****
USACE / NAVFAC / AFCEC **UFGS-31 33 10 (May 2025)**

Preparing Activity: USACE **New**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2025
****

SECTION TABLE OF CONTENTS

DIVISION 31 - EARTHWORK

SECTION 31 33 10

FOUNDATION DRILLING AND GROUTING IN ROCK

05/25

-- End of Section Table of Contents --

****

USACE / NAVFAC / AFCEC **UFGS-31 33 10 (May 2025)**

Preparing Activity: USACE **New**

UNIFIED FACILITIES GUIDE SPECIFICATIONS

References are in agreement with UMRL dated October 2025

****

SECTION 31 33 10

FOUNDATION DRILLING AND GROUTING IN ROCK
05/25

****

NOTE: This specification addresses rock grouting scenarios where grouting occurs directly on the bedrock surface, through soil, or through limited concrete.

This guide specification covers the requirements for drilling holes, washing holes, water pressure testing, grout connections; furnishing, handling, transporting, storing, mixing and injecting grout; care and disposal of drill cuttings; wastewater/grout; and all such other operations incidental to the drilling and the grouting operations.

Several UFGS grouting specifications are available. Use the most appropriate specification for your project. Specification 31 43 13.13 CONCRETE PRESSURE GROUTING, addresses grouting of concrete dams, concrete locks, and gallery grouting.

Specification 31 33 20 addresses permeation and void grouting in soil. Specification 31 33 30 addresses Low Mobility Grouting (LMG) in soil). Specification 31 73 19 addresses tunnel and shaft grouting.

Adhere to UFC 1-300-02 Unified Facilities Guide Specifications (UFGS) Format Standard when editing this guide specification or preparing new project specification sections. Edit this guide specification for project specific requirements by adding, deleting, or revising text. For bracketed items, choose applicable items(s) or insert appropriate information.

Remove information and requirements not required in respective project, whether or not brackets are present.

****

PART 1 GENERAL

****

NOTE: The following Tailoring Options are included:

Tailoring Option 1: "Drilling in Earth Embankment Dams and Levees" to include pertinent requirements for drilling in or near earthen dams, levees, or near locks and dams. For USACE projects include requirements to meet ER 1110-1-1807.

Tailoring Option 2: "Computer Grouting" includes all general, materials, and execution related options if computer grouting is required by the user. Computer grouting is referred to as an Automated Grouting Data Collection System (AGDCS)throughout the specification.

Tailoring Option 3: "Downhole Imaging" includes all related options for downhole surveys, including optical, acoustical, borehole deviation, and any physical caliper downhole surveys required by the user.

There are bracketed options for 'Instrumented Packers'. Instrumented packers read the pressure downhole at the point of grouting rather than at the ground surface. If you are grouting in an embankment dam/levee or through/near an existing concrete lock and/or concrete dam for Department of the Army projects, it is recommended to use Tailoring Options 1-3 along with bracketed options for instrumented packers.

****

****

NOTE: This specification does not address soil grouting (except incidentally) and does not include provisions for solution grouts (i.e., chemical grouts).

The specification may be used as a general outline for chemical grouting or other specialty grouting applications by insertion of the proper equipment, materials, and procedures in the appropriate paragraphs and by modification and deletion of other paragraphs. Specification 31 73 19 Tunnel and Shaft Grouting has example work plan, materials, and execution language that can be inserted into this specification if chemical grouting methods are desired. Engineer Manuals 1110-2-3500, "Chemical Grouting", and 1110-2-3506, "Grouting Technology", should be used as guides when the use of chemical grouts and other specialty grouting applications are being considered. The manufacturer of products that meet the potential job requirements should be contacted for verification. Also, consideration

should be given to conducting laboratory and field tests and evaluations of the system or systems being considered for a given applications.

Due to quickly evolving technologies and techniques, engaging a grouting specialist consultant is often advisable to ensure the most appropriate, cost-effective and approach is used.

For large projects address the potential for multi-shift working conditions.

****

1.1 DESCRIPTION OF WORK

****

NOTE: Provide a brief summary of the project scope, including the required number of exploratory and verification holes anticipated, and any prudent references applicable to the layout, depths, and orientation required for the grouting. It is recommended to include at least 3 exploratory holes and to complete verification holes every 33-84 meters or 100-250 feet. Include any special restrictions or coordination required.

Include a statement that the technical specifications govern over the description of work.

****

Advance drilling and grouting through [concrete][natural soils][fill soils] and bedrock. The total depth of the grout curtain varies between [_____] and [_____] meters feet. Perform exploratory drilling and grouting every [_____] meters feet[or as indicated on the project plans]. Drill and grout production grout holes as required [by exploratory grouting][as indicated on the project plans].[Split space production grout holes in accordance with the split spacing method.] Advance verification holes every [_____] meters feet feet or between stations [_____] and [_____].

1.2 RELATED WORK SPECIFIED ELSEWHERE

[Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION

][Section 02 32 13 SUBSURFACE DRILLING AND SAMPLING

]1.3 UNIT PRICES

****

NOTE: If Section 01 20 00 PRICE AND PAYMENT PROCEDURES is included in the project specifications, this paragraph title (UNIT PRICES) should be deleted from this section and the remaining appropriately edited subparagraphs below should be inserted into Section 01 20 00.

Methods for listing subdivided items are described in Paragraph "Variations in Estimated Quantities - Subdivided Items" of Army Federal Acquisition

Regulation Supplement (AFARS) 5152.211-9001. Subdivided items are recommended on all but the smallest jobs because it is difficult to accurately estimate grouting quantities.

****

1.3.1 [Grouting]Mobilization and Demobilization

****

NOTE: This provision only applies to instances where grouting is the primary feature of work. A separate "Grouting Mobilization and Demobilization" could also be added where grouting is a minor feature of work as part of a much larger project. Another option is to include mobilization costs as part of the overall mobilization bid cost for large projects.

Per the DFARS, there are two separate clauses that involve Mobilization. 252.236-7003 - Payment for Mobilization and Preparatory Work, and 252.236-7004 - Payment for Mobilization and Demobilization. Typically, one or the other clause is used in a contract, not both. If a separate CLIN for mobilizing the grouting equipment is to be used, coordinate it with the clause used for the overall mobilization (if used).

****

1.3.1.1 Payment

Payment will be made for costs associated with mobilization and demobilization, staging areas, temporary construction facilities, Surety Bonds, and for all other work in accordance with [Section 01 50 00 TEMPORARY CONSTRUCTION FACILITIES AND CONTROLS][_____]. Demobilization also includes all site restoration activities. Payment will constitute full compensation for all the work involved in mobilization and demobilization as shown or specified in the Contract Documents, and as directed by the Contracting Officer. Mobilization and Demobilization is cost loaded 60 percent mobilization and 40 percent demobilization.

Intermittent or staged mobilization/demobilization for convenience is considered incidental to this item and does not constitute additional payment unless directed by the Contracting Officer in writing.[The Government makes no additional separate payment for items included herein for this item or by reference.]

1.3.1.2 Unit of Measure

Unit of measure: Job.

1.3.2 Overburden and Fill Drilling of Grout Holes and PVC Casing [Angle][Vertical]

****

NOTE: This section is for general overburden drilling. Remove this section if you are drilling/coring on exposed rock, concrete, or in a dam/levee. The line item is irrespective of series

(primary, secondary, successive series, exploratory or verification).

If both vertical and angled holes are planned, then separate line items should be utilized for the separate types of drilling. Angled overburden drilling is more expensive for multiple reasons.

****

1.3.2.1 Payment

Payment for drilling [vertical][angled] grout holes in [soil] [and][or] [placed fill] is made under this item. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: initial setup onto the hole, additional effort associated with drilling [_____] meters [4][5][_____] feet into the bedrock, care and disposal of drilling waste, annular space grouting, removal of any temporary casing as applicable, clean-up of the site, and providing all records and data. Additional quantities of permanent casing required to complete the project due to defective, damaged, or mis-installed quantities of permanent casing are the responsibility of the Contractor at no additional cost to the Government. Maintain these additional quantities on-site. All measurement for payment must be made by or in the presence of the Contracting Officer.[The Government makes no additional separate payment for items included herein for this item or by reference.]

1.3.2.2 Measurement

Measure boreholes and PVC casing in overburden for payment along the axis of the boring up to the nearest linear meter foot per hole.[Measurement is made from the top of ground surface to the depth of hole cased. Stick-up of casing above the ground surface is not included in this measurement.] All measurements for payment must be made by or in the presence of the Government. Round linear measurements for payment to the nearest meter foot per hole.

1.3.2.3 Unit Of Measure

Unit of measure: Linear meter foot.

