser casings in each well. The steel riser casings are hinged and lockable; however, RJH did not place a lock on either casing.
- Groundwater was measured in boring B-104 at about 10.4 feet bgs prior to drilling activities.
- Drilling B-104 was continued via drive casing advancer methods to a total depth of about 32 feet. A representative from the SEO was onsite during the drilling process. Slow and smooth drilling advanced through clay, gravel, cobbles, and a few boulders. The air compressor was kept at the “low pressure” setting throughout drilling. Intervals with consistent clay materials took up to about 30 minutes to progress about 1.0 foot; however, typical progression rates were about 30 to 40 minutes to progress 5 feet.
- Two Shelby tubes were attempted but were unable to be pushed due to the presence of gravels and cobbles.
- The depth of groundwater in the boring varied throughout drilling. The groundwater was under positive pressure and water was heard entering the boring at a depth of about 26 to 27 feet and a rising head permeability test was performed.
- The drillers began to prepare for the monitoring well installation at B-104 and completed the backfill of cement bentonite grout to about 12 feet. The grout needs to set overnight and is anticipated to settle to about 15 to 16 feet.

- The drillers attached the drive casing head in B-104 to cover and protect the integrity of the boring for overnight.
- At the end of the day, JNH developed wells B-105A(P) and B-105B(P) with a surge block and submersible pump and performed a rising head permeability test on each well.

**Seepage Observations**

- Seepage behind the outlet works right headwall at toe appeared to have typical low flow prior to, during, and post daily activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. No changes in the seepage rate or clarity of water were observed prior to, during, and post daily activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to, during, and post daily activities.
- No other signs of seepage or abnormalities were observed.

**Plan for Next Work Day**

- JNH to meet drillers at Site at 08:30.
- HRL to complete installation of monitoring well B-104(P).
- JNH to develop monitoring well B-104(P) with a surge block and submersible pump if conditions allow. JNH to also perform rising head permeability test if conditions allow.
- HRL to demobilize all equipment from Site in the afternoon.

**Site Coordination Activities**

- None

**Non-RJH Activities**

- About 10-20 fishermen, hunters, and campers were on-site throughout the day; no public were near equipment at dam toe.

*City of Grand Junction (City)*

- People on Site: Slade and Craig from about 09:30 to 09:50 and two men from about 11:45 to 11:55.
- Equipment on Site: City Dodge and Ford pickup trucks
- Slade and Craig were onsite measuring groundwater levels in the crest borings. JNH discussed the Project progress and pumping of B-101(P) on Tuesday 9/18/18 morning, prior to Craig's well measurement, which likely influenced Craig's measurement.

- Two other men from the City were onsite on the dam crest; RJH did not meet with these two City representatives.

- **Photographs**

*Boring B-104:*

Figure 1. B-104 prior to drilling, looking southwest.

Figure 2. B-104 equipment set-up prior to drilling, looking east.

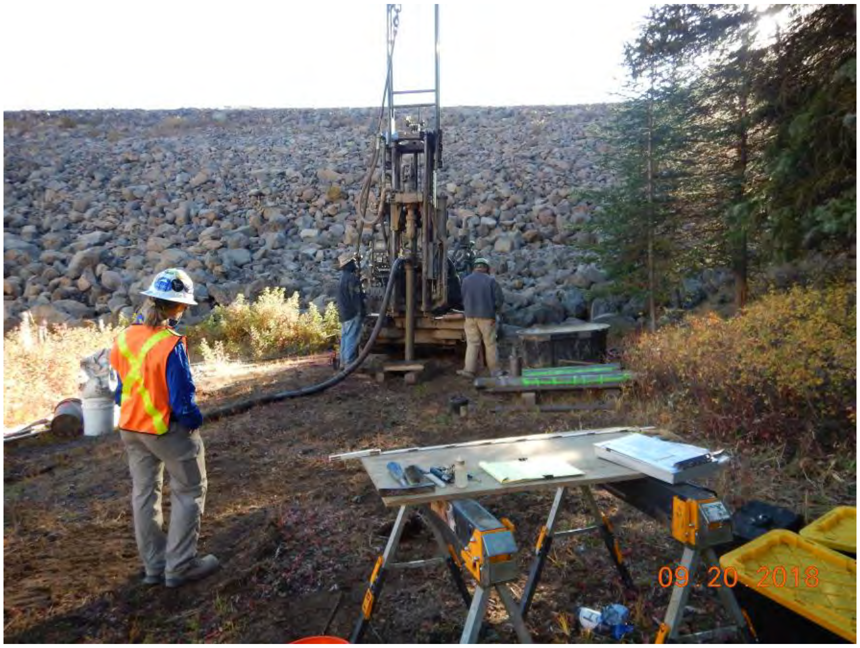



Figure 3. B-104 equipment set-up during drilling, looking east.


Figure 4. B-104 at the end of day, looking east.

*B-105A(P) and B-105B(P):*

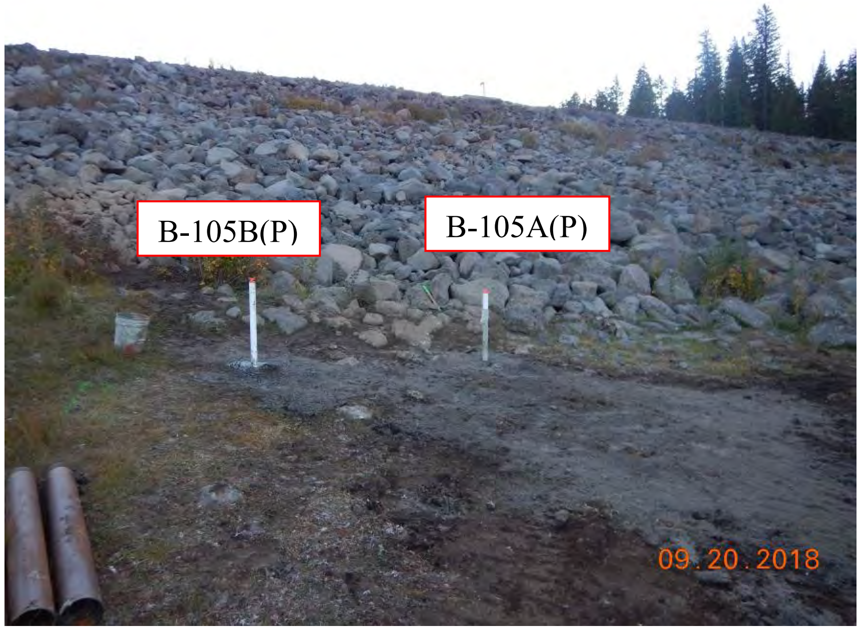



Figure 5. Riser pipes to B-105A(P) on right and B-105B(P) on left in photo at the start of day, looking southeast.

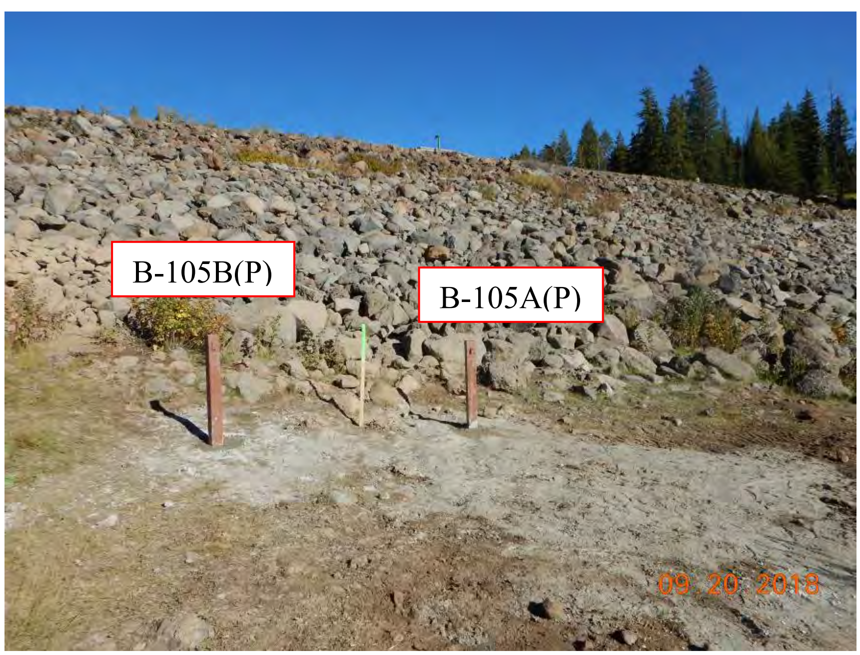



Figure 6. Riser casings to B-105A(P) on right and B-105B(P) on left in photo at the end of day, looking southeast.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 011-JNH**
**Task 1002 Geotechnical Investigation** **Date: Friday, September 21, 2018**


**Prepared By:** JNH
**Weather:** high about 60°, sunny
**Boring(s):** B-104

## People on Site (arrival/departure time)

- RJH: JNH (08:45/14:10)
- HRL:
    - o Jose Suarez & Devin Lucero (08:45/12:55)
    - o Mark Mumby (11:15/12:55)
    - o Chris (11:40/12:55)

## Equipment on Site

*Mobile*
- RJH T3
- HRL Chevy 2500HD
- HRL Dodge diesel pickup truck and trailer
- HRL semi-truck and trailer

*Demobilized*
- HRL support trailer & materials
- Sullair 375HH trailer mounted air compressor
- CME 55LC track mounted drill rig
- New Holland C185 track mounted skid steer

## Material

*At Site Parking Lot*
- About 4 cubic yards (CY) of C-33 fine aggregate sand
- About 3 CY of Chat/minus ¼ inch gravel

*Near B-104*
- About 2 CY of C-33 fine aggregate sand
- About 2 CY Chat/minus ¼ inch gravel

*Used*
*B-104*
- RJH provided:
    - o End cap
    - o 5 ft prepacked well screen 2” PVC (40) pipe

- HRL provided:
  - (2) 10 ft riser 2" PVC (40) pipe
  - 1 bucket of coated bentonite pellets
  - 1 bag of medium bentonite chips (50# bag)
  - J plug
  - 1 bag of concrete (50# bag)
  - 2 bags 10/20 sand (50# bag)
  - 5 ft steel riser casing, 4 in x 4 in square

## Carson Lake Water Level

- About 10 feet below the spillway crest

## Drilling Progress Summary

- JNH measured water levels in B-101(P), B-102A(P), B-103(P), B-105A(P), and B-105B(P) prior to the start of daily activities.
- The cement bentonite grout backfill in B-104 settled to about 17 feet bgs. Coated pellets were placed downhole and allowed to hydrate for 1 hour, bringing the bottom of B-104 up to about 14.5 feet bgs.
- The installation of monitoring well B-104(P) was completed by placing the monitoring well casing, adding backfill and concrete, and setting the steel riser casing. The steel riser casing is hinged and lockable; however, RJH did not place a lock on the casing.
- HRL demobilized all equipment from the Site.
- At the end of the day, JNH developed well B-104(P) with a surge block and submersible pump and performed a rising head permeability test.
- Drilling for this phase of the geotechnical investigation is complete.

## Seepage Observations

- Seepage behind the outlet works right headwall at toe appeared to have typical low flow prior to, during, and post daily activities.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. No changes in the seepage rate or clarity of water were observed prior to, during, and post daily activities.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works prior to, during, and post daily activities.
- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- JNH to measure groundwater levels in monitoring wells B-101(P), B-102A(P), B-103(P), B-104(P), B-105A(P), and B-105B(P).

## Site Coordination Activities

- None

## Non-RJH Activities

- About 10-20 fishermen, hunters, and campers were on-site throughout the day; no public were near equipment at dam toe.

**Photographs**

*Boring B-104:*


Figure 1. B-104 prior to drilling, looking east.


Figure 2. B-104(P) completed well installation at the end of day, looking east.

*B-105A(P) and B-105B(P):*


Figure 3. Riser casings to B-105A(P) on right and B-105B(P) on left in photo at the end of day, looking southeast.

*Other Photos:*


Figure 4. Demobilization of the drill rig and air compressor, looking west.


Figure 5. Site parking lot after equipment demobilization, looking east.


Figure 6. Sand and gravel stockpiles remain near B-104, looking west.


Figure 7. Sand and gravel stockpiles remain at Site parking lot, looking east. Camera case in photo is 6 inches long.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 012-JNH**
**Task 1002 Geotechnical Investigation** **Date: Saturday, September 22, 2018**


**Prepared By:** JNH
**Weather:** high about 45°, clear
**Monitoring Wells:** B-101, B-102A, B-103, B-104, B-105A, B-105B

## People on Site (arrival/departure time)

- RJH: JNH (06:40/07:35)

## Equipment on Site

*Mobile*
- RJH T3

## Material

*At Site Parking Lot*
- About 4 cubic yards (CY) of C-33 fine aggregate sand
- About 3 CY of Chat/minus ¼ inch gravel

*Near B-104*
- About 2 CY of C-33 fine aggregate sand
- About 2 CY Chat/minus ¼ inch gravel

*Used*
- None

## Carson Lake Water Level

- About 10 feet below the spillway crest

## Site Progress Summary

- No drilling occurred today.
- JNH measured water levels in all six monitoring wells:
  - B-101(P)
  - B-102A(P)
  - B-103(P)
  - B-104(P)
  - B-105A(P)
  - B-105B(P)

## Seepage Observations

- Seepage behind the outlet works right headwall at toe appeared to have typical low flow.
- Seepage from drain right of outlet works was flowing at a few gallons per minute with little to no turbidity. No changes in the seepage rate or clarity of water were observed.
- No water was observed in either of the two seepage channels in the willows right (north) of the outlet works.
- No other signs of seepage or abnormalities were observed.

## Plan for Next Work Day

- No further field work is anticipated to be completed by RJH.

## Site Coordination Activities

- RJH removed their temporary keyed lock and closed the gate with the chain link. The gate is not locked. The City is to coordinate with the USFS if needed to replace the lock and secure the access gate.

## Non-RJH Activities

- About 5 fishermen and hunters were on-site in the morning; no public were near equipment at dam toe.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 012-JNH**
**Task 1002 Geotechnical Investigation** **Date: Saturday, September 22, 2018**


**Photographs**

*Access Gate:*


Figure 1. Access gate closed with chain link, but is not secured with lock. Looking east.

# APPENDIX E

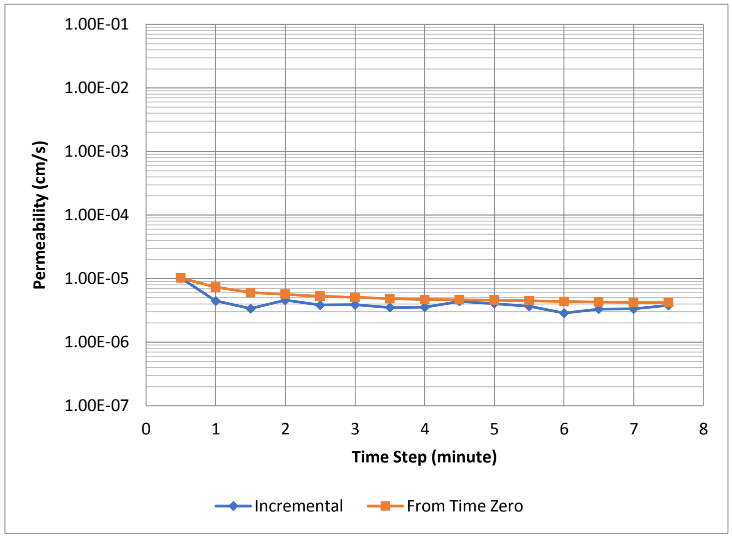
## PERMEABILITY RESULTS

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 7/28/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-101(P)** |
| **Test Number:** | **K-1** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 30.55 | ft |
| Casing Stickup | 0.0 | ft |
| Top Depth of Test Interval | 53.0 | ft |
| Bottom Depth of Test Interval | 74.0 | ft |
| Inside Diameter Pipe | 1.50 | in |
| D = Diameter, intake, sample | 7.75 | in |
| L = Length, intake, sample | 21.0 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 41.50 | 0.0 | 0 | 11.0 | -- | -- | -- | -- |
| 41.22 | 0.5 | 30 | 10.7 | 3.35E-07 | 1.02E-05 | 3.35E-07 | 1.02E-05 |
| 41.10 | 1.0 | 60 | 10.6 | 1.46E-07 | 4.46E-06 | 2.41E-07 | 7.34E-06 |
| 41.01 | 1.5 | 90 | 10.5 | 1.11E-07 | 3.38E-06 | 1.98E-07 | 6.02E-06 |
| 40.89 | 2.0 | 120 | 10.3 | 1.49E-07 | 4.55E-06 | 1.85E-07 | 5.65E-06 |
| 40.79 | 2.5 | 150 | 10.2 | 1.26E-07 | 3.83E-06 | 1.74E-07 | 5.29E-06 |
| 40.69 | 3.0 | 180 | 10.1 | 1.27E-07 | 3.87E-06 | 1.66E-07 | 5.05E-06 |
| 40.60 | 3.5 | 210 | 10.1 | 1.15E-07 | 3.52E-06 | 1.59E-07 | 4.83E-06 |
| 40.51 | 4.0 | 240 | 10.0 | 1.16E-07 | 3.55E-06 | 1.53E-07 | 4.67E-06 |
| 40.40 | 4.5 | 270 | 9.9 | 1.44E-07 | 4.38E-06 | 1.52E-07 | 4.64E-06 |
| 40.30 | 5.0 | 300 | 9.8 | 1.32E-07 | 4.03E-06 | 1.50E-07 | 4.58E-06 |
| 40.21 | 5.5 | 330 | 9.7 | 1.20E-07 | 3.66E-06 | 1.47E-07 | 4.50E-06 |
| 40.14 | 6.0 | 360 | 9.6 | 9.41E-08 | 2.87E-06 | 1.43E-07 | 4.36E-06 |
| 40.06 | 6.5 | 390 | 9.5 | 1.08E-07 | 3.30E-06 | 1.40E-07 | 4.28E-06 |
| 39.98 | 7.0 | 420 | 9.4 | 1.09E-07 | 3.33E-06 | 1.38E-07 | 4.21E-06 |
| 39.89 | 7.5 | 450 | 9.3 | 1.24E-07 | 3.78E-06 | 1.37E-07 | 4.18E-06 |
| | | | | | | | |
| **Estimated Permeability** | | | | **2.9E-06** | **to** | **1.0E-05** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **4.0.E-06** | **(cm/sec)** | |

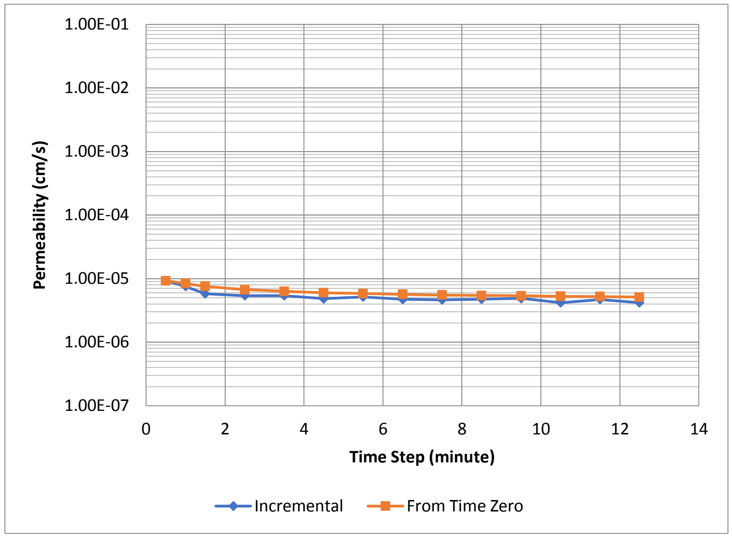
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/18/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-101(P)** |
| **Test Number:** | **K-2** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 38.84 | ft |
| Casing Stickup | 0.0 | ft |
| Top Depth of Test Interval | 53.0 | ft |
| Bottom Depth of Test Interval | 74.0 | ft |
| Inside Diameter Pipe | 1.50 | in |
| D = Diameter, intake, sample | 7.75 | in |
| L = Length, intake, sample | 21.0 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 51.77 | 0.0 | 0 | 12.9 | -- | -- | -- | -- |
| 51.47 | 0.5 | 30 | 12.6 | 3.04E-07 | 9.26E-06 | 3.04E-07 | 9.26E-06 |
| 51.23 | 1.0 | 60 | 12.4 | 2.48E-07 | 7.57E-06 | 2.76E-07 | 8.42E-06 |
| 51.05 | 1.5 | 90 | 12.2 | 1.89E-07 | 5.77E-06 | 2.47E-07 | 7.53E-06 |
| 50.72 | 2.5 | 150 | 11.9 | 1.77E-07 | 5.40E-06 | 2.19E-07 | 6.68E-06 |
| 50.40 | 3.5 | 210 | 11.6 | 1.77E-07 | 5.39E-06 | 2.07E-07 | 6.31E-06 |
| 50.12 | 4.5 | 270 | 11.3 | 1.59E-07 | 4.84E-06 | 1.96E-07 | 5.98E-06 |
| 49.83 | 5.5 | 330 | 11.0 | 1.69E-07 | 5.14E-06 | 1.91E-07 | 5.83E-06 |
| 49.57 | 6.5 | 390 | 10.7 | 1.55E-07 | 4.72E-06 | 1.86E-07 | 5.66E-06 |
| 49.32 | 7.5 | 450 | 10.5 | 1.53E-07 | 4.65E-06 | 1.81E-07 | 5.53E-06 |
| 49.07 | 8.5 | 510 | 10.2 | 1.56E-07 | 4.76E-06 | 1.78E-07 | 5.44E-06 |
| 48.82 | 9.5 | 570 | 10.0 | 1.60E-07 | 4.88E-06 | 1.76E-07 | 5.38E-06 |
| 48.61 | 10.5 | 630 | 9.8 | 1.38E-07 | 4.20E-06 | 1.73E-07 | 5.26E-06 |
| 48.38 | 11.5 | 690 | 9.5 | 1.54E-07 | 4.70E-06 | 1.71E-07 | 5.22E-06 |
| 48.18 | 12.5 | 750 | 9.3 | 1.37E-07 | 4.18E-06 | 1.68E-07 | 5.13E-06 |
| | | | | | | | |
| **Estimated Permeability** | | | | **4.2E-06** | **to** | **9.3E-06** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **5.3.E-06** | **(cm/sec)** | |

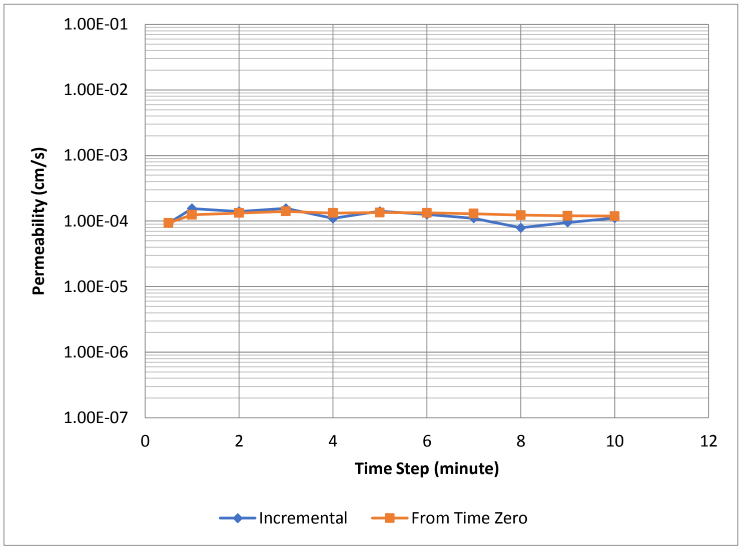
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# Falling Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 7/24/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-102A(P)** |
| **Test Number:** | **K-1** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 35.25 | ft |
| Casing Stickup | 3.9 | ft |
| Top Depth of Test Interval | 46.5 | ft |
| Bottom Depth of Test Interval | 46.5 | ft |
| Inside Diameter Pipe | 4.25 | in |
| D = Diameter, intake, sample | 4.25 | in |
| L = Length, intake, sample | 0.0 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 6.09 | 0.0 | 0 | 33.1 | -- | -- | -- | -- |
| 6.12 | 0.5 | 30 | 33.0 | 3.06E-06 | 9.33E-05 | 3.06E-06 | 9.33E-05 |
| 6.17 | 1.0 | 60 | 33.0 | 5.11E-06 | 1.56E-04 | 4.08E-06 | 1.24E-04 |
| 6.26 | 2.0 | 120 | 32.9 | 4.61E-06 | 1.40E-04 | 4.35E-06 | 1.32E-04 |
| 6.36 | 3.0 | 180 | 32.8 | 5.13E-06 | 1.56E-04 | 4.61E-06 | 1.40E-04 |
| 6.43 | 4.0 | 240 | 32.7 | 3.60E-06 | 1.10E-04 | 4.36E-06 | 1.33E-04 |
| 6.52 | 5.0 | 300 | 32.6 | 4.64E-06 | 1.42E-04 | 4.41E-06 | 1.35E-04 |
| 6.60 | 6.0 | 360 | 32.6 | 4.14E-06 | 1.26E-04 | 4.37E-06 | 1.33E-04 |
| 6.67 | 7.0 | 420 | 32.5 | 3.63E-06 | 1.11E-04 | 4.26E-06 | 1.30E-04 |
| 6.72 | 8.0 | 480 | 32.4 | 2.60E-06 | 7.92E-05 | 4.05E-06 | 1.24E-04 |
| 6.78 | 9.0 | 540 | 32.4 | 3.12E-06 | 9.52E-05 | 3.95E-06 | 1.20E-04 |
| 6.85 | 10.0 | 600 | 32.3 | 3.65E-06 | 1.11E-04 | 3.92E-06 | 1.20E-04 |
| | | | | | | | |
| **Estimated Permeability** | | | | **7.9E-05** | **to** | **1.6E-04** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **1.2.E-04** | **(cm/sec)** | |

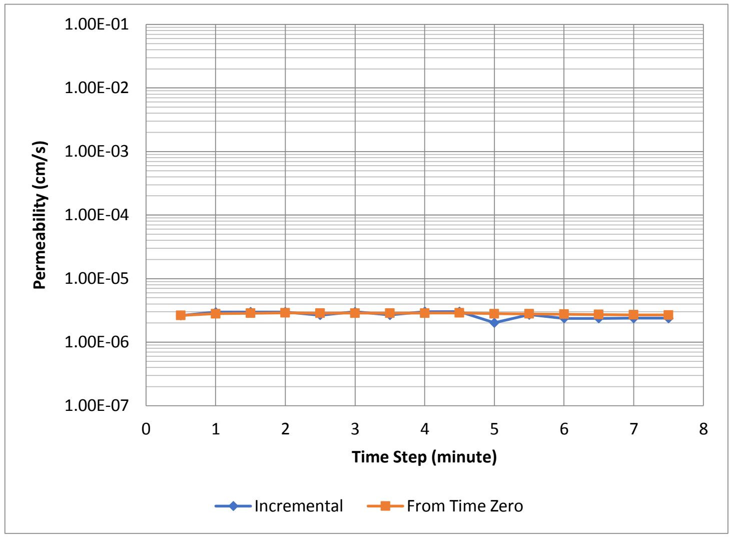
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case C.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 7/26/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-102A(P)** |
| **Test Number:** | **K-2** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 10.36 | ft |
| Casing Stickup | 0.0 | ft |
| Top Depth of Test Interval | 36.5 | ft |
| Bottom Depth of Test Interval | 48.0 | ft |
| Inside Diameter Pipe | 2.00 | in |
| D = Diameter, intake, sample | 7.75 | in |
| L = Length, intake, sample | 11.5 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 43.70 | 0.0 | 0 | 33.3 | -- | -- | -- | -- |
| 43.62 | 0.5 | 30 | 33.3 | 8.64E-08 | 2.63E-06 | 8.64E-08 | 2.63E-06 |
| 43.53 | 1.0 | 60 | 33.2 | 9.75E-08 | 2.97E-06 | 9.19E-08 | 2.80E-06 |
| 43.44 | 1.5 | 90 | 33.1 | 9.77E-08 | 2.98E-06 | 9.39E-08 | 2.86E-06 |
| 43.35 | 2.0 | 120 | 33.0 | 9.80E-08 | 2.99E-06 | 9.49E-08 | 2.89E-06 |
| 43.27 | 2.5 | 150 | 32.9 | 8.73E-08 | 2.66E-06 | 9.34E-08 | 2.85E-06 |
| 43.18 | 3.0 | 180 | 32.8 | 9.85E-08 | 3.00E-06 | 9.42E-08 | 2.87E-06 |
| 43.10 | 3.5 | 210 | 32.7 | 8.78E-08 | 2.68E-06 | 9.33E-08 | 2.84E-06 |
| 43.01 | 4.0 | 240 | 32.7 | 9.90E-08 | 3.02E-06 | 9.40E-08 | 2.87E-06 |
| 42.92 | 4.5 | 270 | 32.6 | 9.93E-08 | 3.03E-06 | 9.46E-08 | 2.88E-06 |
| 42.86 | 5.0 | 300 | 32.5 | 6.63E-08 | 2.02E-06 | 9.18E-08 | 2.80E-06 |
| 42.78 | 5.5 | 330 | 32.4 | 8.86E-08 | 2.70E-06 | 9.15E-08 | 2.79E-06 |
| 42.71 | 6.0 | 360 | 32.4 | 7.77E-08 | 2.37E-06 | 9.03E-08 | 2.75E-06 |
| 42.64 | 6.5 | 390 | 32.3 | 7.79E-08 | 2.37E-06 | 8.94E-08 | 2.72E-06 |
| 42.57 | 7.0 | 420 | 32.2 | 7.81E-08 | 2.38E-06 | 8.86E-08 | 2.70E-06 |
| 42.50 | 7.5 | 450 | 32.1 | 7.82E-08 | 2.38E-06 | 8.79E-08 | 2.68E-06 |
| | | | | | | | |
| **Estimated Permeability** | | | | **2.0E-06** | **to** | **3.0E-06** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **2.7.E-06** | **(cm/sec)** | |

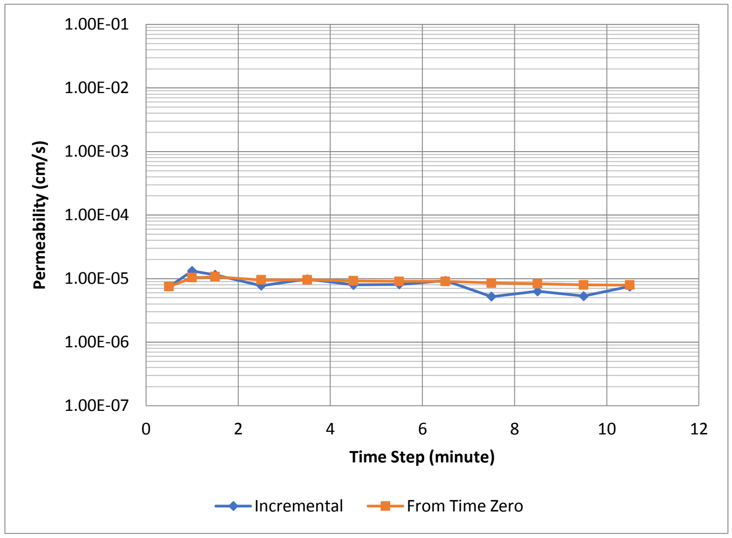
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/17/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-102A(P)** |
| **Test Number:** | **K-3** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 37.48 | ft |
| Casing Stickup | 0.0 | ft |
| Top Depth of Test Interval | 36.5 | ft |
| Bottom Depth of Test Interval | 48.0 | ft |
| Inside Diameter Pipe | 2.00 | in |
| D = Diameter, intake, sample | 7.75 | in |
| L = Length, intake, sample | 11.5 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 43.37 | 0.0 | 0 | 5.9 | -- | -- | -- | -- |
| 43.33 | 0.5 | 30 | 5.9 | 2.45E-07 | 7.47E-06 | 2.45E-07 | 7.47E-06 |
| 43.26 | 1.0 | 60 | 5.8 | 4.33E-07 | 1.32E-05 | 3.39E-07 | 1.03E-05 |
| 43.20 | 1.5 | 90 | 5.7 | 3.75E-07 | 1.14E-05 | 3.51E-07 | 1.07E-05 |
| 43.12 | 2.5 | 150 | 5.6 | 2.53E-07 | 7.72E-06 | 3.12E-07 | 9.51E-06 |
| 43.02 | 3.5 | 210 | 5.5 | 3.22E-07 | 9.81E-06 | 3.15E-07 | 9.59E-06 |
| 42.94 | 4.5 | 270 | 5.5 | 2.62E-07 | 7.97E-06 | 3.03E-07 | 9.23E-06 |
| 42.86 | 5.5 | 330 | 5.4 | 2.65E-07 | 8.09E-06 | 2.96E-07 | 9.03E-06 |
| 42.77 | 6.5 | 390 | 5.3 | 3.03E-07 | 9.25E-06 | 2.97E-07 | 9.06E-06 |
| 42.72 | 7.5 | 450 | 5.2 | 1.71E-07 | 5.21E-06 | 2.80E-07 | 8.55E-06 |
| 42.66 | 8.5 | 510 | 5.2 | 2.07E-07 | 6.31E-06 | 2.72E-07 | 8.28E-06 |
| 42.61 | 9.5 | 570 | 5.1 | 1.74E-07 | 5.32E-06 | 2.62E-07 | 7.97E-06 |
| 42.54 | 10.5 | 630 | 5.1 | 2.47E-07 | 7.53E-06 | 2.60E-07 | 7.93E-06 |
| | | | | | | | |
| **Estimated Permeability** | | | | **5.2E-06** | **to** | **1.3E-05** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **8.0.E-06** | **(cm/sec)** | |

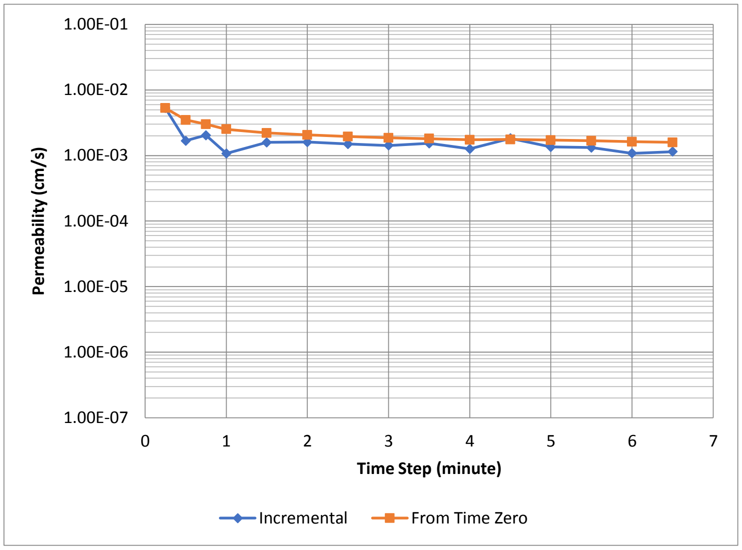
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# Falling Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 7/23/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-103(P)** |
| **Test Number:** | **K-1** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 25.5 | ft |
| Casing Stickup | 0.4 | ft |
| Top Depth of Test Interval | 30.0 | ft |
| Bottom Depth of Test Interval | 30.0 | ft |
| Inside Diameter Pipe | 4.25 | in |
| D = Diameter, intake, sample | 4.25 | in |
| L = Length, intake, sample | 0.0 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 1.87 | 0.0 | 0 | 24.0 | -- | -- | -- | -- |
| 2.48 | 0.3 | 15 | 23.4 | 1.73E-04 | 5.28E-03 | 1.73E-04 | 5.28E-03 |
| 2.67 | 0.5 | 30 | 23.2 | 5.49E-05 | 1.67E-03 | 1.14E-04 | 3.48E-03 |
| 2.90 | 0.8 | 45 | 23.0 | 6.71E-05 | 2.05E-03 | 9.85E-05 | 3.00E-03 |
| 3.02 | 1.0 | 60 | 22.9 | 3.53E-05 | 1.08E-03 | 8.27E-05 | 2.52E-03 |
| 3.37 | 1.5 | 90 | 22.5 | 5.20E-05 | 1.58E-03 | 7.24E-05 | 2.21E-03 |
| 3.72 | 2.0 | 120 | 22.2 | 5.28E-05 | 1.61E-03 | 6.75E-05 | 2.06E-03 |
| 4.04 | 2.5 | 150 | 21.9 | 4.90E-05 | 1.49E-03 | 6.38E-05 | 1.95E-03 |
| 4.34 | 3.0 | 180 | 21.6 | 4.66E-05 | 1.42E-03 | 6.10E-05 | 1.86E-03 |
| 4.66 | 3.5 | 210 | 21.2 | 5.04E-05 | 1.54E-03 | 5.94E-05 | 1.81E-03 |
| 4.92 | 4.0 | 240 | 21.0 | 4.15E-05 | 1.27E-03 | 5.72E-05 | 1.74E-03 |
| 5.29 | 4.5 | 270 | 20.6 | 6.00E-05 | 1.83E-03 | 5.75E-05 | 1.75E-03 |
| 5.56 | 5.0 | 300 | 20.3 | 4.45E-05 | 1.36E-03 | 5.62E-05 | 1.71E-03 |
| 5.82 | 5.5 | 330 | 20.1 | 4.34E-05 | 1.32E-03 | 5.50E-05 | 1.68E-03 |
| 6.03 | 6.0 | 360 | 19.9 | 3.54E-05 | 1.08E-03 | 5.34E-05 | 1.63E-03 |
| 6.25 | 6.5 | 390 | 19.7 | 3.75E-05 | 1.14E-03 | 5.22E-05 | 1.59E-03 |
| | | | | | | | |
| **Estimated Permeability** | | | | **1.1E-03** | **to** | **5.3E-03** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **1.6.E-03** | **(cm/sec)** | |

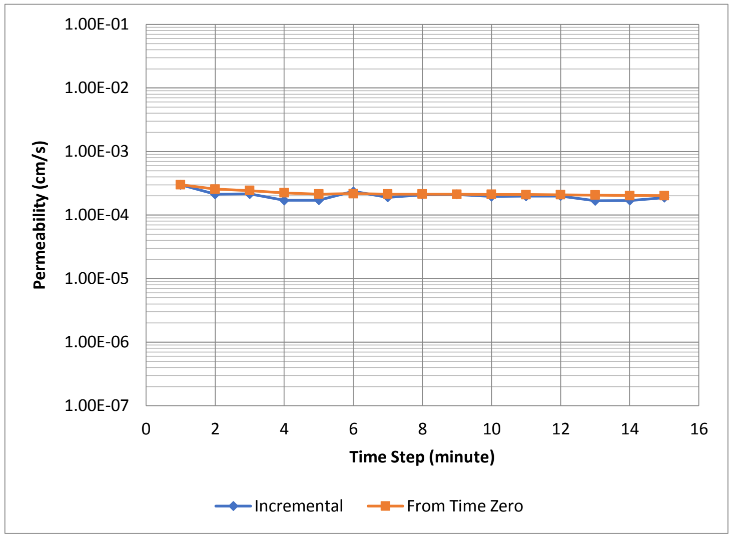
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case C.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/20/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-104(P)** |
| **Test Number:** | **K-1** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 10.4 | ft |
| Casing Stickup | 2.1 | ft |
| Top Depth of Test Interval | 26.0 | ft |
| Bottom Depth of Test Interval | 27.0 | ft |
| Inside Diameter Pipe | 5.75 | in |
| D = Diameter, intake, sample | 5.75 | in |
| L = Length, intake, sample | 1.0 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 27.00 | 0.0 | 0 | 14.5 | -- | -- | -- | -- |
| 26.80 | 1.0 | 60 | 14.3 | 9.84E-06 | 3.00E-04 | 9.84E-06 | 3.00E-04 |
| 26.66 | 2.0 | 120 | 14.16 | 6.97E-06 | 2.13E-04 | 8.41E-06 | 2.56E-04 |
| 26.52 | 3.0 | 180 | 14.0 | 7.04E-06 | 2.15E-04 | 7.95E-06 | 2.42E-04 |
| 26.41 | 4.0 | 240 | 13.9 | 5.58E-06 | 1.70E-04 | 7.36E-06 | 2.24E-04 |
| 26.30 | 5.0 | 300 | 13.8 | 5.63E-06 | 1.72E-04 | 7.01E-06 | 2.14E-04 |
| 26.15 | 6.0 | 360 | 13.65 | 7.75E-06 | 2.36E-04 | 7.14E-06 | 2.18E-04 |
| 26.03 | 7.0 | 420 | 13.53 | 6.26E-06 | 1.91E-04 | 7.01E-06 | 2.14E-04 |
| 25.90 | 8.0 | 480 | 13.4 | 6.84E-06 | 2.09E-04 | 6.99E-06 | 2.13E-04 |
| 25.77 | 9.0 | 540 | 13.3 | 6.91E-06 | 2.11E-04 | 6.98E-06 | 2.13E-04 |
| 25.65 | 10.0 | 600 | 13.2 | 6.44E-06 | 1.96E-04 | 6.93E-06 | 2.11E-04 |
| 25.53 | 11.0 | 660 | 13.03 | 6.50E-06 | 1.98E-04 | 6.89E-06 | 2.10E-04 |
| 25.41 | 12.0 | 720 | 12.91 | 6.56E-06 | 2.00E-04 | 6.86E-06 | 2.09E-04 |
| 25.31 | 13.0 | 780 | 12.81 | 5.51E-06 | 1.68E-04 | 6.76E-06 | 2.06E-04 |
| 25.21 | 14.0 | 840 | 12.7 | 5.56E-06 | 1.69E-04 | 6.67E-06 | 2.03E-04 |
| 25.10 | 15.0 | 900 | 12.6 | 6.16E-06 | 1.88E-04 | 6.64E-06 | 2.02E-04 |
| | | | | | | | |
| **Estimated Permeability** | | | | **1.7E-04** | **to** | **3.0E-04** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **2.0.E-04** | **(cm/sec)** | |

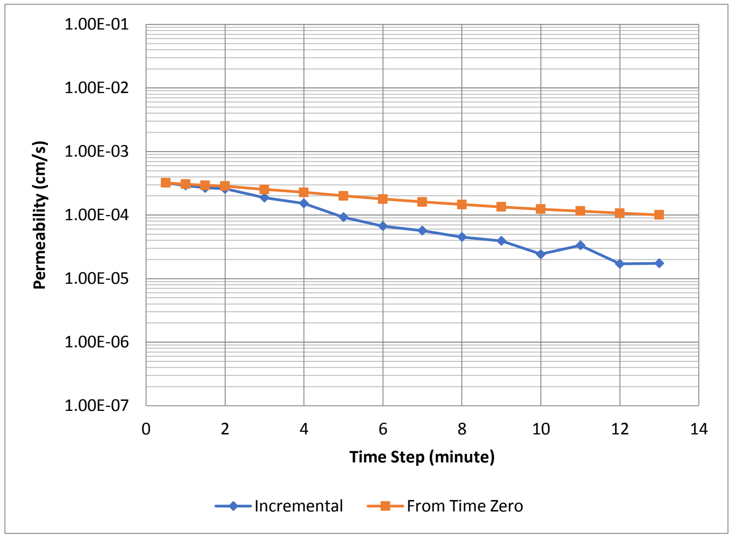
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/21/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-104(P)** |
| **Test Number:** | **K-2** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 5.99 | ft |
| Casing Stickup | 2.9 | ft |
| Top Depth of Test Interval | 8.9 | ft |
| Bottom Depth of Test Interval | 14.5 | ft |
| Inside Diameter Pipe | 2.00 | in |
| D = Diameter, intake, sample | 5.75 | in |
| L = Length, intake, sample | 5.6 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 13.10 | 0.0 | 0 | 4.21 | -- | -- | -- | -- |
| 12.47 | 0.5 | 30 | 3.58 | 1.06E-05 | 3.22E-04 | 1.06E-05 | 3.22E-04 |
| 11.98 | 1.0 | 60 | 3.09 | 9.58E-06 | 2.92E-04 | 1.01E-05 | 3.07E-04 |
| 11.59 | 1.5 | 90 | 2.70 | 8.78E-06 | 2.68E-04 | 9.64E-06 | 2.94E-04 |
| 11.26 | 2.0 | 120 | 2.37 | 8.49E-06 | 2.59E-04 | 9.35E-06 | 2.85E-04 |
| 10.85 | 3.0 | 180 | 1.96 | 6.18E-06 | 1.88E-04 | 8.29E-06 | 2.53E-04 |
| 10.57 | 4.0 | 240 | 1.68 | 5.02E-06 | 1.53E-04 | 7.48E-06 | 2.28E-04 |
| 10.42 | 5.0 | 300 | 1.53 | 3.04E-06 | 9.28E-05 | 6.59E-06 | 2.01E-04 |
| 10.32 | 6.0 | 360 | 1.43 | 2.20E-06 | 6.71E-05 | 5.86E-06 | 1.79E-04 |
| 10.24 | 7.0 | 420 | 1.35 | 1.87E-06 | 5.71E-05 | 5.29E-06 | 1.61E-04 |
| 10.18 | 8.0 | 480 | 1.29 | 1.48E-06 | 4.51E-05 | 4.81E-06 | 1.47E-04 |
| 10.13 | 9.0 | 540 | 1.24 | 1.29E-06 | 3.92E-05 | 4.42E-06 | 1.35E-04 |
| 10.10 | 10.0 | 600 | 1.21 | 7.97E-07 | 2.43E-05 | 4.06E-06 | 1.24E-04 |
| 10.06 | 11.0 | 660 | 1.17 | 1.09E-06 | 3.33E-05 | 3.79E-06 | 1.15E-04 |
| 10.04 | 12.0 | 720 | 1.15 | 5.61E-07 | 1.71E-05 | 3.52E-06 | 1.07E-04 |
| 10.02 | 13.0 | 780 | 1.13 | 5.71E-07 | 1.74E-05 | 3.29E-06 | 1.00E-04 |
| | | | | | | | |
| **Estimated Permeability** | | | | **1.7E-05** | **to** | **3.2E-04** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **7.9.E-05** | **(cm/sec)** | |