1.3.3 Overburden and Embankment Drilling of Grout Holes and PVC Casing [Dam][Levee] [Angle][Vertical]

****

NOTE: This line item is for drilling in dams and levees. If both dam/levee drilling and non-dam/levee drilling is planned, then utilize both this line item and the previous line item. If only dam drilling is planned, delete the previous line item.

Delete measurement and payment items for Overburden Drilling of Grout Holes and PVC Casing Angle or Vertical. A Government Geotech/Geologist should have approval of the rock sockets for this item. This will need to be included in the contract and coordinated as part of the construction team. Grout should be tracked as material pay item and not be

incidental to this item.

If both vertical and angled holes are planned, then separate line items should be utilized for the separate types of drilling. Angled overburden drilling is more expensive for multiple reasons.

The embedment depth into rock (rock socket) must be specified. Sonic drills can penetrate tens of feet into bedrock, but that much embedment is not typically necessary. Previous jobs have frequently required 1.5 meters5 feet embedment into bedrock, but sometimes as little as 0.6 meters2 feet. The weathering depth of the bedrock will strongly influence the embedment because penetrating into less weathered bedrock is desirable.

****

1.3.3.1 Payment

Payment includes costs associated with advancing [vertical][angled] grout holes in the embankment[and underlying native soil]. All incidental costs associated with the performance of work in this section are included in the Contract price for this item, including but not limited to: providing all equipment, labor, supplies, initial set-up on the hole, drilling through the embankment, additional effort associated with setting the casing [_____] meters [4][5][_____] feet into the bedrock, care and disposal of drilling wastes[, and annular space grouting], and providing all records and data. Additional quantities of permanent casing required to complete the project due to defective, damaged, or mis-installed quantities of permanent casing is the responsibility of the Contractor at no additional cost to the Government. These additional quantities must be maintained on-site. Perform all embankment drilling in accordance with ER 1110-1-1807.[The Government makes no additional separate payment for items included herein for this item or by reference.]

1.3.3.2 Measurement

Measure boreholes and PVC casing in overburden for payment along the axis of the boring up to the nearest linear meter foot per hole. All measurements for payment must be made by, or in the presence of the Government.[Measurement is made from the top of ground surface to the depth of hole cased. Stick-up of casing is not included in this measurement.] Top of rock determinations are to be made in the field by a Government Geotechnical Engineer or Geologist for measurement and payment purposes. Install each geotextile barrier bag with the permanent casing for each borehole. The costs for permanent casing and geotextile barrier bags are incidental to this item. Make linear measurements for payment to the nearest meter foot. Additional drilling required to obtain a suitable rock socket are included under this item and tracked as additional footage.

1.3.3.3 Unit of Measure

Unit of measure: Linear meter foot.

1.3.4 Rock Drilling of Grout Holes, [Angle][Vertical]

****

NOTE: This section will apply to all cases. It

does not vary according to hole series.

This guide specification allows for flushing with water for a defined period to 'wash' the hole. There may be foundation conditions that warrant additional cleaning using the optional 'pressure washing' line item as a separate pay item, as a separate step, using a separate piece of machinery.

If both vertical and angled holes are planned, then separate line items should be utilized for the separate types of drilling. Angled rock drilling is more expensive.

****

1.3.4.1 Payment

****

NOTE: Measurement While Drilling (MWD) is incidental to this item and includes all general, materials, and execution related options if MWD is required by the user.

****

Payment will be made for costs associated with drilling holes in rock at the required angles and [in the required areas][as assigned by the Contracting Officer].[Where casing is installed, payment is measured from the top of the casing to the final tip depth.] All incidental costs associated with the performance of work in this section are included in the Contract price for this item. This item includes but is not limited to: initial hole set-up, removal and disposal of cuttings, hole washing in rock by flushing with clean water at the end of drilling, care and disposal of wastewater and effluent,[conducting measurement while drilling (MWD),] clean-up of the site, [soil][rock] interface treatment (such as sleeve port pipe), providing all records and data, and providing all equipment, labor and supplies necessary as incidental to complete the work.[Linear meters feet drilled must be subdivided into "initial quantity" and "over initial quantity".][The Government makes no additional separate payment for items included herein for this item or by reference.]

1.3.4.2 Measurement

Measure drilling in grout holes for payment by the linear footage of hole drilled in[concrete or] rock as required in the scope, or as directed by the Contracting Officer. Measure from the top of the[concrete or] rock to the bottom of the hole along the axis. Re-drilling of inside the casing is incidental to production and is not measured for payment. Re-drilling in rock due to negligence or non-compliance to the specification or work plan is not included for payment. Measure re-drilling below the casing that is associated with downstage drilling or grouting activities using the RECONNECTIONS AND REDRILLING FOR DOWNSTAGE GROUTING line item. All measurements for payment must be made by or in the presence of the Government. Round linear measurements for payment to the nearest meter foot per hole. Over drilling beyond the targeted or specified depth/elevation is not measured for payment.

1.3.4.3 Unit of Measure

Unit of measure: linear meter foot.

1.3.5 [Rock [Concrete] Coring of Grout Holes, [Angled][Vertical]]

****

NOTE: Rock coring is optional but often used as a method to confirm rock drilling. Recommend to core at least 1 hole every 100 horizontal feet/30 horizontal meters along the grout curtain alignment, or to keep up to 25% of total drilling quantity available as coring to be assigned by the Government. All verification holes are recommended to be cored. If you are using rock drilling without coring, it is recommended to use tailoring option "Downhole Imaging" as a method of borehole confirmation. Edit text to reflect coring in rock and/or concrete. This item applies regardless of hole series.

If both vertical and angled holes are planned, then separate line items should be utilized for the separate types of drilling. Angled coring is more expensive.

****

1.3.5.1 Payment

All incidental costs associated with the performance of work in this section are included in the Contract price for this item. Activities include, but are not limited to, advancing borings at the required orientations, initial set-up on the hole, coring, logging of core samples, photographing of core runs and core boxes, washing the rock portion of hole by flushing with clean water at the end of drilling, care and disposal of wastewater, clean-up of the site, care and disposal of coring effluent, providing all incidental equipment and core boxes, transportation and storage of core boxes, providing all records and data, and labor and other supplies as required to complete the work.[Subdivide linear meters feet drilled into "initial quantity" and "over initial quantity".][The Government makes no additional separate payment for items included herein for this item or by reference.]

1.3.5.2 Measurement

Rock coring for grout holes is measured for payment on the linear meters feet basis of holes drilled in concrete or rock, as shown in the scope or as directed by the Contracting Officer. All measurements are made from top of rock[or concrete] to bottom of hole. No additional payment will be made for drilling depths lower than required by these specifications due to negligence. Measurements for payment must be made by, or in the presence of the Government. Linear measurements for payment must be rounded to the nearest meter foot per hole.

1.3.5.3 Unit of Measurement

Unit of measure: Linear meter foot.

1.3.6 Hole Redrilling

****

NOTE: To clarify, 'Hole Redrilling' is drilling of hardened grout in a previously drilled length of hole. While this pay item is much more common on downstage work, communication between boreholes could create the need for hole re-drilling. Consider how setting up on holes will be paid and select brackets accordingly.

****

1.3.6.1 Payment

All incidental costs associated with the performance of work in this section are included in the Contract price for this item when a hole needs to be redrilled or downstage grouted below the bottom of the installed casing. This item also includes, but is not limited to, costs associated with[hole set-up,] care and disposal of wastewater and waste grout, hole washing in rock by flushing with clean water at the end of drilling, clean-up of the site, providing all records and data, and for providing all labor and supplies incidental to the work.[The Government makes no additional separate payment for items included herein or by reference.]

When downstaging is required under the conditions specified, or as directed by the Contracting Officer, the footage of drilling required for the downstage action must be tracked by the Contractor and the Government. Costs associated with reconnecting grouting equipment to grout holes necessitated by switching to downstage grouting from upstage grouting is not paid for as part of this item, and is included in paragraph ADDITIONAL WATER PRESSURE TESTING (WPT)/GROUTING SETUP.[The Government makes no additional separate payment for items included herein or by reference.]

1.3.6.2 Measurement

Measure hole re-drilling for payment based on the linear meters feet of hole re-drilled below the bottom of the PVC casing and along the axis of the boring previously drilled in this Contract measured to the nearest linear meter foot drilled per hole. The Government does not allow payment for drilling wasted grout in the hole above the grout stage after washing. All measurement for payment must be made by or in the presence of the Government. Do not measure setups made for convenience, such as an additional setup to replace a drill or repair a drill.

1.3.6.3 Unit of Measure

Unit of measure: Linear meter foot

[1.3.7 Pressure Washing

****

NOTE: Pressure washing can be used as a separate line item, as shown here. The designer could decide to utilize washing only via flushing through existing drill rods, which would be incidental to drilling, and delete this line item.

While in theory, pressure washing could be paid as "each", but paying by time (as shown here) allows

for washing to continue until water becomes clean, which is technically superior to a predetermined washing time.

****

1.3.7.1 Payment

Payment made for incidental costs associated with pressure washing grout holes includes, but is not limited to, initial setup over the hole, making and breaking connections, inflating and deflating packers, moving packers down the hole or from hole to hole, replacing broken gauges and hoses, providing records and data, and daily proof testing of packers. Subdivide pressure washing into "initial quantity", and "over initial quantity".[The Government makes no additional separate payment for items included herein or by reference.]

1.3.7.2 Measurement

Measure pressure washing for payment based on the number of hours of pressure washing completed, as specified in the scope, or as directed by the Contracting Officer. Wash all holes for a minimum of five minutes. Measure every hole washed by the minute, with the sum of pressure washing rounded to the nearest hour for each pay request. Only the time that the washing is performed is to be measured for payment. All other associated activities are considered incidental and will not be measured separately. All measurement for payment must be made by or in the presence of the Government.

1.3.7.3 Unit of Measure

Unit of Measure: Nearest Whole Hour

]1.3.8 Water Pressure Testing

****

NOTE: While paying for water pressure testing by "each" is simpler, it does not provide a way for the Contracting Officer to extend the duration of a water pressure stage or for implementation of 'step water pressure testing'. If step water pressure tests or variable durations are required, it is strongly recommended to pay by the hour, with each test being rounded up to the nearest minute. Designers may replace "time" with "stages" if measurement and payment by test is desired.

****

1.3.8.1 Payment

****

NOTE: Use of Instrumented packers is required when grouting through existing embankment dams and levees.

****

Payment made for incidental costs associated with water pressure testing grout holes includes, but is not limited to, initial setup over the hole, making and breaking connections, inflating and deflating packers, moving packers up and down the hole and from hole to hole, replacing broken gauges and hoses, providing all records and data, and daily proof testing

of packers. Subdivide each water pressure test into "initial quantity" and "over initial quantity".[The Government makes no additional separate payment for items included herein or by reference.] Instrumented packers are required and incidental to this item.

1.3.8.2 Measurement

Measure water pressure testing for payment based on the number of hours of water pressure testing completed, as specified in the scope, or as directed by the Contracting Officer. Measure each test by the minute, with the sum of pressure tests rounded to the nearest hour for each pay request. Only the time that the testing is performed is to be measured for payment. All other associated activities are considered incidental and will not be measured separately. All measurement for payment must be made by or in the presence of the Government.

1.3.8.3 Unit of Measure

Unit of Measure: Nearest Whole Hour

1.3.9 Placing Grout

1.3.9.1 Payment

****

NOTE: Use of Instrumented packers is required when grouting through existing embankment dams and levees.

****

Payment is made for costs associated with placing grout in grout holes, which includes full compensation for backfilling the annulus, injecting the grout, [and][or] backfilling the hole as specified in the scope. All incidental costs associated with the performance of work in this section are included in the Contract unit price for this item. Incidental work includes, but is not limited to, initial grout hole setup and grout hole connection, grout mixing time, providing all records and data[, and [_____]]. No payment will be made for time lost due to fault, negligence, or defective equipment. Costs for grout mixes will be paid separate for the grout mix successfully injected in the hole, including rock sockets and interface zones, and is not included in this pay item.[The Government is to make no additional separate payment for items included herein or by reference.] Instrumented packers are required and incidental to this item.

1.3.9.2 Measurement

Measure grout placement for payment based on the actual grout pumping time. Start time measurement when grout pumps begin pumping on a hole or grout stage, and continue until the pumping is completed on that hole or grout stage, as determined by the Contracting Officer.[The minimum required injection rate when maximum injection pressure is not achieved is 37 liters 10 gallons per minute, unless directed otherwise by the Contracting Officer.] If multiple injections are conducted on several holes simultaneously, measure each injection separately for payment, in the presence of the Government. Determine time for the placement of grout by rounding to the nearest whole minute. The total duration for this activity is then summed for all holes and rounded to the nearest whole hour for each pay request.

1.3.9.3 Unit of Measure

Unit of measure: Nearest whole hour.

1.3.10 Additional Water Pressure Testing (WPT)/Grouting Setup

1.3.10.1 Payment

Payment is made for material and labor cost associated with setting up a hose reel system at a hole location due to downstage grouting, or as directed by the Contracting Officer. A setup is when a hose-reel system is placed over the top of a hole, and either water pressure testing (WPT), or grouting, is accomplished thereafter with one or multiple connections. This includes providing all records and data associated with this item. Additional setups made for convenience will not be paid for by the Government. The movement of a packer, or paired-packers, up or down the hole does not constitute a setup. If water pressure testing is immediately followed by grouting in the same hole, then this will constitute a single 'additional WPT/Grouting Setup', not two setups.[The Government makes no additional separate payment for items included herein or by reference.]

1.3.10.2 Measurement

The initial setup on any given hole is incidental to the bid item "Placing Grout" and is not included for payment under this item. Measurement includes each directed setup required for downstage drilling and grouting. Measurement will not be made for unnecessary non-directed set-ups as determined by the Contracting Officer. Do not measure movement of a packer (or paired packers) up or down the hole for payment under this item.

1.3.10.3 Unit of Measure

Unit of measure: Each

1.3.11 Additional Drilling Setup

1.3.11.1 Payment

Payment is made for material and labor cost associated with setting up a drill at a hole location due to downstage grouting, or as directed by the Contracting Officer. A setup is when a drill is placed over the top of a hole, and drilling accomplished thereafter. This includes providing all records and data associated with this item. Unnecessary setups will not be paid for by the Government.[The Government makes no additional separate payment for items included herein or by reference.]

1.3.11.2 Measurement

The initial setup on any given hole is incidental to the drilling line item and is not included for payment under this item. Measurement includes each directed setup required for downstage drilling. Measurement will not be made for unnecessary non-directed set-ups as determined by the Contracting Officer.

1.3.11.3 Unit of Measure

Unit of Measure: Each

1.3.12 Downhole Imaging

1.3.12.1 Payment

All incidental costs associated with the performance of work in this section are included in the Contract price for this item. Payment will be made for costs associated with completing[optical televiewer] [and][or] [acoustic televiewer,][with deviation surveys] of identified drilled holes. This price will constitute full compensation for provdiing all labor, equipment and supplies necessary to perform the operations and techniques specified, including data management, records, and reporting.[The Government makes no additional separate payment for items included herein for this item or by reference.]

1.3.12.2 Measurement

Measure along the axis of the hole, rounded to the nearest linear meter foot. Measure borehole imaging for payment based on the number of linear meters feet surveyed from [_____] meters 1 foot above top of rock, to the bottom of the borehole. Include measurement on analyses, data, and records. Accurately index the downhole images for depth or repeat at no cost to the Government. Downhole images that are incomplete, cloudy, smeared, too dark/bright to distinguish features, are not indexed for depth, or are otherwise unreadable are not to be measured for payment.

1.3.12.3 Unit of Measure

Unit of Measure: Linear meter foot.

[1.3.13 Borehole Deviation Survey

****
NOTE: Depending on the size of the job, borehole deviation survey may be accomplished with equipment from the downhole imaging.
****

1.3.13.1 Payment

Payment will be made for costs associated with performing a borehole deviation survey of a full-depth grout hole. This price constitutes full compensation for providing all labor, equipment and supplies necessary to perform all operations specified. All costs incurred, including the inspector, laborers, necessary flushing of the hole, as well as all data, records and reports, must be included in the [linear meter foot] [per hole] price. All surveys must include a report with all raw deviation data, a 1-page summary table of the deviation measurements, all data in tabular format, and a visual deviation report with graphs showing deviation in two section views perpendicular to each other (left-right and upstream-downstream), and in plan view.[The Government makes no additional separate payment for items included herein or by reference.]

1.3.13.2 Measurement

Borehole surveys must be measured by the [linear meter foot][hole]. No surveys are to be measured for payment that are missing part of the hole or are otherwise unreadable. The surveys must be accurately indexed for depth, or they must be repeated. Only surveys included in the scope of

work, or are directed by the Contracting Officer, will be paid for.

1.3.13.3 Unit of Measure

Unit of Measure: [Linear meter foot][Per hole].

]1.3.14 Automated Grouting Data Collection System

****

NOTE: When computer grouting is utilized, considerations for use of Instrumented packers is recommended. For USACE dams, both an automated data collection system and instrumented packers are required to be utilized.