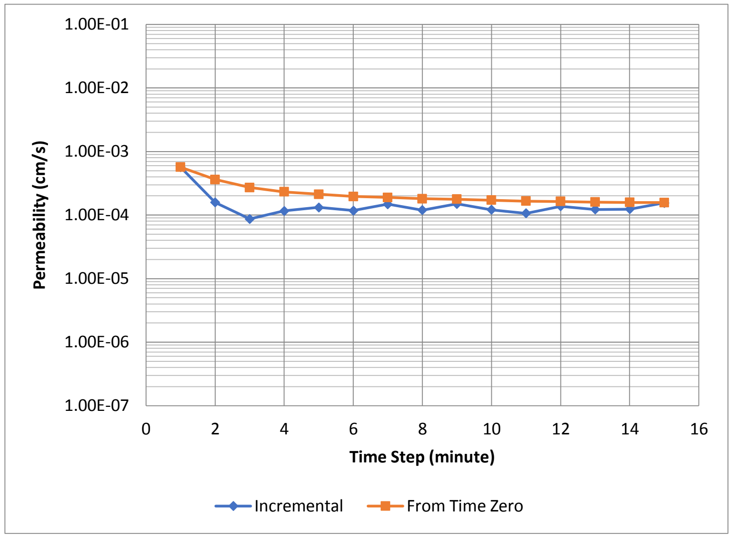
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/17/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-105A(P)** |
| **Test Number:** | **K-1** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 4.8 | ft |
| Casing Stickup | 2.9 | ft |
| Top Depth of Test Interval | 21.0 | ft |
| Bottom Depth of Test Interval | 22.0 | ft |
| Inside Diameter Pipe | 5.75 | in |
| D = Diameter, intake, sample | 5.75 | in |
| L = Length, intake, sample | 1.0 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 23.15 | 0.0 | 0 | 15.45 | -- | -- | -- | -- |
| 22.75 | 1.0 | 60 | 15.05 | 1.86E-05 | 5.67E-04 | 1.86E-05 | 5.67E-04 |
| 22.64 | 2.0 | 120 | 14.94 | 5.20E-06 | 1.58E-04 | 1.19E-05 | 3.63E-04 |
| 22.58 | 3.0 | 180 | 14.88 | 2.85E-06 | 8.69E-05 | 8.88E-06 | 2.71E-04 |
| 22.50 | 4.0 | 240 | 14.80 | 3.82E-06 | 1.16E-04 | 7.62E-06 | 2.32E-04 |
| 22.41 | 5.0 | 300 | 14.71 | 4.32E-06 | 1.32E-04 | 6.96E-06 | 2.12E-04 |
| 22.33 | 6.0 | 360 | 14.63 | 3.87E-06 | 1.18E-04 | 6.44E-06 | 1.96E-04 |
| 22.23 | 7.0 | 420 | 14.53 | 4.86E-06 | 1.48E-04 | 6.22E-06 | 1.89E-04 |
| 22.15 | 8.0 | 480 | 14.45 | 3.91E-06 | 1.19E-04 | 5.93E-06 | 1.81E-04 |
| 22.05 | 9.0 | 540 | 14.35 | 4.92E-06 | 1.50E-04 | 5.82E-06 | 1.77E-04 |
| 21.97 | 10.0 | 600 | 14.27 | 3.96E-06 | 1.21E-04 | 5.63E-06 | 1.72E-04 |
| 21.90 | 11.0 | 660 | 14.20 | 3.49E-06 | 1.06E-04 | 5.44E-06 | 1.66E-04 |
| 21.81 | 12.0 | 720 | 14.11 | 4.51E-06 | 1.37E-04 | 5.36E-06 | 1.63E-04 |
| 21.73 | 13.0 | 780 | 14.03 | 4.03E-06 | 1.23E-04 | 5.26E-06 | 1.60E-04 |
| 21.65 | 14.0 | 840 | 13.95 | 4.05E-06 | 1.24E-04 | 5.17E-06 | 1.58E-04 |
| 21.55 | 15.0 | 900 | 13.85 | 5.10E-06 | 1.55E-04 | 5.17E-06 | 1.57E-04 |
| | | | | | | | |
| **Estimated Permeability** | | | | **8.7E-05** | **to** | **5.7E-04** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **1.4.E-04** | **(cm/sec)** | |

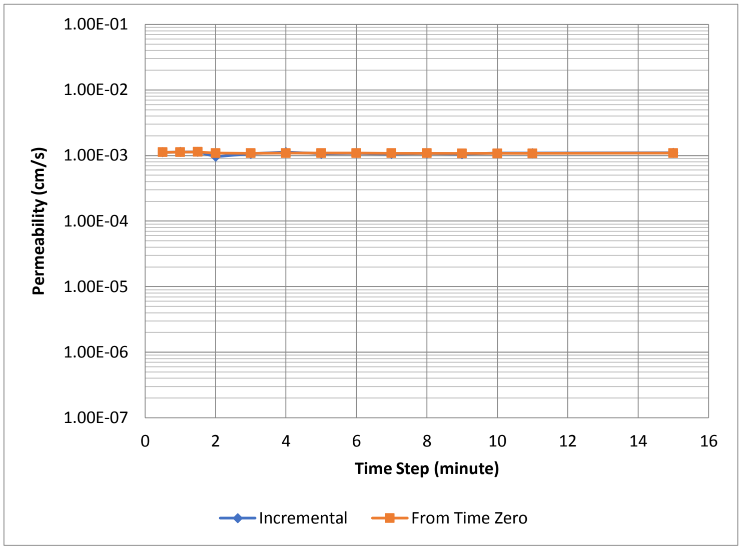
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/18/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-105A(P)** |
| **Test Number:** | **K-2** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 9.18 | ft |
| Casing Stickup | 1.3 | ft |
| Top Depth of Test Interval | 52.0 | ft |
| Bottom Depth of Test Interval | 52.0 | ft |
| Inside Diameter Pipe | 5.38 | in |
| D = Diameter, intake, sample | 5.38 | in |
| L = Length, intake, sample | 0.0 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 45.40 | 0.0 | 0 | 34.92 | -- | -- | -- | -- |
| 45.10 | 0.5 | 30 | 34.62 | 3.68E-05 | 1.12E-03 | 3.68E-05 | 1.12E-03 |
| 44.80 | 1.0 | 60 | 34.32 | 3.71E-05 | 1.13E-03 | 3.70E-05 | 1.13E-03 |
| 44.50 | 1.5 | 90 | 34.02 | 3.74E-05 | 1.14E-03 | 3.71E-05 | 1.13E-03 |
| 44.25 | 2.0 | 120 | 33.77 | 3.15E-05 | 9.59E-04 | 3.57E-05 | 1.09E-03 |
| 43.70 | 3.0 | 180 | 33.22 | 3.50E-05 | 1.07E-03 | 3.55E-05 | 1.08E-03 |
| 43.13 | 4.0 | 240 | 32.65 | 3.69E-05 | 1.12E-03 | 3.58E-05 | 1.09E-03 |
| 42.60 | 5.0 | 300 | 32.12 | 3.49E-05 | 1.06E-03 | 3.56E-05 | 1.09E-03 |
| 42.07 | 6.0 | 360 | 31.59 | 3.55E-05 | 1.08E-03 | 3.56E-05 | 1.09E-03 |
| 41.56 | 7.0 | 420 | 31.08 | 3.47E-05 | 1.06E-03 | 3.55E-05 | 1.08E-03 |
| 41.05 | 8.0 | 480 | 30.57 | 3.53E-05 | 1.08E-03 | 3.55E-05 | 1.08E-03 |
| 40.56 | 9.0 | 540 | 30.08 | 3.45E-05 | 1.05E-03 | 3.53E-05 | 1.08E-03 |
| 40.06 | 10.0 | 600 | 29.58 | 3.57E-05 | 1.09E-03 | 3.54E-05 | 1.08E-03 |
| 39.57 | 11.0 | 660 | 29.09 | 3.56E-05 | 1.09E-03 | 3.54E-05 | 1.08E-03 |
| 37.66 | 15.0 | 900 | 27.18 | 3.62E-05 | 1.10E-03 | 3.56E-05 | 1.09E-03 |
| | | | | | | | |
| **Estimated Permeability** | | | | **9.6E-04** | **to** | **1.1E-03** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **1.1.E-03** | **(cm/sec)** | |

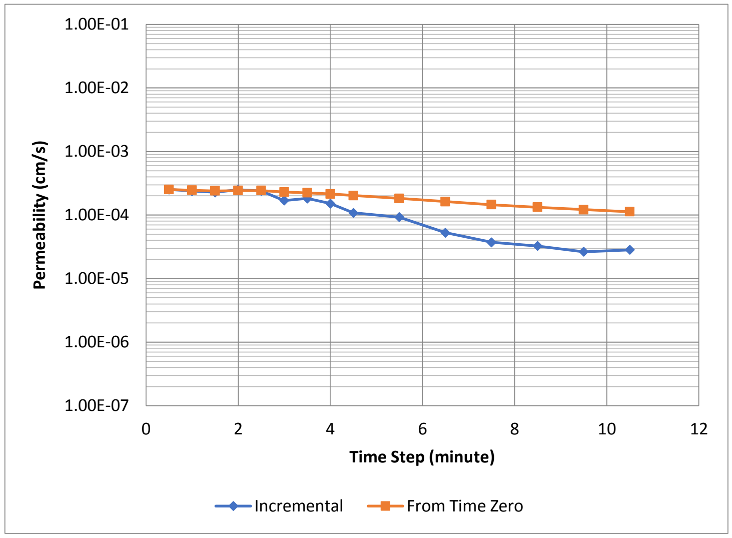
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case C.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/20/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-105A(P)** |
| **Test Number:** | **K-3** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 9.74 | ft |
| Casing Stickup | 2.8 | ft |
| Top Depth of Test Interval | 53.0 | ft |
| Bottom Depth of Test Interval | 73.5 | ft |
| Inside Diameter Pipe | 2.00 | in |
| D = Diameter, intake, sample | 5.75 | in |
| L = Length, intake, sample | 20.5 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 21.11 | 0.0 | 0 | 8.57 | -- | -- | -- | -- |
| 18.70 | 0.5 | 30 | 6.16 | 8.29E-06 | 2.53E-04 | 8.29E-06 | 2.53E-04 |
| 17.05 | 1.0 | 60 | 4.51 | 7.83E-06 | 2.39E-04 | 8.06E-06 | 2.46E-04 |
| 15.89 | 1.5 | 90 | 3.35 | 7.47E-06 | 2.28E-04 | 7.87E-06 | 2.40E-04 |
| 14.95 | 2.0 | 120 | 2.41 | 8.27E-06 | 2.52E-04 | 7.97E-06 | 2.43E-04 |
| 14.30 | 2.5 | 150 | 1.76 | 7.90E-06 | 2.41E-04 | 7.95E-06 | 2.42E-04 |
| 13.95 | 3.0 | 180 | 1.41 | 5.57E-06 | 1.70E-04 | 7.56E-06 | 2.30E-04 |
| 13.65 | 3.5 | 210 | 1.11 | 6.01E-06 | 1.83E-04 | 7.33E-06 | 2.24E-04 |
| 13.45 | 4.0 | 240 | 0.91 | 4.99E-06 | 1.52E-04 | 7.04E-06 | 2.15E-04 |
| 13.33 | 4.5 | 270 | 0.79 | 3.55E-06 | 1.08E-04 | 6.65E-06 | 2.03E-04 |
| 13.16 | 5.5 | 330 | 0.62 | 3.04E-06 | 9.28E-05 | 6.00E-06 | 1.83E-04 |
| 13.08 | 6.5 | 390 | 0.54 | 1.74E-06 | 5.29E-05 | 5.34E-06 | 1.63E-04 |
| 13.03 | 7.5 | 450 | 0.49 | 1.22E-06 | 3.72E-05 | 4.79E-06 | 1.46E-04 |
| 12.99 | 8.5 | 510 | 0.45 | 1.07E-06 | 3.26E-05 | 4.35E-06 | 1.33E-04 |
| 12.96 | 9.5 | 570 | 0.42 | 8.67E-07 | 2.64E-05 | 3.99E-06 | 1.22E-04 |
| 12.93 | 10.5 | 630 | 0.39 | 9.31E-07 | 2.84E-05 | 3.70E-06 | 1.13E-04 |
| | | | | | | | |
| **Estimated Permeability** | | | | **2.6E-05** | **to** | **2.5E-04** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **1.0.E-04** | **(cm/sec)** | |

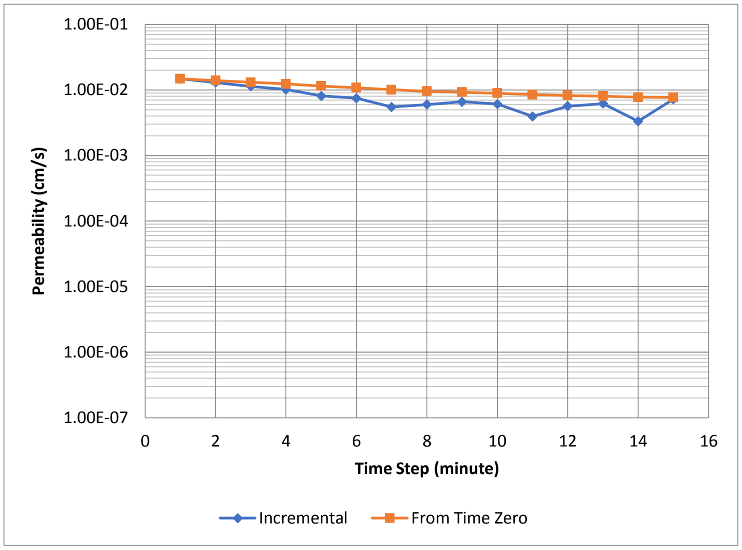
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/19/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-105B(P)** |
| **Test Number:** | **K-1** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 8.24 | ft |
| Casing Stickup | 1.4 | ft |
| Top Depth of Test Interval | 12.6 | ft |
| Bottom Depth of Test Interval | 12.6 | ft |
| Inside Diameter Pipe | 5.38 | in |
| D = Diameter, intake, sample | 5.38 | in |
| L = Length, intake, sample | 0.0 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 11.65 | 0.0 | 0 | 2.01 | -- | -- | -- | -- |
| 11.24 | 1.0 | 60 | 1.60 | 4.86E-04 | 1.48E-02 | 4.86E-04 | 1.48E-02 |
| 10.95 | 2.0 | 120 | 1.31 | 4.26E-04 | 1.30E-02 | 4.56E-04 | 1.39E-02 |
| 10.74 | 3.0 | 180 | 1.10 | 3.73E-04 | 1.14E-02 | 4.28E-04 | 1.31E-02 |
| 10.58 | 4.0 | 240 | 0.94 | 3.35E-04 | 1.02E-02 | 4.05E-04 | 1.23E-02 |
| 10.47 | 5.0 | 300 | 0.83 | 2.65E-04 | 8.09E-03 | 3.77E-04 | 1.15E-02 |
| 10.38 | 6.0 | 360 | 0.74 | 2.45E-04 | 7.46E-03 | 3.55E-04 | 1.08E-02 |
| 10.32 | 7.0 | 420 | 0.68 | 1.80E-04 | 5.50E-03 | 3.30E-04 | 1.01E-02 |
| 10.26 | 8.0 | 480 | 0.62 | 1.97E-04 | 6.00E-03 | 3.13E-04 | 9.55E-03 |
| 10.20 | 9.0 | 540 | 0.56 | 2.17E-04 | 6.61E-03 | 3.03E-04 | 9.23E-03 |
| 10.15 | 10.0 | 600 | 0.51 | 1.99E-04 | 6.08E-03 | 2.92E-04 | 8.91E-03 |
| 10.12 | 11.0 | 660 | 0.48 | 1.29E-04 | 3.94E-03 | 2.78E-04 | 8.46E-03 |
| 10.08 | 12.0 | 720 | 0.44 | 1.86E-04 | 5.65E-03 | 2.70E-04 | 8.23E-03 |
| 10.04 | 13.0 | 780 | 0.40 | 2.03E-04 | 6.19E-03 | 2.65E-04 | 8.07E-03 |
| 10.02 | 14.0 | 840 | 0.38 | 1.09E-04 | 3.33E-03 | 2.54E-04 | 7.73E-03 |
| 9.98 | 15.0 | 900 | 0.34 | 2.37E-04 | 7.23E-03 | 2.53E-04 | 7.70E-03 |
| | | | | | | | |
| **Estimated Permeability** | | | | **3.3E-03** | **to** | **1.5E-02** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **7.1.E-03** | **(cm/sec)** | |

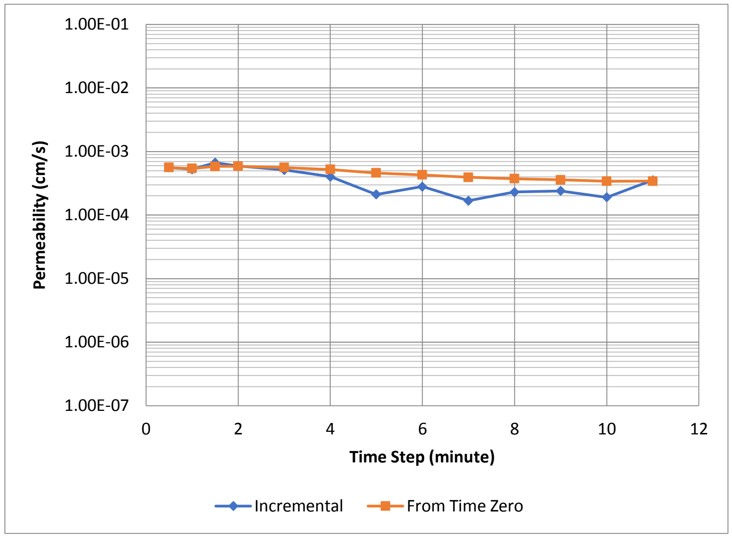
(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case C.

# Rising Head Test - Data Reduction Calculation Sheet

| | | |
|---|---|---|
| Field Engineer/Geologist: | JNH | 9/20/2018 |
| Calculated By: | JNH | 11/20/2018 |
| Checked By: | ALC | 11/20/2018 |
| Approved By: | GOJ | 11/26/2018 |

| | |
|---|---|
| **Project Number:** | **18115** |
| **Boring:** | **B-105B(P)** |
| **Test Number:** | **K-2** |

| | | |
|---|---|---|
| Depth to top of Ground Water | 5.55 | ft |
| Casing Stickup | 2.9 | ft |
| Top Depth of Test Interval | 8.6 | ft |
| Bottom Depth of Test Interval | 12.6 | ft |
| Inside Diameter Pipe | 2.00 | in |
| D = Diameter, intake, sample | 5.75 | in |
| L = Length, intake, sample | 4.1 | ft |
| M = Transformation Ratio | 1.00 | -- |




| Depth to Water Surface In Pipe From Top of Riser Pipe | Time, t | Time, t | Length of Water Column at time, H | Incremental | | From Time Zero | |
|---|---|---|---|---|---|---|---|
| | | | | Permeability | Permeability | Permeability | Permeability |
| (ft) | (min) | (sec) | (ft) | (ft/s) | (cm/s) | (ft/s) | (cm/s) |
| 12.25 | 0.0 | 0 | 3.8 | -- | -- | -- | -- |
| 11.48 | 0.5 | 30 | 3.0 | 1.83E-05 | 5.58E-04 | 1.83E-05 | 5.58E-04 |
| 10.90 | 1.0 | 60 | 2.5 | 1.72E-05 | 5.24E-04 | 1.78E-05 | 5.41E-04 |
| 10.32 | 1.5 | 90 | 1.9 | 2.19E-05 | 6.66E-04 | 1.91E-05 | 5.83E-04 |
| 9.92 | 2.0 | 120 | 1.5 | 1.95E-05 | 5.94E-04 | 1.92E-05 | 5.86E-04 |
| 9.42 | 3.0 | 180 | 1.0 | 1.68E-05 | 5.13E-04 | 1.84E-05 | 5.61E-04 |
| 9.15 | 4.0 | 240 | 0.7 | 1.32E-05 | 4.02E-04 | 1.71E-05 | 5.21E-04 |
| 9.04 | 5.0 | 300 | 0.6 | 6.92E-06 | 2.11E-04 | 1.51E-05 | 4.59E-04 |
| 8.92 | 6.0 | 360 | 0.5 | 9.20E-06 | 2.80E-04 | 1.41E-05 | 4.30E-04 |
| 8.86 | 7.0 | 420 | 0.4 | 5.52E-06 | 1.68E-04 | 1.29E-05 | 3.92E-04 |
| 8.79 | 8.0 | 480 | 0.3 | 7.57E-06 | 2.31E-04 | 1.22E-05 | 3.72E-04 |
| 8.73 | 9.0 | 540 | 0.3 | 7.85E-06 | 2.39E-04 | 1.17E-05 | 3.57E-04 |
| 8.69 | 10.0 | 600 | 0.2 | 6.24E-06 | 1.90E-04 | 1.12E-05 | 3.41E-04 |
| 8.63 | 11.0 | 660 | 0.2 | 1.16E-05 | 3.55E-04 | 1.12E-05 | 3.42E-04 |
| | | | | | | | |
| **Estimated Permeability** | | | | **1.7E-04** | **to** | **6.7E-04** | **(cm/sec)** |
| **Geometric Mean of Incremental Permeability** | | | | | **3.4.E-04** | **(cm/sec)** | |

(1) Calculations above the water table are from USBR, Engineering Geology Field Manual, Volume 2, pp 162-165.
Calculations below the water table are from Hvorslev printed in Lambe & Whitman, Soil Mechanics, 1969, pp 285, case G.

# APPENDIX F

# FIELD INVEST WATER LEVEL DATA

18115 Hogchute Dam Safety Evaluation
Field Investigation Water Levels

| | B-101(P) | B-102A(P) | B-103(P) | B-104(P) | B-105A(P) | B-105B(P) | Reservoir Level |
|---|---|---|---|---|---|---|---|
| **Top of Casing or PVC Riser Elevation (ft)** | **Same as ground** | **Same as ground** | **Same as ground** | **9849.0** | **9868.5** | **9869.8** | |
| **Ground Elevation (ft)** | **9902.2 CAD survey elev** | **9902.1 CAD survey elev** | **9901.8 CAD survey elev** | **9846.1 CAD survey elev** | **9865.7 CAD survey elev** | **9866.9 CAD survey elev** | **9902.0 CAD survey elev** |

Note:

**1. B-101, B-102A, and B-103: depths are referenced from top of ground surface. B-104, B-105A, and B-105B: depths are referenced from top of pvc riser pipe.**

| | B-101(P) | | | B-102A(P) | | | B-103(P) | | | B-104(P) | | | B-105A(P) | | | B-105B(P) | | | Reservoir Level | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Depth[1]** | **El** | **Notes** | **Depth[1]** | **El** | **Notes** | **Depth[1]** | **El** | **Notes** | **Depth[1]** | **El** | **Notes** | **Depth[1]** | **El** | **Notes** | **Depth[1]** | **El** | **Notes** | **Depth[1]** | **El** | **Notes** |
| 7/23/2018 | | #N/A | | | #N/A | | 25.5 | 9876.3 | During drilling. Time: 1605, 80° mostly sunny. | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 7/24/2018 | | #N/A | | 41.5 | 9860.6 | During drilling. Time: 1425, 75° mostly sunny. | | #N/A | | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 7/24/2018 | | #N/A | | 35.3 | 9866.9 | During drilling, prior to K-1. Time: 1520, 75° mostly sunny. | | #N/A | | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 7/25/2018 | | #N/A | | | #N/A | | 21.7 | 9880.1 | In well, well developed 7/24/18. Time: 0845, 70° sunny. | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 7/26/2018 | 24.2 | 9878.0 | During drilling. Perched zone in embankment? Time: 0840, 65° mostly sunny. | | #N/A | | 22.5 | 9879.3 | Time: 0805, 65° mostly sunny. | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 7/26/2018 | 55.3 | 9846.9 | During drilling. Level in foundation. Time: 1405, 73° mostly sunny. | | #N/A | | | #N/A | | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 7/27/2018 | 38.3 | 9863.9 | During drilling. Time: 0803, 60° mostly sunny. | 33.6 | 9868.5 | In well, well developed 7/26/18. Time: 0813, 60° mostly sunny. | 22.6 | 9879.2 | Time: 0822, 60° mostly sunny. | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 7/28/2018 | 30.6 | 9871.7 | In well. Prior to developing well. Time: 0745, 55° partly cloudy. Well developed after measurement. | 33.6 | 9868.5 | Time: 0845, 70° mostly cloudy. | 22.6 | 9879.3 | Time: 0840, 65° mostly cloudy. | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 8/3/2018 | 34.2 | 9868.0 | ~60° | 32.9 | 9869.2 | ~60° | Dry | #N/A | ~60° | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 8/9/2018 | 34.2 | 9868.0 | Measured by SEO. | 32.9 | 9869.2 | Measured by SEO. | Dry | #N/A | Measured by SEO. | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 8/23/2018 | 27.7 | 9874.5 | Measured by City. | 33.6 | 9868.5 | Measured by City. | 22.5 | 9879.3 | Measured by City. | | #N/A | | | #N/A | | | #N/A | | 7.0 | 9895.0 | Reservoir elevation assumed ~ 7' below crest. |
| 9/6/2018 | 32.0 | 9870.2 | Measured by City. | 33.6 | 9868.5 | Measured by City. | 22.7 | 9879.1 | Measured by City. | | #N/A | | | #N/A | | | #N/A | | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |

| | B-101(P) | | | B-102A(P) | | | B-103(P) | | | B-104(P) | | | B-105A(P) | | | B-105B(P) | | | Reservoir Level | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Date | Depth(1) | El | Notes | Depth(1) | El | Notes | Depth(1) | El | Notes | Depth(1) | El | Notes | Depth(1) | El | Notes | Depth(1) | El | Notes | Depth(1) | El | Notes |
| 9/11/2018 | 36.9 | 9865.4 | Measured by City. | 35.2 | 9866.9 | Measured by City. | 22.5 | 9879.3 | Measured by City. | | #N/A | | | #N/A | | | #N/A | | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |
| 9/13/2018 | 37.6 | 9864.6 | Measured by City. | 36.4 | 9865.8 | Measured by City. | 22.6 | 9879.2 | Measured by City. | | #N/A | | | #N/A | | | #N/A | | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |
| 9/17/2018 | 38.6 | 9863.6 | Time: 1036, 65° mostly sunny. | 37.5 | 9864.6 | Time: 1042, 65° mostly sunny. | 22.6 | 9879.2 | Time: 1050, 65° mostly sunny. | | #N/A | | 4.8 | 9863.7 | During drilling. Time: 1345, 70° sunny. | | #N/A | | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |
| 9/18/2018 | 38.8 | 9863.4 | Time: 0655, 50° clear. Well pumped with submersible pump after reading. | 37.7 | 9864.4 | Time: 1732, 70° sunny. | 22.6 | 9879.2 | Measured by City. | | #N/A | | 9.2 | 9859.3 | In boring, measured prior to daily drilling. Time: 0740, 55° clear. | | #N/A | | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |
| 9/18/2018 | 39.7 | 9862.5 | Time: 1726, 70° sunny. Measured after well pumped this morning. Recharging. | | #N/A | | | #N/A | | | #N/A | | | #N/A | | | #N/A | | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |
| 9/19/2018 | 39.0 | 9863.2 | Time: 0724, 50° partly cloudy. | 37.8 | 9864.3 | Time: 0728, 50° partly cloudy. | 22.6 | 9879.2 | Time: 0732, 50° partly cloudy. | | #N/A | | 9.1 | 9859.5 | In boring, measured prior to daily activity. Time: 0755, 50° partly cloudy. | 8.2 | 9861.5 | During drilling. Time: 1120, 55° overcast. | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |
| 9/20/2018 | 39.1 | 9863.1 | Time: 0727, 50° clear. | 37.9 | 9864.2 | Time: 0731, 50° clear. | 22.6 | 9879.2 | Time: 0735, 50° clear. | 10.4 | 9838.6 | During drilling. Time: 0825, 50° clear. | 12.5 | 9856.0 | In well. Prior to develop well. Time: 1445, 60° sunny. Developed well after measurement. | 8.6 | 9861.2 | In well. Prior to develop well. Time: 1448, 60° sunny. Developed well after measurement. | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |
| 9/21/2018 | 39.0 | 9863.2 | Time: 0907, 50° sunny. | 38.0 | 9864.1 | Time: 0913, 50° sunny. | 22.6 | 9879.2 | Time: 0917, 50° sunny. | 8.9 | 9840.1 | In well. Prior to develop well. Time: 1315, 60° sunny. Developed well after measurement. | 12.6 | 9855.9 | Time: 0923, 50° sunny. | 8.3 | 9861.4 | Time: 0925, 50° sunny. | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |
| 9/22/2018 | 39.1 | 9863.1 | Time: 0704, 45° clear. | 38.2 | 9863.9 | Time: 0707, 45° clear. | 22.6 | 9879.2 | Time: 0711, 45° clear. | 8.5 | 9840.5 | Time: 0658, 45° clear. | 12.6 | 9855.9 | Time: 0652, 45° clear. | 8.4 | 9861.4 | Time: 0654, 45° clear. | 17.0 | 9885.0 | Reservoir elevation lowered 10' below normal, so ~ 17' below crest. |

## Jacquelyn Hagbery

**From:** Mark Mumby <mmumby@hrlcomp.com>
**Sent:** Monday, August 06, 2018 1:31 PM
**To:** Garrett Jackson
**Cc:** Jacquelyn Hagbery
**Subject:** Hogchute Dam Water Levels

Good afternoon Garrett,

Great news on the additional drilling. I did get the J-Plug installed on B 101.

I also collected a round of water levels which are as follows:

B-101 34.20 feet from TOC
B-102 32.94 feet From TOC
B-103 was dry.

I have us penciled in for the 17th of September

Regards

Mark

**Mark Mumby, RPG** | Drilling Program Manager
HRL Compliance Solutions, Inc.
2385 F 1/2 Road | Grand Junction, CO 81505
main 970.243.3271 Ex. 404 | mobile 970.260.1576
Web | vCard | Map | |

HRL COMPLIANCE SOLUTIONS

**Hogchute Dam (DAMID 420127) Monitoring Record**

Piezometers

| | | B-101(P) | | B-102(P) | | B-103(P) | | |
|---|---|---|---|---|---|---|---|---|
| | | TOC[1] Elev. | 151.00 | TOC[1] Elev. | 151.00 | TOC[1] Elev. | 151.00 | |
| Date | Res. Elev. | DTW[2] | Water Elev. | DTW[2] | Water Elev. | DTW[2] | Water Elev. | Comments |
| 7/28/2018 | 144.00 | -- | -- | -- | -- | 22.55 | 128.45 | Top of Casing not yet surveyed, used dam crest elev = 151. Reservoir elevation assumed ~ 7' below crest. |
| 8/3/2018 | 144.00 | 34.20 | 116.80 | 32.94 | 118.06 | dry (22) | -- | Top of Casing not yet surveyed, used dam crest elev = 151. Reservoir elevation assumed ~ 7' below crest. |
| 8/9/2018 | 144.00 | 34.16 | 116.84 | 32.87 | 118.13 | dry (22) | -- | Top of Casing not yet surveyed, used dam crest elev = 151. Reservoir elevation assumed ~ 7' below crest. |
| 8/23/2018 | 144.00 | 27.68 | 123.32 | 33.62 | 117.38 | 22.50 | 128.50 | Top of Casing not yet surveyed, used dam crest elev = 151. Reservoir elevation assumed ~ 7' below crest. |

Notes:
1 - TOC = Top of Casing elevation (to be surveyed by City)
2 - DTW = Depth to Water below TOC

# City of Grand Junction
# Carson Reservoir
# Piezometer Readings

| **Date** | 9/6/2018 | 9/11/2018 | 9/13/2018 | 9/18/2018 | 9/20/2018 | | | |
|---|---|---|---|---|---|---|---|---|
| **Recorder** | SC/CP | SC/CP | SC/CP | CP | CP | | | |
| **PZ-N** | 22.7 | 22.5 | 22.6 | 22.58 | 22.58 | | | |
| **PZ-M** | 33.6 | 35.2 | 36.35 | 37.71 | 38.01 | | | |
| **PZ-S** | 32 | 36.85 | 37.62 | 41.2--RJH pumped down | 39.02 | | | |
| **Toe Drain** | 5 gpm | 5 gpm | 4.25 gpm | | | | | |
| **Level** | 47.6 | 41.8 | 38.35 | 38.35 | 38.35 | | | |

| | | | | | |
|---|---|---|---|---|---|
| **AF** | 637 | 425 | 320 | 320 | 320 |

# APPENDIX G

## LABORATORY TESTING RESULTS

# Moisture Content and Density
# ASTM D2216 and D7263

ADVANCED TERRA TESTING

# Moisture and Density
# ASTM D 2216 and ASTM D 7263

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | LOCATION | -- |
| PROJECT NO. | 18115 | | |

| | |
|---|---|
| BORING NO. | B-101 |
| DEPTH | 30-31' |
| SAMPLE NO. | CA-11 |
| DATE SAMPLED | |
| DATE TESTED | 10/26/18 |
| TECHNICIAN | BDF |
| DESCRIPTION | |
| Mass of Wet Pan and Soil (g): | 262.24 |
| Mass of Dry Pan and Soil (g): | 230.30 |
| Mass of Pan (g): | 6.71 |
| Moisture (%): | **14.3** |
| Diameter (in): | 1.94 |
| Height (in): | 2.22 |
| Mass of Wet Soil and Ring (g): | 956.35 |
| Mass of Ring (g): | 740.98 |
| Wet Density (lbs/ft³): | **125.3** |
| Dry Density (lbs/ft³): | **109.6** |
| Wet Density (kg/m³): | **2007** |
| Dry Density (kg/m³): | **1756** |
| BORING NO. | |
| DEPTH | |
| SAMPLE NO. | |
| DATE SAMPLED | |
| DATE TESTED | |
| TECHNICIAN | |
| DESCRIPTION | |
| Mass of Wet Pan and Soil (g): | |
| Mass of Dry Pan and Soil (g): | |
| Mass of Pan (g): | |
| Moisture (%): | |
| Diameter (in): | |
| Height (in): | |
| Mass of Wet Soil and Ring (g): | |
| Mass of Ring (g): | |
| Wet Density (lbs/ft³): | |
| Dry Density (lbs/ft³): | |
| Wet Density (kg/m³): | |
| Dry Density (kg/m³): | |
| NOTES | Significant amount of filling required. |

| | | | |
|---|---|---|---|
| Data entry by: | CAL | Date: | 10/29/2018 |
| Checked by: | KMS | Date: | 10/29/18 |
| File name: | 2679130_Moisture and Density ASTM D7236_1.xls | | |

ADVANCED TERRA TESTING

# Moisture and Density
# ASTM D 2216 and ASTM D 7263

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | LOCATION | -- |
| PROJECT NO. | 18115 | | |

| | |
|---|---|
| BORING NO. | B-102A |
| DEPTH | 44-45' |
| SAMPLE NO. | CA-20 |
| DATE SAMPLED | 07/24/18 |
| DATE TESTED | 10/19/18 |
| TECHNICIAN | SKS |
| DESCRIPTION | |
| Mass of Wet Pan and Soil (g): | 75.44 |
| Mass of Dry Pan and Soil (g): | 61.76 |
| Mass of Pan (g): | 7.92 |
| Moisture (%): | **25.4** |
| Diameter (in): | 2.03 |
| Height (in): | 4.20 |
| Mass of Wet Soil and Ring (g): | 535.00 |
| Mass of Ring (g): | 108.80 |
| Wet Density (lbs/ft³): | **119.8** |
| Dry Density (lbs/ft³): | **95.6** |
| Wet Density (kg/m³): | **1920** |
| Dry Density (kg/m³): | **1531** |
| BORING NO. | |
| DEPTH | |
| SAMPLE NO. | |
| DATE SAMPLED | |
| DATE TESTED | |
| TECHNICIAN | |
| DESCRIPTION | |
| Mass of Wet Pan and Soil (g): | |
| Mass of Dry Pan and Soil (g): | |
| Mass of Pan (g): | |
| Moisture (%): | |
| Diameter (in): | |
| Height (in): | |
| Mass of Wet Soil and Ring (g): | |
| Mass of Ring (g): | |
| Wet Density (lbs/ft³): | |
| Dry Density (lbs/ft³): | |
| Wet Density (kg/m³): | |
| Dry Density (kg/m³): | |
| NOTES | |

| | | | |
|---|---|---|---|
| Data entry by: | SKS | Date: | 10/23/2018 |
| Checked by: | KMS | Date: | 10/24/18 |
| File name: | 2679130__Moisture and Density ASTM D7236_0.xls | | |

ADVANCED TERRA TESTING

# Moisture and Density
# ASTM D 2216 and ASTM D 7263

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | LOCATION | -- |
| PROJECT NO. | 18115 | | |

| | |
|---|---|
| BORING NO. | B-103 |
| DEPTH | 15-16' |
| SAMPLE NO. | CA-8 |
| DATE SAMPLED | |
| DATE TESTED | 10/26/18 |
| TECHNICIAN | BDF |
| DESCRIPTION | |
| Mass of Wet Pan and Soil (g): | 598.84 |
| Mass of Dry Pan and Soil (g): | 566.35 |
| Mass of Pan (g): | 266.20 |
| Moisture (%): | **10.8** |
| Diameter (in): | 1.94 |
| Height (in): | 2.50 |
| Mass of Wet Soil and Ring (g): | 648.18 |
| Mass of Ring (g): | 422.73 |
| Wet Density (lbs/ft³): | **116.5** |
| Dry Density (lbs/ft³): | **105.1** |
| Wet Density (kg/m³): | **1866** |
| Dry Density (kg/m³): | **1683** |
| BORING NO. | |
| DEPTH | |
| SAMPLE NO. | |
| DATE SAMPLED | |
| DATE TESTED | |
| TECHNICIAN | |
| DESCRIPTION | |
| Mass of Wet Pan and Soil (g): | |
| Mass of Dry Pan and Soil (g): | |
| Mass of Pan (g): | |
| Moisture (%): | |
| Diameter (in): | |
| Height (in): | |
| Mass of Wet Soil and Ring (g): | |
| Mass of Ring (g): | |
| Wet Density (lbs/ft³): | |
| Dry Density (lbs/ft³): | |
| Wet Density (kg/m³): | |
| Dry Density (kg/m³): | |
| NOTES | Filling required for density. |

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 10/30/2018 |
| Checked by: | KMS | Date: | 10/31/18 |
| File name: | 2679130__Moisture and Density ASTM D7236_2.xls | | |

# Atterberg Limits
# ASTM D4318

ADVANCED TERRA TESTING

# Atterberg Limits
## ASTM D 4318

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 25-40' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-13 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | SAMPLED BY | -- |
| DATE TESTED | 11/06/18 | DESCRIPTION | -- |
| TECHNICIAN | SPH | | |

### Plastic Limits

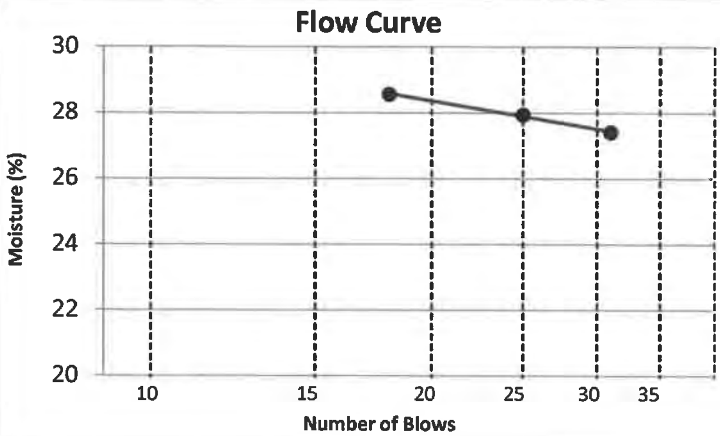
| | | |
|---|---|---|
| Mass of Wet Pan and Soil (g): | 9.93 | 9.90 |
| Mass of Dry Pan and Soil (g): | 8.68 | 8.65 |
| Mass of Pan (g): | 1.16 | 1.15 |
| Moisture (%) | **16.7** | **16.7** |

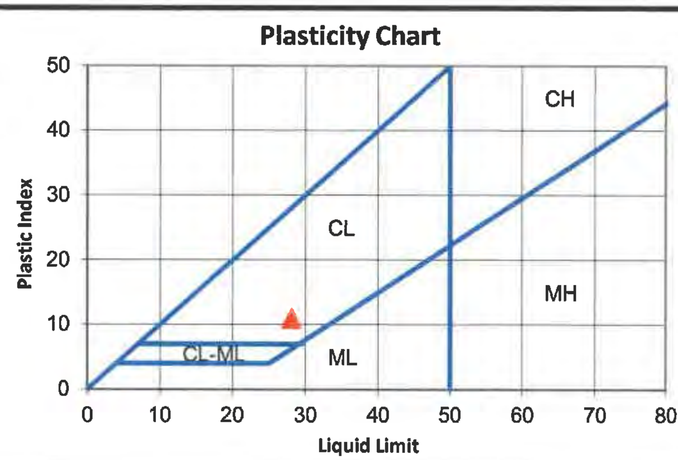
### Liquid Limits

| | | | |
|---|---|---|---|
| Number of Blows | 18 | 25 | 31 |
| Mass of Wet Pan and Soil (g): | 8.94 | 9.50 | 9.99 |
| Mass of Dry Pan and Soil (g): | 7.21 | 7.68 | 8.10 |
| Mass of Pan (g): | 1.13 | 1.14 | 1.18 |
| Moisture (%) | **28.6** | **27.9** | **27.4** |

### Plastic Index

| | | | |
|---|---|---|---|
| Plastic Limit: | **17** | Atterberg Classification: | CL |
| Liquid Limit: | **28** | Method: | A |
| Plastic Index: | **11** | | |




NOTES

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 11/7/2018 |
| Checked by: | KMS | Date: | 11/8/18 |
| File name: | 2679130__Atterberg ASTM D4318_1.xlsm | | |

ADVANCED TERRA TESTING

# Atterberg Limits
## ASTM D 4318

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 51-65' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-20 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | SAMPLED BY | -- |
| DATE TESTED | 11/07/18 | DESCRIPTION | -- |
| TECHNICIAN | AD | | |

**Plastic Limits**

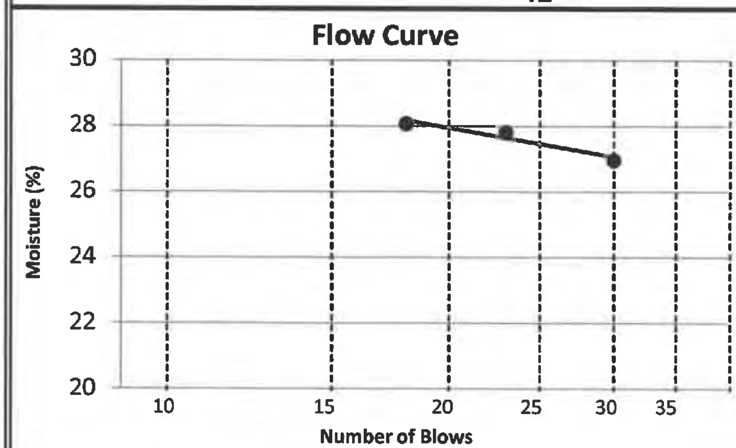
| | | |
|---|---|---|
| Mass of Wet Pan and Soil (g): | 7.61 | 7.53 |
| Mass of Dry Pan and Soil (g): | 6.77 | 6.71 |
| Mass of Pan (g): | 1.09 | 1.11 |
| Moisture (%) | **14.9** | **14.8** |

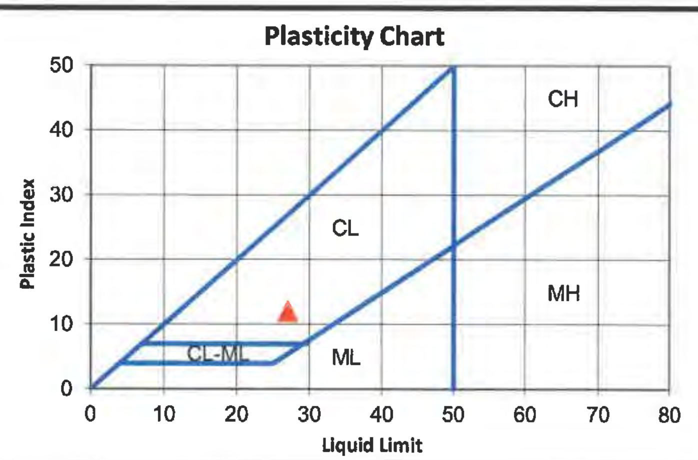
**Liquid Limits**

| | | | |
|---|---|---|---|
| Number of Blows | 18 | 23 | 30 |
| Mass of Wet Pan and Soil (g): | 11.55 | 10.96 | 11.78 |
| Mass of Dry Pan and Soil (g): | 9.27 | 8.83 | 9.52 |
| Mass of Pan (g): | 1.14 | 1.14 | 1.13 |
| Moisture (%) | **28.1** | **27.8** | **27.0** |

**Plastic Index**

| | | | |
|---|---|---|---|
| Plastic Limit: | **15** | Atterberg Classification: | CL |
| Liquid Limit: | **27** | Method: | A |
| Plastic Index: | **12** | | |




NOTES

| | | | |
|---|---|---|---|
| Data entry by: | KMS | Date: | 11/8/2018 |
| Checked by: | KR | Date: | 11/8/18 |
| File name: | 2679130__Atterberg ASTM D4318_4.xlsm | | |

ADVANCED TERRA TESTING

# Atterberg Limits
## ASTM D 4318

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-102A |
| JOB NO. | 2679-130 | DEPTH | 18-41.5' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-10 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | SAMPLED BY | -- |
| DATE TESTED | 11/05/18 | DESCRIPTION | -- |
| TECHNICIAN | SPH | | |

### Plastic Limits

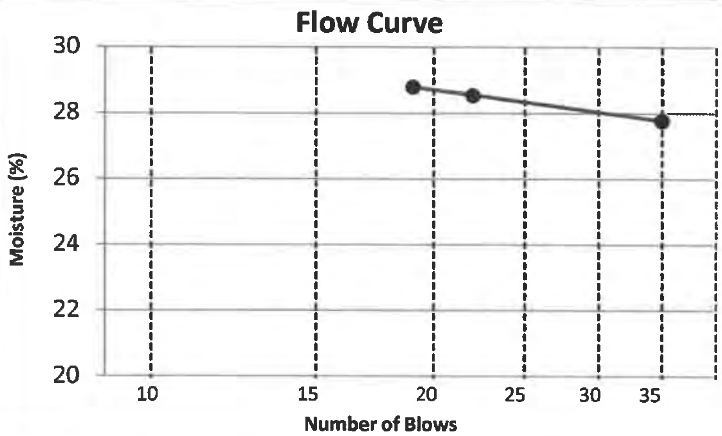
| | | |
|---|---|---|
| Mass of Wet Pan and Soil (g): | 9.17 | 9.20 |
| Mass of Dry Pan and Soil (g): | 8.02 | 8.03 |
| Mass of Pan (g): | 1.17 | 1.07 |
| Moisture (%) | **16.7** | **16.7** |

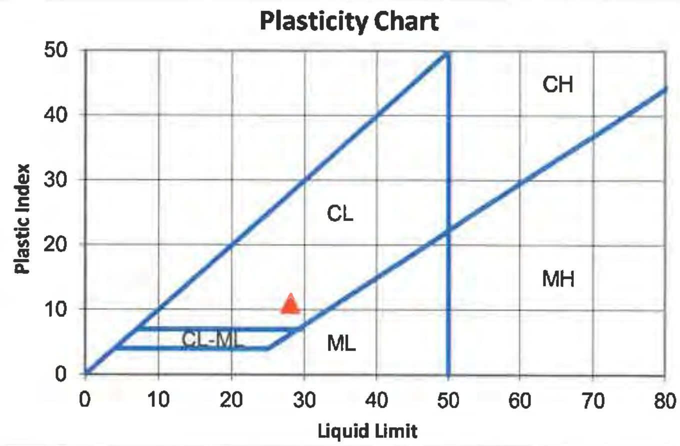
### Liquid Limits

| | | | |
|---|---|---|---|
| Number of Blows | 19 | 22 | 35 |
| Mass of Wet Pan and Soil (g): | 13.22 | 14.23 | 13.44 |
| Mass of Dry Pan and Soil (g): | 10.51 | 11.32 | 10.76 |
| Mass of Pan (g): | 1.12 | 1.14 | 1.10 |
| Moisture (%) | **28.8** | **28.5** | **27.8** |

### Plastic Index

| | | | |
|---|---|---|---|
| Plastic Limit: | **17** | Atterberg Classification: | CL |
| Liquid Limit: | **28** | Method: | A |
| Plastic Index: | **11** | | |




NOTES

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 11/7/2018 |
| Checked by: | KMS | Date: | 11/7/18 |
| File name: | 2679130__Atterberg ASTM D4318_2.xlsm | | |

# Atterberg Limits
# ASTM D 4318

ADVANCED TERRA TESTING

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 10-17.5' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-11 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | SAMPLED BY | -- |
| DATE TESTED | 11/07/18 | DESCRIPTION | -- |
| TECHNICIAN | CAL | | |

## Plastic Limits

| | | |
|---|---|---|
| Mass of Wet Pan and Soil (g): | 9.35 | 8.35 |
| Mass of Dry Pan and Soil (g): | 8.24 | 7.38 |
| Mass of Pan (g): | 1.15 | 1.13 |
| Moisture (%) | **15.7** | **15.6** |

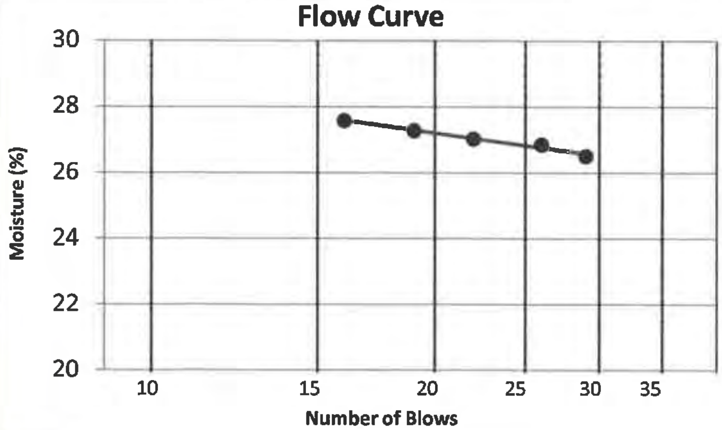
## Liquid Limits

| | | | | | |
|---|---|---|---|---|---|
| Number of Blows | 16 | 19 | 22 | 26 | 29 |
| Mass of Wet Pan and Soil (g): | 10.62 | 10.48 | 9.39 | 11.05 | 10.09 |
| Mass of Dry Pan and Soil (g): | 8.57 | 8.48 | 7.63 | 8.96 | 8.22 |
| Mass of Pan (g): | 1.14 | 1.18 | 1.15 | 1.15 | 1.14 |
| Moisture (%) | **27.6** | **27.3** | **27.0** | **26.9** | **26.5** |

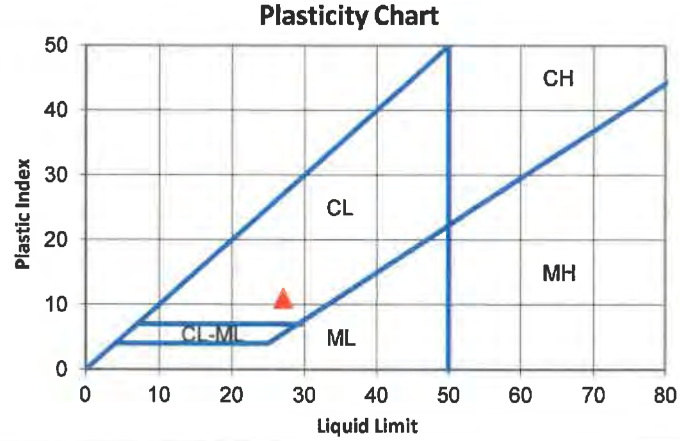
## Plastic Index

| | | | |
|---|---|---|---|
| Plastic Limit: | **16** | Atterberg Classification: | CL |
| Liquid Limit: | **27** | Method: | A |
| Plastic Index: | **11** | | |

**Flow Curve**




**Plasticity Chart**




NOTES

| | | | |
|---|---|---|---|
| Data entry by: | CAL | Date: | 11/8/2018 |
| Checked by: | KMS | Date: | 11/8/18 |
| File name: | 2679130__Atterberg ASTM D4318_3.xlsm | | |

ADVANCED TERRA TESTING

# Atterberg Limits
## ASTM D 4318

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | SAMPLED BY | -- |
| DATE TESTED | 10/25/18 | DESCRIPTION | -- |
| TECHNICIAN | KJT | | |

**Plastic Limits**

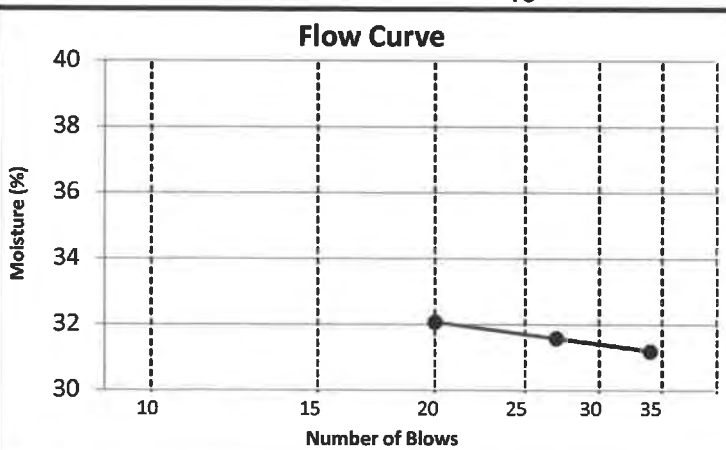
| | | |
|---|---|---|
| Mass of Wet Pan and Soil (g): | 7.69 | 7.79 |
| Mass of Dry Pan and Soil (g): | 6.64 | 6.74 |
| Mass of Pan (g): | 1.13 | 1.15 |
| Moisture (%) | **19.0** | **18.7** |

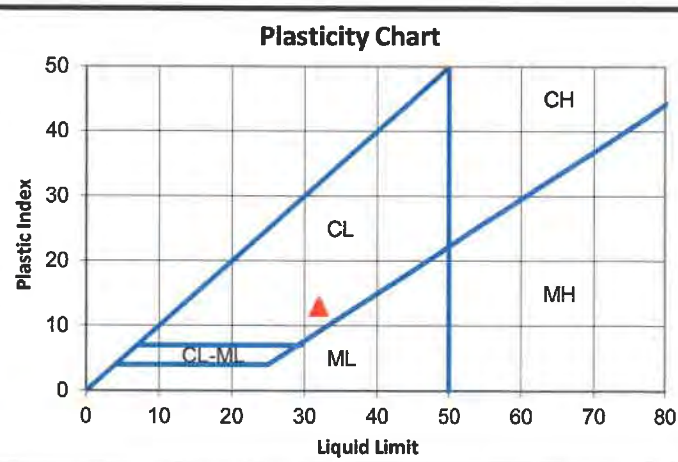
**Liquid Limits**

| | | | |
|---|---|---|---|
| Number of Blows | 20 | 27 | 34 |
| Mass of Wet Pan and Soil (g): | 10.64 | 11.64 | 10.28 |
| Mass of Dry Pan and Soil (g): | 8.32 | 9.12 | 8.09 |
| Mass of Pan (g): | 1.08 | 1.11 | 1.09 |
| Moisture (%) | **32.1** | **31.6** | **31.2** |

**Plastic Index**

| | | | |
|---|---|---|---|
| Plastic Limit: | 19 | Atterberg Classification: | CL |
| Liquid Limit: | 32 | Method: | A |
| Plastic Index: | 13 | | |




NOTES

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 10/26/2018 |
| Checked by: | CKL | Date: | 10/26/18 |
| File name: | 2679130__Atterberg ASTM D4318_0.xlsm | | |

# Grain Size Analysis
# ASTM D6913

# Grain Size Analysis
# ASTM D 6913

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 25-40' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-13 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 11/01/18 | | |
| TECHNICIAN | AD | | |

**Hygroscopic Moisture of Fines**

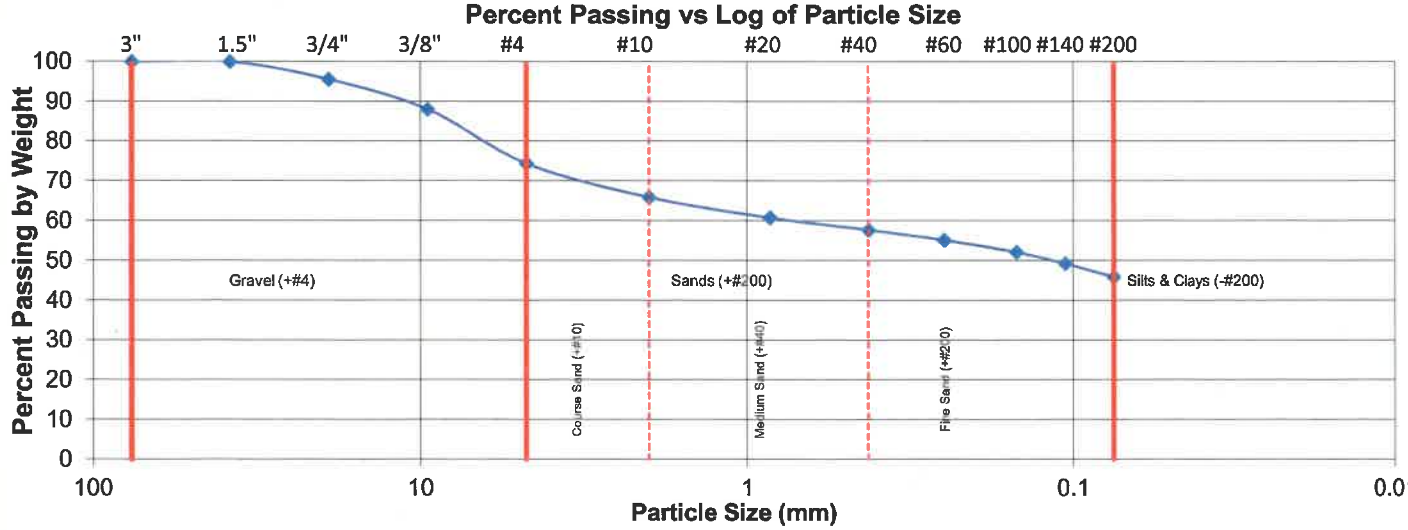
Mass Wet Pan and Soil (g): 1409.38
Mass Dry Pan and Soil (g): 1399.33
Mass of Pan (g): 782.51
Moisture (%): **1.6**

**Sample Data**

Total Wet Mass of Sample (g): 23501.7
Total Dry Mass of Sample (g): 23169.2
Split Fraction: 3/8"
Mass of Sub-Sample Fraction (g): 626.87

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **3"** | 76.2 | -- | -- | -- | -- | **--** |
| **1.5"** | 38.1 | 0.0 | -- | -- | -- | **100%** |
| **3/4"** | 19.05 | 1014.6 | -- | 1014.6 | 1.00 | **95.6** |
| **3/8"** | 9.53 | 1748.4 | -- | 1748.4 | 1.00 | **88.1** |
| **#4** | 4.75 | 95.3 | -- | 95.3 | 0.88 | **74.5** |
| **#10** | 2.00 | 59.5 | -- | 59.5 | 0.88 | **66.0** |
| **#20** | 0.850 | 36.0 | -- | 36.0 | 0.88 | **60.8** |
| **#40** | 0.425 | 21.7 | -- | 21.7 | 0.88 | **57.7** |
| **#60** | 0.250 | 17.9 | -- | 17.9 | 0.88 | **55.2** |
| **#100** | 0.150 | 21.1 | -- | 21.1 | 0.88 | **52.2** |
| **#140** | 0.106 | 20.1 | -- | 20.1 | 0.88 | **49.3** |
| **#200** | 0.075 | 23.6 | -- | 23.6 | 0.88 | **45.9** |

**Percent Passing vs Log of Particle Size**




**USCS Classification ASTM D 2487**

Atterberg Classification: CL
Group Symbol: SC
USCS Classification: Clayey Sand With Gravel
Coefficient of Curvature - $C_c$: --
Coefficient of Uniformity - $C_u$: --

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 11/7/2018 |
| Checked by: | KMS | Date: | 11/7/18 |
| File name: | 2679130__Grain Size Analysis ASTM D6913_2.xlsm | | |

ADVANCED TERRA TESTING

# Grain Size Analysis
## ASTM D 6913

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-102A |
| JOB NO. | 2679-130 | DEPTH | 18-41.5' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-10 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 11/05/18 | | |
| TECHNICIAN | AD | | |

**Hygroscopic Moisture of Fines**

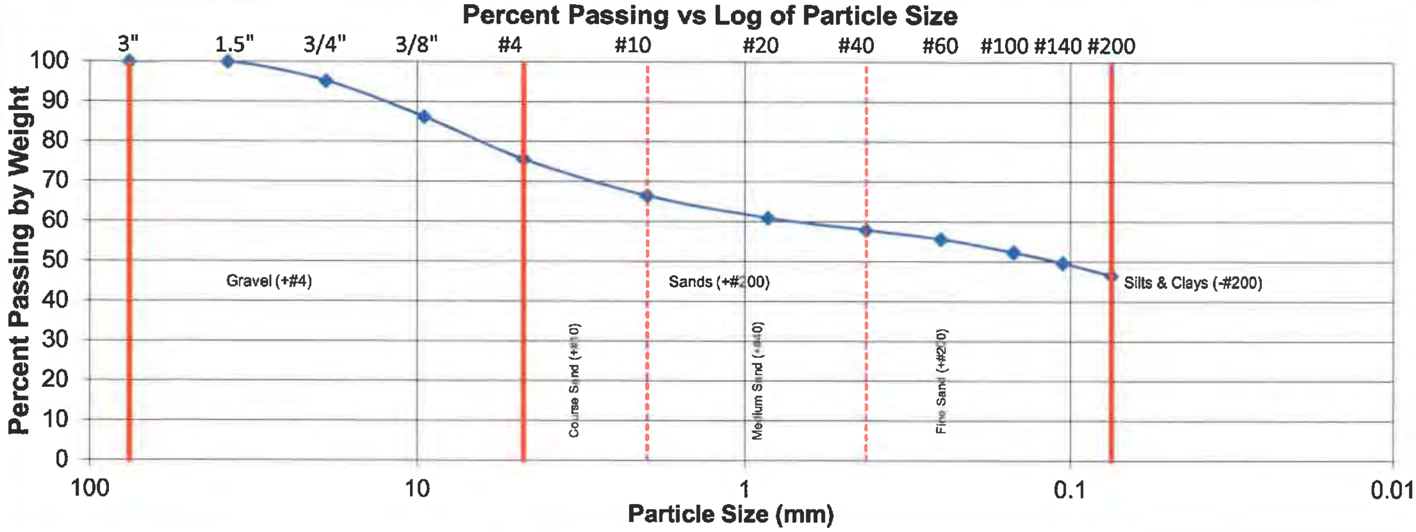
Mass Wet Pan and Soil (g): 1809.96
Mass Dry Pan and Soil (g): 1794.70
Mass of Pan (g): 843.18
Moisture (%): **1.6**

**Sample Data**

Total Wet Mass of Sample (g): 24771.5
Total Dry Mass of Sample (g): 24433.6
Split Fraction: 3/8"
Mass of Sub-Sample Fraction (g): 966.78

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **3"** | 76.2 | -- | -- | -- | -- | **--** |
| **1.5"** | 38.1 | 0.0 | -- | -- | -- | **100%** |
| **3/4"** | 19.05 | 1165.8 | -- | 1165.8 | 1.00 | **95.2** |
| **3/8"** | 9.53 | 2201.0 | -- | 2201.0 | 1.00 | **86.2** |
| **#4** | 4.75 | 116.4 | -- | 116.4 | 0.86 | **75.7** |
| **#10** | 2.00 | 100.5 | -- | 100.5 | 0.86 | **66.6** |
| **#20** | 0.850 | 61.0 | -- | 61.0 | 0.86 | **61.0** |
| **#40** | 0.425 | 33.7 | -- | 33.7 | 0.86 | **58.0** |
| **#60** | 0.250 | 24.9 | -- | 24.9 | 0.86 | **55.7** |
| **#100** | 0.150 | 36.7 | -- | 36.7 | 0.86 | **52.4** |
| **#140** | 0.106 | 29.3 | -- | 29.3 | 0.86 | **49.7** |
| **#200** | 0.075 | 35.2 | -- | 35.2 | 0.86 | **46.6** |

**Percent Passing vs Log of Particle Size**




**USCS Classification ASTM D 2487**

Atterberg Classification: CL
Group Symbol: SC
USCS Classification: Clayey Sand With Gravel

Coefficient of Curvature - $C_c$: --
Coefficient of Uniformity - $C_u$: --

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 11/7/2018 |
| Checked by: | KMS | Date: | 11/7/18 |
| File name: | 2679130__Grain Size Analysis ASTM D6913_3.xlsm | | |

# Grain Size Analysis
# ASTM D 6913

ADVANCED TERRA TESTING

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 27.5-29.9 |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | u-14 |
| PROJECT NO. | 18115 | DATE SAMPLED | 07/23/18 |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/30/18 | | |
| TECHNICIAN | KJT | | |

**Hygroscopic Moisture of Fines**

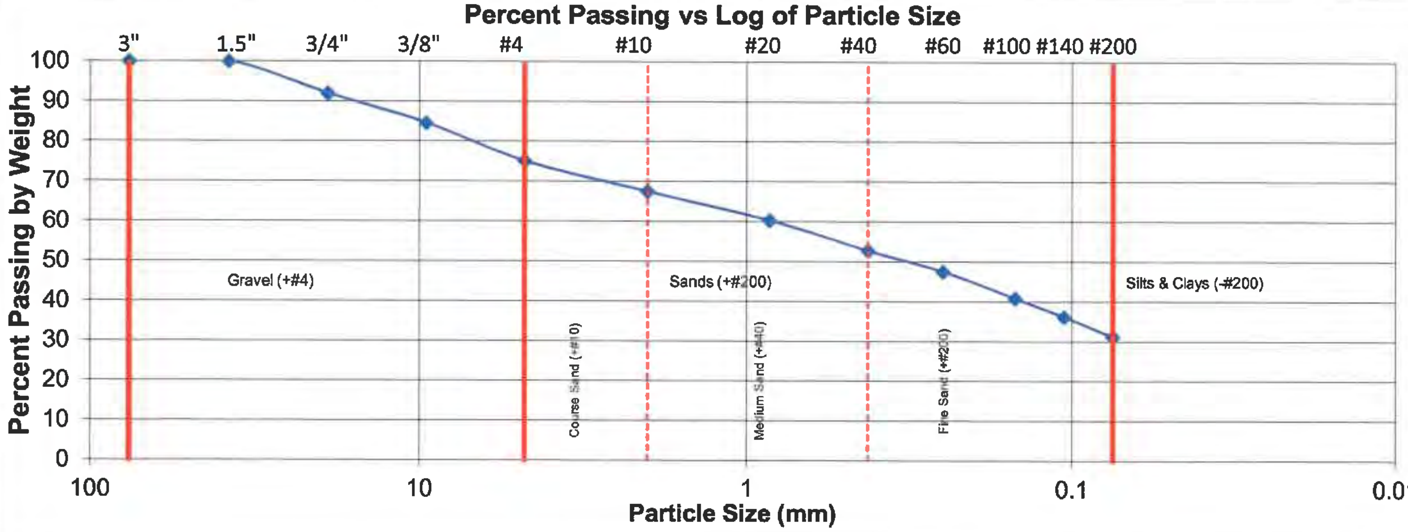
Mass Wet Pan and Soil (g): 1325.03
Mass Dry Pan and Soil (g): 1317.04
Mass of Pan (g): 811.12
Moisture (%): **1.6**

**Sample Data**

Total Wet Mass of Sample (g): 687.1
Total Dry Mass of Sample (g): 679.0
Split Fraction: #4
Mass of Sub-Sample Fraction (g): 513.86

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **3"** | 76.2 | -- | -- | -- | -- | **--** |
| **1.5"** | 38.1 | 0.0 | -- | -- | -- | **100%** |
| **3/4"** | 19.05 | 53.9 | -- | 53.9 | 1.00 | **92.1** |
| **3/8"** | 9.53 | 50.2 | -- | 50.2 | 1.00 | **84.7** |
| **#4** | 4.75 | 64.3 | -- | 64.3 | 1.00 | **75.2** |
| **#10** | 2.00 | 51.4 | -- | 51.4 | 0.75 | **67.6** |
| **#20** | 0.850 | 48.6 | -- | 48.6 | 0.75 | **60.3** |
| **#40** | 0.425 | 50.7 | -- | 50.7 | 0.75 | **52.8** |
| **#60** | 0.250 | 35.2 | -- | 35.2 | 0.75 | **47.6** |
| **#100** | 0.150 | 44.8 | -- | 44.8 | 0.75 | **40.9** |
| **#140** | 0.106 | 31.1 | -- | 31.1 | 0.75 | **36.3** |
| **#200** | 0.075 | 33.7 | -- | 33.7 | 0.75 | **31.3** |

**Percent Passing vs Log of Particle Size**




**USCS Classification ASTM D 2487**

Atterberg Classification: --
Group Symbol: --
USCS Classification: --

Coefficient of Curvature - $C_c$: --
Coefficient of Uniformity - $C_u$: --

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 11/5/2018 |
| Checked by: | CAL | Date: | 11/5/18 |
| File name: | 2679130__Grain Size Analysis ASTM D6913_1.xlsm | | |

ADVANCED TERRA TESTING

# Grain Size Analysis
# ASTM D 6913

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32.0-33.0 |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 09/20/18 |
| LOCATION | -- | DESCRIPTION | Lean Clay w/ Sand |
| DATE TESTED | 10/19/18 | | |
| TECHNICIAN | CAL | | |

**Hygroscopic Moisture**

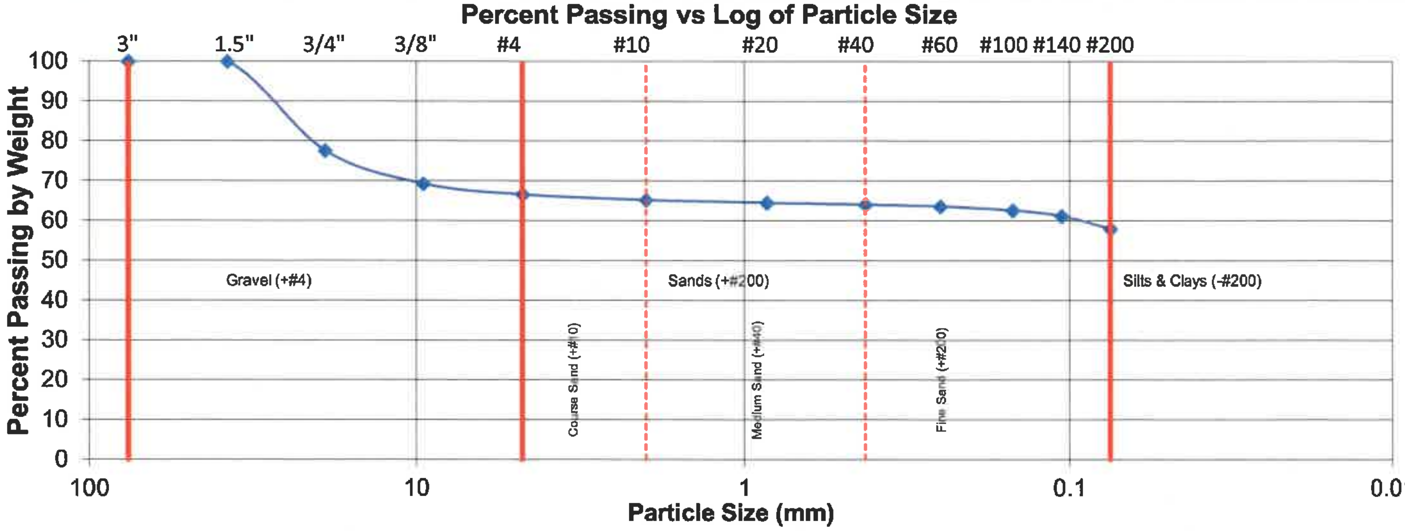
Mass Wet Pan and Soil (g): 531.36
Mass Dry Pan and Soil (g): 466.78
Mass of Pan (g): 139.65
Moisture (%): **19.7**

**Sample Data**

Total Wet Mass of Sample (g): 391.7
Total Dry Mass of Sample (g): 327.1

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **3"** | 76.2 | -- | -- | -- | -- | **--** |
| **1.5"** | 38.1 | -- | -- | -- | -- | **--** |
| **3/4"** | 19.05 | 73.1 | -- | 73.1 | 1.00 | **77.6** |
| **3/8"** | 9.53 | 27.1 | -- | 27.1 | 1.00 | **69.4** |
| **#4** | 4.75 | 9.0 | -- | 9.0 | 1.00 | **66.6** |
| **#10** | 2.00 | 4.4 | -- | 4.4 | 1.00 | **65.2** |
| **#20** | 0.850 | 2.2 | -- | 2.2 | 1.00 | **64.6** |
| **#40** | 0.425 | 1.5 | -- | 1.5 | 1.00 | **64.1** |
| **#60** | 0.250 | 1.4 | -- | 1.4 | 1.00 | **63.7** |
| **#100** | 0.150 | 3.3 | -- | 3.3 | 1.00 | **62.7** |
| **#140** | 0.106 | 4.6 | -- | 4.6 | 1.00 | **61.3** |
| **#200** | 0.075 | 10.5 | -- | 10.5 | 1.00 | **58.1** |

**Percent Passing vs Log of Particle Size**




**USCS Classification ASTM D 2487**

Atterberg Classification: CL
Group Symbol: CL
USCS Classification: Gravelly Lean Clay

Coefficient of Curvature - $C_c$: --
Coefficient of Uniformity - $C_u$: --

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 10/26/2018 |
| Checked by: | CAL | Date: | 10/26/18 |
| File name: | 2679130__Grain Size Analysis ASTM D6913_0.xlsm | | |

# Grain Size Analysis with Hydrometer
# ASTM D6913 and D7928

ADVANCED TERRA TESTING

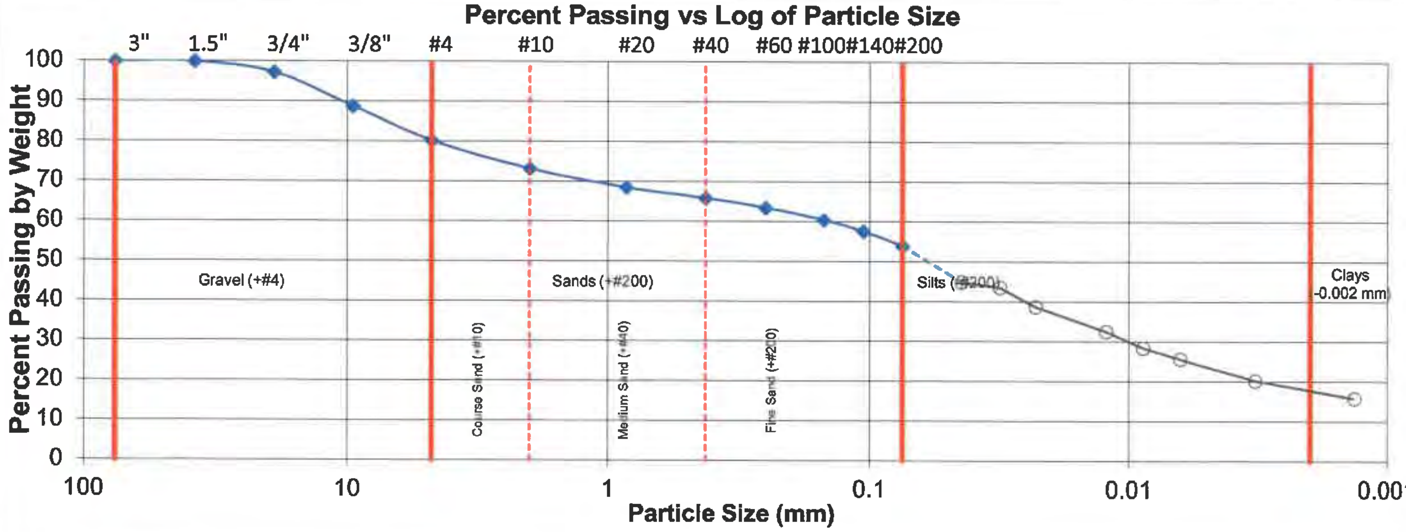
# Grain Size Analysis with Hydrometer
# ASTM D 6913 And D 7928

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 51-65' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-20 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 11/07/18 | | |
| TECHNICIAN | BDF | | |

| **Hygroscopic Moisture of Fines** | | **Sample Data** | | |
|---|---|---|---|---|
| Mass Wet Pan and Soil (g): | 116.73 | Total Wet Mass of Sample (g): | 19133.2 | |
| Mass Dry Pan and Soil (g): | 114.50 | Total Dry Mass of Sample (g): | 18857.9 | |
| Mass of Pan (g): | 3.16 | Split Fraction: | #10 | 3/8" |
| Moisture (%): | **2.0** | Mass of Sub-Sample Fraction (g): | 60.91 | 1123.80 |

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **3"** | 76.2 | 0.0 | -- | -- | -- | -- |
| **1.5"** | 38.1 | 0.0 | -- | -- | -- | -- |
| **3/4"** | 19.05 | 507.2 | -- | 507.2 | 1.00 | **97.3** |
| **3/8"** | 9.53 | 1605.3 | -- | 1605.3 | 1.00 | **88.8** |
| **#4** | 4.75 | 106.8 | -- | 106.8 | 0.89 | **80.2** |
| **#10** | 2.00 | 87.4 | -- | 87.39 | 0.888 | **73.2** |
| **#20** | 0.850 | 3.8 | -- | 3.80 | 0.731 | **68.5** |
| **#40** | 0.425 | 2.2 | -- | 2.15 | 0.731 | **65.9** |
| **#60** | 0.250 | 2.0 | -- | 1.95 | 0.731 | **63.5** |
| **#100** | 0.150 | 2.5 | -- | 2.50 | 0.731 | **60.5** |
| **#140** | 0.106 | 2.3 | -- | 2.31 | 0.731 | **57.6** |
| **#200** | 0.075 | 3.0 | -- | 2.98 | 0.731 | **54.0** |

**Percent Passing vs Log of Particle Size**




**USCS Classification ASTM D 2487**

| | | | |
|---|---|---|---|
| Atterberg Classification: | CL | Coefficient of Curvature - $C_c$: | -- |
| Group Symbol: | CL | Coefficient of Uniformity - $C_u$: | -- |
| USCS Classification: | Sandy Lean Clay With Gravel | | |

| | | | |
|---|---|---|---|
| Data entry by: | KMS | Date: | 11/8/2018 |
| Checked by: | KR | Date: | 11/8/18 |
| File name: | 2679130__Grain Size with Hydrometer ASTM D6913 D7928_0.xlsm | | |

ADVANCED TERRA TESTING

# Grain Size Analysis with Hydrometer
## ASTM D 6913 And D 7928

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 51-65' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-20 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 11/07/18 | | |
| TECHNICIAN | BDF | | |

**Hydrometer and Flask Parameters**

| | | | |
|---|---|---|---|
| Hydrometer ID: | 0805 | Flask ID: | 1186 |
| Average Mass Offset (g/L): | 9.87 | Flask Volume ($cm^3$): | 996.8 |
| Hydrometer Bulb Volume ($cm^3$): | 56.50 | Flask Surface Area ($cm^2$): | 28.60 |
| Meniscus Correction (g/L): | 1.00 | Assumed Specific Gravity | 2.65 |
| $H_b$ (cm): | 24.5 | Hydrometer Type: | 152H |
| $H_{cb}$ (cm): | 6.8 | | |
| $H_s$ (cm): | 8.2 | Percent Finer by Mass at 2 μm: | **17.3** |

**Hydrometer Data**

| Elapsed Time (minutes) | Hydrometer Reading (g/L) | Offset Reading (g/L) | Temperature (°C) | Effective Depth (cm) | Maximum Particle Diameter in Suspension (mm) | Percent Finer by Mass (%) |
|---|---|---|---|---|---|---|
| 1 | 38.00 | 5.34 | 23.1 | 10.62 | 0.044 | **44.9** |
| 2 | 37.00 | 5.34 | 23.1 | 10.79 | 0.032 | **43.5** |
| 4 | 33.50 | 5.34 | 23.1 | 11.36 | 0.023 | **38.7** |
| 15 | 29.00 | 5.34 | 23.1 | 12.10 | 0.012 | **32.5** |
| 30 | 26.00 | 5.34 | 23.1 | 12.60 | 0.009 | **28.4** |
| 60 | 24.00 | 5.34 | 23.1 | 12.93 | 0.006 | **25.7** |
| 240 | 20.00 | 5.30 | 23.2 | 13.58 | 0.003 | **20.2** |
| 1440 | 17.00 | 5.53 | 22.6 | 14.08 | 0.001 | **15.8** |

NOTES:

File name: 2679130__Grain Size with Hydrometer ASTM D6913 D7928_0.xlsm

Page 2 of 2

ADVANCED TERRA TESTING

# Grain Size Analysis with Hydrometer
## ASTM D 6913 And D 7928

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 10-17.5' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-11 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 11/07/18 | | |
| TECHNICIAN | BDF | | |

**Hygroscopic Moisture of Fines**

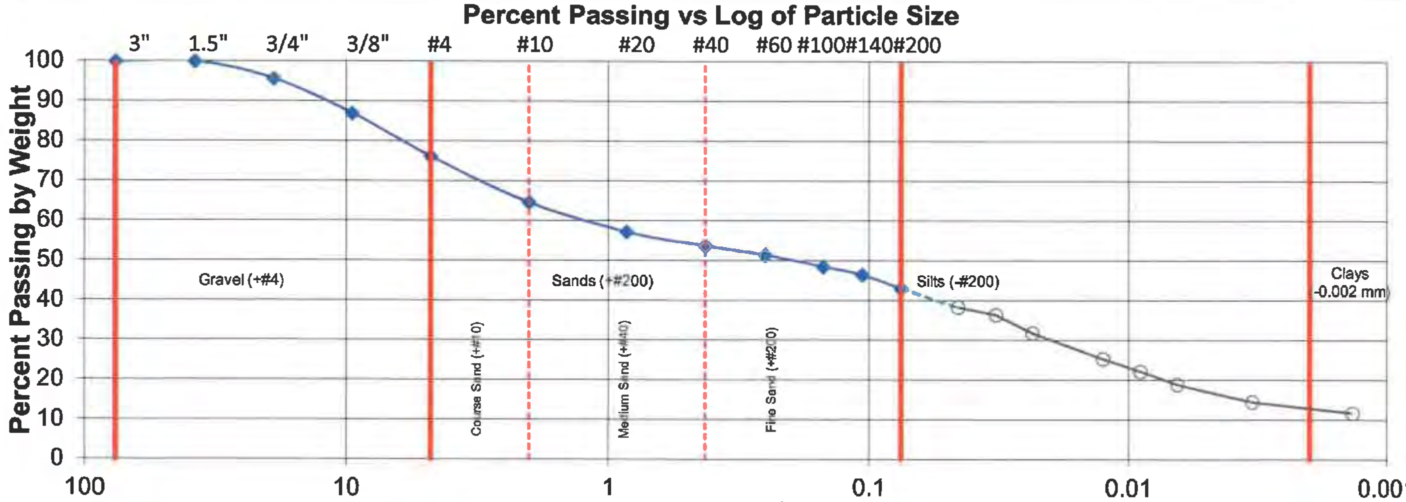
| | |
|---|---|
| Mass Wet Pan and Soil (g): | 121.30 |
| Mass Dry Pan and Soil (g): | 119.10 |
| Mass of Pan (g): | 3.15 |
| Moisture (%): | **1.9** |

**Sample Data**

| | | |
|---|---|---|
| Total Wet Mass of Sample (g): | 26704.1 | |
| Total Dry Mass of Sample (g): | 26381.7 | |
| Split Fraction: | #10 | 3/8" |
| Mass of Sub-Sample Fraction (g): | 57.98 | 1427.90 |

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **3"** | 76.2 | 0.0 | -- | -- | -- | **--** |
| **1.5"** | 38.1 | 0.0 | -- | -- | -- | **--** |
| **3/4"** | 19.05 | 1138.5 | -- | 1138.5 | 1.00 | **95.7** |
| **3/8"** | 9.53 | 2287.5 | -- | 2287.5 | 1.00 | **87.0** |
| **#4** | 4.75 | 175.9 | -- | 175.9 | 0.87 | **76.1** |
| **#10** | 2.00 | 186.6 | -- | 186.55 | 0.870 | **64.6** |
| **#20** | 0.850 | 6.5 | -- | 6.52 | 0.646 | **57.2** |
| **#40** | 0.425 | 3.1 | -- | 3.12 | 0.646 | **53.7** |
| **#60** | 0.250 | 2.0 | -- | 2.00 | 0.646 | **51.4** |
| **#100** | 0.150 | 2.5 | -- | 2.52 | 0.646 | **48.6** |
| **#140** | 0.106 | 1.8 | -- | 1.83 | 0.646 | **46.5** |
| **#200** | 0.075 | 3.1 | -- | 3.05 | 0.646 | **43.0** |

**Percent Passing vs Log of Particle Size**




**USCS Classification ASTM D 2487**

| | | | |
|---|---|---|---|
| Atterberg Classification: | CL | Coefficient of Curvature - $C_c$: | -- |
| Group Symbol: | SC | Coefficient of Uniformity - $C_u$: | -- |
| USCS Classification: | Clayey Sand With Gravel | | |

| | | | |
|---|---|---|---|
| Data entry by: | KMS | Date: | 11/8/2018 |
| Checked by: | KP | Date: | 11/8/18 |
| File name: | 2679130__Grain Size with Hydrometer ASTM D6913 D7928_1.xlsm | | |

ADVANCED TERRA TESTING

# Grain Size Analysis with Hydrometer
## ASTM D 6913 And D 7928

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 10-17.5' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-11 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 11/07/18 | | |
| TECHNICIAN | BDF | | |

**Hydrometer and Flask Parameters**

| | | | |
|---|---|---|---|
| Hydrometer ID: | 0805 | Flask ID: | 1185 |
| Average Mass Offset (g/L): | 9.87 | Flask Volume ($cm^3$): | 995.9 |
| Hydrometer Bulb Volume ($cm^3$): | 56.50 | Flask Surface Area ($cm^2$): | 28.45 |
| Meniscus Correction (g/L): | 1.00 | Assumed Specific Gravity | 2.65 |
| $H_b$ (cm): | 24.5 | Hydrometer Type: | 152H |
| $H_{cb}$ (cm): | 6.8 | | |
| $H_s$ (cm): | 8.2 | Percent Finer by Mass at 2 μm: | **12.6** |

**Hydrometer Data**

| Elapsed Time (minutes) | Hydrometer Reading (g/L) | Offset Reading (g/L) | Temperature (°c) | Effective Depth (cm) | Maximum Particle Diameter in Suspension (mm) | Percent Finer by Mass (%) |
|---|---|---|---|---|---|---|
| 1 | 35.00 | 5.49 | 22.7 | 11.11 | 0.045 | **38.3** |
| 2 | 33.50 | 5.49 | 22.7 | 11.36 | 0.032 | **36.4** |
| 4 | 30.00 | 5.49 | 22.7 | 11.93 | 0.024 | **31.8** |
| 15 | 25.00 | 5.49 | 22.7 | 12.76 | 0.013 | **25.3** |
| 30 | 22.50 | 5.45 | 22.8 | 13.17 | 0.009 | **22.1** |
| 60 | 20.00 | 5.45 | 22.8 | 13.58 | 0.006 | **18.9** |
| 240 | 16.50 | 5.34 | 23.1 | 14.16 | 0.003 | **14.5** |
| 1440 | 14.50 | 5.53 | 22.6 | 14.48 | 0.001 | **11.7** |

NOTES:

File name: 2679130__Grain Size with Hydrometer ASTM D6913 D7928_1.xlsm

# Percent Minus #200
# ASTM D1140

ADVANCED TERRA TESTING

# Percent Minus #200
# ASTM D 1140

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 42.5-43.5 |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-16 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/31/18 | | |
| TECHNICIAN | AD | | |

**Hygroscopic Moisture of Fines**

| | |
|---|---|
| Mass Wet Pan and Soil (g): | 1261.71 |
| Mass Dry Pan and Soil (g): | 1250.69 |
| Mass of Pan (g): | 829.11 |
| Moisture (%): | **2.6** |

**Sample Data**

| | |
|---|---|
| Total Wet Mass of Sample (g): | 625.3 |
| Total Dry Mass of Sample (g): | 614.0 |
| Split Fraction: | #4 |
| Mass of Sub-Sample Fraction (g): | 432.59 |

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **#4** | 4.75 | 184.7 | -- | 184.7 | 1.00 | **69.9** |
| **#200** | 0.075 | 184.9 | -- | 184.9 | 0.70 | **39.3** |

**USCS Classification ASTM D 2487**

Atterberg Classification: --
Group Symbol: --
USCS Classification: --

NOTES

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 11/1/2018 |
| Checked by: | cm | Date: | 11/02/18 |
| File name: | 2679130__Percent Minus #200 ASTM D1140_1.xls | | |

ADVANCED TERRA TESTING

# Percent Minus #200
# ASTM D 1140

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-102A |
| JOB NO. | 2679-130 | DEPTH | 29-30' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-14 |
| PROJECT NO. | 18115 | DATE SAMPLED | 07/24/18 |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/30/18 | | |
| TECHNICIAN | KJT | | |

**Hygroscopic Moisture**

Mass Wet Pan and Soil (g): 1620.42
Mass Dry Pan and Soil (g): 1613.74
Mass of Pan (g): 1024.97
Moisture (%): **1.1**

**Sample Data**

Total Wet Mass of Sample (g): 595.5
Total Dry Mass of Sample (g): 588.8

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **#4** | 4.75 | 335.6 | 0.0 | 335.6 | 1.00 | **43.0** |
| **#200** | 0.075 | 1484.5 | 1025.0 | 459.6 | 1.00 | **21.9** |

**USCS Classification ASTM D 2487**

Atterberg Classification: --
Group Symbol: --
USCS Classification: --

NOTES

Data entry by: CAL Date: 11/5/2018
Checked by: SPH Date: 11-5-18
File name: 2679130__Percent Minus #200 ASTM D1140_2.xls

ADVANCED TERRA TESTING

# Percent Minus #200
# ASTM D 1140

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 15-16' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-8 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/29/18 | | |
| TECHNICIAN | CAL | | |

**Hygroscopic Moisture**

Mass Wet Pan and Soil (g): 598.84
Mass Dry Pan and Soil (g): 566.35
Mass of Pan (g): 266.20
Moisture (%): **10.8**

**Sample Data**

Total Wet Mass of Sample (g): 332.6
Total Dry Mass of Sample (g): 300.2

| Sieve Number | Sieve Size (mm) | Mass of Pan and Soil (g) | Mass of Pan (g) | Mass of Individual Retained Soil (g) | Correction Factor | Percent Passing by Weight (%) |
|---|---|---|---|---|---|---|
| **#4** | 4.75 | 138.1 | -- | 138.1 | 1.00 | **54.0** |
| **#200** | 0.075 | 468.5 | 266.2 | 202.2 | 1.00 | **32.6** |