The designer will need to choose between measurement by the week or month. Large jobs should be paid for by the month. For very small jobs measurement by the week, or by job, may be more appropriate. Edit the paragraphs below as needed to fit the project.

****

1.3.14.1 Payment

Payment will be made for supplying and operating an Automated Grouting Data Collection System (AGDCS) to grouting operations required herein[and in accordance with Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION].

This item includes but is not limited to all incidental labor, equipment, and materials required for: AGDCS operation, AGDCS data collection, drilling and borehole logging, water pressure testing records, grouting records, [weekly][monthly] [plans][profiles], and test logging and grout logging equipment. These items must be submitted in portable document format (pdf), MicroStation format, as well as in Excel and database format[, and updated electronically in accordance with 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION]).[The Government makes no additional separate payment for items included herein for this item or by reference.][Use of Instrumented packers and integration into the AGDCS is required.]

1.3.14.2 Measurement

Measurement will be made by the Month. The month will be measured not by calendar month, but by operation at least 5 days a week for a 30-day period. This period may span across 2 calendar months. No additional payment will be made for additional shifts or additional workdays. Measurement will not precede Contracting Offer approval of required submittals, the presence of the approved AGDCS operator, or the preparatory inspection. Measurement will begin when the first hole is grouted. No more than one day of the monthly measurement may be counted for by calibration of the system.

1.3.14.3 Unit of Measure

Unit of Measure: Month

1.3.15 Grout Mixes

****

NOTE: The intent of this line item is that each specific grout mix would have a unique cost. The thicker mixes cost more because they contain less water and more solid constituent components, as well as being more difficult to pump.

****

1.3.15.1 Payment

All incidental costs associated with the performance of work in this section are included in the Contract price for this item. Payment is made for costs associated with providing the various grout mixes specified herein, including but not limited to providing, handling, transporting and storing of grout materials, proportioning the mixes, mixing, quality control of grout, providing access to lab space and equipment for Government personnel to perform quality assurance testing, providing all records and data, and storage and transportation of grout cores. Payment of grout will only be made for grout installed and accepted by the Contracting Officer in accordance with the plans and specifications. No payment is made for wasted grout from excessive batching, grout wasted due to improper anchorage of grout pipe or connections, or which is wasted due to negligence, nor for grout which is rejected by the Contracting Officer because of improper mixing.

Subdivide grouting into "initial quantity" and "over initial quantity".[The Government makes no additional separate payment for items included herein or by reference.]

Grout Mix A
[Grout Mix B]
[Grout Mix C]
[Grout Mix D]
[Grout Mix E]
[Grout Mix F]
[Grout Mix G]

1.3.15.2 Measurement

The grout mixes are measured for payment based on the number of liters gallons of each grout mix placed in grout holes. All work done at the direction of the Contracting Officer above and beyond the quantities shown for the base quantity are the responsibility of the Government.

Grout Mix A
[Grout Mix B]
[Grout Mix C]
[Grout Mix D]
[Grout Mix E]
[Grout Mix F]
[Grout Mix G]

1.3.15.3 Unit of Measure

Unit of Measure:
Grout Mix A in liters gallons
[Grout Mix B in liters gallons]

[Grout Mix C in liters gallons]
[Grout Mix D in liters gallons]
[Grout Mix E in liters gallons]
[Grout Mix F in liters gallons]
[Grout Mix G in liters gallons]

[1.3.16 Drilling and Grouting Closeout Records

****
NOTE: 01 78 00 spec covers closeout submittals. Verify if closeout submittals are covered in a Contracting Specification or not. If so, delete this section.

Consider adding this requirement if grouting is part of a larger project and closeout submittals for grouting are required before the official closeout for the project.

Hole records are incidental to their line items, this line item is for these specific submittals: Final Closure Analysis, Drilling and Grouting Final Report, Database of Water Pressure Testing and Grouting Results, and As-Built Drilling and Grouting Drawings.

The designer will need to determine if partial payment can be made, but partial payment should not exceed 40 percent.
****

1.3.16.1 Payment

[Payment is made for material and labor cost associated with completion of all closeout records under paragraph DRILLING AND GROUTING CLOSEOUT RECORDS.][No more than 40 percent of this line item will be paid before final approval of all closeout records.]

1.3.16.2 Measurement

[Measurement will be made when closeout records have been submitted and given final approval by the Government.][Partial payments up to 40 percent of the lump sum value may be accomplished as specific closeout submittals receive final Government approval.]

1.3.16.3 Unit of Measure

Unit of Measure: Lump Sum

][1.3.17 Government Directed Stand-by Time for WPT and Grouting

****
NOTE: This paragraph has been used on previous grouting jobs where stand-by may be needed. It should not be reflexively utilized unless either intermittent grouting is likely or else the Contracting Officer determines they would like to have a mechanism to pause grouting. If not needed, delete this item.

****

1.3.17.1 Payment

Payment will be made for time that the Government directs a temporary cessation of either water pressure testing (WPT) or grouting or both for its convenience and not through fault of the Contractor. Payment will not be made for time expended between intermittent grouting.

1.3.17.2 Measurement

Stand-by time begins when the Government directs stand-by and grouting ceases. Stand-by time ends when the Government directs grouting or water pressure testing to resume. Stand-by time is measured to the nearest whole minute. Measure and accumulate time to the nearest minute for each shift, total shift minutes per month, then round to the nearest hour for the month.

1.3.17.3 Unit of Measure

Unit of Measure: Hour

]1.4 REFERENCES

****

NOTE: This paragraph is used to list the publications cited in the text of the guide specification. The publications are referred to in the text by basic designation only and listed in this paragraph by organization, designation, date, and title.

Use the Reference Wizard's Check Reference feature when you add a RID outside of the Section's Reference Article to automatically place the reference in the Reference Article. Also use the Reference Wizard's Check Reference feature to update the issue dates.

References not used in the text will automatically be deleted from this section of the project specification when you choose to reconcile references in the publish print process.

****

The publications listed below form a part of this specification to the extent referenced. The publications are referred to within the text by the basic designation only.

AMERICAN PETROLEUM INSTITUTE (API)

API RP 13B-1	(2009; R 2016) Recommended Practice for Field Testing Water-Based Drilling Fluids

ASTM INTERNATIONAL (ASTM)

ASTM C31/C31M	(2025b) Standard Practice for Making and Curing Concrete Test Specimens in the Field

ASTM C39/C39M	(2024) Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM C40/C40M	(2020) Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
ASTM C70	(2020) Standard Test Method for Surface Moisture in Fine Aggregate
ASTM C87/C87M	(2023) Standard Test Method for Effect of Organic Impurities in Fine Aggregate on Strength of Mortar
ASTM C109/C109M	(2024) Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or (50-mm) Cube Specimens)
ASTM C117	(2023) Standard Test Method for Materials Finer than 75-um (No. 200) Sieve in Mineral Aggregates by Washing
ASTM C128	(2022) Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Fine Aggregate
ASTM C136/C136M	(2019) Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM C142/C142M	(2017; R 2023) Standard Test Method for Clay Lumps and Friable Particles in Aggregates
ASTM C150/C150M	(2024) Standard Specification for Portland Cement
ASTM C191	(2021) Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle
ASTM C204	(2025) Standard Test Methods for Fineness of Hydraulic Cement by Air Permeability Apparatus
ASTM C207	(2024) Standard Specification for Hydrated Lime for Masonry Purposes
ASTM C494/C494M	(2024) Standard Specification for Chemical Admixtures for Concrete
ASTM C566	(2013) Standard Test Method for Total Evaporable Moisture Content of Aggregate by Drying
ASTM C595/C595M	(2025) Standard Specification for Blended Hydraulic Cements
ASTM C618	(2025a) Standard Specification for Coal Fly Ash and Raw or Calcined Natural

	Pozzolan for Use in Concrete
ASTM C937	(2023) Grout Fluidifier for Preplaced-Aggregate Concrete
ASTM C939/C939M	(2022) Standard Test Method for Flow of Grout for Preplaced-Aggregate Concrete (Flow Cone Method)
ASTM C940	(2022) Standard Test Method for Expansion and Bleeding of Freshly Mixed Grouts for Preplaced-Aggregate Concrete in the Laboratory
ASTM C979/C979M	(2024) Standard Specification for Pigments for Integrally Colored Concrete
ASTM C989/C989M	(2025) Standard Specification for Slag Cement for Use in Concrete and Mortars
ASTM C1064/C1064M	(2023) Standard Test Method for Temperature of Freshly Mixed Hydraulic-Cement Concrete
ASTM C1077	(2025a) Standard Practice for Agencies Testing Concrete and Concrete Aggregates for Use in Construction and Criteria for Testing Agency Evaluation
ASTM C1240	(2020) Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C1602/C1602M	(2022) Standard Specification for Mixing Water Used in Production of Hydraulic Cement Concrete
ASTM C1603	(2018a) Standard Test Method for Measurement of Solids in Water
ASTM C1797	(2023) Standard Specification for Ground Calcium Carbonate and Aggregate Mineral Fillers for use in Hydraulic Cement Concrete
ASTM D1785	(2021) Standard Specification for Poly(Vinyl Chloride) (PVC), Plastic Pipe, Schedules 40, 80, and 120
ASTM D4380	(2020) Standard Test Method for Determining Density of Construction Slurries
ASTM D4832	(2016; E 2018) Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders
ASTM D5753	(2018) Standard Guide for Planning and Conducting Geotechnical Borehole Geophysical Logging