**USCS Classification ASTM D 2487**

Atterberg Classification: --
Group Symbol: --
USCS Classification: --

NOTES

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 10/30/2018 |
| Checked by: | KR | Date: | 11/26/18 |
| File name: | 2679130__Percent Minus #200 ASTM D1140_0.xls | | |

# Standard Proctor Compaction
# ASTM D698

ADVANCED TERRA TESTING

# Laboratory Compaction Characteristics

## ASTM D 698

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 15-25' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-6 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/22/18 | | |
| TECHNICIAN | WAR | | |

## Laboratory Compaction Characteristics

**Hygroscopic Moisture**

| | |
|---|---|
| Mass of Wet Pan and Soil (g): | 321.59 |
| Mass of Dry Pan and Soil (g): | 316.49 |
| Mass of Pan (g): | 14.17 |
| Moisture (%): | 1.7 |

**Rock Correction ASTM D 4718**

| | |
|---|---|
| Method: | B |
| Course Fraction (%): | 12.4 |
| Rock Correction Applied: | YES |
| Mass of Dry Aggregate (g): | 3374.2 |
| Mass of SSD Aggregate (g): | 3494.0 |
| Mass of Aggregate in Water (g): | 2173.3 |
| Rock Specific Gravity: | 2.55 |
| Zero Air Voids Specific Gravity: | 2.8 |

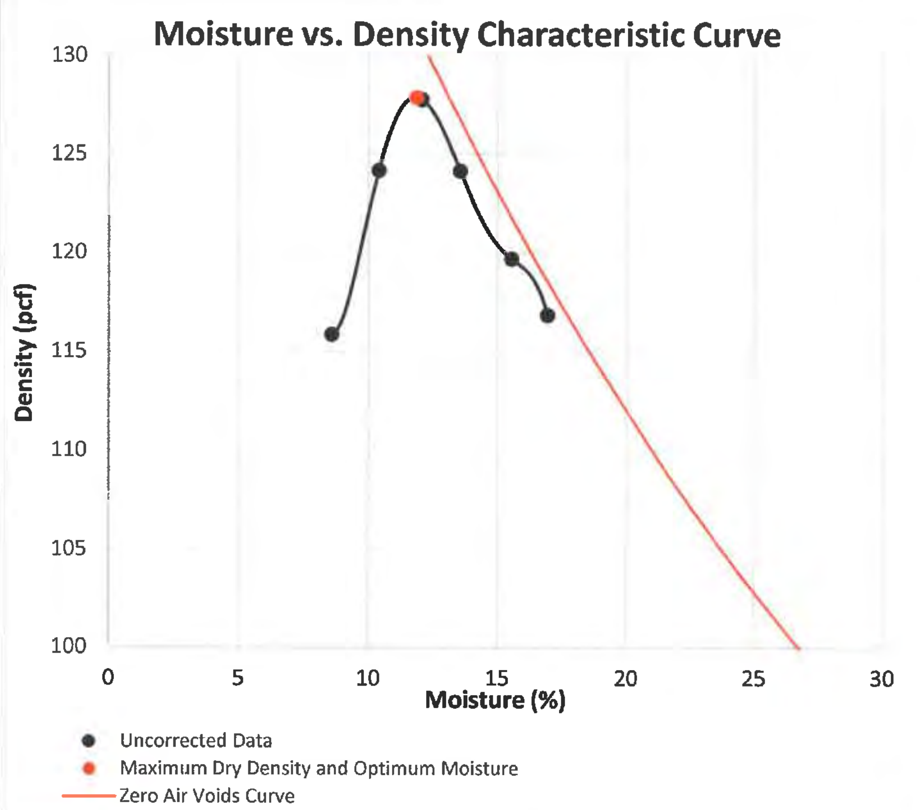
**Optimum Dry Density and Moisture**

**Uncorrected**

| | |
|---|---|
| Dry Density (pcf): | **127.9** |
| Dry Density (kg/m³): | **2048** |
| Moisture (%): | **11.9** |

**Corrected**

| | |
|---|---|
| Dry Density (pcf): | **131.1** |
| Dry Density (kg/m³): | **2100** |
| Moisture (%): | **10.4** |




| Sample Number: | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| Mass of Wet Pan and Soil (g): | 515.29 | 469.19 | 502.78 | 484.74 | 579.30 | 328.99 |
| Mass of Dry Soil and Pan (g): | 441.62 | 406.98 | 443.62 | 433.27 | 525.32 | 303.47 |
| Mass of Pan (g); | 6.79 | 6.74 | 6.78 | 6.62 | 6.69 | 6.62 |
| Moisture (%): | 16.9 | 15.5 | 13.5 | 12.1 | 10.4 | 8.6 |
| Mass of Wet Soil and Mold (g): | 6650.0 | 6675.1 | 6715.4 | 6748.9 | 6657.1 | 6486.6 |
| Mass of Mold (g): | 4584.1 | 4584.1 | 4584.1 | 4584.1 | 4584.1 | 4584.1 |
| Wet Density (pcf): | 125.8 | 137.1 | 143.2 | 141.0 | 138.3 | 136.6 |
| Dry Density (pcf): | 115.9 | 124.2 | 127.8 | 124.1 | 119.7 | 116.8 |
| Wet Density (kg/m³): | 2016 | 2196 | 2293 | 2258 | 2215 | 2189 |
| Dry Density (kg/m³): | 1856 | 1989 | 2047 | 1989 | 1917 | 1872 |

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 10/25/2018 |
| Checked by: | KMS | Date: | 11/8/18 |
| File name: | 2679130__compaction ASTM D698 D1557_1.xls | | |

ADVANCED TERRA TESTING

# Laboratory Compaction Characteristics

## ASTM D 698

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 51-65' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-20 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/25/18 | | |
| TECHNICIAN | BDF | | |

### Laboratory Compaction Characteristics

**Hygroscopic Moisture**

| | |
|---|---|
| Mass of Wet Pan and Soil (g): | 293.70 |
| Mass of Dry Pan and Soil (g): | 288.60 |
| Mass of Pan (g): | 6.61 |
| Moisture (%): | 1.8 |

**Rock Correction ASTM D 4718**

| | |
|---|---|
| Method: | B |
| Course Fraction (%): | 11.9 |
| Rock Correction Applied: | YES |
| Mass of Dry Aggregate (g): | 2131.3 |
| Mass of SSD Aggregate (g): | 2205.6 |
| Mass of Aggregate in Water (g): | 1377.7 |
| Rock Specific Gravity: | 2.57 |
| Zero Air Voids Specific Gravity: | 2.76 |

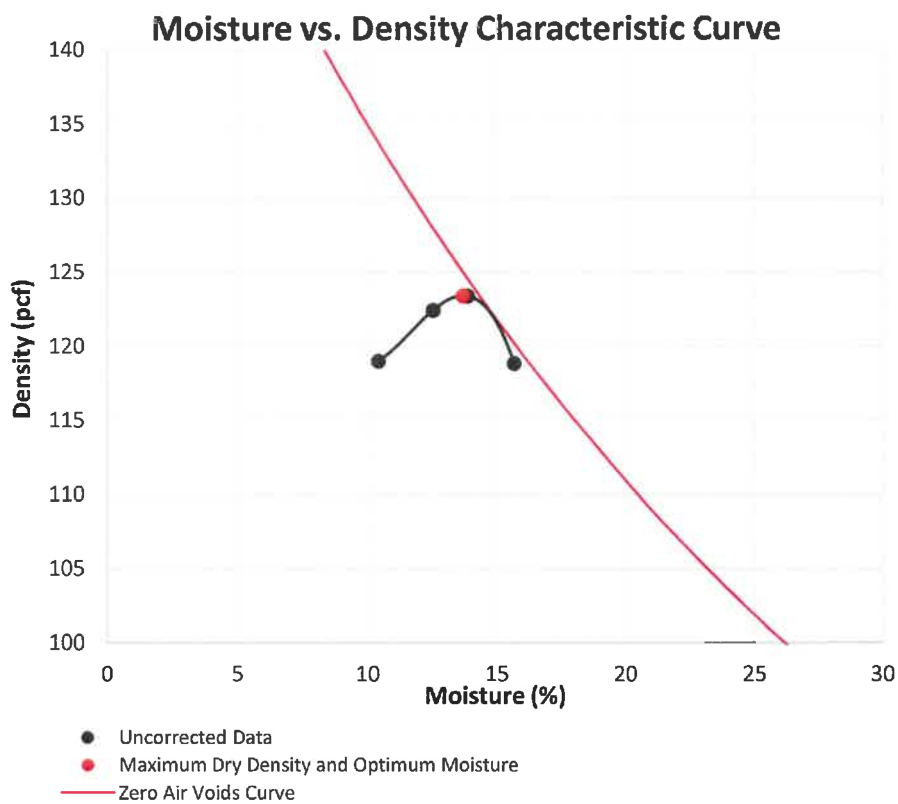
**Optimum Dry Density and Moisture**

**Uncorrected**

| | |
|---|---|
| Dry Density (pcf): | **123.4** |
| Dry Density (kg/m³): | **1977** |
| Moisture (%): | **13.7** |

**Corrected**

| | |
|---|---|
| Dry Density (pcf): | **126.9** |
| Dry Density (kg/m³): | **2033** |
| Moisture (%): | **12.1** |




| Sample Number: | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Mass of Wet Pan and Soil (g): | 310.62 | 360.16 | 431.81 | 288.79 |
| Mass of Dry Soil and Pan (g): | 276.78 | 317.10 | 374.17 | 262.13 |
| Mass of Pan (g); | 6.92 | 6.62 | 6.55 | 6.56 |
| Moisture (%): | 12.5 | 13.9 | 15.7 | 10.4 |
| Mass of Wet Soil and Mold (g): | 6667.1 | 6708.3 | 6662.5 | 6570.8 |
| Mass of Mold (g): | 4584.0 | 4584.0 | 4584.0 | 4584.0 |
| Wet Density (pcf): | 131.4 | 137.8 | 140.5 | 137.5 |
| Dry Density (pcf): | 119.0 | 122.4 | 123.4 | 118.8 |
| Wet Density (kg/m³): | 2105 | 2207 | 2251 | 2202 |
| Dry Density (kg/m³): | 1906 | 1961 | 1976 | 1904 |

| | | | |
|---|---|---|---|
| Data entry by: | CAL | Date: | 10/29/2018 |
| Checked by: | SPH | Date: | 10-30-18 |
| File name: | 2679130__compaction ASTM D698 D1557_2.xls | | |

# Laboratory Compaction Characteristics

## ASTM D 698

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 10-17.5' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-11 |
| PROJECT NO. | 18115 | DATE SAMPLED | -- |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/22/18 | | |
| TECHNICIAN | WAR | | |

### Laboratory Compaction Characteristics

**Hygroscopic Moisture**

| | |
|---|---|
| Mass of Wet Pan and Soil (g): | 396.44 |
| Mass of Dry Pan and Soil (g): | 389.75 |
| Mass of Pan (g): | 6.56 |
| Moisture (%): | 1.7 |

**Rock Correction ASTM D 4718**

| | |
|---|---|
| Method: | B |
| Course Fraction (%): | 14.1 |
| Rock Correction Applied: | YES |
| Mass of Dry Aggregate (g): | 3506.1 |
| Mass of SSD Aggregate (g): | 3587.6 |
| Mass of Aggregate in Water (g): | 2237.2 |
| Rock Specific Gravity: | 2.60 |
| Zero Air Voids Specific Gravity: | 2.75 |

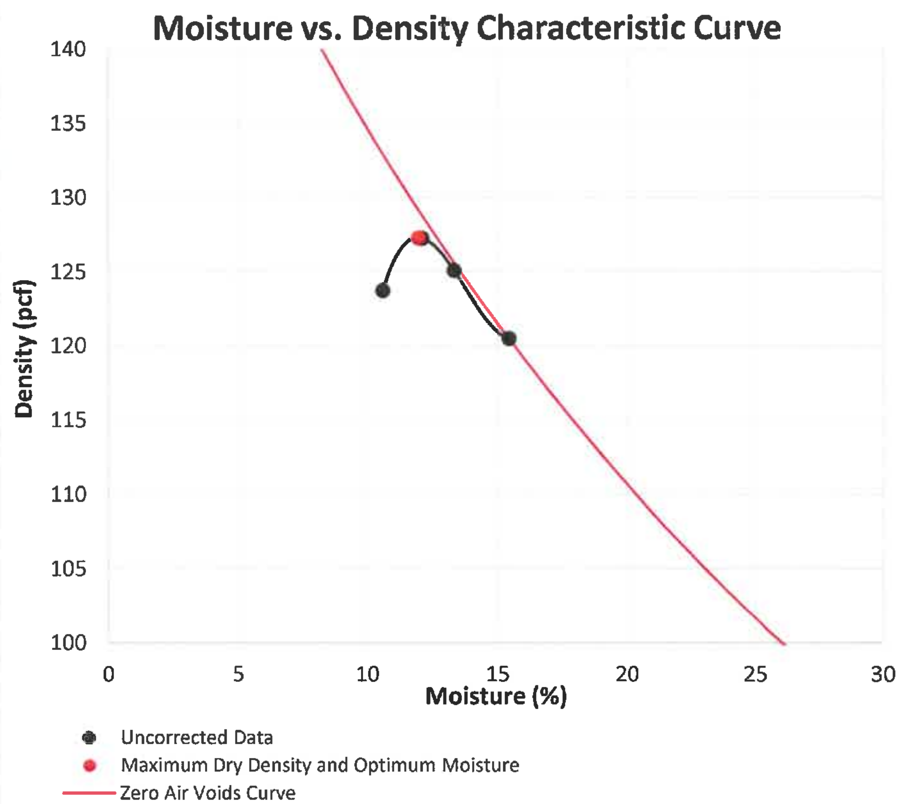
**Optimum Dry Density and Moisture**

**Uncorrected**

| | |
|---|---|
| Dry Density (pcf): | **127.3** |
| Dry Density (kg/m³): | **2039** |
| Moisture (%): | **11.9** |

**Corrected**

| | |
|---|---|
| Dry Density (pcf): | **131.3** |
| Dry Density (kg/m³): | **2103** |
| Moisture (%): | **10.3** |




| Sample Number: | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| Mass of Wet Pan and Soil (g): | 397.72 | 461.20 | 491.64 | 419.00 |
| Mass of Dry Soil and Pan (g): | 345.67 | 407.78 | 439.33 | 379.57 |
| Mass of Pan (g); | 8.51 | 6.74 | 6.78 | 7.11 |
| Moisture (%): | 15.4 | 13.3 | 12.1 | 10.6 |
| Mass of Wet Soil and Mold (g): | 6687.3 | 6727.4 | 6741.1 | 6653.1 |
| Mass of Mold (g): | 4584.1 | 4584.1 | 4584.1 | 4584.1 |
| Wet Density (pcf): | 136.8 | 142.7 | 141.8 | 139.1 |
| Dry Density (pcf): | 123.7 | 127.3 | 125.1 | 120.5 |
| Wet Density (kg/m³): | 2192 | 2285 | 2271 | 2228 |
| Dry Density (kg/m³): | 1982 | 2039 | 2004 | 1930 |

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 10/25/2018 |
| Checked by: | CH | Date: | 10/26/18 |
| File name: | 2679130__compaction ASTM D698 D1557_0.xls | | |

# One-Dimensional Consolidation
# ASTM D2435

ADVANCED TERRA TESTING

# One-Dimensional Consolidation

## ASTM D 2435

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 27.5-29.9' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | u-14 |
| PROJECT NO. | 18115 | DATE SAMPLED | 07/23/18 |
| LOCATION | -- | SAMPLED BY | -- |
| DATE TESTED | 10/22/18 | DESCRIPTION | -- |
| TECHNICIAN | AD | | |

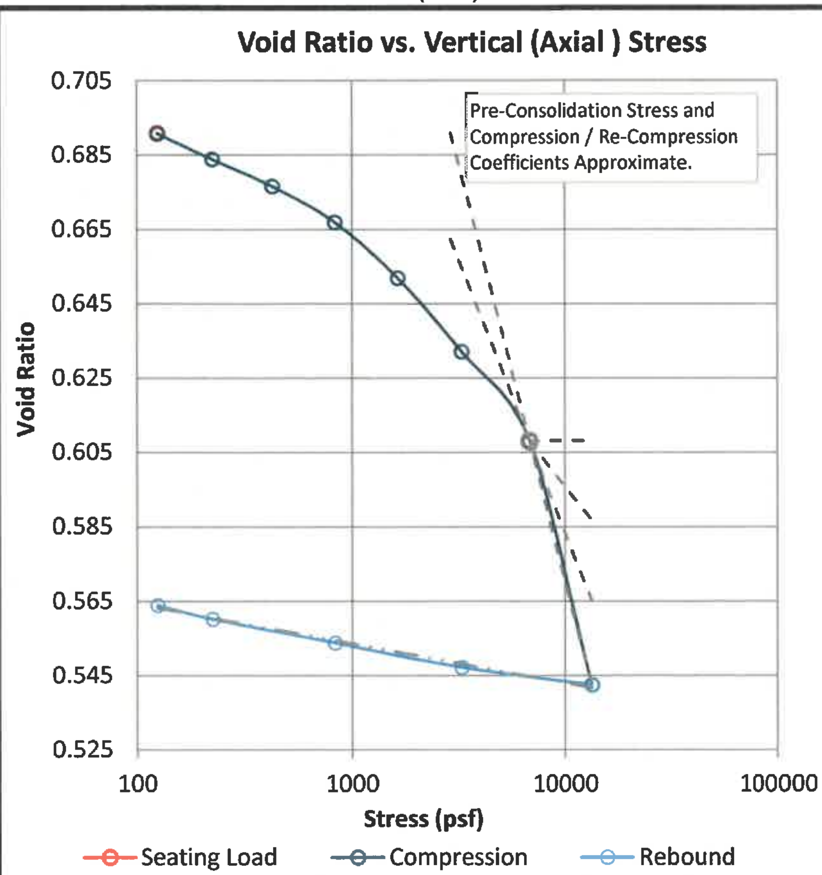
### Sample Conditions

| | | | |
|---|---|---|---|
| Before Test Mass of Wet Soil and Ring (g): | 189.07 | Initial Wet Density (pcf): | 123.2 |
| After Test Mass of Wet Soil and Ring (g): | 185.90 | Initial Dry Density (pcf): | 97.8 |
| Mass of Dry Soil, Ring, and Pan (g): | 161.80 | Initial Wet Density (kg/m³): | 1973 |
| Diameter (in): | 2.41 | Initial Dry Density (kg/m³): | 1567 |
| Initial Height (in): | 1.00 | Initial Moisture (%): | 25.9 |
| Mass of Ring (g): | 41.57 | Final Wet Density (pcf): | 130.3 |
| Mass of Pan (g): | 3.08 | Final Dry Density (pcf): | 105.8 |
| Assumed Specific Gravity: | 2.65 | Final Wet Density (kg/m³): | 2088 |
| Initial Saturation (%): | 99.6 | Final Dry Density (kg/m³): | 1694 |
| Final Saturation (%): | 100.0 | Final Moisture (%): | 23.2 |

### Swell / Collapse Data

| | | | |
|---|---|---|---|
| Coefficient of Compression: | 0.224 | Pre-Consolidation Stress (psf): | 6780 |
| Coefficient of Re-Compression: | 0.011 | Pre-Consolidation Stress (kPa): | 325 |

| Load (psf) | Void Ratio | Deformation (in) | Strain (%) |
|---|---|---|---|
| 125 | 0.691 | 0.0000 | 0.00 |
| Inundation | 0.691 | 0.0001 | 0.01 |
| 225 | 0.684 | 0.0042 | 0.42 |
| 428 | 0.677 | 0.0085 | 0.85 |
| 832 | 0.667 | 0.0142 | 1.42 |
| 1636 | 0.652 | 0.0231 | 2.31 |
| 3248 | 0.632 | 0.0348 | 3.48 |
| 6780 | 0.608 | 0.0490 | 4.90 |
| 13314 | 0.543 | 0.0878 | 8.78 |
| Rebound | | | |
| 13314 | 0.543 | 0.0878 | 8.78 |
| 3248 | 0.547 | 0.0850 | 8.50 |
| 832 | 0.554 | 0.0811 | 8.11 |
| 225 | 0.560 | 0.0773 | 7.73 |
| 125 | 0.564 | 0.0751 | 7.51 |




| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 11/5/2018 |
| Checked by: | DPM | Date: | 11/7/18 |
| File name: | 2679130__Consol ASTM D2435_0.xlsm | | |

ADVANCED TERRA TESTING

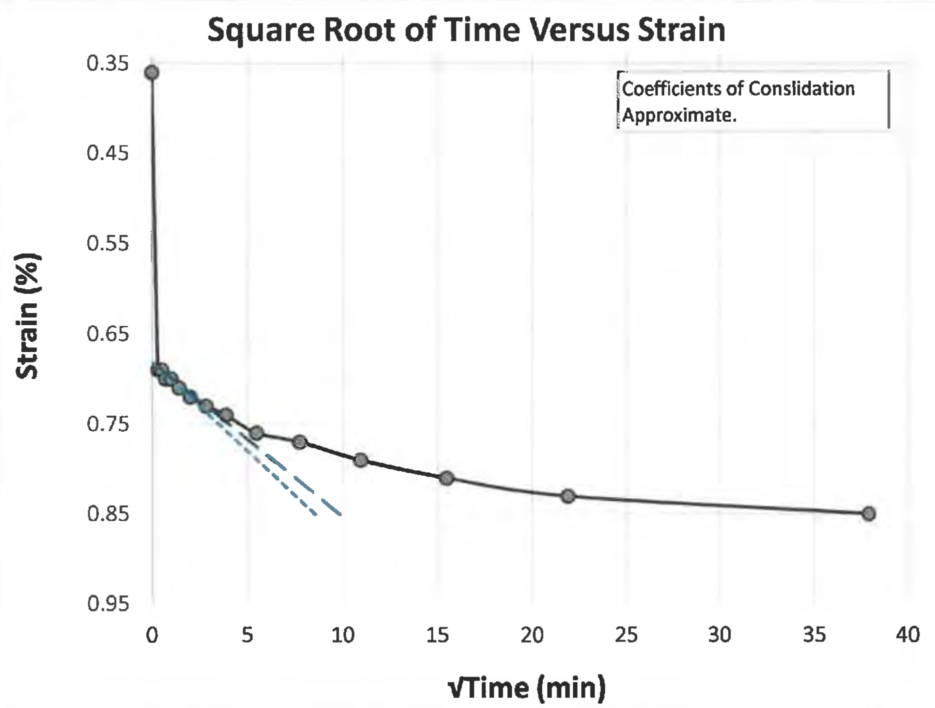
# One-Dimensional Consolidation

## ASTM D 2435

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 27.5-29.9' |
| PROJECT | Hogchute Dam Safety Evaluatioi | SAMPLE NO. | u-14 |
| PROJECT NO. | 18115 | DATE SAMPLED | 07/23/18 |
| LOCATION | -- | SAMPLED BY | -- |
| DATE TESTED | 10/22/18 | DESCRIPTION | -- |
| TECHNICIAN | AD | | |

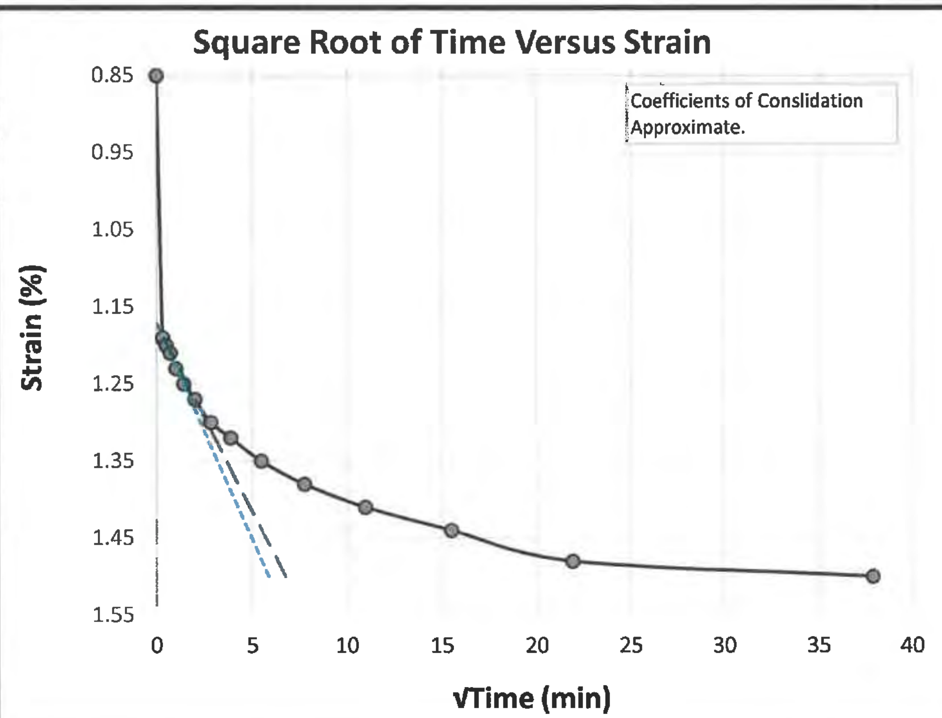
| Coefficient of Consolidation ($cm^2/s$) | T90 (min) | Load (psf) |
|---|---|---|
| 0.003 | 8.321 | 428 |

| Ellapsed Time (min) | Deformation (in) | Strain (%) |
|---|---|---|
| 0 | -0.0045 | 0.36 |
| 0.1 | -0.0078 | 0.69 |
| 0.25 | -0.0078 | 0.69 |
| 0.5 | -0.0079 | 0.70 |
| 1 | -0.0079 | 0.70 |
| 2 | -0.0080 | 0.71 |
| 4 | -0.0081 | 0.72 |
| 8 | -0.0082 | 0.73 |
| 15 | -0.0083 | 0.74 |
| 30 | -0.0085 | 0.76 |
| 60 | -0.0086 | 0.77 |
| 120 | -0.0088 | 0.79 |
| 240 | -0.0090 | 0.81 |
| 480 | -0.0092 | 0.83 |
| 1439 | -0.0094 | 0.85 |




| Coefficient of Consolidation ($cm^2/s$) | T90 (min) | Load (psf) |
|---|---|---|
| 0.005 | 4.280 | 832 |

| Ellapsed Time (min) | Deformation (in) | Strain (%) |
|---|---|---|
| 0 | -0.0094 | 0.85 |
| 0.1 | -0.0128 | 1.19 |
| 0.25 | -0.0129 | 1.20 |
| 0.5 | -0.0130 | 1.21 |
| 1 | -0.0132 | 1.23 |
| 2 | -0.0134 | 1.25 |
| 4 | -0.0136 | 1.27 |
| 8 | -0.0139 | 1.30 |
| 15 | -0.0141 | 1.32 |
| 30 | -0.0144 | 1.35 |
| 60 | -0.0147 | 1.38 |
| 120 | -0.0150 | 1.41 |
| 240 | -0.0153 | 1.44 |
| 480 | -0.0157 | 1.48 |
| 1438 | -0.0159 | 1.50 |






File name: 2679130__Consol ASTM D2435_1.xlsm

ADVANCED TERRA TESTING

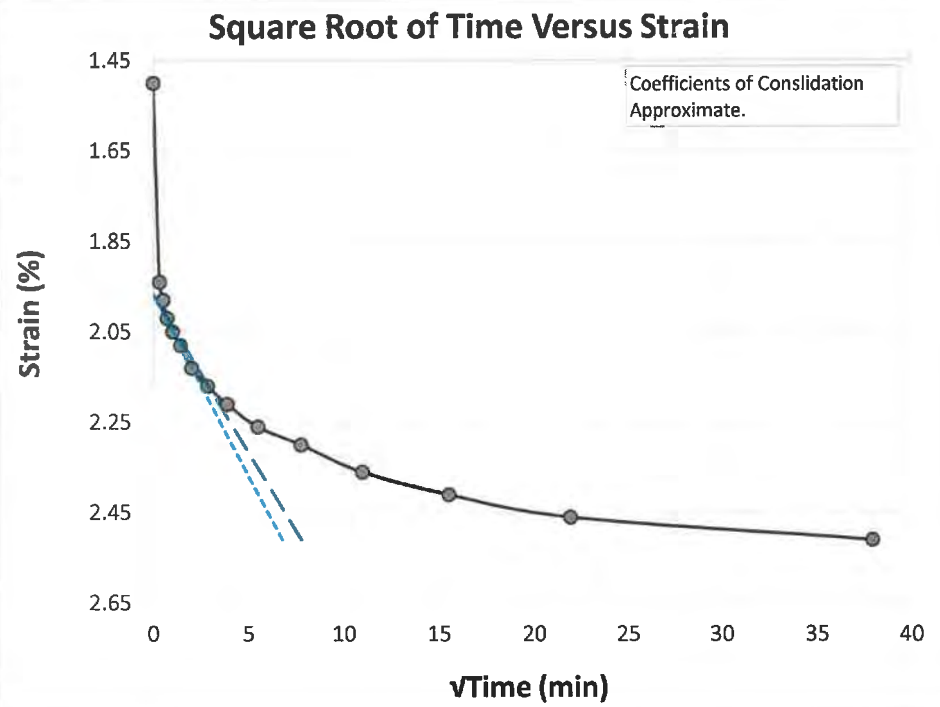
# One-Dimensional Consolidation

## ASTM D 2435

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-103 |
| JOB NO. | 2679-130 | DEPTH | 27.5-29.9' |
| PROJECT | Hogchute Dam Safety Evaluatior | SAMPLE NO. | u-14 |
| PROJECT NO. | 18115 | DATE SAMPLED | 07/23/18 |
| LOCATION | -- | SAMPLED BY | -- |
| DATE TESTED | 10/22/18 | DESCRIPTION | -- |
| TECHNICIAN | AD | | |

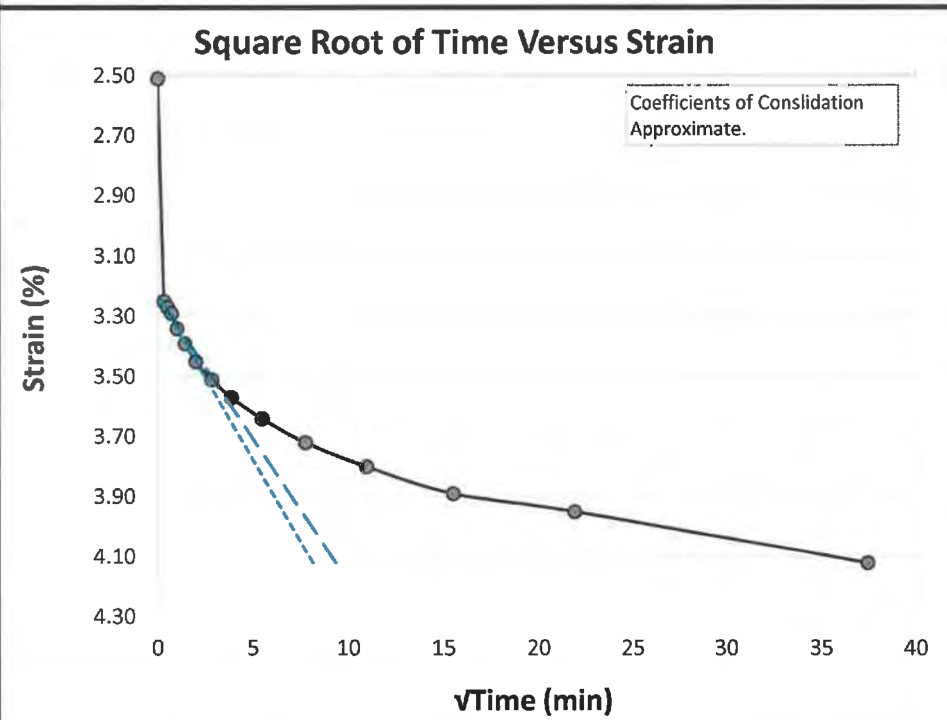
| Coefficient of Consolidation ($cm^2/s$) | T90 (min) | Load (psf) |
|---|---|---|
| 0.003 | 8.720 | 1636 |

| Ellapsed Time (min) | Deformation (in) | Strain (%) |
|---|---|---|
| 0 | -0.0159 | 1.50 |
| 0.1 | -0.0203 | 1.94 |
| 0.25 | -0.0207 | 1.98 |
| 0.5 | -0.0211 | 2.02 |
| 1 | -0.0214 | 2.05 |
| 2 | -0.0217 | 2.08 |
| 4 | -0.0222 | 2.13 |
| 8 | -0.0226 | 2.17 |
| 15 | -0.0230 | 2.21 |
| 30 | -0.0235 | 2.26 |
| 60 | -0.0239 | 2.30 |
| 120 | -0.0245 | 2.36 |
| 240 | -0.0250 | 2.41 |
| 480 | -0.0255 | 2.46 |
| 1442 | -0.0260 | 2.51 |




| Coefficient of Consolidation ($cm^2/s$) | T90 (min) | Load (psf) |
|---|---|---|
| 0.002 | 9.319 | 3248 |

| Ellapsed Time (min) | Deformation (in) | Strain (%) |
|---|---|---|
| 0 | -0.0260 | 2.51 |
| 0.1 | -0.0334 | 3.25 |
| 0.25 | -0.0336 | 3.27 |
| 0.5 | -0.0338 | 3.29 |
| 1 | -0.0343 | 3.34 |
| 2 | -0.0348 | 3.39 |
| 4 | -0.0354 | 3.45 |
| 8 | -0.0360 | 3.51 |
| 15 | -0.0366 | 3.57 |
| 30 | -0.0373 | 3.64 |
| 60 | -0.0381 | 3.72 |
| 120 | -0.0389 | 3.80 |
| 240 | -0.0398 | 3.89 |
| 480 | -0.0404 | 3.95 |
| 1406 | -0.0421 | 4.12 |






File name: 2679130__Consol ASTM D2435_0.xlsm

# Consolidated Undrained Triaxial Compression ASTM D4767

## Consolidated Undrained Triaxial Compression Test for Cohesive Soils
## ASTM D 4767

| | | | |
|---|---|---|---|
| Client | RJH Consultants | Boring Number: | B-103 |
| Job Number | 2679-130 | Depth: | 27.5-29.9' |
| Project | Hogchute Dam Safety Evaluation | Sample Number: | u-14 Pts A, B & C |
| Location | -- | Sampled Date: | 7/23/2018 |
| Project Number | 18115 | Sampled By: | -- |

Tested By: SPH/CAL

TEST TYPE TX/CUPP

| $\sigma_3$ Confining Stresses (psf) | |
|---|---|
| SAMPLE A | 10000 |
| SAMPLE B | 6000 |
| SAMPLE C | 3000 |

| Peak Points | p' (psf) | q (psf) |
|---|---|---|
| SAMPLE A | 8852 | 5102 |
| SAMPLE B | 4720 | 2810 |
| SAMPLE C | 3584 | 2096 |

| Stress Condition at Maximum Deviator Stress (PSF) | | | | |
|---|---|---|---|---|
| | σ3 | σ1 | σ'3 | σ'1 |
| SAMPLE A | 10000 | 20204 | 3750 | 13954 |
| SAMPLE B | 6000 | 11620 | 1910 | 7530 |
| SAMPLE C | 3000 | 7192 | 1488 | 5680 |

**SAMPLE A DATA**

| $\sigma_3'$ (psf) | $\sigma_1'$ (psf) | Deviator Stress $(\sigma_1-\sigma_3)$ (psf) | $p' = (\sigma_1'+\sigma_3')/2$ (psf) | $q = (\sigma_1-\sigma_3)/2$ (psf) |
|---|---|---|---|---|
| 10000 | 10000 | 0 | 10000 | 0 |
| 9870 | 10502 | 632 | 10186 | 316 |
| 9640 | 10879 | 1239 | 10260 | 620 |
| 9078 | 11602 | 2524 | 10340 | 1262 |
| 8387 | 12029 | 3642 | 10208 | 1821 |
| 7710 | 12259 | 4549 | 9985 | 2275 |
| 7062 | 12282 | 5220 | 9672 | 2610 |
| 6486 | 12213 | 5727 | 9350 | 2864 |
| 5982 | 12075 | 6093 | 9029 | 3047 |
| 5550 | 11963 | 6413 | 8757 | 3207 |
| 5176 | 11790 | 6614 | 8483 | 3307 |
| 4874 | 11668 | 6794 | 8271 | 3397 |
| 3894 | 11161 | 7267 | 7528 | 3634 |
| 3448 | 10977 | 7529 | 7213 | 3765 |
| 3218 | 10957 | 7739 | 7088 | 3870 |
| 3102 | 11053 | 7951 | 7078 | 3976 |
| 3045 | 11363 | 8318 | 7204 | 4159 |
| 3074 | 11728 | 8654 | 7401 | 4327 |
| 3146 | 12171 | 9025 | 7659 | 4513 |
| 3232 | 12551 | 9319 | 7892 | 4660 |
| 3333 | 12897 | 9564 | 8115 | 4782 |
| 3419 | 13135 | 9716 | 8277 | 4858 |
| 3506 | 13367 | 9861 | 8437 | 4931 |
| 3578 | 13536 | 9958 | 8557 | 4979 |
| 3621 | 13692 | 10071 | 8657 | 5036 |
| 3693 | 13814 | 10121 | 8754 | 5061 |
| 3750 | 13954 | 10204 | 8852 | 5102 |
| 3808 | 14010 | 10202 | 8909 | 5101 |

**SAMPLE B DATA**

| $\sigma_3'$ (psf) | $\sigma_1'$ (psf) | Deviator Stress $(\sigma_1-\sigma_3)$ (psf) | $p' = (\sigma_1'+\sigma_3')/2$ (psf) | $q = (\sigma_1-\sigma_3)/2$ (psf) |
|---|---|---|---|---|
| 6000 | 6000 | 0 | 6000 | 0 |
| 5942 | 6119 | 177 | 6031 | 89 |
| 5784 | 6259 | 475 | 6022 | 238 |
| 5237 | 6932 | 1695 | 6085 | 848 |
| 4618 | 7232 | 2614 | 5925 | 1307 |
| 4070 | 7260 | 3190 | 5665 | 1595 |
| 3638 | 7171 | 3533 | 5405 | 1767 |
| 3278 | 7061 | 3783 | 5170 | 1892 |
| 3005 | 6969 | 3964 | 4987 | 1982 |
| 2789 | 6864 | 4075 | 4827 | 2038 |
| 2616 | 6802 | 4186 | 4709 | 2093 |
| 2098 | 6583 | 4485 | 4341 | 2243 |
| 1882 | 6525 | 4643 | 4204 | 2322 |
| 1795 | 6574 | 4779 | 4185 | 2390 |
| 1752 | 6664 | 4912 | 4208 | 2456 |
| 1694 | 6802 | 5108 | 4248 | 2554 |
| 1723 | 7019 | 5296 | 4371 | 2648 |
| 1795 | 7231 | 5436 | 4513 | 2718 |
| 1838 | 7389 | 5551 | 4614 | 2776 |
| 1910 | 7530 | 5620 | 4720 | 2810 |
| 1954 | 7554 | 5600 | 4754 | 2800 |
| 1982 | 7458 | 5476 | 4720 | 2738 |
| 1968 | 7238 | 5270 | 4603 | 2635 |
| 1910 | 7018 | 5108 | 4464 | 2554 |
| 1882 | 6851 | 4969 | 4367 | 2485 |
| 1853 | 6684 | 4831 | 4269 | 2416 |
| 1781 | 6471 | 4690 | 4126 | 2345 |

**SAMPLE C DATA**

| $\sigma_3'$ (psf) | $\sigma_1'$ (psf) | Deviator Stress $(\sigma_1-\sigma_3)$ (psf) | $p' = (\sigma_1'+\sigma_3')/2$ (psf) | $q = (\sigma_1-\sigma_3)/2$ (psf) |
|---|---|---|---|---|
| 3000 | 3000 | 0 | 3000 | 0 |
| 2654 | 2931 | 277 | 2793 | 139 |
| 2568 | 3028 | 460 | 2798 | 230 |
| 2222 | 3302 | 1080 | 2762 | 540 |
| 1920 | 3503 | 1583 | 2712 | 792 |
| 1690 | 3593 | 1903 | 2642 | 952 |
| 1531 | 3662 | 2131 | 2597 | 1066 |
| 1416 | 3705 | 2289 | 2561 | 1145 |
| 1330 | 3730 | 2400 | 2530 | 1200 |
| 1258 | 3747 | 2489 | 2503 | 1245 |
| 1214 | 3769 | 2555 | 2492 | 1278 |
| 1171 | 3792 | 2621 | 2482 | 1311 |
| 1042 | 3921 | 2879 | 2482 | 1440 |
| 1013 | 4058 | 3045 | 2536 | 1523 |
| 1027 | 4237 | 3210 | 2632 | 1605 |
| 1056 | 4383 | 3327 | 2720 | 1664 |
| 1114 | 4630 | 3516 | 2872 | 1758 |
| 1142 | 4841 | 3699 | 2992 | 1850 |
| 1214 | 5068 | 3854 | 3141 | 1927 |
| 1272 | 5235 | 3963 | 3254 | 1982 |
| 1330 | 5354 | 4024 | 3342 | 2012 |
| 1358 | 5465 | 4107 | 3412 | 2054 |
| 1416 | 5560 | 4144 | 3488 | 2072 |
| 1459 | 5618 | 4159 | 3539 | 2080 |
| 1488 | 5680 | 4192 | 3584 | 2096 |
| 1531 | 5715 | 4184 | 3623 | 2092 |
| 1546 | 5701 | 4155 | 3624 | 2078 |
| 1560 | 5647 | 4087 | 3604 | 2044 |

Data entry by: SPH
Date: 10/24/18
FileName: 2679_130_PQPlots-ASTM-D4767-withmetric-R2_0.xls

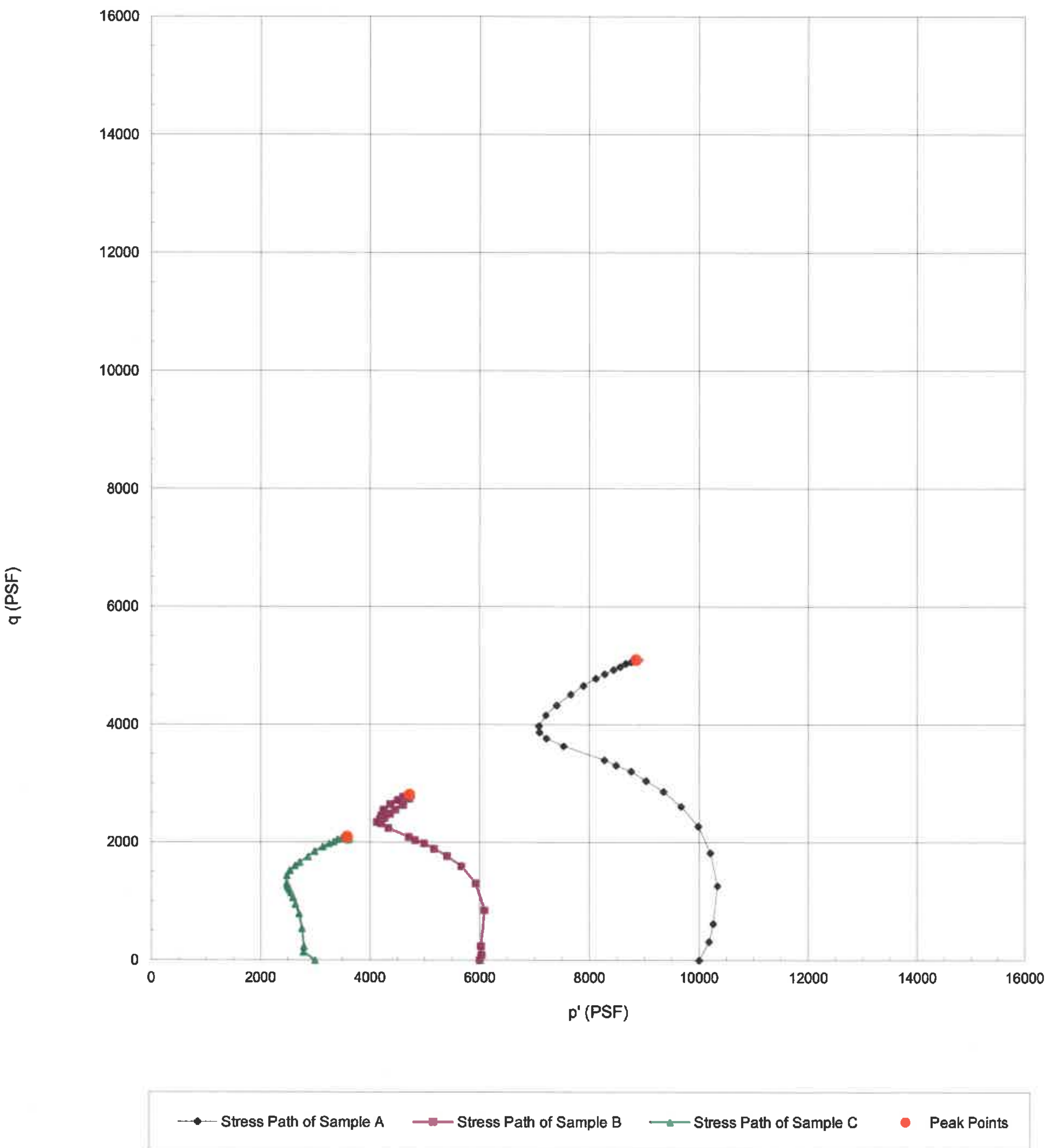
Data checked by: CAL
Date: 10/25/18



ATT

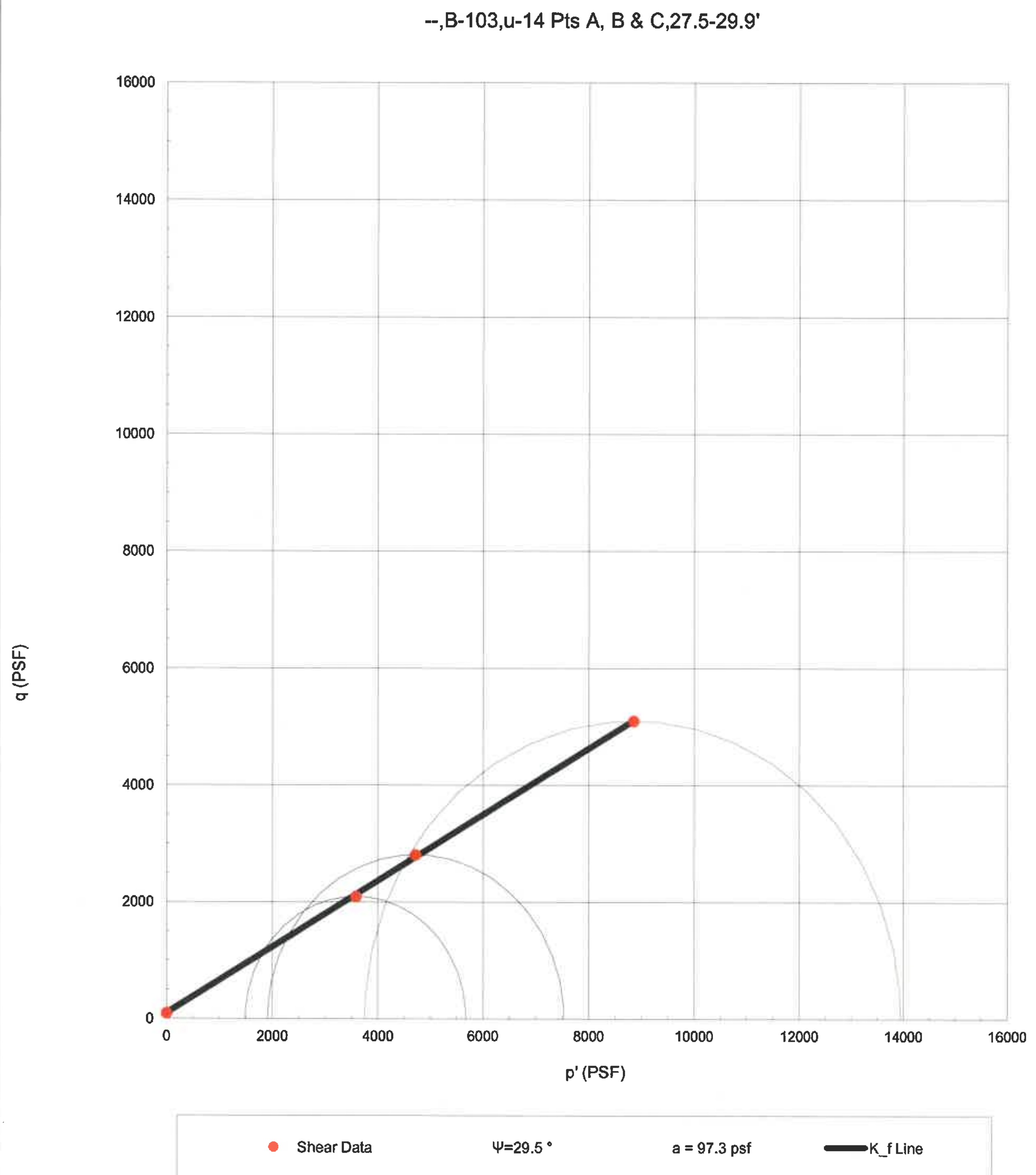
# Effective Stress Path Analysis - p' q Plots

--,B-103,u-14 Pts A, B & C,27.5-29.9'




NOTE 1: The peak points shown in the plot represent maximum values of q [(σ1-σ3)/2].

# Effective Stress Path Analysis - p'-q Regression Plot at Maximum q




NOTE 2: The line presented in the graph is the K_f line taken at Peak q values defined by the equation q=a+p' tan(Ψ) where a = the intercept on the q-axis in stress units and Ψ = the angle of the K_f line with respect to the horizontal in degrees.

NOTE 3: The K_f is NOT the Mohr-Coulomb failure envelope defined by the equation τ=c+σ tan(Φ). The equations sin(Φ)=tan(Ψ) and c=a/cos(Φ) may be used to approximate values for Φ and c at the effective stress condition described in NOTE 1.

ATT
ADVANCED TERRA TESTING

# CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
ASTM D4767

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/19/2018 |
| BORING NO. | B-103 | CELL NUMBER | 24S |
| DEPTH | 27.5-29.9' (29.15-29.65) | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. A | CONF. PRES. (psf) | 10000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

| MOISTURE/DENSITY DATA | BEFORE TEST | AFTER TEST |
|---|---|---|
| Wt. Soil + Moisture (g) | 1266.40 | 1226.21 |
| Wt. Wet Soil & Pan (g) | 1280.85 | 1240.66 |
| Wt. Dry Soil & Pan (g) | 1017.19 | 1017.19 |
| Wt. Lost Moisture (g) | 263.66 | 223.47 |
| Wt. of Pan Only (g) | 14.45 | 14.45 |
| Wt. of Dry Soil (g) | 1002.74 | 1002.74 |
| Moisture Content % | 26.3 | 22.3 |
| Wet Density (pcf) | 127.3 | 133.3 |
| Dry Density (pcf) | 100.8 | 109.0 |
| Init. Diameter (in) | 2.872 | |
| Init. Area (sq in) | 6.478 | |
| Init. Height (in) | 5.852 | |
| Vol. Bef. Consol. (cu ft) | 0.02194 | |
| Vol. After Consol. (cu ft) | 0.02028 | |

Notes & Comments: Did not use slotted filter paper drains due to permeability test prior to shear.

| | | | | | |
|---|---|---|---|---|---|
| Data entry by: | SPH | Date: | 10/23/2018 | Technician | CAL |
| Data checked by: | CAL | Date: | 10/23/18 | | |
| FileName: | 2679_130_TX_CUpp_ASTMD_4767_R0_1.xls | | | | Page 1 of 4 |

ADVANCED TERRA TESTING

# CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
## ASTM D4767

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/19/2018 |
| BORING NO. | B-103 | CELL NUMBER | 24S |
| DEPTH | 27.5-29.9' (29.15-29.65) | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. A | CONF. PRES. (psf) | 10000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

### SATURATION DATA

| Cell Pressure (psi) | Back Pressure (psi) | Burette Reading (cc) Close | Burette Reading (cc) Open | Pore Pressure (psi) Close | Pore Pressure (psi) Open | Change | B |
|---|---|---|---|---|---|---|---|
| 40.0 | 38.0 | 3.2 | 19.3 | | | | |
| 50.0 | | 20.0 | 20.3 | 38.7 | 48.4 | 9.7 | 0.97 |

### CONSOLIDATION DATA

| Elapsed Time (min) | SQRT TIME (min) | Burette Reading (cc) | Volume Deflection (cc) |
|---|---|---|---|
| 0.00 | 0.0 | 0.80 | 0.00 |
| 0.25 | 0.5 | 34.60 | -33.80 |
| 0.5 | 0.7 | 36.70 | -35.90 |
| 1 | 1.0 | 37.80 | -37.00 |
| 2 | 1.4 | 38.60 | -37.80 |
| 4 | 2.0 | 39.30 | -38.50 |
| 9 | 3.0 | 40.10 | -39.30 |
| 16 | 4.0 | 40.80 | -40.00 |
| 30 | 5.5 | 41.50 | -40.70 |
| 88 | 9.4 | 42.70 | -41.90 |
| 120 | 11.0 | 43.10 | -42.30 |
| 240 | 15.5 | 43.90 | -43.10 |
| 360 | 19.0 | 44.30 | -43.50 |
| 1450 | 38.1 | 45.90 | -45.10 |

| | | | |
|---|---|---|---|
| Initial Height (in) | 5.852 | Initial Vol. (cc) | 621.358 |
| Height Change (in) | 0.151 | Vol. Change (cc) | 62.800 |
| Ht. After Cons. (in) | 5.701 | Cell Exp. (cc) | 15.703 |
| Initial Area (sq in) | 6.478 | Net Change (cc) | 47.097 |
| Area After Cons. (sq in) | 6.146 | Cons. Vol. (cc) | 574.261 |

ADVANCED TERRA TESTING

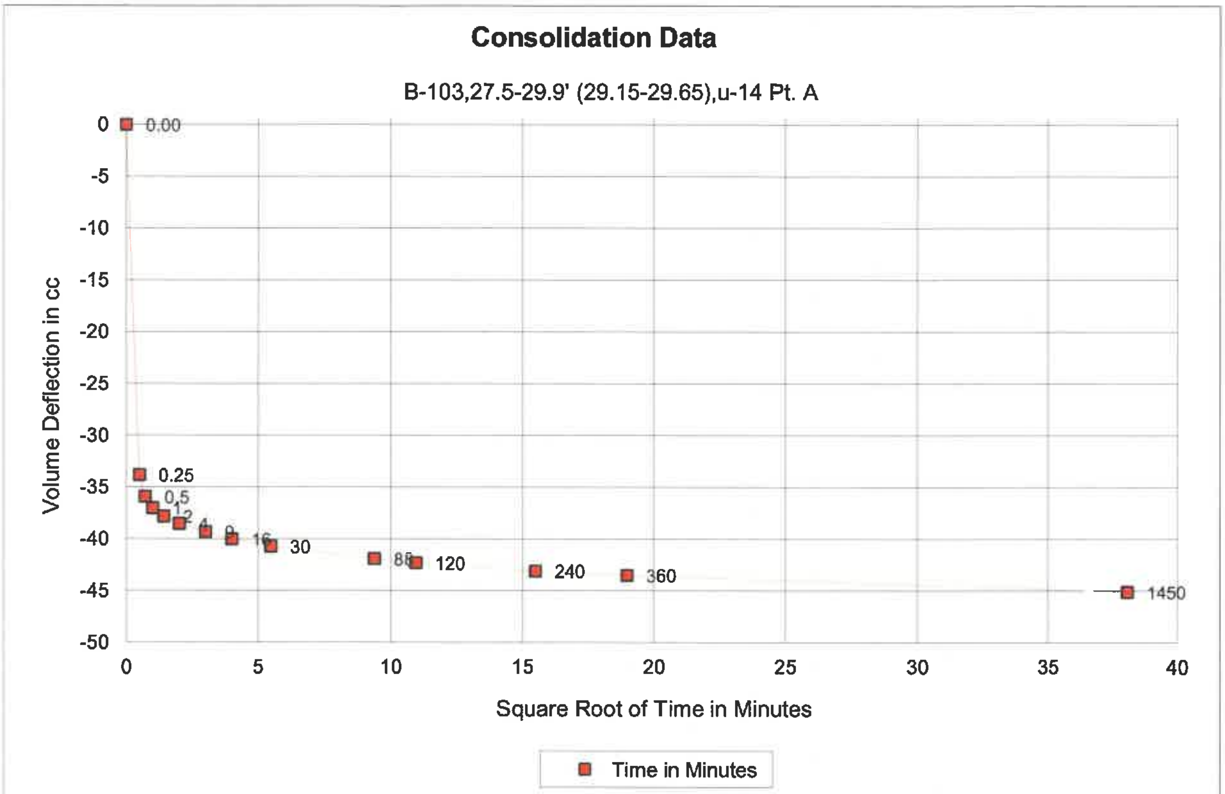
# CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
ASTM D 4767

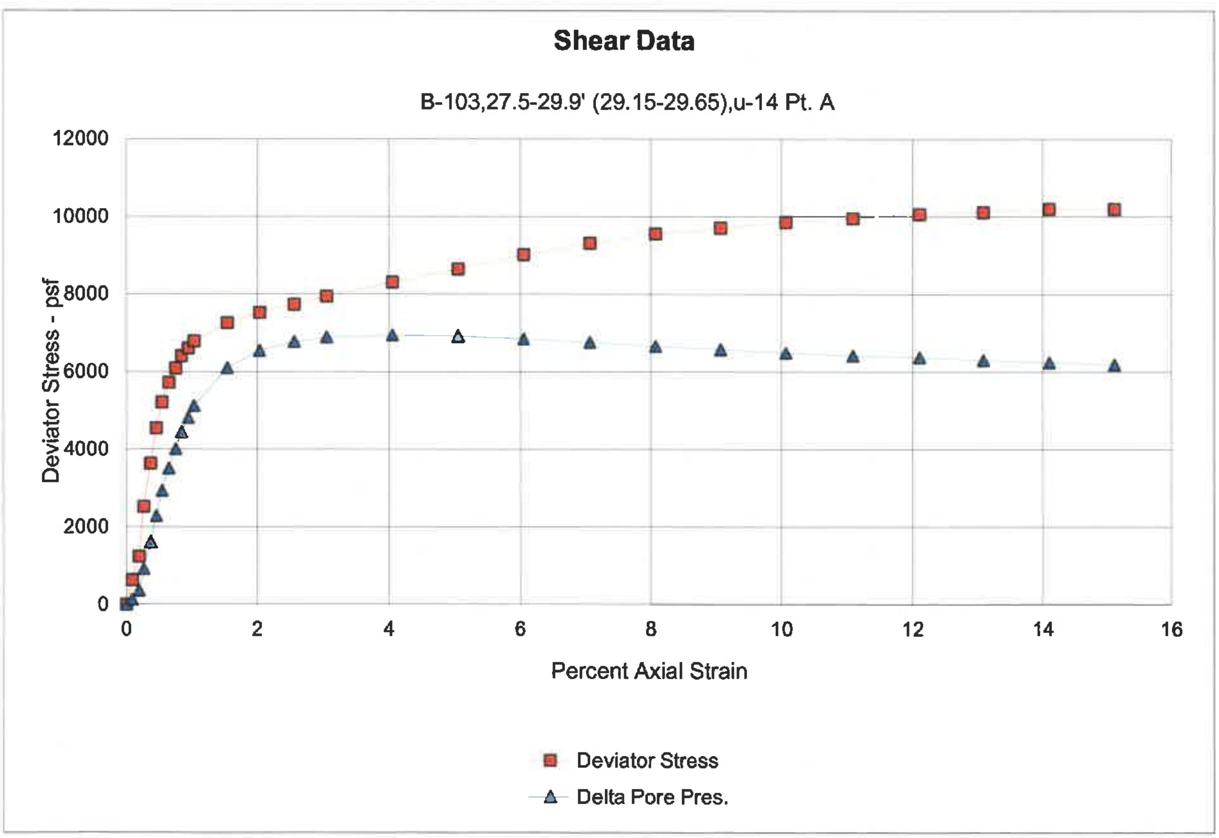
| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/19/2018 |
| BORING NO. | B-103 | CELL NUMBER | 24S |
| DEPTH | 27.5-29.9' (29.15-29.65) | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. A | CONF. PRES. (psf) | 10000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

| | | | |
|---|---|---|---|
| Init. Ht. (in) | 5.852 | Init. Area (sq in) | 6.478 |
| Consol. Ht. (in) | 5.701 | Consol. Area (sq in) | 6.146 |
| Back Pres. (psi) | 38.3 | Strain Rate (in/min) | 0.0027 |

| Axial Load (lbs.) | Axial Load (psf) | Delta Ht. (in) | Axial Strain (%) | Area Final (sq in) | Dev. Stress (psf) | Pore Pres. (psi) | Delta Pres. (psf) | Sigma 3' (psf) | Sigma 1' (psf) | Prin. Stress Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0 | 0.000 | 0.00 | 6.146 | 0 | 38.3 | 0 | 10000 | 10000 | 1.00 |
| 27 | 633 | 0.005 | 0.09 | 6.151 | 632 | 39.2 | 130 | 9870 | 10502 | 1.06 |
| 53 | 1242 | 0.011 | 0.19 | 6.158 | 1239 | 40.8 | 360 | 9640 | 10879 | 1.13 |
| 108 | 2531 | 0.015 | 0.26 | 6.162 | 2524 | 44.7 | 922 | 9078 | 11602 | 1.28 |
| 156 | 3655 | 0.021 | 0.37 | 6.169 | 3642 | 49.5 | 1613 | 8387 | 12029 | 1.43 |
| 195 | 4569 | 0.026 | 0.46 | 6.174 | 4548 | 54.2 | 2290 | 7710 | 12259 | 1.59 |
| 224 | 5248 | 0.031 | 0.54 | 6.179 | 5220 | 58.7 | 2938 | 7062 | 12282 | 1.74 |
| 246 | 5764 | 0.037 | 0.65 | 6.186 | 5727 | 62.7 | 3514 | 6486 | 12213 | 1.88 |
| 262 | 6139 | 0.043 | 0.75 | 6.193 | 6093 | 66.2 | 4018 | 5982 | 12075 | 2.02 |
| 276 | 6467 | 0.048 | 0.84 | 6.198 | 6412 | 69.2 | 4450 | 5550 | 11963 | 2.16 |
| 285 | 6678 | 0.054 | 0.95 | 6.205 | 6614 | 71.8 | 4824 | 5176 | 11790 | 2.28 |
| 293 | 6865 | 0.059 | 1.03 | 6.210 | 6794 | 73.9 | 5126 | 4874 | 11668 | 2.39 |
| 315 | 7381 | 0.088 | 1.54 | 6.242 | 7267 | 80.7 | 6106 | 3894 | 11161 | 2.87 |
| 328 | 7685 | 0.116 | 2.03 | 6.273 | 7529 | 83.8 | 6552 | 3448 | 10977 | 3.18 |
| 339 | 7943 | 0.146 | 2.56 | 6.307 | 7740 | 85.4 | 6782 | 3218 | 10957 | 3.41 |
| 350 | 8201 | 0.174 | 3.05 | 6.339 | 7950 | 86.2 | 6898 | 3102 | 11053 | 3.56 |
| 370 | 8669 | 0.231 | 4.05 | 6.405 | 8318 | 86.6 | 6955 | 3045 | 11363 | 3.73 |
| 389 | 9114 | 0.288 | 5.05 | 6.473 | 8654 | 86.4 | 6926 | 3074 | 11728 | 3.82 |
| 410 | 9607 | 0.345 | 6.05 | 6.542 | 9025 | 85.9 | 6854 | 3146 | 12171 | 3.87 |
| 428 | 10028 | 0.403 | 7.07 | 6.613 | 9319 | 85.3 | 6768 | 3232 | 12551 | 3.88 |
| 444 | 10403 | 0.460 | 8.07 | 6.685 | 9564 | 84.6 | 6667 | 3333 | 12897 | 3.87 |
| 456 | 10684 | 0.517 | 9.07 | 6.759 | 9715 | 84.0 | 6581 | 3419 | 13135 | 3.84 |
| 468 | 10966 | 0.574 | 10.07 | 6.834 | 9861 | 83.4 | 6494 | 3506 | 13367 | 3.81 |
| 478 | 11200 | 0.632 | 11.09 | 6.912 | 9958 | 82.9 | 6422 | 3578 | 13536 | 3.78 |
| 489 | 11458 | 0.690 | 12.10 | 6.992 | 10071 | 82.6 | 6379 | 3621 | 13692 | 3.78 |
| 497 | 11645 | 0.746 | 13.09 | 7.071 | 10121 | 82.1 | 6307 | 3693 | 13814 | 3.74 |
| 507 | 11879 | 0.804 | 14.10 | 7.155 | 10204 | 81.7 | 6250 | 3750 | 13954 | 3.72 |
| 513 | 12020 | 0.862 | 15.12 | 7.241 | 10202 | 81.3 | 6192 | 3808 | 14010 | 3.68 |

# CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST
# FOR COHESIVE SOILS
# ASTM D4767

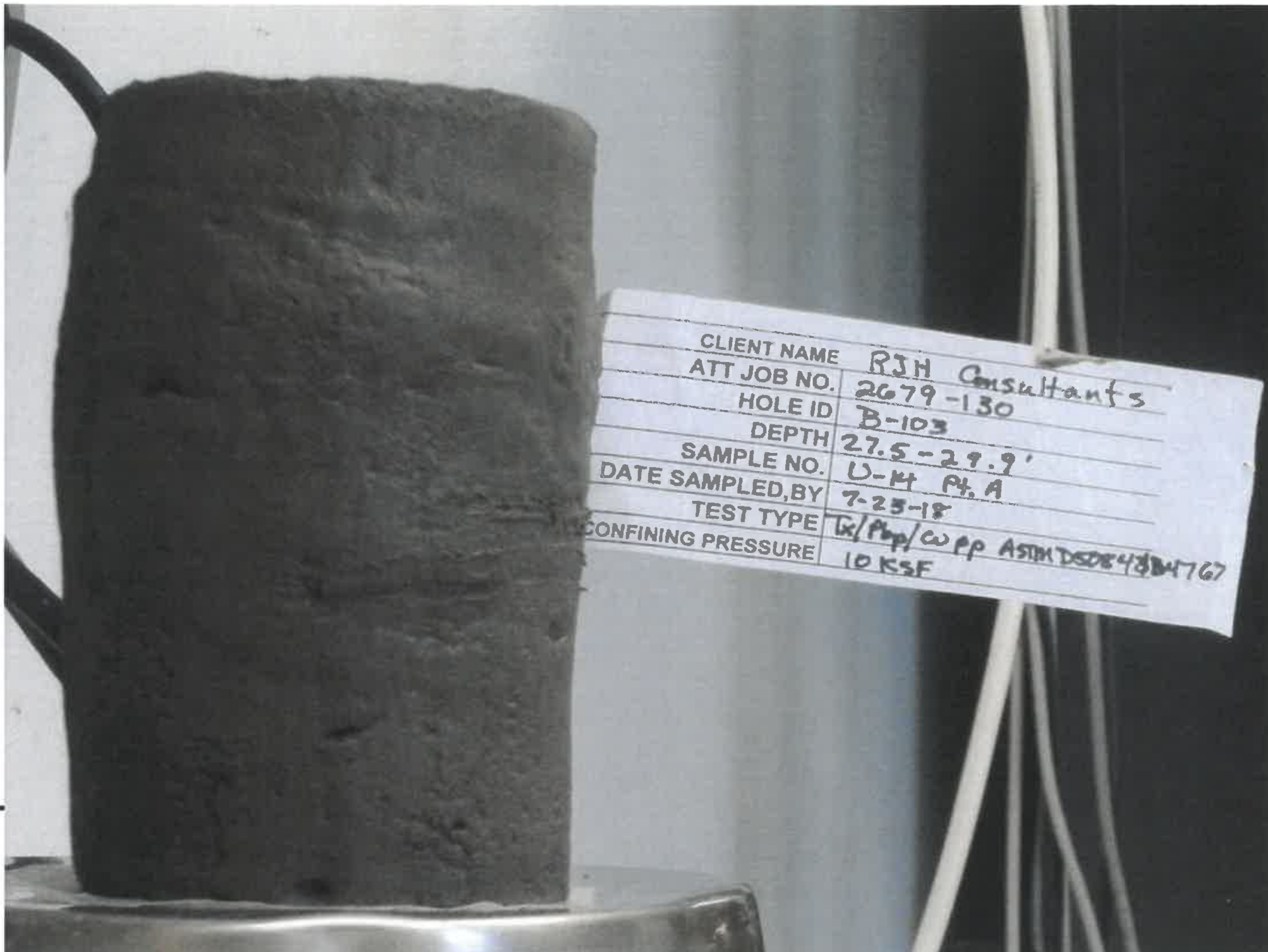


# Image Attachment

ADVANCED TERRA TESTING

| | |
|---|---|
| CLIENT | RJH Consultants |
| JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation |
| PROJECT NO. | 18115 |
| LOCATION | -- |




File name: 2679130__Image_18_10_22_06_53_56

ATT
ADVANCED TERRA TESTING

## CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
ASTM D4767

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/22/2018 |
| BORING NO. | B-103 | CELL NUMBER | 18S |
| DEPTH | 27.5-29.9' (28.65-29.15') | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. B | CONF. PRES. (psf) | 6000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

| MOISTURE/DENSITY DATA | BEFORE TEST | AFTER TEST |
|---|---|---|
| Wt. Soil + Moisture (g) | 1281.53 | 1261.98 |
| Wt. Wet Soil & Pan (g) | 1295.34 | 1275.79 |
| Wt. Dry Soil & Pan (g) | 1037.24 | 1037.24 |
| Wt. Lost Moisture (g) | 258.10 | 238.55 |
| Wt. of Pan Only (g) | 13.81 | 13.81 |
| Wt. of Dry Soil (g) | 1023.43 | 1023.43 |
| Moisture Content % | 25.2 | 23.3 |
| Wet Density (pcf) | 126.4 | 132.4 |
| Dry Density (pcf) | 101.0 | 107.3 |
| Init. Diameter (in) | 2.869 | |
| Init. Area (sq in) | 6.465 | |
| Init. Height (in) | 5.973 | |
| Vol. Bef. Consol. (cu ft) | 0.02235 | |
| Vol. After Consol. (cu ft) | 0.02102 | |

Notes & Comments: Did not use slotted filter paper drains due to permeability test prior to shear.

Data entry by: CAL  Date: 10/24/2018  Technician CAL
Data checked by: SPH  Date: 10-24-18
FileName: 2679_130_TX_CUpp_ASTMD_4767_R0_2.xls

ADVANCED TERRA TESTING

# CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
ASTM D4767

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/22/2018 |
| BORING NO. | B-103 | CELL NUMBER | 18S |
| DEPTH | 27.5-29.9' (28.65-29.15') | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. B | CONF. PRES. (psf) | 6000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

## SATURATION DATA

| Cell Pressure (psi) | Back Pressure (psi) | Burette Reading (cc) | | Pore Pressure (psi) | | Change | B |
|---|---|---|---|---|---|---|---|
| | | Close | Open | Close | Open | | |
| 40.0 | 38.0 | 4.0 | 18.3 | | | | |
| 50.0 | 48.0 | 19.3 | 20.1 | 38.4 | 47.8 | 9.4 | 0.94 |
| 60.0 | | 20.4 | 20.5 | 48.5 | 58.0 | 9.5 | 0.95 |

## CONSOLIDATION DATA

| Elapsed Time (min) | SQRT TIME (min) | Burette Reading (cc) | Volume Deflection (cc) |
|---|---|---|---|
| 0.00 | 0.0 | 0.30 | 0.00 |
| 0.25 | 0.5 | 24.30 | -24.00 |
| 0.5 | 0.7 | 25.40 | -25.10 |
| 1 | 1.0 | 26.10 | -25.80 |
| 2 | 1.4 | 26.60 | -26.30 |
| 4 | 2.0 | 27.20 | -26.90 |
| 9 | 3.0 | 27.80 | -27.50 |
| 16 | 4.0 | 28.30 | -28.00 |
| 30 | 5.5 | 28.90 | -28.60 |
| 60 | 7.7 | 29.50 | -29.20 |
| 120 | 11.0 | 30.10 | -29.80 |
| 240 | 15.5 | 30.80 | -30.50 |
| 360 | 19.0 | 31.10 | -30.80 |
| 1440 | 37.9 | 32.20 | -31.90 |

| | | | |
|---|---|---|---|
| Initial Height (in) | 5.973 | Initial Vol. (cc) | 632.882 |
| Height Change (in) | 0.116 | Vol. Change (cc) | 49.500 |
| Ht. After Cons. (in) | 5.857 | Cell Exp. (cc) | 11.962 |
| Initial Area (sq in) | 6.465 | Net Change (cc) | 37.538 |
| Area After Cons. (sq in) | 6.202 | Cons. Vol. (cc) | 595.343 |

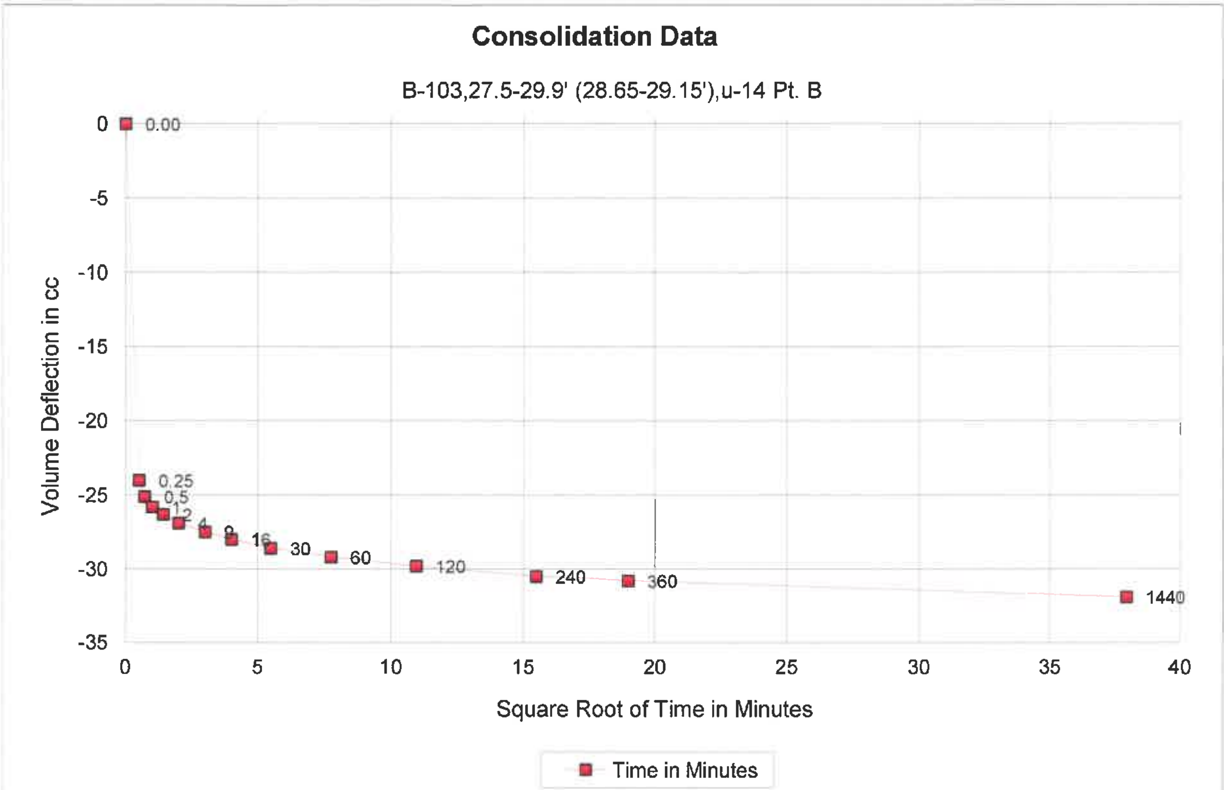
ADVANCED TERRA TESTING

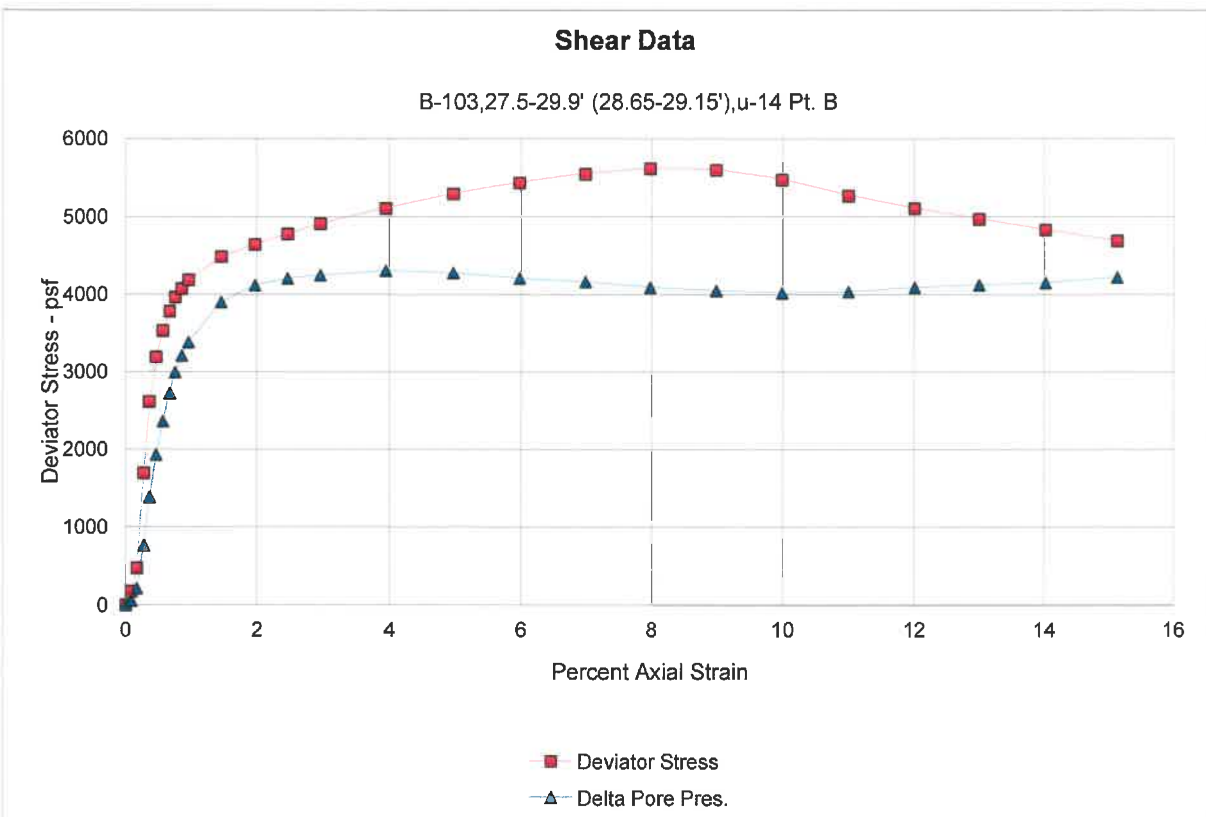
# CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
## ASTM D 4767

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/22/2018 |
| BORING NO. | B-103 | CELL NUMBER | 18S |
| DEPTH | 27.5-29.9' (28.65-29.15') | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. B | CONF. PRES. (psf) | 6000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

| | | | |
|---|---|---|---|
| Init. Ht. (in) | 5.973 | Init. Area (sq in) | 6.465 |
| Consol. Ht. (in) | 5.857 | Consol. Area (sq in) | 6.202 |
| Back Pres. (psi) | 48.3 | Strain Rate (in/min) | 0.0023 |

| Axial Load (lbs.) | Axial Load (psf) | Delta Ht. (in) | Axial Strain (%) | Area Final (sq in) | Dev. Stress (psf) | Pore Pres. (psi) | Delta Pres. (psf) | Sigma 3' (psf) | Sigma 1' (psf) | Prin. Stress Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0 | 0.000 | 0.00 | 6.202 | 0 | 48.3 | 0 | 6000 | 6000 | 1.00 |
| 7.6 | 176 | 0.005 | 0.09 | 6.207 | 176 | 48.7 | 58 | 5942 | 6119 | 1.03 |
| 20.5 | 476 | 0.010 | 0.17 | 6.212 | 475 | 49.8 | 216 | 5784 | 6259 | 1.08 |
| 73.2 | 1700 | 0.016 | 0.27 | 6.219 | 1695 | 53.6 | 763 | 5237 | 6932 | 1.32 |
| 113 | 2624 | 0.021 | 0.36 | 6.224 | 2614 | 57.9 | 1382 | 4618 | 7232 | 1.57 |
| 138 | 3204 | 0.027 | 0.46 | 6.230 | 3189 | 61.7 | 1930 | 4070 | 7260 | 1.78 |
| 153 | 3553 | 0.033 | 0.56 | 6.237 | 3533 | 64.7 | 2362 | 3638 | 7171 | 1.97 |
| 164 | 3808 | 0.039 | 0.67 | 6.243 | 3783 | 67.2 | 2722 | 3278 | 7061 | 2.15 |
| 172 | 3994 | 0.044 | 0.75 | 6.249 | 3964 | 69.1 | 2995 | 3005 | 6969 | 2.32 |
| 177 | 4110 | 0.050 | 0.85 | 6.255 | 4075 | 70.6 | 3211 | 2789 | 6864 | 2.46 |
| 182 | 4226 | 0.056 | 0.96 | 6.262 | 4186 | 71.8 | 3384 | 2616 | 6802 | 2.60 |
| 196 | 4551 | 0.085 | 1.45 | 6.293 | 4485 | 75.4 | 3902 | 2098 | 6583 | 3.14 |
| 204 | 4737 | 0.115 | 1.96 | 6.326 | 4644 | 76.9 | 4118 | 1882 | 6525 | 3.47 |
| 211 | 4899 | 0.144 | 2.46 | 6.358 | 4779 | 77.5 | 4205 | 1795 | 6574 | 3.66 |
| 218 | 5062 | 0.173 | 2.95 | 6.390 | 4912 | 77.8 | 4248 | 1752 | 6664 | 3.80 |
| 229 | 5317 | 0.231 | 3.94 | 6.456 | 5108 | 78.2 | 4306 | 1694 | 6802 | 4.01 |
| 240 | 5573 | 0.291 | 4.97 | 6.526 | 5296 | 78.0 | 4277 | 1723 | 7019 | 4.07 |
| 249 | 5782 | 0.350 | 5.98 | 6.596 | 5436 | 77.5 | 4205 | 1795 | 7231 | 4.03 |
| 257 | 5967 | 0.409 | 6.98 | 6.667 | 5551 | 77.2 | 4162 | 1838 | 7389 | 4.02 |
| 263 | 6107 | 0.467 | 7.97 | 6.739 | 5620 | 76.7 | 4090 | 1910 | 7530 | 3.94 |
| 265 | 6153 | 0.526 | 8.98 | 6.814 | 5601 | 76.4 | 4046 | 1954 | 7554 | 3.87 |
| 262 | 6083 | 0.585 | 9.99 | 6.890 | 5476 | 76.2 | 4018 | 1982 | 7458 | 3.76 |
| 255 | 5921 | 0.644 | 11.00 | 6.968 | 5270 | 76.3 | 4032 | 1968 | 7238 | 3.68 |
| 250 | 5805 | 0.703 | 12.00 | 7.048 | 5108 | 76.7 | 4090 | 1910 | 7018 | 3.67 |
| 246 | 5712 | 0.761 | 12.99 | 7.128 | 4970 | 76.9 | 4118 | 1882 | 6851 | 3.64 |
| 242 | 5619 | 0.821 | 14.02 | 7.213 | 4831 | 77.1 | 4147 | 1853 | 6684 | 3.61 |
| 238 | 5526 | 0.886 | 15.13 | 7.307 | 4690 | 77.6 | 4219 | 1781 | 6471 | 3.63 |

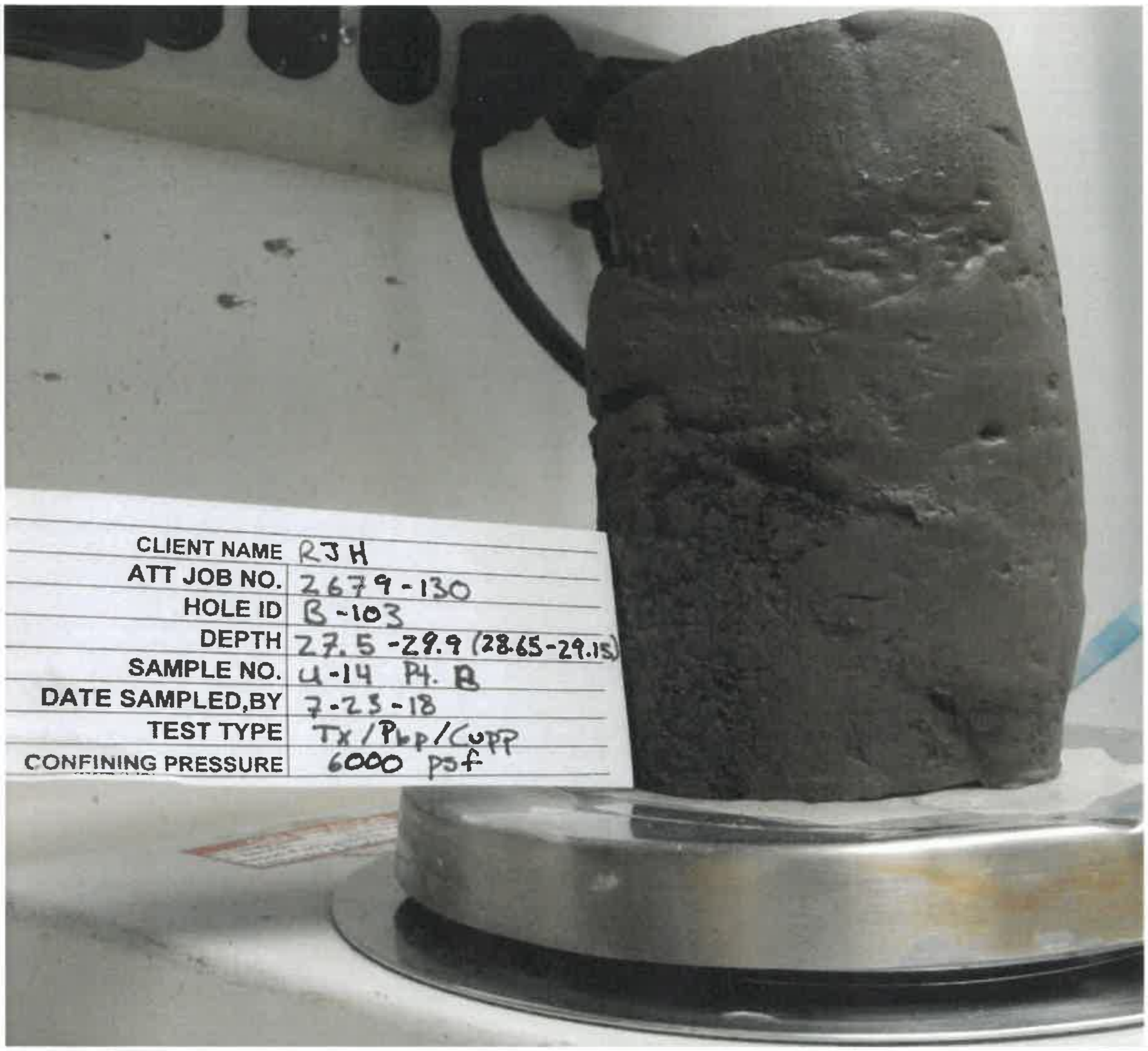

Consolidation Data
B-103,27.5-29.9' (28.65-29.15'),u-14 Pt. B
Volume Deflection in cc
Square Root of Time in Minutes
0.00
0.25
0.5
1
2
4
9
16
30
60
120
240
360
1440
Time in Minutes


Shear Data
B-103,27.5-29.9' (28.65-29.15'),u-14 Pt. B
Deviator Stress - psf
Percent Axial Strain
Deviator Stress
Delta Pore Pres.

ADVANCED TERRA TESTING

# Image Attachment

| | |
|---|---|
| CLIENT | RJH Consultants |
| JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation |
| PROJECT NO. | 18115 |
| LOCATION | -- |




| NOTES | |
|---|---|

File name: 2679130__Image_18_10_24_07_21_35

ADVANCED TERRA TESTING

# CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
ASTM D4767

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/22/2018 |
| BORING NO. | B-103 | CELL NUMBER | 16S |
| DEPTH | 28.15-28.65' | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. C | CONF. PRES. (psf) | 3000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

| MOISTURE/DENSITY DATA | BEFORE TEST | AFTER TEST |
|---|---|---|
| Wt. Soil + Moisture (g) | 1321.10 | 1316.30 |
| Wt. Wet Soil & Pan (g) | 1335.31 | 1330.51 |
| Wt. Dry Soil & Pan (g) | 1081.21 | 1081.21 |
| Wt. Lost Moisture (g) | 254.10 | 249.30 |
| Wt. of Pan Only (g) | 14.21 | 14.21 |
| Wt. of Dry Soil (g) | 1067.00 | 1067.00 |
| Moisture Content % | 23.8 | 23.4 |
| Wet Density (pcf) | 127.5 | 132.5 |
| Dry Density (pcf) | 103.0 | 107.4 |
| Init. Diameter (in) | 2.868 | |
| Init. Area (sq in) | 6.460 | |
| Init. Height (in) | 6.109 | |
| Vol. Bef. Consol. (cu ft) | 0.02284 | |
| Vol. After Consol. (cu ft) | 0.02191 | |

Notes & Comments: Did not use slotted filter paper drains due to permeability test prior to shear.