ASTM D6167	(2019) Standard Guide for Conducting Borehole Geophysical Logging: Mechanical Caliper
ASTM D6910/D6910M	(2019) Standard Test Method for Marsh Funnel Viscosity of Construction Slurries

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 19115	(2003; Corr 1 2006) Geographic Information - Metadata - First Edition

U.S. ARMY CORPS OF ENGINEERS (USACE)

COE CRD-C 100	(1975) Method of Sampling Concrete Aggregate and Aggregate Sources, and Selection of Material for Testing
COE CRD-C 112	(1969) Method of Test for Surface Moisture in Aggregate by Water Displacement
COE CRD-C 120	(1994) Test Method for Flat and Elongated Particles in Fine Aggregate
COE CRD-C 661	(2006) Specification for Antiwashout Admixtures for Concrete
EM 1110-1-1804	(2001) Engineering and Design -- Geotechnical Investigations
EM 1110-2-3506	(2017) Engineering and Design -- Grouting Technology
ER 1110-1-1807	(2014) Drilling in Earth Embankment Dams and Levees
ER 1110-1-8100	(1997) Laboratory Investigations and Testing

U.S. DEPARTMENT OF DEFENSE (DOD)

SDSFIE Standards	Spatial Data Standards for Facilities, Infrastructure, and Environment

1.5 DEFINITIONS

1.5.1 Apparent Lugeon

Apparent Lugeon refers to the grouting permeability of the geologic formation or zone, using a grout that behaves as a Bingham fluid with a known apparent viscosity. The evolution of the apparent Lugeon value during grouting must govern the variation of the grout mix and other injection parameters. Correct the apparent Lugeon for pressure as appropriate.

1.5.2 Automated Grouting Data Collection System (AGDCS)

****

NOTE: The maturation of computer monitoring of pressure grouting now allows for a second-by-second real-time review of ongoing grouting work and a permanent record of the grouting process. Several contractors have developed advanced Automated Grouting Data Collection Systems, historically referred to as "Computer Grouting". For grouting jobs on structures under the governance of ER 1110-1-1807, or greater than 10,000 linear feet, using an AGDCS is preferred because it provides accurate and precise real-time records that could not be generated by hand. It also saves manpower and cost.

****

A computerized system for receiving, translating, recording, storing, and displaying water pressure testing and pressure grouting data. The system is capable of viewing results in real-time or at any time after the stage is tested or grouted. The system is capable of producing graphic and numerical outputs for grouting and water pressure test data in real-time, with digital files, including but not limited to, PDF, excel, spreadsheets, and raw data files.

1.5.3 Back Pressure

Back pressure is measured to determine if jacking or fracturing occurred during grouting. If there is any measurable pressure, then the grout is returning to the surface of the hole and jacking (if in the rock), or fracturing (if in soil), may have occurred. Measure and records back pressure for each stage.

1.5.4 Back Pressure Measurement

To measure back pressure, measurement is performed via the following process: shut off the valves above and below the gauge, drain the gauge with the bleeder valve to zero and close the bleeder valve, then open the bottom valve from the hole. The presence of backpressure may be an indication that jacking of rock or hydrofracturing of soil has occurred.

1.5.5 Balanced and Stable Grout

"Stable" means that the grout has nearly zero bleed. "Balanced" means a balance of ingredients to meet desired properties. A balanced and stable grout mixture is a homogenous, balanced blend of water and cement combined with selected additives and admixtures to produce a stable product that experiences minimal to near zero bleed and maintains a constant rheology (viscosity, cohesion, pressure filtration) during placement. Therefore, 1 liter gallon of injected fluid grout becomes 1 liter gallon of cured hard grout in the foundation eliminating water pathways.

1.5.6 Barrier Bag

Inflatable bag that is used to isolate the soil-bed rock interface for treatment. The barrier bag is fitted around the PVC pipe at the correct interface elevation prior to grouting installation down hole.

1.5.7 Bentonite

A clay composed principally of minerals of the montmorillonite group.

Characterized by high adsorption and very large volume change with wetting.

1.5.8 Blaine Fineness

A measure of the fineness of powdered materials, such as cement and pozzolans. Blaine fineness is measured in accordance with ASTM C204.

1.5.9 Bleed

Separation of excess water from a particulate suspension grout as a result of settlement. Commonly expressed as a percentage of the initial volume of the mixed grout.

1.5.10 Closure

Closure is defined as the completion of all grouting within a section to established criteria;, including refusal, split spacing, and permeability closure criteria. Closure is confirmed through grout takes, water pressure testing, and verification holes where the residual permeabilities following grouting are reduced and measured in each completed section.

1.5.11 Communication

Communication is the passage of water or grout from one hole to another or to any opening/observation point during the course of drilling, water pressure testing, [and][or] grouting.

1.5.12 Downstage Grouting

Downstage grouting is the drilling and grouting of a zone before proceeding to the next deeper zone within the same borehole. It is the installation of a grout curtain by repeated drilling and grouting in successively deeper stages in the downward direction in each hole.[In USACE's Engineering Manual, EM 1110-2-3506, this is termed as "Stage Grouting".]

1.5.13 Drilling Setup

A drilling setup is when a drill is placed over the top of a hole prior to drilling (overburden drilling or [concrete][rock] drilling).

1.5.14 Effective Pressure

The sum of all head losses and head gains in the injection system and the ground.

[1.5.15 Effective Water Pressure

The effective pressure is determined by subtracting the initial water pressure from the measured total pressure. The initial water pressure must be determined by piezometers near the drilling operation.[The instrumented packer can be used to obtain a direct measurement of water pressure in the borehole; however, this value may be skewed based on drill water present in the borehole.] The initial water pressure must be determined by both methods and compared to determine if localized water pressure adjustments are required for the analysis.

]1.5.16 Effective Grouting Pressure

Effective grouting pressure is the pressure exerted by an injected fluid on the formation at the point of injection minus the initial water pressure. Calculate effective pressure based on the sum of all head losses and head gains in the injection system and the ground.

[

For instrumented packers, measure effective grouting pressure in the ground with the use of an instrumented packer. The effective pressure at the instrumented packer sensor can be determined by subtracting the initial water pressure from the measured total pressure. To obtain the effective pressure at the middle of the stage, the static pressure from the ground water and grout between the sensor and the middle of the stage elevation is to be considered.]

1.5.17 Equivalent Gravity Pressure

The down hole pressure equivalent to a fully grouted casing to the ground surface.

1.5.18 Exploratory Hole

Exploratory holes are drilled to investigate subsurface conditions across the site ahead of grout holes.

1.5.19 Final Set

A degree of stiffening of a grout mixture indicating the time in hours and minutes required for cement paste to stiffen sufficiently to resist the penetration of a weighted test needle (Vicat needle). Also called 'Final Set Time' or 'Time of Final Set'.

1.5.20 Gravity Stage

****

NOTE: NOTE: Stages typically range from 5 to 35 feet in length, or attempt to isolate a specific stratigraphic layer. Stage assignments are site-specific, and should be defined by the specification designer. Longer stages are cheaper but can combine dissimilar layers and make determinations of the foundation more difficult. The typical range can be given in the specification and then adjusted in the field based on conditions encountered.

****

The [3][4.5][6][7][7.5] meter [5][10][15][20][25] foot downstage grouting zone which must occur across the entire zone before additional down hole drilling or grouting can commence.

1.5.21 Grout

A mixture of cementitious or non-cementitious material, with or without aggregate, to which sufficient water or other fluid is added to produce a flowing consistency.

1.5.22 Grout Take

The volume of grout placed. This can be for a specific grout stage, specific grout hole, a grout line, or for the entire job - the take referenced should specify which.

1.5.23 Grouting Setup

A grouting setup is when a hose-reel system is placed over the top of a hole and grouting performed thereafter with one or multiple connections. The movement of a packer or paired packers up or down the hole does not constitute a setup.