Data entry by: SPH  Date: 10/23/2018  Technician CAL

Data checked by: CLL  Date: 10/23/2018

FileName: 2679_130_TX_CUpp_ASTMD_4767_R0_0.xls

ADVANCED TERRA TESTING

# CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
ASTM D4767

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/22/2018 |
| BORING NO. | B-103 | CELL NUMBER | 16S |
| DEPTH | 28.15-28.65' | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. C | CONF. PRES. (psf) | 3000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

## SATURATION DATA

| Cell Pressure (psi) | Back Pressure (psi) | Burette Reading (cc) Close | Burette Reading (cc) Open | Pore Pressure (psi) Close | Pore Pressure (psi) Open | Change | B |
|---|---|---|---|---|---|---|---|
| 40.0 | 38.0 | 4.0 | 19.8 | | | | |
| 50.0 | 48.0 | 20.6 | 21.6 | 38.9 | 48.2 | 9.3 | 0.93 |
| 60.0 | | 21.9 | 22.0 | 48.7 | 58.3 | 9.6 | 0.96 |

## CONSOLIDATION DATA

| Elapsed Time (min) | SQRT TIME (min) | Burette Reading (cc) | Volume Deflection (cc) |
|---|---|---|---|
| 0.00 | 0.0 | 0.50 | 0.00 |
| 0.25 | 0.5 | 12.45 | -11.95 |
| 0.5 | 0.7 | 13.70 | -13.20 |
| 1 | 1.0 | 14.80 | -14.30 |
| 2 | 1.4 | 15.40 | -14.90 |
| 4 | 2.0 | 15.90 | -15.40 |
| 9 | 3.0 | 16.25 | -15.75 |
| 16 | 4.0 | 16.65 | -16.15 |
| 30 | 5.5 | 17.00 | -16.50 |
| 60 | 7.7 | 17.50 | -17.00 |
| 120 | 11.0 | 17.90 | -17.40 |
| 240 | 15.5 | 18.30 | -17.80 |
| 360 | 19.0 | 18.50 | -18.00 |
| 1440 | 37.9 | 19.30 | -18.80 |

| | | | |
|---|---|---|---|
| Initial Height (in) | 6.109 | Initial Vol. (cc) | 646.841 |
| Height Change (in) | 0.054 | Vol. Change (cc) | 37.800 |
| Ht. After Cons. (in) | 6.055 | Cell Exp. (cc) | 11.361 |
| Initial Area (sq in) | 6.460 | Net Change (cc) | 26.439 |
| Area After Cons. (sq in) | 6.252 | Cons. Vol. (cc) | 620.401 |

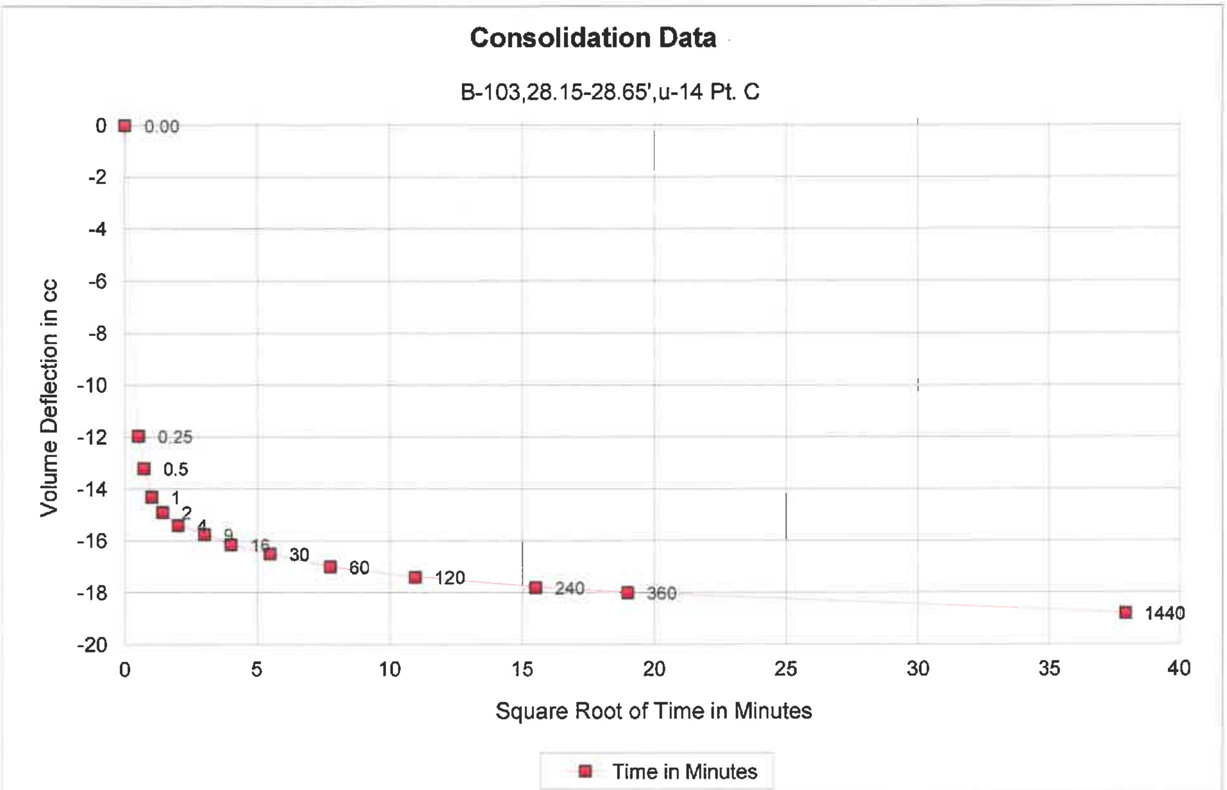
ADVANCED TERRA TESTING

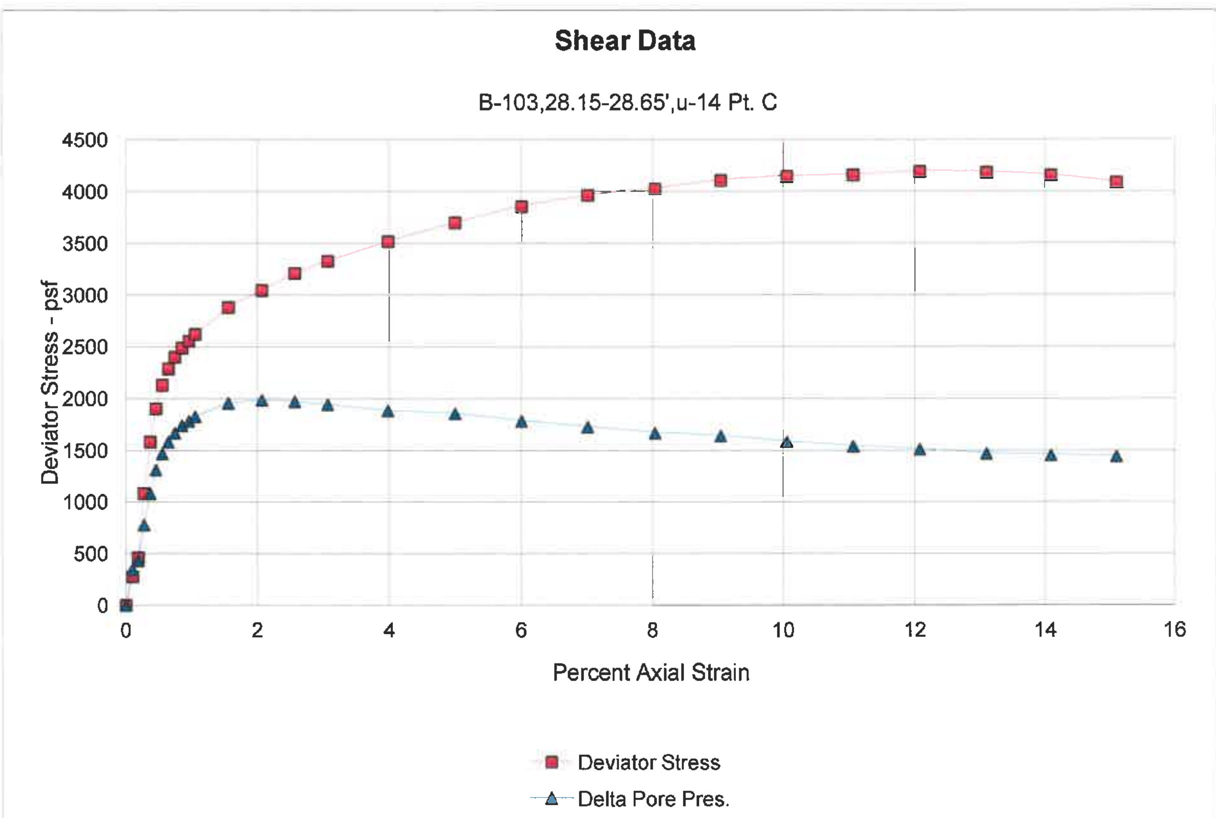
## CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST FOR COHESIVE SOILS
ASTM D 4767

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |
| PROJECT | Hogchute Dam Safety Evaluation | Date Sampled | 7/23/2018 |
| PROJECT NO. | 18115 | Date Tested | 10/22/2018 |
| BORING NO. | B-103 | CELL NUMBER | 16S |
| DEPTH | 28.15-28.65' | SATURATED TEST | Yes |
| SAMPLE NO. | u-14 Pt. C | CONF. PRES. (psf) | 3000 |
| LOCATION | -- | | |
| SAMPLE TYPE | Shelby Tube | | |

| | | | |
|---|---|---|---|
| Init. Ht. (in) | 6.109 | Init. Area (sq in) | 6.460 |
| Consol. Ht. (in) | 6.055 | Consol. Area (sq in) | 6.252 |
| Back Pres. (psi) | 48.3 | Strain Rate (in/min) | 0.0036 |

| Axial Load (lbs.) | Axial Load (psf) | Delta Ht. (in) | Axial Strain (%) | Area Final (sq in) | Dev. Stress (psf) | Pore Pres. (psi) | Delta Pres. (psf) | Sigma 3' (psf) | Sigma 1' (psf) | Prin. Stress Ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.0 | 0 | 0.000 | 0.00 | 6.252 | 0 | 48.3 | 0 | 3000 | 3000 | 1.00 |
| 12 | 276 | 0.006 | 0.10 | 6.258 | 276 | 50.7 | 346 | 2654 | 2931 | 1.10 |
| 20 | 461 | 0.011 | 0.19 | 6.263 | 460 | 51.3 | 432 | 2568 | 3028 | 1.18 |
| 47 | 1083 | 0.017 | 0.27 | 6.269 | 1080 | 53.7 | 778 | 2222 | 3302 | 1.49 |
| 69 | 1589 | 0.022 | 0.37 | 6.275 | 1583 | 55.8 | 1080 | 1920 | 3503 | 1.82 |
| 83 | 1912 | 0.028 | 0.45 | 6.280 | 1903 | 57.4 | 1310 | 1690 | 3593 | 2.13 |
| 93 | 2142 | 0.033 | 0.55 | 6.286 | 2130 | 58.5 | 1469 | 1531 | 3662 | 2.39 |
| 100 | 2303 | 0.039 | 0.64 | 6.292 | 2289 | 59.3 | 1584 | 1416 | 3705 | 2.62 |
| 105 | 2419 | 0.045 | 0.74 | 6.299 | 2401 | 59.9 | 1670 | 1330 | 3730 | 2.81 |
| 109 | 2511 | 0.052 | 0.85 | 6.305 | 2489 | 60.4 | 1742 | 1258 | 3747 | 2.98 |
| 112 | 2580 | 0.058 | 0.96 | 6.312 | 2555 | 60.7 | 1786 | 1214 | 3769 | 3.10 |
| 115 | 2649 | 0.064 | 1.05 | 6.318 | 2621 | 61.0 | 1829 | 1171 | 3792 | 3.24 |
| 127 | 2925 | 0.094 | 1.56 | 6.351 | 2880 | 61.9 | 1958 | 1042 | 3921 | 3.76 |
| 135 | 3110 | 0.125 | 2.06 | 6.384 | 3045 | 62.1 | 1987 | 1013 | 4058 | 4.01 |
| 143 | 3294 | 0.155 | 2.56 | 6.416 | 3209 | 62.0 | 1973 | 1027 | 4237 | 4.12 |
| 149 | 3432 | 0.186 | 3.07 | 6.449 | 3327 | 61.8 | 1944 | 1056 | 4383 | 4.15 |
| 159 | 3662 | 0.241 | 3.98 | 6.511 | 3517 | 61.4 | 1886 | 1114 | 4630 | 4.16 |
| 169 | 3893 | 0.302 | 4.99 | 6.580 | 3698 | 61.2 | 1858 | 1142 | 4841 | 4.24 |
| 178 | 4100 | 0.364 | 6.00 | 6.651 | 3854 | 60.7 | 1786 | 1214 | 5068 | 4.17 |
| 185 | 4261 | 0.424 | 7.01 | 6.723 | 3963 | 60.3 | 1728 | 1272 | 5235 | 4.12 |
| 190 | 4376 | 0.487 | 8.04 | 6.798 | 4025 | 59.9 | 1670 | 1330 | 5354 | 4.03 |
| 196 | 4515 | 0.547 | 9.04 | 6.873 | 4107 | 59.7 | 1642 | 1358 | 5465 | 4.02 |
| 200 | 4607 | 0.609 | 10.05 | 6.950 | 4144 | 59.3 | 1584 | 1416 | 5560 | 3.93 |
| 203 | 4676 | 0.670 | 11.06 | 7.029 | 4158 | 59.0 | 1541 | 1459 | 5618 | 3.85 |
| 207 | 4768 | 0.731 | 12.07 | 7.110 | 4192 | 58.8 | 1512 | 1488 | 5680 | 3.82 |
| 209 | 4814 | 0.793 | 13.10 | 7.194 | 4183 | 58.5 | 1469 | 1531 | 5715 | 3.73 |
| 210 | 4837 | 0.853 | 14.09 | 7.277 | 4156 | 58.4 | 1454 | 1546 | 5701 | 3.69 |
| 209 | 4814 | 0.915 | 15.11 | 7.364 | 4087 | 58.3 | 1440 | 1560 | 5647 | 3.62 |

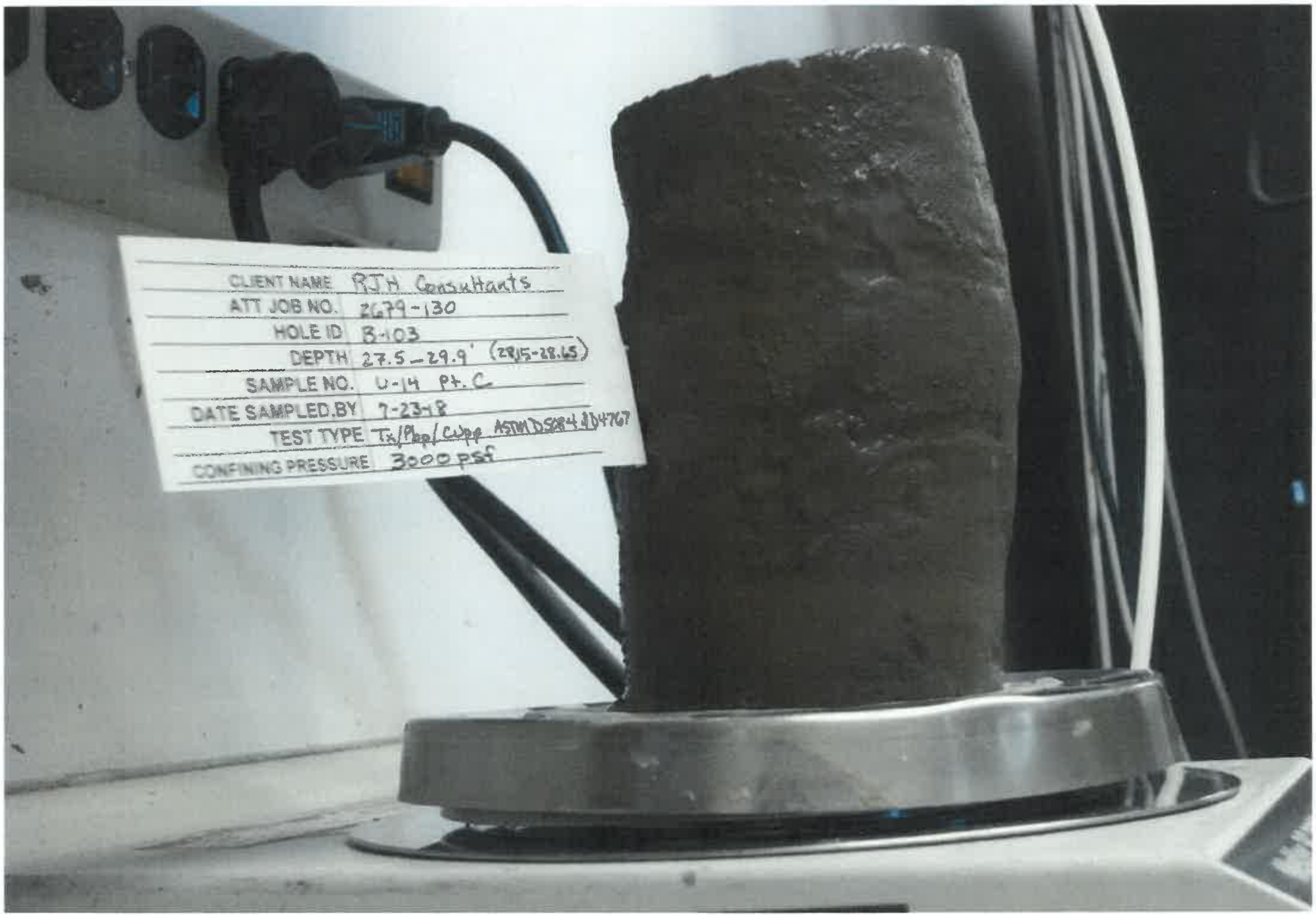

Consolidation Data
B-103,28.15-28.65',u-14 Pt. C
Volume Deflection in cc
Square Root of Time in Minutes
0.00
0.25
0.5
1
2
4
9
16
30
60
120
240
360
1440
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
5
10
15
20
25
30
35
40
Time in Minutes


Shear Data
B-103,28.15-28.65',u-14 Pt. C
Deviator Stress - psf
Percent Axial Strain
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0
2
4
6
8
10
12
14
16
Deviator Stress
Delta Pore Pres.

ADVANCED TERRA TESTING

# Image Attachment

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |




| | |
|---|---|
| NOTES | |

File name: 2679130__Image_18_10_23_07_17_37

Permeability Test
Flow Pump
ASTM D5084, Method D

ATT ADVANCED TERRA TESTING

# PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD

ASTM D5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |

| | | | | |
|---|---|---|---|---|
| PROJECT | Hogchute Dam Safety Evaluation | | | |
| PROJECT NO. | 18115 | SAMPLED | 7/23/2018 | By: -- |
| BORING NO. | B-103 | TEST STARTED | 10/16/2018 | By: CAL |
| DEPTH | 27.5-29.9' (29.15-29.65) | TEST FINISHED | 10/19/2018 | By: CAL |
| SAMPLE NO. | u-14 Pt. A | CELL NUMBER | 24S | |
| LOCATION | -- | PERMEANT | Tap Water | |
| SAMPLE TYPE | Shelby Tube | CONF. PRES. - (psf) | 10000 | |

| MOISTURE / DENSITY DATA | BEFORE TEST | AFTER TEST |
|---|---|---|
| Wt. Soil + Moisture - (g) | 1266.40 | 1226.21 |
| Wt. Wet Soil & Pan - (g) | 1280.85 | 1240.66 |
| Wt. Dry Soil & Pan - (g) | 1017.19 | 1017.19 |
| Wt. Lost Moisture - (g) | 263.66 | 223.47 |
| Wt. of Pan Only - (g) | 14.45 | 14.45 |
| Wt. of Dry Soil - (g) | 1002.74 | 1002.74 |
| Moisture Content - (%) | 26.3 | 22.3 |
| Wet Density - (pcf) | 127.3 | 133.3 |
| Dry Density - (pcf) | 100.8 | 109.0 |
| Init. Diameter - (in) | 2.872 | |
| Init. Area - (sq in) | 6.478 | |
| Init. Height - (in) | 5.852 | |
| Vol. Bef. Consol. - (cu ft) | 0.02194 | |
| Vol. After Consol. - (cu ft) | 0.02028 | |
| Porosity - (%) | 38.91 | |

## FLOW PUMP CALCULATIONS

| | |
|---|---|
| Pump Setting (gear number) | 7 |
| Percentage of Pump Setting | 100 |
| Q - (cc/s) | 3.54E-04 |
| Height - (in) | 5.701 |
| Diameter - (in) | 2.797 |
| Pressure - (psi) | 0.107 |
| Area after consol. - (sq cm) | 39.650 |
| Gradient | 0.520 |
| Permeability k - (cm/s) | 1.7E-05 |
| Permeability k - (m/s) | 1.7E-07 |
| Back Pressure - (psi) | 38.0 |
| Cell Pressure - (psi) | 107.4 |
| Ave. Effective Stress - (psi) | 69.347 |
| Average temperature degree - (c°) | 22.0 |

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 10/23/2018 |
| Checked by: | ch | Date: | 10/23/2018 |

FileName: 2679_130_HarvardFlowPump-Perm-ASTMD-5084-R3_1.xls

ATT ADVANCED TERRA TESTING

# PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD

ASTM D5084 Method D

| | | | | | |
|---|---|---|---|---|---|
| CLIENT | RJH Consultants | | JOB NO. | 2679-130 | |
| PROJECT | Hogchute Dam Safety Evaluation | | | | |
| PROJECT NO. | 18115 | SAMPLED | 7/23/2018 | By: -- | |
| BORING NO. | B-103 | TEST STARTED | 10/16/2018 | By: CAL | |
| DEPTH | 27.5-29.9' (29.15-29.65) | TEST FINISHED | 10/19/2018 | By: CAL | |
| SAMPLE NO. | u-14 Pt. A | CELL NUMBER | 24S | | |
| LOCATION | -- | PERMEANT | Tap Water | | |
| SAMPLE TYPE | Shelby Tube | CONF. PRES. - (psf) | 10000 | | |

## SATURATION DATA

| Cell Press. (psi) | Back Press. (psi) | Burette Reading (cc) Close | Burette Reading (cc) Open | Pore Press. (psi) Close | Pore Press. (psi) Open | Change | B |
|---|---|---|---|---|---|---|---|
| 40.0 | 38.0 | 3.2 | 19.3 | | | | |
| 50.0 | | 20.0 | 20.3 | 38.7 | 48.4 | 9.7 | 0.97 |

## CONSOLIDATION DATA

| Elapsed Time (Min) | SQRT Time (Min) | Burette Reading (cc) | Volume Defl. (cc) |
|---|---|---|---|
| 0.00 | 0.00 | 0.80 | 0.00 |
| 0.25 | 0.50 | 34.60 | -33.80 |
| 0.5 | 0.71 | 36.70 | -35.90 |
| 1 | 1.00 | 37.80 | -37.00 |
| 2 | 1.41 | 38.60 | -37.80 |
| 4 | 2.00 | 39.30 | -38.50 |
| 9 | 3.00 | 40.10 | -39.30 |
| 16 | 4.00 | 40.80 | -40.00 |
| 30 | 5.48 | 41.50 | -40.70 |
| 88 | 9.38 | 42.70 | -41.90 |
| 120 | 10.95 | 43.10 | -42.30 |
| 240 | 15.49 | 43.90 | -43.10 |
| 360 | 18.97 | 44.30 | -43.50 |

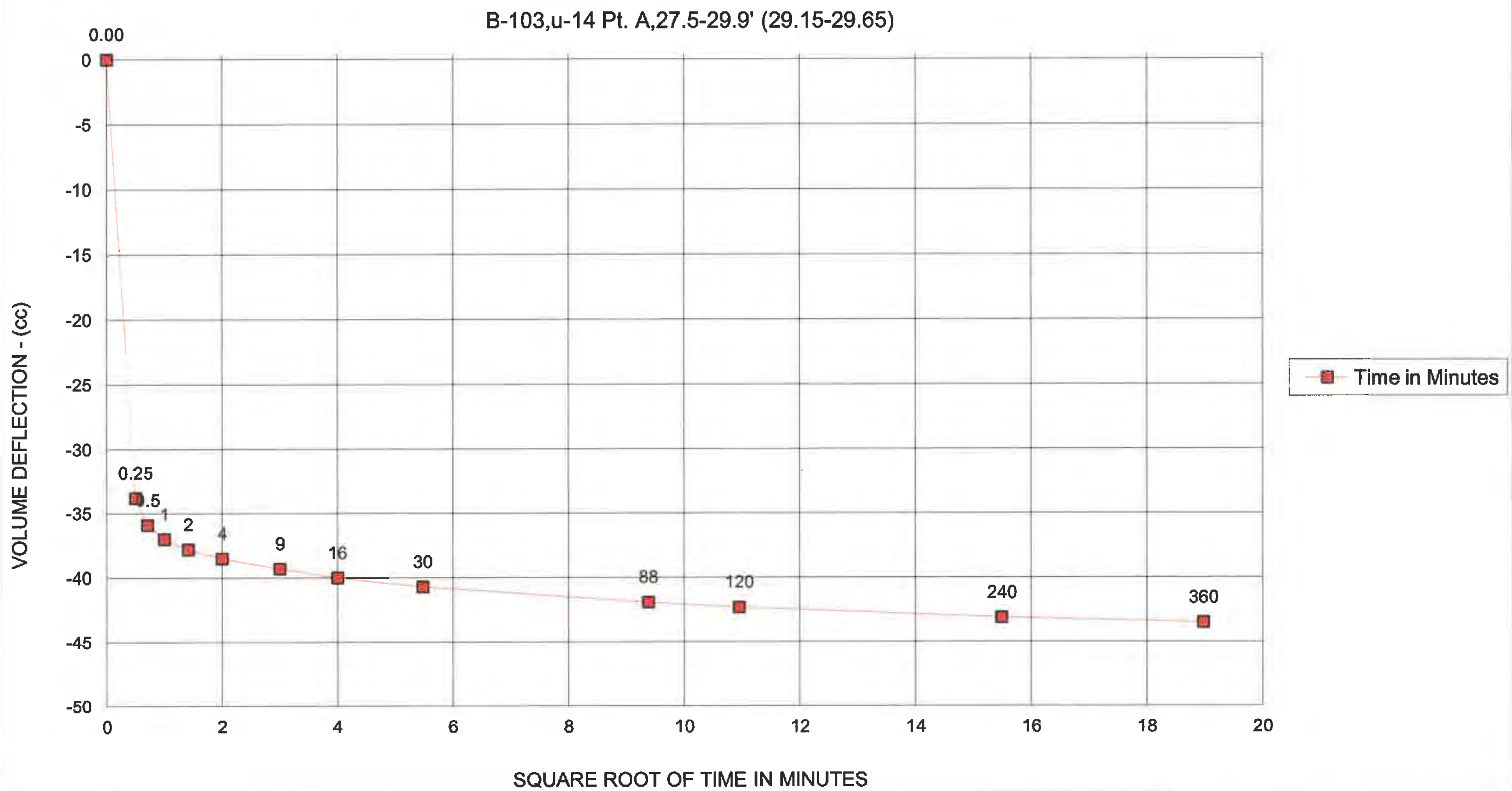
| | | | |
|---|---|---|---|
| Initial Height - (in) | 5.852 | Init. Vol. - (cc) | 621.36 |
| Height Change - (in) | 0.151 | Vol. Change - (cc) | 62.80 |
| Ht. After Cons. - (in) | 5.701 | Cell Exp. - (cc) | 15.70 |
| Initial Area - (sq in) | 6.478 | Net Change - (cc) | 47.10 |
| Area After Cons. - sq in | 6.146 | Cons. Vol. - (cc) | 574.26 |

FileName: 2679_130_HarvardFlowPump-Perm-ASTMD-5084-R3_1.xls

**PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD**
ASTM D5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |

## CONSOLIDATION DATA

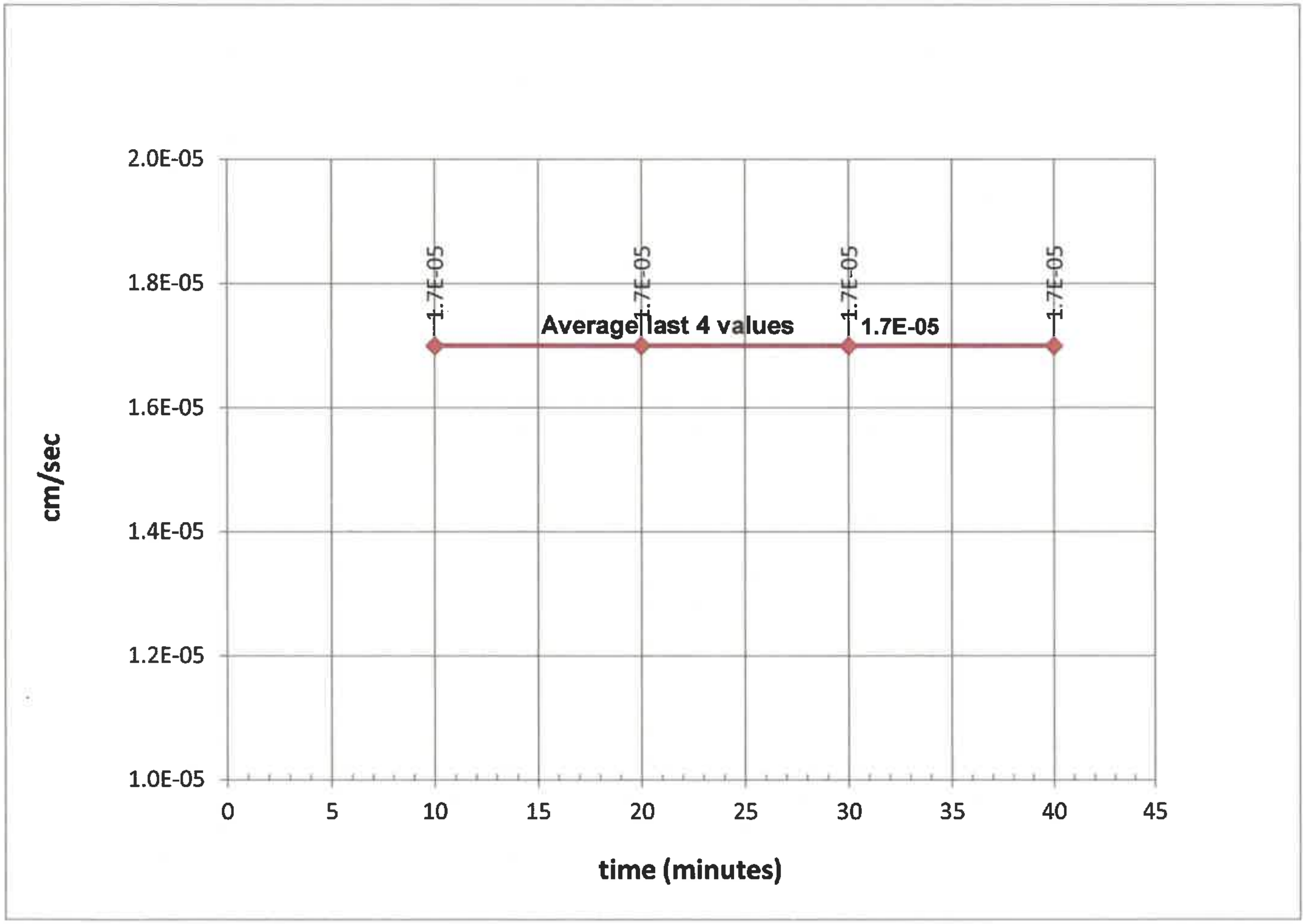



FileName: 2679_130_HarvardFlowPump-Perm-ASTMD-5084-R3_1.xls

# Preliminary Flow Pump Test Data
# ASTM D5084

ADVANCED TERRA TESTING

| | | | | | |
|---|---|---|---|---|---|
| Client: | RJH Consultants | Boring Number: | b-103 | | |
| Job Number: | 2679-130 | Depth: | 27.5'-29.9' | | |
| Project: | Hogchute Dam Safety Evaluation | Sample Number: | U-14 Pt. A | | |
| Location: | -- | Sampled Date: | 7/23/2018 | Sampled By: | -- |
| Project Number: | 18115 | Test Date: | 10/19/2018 | Technician: | CAL |




| | | | |
|---|---|---|---|
| Data Entered By: | CAL | | |
| Date: | 10/19/2018 | Checked By: | SPH |
| File Name: | 2679_130_PrelimPerm_ASTMD-5084-methodD-R0_0.xls | Date: | 10-23-18 |

ATT ADVANCED TERRA TESTING

# PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD

ASTM D5084 Method D

| | | | | |
|---|---|---|---|---|
| CLIENT | RJH Consultants | | JOB NO. | 2679-130 |

| | | | | |
|---|---|---|---|---|
| PROJECT | Hogchute Dam Safety Evaluation | | | |
| PROJECT NO. | 18115 | SAMPLED | 7/23/2018 | By: -- |
| BORING NO. | B-103 | TEST STARTED | 10/16/2018 | By: SPH/CAL |
| DEPTH | 27.5-29.9' (28.65-29.15') | TEST FINISHED | 10/22/2018 | By: SPH/CAL |
| SAMPLE NO. | u-14 Pt. B | CELL NUMBER | 18S | |
| LOCATION | -- | PERMEANT | Tap Water | |
| SAMPLE TYPE | shelby tube | CONF. PRES. - (psf) | 6000 | |

| MOISTURE / DENSITY DATA | BEFORE TEST | AFTER TEST |
|---|---|---|
| Wt. Soil + Moisture - (g) | 1281.53 | 1261.98 |
| Wt. Wet Soil & Pan - (g) | 1295.34 | 1275.79 |
| Wt. Dry Soil & Pan - (g) | 1037.24 | 1037.24 |
| Wt. Lost Moisture - (g) | 258.10 | 238.55 |
| Wt. of Pan Only - (g) | 13.81 | 13.81 |
| Wt. of Dry Soil - (g) | 1023.43 | 1023.43 |
| Moisture Content - (%) | 25.2 | 23.3 |
| Wet Density - (pcf) | 126.4 | 132.1 |
| Dry Density - (pcf) | 101.0 | 107.1 |
| Init. Diameter - (in) | 2.869 | |
| Init. Area - (sq in) | 6.465 | |
| Init. Height - (in) | 5.973 | |
| Vol. Bef. Consol. - (cu ft) | 0.02235 | |
| Vol. After Consol. - (cu ft) | 0.02106 | |
| Porosity - (%) | 40.00 | |

## FLOW PUMP CALCULATIONS

| | |
|---|---|
| Pump Setting (gear number) | 1 |
| Percentage of Pump Setting | 100 |
| Q - (cc/s) | 3.59E-02 |
| Height - (in) | 5.857 |
| Diameter - (in) | 2.813 |
| Pressure - (psi) | 0.060 |
| Area after consol. - (sq cm) | 40.085 |
| Gradient | 0.284 |
| Permeability k - (cm/s) | 3.2E-03 |
| Permeability k - (m/s) | 3.2E-05 |
| Back Pressure - (psi) | 48.0 |
| Cell Pressure - (psi) | 89.7 |
| Ave. Effective Stress - (psi) | 41.670 |
| Average temperature degree - (c°) | 22.2 |

| | | | |
|---|---|---|---|
| Data entry by: | CAL | Date: | 10/24/2018 |
| Checked by: | SPH | Date: | 10-24-18 |

ATT ADVANCED TERRA TESTING

# PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD

ASTM D5084 Method D

| | | | | | |
|---|---|---|---|---|---|
| CLIENT | RJH Consultants | | JOB NO. | 2679-130 | |
| PROJECT | Hogchute Dam Safety Evaluation | | | | |
| PROJECT NO. | 18115 | SAMPLED | 7/23/2018 | By: -- | |
| BORING NO. | B-103 | TEST STARTED | 10/16/2018 | By: SPH/CAL | |
| DEPTH | 27.5-29.9' (28.65-29.15') | TEST FINISHED | 10/22/2018 | By: SPH/CAL | |
| SAMPLE NO. | u-14 Pt. B | CELL NUMBER | 18S | | |
| LOCATION | -- | PERMEANT | Tap Water | | |
| SAMPLE TYPE | shelby tube | CONF. PRES. - (psf) | 6000 | | |

## SATURATION DATA

| Cell Press. (psi) | Back Press. (psi) | Burette Reading (cc) Close | Burette Reading (cc) Open | Pore Press. (psi) Close | Pore Press. (psi) Open | Change | B |
|---|---|---|---|---|---|---|---|
| 40.0 | 38.0 | 4.0 | 18.3 | | | | |
| 50.0 | 48.0 | 19.3 | 20.1 | 38.4 | 47.8 | 9.4 | 0.94 |
| 60.0 | | 20.4 | 20.5 | 48.5 | 58.0 | 9.5 | 0.95 |

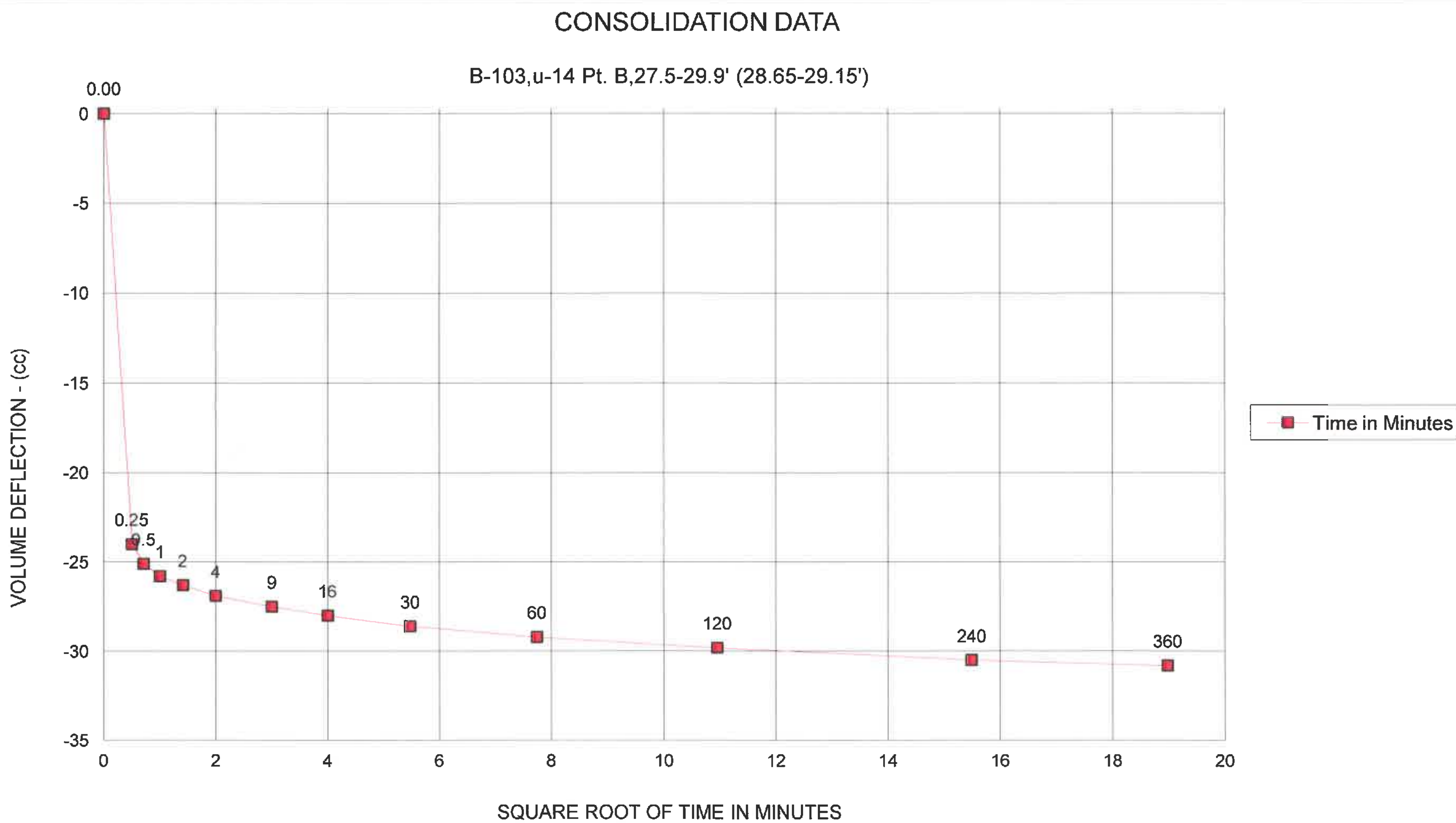
## CONSOLIDATION DATA

| Elapsed Time (Min) | SQRT Time (Min) | Burette Reading (cc) | Volume Defl. (cc) |
|---|---|---|---|
| 0.00 | 0.00 | 0.30 | 0.00 |
| 0.25 | 0.50 | 24.30 | -24.00 |
| 0.5 | 0.71 | 25.40 | -25.10 |
| 1 | 1.00 | 26.10 | -25.80 |
| 2 | 1.41 | 26.60 | -26.30 |
| 4 | 2.00 | 27.20 | -26.90 |
| 9 | 3.00 | 27.80 | -27.50 |
| 16 | 4.00 | 28.30 | -28.00 |
| 30 | 5.48 | 28.90 | -28.60 |
| 60 | 7.75 | 29.50 | -29.20 |
| 120 | 10.95 | 30.10 | -29.80 |
| 240 | 15.49 | 30.80 | -30.50 |
| 360 | 18.97 | 31.10 | -30.80 |

| | | | |
|---|---|---|---|
| Initial Height - (in) | 5.973 | Init. Vol. - (cc) | 632.88 |
| Height Change - (in) | 0.116 | Vol. Change - (cc) | 48.40 |
| Ht. After Cons. - (in) | 5.857 | Cell Exp. - (cc) | 11.96 |
| Initial Area - (sq in) | 6.465 | Net Change - (cc) | 36.44 |
| Area After Cons. - sq in | 6.213 | Cons. Vol. - (cc) | 596.44 |

**PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD**
ASTM D5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |

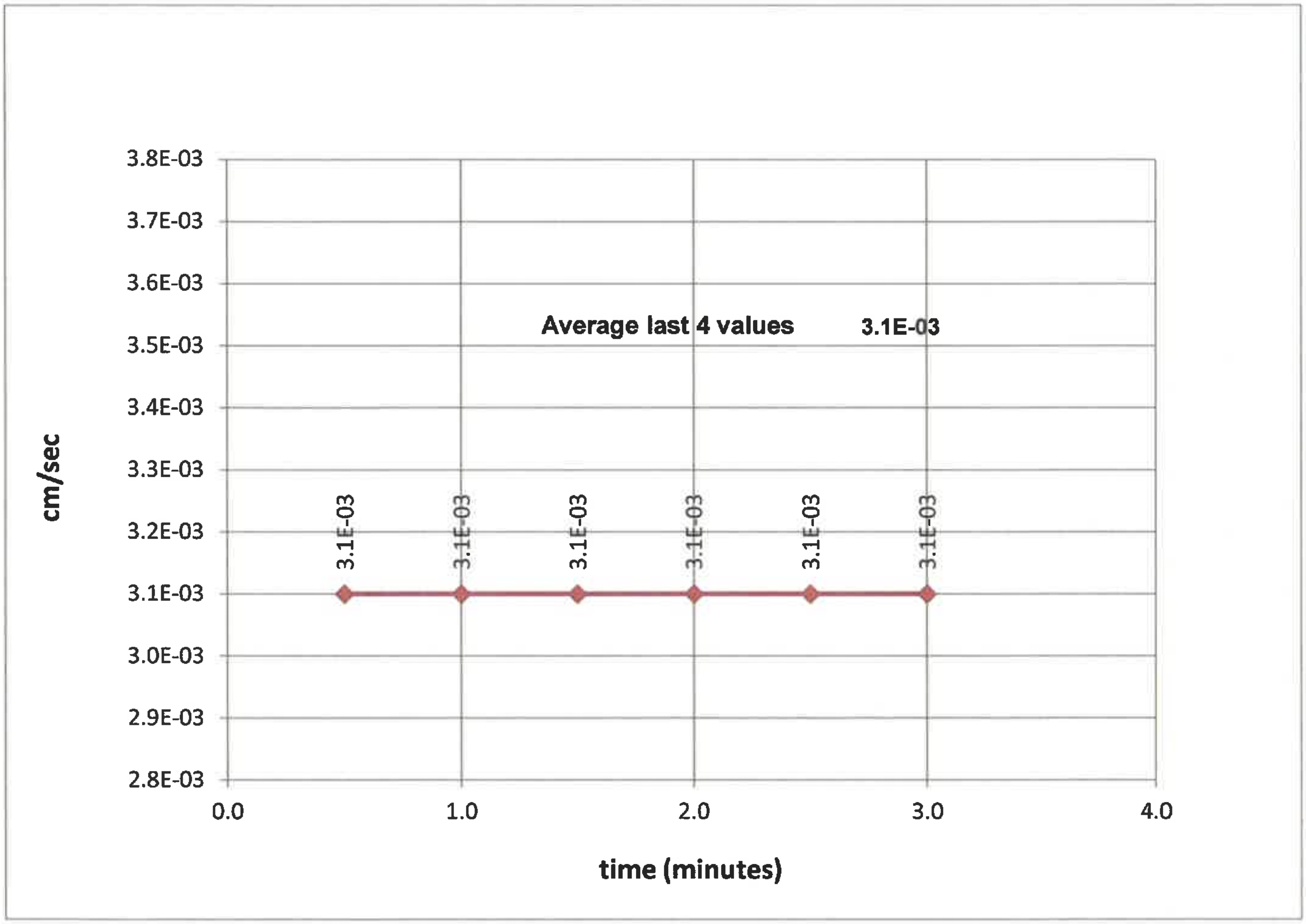



FileName: 2679_130_HarvardFlowPump-Perm-ASTMD-5084-R3_2.xls

# Preliminary Flow Pump Test Data
# ASTM D5084

ADVANCED TERRA TESTING

| | | | | | |
|---|---|---|---|---|---|
| Client: | RJH Consultants | Boring Number: | B-103 | | |
| Job Number: | 2679-130 | Depth: | 27.5-29.9' | | |
| Project: | Hogchute Dam Safety Evaluation | Sample Number: | U-14 Pt. B | | |
| Location: | -- | Sampled Date: | 7/23/2018 | Sampled By: | -- |
| Project Number: | 18115 | Test Date: | 10/19/2018 | Technician: | CAL |




| | | | |
|---|---|---|---|
| Data Entered By: | CAL | | |
| Date: | 10/19/2018 | Checked By: | SPH |
| File Name: | 2679_130_PrelimPerm_ASTMD-5084-methodD-R0_1.xls | Date: | 10-24-18 |

ATT ADVANCED TERRA TESTING

# PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD

ASTM D5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |

| | | | | |
|---|---|---|---|---|
| PROJECT | Hogchute Dam Safety Evaluation | | | |
| PROJECT NO. | 18115 | SAMPLED | 7/23/2018 | By: -- |
| BORING NO. | B-103 | TEST STARTED | 10/16/2018 | By: SPH/CAL |
| DEPTH | 28.15-25.65' | TEST FINISHED | 10/19/2018 | By: SPH/CAL |
| SAMPLE NO. | u-14 Pt. C | CELL NUMBER | 16S | |
| LOCATION | -- | PERMEANT | Tap Water | |
| SAMPLE TYPE | Shelby Tube | CONF. PRES. - (psf) | 3000 | |

| MOISTURE / DENSITY DATA | BEFORE TEST | AFTER TEST |
|---|---|---|
| Wt. Soil + Moisture - (g) | 1321.10 | 1316.30 |
| Wt. Wet Soil & Pan - (g) | 1335.31 | 1330.51 |
| Wt. Dry Soil & Pan - (g) | 1081.21 | 1081.21 |
| Wt. Lost Moisture - (g) | 254.10 | 249.30 |
| Wt. of Pan Only - (g) | 14.21 | 14.21 |
| Wt. of Dry Soil - (g) | 1067.00 | 1067.00 |
| Moisture Content - (%) | 23.8 | 23.4 |
| Wet Density - (pcf) | 127.5 | 132.3 |
| Dry Density - (pcf) | 103.0 | 107.2 |
| Init. Diameter - (in) | 2.868 | |
| Init. Area - (sq in) | 6.460 | |
| Init. Height - (in) | 6.109 | |
| Vol. Bef. Consol. - (cu ft) | 0.02284 | |
| Vol. After Consol. - (cu ft) | 0.02194 | |
| Porosity - (%) | 40.12 | |

| FLOW PUMP CALCULATIONS | |
|---|---|
| Pump Setting (gear number) | 6 |
| Percentage of Pump Setting | 100 |
| Q - (cc/s) | 7.07E-04 |
| Height - (in) | 6.055 |
| Diameter - (in) | 2.824 |
| Pressure - (psi) | 0.111 |
| Area after consol. - (sq cm) | 40.399 |
| Gradient | 0.507 |
| Permeability k - (cm/s) | 3.4E-05 |
| Permeability k - (m/s) | 3.4E-07 |
| Back Pressure - (psi) | 48.0 |
| Cell Pressure - (psi) | 68.8 |
| Ave. Effective Stress - (psi) | 20.745 |
| Average temperature degree - (c°) | 22.1 |

| | | | |
|---|---|---|---|
| Data entry by: | SPH | Date: | 10/23/2018 |
| Checked by: | CAL | Date: | 10/23/2018 |

ATT ADVANCED TERRATESTING

# PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD

ASTM D5084 Method D

| | | | | |
|---|---|---|---|---|
| CLIENT | RJH Consultants | | JOB NO. | 2679-130 |

| | | | | |
|---|---|---|---|---|
| PROJECT | Hogchute Dam Safety Evaluation | | | |
| PROJECT NO. | 18115 | SAMPLED | 7/23/2018 | By: -- |
| BORING NO. | B-103 | TEST STARTED | 10/16/2018 | By: SPH/CAL |
| DEPTH | 28.15-25.65' | TEST FINISHED | 10/19/2018 | By: SPH/CAL |
| SAMPLE NO. | u-14 Pt. C | CELL NUMBER | 16S | |
| LOCATION | -- | PERMEANT | Tap Water | |
| SAMPLE TYPE | Shelby Tube | CONF. PRES. - (psf) | 3000 | |

## SATURATION DATA

| Cell Press. (psi) | Back Press. (psi) | Burette Reading (cc) | | Pore Press. (psi) | | | |
|---|---|---|---|---|---|---|---|
| | | Close | Open | Close | Open | Change | B |
| 40.0 | 38.0 | 4.0 | 19.8 | | | | |
| 50.0 | 48.0 | 20.6 | 21.6 | 38.9 | 48.2 | 9.3 | 0.93 |
| 60.0 | | 21.9 | 22.0 | 48.7 | 58.3 | 9.6 | 0.96 |

## CONSOLIDATION DATA

| Elapsed Time (Min) | SQRT Time (Min) | Burette Reading (cc) | Volume Defl. (cc) |
|---|---|---|---|
| 0.00 | 0.00 | 0.50 | 0.00 |
| 0.25 | 0.50 | 12.45 | -11.95 |
| 0.5 | 0.71 | 13.70 | -13.20 |
| 1 | 1.00 | 14.80 | -14.30 |
| 2 | 1.41 | 15.40 | -14.90 |
| 4 | 2.00 | 15.90 | -15.40 |
| 9 | 3.00 | 16.25 | -15.75 |
| 16 | 4.00 | 16.65 | -16.15 |
| 30 | 5.48 | 17.00 | -16.50 |
| 60 | 7.75 | 17.50 | -17.00 |
| 120 | 10.95 | 17.90 | -17.40 |
| 240 | 15.49 | 18.30 | -17.80 |
| 360 | 18.97 | 18.50 | -18.00 |

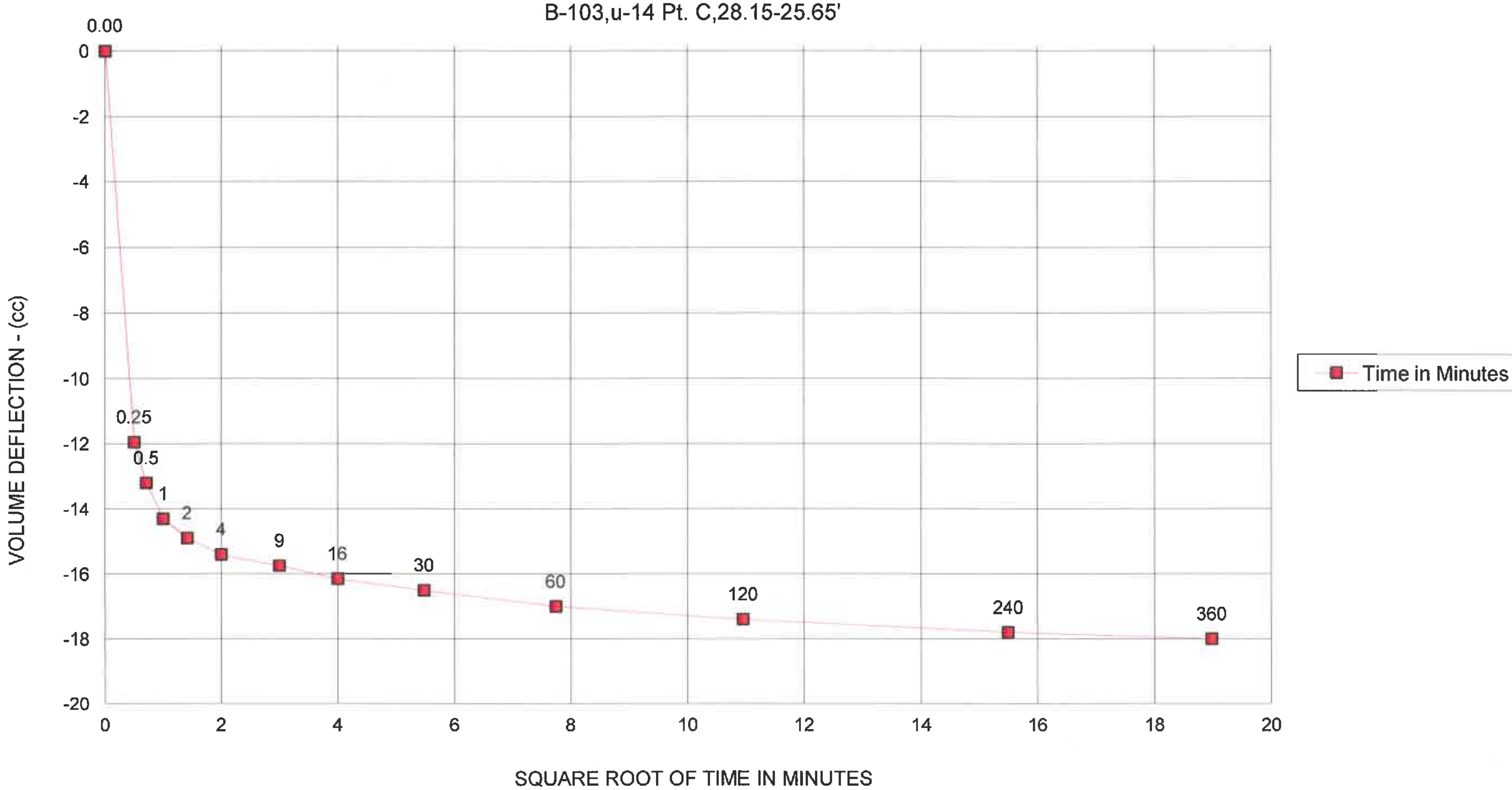
| | | | |
|---|---|---|---|
| Initial Height - (in) | 6.109 | Init. Vol. - (cc) | 646.84 |
| Height Change - (in) | 0.054 | Vol. Change - (cc) | 36.80 |
| Ht. After Cons. - (in) | 6.055 | Cell Exp. - (cc) | 11.36 |
| Initial Area - (sq in) | 6.460 | Net Change - (cc) | 25.44 |
| Area After Cons. - sq in | 6.262 | Cons. Vol. - (cc) | 621.40 |

**PERMEABILITY TEST - BACK PRESSURE SATURATED - FLOW PUMP METHOD**
ASTM D5084 Method D

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | JOB NO. | 2679-130 |

CONSOLIDATION DATA

B-103,u-14 Pt. C,28.15-25.65'

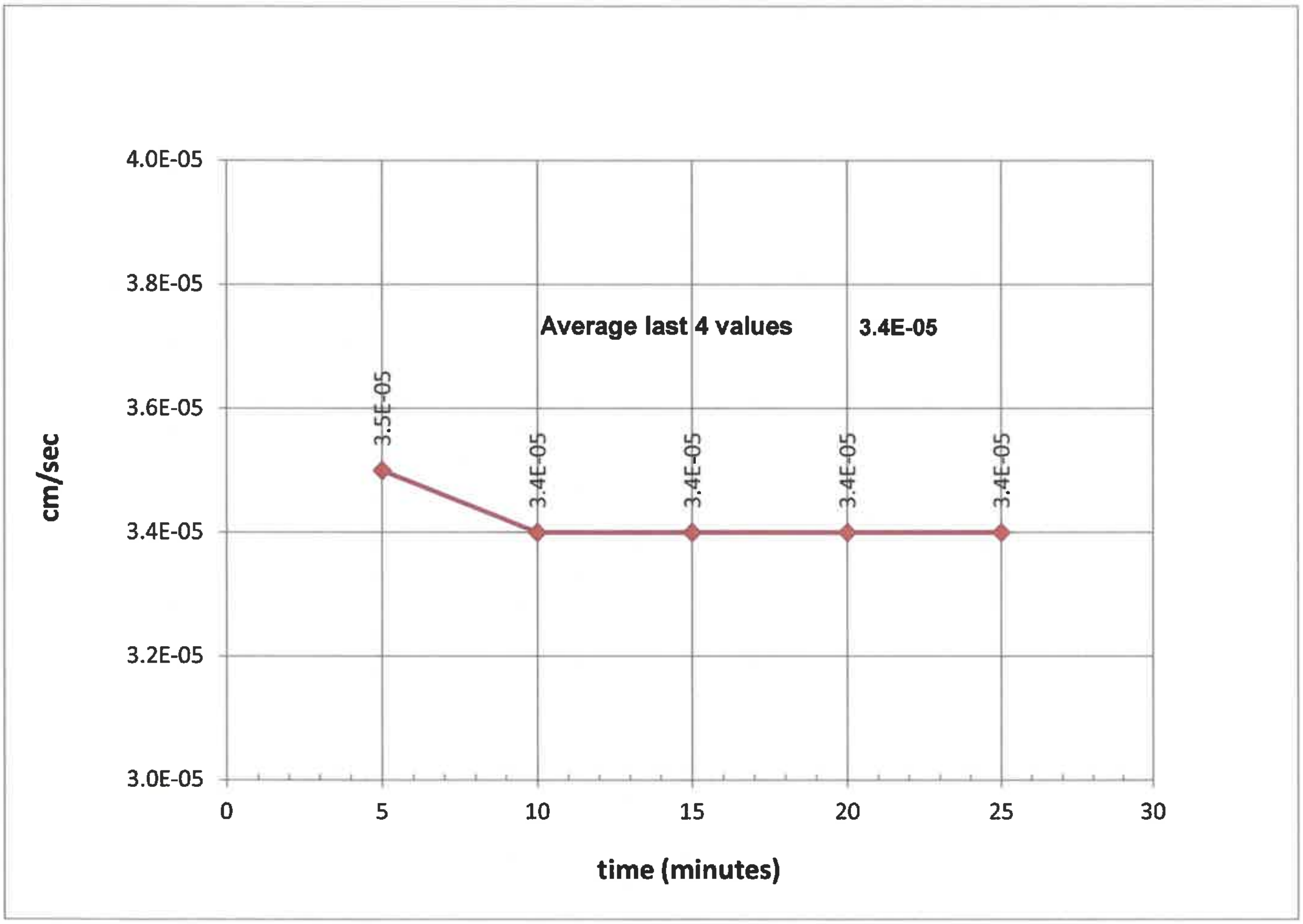



FileName: 2679_130_HarvardFlowPump-Perm-ASTMD-5084-R3_0.xls

ADVANCED TERRA TESTING

# Preliminary Flow Pump Test Data
# ASTM D5084

| | | | | | |
|---|---|---|---|---|---|
| Client: | RJH Consultants | Boring Number: | B-103 | | |
| Job Number: | 2679-130 | Depth: | 27.5-29.9' | | |
| Project: | Hogchute Dam Safety Evaluation | Sample Number: | U-14 Pt. C | | |
| Location: | -- | Sampled Date: | 7/23/2018 | Sampled By: | -- |
| Project Number: | 18115 | Test Date: | 10/19/2018 | Technician: | CAL |




| | | | |
|---|---|---|---|
| Data Entered By: | CAL | | |
| Date: | 10/19/2018 | Checked By: | SPH |
| File Name: | 2679_130_PrelimPerm_ASTMD-5084-methodD-R0_2.xls | Date: | 10-23-18 |

# Unconfined Compressive Strength
# ASTM D2166

# Unconfined Compressive Strength
## ASTM D 2166

ADVANCED TERRA TESTING

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33.0' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 9/20/2018 |
| LOCATION | -- | DESCRIPTION | lean clay w/gravel |
| DATE TESTED | 10/17/18 | | |
| TECHNICIAN | SPH/CAL | | |

**Test Parameters**

| | |
|---|---|
| Strain Rate (in/min): | 0.037 |
| Strain Rate (cm/min): | 0.09398 |

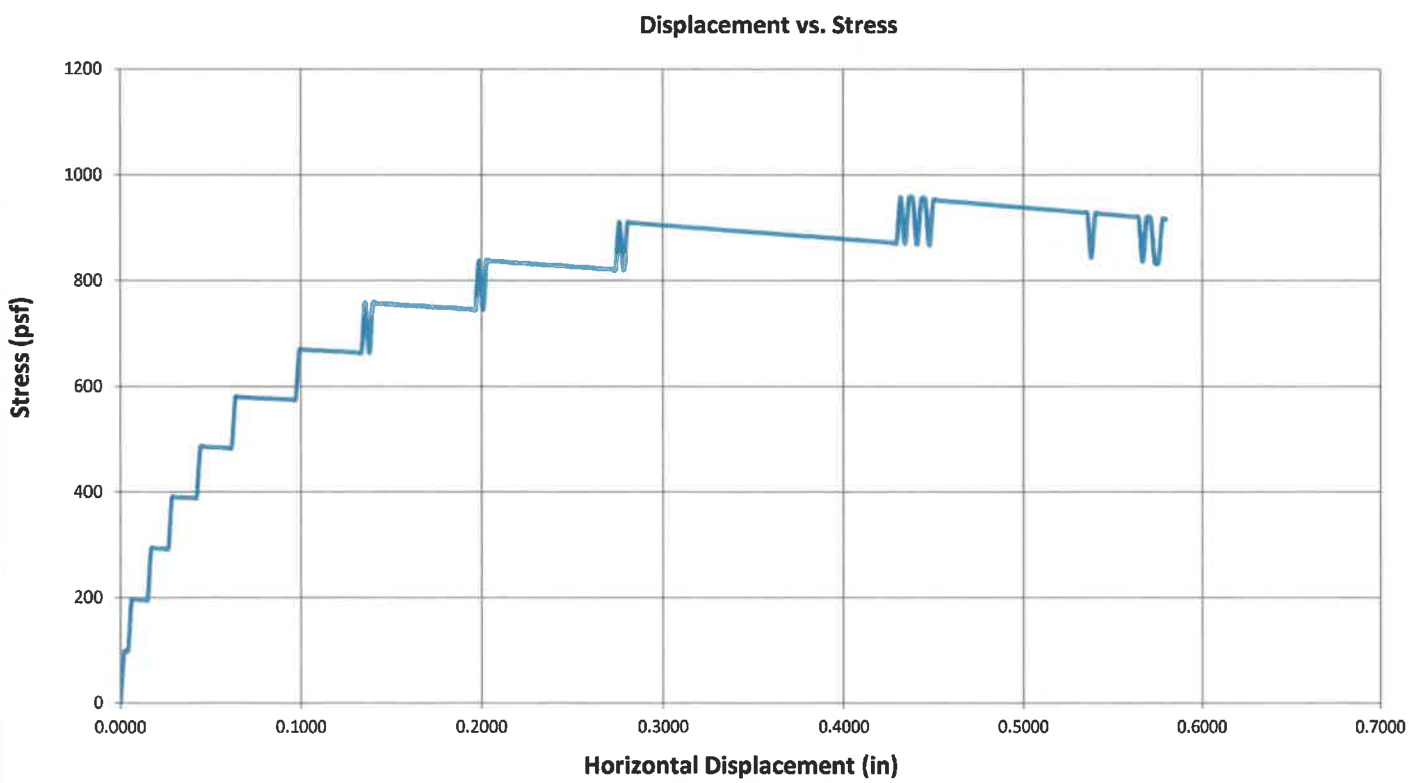
Raw Data Files: RJH_2679_130_CA-9_B-104.txt

**Moisture & Density Data**

| | | | |
|---|---|---|---|
| Mass of Wet Soil and Pan (g): | 531.30 | Initial Wet Density (pcf): | 133.9 |
| Mass of Dry Soil and Pan (g): | 466.78 | Initial Dry Density (pcf): | 111.8 |
| Mass of Pan (g): | 139.65 | Initial Wet Density (kg/m³): | 2144 |
| Mass of Wet Soil (g): | 391.7 | Initial Dry Density (kg/m³): | 1791 |
| Initial Diameter (in): | 1.93 | Initial Moisture (%): | 19.7 |
| Initial Height (in): | 3.80 | | |

**Test Results**

| | | | |
|---|---|---|---|
| Peak Stress (psf): | 958 | Axial Strain at Peak Stress(%): | 11.4 |
| Peak Stress (kPa): | 46 | Height to Diameter Ratio: | 2.0:1 |




| | |
|---|---|
| NOTES: | Short Sample! Filling required due to gravel. |

| | | | |
|---|---|---|---|
| Data entry by: | CAL | Date: | 10/18/2018 |
| Checked by: | SPH | Date: | 10-19-18 |
| File name: | 2679130__UCS ASTM D2166_0.xlsm | | |

## Unconfined Compressive Strength
## ASTM D2166

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33.0' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 9/20/2018 |
| LOCATION | -- | DESCRIPTION | lean clay w/gravel |
| DATE TESTED | 10/17/18 | | |
| TECHNICIAN | SPH/CAL | | |

| Displacement (in) | Displacement (cm) | Strain (%) | Average Cross Sectional Area (in²) | Load (lbs) | Load (N) | Stress (psf) | Stress (kPa) |
|---|---|---|---|---|---|---|---|
| 0.0000 | 0.000 | 0.00 | 2.93 | 0 | 0 | 0 | 0 |
| 0.0022 | 0.006 | 0.06 | 2.93 | 2 | 9 | 98 | 5 |
| 0.0043 | 0.011 | 0.11 | 2.93 | 2 | 9 | 98 | 5 |
| 0.0064 | 0.016 | 0.17 | 2.94 | 4 | 18 | 196 | 9 |
| 0.0086 | 0.022 | 0.23 | 2.94 | 4 | 18 | 196 | 9 |
| 0.0106 | 0.027 | 0.28 | 2.94 | 4 | 18 | 196 | 9 |
| 0.0127 | 0.032 | 0.33 | 2.94 | 4 | 18 | 196 | 9 |
| 0.0150 | 0.038 | 0.39 | 2.94 | 4 | 18 | 196 | 9 |
| 0.0170 | 0.043 | 0.45 | 2.94 | 6 | 27 | 293 | 14 |
| 0.0192 | 0.049 | 0.50 | 2.95 | 6 | 27 | 293 | 14 |
| 0.0218 | 0.055 | 0.57 | 2.95 | 6 | 27 | 293 | 14 |
| 0.0240 | 0.061 | 0.63 | 2.95 | 6 | 27 | 293 | 14 |
| 0.0263 | 0.067 | 0.69 | 2.95 | 6 | 27 | 293 | 14 |
| 0.0284 | 0.072 | 0.75 | 2.95 | 8 | 36 | 390 | 19 |
| 0.0307 | 0.078 | 0.81 | 2.96 | 8 | 36 | 390 | 19 |
| 0.0328 | 0.083 | 0.86 | 2.96 | 8 | 36 | 390 | 19 |
| 0.0352 | 0.089 | 0.93 | 2.96 | 8 | 36 | 389 | 19 |
| 0.0376 | 0.096 | 0.99 | 2.96 | 8 | 36 | 389 | 19 |
| 0.0399 | 0.101 | 1.05 | 2.96 | 8 | 36 | 389 | 19 |
| 0.0419 | 0.106 | 1.10 | 2.96 | 8 | 36 | 389 | 19 |
| 0.0441 | 0.112 | 1.16 | 2.97 | 10 | 44 | 486 | 23 |
| 0.0464 | 0.118 | 1.22 | 2.97 | 10 | 44 | 485 | 23 |
| 0.0486 | 0.123 | 1.28 | 2.97 | 10 | 44 | 485 | 23 |
| 0.0507 | 0.129 | 1.33 | 2.97 | 10 | 44 | 485 | 23 |
| 0.0531 | 0.135 | 1.40 | 2.97 | 10 | 44 | 484 | 23 |
| 0.0551 | 0.140 | 1.45 | 2.97 | 10 | 44 | 484 | 23 |
| 0.0572 | 0.145 | 1.50 | 2.98 | 10 | 44 | 484 | 23 |
| 0.0592 | 0.150 | 1.56 | 2.98 | 10 | 44 | 484 | 23 |
| 0.0614 | 0.156 | 1.61 | 2.98 | 10 | 44 | 483 | 23 |
| 0.0636 | 0.162 | 1.67 | 2.98 | 12 | 53 | 580 | 28 |
| 0.0656 | 0.167 | 1.73 | 2.98 | 12 | 53 | 579 | 28 |
| 0.0679 | 0.172 | 1.79 | 2.98 | 12 | 53 | 579 | 28 |
| 0.0700 | 0.178 | 1.84 | 2.99 | 12 | 53 | 579 | 28 |
| 0.0723 | 0.184 | 1.90 | 2.99 | 12 | 53 | 578 | 28 |
| 0.0745 | 0.189 | 1.96 | 2.99 | 12 | 53 | 578 | 28 |
| 0.0768 | 0.195 | 2.02 | 2.99 | 12 | 53 | 578 | 28 |
| 0.0791 | 0.201 | 2.08 | 2.99 | 12 | 53 | 577 | 28 |
| 0.0813 | 0.207 | 2.14 | 3.00 | 12 | 53 | 577 | 28 |
| 0.0836 | 0.212 | 2.20 | 3.00 | 12 | 53 | 576 | 28 |
| 0.0859 | 0.218 | 2.26 | 3.00 | 12 | 53 | 576 | 28 |
| 0.0880 | 0.224 | 2.31 | 3.00 | 12 | 53 | 576 | 28 |
| 0.0903 | 0.229 | 2.38 | 3.00 | 12 | 53 | 575 | 28 |
| 0.0924 | 0.235 | 2.43 | 3.00 | 12 | 53 | 575 | 28 |

## Unconfined Compressive Strength
## ASTM D2166

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33.0' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 9/20/2018 |
| LOCATION | -- | DESCRIPTION | lean clay w/gravel |
| DATE TESTED | 10/17/18 | | |
| TECHNICIAN | SPH/CAL | | |

| Displacement (in) | Displacement (cm) | Strain (%) | Average Cross Sectional Area (in²) | Load (lbs) | Load (N) | Stress (psf) | Stress (kPa) |
|---|---|---|---|---|---|---|---|
| 0.0947 | 0.241 | 2.49 | 3.01 | 12 | 53 | 575 | 28 |
| 0.0968 | 0.246 | 2.55 | 3.01 | 12 | 53 | 574 | 28 |
| 0.0991 | 0.252 | 2.61 | 3.01 | 14 | 62 | 670 | 32 |
| 0.1012 | 0.257 | 2.66 | 3.01 | 14 | 62 | 669 | 32 |
| 0.1035 | 0.263 | 2.72 | 3.01 | 14 | 62 | 669 | 32 |
| 0.1057 | 0.268 | 2.78 | 3.02 | 14 | 62 | 669 | 32 |
| 0.1079 | 0.274 | 2.84 | 3.02 | 14 | 62 | 668 | 32 |
| 0.1100 | 0.279 | 2.89 | 3.02 | 14 | 62 | 668 | 32 |
| 0.1120 | 0.284 | 2.95 | 3.02 | 14 | 62 | 667 | 32 |
| 0.1142 | 0.290 | 3.00 | 3.02 | 14 | 62 | 667 | 32 |
| 0.1162 | 0.295 | 3.06 | 3.02 | 14 | 62 | 667 | 32 |
| 0.1183 | 0.300 | 3.11 | 3.03 | 14 | 62 | 666 | 32 |
| 0.1204 | 0.306 | 3.17 | 3.03 | 14 | 62 | 666 | 32 |
| 0.1224 | 0.311 | 3.22 | 3.03 | 14 | 62 | 666 | 32 |
| 0.1247 | 0.317 | 3.28 | 3.03 | 14 | 62 | 665 | 32 |
| 0.1268 | 0.322 | 3.34 | 3.03 | 14 | 62 | 665 | 32 |
| 0.1291 | 0.328 | 3.40 | 3.03 | 14 | 62 | 664 | 32 |
| 0.1312 | 0.333 | 3.45 | 3.04 | 14 | 62 | 664 | 32 |
| 0.1335 | 0.339 | 3.51 | 3.04 | 14 | 62 | 664 | 32 |
| 0.1356 | 0.344 | 3.57 | 3.04 | 16 | 71 | 758 | 36 |
| 0.1379 | 0.350 | 3.63 | 3.04 | 14 | 62 | 663 | 32 |
| 0.1399 | 0.355 | 3.68 | 3.04 | 16 | 71 | 757 | 36 |
| 0.1420 | 0.361 | 3.73 | 3.05 | 16 | 71 | 757 | 36 |
| 0.1443 | 0.367 | 3.80 | 3.05 | 16 | 71 | 756 | 36 |
| 0.1464 | 0.372 | 3.85 | 3.05 | 16 | 71 | 756 | 36 |
| 0.1487 | 0.378 | 3.91 | 3.05 | 16 | 71 | 755 | 36 |
| 0.1508 | 0.383 | 3.97 | 3.05 | 16 | 71 | 755 | 36 |
| 0.1531 | 0.389 | 4.03 | 3.05 | 16 | 71 | 754 | 36 |
| 0.1552 | 0.394 | 4.08 | 3.06 | 16 | 71 | 754 | 36 |
| 0.1572 | 0.399 | 4.13 | 3.06 | 16 | 71 | 753 | 36 |
| 0.1594 | 0.405 | 4.19 | 3.06 | 16 | 71 | 753 | 36 |
| 0.1616 | 0.410 | 4.25 | 3.06 | 16 | 71 | 753 | 36 |
| 0.1638 | 0.416 | 4.31 | 3.06 | 16 | 71 | 752 | 36 |
| 0.1660 | 0.422 | 4.37 | 3.07 | 16 | 71 | 752 | 36 |
| 0.1682 | 0.427 | 4.42 | 3.07 | 16 | 71 | 751 | 36 |
| 0.1704 | 0.433 | 4.48 | 3.07 | 16 | 71 | 751 | 36 |
| 0.1726 | 0.438 | 4.54 | 3.07 | 16 | 71 | 750 | 36 |
| 0.1748 | 0.444 | 4.60 | 3.07 | 16 | 71 | 750 | 36 |
| 0.1771 | 0.450 | 4.66 | 3.07 | 16 | 71 | 749 | 36 |
| 0.1792 | 0.455 | 4.71 | 3.08 | 16 | 71 | 749 | 36 |
| 0.1815 | 0.461 | 4.77 | 3.08 | 16 | 71 | 748 | 36 |
| 0.1836 | 0.466 | 4.83 | 3.08 | 16 | 71 | 748 | 36 |
| 0.1859 | 0.472 | 4.89 | 3.08 | 16 | 71 | 747 | 36 |

## Unconfined Compressive Strength
## ASTM D2166

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33.0' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 9/20/2018 |
| LOCATION | -- | DESCRIPTION | lean clay w/gravel |
| DATE TESTED | 10/17/18 | | |
| TECHNICIAN | SPH/CAL | | |

| Displacement (in) | Displacement (cm) | Strain (%) | Average Cross Sectional Area (in²) | Load (lbs) | Load (N) | Stress (psf) | Stress (kPa) |
|---|---|---|---|---|---|---|---|
| 0.1880 | 0.478 | 4.94 | 3.08 | 16 | 71 | 747 | 36 |
| 0.1900 | 0.483 | 5.00 | 3.09 | 16 | 71 | 747 | 36 |
| 0.1922 | 0.488 | 5.06 | 3.09 | 16 | 71 | 746 | 36 |
| 0.1943 | 0.494 | 5.11 | 3.09 | 16 | 71 | 746 | 36 |
| 0.1964 | 0.499 | 5.17 | 3.09 | 16 | 71 | 745 | 36 |
| 0.1987 | 0.505 | 5.23 | 3.09 | 18 | 80 | 838 | 40 |
| 0.2007 | 0.510 | 5.28 | 3.09 | 16 | 71 | 744 | 36 |
| 0.2027 | 0.515 | 5.33 | 3.10 | 18 | 80 | 837 | 40 |
| 0.2048 | 0.520 | 5.39 | 3.10 | 18 | 80 | 837 | 40 |
| 0.2069 | 0.526 | 5.44 | 3.10 | 18 | 80 | 836 | 40 |
| 0.2091 | 0.531 | 5.50 | 3.10 | 18 | 80 | 836 | 40 |
| 0.2112 | 0.536 | 5.55 | 3.10 | 18 | 80 | 835 | 40 |
| 0.2134 | 0.542 | 5.61 | 3.11 | 18 | 80 | 835 | 40 |
| 0.2155 | 0.547 | 5.67 | 3.11 | 18 | 80 | 834 | 40 |
| 0.2176 | 0.553 | 5.72 | 3.11 | 18 | 80 | 834 | 40 |
| 0.2196 | 0.558 | 5.78 | 3.11 | 18 | 80 | 833 | 40 |
| 0.2219 | 0.564 | 5.84 | 3.11 | 18 | 80 | 833 | 40 |
| 0.2239 | 0.569 | 5.89 | 3.12 | 18 | 80 | 832 | 40 |
| 0.2259 | 0.574 | 5.94 | 3.12 | 18 | 80 | 832 | 40 |
| 0.2280 | 0.579 | 6.00 | 3.12 | 18 | 80 | 831 | 40 |
| 0.2300 | 0.584 | 6.05 | 3.12 | 18 | 80 | 831 | 40 |
| 0.2320 | 0.589 | 6.10 | 3.12 | 18 | 80 | 830 | 40 |
| 0.2341 | 0.595 | 6.16 | 3.12 | 18 | 80 | 830 | 40 |
| 0.2363 | 0.600 | 6.22 | 3.13 | 18 | 80 | 829 | 40 |
| 0.2385 | 0.606 | 6.27 | 3.13 | 18 | 80 | 829 | 40 |
| 0.2407 | 0.611 | 6.33 | 3.13 | 18 | 80 | 828 | 40 |
| 0.2427 | 0.616 | 6.38 | 3.13 | 18 | 80 | 828 | 40 |
| 0.2449 | 0.622 | 6.44 | 3.13 | 18 | 80 | 827 | 40 |
| 0.2472 | 0.628 | 6.50 | 3.14 | 18 | 80 | 827 | 40 |
| 0.2495 | 0.634 | 6.56 | 3.14 | 18 | 80 | 826 | 40 |
| 0.2517 | 0.639 | 6.62 | 3.14 | 18 | 80 | 826 | 40 |
| 0.2540 | 0.645 | 6.68 | 3.14 | 18 | 80 | 825 | 40 |
| 0.2563 | 0.651 | 6.74 | 3.14 | 18 | 80 | 825 | 39 |
| 0.2586 | 0.657 | 6.80 | 3.15 | 18 | 80 | 824 | 39 |
| 0.2608 | 0.662 | 6.86 | 3.15 | 18 | 80 | 824 | 39 |
| 0.2628 | 0.668 | 6.91 | 3.15 | 18 | 80 | 823 | 39 |
| 0.2651 | 0.673 | 6.97 | 3.15 | 18 | 80 | 823 | 39 |
| 0.2673 | 0.679 | 7.03 | 3.15 | 18 | 80 | 822 | 39 |
| 0.2695 | 0.685 | 7.09 | 3.16 | 18 | 80 | 821 | 39 |
| 0.2715 | 0.690 | 7.14 | 3.16 | 18 | 80 | 821 | 39 |
| 0.2736 | 0.695 | 7.20 | 3.16 | 18 | 80 | 821 | 39 |
| 0.2759 | 0.701 | 7.26 | 3.16 | 20 | 89 | 911 | 44 |
| 0.2781 | 0.706 | 7.31 | 3.16 | 18 | 80 | 819 | 39 |

## Unconfined Compressive Strength
## ASTM D2166

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33.0' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 9/20/2018 |
| LOCATION | -- | DESCRIPTION | lean clay w/gravel |
| DATE TESTED | 10/17/18 | | |
| TECHNICIAN | SPH/CAL | | |

| Displacement (in) | Displacement (cm) | Strain (%) | Average Cross Sectional Area (in²) | Load (lbs) | Load (N) | Stress (psf) | Stress (kPa) |
|---|---|---|---|---|---|---|---|
| 0.2804 | 0.712 | 7.38 | 3.17 | 20 | 89 | 910 | 44 |
| 0.2825 | 0.718 | 7.43 | 3.17 | 20 | 89 | 909 | 44 |
| 0.2847 | 0.723 | 7.49 | 3.17 | 20 | 89 | 909 | 44 |
| 0.2867 | 0.728 | 7.54 | 3.17 | 20 | 89 | 908 | 43 |
| 0.2888 | 0.734 | 7.60 | 3.17 | 20 | 89 | 908 | 43 |
| 0.2911 | 0.739 | 7.66 | 3.17 | 20 | 89 | 907 | 43 |
| 0.2932 | 0.745 | 7.71 | 3.18 | 20 | 89 | 907 | 43 |
| 0.2955 | 0.751 | 7.77 | 3.18 | 20 | 89 | 906 | 43 |
| 0.2978 | 0.756 | 7.83 | 3.18 | 20 | 89 | 905 | 43 |
| 0.2999 | 0.762 | 7.89 | 3.18 | 20 | 89 | 905 | 43 |
| 0.3019 | 0.767 | 7.94 | 3.18 | 20 | 89 | 904 | 43 |
| 0.3040 | 0.772 | 8.00 | 3.19 | 20 | 89 | 904 | 43 |
| 0.3062 | 0.778 | 8.05 | 3.19 | 20 | 89 | 903 | 43 |
| 0.3084 | 0.783 | 8.11 | 3.19 | 20 | 89 | 903 | 43 |
| 0.3106 | 0.789 | 8.17 | 3.19 | 20 | 89 | 902 | 43 |
| 0.3127 | 0.794 | 8.22 | 3.19 | 20 | 89 | 902 | 43 |
| 0.3149 | 0.800 | 8.28 | 3.20 | 20 | 89 | 901 | 43 |
| 0.3171 | 0.805 | 8.34 | 3.20 | 20 | 89 | 900 | 43 |
| 0.3192 | 0.811 | 8.40 | 3.20 | 20 | 89 | 900 | 43 |
| 0.3212 | 0.816 | 8.45 | 3.20 | 20 | 89 | 899 | 43 |
| 0.3235 | 0.822 | 8.51 | 3.20 | 20 | 89 | 899 | 43 |
| 0.3256 | 0.827 | 8.56 | 3.21 | 20 | 89 | 898 | 43 |
| 0.3277 | 0.832 | 8.62 | 3.21 | 20 | 89 | 898 | 43 |
| 0.3300 | 0.838 | 8.68 | 3.21 | 20 | 89 | 897 | 43 |
| 0.3321 | 0.844 | 8.73 | 3.21 | 20 | 89 | 897 | 43 |
| 0.3343 | 0.849 | 8.79 | 3.21 | 20 | 89 | 896 | 43 |
| 0.3364 | 0.854 | 8.85 | 3.22 | 20 | 89 | 895 | 43 |
| 0.3387 | 0.860 | 8.91 | 3.22 | 20 | 89 | 895 | 43 |
| 0.3407 | 0.865 | 8.96 | 3.22 | 20 | 89 | 894 | 43 |
| 0.3427 | 0.870 | 9.01 | 3.22 | 20 | 89 | 894 | 43 |
| 0.3448 | 0.876 | 9.07 | 3.22 | 20 | 89 | 893 | 43 |
| 0.3471 | 0.882 | 9.13 | 3.23 | 20 | 89 | 893 | 43 |
| 0.3492 | 0.887 | 9.18 | 3.23 | 20 | 89 | 892 | 43 |
| 0.3514 | 0.893 | 9.24 | 3.23 | 20 | 89 | 892 | 43 |
| 0.3535 | 0.898 | 9.30 | 3.23 | 20 | 89 | 891 | 43 |
| 0.3557 | 0.903 | 9.36 | 3.23 | 20 | 89 | 890 | 43 |
| 0.3579 | 0.909 | 9.41 | 3.24 | 20 | 89 | 890 | 43 |
| 0.3600 | 0.914 | 9.47 | 3.24 | 20 | 89 | 889 | 43 |
| 0.3623 | 0.920 | 9.53 | 3.24 | 20 | 89 | 889 | 43 |
| 0.3644 | 0.926 | 9.58 | 3.24 | 20 | 89 | 888 | 43 |
| 0.3666 | 0.931 | 9.64 | 3.24 | 20 | 89 | 888 | 43 |
| 0.3687 | 0.936 | 9.70 | 3.25 | 20 | 89 | 887 | 42 |
| 0.3708 | 0.942 | 9.75 | 3.25 | 20 | 89 | 887 | 42 |

## Unconfined Compressive Strength
## ASTM D2166

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33.0' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 9/20/2018 |
| LOCATION | -- | DESCRIPTION | lean clay w/gravel |
| DATE TESTED | 10/17/18 | | |
| TECHNICIAN | SPH/CAL | | |

| Displacement (in) | Displacement (cm) | Strain (%) | Average Cross Sectional Area (in²) | Load (lbs) | Load (N) | Stress (psf) | Stress (kPa) |
|---|---|---|---|---|---|---|---|
| 0.3728 | 0.947 | 9.81 | 3.25 | 20 | 89 | 886 | 42 |
| 0.3748 | 0.952 | 9.86 | 3.25 | 20 | 89 | 886 | 42 |
| 0.3771 | 0.958 | 9.92 | 3.25 | 20 | 89 | 885 | 42 |
| 0.3794 | 0.964 | 9.98 | 3.26 | 20 | 89 | 884 | 42 |
| 0.3816 | 0.969 | 10.04 | 3.26 | 20 | 89 | 884 | 42 |
| 0.3838 | 0.975 | 10.09 | 3.26 | 20 | 89 | 883 | 42 |
| 0.3860 | 0.980 | 10.15 | 3.26 | 20 | 89 | 883 | 42 |
| 0.3883 | 0.986 | 10.21 | 3.27 | 20 | 89 | 882 | 42 |
| 0.3905 | 0.992 | 10.27 | 3.27 | 20 | 89 | 881 | 42 |
| 0.3928 | 0.998 | 10.33 | 3.27 | 20 | 89 | 881 | 42 |
| 0.3951 | 1.004 | 10.39 | 3.27 | 20 | 89 | 880 | 42 |
| 0.3973 | 1.009 | 10.45 | 3.27 | 20 | 89 | 880 | 42 |
| 0.3996 | 1.015 | 10.51 | 3.28 | 20 | 89 | 879 | 42 |
| 0.4019 | 1.021 | 10.57 | 3.28 | 20 | 89 | 879 | 42 |
| 0.4040 | 1.026 | 10.63 | 3.28 | 20 | 89 | 878 | 42 |
| 0.4063 | 1.032 | 10.69 | 3.28 | 20 | 89 | 877 | 42 |
| 0.4084 | 1.037 | 10.74 | 3.28 | 20 | 89 | 877 | 42 |
| 0.4104 | 1.042 | 10.79 | 3.29 | 20 | 89 | 876 | 42 |
| 0.4126 | 1.048 | 10.85 | 3.29 | 20 | 89 | 876 | 42 |
| 0.4148 | 1.054 | 10.91 | 3.29 | 20 | 89 | 875 | 42 |
| 0.4168 | 1.059 | 10.96 | 3.29 | 20 | 89 | 875 | 42 |
| 0.4190 | 1.064 | 11.02 | 3.29 | 20 | 89 | 874 | 42 |
| 0.4212 | 1.070 | 11.08 | 3.30 | 20 | 89 | 874 | 42 |
| 0.4235 | 1.076 | 11.14 | 3.30 | 20 | 89 | 873 | 42 |
| 0.4255 | 1.081 | 11.19 | 3.30 | 20 | 89 | 872 | 42 |
| 0.4275 | 1.086 | 11.24 | 3.30 | 20 | 89 | 872 | 42 |
| 0.4297 | 1.091 | 11.30 | 3.31 | 20 | 89 | 871 | 42 |
| 0.4320 | 1.097 | 11.36 | 3.31 | 22 | 98 | 958 | 46 |
| 0.4343 | 1.103 | 11.42 | 3.31 | 20 | 89 | 870 | 42 |
| 0.4366 | 1.109 | 11.48 | 3.31 | 22 | 98 | 957 | 46 |
| 0.4388 | 1.115 | 11.54 | 3.31 | 22 | 98 | 956 | 46 |
| 0.4411 | 1.120 | 11.60 | 3.32 | 20 | 89 | 868 | 42 |
| 0.4435 | 1.126 | 11.66 | 3.32 | 22 | 98 | 955 | 46 |
| 0.4457 | 1.132 | 11.72 | 3.32 | 22 | 98 | 954 | 46 |
| 0.4479 | 1.138 | 11.78 | 3.32 | 20 | 89 | 867 | 41 |
| 0.4502 | 1.144 | 11.84 | 3.33 | 22 | 98 | 953 | 46 |
| 0.4524 | 1.149 | 11.90 | 3.33 | 22 | 98 | 952 | 46 |
| 0.4547 | 1.155 | 11.96 | 3.33 | 22 | 98 | 951 | 46 |
| 0.4568 | 1.160 | 12.01 | 3.33 | 22 | 98 | 951 | 46 |
| 0.4591 | 1.166 | 12.08 | 3.33 | 22 | 98 | 950 | 45 |
| 0.4614 | 1.172 | 12.14 | 3.34 | 22 | 98 | 949 | 45 |
| 0.4636 | 1.178 | 12.19 | 3.34 | 22 | 98 | 949 | 45 |
| 0.4659 | 1.183 | 12.25 | 3.34 | 22 | 98 | 948 | 45 |

## Unconfined Compressive Strength
## ASTM D2166

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33.0' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 9/20/2018 |
| LOCATION | -- | DESCRIPTION | lean clay w/gravel |
| DATE TESTED | 10/17/18 | | |
| TECHNICIAN | SPH/CAL | | |

| Displacement (in) | Displacement (cm) | Strain (%) | Average Cross Sectional Area (in²) | Load (lbs) | Load (N) | Stress (psf) | Stress (kPa) |
|---|---|---|---|---|---|---|---|
| 0.4680 | 1.189 | 12.31 | 3.34 | 22 | 98 | 948 | 45 |
| 0.4703 | 1.195 | 12.37 | 3.35 | 22 | 98 | 947 | 45 |
| 0.4724 | 1.200 | 12.43 | 3.35 | 22 | 98 | 946 | 45 |
| 0.4744 | 1.205 | 12.48 | 3.35 | 22 | 98 | 946 | 45 |
| 0.4766 | 1.211 | 12.54 | 3.35 | 22 | 98 | 945 | 45 |
| 0.4789 | 1.216 | 12.60 | 3.35 | 22 | 98 | 945 | 45 |
| 0.4811 | 1.222 | 12.65 | 3.36 | 22 | 98 | 944 | 45 |
| 0.4834 | 1.228 | 12.71 | 3.36 | 22 | 98 | 943 | 45 |
| 0.4856 | 1.233 | 12.77 | 3.36 | 22 | 98 | 943 | 45 |
| 0.4879 | 1.239 | 12.83 | 3.36 | 22 | 98 | 942 | 45 |
| 0.4900 | 1.245 | 12.89 | 3.37 | 22 | 98 | 941 | 45 |
| 0.4923 | 1.250 | 12.95 | 3.37 | 22 | 98 | 941 | 45 |
| 0.4944 | 1.256 | 13.00 | 3.37 | 22 | 98 | 940 | 45 |
| 0.4964 | 1.261 | 13.06 | 3.37 | 22 | 98 | 940 | 45 |
| 0.4986 | 1.266 | 13.11 | 3.37 | 22 | 98 | 939 | 45 |
| 0.5008 | 1.272 | 13.17 | 3.38 | 22 | 98 | 938 | 45 |
| 0.5030 | 1.278 | 13.23 | 3.38 | 22 | 98 | 938 | 45 |
| 0.5067 | 1.287 | 13.33 | 3.38 | 22 | 98 | 937 | 45 |
| 0.5090 | 1.293 | 13.39 | 3.38 | 22 | 98 | 936 | 45 |
| 0.5112 | 1.298 | 13.45 | 3.39 | 22 | 98 | 935 | 45 |
| 0.5135 | 1.304 | 13.51 | 3.39 | 22 | 98 | 935 | 45 |
| 0.5184 | 1.317 | 13.63 | 3.39 | 22 | 98 | 933 | 45 |
| 0.5207 | 1.323 | 13.70 | 3.40 | 22 | 98 | 933 | 45 |
| 0.5228 | 1.328 | 13.75 | 3.40 | 22 | 98 | 932 | 45 |
| 0.5251 | 1.334 | 13.81 | 3.40 | 22 | 98 | 931 | 45 |
| 0.5273 | 1.339 | 13.87 | 3.40 | 22 | 98 | 931 | 45 |
| 0.5295 | 1.345 | 13.93 | 3.41 | 22 | 98 | 930 | 45 |
| 0.5315 | 1.350 | 13.98 | 3.41 | 22 | 98 | 930 | 45 |
| 0.5336 | 1.355 | 14.03 | 3.41 | 22 | 98 | 929 | 44 |
| 0.5358 | 1.361 | 14.09 | 3.41 | 22 | 98 | 928 | 44 |
| 0.5380 | 1.367 | 14.15 | 3.41 | 20 | 89 | 843 | 40 |
| 0.5403 | 1.372 | 14.21 | 3.42 | 22 | 98 | 927 | 44 |
| 0.5424 | 1.378 | 14.27 | 3.42 | 22 | 98 | 926 | 44 |
| 0.5447 | 1.384 | 14.33 | 3.42 | 22 | 98 | 926 | 44 |
| 0.5468 | 1.389 | 14.38 | 3.42 | 22 | 98 | 925 | 44 |
| 0.5491 | 1.395 | 14.44 | 3.43 | 22 | 98 | 925 | 44 |
| 0.5512 | 1.400 | 14.50 | 3.43 | 22 | 98 | 924 | 44 |
| 0.5533 | 1.405 | 14.55 | 3.43 | 22 | 98 | 923 | 44 |
| 0.5555 | 1.411 | 14.61 | 3.43 | 22 | 98 | 923 | 44 |
| 0.5578 | 1.417 | 14.67 | 3.44 | 22 | 98 | 922 | 44 |
| 0.5600 | 1.422 | 14.73 | 3.44 | 22 | 98 | 921 | 44 |
| 0.5623 | 1.428 | 14.79 | 3.44 | 22 | 98 | 921 | 44 |
| 0.5644 | 1.434 | 14.84 | 3.44 | 22 | 98 | 920 | 44 |