1.5.24 Holding Pressure

Pressure during grouting operations that is maintained at a given grouting stage.

1.5.25 [Hydrofracture][Hydrofracturing]

The fracturing of an embankment or in-situ material by pumping water, drilling fluid, air or grout under a pressure in excess of the tensile strength and minor principal stress.

1.5.26 Initial Set

A degree of stiffening of a grout mixture indicating the time in hours and minutes required for cement paste to stiffen sufficiently to limit penetration of a weighted test needle (Vicat needle) to 25 mm. Also called 'Initial Set Time' or 'Time of Initial Set'.

[1.5.27 [Instrumented Packer][Instrumented Packer Assembly]

An instrumented packer assembly measures total pressures during water pressure testing and grouting either: a) between the base of the packer and the bottom of the borehole, b) between the packers of a double-packer assembly, or c) immediately above the packer. The assembly is part of a system that [measures][indicates] total pressure in real-time by monitor display, and records pressure data for later comparison with the water pressure and grouting pressure versus time. The instrumented packer assembly system is to be used in 100 percent of the grout holes requiring pressure grouting and water pressure testing unless otherwise directed by the Contracting Officer. A manually read gauge is not acceptable for use as an instrumented packer.

]1.5.28 Interface Stage

The portion of the hole at the contact between the base of the [soil][structure][concrete] and the top-of-rock.

1.5.29 Intermittent Grouting

Intermittent grouting is the process whereby the Government directs that grouting cease after either 1) a certain volume of grout has been pumped into a stage, or 2) a period of time of pumping grout has elapsed. A period of time follows, to allow the grout placed in the stage to reach either: 1) 'initial set' or 2) 'final set'. At that point either, 1) resume grouting if the grout has only reached 'initial set', or 2) re-drill the stage and later attempt to re-grout the stage, if the grout

has reached 'final set'.

1.5.30 Lugeon

Lugeon value refers to the permeability of the geologic formation or zone. A Lugeon unit is a metric unit defined as a flow of 1 liter of water per minute per meter of borehole length at a pressure of 10 bars. The English measurement would be 0.26 gallons per minute per 3.28 feet of borehole length at a pressure of 145 psi.

1.5.31 Modified Lugeon

A modified Lugeon is a permeability value corrected for a pressure lower than the 10 bar pressure, equivalent to 145 psi, defined for the Lugeon. When pressures anticipated for work are below 10 bars (145 psi), or the length of the stage is greater than 1 meter 3 feet, the Modified Lugeon is the normal unit of measure, and for convenience is referred to as a Lugeon.

1.5.32 Pressure Washing

A process of washing, using pressurized water, to remove sediment, cuttings, and loose material from cracks and seams in the rock.

1.5.33 Primary Hole

The first series of holes to be drilled and grouted, usually at the maximum allowable spacing. Grouting of primary holes is completed prior to secondary holes being drilled.

1.5.34 Production Grout

Production Grout is the grout that is mixed onsite to use on the project. It specifically excludes the grout mixed for the trial grout mixes submittals.

1.5.35 Refusal

The point during grout injection when little or no grout is accepted under the maximum allowable pressure or other specified conditions.

1.5.36 Refusal Criteria

Refusal Criteria is defined in each grout stage of each hole. Rate-of-take criteria is satisfied by the measurement of apparent Lugeon value for grout or Lugeon value for water. Refusal determines when grouting operations stop at each stage.

1.5.37 Residual Permeability

Residual permeability is the permeability at the conclusion of the grouting work.

1.5.38 Secondary Hole

Secondary holes must be drilled midway between primary holes and the grouting completed before drilling the tertiary series of holes.

1.5.39 Section

A linear or a real subdivision of the grout treatment pattern without regard to the depth of treatment.

1.5.40 Set Time

See "initial set time" and "final set time".

[1.5.41 Sleeve Port Pipe

Sleeve Port Pipe (also known as, Sleeve pipe, or tube-á-manchette) is PVC casing with holes drilled through the side, with a rubber 'sleeve' attached around the casing at the point where holes are drilled, acting as a one-way-valve.

]1.5.42 Sounding

When a hole is measured from the surface to the top of firm or hard material using a weighted tape.

1.5.43 Split Spacing

The procedure by which additional grout injection holes are located equidistant from previously grouted holes. Split spacing is utilized when a higher order of hole fails the split-spacing criteria.

1.5.44 Split Space Criteria

The split space criteria (or split space criterion) is a minimum lugeon value or grout take value that mandates that additional holes be added through the split spacing method. The split space criteria may vary depending on the stage, zone, series, or section that is under consideration.

1.5.45 Stage

****
NOTE: Stages typically range from 5 to 35 feet in length, or attempt to isolate a specific stratigraphic layer. Stage assignments are site-specific, and should be defined by the specification designer. Longer stages are cheaper but can combine dissimilar layers and make determinations of the foundation more difficult. The typical range can be given in the specification and then adjusted in the field based on conditions encountered.
****

A stage is a specific segment of a hole that is grouted or water pressure tested.

1.5.46 Stop

A stop is a predetermined depth at which the expanding plug or packer is positioned.

1.5.47 Succeeding Series

Locate each of the succeeding series of holes based on the split space criteria.

1.5.48 Target Pressure

The unique pressure for each stage that is to be reached and held constant during water pressure testing or pressure grouting.

1.5.49 Tertiary Hole

Tertiary holes are drilled midway between the secondary and primary holes along the grout lines. Drilling and grouting is completed in the tertiary hole before any succeeding series of holes are drilled or grouted.

1.5.50 Tremie

A grout placement procedure in which the material is injected through a pipe extending to the bottom of a drill hole.

1.5.51 Upstage Grouting

Upstage grouting involves drilling a grout hole to its final depth and grouting from the bottom up in stages.[In USACE's Engineering Manual ; EM 1110-2-3506, this is termed as "stop grouting".]

1.5.52 Verification Hole

A verification hole is drilled to verify the grouting results meet closure criteria at the conclusion of grouting. The location of verification holes are selected by the Contracting Officer.

1.5.53 Viscosity

Friction within a liquid due to mutual adherence of its particles, i.e., the "thickness" of a mixture.

1.5.54 [Water Pressure Test][Water Pressure Testing]

A test performed to measure the rate at which water can be forced into a hole under a specific pressure.[Colloquially (and in USACE's Engineering Manual, EM 1110-2-3506) called "pressure test" or "pressure testing".]

1.5.55 Water Pressure Testing Setup

A water pressure testing setup is when a hose-reel system is placed over the top of a hole and water pressure testing accomplished thereafter with one or multiple connections. The movement of a packer or paired packers up or down the hole does not constitute a setup.

1.5.56 Zone

****

NOTE: Stages typically range from 5 to 35 feet in length, or attempt to isolate a specific stratigraphic layer. Stage assignments are site-specific, and should be defined by the specification designer. Longer stages are cheaper

but can combine dissimilar layers and make determinations of the foundation more difficult. The typical range can be given in the specification and then adjusted in the field based on conditions encountered.

****

A zone is a predetermined partial depth of a grout hole that includes multiple grout stages. A single zone may make up the full depth of treatment, or the hole may be divided into several zones. Required zones exist from:

[_____] to [_____] meter feet
[_____] to [_____] meter feet
[_____] to [_____] meter feet

1.6 SUBMITTALS

****

NOTE: Review submittal description (SD) definitions in Section 01 33 00 SUBMITTAL PROCEDURES and edit the following list, and corresponding submittal items in the text, to reflect only the submittals required for the project. The Guide Specification technical editors have classified those items that require Government approval, due to their complexity or criticality, with a "G." Generally, other submittal items can be reviewed by the Contractor's Quality Control System. Only add a "G" to an item, if the submittal is sufficiently important or complex in context of the project.

For Army projects, fill in the empty brackets following the "G" classification, with a code of up to three characters to indicate the approving authority. Codes for Army projects using the Resident Management System (RMS) are: "AE" for Architect-Engineer; "DO" for District Office (Engineering Division or other organization in the District Office); "AO" for Area Office; "RO" for Resident Office; and "PO" for Project Office. Codes following the "G" typically are not used for Navy and Air Force projects.

The "S" classification indicates submittals required as proof of compliance for sustainability Guiding Principles Validation or Third Party Certification and as described in Section 01 33 00 SUBMITTAL PROCEDURES.

****

Government approval is required for submittals with a "G" or "S" classification. Submittals not having a "G" or "S" classification are for Contractor Quality Control approval. Submittals not having a "G" or "S" classification are for information only. When used, a code following the "G" classification identifies the office that will review the submittal for the Government. Submit the following in accordance with Section 01 33 00 SUBMITTAL PROCEDURES:

SD-01 Preconstruction Submittals

Drilling and Grouting Work Plan; G, [_____]

Grout Mix Design and Trial Batches; G, [_____]

Automated Grouting Data Collection System (AGDCS); G, [_____]

Drilling and Invasive Program Plan (DIPP); G, [_____]

Laboratory Accreditation; G, [_____]

Overburden-Rock Interface Special Procedures; G, [_____]

SD-02 Shop Drawings

Weekly Grouting Progress Drawings; G, [_____]

Monthly Grouting Red Line Drawings; G, [_____]

SD-03 Product Data

Drilling Rigs and Equipment; G, [_____]

Pressure Washing Equipment; G, [_____]

Grouting Equipment; G, [_____]

Barrier Bag Equipment; G, [_____]

Instrumented Packer Equipment; G, [_____]

Optical Televiewer Equipment; G, [_____]

Acoustic Televiewer Equipment; G, [_____]

Borehole Deviation Equipment; G, [_____]

Mechanical Caliper Equipment; G, [_____]

Permits, Certifications, and Licenses; G, [_____]

SD-06 Test Reports

Initial Calibration Reports for AGDCS; G, [_____]

Grout Materials Test Reports; G, [_____]

Mixing Water Test Reports; G, [_____]

Closure Analysis for [_____] Line; G, [_____]

Drilling and Grouting Test Section Report; G, [_____]

Drilling And Grouting Test Section Drawings; G, [_____]

Weekly Grout Test Results; G, [_____]

Pressure Washing Log; G, [_____]

Drill Logs; G, [_____]

Water Pressure Testing Reports; G, [_____]

Grouting Reports; G, [_____]

Backfill of Overburden Casing Report; G, [_____]

Optical Televiewer Survey Records; G, [_____]

Acoustic Televiewer Survey Records; G, [_____]

Borehole Deviation Survey Records; G, [_____]

Mechanical Caliper Survey Records; G, [_____]

Weekly Calibration For AGDCS; G, [_____]

SD-07 Certificates

Lead Grouting Geologist or Lead Grouting Geotechnical Engineer Qualifications; G, [_____]

Drilling Inspector Qualifications; G, [_____]

Automated Grouting Data Collection System Operator Qualifications; G, [_____]

Field Supervisor (Geologist or Geotechnical Engineer) Qualifications; G, [_____]

Optical And Acoustic Televiewer Operator Qualifications; G, [_____]

Laboratory Testing Procedures and Standards for Mixed Grout; G, [_____]

Drill Rig Operator Qualifications; G, [_____]

SD-11 Closeout Submittals

Database of Water Pressure Testing and Pressure Grouting Results; G, [_____]

Final Closure Analysis; G, [_____]

Drilling and Grouting Final Report; G, [_____]

As-Built Drilling and Grouting Drawings; G, [_____]

1.7 CARE AND DELIVERY OF SAMPLES

Do not leave samples or core unprotected or staged at the hole location. Ensure all descriptive labels and designations on sample jars, tubes, and boxes remain clean, and legible, until final delivery of samples to and acceptance by, the Contracting Officer. Keep samples[protected from freezing][in a climate-controlled environment] suitably protected from moisture and undue exposure to the elements in a temporary storage

facility. Deposit the samples and cores in the storage facility no later than the completion of each shift, or more frequent pending prevailing weather conditions. Reserve the Temporary Storage Facility for the use of the Government for logging, classifying, and studying the samples and cores, and do not use the facility for storing equipment or supplies. The minimum floor space to adequately lay out core must have dimensions of at least [_____]. Keep the storage facility organized and safe, with aisles unobstructed and core boxes stacked securely. At all times, stack core boxes such that all side labels are upright and visible from isles. Do not stack full pallets over 2 pallets high, with a maximum of 20 core boxes per pallet.

1.8 [PROJECT][SITE] CONDITIONS

****

NOTE: This paragraph, or elsewhere in the specifications, should describe the geologic conditions that the Contractor could expect to encounter during drilling and grouting. This paragraph should also reference the Geotechnical Baseline Report (GBR or GDR). Add text to properly describe the geologic conditions and parameter values that could impact the Contractor's ability or effectiveness to complete the work.

****

Pre-existing Subsurface information and boring logs are provided in the[Geotechnical Baseline Report (GBR),][Geotechnical Interpretive Report (GIR),][Geotechnical Data Report (GDR),][Attached to these Specifications,][described herein].[Additional site information is provided in the Contract Drawings.][Select rock samples from recent foundation explorations are available for inspection as detailed in Section 31 00 00 EARTHWORK.]

The program shown and described is based on currently available information. Conditions encountered during construction may require additions or deletions as approved by the Contracting Officer.

1.9 PERSONNEL QUALIFICATIONS AND DUTIES

****

NOTE: If drilling in or adjacent to a levee embankment, earth dam, a lock-and-dam, or concrete dam, please ensure that all additional personnel requirements associated with USACE Engineering Regulation 1110-1-1807 are included, using the tailoring option. These are: Drill Rig Operator Qualifications, "Field Supervisor" Qualifications, and Drilling Inspector Qualifications. If one or more of these is desired on a non-dam job, the tailoring can be tailored on and off to allow copying of the text.

One job is associated with the downhole imaging tailoring option in this sub-section, specifically the Optical And Acoustic Televiewer Operator.

This sub-section must be coordinated with the Contractor Quality Control Staff in the 01 45 04

Specification.

****

Submit the qualifications of individuals as listed in the paragraphs below not less than [30][_____] days prior to the start of drilling and grouting.

[

All of the individuals in the roles listed below will be permitted to answer questions by the Government related specifically to the roles and work while they are present on-site.]

1.9.1 Lead Grouting Geologist or Lead Grouting Geotechnical Engineer Qualifications

****

NOTE: If grouting is scheduled for 2 shifts or allowed to run 2 shifts, there should be a requirement for one of these persons for each shift.

This section has a Professional Engineer (PE), Professional Geologist (PG) requirement, but experienced EITs and GITs may provide adequate oversight, with enough experience, on lower-risk jobs.

The qualifications for a grouting lead is a risk decision. For high-risk dams, more experience may be needed than on a simple job with no structure or a shallow structure.

On a very small job (such as with a single drill rig and a single grout mixer), it may make sense for the lead grouting engineer/geologist to also be the AGDCS operator. On a large jobs, this does not make sense.

****

Submit the qualifications at least [30][_____] days prior to commencement of drilling activities. Must be in accordance with Section 01 45 00 QUALITY CONTROL. The Lead oversees all[AGDCS operators,] water pressure testing, grouting, and equipment calibrations.[The individual[s] must be responsible for the AGDCS and for the preparation of separate plots and reports for each water pressure test and grout stage.]

The lead grouting geologist or leading grouting geotechnical engineer must be licensed as a PE or PG. The professional must have [[3 years][1 year][6 months] of experience over the past [10] years], or equivalent engineering and construction experience, specific to foundation drilling and grouting with at least 1-year specializing in grouting applications for high hazard dams.[The operator must receive onsite dam safety training provided from the Government before commencement of grouting operations]. The lead grouting geologist or lead grouting geotechnical engineer is a full-time position and no collateral duties are permitted.[At least [25][35] percent of the time every day, the lead must be in the field observing both the drilling and grouting work.][The lead grouting geologist or lead grouting geotechnical engineer must report directly to the QC System Manager.] There must be one approved grout lead per shift on-site during all grouting operations. The duty shift of the lead must not exceed [12][_____] hours.

1.9.2 Automated Grouting Data Collection System Operator Qualifications

****

NOTE: The experience requirement for the AGDCS Operator is a risk-based decision. For risk reduction work on dams or levees, more experience on projects of that type should be required. For other projects, only competency is needed.

Designers could determine that non-college-educated personnel could be computer grout operators, but much more operating experience, as well as demonstrated maturity, must be required. This is not appropriate for risk reduction work on dams and levees (or other structures).

****

Submit the qualifications at least [30][_____] days prior to commencement of drilling activities. The Automated Grouting Data Collection System (AGDCS) Operator must be a geologist or [geotechnical][civil] engineer with a four-year degree from an accredited University. The Operator(s) must have a minimum of [6 months][3 months] experience operating the equipment and [1 years][6 months] of foundation grouting experience in the past [5][10] years. The Automated Grouting Data Collection System cannot be used until the Operator(s) is approved by the Contracting Officer.[The operator must receive onsite dam safety training prior to the commencement of grouting operations.][Only the approved operators are permitted to operate the automated grouting data collection system.][The AGDCS Operator is a 100-percent duty position when the AGDCS is operating.]