## Unconfined Compressive Strength
## ASTM D2166

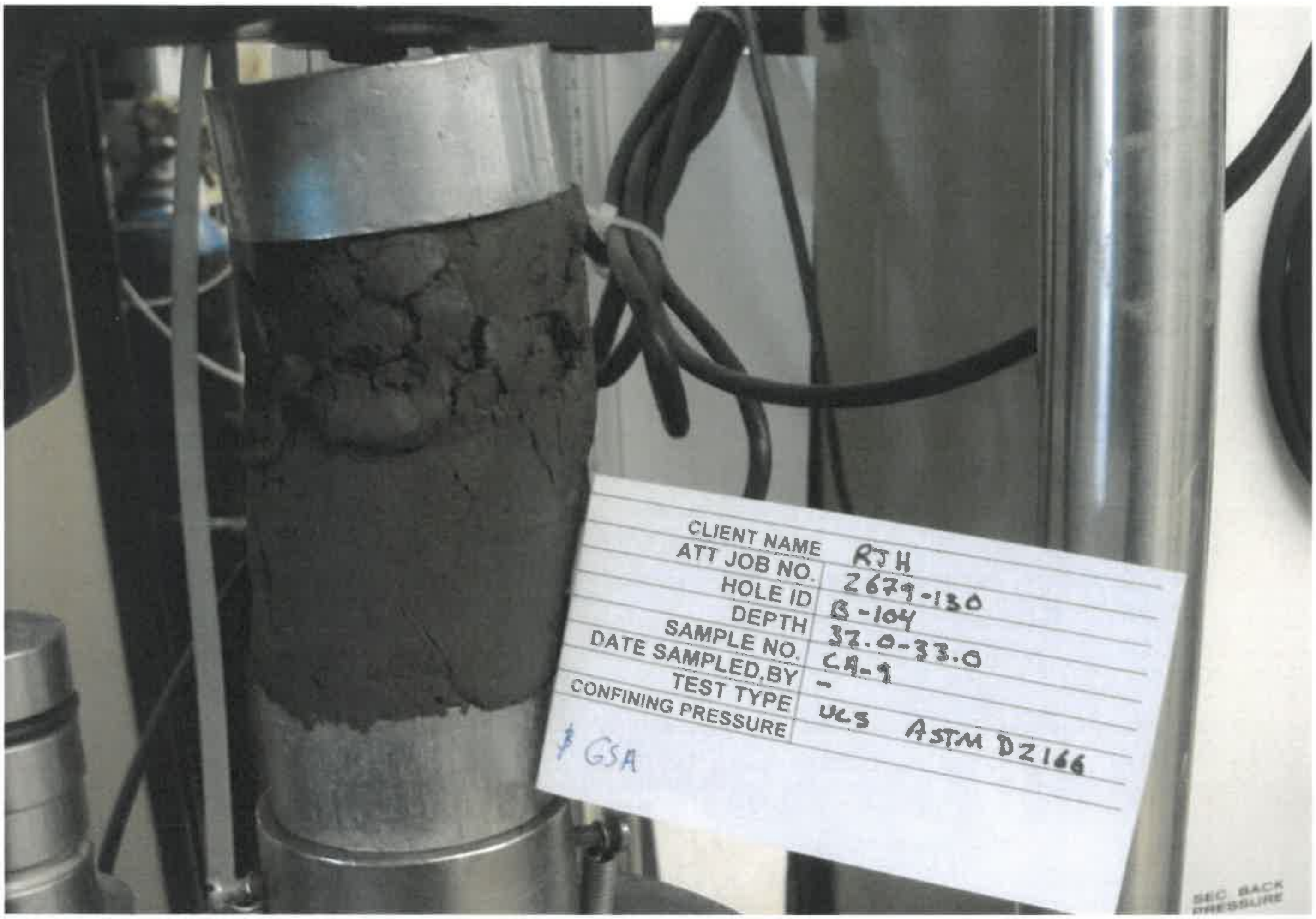
| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-104 |
| JOB NO. | 2679-130 | DEPTH | 32-33.0' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-9 |
| PROJECT NO. | 18115 | DATE SAMPLED | 9/20/2018 |
| LOCATION | -- | DESCRIPTION | lean clay w/gravel |
| DATE TESTED | 10/17/18 | | |
| TECHNICIAN | SPH/CAL | | |

| Displacement (in) | Displacement (cm) | Strain (%) | Average Cross Sectional Area (in²) | Load (lbs) | Load (N) | Stress (psf) | Stress (kPa) |
|---|---|---|---|---|---|---|---|
| 0.5666 | 1.439 | 14.90 | 3.44 | 20 | 89 | 836 | 40 |
| 0.5687 | 1.444 | 14.96 | 3.45 | 22 | 98 | 919 | 44 |
| 0.5709 | 1.450 | 15.02 | 3.45 | 22 | 98 | 918 | 44 |
| 0.5732 | 1.456 | 15.08 | 3.45 | 20 | 89 | 834 | 40 |
| 0.5753 | 1.461 | 15.13 | 3.45 | 20 | 89 | 834 | 40 |
| 0.5775 | 1.467 | 15.19 | 3.46 | 22 | 98 | 916 | 44 |
| 0.5797 | 1.472 | 15.25 | 3.46 | 22 | 98 | 916 | 44 |

# Image Attachment

ADVANCED TERRA TESTING

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |




NOTES

File name: 2679130__Image_18_10_18_07_47_43

ADVANCED TERRA TESTING

# Image Attachment

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |


NOTES

File name: 2679130__Image_18_10_18_07_48_14

Corrosion Suite
ASTM C1580, D4972, D1411, G187

ADVANCED TERRA TESTING

# Corrosion Suite
## ASTM C1580 D4972 D1411 G187

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 45-50' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | Bu-15 |
| PROJECT NO. | 18115 | DATE SAMPLED | 07/26/18 |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/29/18 | | |
| TECHNICIAN | SKS | | |

| | |
|---|---|
| Measured Sulfate Concentration (ppm): | 23 |
| Dilution: | 1.00:1 |
| Sulfate Concentration (ppm): | 23 |
| Measured Chloride Concentration (ppm): | 7.7 |
| Dilution: | 5.00:1 |
| Chloride Concentration (ppm): | 38.5 |
| pH: | 6.8 |
| Minimum Measured Resistivity (Ω): | 1200 |
| Box Correction Factor (cm): | 2.00 |
| Minimum Resistivity (Ω·cm): | 2400 |
| Measured Sulfide Concentration (ppm): | 0.104 |
| Dilution: | 1.00:1 |
| Sulfide Concentration (ppm): | 0.104 |

NOTES

| | | | |
|---|---|---|---|
| Data entry by: | SKS | Date: | 11/7/2018 |
| Checked by: | WAR | Date: | 11/7/18 |
| File name: | 2679130__Corrosion Test ASTM C1580 D4972 D1411 G187_2.xlsm | | |

ADVANCED TERRA TESTING

# Corrosion Suite
## ASTM C1580 D4972 D1411 G187

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-101 |
| JOB NO. | 2679-130 | DEPTH | 50.6-51.5' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | S-19 |
| PROJECT NO. | 18115 | DATE SAMPLED | 07/26/18 |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/27/18 | | |
| TECHNICIAN | SKS | | |

| | |
|---|---|
| Measured Sulfate Concentration (ppm): | 11 |
| Dilution: | 10.00:1 |
| Sulfate Concentration (ppm): | 107 |
| Measured Chloride Concentration (ppm): | 14.4 |
| Dilution: | 10.00:1 |
| Chloride Concentration (ppm): | 144.0 |
| pH: | 7.3 |
| Minimum Measured Resistivity (Ω): | 1300 |
| Box Correction Factor (cm): | 2.00 |
| Minimum Resistivity (Ω·cm): | 2600 |
| Measured Sulfide Concentration (ppm): | 0.092 |
| Dilution: | 2.00:1 |
| Sulfide Concentration (ppm): | 0.184 |

NOTES

| | | | |
|---|---|---|---|
| Data entry by: | SKS | Date: | 11/7/2018 |
| Checked by: | WAK | Date: | 11/7/18 |
| File name: | 2679130__Corrosion Test ASTM C1580 D4972 D1411 G187_0.xlsm | | |

ADVANCED TERRA TESTING

# Corrosion Suite
## ASTM C1580 D4972 D1411 G187

| | | | |
|---|---|---|---|
| CLIENT | RJH Consultants | BORING NO. | B-102A |
| JOB NO. | 2679-130 | DEPTH | 44-45' |
| PROJECT | Hogchute Dam Safety Evaluation | SAMPLE NO. | CA-20 |
| PROJECT NO. | 18115 | DATE SAMPLED | 07/24/18 |
| LOCATION | -- | DESCRIPTION | -- |
| DATE TESTED | 10/28/18 | | |
| TECHNICIAN | SKS | | |

| | |
|---|---|
| Measured Sulfate Concentration (ppm): | 5 |
| Dilution: | 1.00:1 |
| Sulfate Concentration (ppm): | 5 |
| Measured Chloride Concentration (ppm): | 10.8 |
| Dilution: | 10.00:1 |
| Chloride Concentration (ppm): | 108.0 |
| pH: | 7.4 |
| Minimum Measured Resistivity (Ω): | 770 |
| Box Correction Factor (cm): | 2.00 |
| Minimum Resistivity (Ω·cm): | 1540 |
| Measured Sulfide Concentration (ppm): | 0.01 |
| Dilution: | 1.00:1 |
| Sulfide Concentration (ppm): | 0.01 |

NOTES

| | | | |
|---|---|---|---|
| Data entry by: | SKS | Date: | 11/7/2018 |
| Checked by: | WAR | Date: | 11/7/18 |
| File name: | 2679130__Corrosion Test ASTM C1580 D4972 D1411 G187_1.xlsm | | |

# Pinhole Dispersion Test
# ASTM D4647, Method A

Identification and Classification of Dispersive Clay Soils by the Pinhole Test
ASTM D 4647 Method A

Client: RJH Consultants
Job No.: 2679-130
Project: Hogchute Dam Safety Evaluation
Location: --
Project No.: 18115

Boring No.: B-101
Depth: 30-31'
Sample No.: CA-11
Date Tested: 11/6/2018
By: BDF

**Before Test Moisture Content**

Wet Weight Soil & Dish: 29.84g
Dry Weight Soil & Dish: 25.99g
Weight Of Water: 3.86g
Dish Weight: 3.14g
Dry Weight Soil: 22.84g
Moisture Content: 16.89%

**Classification:** ND1
Original Pinhole Diameter: 0.04in, 0.0010m
Final Pinhole Diameter: 0.04in, 0.0010m
**Sample Type:** Remolded

**Before Test Density**

Height: 1.50in, 0.0381m
Diameter: 1.94in, 0.0492m
Weight: 0.3297lbs, 149.57g
Wet Density: 128.78lbs/ft³, 2063kg/m³
Dry Density: 110.17lbs/ft³, 1765kg/m³

**Test Data**

| Two Inch Head Height | Flow | Elapsed Time | Flow Rate | Turbidity | Observations |
|---|---|---|---|---|---|
| | 30ml | 60s | 0.008gal/min, 0.5ml/s | Clear | |
| | 29ml | 60s | 0.008gal/min, 0.5ml/s | Clear | |
| | 28ml | 60s | 0.007gal/min, 0.5ml/s | Clear | |
| | 28ml | 60s | 0.007gal/min, 0.5ml/s | Clear | |
| | 27ml | 60s | 0.007gal/min, 0.5ml/s | Clear | |
| | 27ml | 60s | 0.007gal/min, 0.5ml/s | Clear | |
| | 27ml | 60s | 0.007gal/min, 0.5ml/s | Clear | |
| | 27ml | 60s | 0.007gal/min, 0.5ml/s | Clear | |
| | 25ml | 60s | 0.007gal/min, 0.4ml/s | Clear | |
| | 26ml | 60s | 0.007gal/min, 0.4ml/s | Clear | |
| **Seven Inch Head Height** | **Flow** | **Elapsed Time** | **Flow Rate** | **Turbidity** | **Observations** |
| | 48ml | 60s | 0.013gal/min, 0.8ml/s | Barely Visible | Particles at bottom |
| | 48ml | 60s | 0.013gal/min, 0.8ml/s | Clear | |
| | 47ml | 60s | 0.012gal/min, 0.8ml/s | Clear | |
| | 47ml | 60s | 0.012gal/min, 0.8ml/s | Clear | |
| | 46ml | 60s | 0.012gal/min, 0.8ml/s | Clear | |
| **Fifteen Inch Head Height** | **Flow** | **Elapsed Time** | **Flow Rate** | **Turbidity** | **Observations** |
| | 79ml | 60s | 0.021gal/min, 1.3ml/s | Barely Visible | |
| | 79ml | 60s | 0.021gal/min, 1.3ml/s | Clear | |
| | 78ml | 60s | 0.021gal/min, 1.3ml/s | Clear | |
| | 78ml | 60s | 0.021gal/min, 1.3ml/s | Clear | |
| | 78ml | 60s | 0.021gal/min, 1.3ml/s | Clear | |
| **Forty Inch Head Height** | **Flow** | **Elapsed Time** | **Flow Rate** | **Turbidity** | **Observations** |
| | 69ml | 30s | 0.036gal/min, 2.3ml/s | Barely Visible | |
| | 70ml | 30s | 0.037gal/min, 2.3ml/s | Clear | |
| | 72ml | 30s | 0.038gal/min, 2.4ml/s | Clear | |
| | 70ml | 30s | 0.037gal/min, 2.3ml/s | Clear | Particles at bottom |
| | 70ml | 30s | 0.037gal/min, 2.3ml/s | Clear | |

File Name: 2679_130_pinhole-ASTMD-4647-R3_0.xls
Entered By: SPH
Date: 11/7/2018

Data Checked By: KMS
Date: 11/8/18

ADVANCED TERRA TESTING

**Image Attachment**

ADVANCED TERRA TESTING

| | | |
|---|---|---|
| CLIENT | RJH Consultants | B-101 |
| JOB NO. | 2679-130 | 30-31' |
| PROJECT | Hogchute Dam Safety Evaluation | CA-11 |
| PROJECT NO. | 18115 | |
| LOCATION | -- | AFTER TEST |


NOTES

File name: 2679130__Image_18_11_07_16_16_39

Identification and Classification of Dispersive Clay Soils by the Pinhole Test
ASTM D 4647 Method A

Client: RJH Consultants
Job No.: 2679-130
Project: Hogchute Dam Safety Evaluation
Location: --
Project No.: 18115

Boring No.: B-103
Depth: 15-16'
Sample No.: CA-8
Date Tested: 11/6/2018
By: BDF

**Before Test Moisture Content**

Wet Weight Soil & Dish: 39.71g
Dry Weight Soil & Dish: 35.33g
Weight Of Water: 4.38g
Dish Weight: 3.13g
Dry Weight Soil: 32.20g
Moisture Content: 13.60%

**Classification:** $\boxed{\text{ND1}}$
Original Pinhole Diameter: 0.04in, 0.0010m
Final Pinhole Diameter: 0.04in, 0.0010m
**Sample Type:** Remolded

**Before Test Density**

Height: 1.50in, 0.0381m
Diameter: 1.94in, 0.0492m
Weight: 0.3068lbs, 139.16g
Wet Density: 119.81lbs/ft³, 1919kg/m³
Dry Density: 105.47lbs/ft³, 1689kg/m³

**Test Data**

| Two Inch Head Height | Flow | Elapsed Time | Flow Rate | Turbidity | Observations |
|---|---|---|---|---|---|
| | 10ml | 30s | 0.005gal/min, 0.3ml/s | Clear | Particles on bottom |
| | 8ml | 30s | 0.004gal/min, 0.3ml/s | Clear | Particles on bottom |
| | 8ml | 30s | 0.004gal/min, 0.3ml/s | Clear | Particles on bottom |
| | 9ml | 30s | 0.005gal/min, 0.3ml/s | Clear | |
| | 9ml | 30s | 0.005gal/min, 0.3ml/s | Clear | |
| | 8ml | 30s | 0.004gal/min, 0.3ml/s | Clear | |
| | 12ml | 30s | 0.006gal/min, 0.4ml/s | Clear | |
| | 7ml | 30s | 0.004gal/min, 0.2ml/s | Clear | |
| | 8ml | 30s | 0.004gal/min, 0.3ml/s | Clear | |
| | 9ml | 30s | 0.005gal/min, 0.3ml/s | Clear | |
| **Seven Inch Head Height** | **Flow** | **Elapsed Time** | **Flow Rate** | **Turbidity** | **Observations** |
| | 42ml | 60s | 0.011gal/min, 0.7ml/s | Barely Visible | Particles on bottom |
| | 41ml | 60s | 0.011gal/min, 0.7ml/s | Barely Visible | |
| | 42ml | 60s | 0.011gal/min, 0.7ml/s | Clear | |
| | 42ml | 60s | 0.011gal/min, 0.7ml/s | Clear | |
| | 40ml | 60s | 0.011gal/min, 0.7ml/s | Clear | |
| **Fifteen Inch Head Height** | **Flow** | **Elapsed Time** | **Flow Rate** | **Turbidity** | **Observations** |
| | 78ml | 60s | 0.021gal/min, 1.3ml/s | Barely Visible | Particles on bottom |
| | 89ml | 60s | 0.024gal/min, 1.5ml/s | Clear | Particles on bottom |
| | 90ml | 60s | 0.024gal/min, 1.5ml/s | Clear | |
| | 88ml | 60s | 0.023gal/min, 1.5ml/s | Clear | |
| | 87ml | 60s | 0.023gal/min, 1.5ml/s | Clear | |
| **Forty Inch Head Height** | **Flow** | **Elapsed Time** | **Flow Rate** | **Turbidity** | **Observations** |
| | 74ml | 30s | 0.039gal/min, 2.5ml/s | Barely Visible | Particles on bottom |
| | 75ml | 30s | 0.040gal/min, 2.5ml/s | Clear | Particles on bottom |
| | 74ml | 30s | 0.039gal/min, 2.5ml/s | Clear | |
| | 73ml | 30s | 0.039gal/min, 2.4ml/s | Clear | |
| | 74ml | 30s | 0.039gal/min, 2.5ml/s | Clear | |

File Name: 2679_130_pinhole-ASTMD-4647-R3_1.xls
Entered By: SPH Date: 11/7/2018

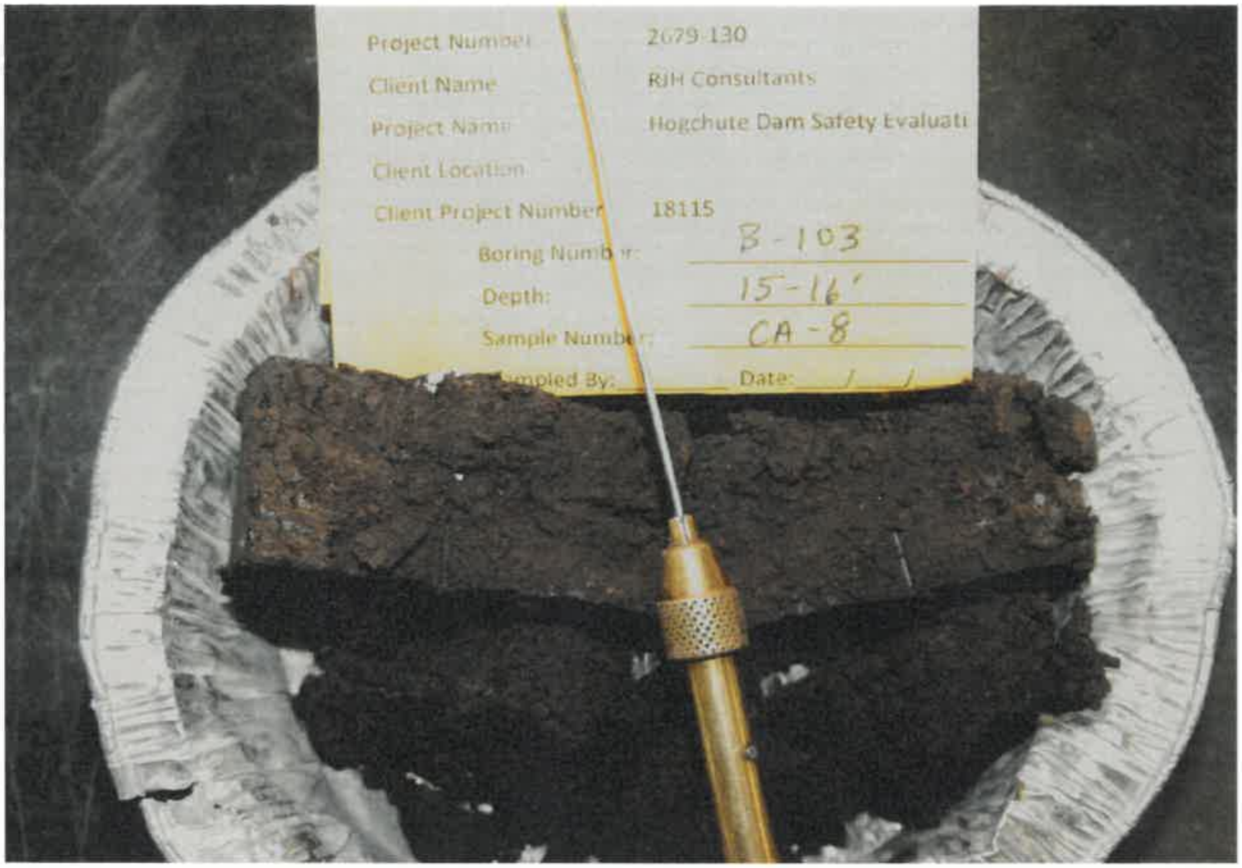
Data Checked By: KMS
Date: 11/8/18


ADVANCED TERRA TESTING

## Image Attachment

ADVANCED TERRA TESTING

| | | |
|---|---|---|
| CLIENT | RJH Consultants | B-103 |
| JOB NO. | 2679-130 | 15-16' |
| PROJECT | Hogchute Dam Safety Evaluation | CA-8 |
| PROJECT NO. | 18115 | |
| LOCATION | -- | AFTER TEST |




NOTES

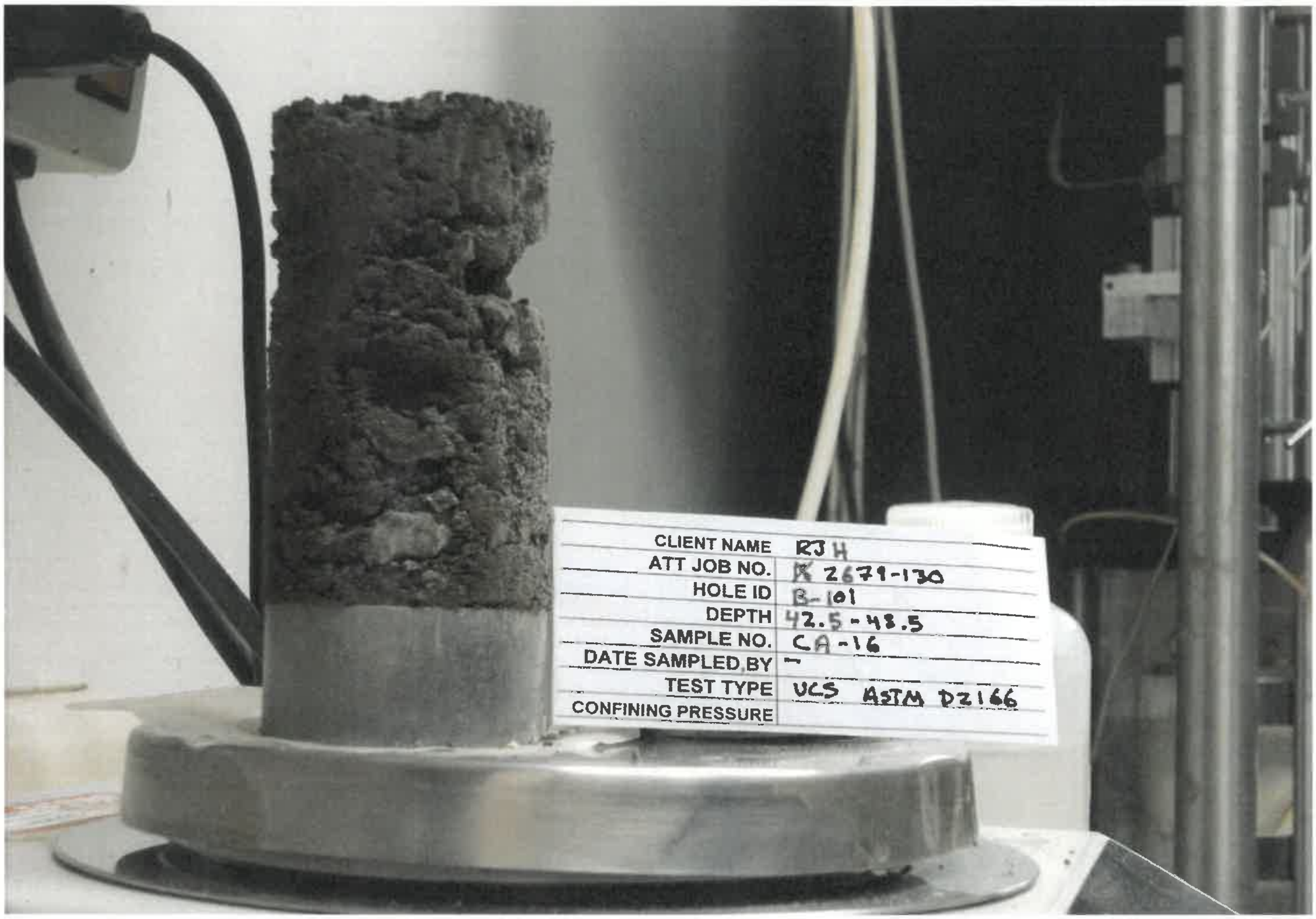
File name: 2679130__Image_18_11_07_16_19_51

# Other - Sample Photographs

# Image Attachment

ADVANCED TERRA TESTING

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |



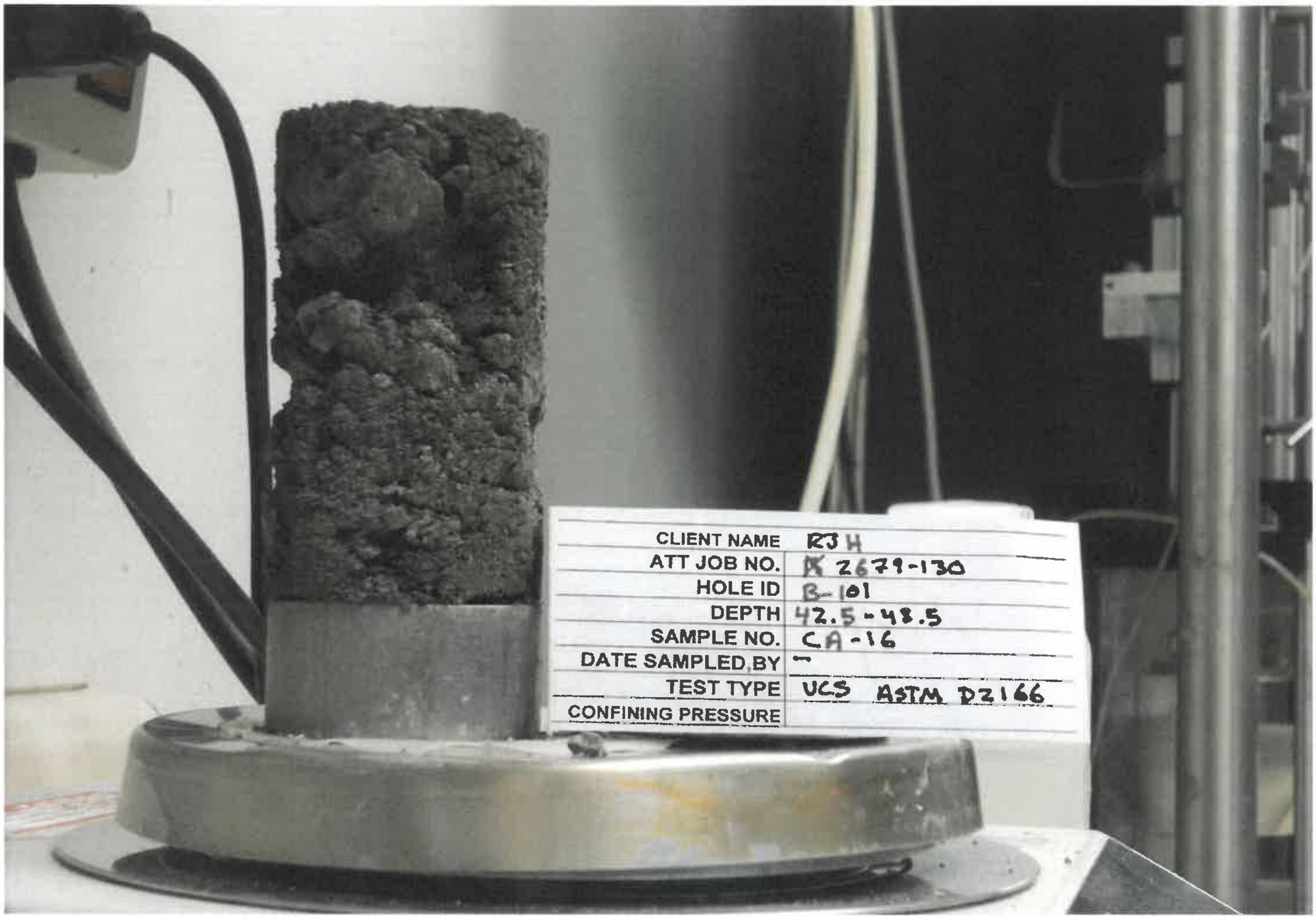

NOTES

File name: 2679130__Image_18_10_18_07_42_26

ADVANCED TERRA TESTING

# Image Attachment

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |




NOTES

File name: 2679130__Image_18_10_18_07_43_12

# Image Attachment

ADVANCED TERRA TESTING

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |


NOTES

File name: 2679130__Image_18_10_18_07_44_01

# Image Attachment

ADVANCED TERRA TESTING

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |


NOTES

File name: 2679130__Image_18_10_18_07_44_41

# Image Attachment

ADVANCED TERRA TESTING

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |

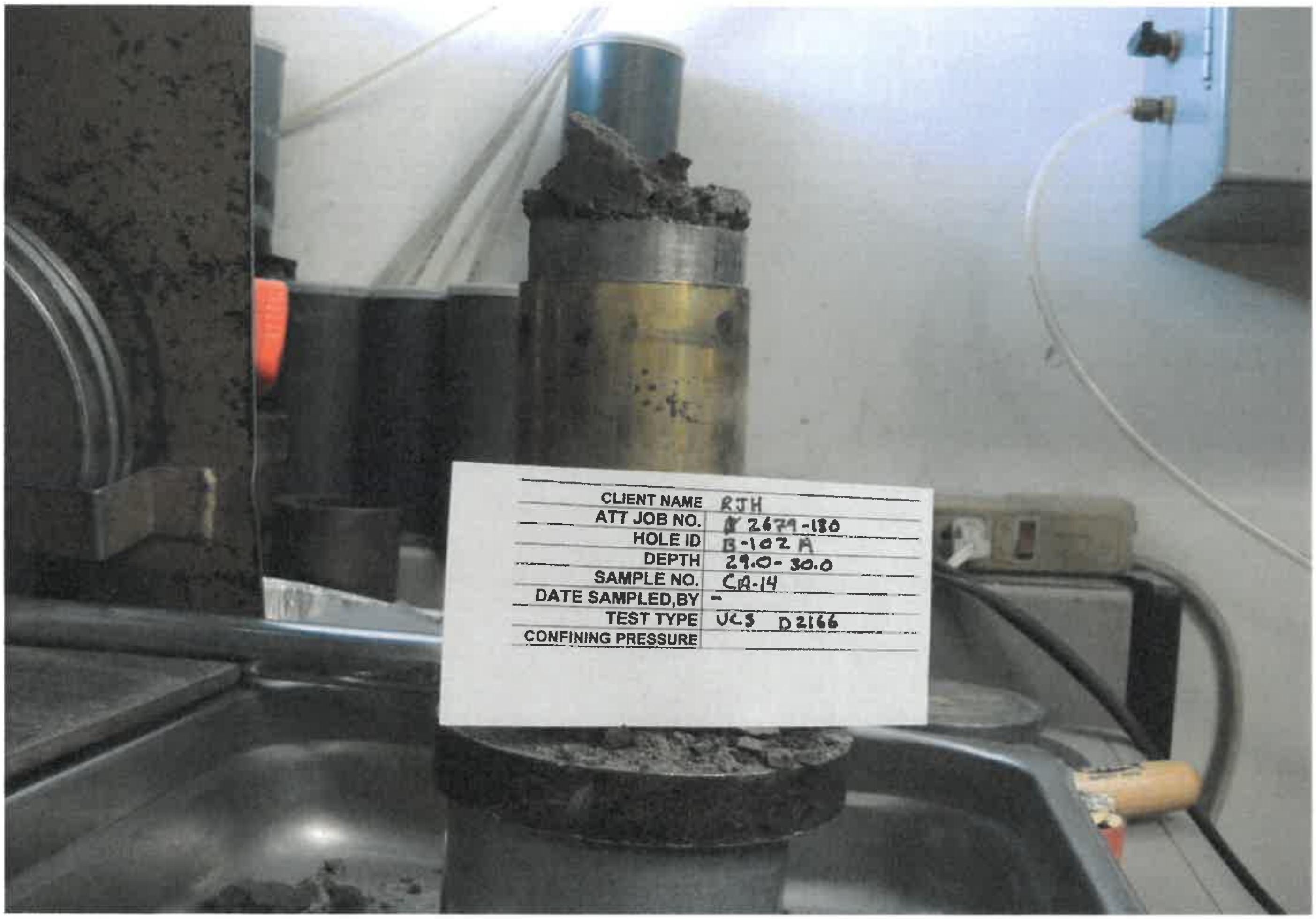

NOTES

File name: 2679130__Image_18_10_18_07_45_19

# Image Attachment

ADVANCED TERRA TESTING

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |




NOTES

File name: 2679130__Image_18_10_18_07_46_14

ADVANCED TERRA TESTING

# Image Attachment

| | | |
|---|---|---|
| CLIENT | RJH Consultants | -- |
| JOB NO. | 2679-130 | -- |
| PROJECT | Hogchute Dam Safety Evaluation | -- |
| PROJECT NO. | 18115 | -- |
| LOCATION | -- | -- |


NOTES

File name: 2679130__Image_18_10_18_07_46_52

# Appendix E

## Seepage Investigation Daily Field Reports

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 001-GOJ**
**Task 1002 Seepage Investigation** **Date: Wednesday, August 8, 2018**



**Prepared By:** Garrett Jackson (GOJ)
**Weather:** low 80's, mostly sunny, light-moderate breeze

## People on Site (arrival/departure time)

- RJH:
  - GOJ (09:45/18:00)
- Sorter:
  - Bill Ogle (10:25/17:45)
- Slade Connell, Ron Key from City of Grand Junction (~11:30-12:00) observing from dam crest

## Equipment on Site

*Mobile*

- GOJ Chevy Silverado
- Sorter Ford F250

*At Dam Site Overnight*

- Cat 320N backhoe

## Excavation Progress Summary

- Sorter mobilized to the site, unloaded the backhoe from the low-boy at the intersection of the Hogchute road and Land's End Road, walked the hoe down to the dam.
- The backhoe was used to move rocks on the right side of the downstream dam slope and over the outlet conduit to construct a working pad from which to reach the left (south) side of the conduit. The backhoe moved rocks from this area to expose the native soil under the riprap to a level below the top of the outlet conduit encasement. No wetness was encountered in the area left of the outlet conduit.
- The backhoe moved slightly and excavated rock to expose the top of the concrete-encased outlet conduit and the area right (north) of the conduit. Water has historically been observed right of the outlet conduit, pooled under the riprap behind (upstream of) the remains of the original outlet control structure at the downstream end of the conduit. Water was encountered during excavation along the right of the outlet about 12"-16" below the top of the encasement. Water appeared to be entering the excavation from along the conduit, but a specific location could not be identified. The backhoe continued removing rock along the conduit to follow the ponded water back under the riprap to about 25' upstream of the concrete structure headwall.
- The backhoe repositioned to the top of the outlet channel bank above the right end of the headwall to finish cleaning the excavation. Sorter used the backhoe and a hand

shovel to clear the excavation bottom and drain standing water around the right end of the headwall. To drain the water from the deeper portions of the excavation, a trench was excavated around the right end of the headwall, which bypassed the existing seepage measuring sump used for monitoring the flow. The sump and old drain pipe are now dry, and water from the excavated area drains under the outlet channel riprap into the channel downstream of the headwall.

## Seepage Observations

- At the beginning of the day, water was standing in the riprap behind the headwall and draining to the sump as usual. No flow measurement was taken, but visually the discharge appeared to be about 4-5 gpm, and was clear.
- Minor wetness was observed in a backhoe track on the native ground above the riprap on the right side of the dam toe. Wetness persisted through the day but dried slightly in the sun and breeze.
- At the end of the day, after the excavation had drained, very minor seepage was observed coming from under the thin layer of riprap at the north corner of the upstream end of the excavation. It is unknown at this time if this is a remnant of ponded water draining to the excavation, or if this is potentially groundwater discharging from the excavated natural hillside at the toe of the dam.
- Water was observed seeping from under the headwall slab when the rock and soil were excavated along the right side of the conduit. Discharge was from the gravel beneath the slab, was somewhat episodic, and was clear. Maximum discharge was estimated to be about 1 gpm.
- Minor wetness (no flow) was observed high on the slope in the dense willows above the two historic seepage channels through the willows.

## Plan for Next Work Day

- GOJ will call USFS and USACE first thing in the morning to discuss the work to date and invite them to observe conditions at the site.
- GOJ and Sorter to meet at the site tomorrow at 8:30 am.
- GOJ and Sorter will inspect the excavation to identify any sources of seepage from the outlet conduit, the dam toe, or the natural hillside.
- The outlet conduit concrete encasement will be cleaned with hand shovels to expose any seepage discharge location(s).
- All seepage locations will be documented with photos and measurements.
- SEO will be onsite to observe the excavation and seepage conditions.

## Site Coordination Activities

- Did not have a gate key or combination, so GOJ cut the chain on the gate to the reservoir. Slade Connell (City) placed a padlock on the gate later in the morning, combination is 1564. Gate is locked.

## Photographs

| | |
|---|---|
|  | Downstream toe of slope above the remains of the old outlet control structure and headwall prior to excavation for seepage investigation.<br><br>Standing water has been observed for many years under the rocks in the area behind the headwall and along the right side of the conduit. |

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 001-GOJ**
**Task 1002 Seepage Investigation** **Date: Wednesday, August 8, 2018**


Excavating the right (north) side of the outlet conduit, where water has been observed pooled behind the headwall for many years.

Note the left side of the conduit is dry.

Top of concrete-encased outlet conduit.

Water pooled right of the conduit behind the headwall.

Pooled seepage water draining around right end of headwall.

| | |
|---|---|
|  | Backhoe cleaning channel for draining excavation along right side of conduit. |

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 002-GOJ**
**Task 1002 Seepage Investigation** **Date: Wednesday, August 9, 2018**


**Prepared By:** Garrett Jackson (GOJ)
**Weather:** mid 80's, sunny, light-moderate breeze

## People on Site (arrival/departure time)

- RJH:
  - GOJ (08:00-14:45)
- Sorter:
  - Bill Ogle (08:50-14:45)
- Jackie Blumberg (JB) and Jason Ward (JW) (SEO) (~08:50-13:30)

## Equipment on Site

*Mobile*
- GOJ Chevy Silverado
- Sorter Ford F250
- SEO Chevy Blazer and Ford F150

*At Dam Site Overnight*
- All equipment demobilized from site

## Excavation Progress Summary

- After draining overnight, the excavated area right of the outlet conduit was essentially dry, except for water standing in several puddles. The seepage entering the excavation from under the rocks at the upstream end is a steady but barely-noticeable trickle. The only measurable water entering the excavation came from under the old control structure foundation slab at the downstream end of the conduit. The seepage flow was visually estimated to be about 4-5 gpm and was clear.
- After clearing the top of the concrete encasement under the slab, water was observed bubbling from an old broken approximately 3/4" inch diameter pipe in the top of the encasement. Based on a review of the 1947 design drawings, this pipe is believed to be the remnant of the reservoir level measurement line extending from the upstream end of the conduit to the old control structure at the downstream end. The line is shown as passing along the conduit within the concrete encasement. The pipe is located inside the old structure, about18" downstream of the upstream structure wall. An earlier patch is visible in the floor of the structure remains over the broken pipe, and the file mentions a previous repair to the reservoir level pressure line.
- With the excavation drained, I observed that the outlet conduit is founded on clayey soils that are very similar to the materials encountered in the piezometer borings drilled on the crest of the dam.

- Sorter backfilled the investigation excavation with the rock removed yesterday. Generally, and as feasible, Sorter placed smaller (< ~12") rocks in the bottom of the excavation at the concrete structure where the flowing water enters the excavation. Larger rocks were placed above these smaller rocks, taking care to not drop large rocks on top of the outlet conduit.
- Since the bottom of the new trench draining the excavation is lower than the existing drain pipe and sump, the drain was reconstructed by laying the old 4" PVC pipe in the bottom of the new trench. The old plastic sump was relocated to a new hole excavated in the riprap on the right side of the outlet channel downstream of the headwall, and the 4" pipe was anchored to drain into the relocated sump.

**SEO Discussion**

- GOJ, JB, and JW discussed the seepage investigation. All agreed that the major source of the water historically pooled behind the headwall has been identified, and this leakage from the broken pipe is not an immediate threat to the dam's safety. The broken reservoir level measurement pipe will be repaired or properly abandoned during rehabilitation of the outlet works.
- Other evidences of seepage (in the upstream corner of the excavation and in the dense willows at the top of the hill right of the outlet channel) will need to be evaluated and addressed, but there is no evidence at this time indicating this seepage is a dam safety concern.
- The City is considering not draining the reservoir for the outlet works assessment task of this dam safety evaluation. They will likely skip the assessment and proceed directly to design of the outlet works rehabilitation, which will include eliminating the twin 20-inch lines and extending the 30-inch conduit upstream to a new intake structure. In this case, there would be no need to drain the reservoir until it is required for construction. JB agreed that, if this is the City's plan, there will be no need to inspect the existing conduit this year. The post-construction inspection will restart the 10-year inspection cycle.

**Seepage Observations**

- Minor wetness (no flow) was observed in the two historic seepage channels through the willows.
- The shallow wetness exposed yesterday by the backhoe track on top of the hill above the excavation is dry.
- The ground in the dense willows at the top of the hill above the two historic seepage channels is very wet where it has been disturbed by the backhoe.

**Plan for Next Work Day**

Seepage investigation is complete.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project**
**Task 1002 Seepage Investigation**

**Report No.: 002-GOJ**
**Date: Wednesday, August 9, 2018**


**Site Coordination Activities**

- Sorter tracked the backhoe back up to the parking lot at about 12:45. Bill Ogle drove out to the observatory and called for the truck to come pick up the hoe. GOJ drove Bill back down to the parking lot, and Bill started driving the hoe up to Land's End Road for loading.
- 14:15 GOJ departed site.

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 002-GOJ**
**Task 1002 Seepage Investigation** **Date: Wednesday, August 9, 2018**


## Photographs

| | |
|---|---|
|  | Seepage emerging from under the old control structure foundation slab is the only measurable water entering the excavation. |
|  | Water is bubbling from a broken pipe in the top of the outlet conduit encasement. The pipe is believed to extend to the upstream end of the conduit, passing along the conduit within the concrete encasement. |

# DAILY SITE REPORT

**18115 Hogchute Dam Safety Evaluation Project** **Report No.: 002-GOJ**
**Task 1002 Seepage Investigation** **Date: Wednesday, August 9, 2018**



| | |
|---|---|
|  | Water from the broken pipe emerges from under the slab and drains to the right side of the conduit, where it is collected in the excavation and routed around the right end of the headwall for measurement. |
|  | Backhoe replacing excavated rock in the investigation excavation. |