1.9.3 Drilling Inspector Qualifications

****

NOTE: The experience requirement for the Drilling Inspector is a risk-based decision. For risk reduction work on dams or levees, more experience on projects of that type should be required. For other projects, only competency is needed. The designer should determine if dam safety training is needed.

****

Submit the qualifications at least [30][_____] days prior to commencement of drilling activities. The Drilling Inspector must be a geologist or geotechnical engineer with a four-year degree from an accredited University. At a minimum, the Drilling Inspector must have [1 year][3 months] of drill inspection experience and [2 years][1 year] of similar experience. Drilling must not commence until drilling inspector(s) have been approved by the Contracting Officer. The drilling inspector must receive onsite dam safety training from the Government prior to logging of drilling onsite.

[

The Drilling Inspector is a 100-percent duty position when drilling or backfilling is occurring.]

1.9.4 Drill Rig Operator Qualifications

Submit the qualifications at least [30][_____] days prior to commencement of drilling activities. The drill rig operator(s) must meet the requirements of Section 01 45 00 QUALITY CONTROL and ER 1110-1-1807..

Changes in personnel require additional submittals for approval of these key personnel. The rig operator must take onsite dam safety training prior to the commencement of grouting operations.

1.9.5 Field Supervisor (Geologist or Geotechnical Engineer) Qualifications

****

NOTE: USACE's Engineering Regulation (ER) 1110-1-1807 allows for the field supervisor and logger to be simultaneous duties for a single person, but this guide spec allows for this to be prohibited, if the designer desires.

Field Supervisor responsibilities cannot be met if not directly monitoring the work in the field, i.e. administrative functions in the office.

****

Submit the qualifications at least [30][_____] days prior to commencement of drilling activities. The professional must have [[3 years][1 year][6 months] of experience over the past [10] years], or equivalent engineering and construction experience, specific to foundation drilling and grouting In accordance with ER 1110-1-1807, employ a "field supervisor" who is either: 1) a licensed geologist or 2) a licensed geotechnical (civil) engineer. The field supervisor must be in the field overseeing the drilling and ensuring compliance in accordance with ER 1110-1-1807.[The field supervisor must receive onsite dam safety training prior to the commencement of grouting operations.][This position can be filled by the Lead Geologist or Lead Geotechnical Engineer provided requirements for both sections are fulfilled.][This position must not be combined with the drill hole logger.]

1.9.6 Optical And Acoustic Televiewer Operator Qualifications

Submit the qualifications at least [30][_____] days prior to commencement of activities. The optical and acoustic televiewer (OATV) operator must possess at least [6][_____] months of experience in the past [5][_____] years in the operation and maintenance of optical and acoustic televiewer, and any other related field operated recording equipment, post-processing of video to create virtual images of the concrete cores, and plotting required data and as-built locations of the video images. Include certificates of training in use of borehole cameras, and at least three examples of work products in the submittal.[The optical and acoustic televiewer operator can have a dual role if concurrent features of work are not occurring.]

1.10 DRILLING AND GROUTING WORK PLAN

****

NOTE: Delete items i. through k. if drilling directly in rock.

Include project specific thickening requirements for grout mixes in the Execution Section. Keep in mind the typical batch volumes that will be mixed and coincide thickening mixes to minimize wasted grout.

Items t. through x. are required for USACE

Embankment Dams and Levees and are bundled as part of a tailoring option. These items may be used for other grouting projects as required.

****

At least [30][45][60][90] days prior to the commencement of drilling foundation grout holes, submit the Drilling and Grouting Work Plan that includes but is not limited to details of the following:

a. A list, details, and data on the drilling equipment demonstrating equipment meets all functional specifications; and example boring logs.

b. A list, details, and data on the grouting equipment and grout monitoring equipment demonstrating equipment meets all functional specifications, and example grouting data.

c. The overall sequence and schedule of work including the anticipated staffing and shifts. Include a personnel chart identifying key personnel, points of contact and their responsibilities.

d. Layout for equipment and grout plant on detail drawings.

e. The [specified][proposed] grout hole layout and naming convention.

f. Grouting progress drawing proposed format.

g. Contingency plan in the event of early stoppage of grouting (i.e., equipment breakdown, severe weather stand downs, end-of-work shift, or other factors that could cause early cessation of grouting activities).

h. Rock drilling and coring of grout holes procedures.

i. Details of the sequence of casing installation.

j. Detailed plans for the care and disposal of soil and grout cuttings, wastewater, and waste grout. List any environmental permits/compliance, and details of required clean up including procedures, locations, and time intervals.

k. Proposed format for records of injected volume, pressure, and rate of flow during grouting for each stage.

l. General guidelines and procedures for identifying and isolating zones and stages of high grout takes, and procedures to be followed in the event of communication in grout holes.

m. Grout mix changes, include the procedures, protocols, means, and methods for changing grout mixes expeditiously to the grout hole during production.

n. Grouting operations including backfilling and casing installation, details of [soil][rock] interface treatment, grouting the casing annulus and [soil][rock] interface and washing the grout within the casing from top of rock after grouting the upper [5] meters [15] feet zone(s) of foundation rock.

o. Grout testing protocols, time frames and procedures, frequency of testing, including a plan that identifies quality control procedures and the individual responsible for management of each grouting stage

and the quality control measures that must be implemented.

p. Production estimates including the identification of steps in communications and decision-making processes that impact the progress of work.

q. Identify any discrepancies between the Contract drawings and Contractor's survey.

r. A sample of weekly grouting drawings with drilling, water pressure testing and grouting work progress.

s. A sample of measurement while drilling outputs as described in the paragraph "Measurement While Drilling".

t. A detailed description of the proposed activities associated with embankment and overburden drilling including the proposed methods of dealing with the instance of grout hole drilling encountering zones of karst features, boulders, cobbles, or gravels in the embankment and foundation soils, and at the [soil][rock] interface during the grout hole drilling process.

u. A detailed list of all downhole survey equipment and materials to be used.

v. How optical and acoustic televiewer surveys are conducted to achieve well-lit, accurate, legible, high-quality images.

w. Equipment, personnel, and procedures for how deviation surveys are to be conducted.

x. Sample Automated Grouting Data Collection System export in .csv format.

1.11 DRILLING AND INVASIVE PROGRAM PLAN (DIPP)

Submit a Drilling and Invasive Program Plan (DIPP). The requirements for the DIPP are found in ER 1110-1-1807. Complete the DIPP using the outline sequence found in the ER. Address every part of the regulatory outline. Sections that do not apply require at least one sentence explaining why the section is not applicable. Perform all drilling through the embankment in accordance with the DIPP requirements.

1.12 DISPOSAL OF DRILL CUTTINGS AND WASTE GROUT

****

NOTE: Either provide for onsite or offsite disposal of drill cuttings and waste grout. Select the appropriate paragraph, and delete the other three paragraphs.

****

[All drill cuttings may be disposed of on-site, in a location designated by the Contracting Officer. All waste grout, once solidified, may also be disposed of in the same location.

][All drill cuttings may be disposed of off site, approximately [_____] kilometers [_____] miles away from the work site, at a [Government][Sponsor] location designated by the Contracting Officer. All waste grout, once solidified, may also be disposed of in the same location.

][All drill cuttings may be disposed of, on-site, in a location designated by the Contracting Officer. Remove all waste grout from the site for disposal at a construction waste landfill. If an alternate disposal site, to a construction waste landfill is preferred, propose an alternate disposal site in writing to the Contracting Officer. Any alternative must be approved in writing prior to utilization.

][Remove all drill cuttings and waste grout from the site for disposal at a construction waste landfill. An alternate disposal site, to a construction waste landfill, must be submitted in writing to the Contracting Officer for written approval before utilization.]

1.13 DATA REQUIREMENTS

Provide all generated data - no data source or format is subject to exemption. All data generated as part of this specification is subject to the requirements in Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION. In case of a conflict in Contract language, the requirement must be whichever is more detailed, rigorous, specific, precise, and complete as determined by the Contracting Officer.

[1.14 TEST SECTION REQUIREMENTS

****

NOTE: This paragraph should only be used when utilizing a test section, which is atypical. If no test section is utilized, then this paragraph needs to be deleted.

A second test section is required if the first test section fails. Clarify what additional demonstrations may be required in the text below.

****

A test section is required using the same personnel, equipment, and materials required for production. The test section must include the full scale production of a primary and secondary hole sequence with all steps executed in sequential order. In addition, the following criteria are required:

a. All of the Contractor-proposed [rock-soil] [rock-concrete] interface options will be trialed in the test section.

b. A separate drilling and grouting test section report is required.

c. Separate drilling and grouting test section drawings are required.

[

d. If the Test Section is rejected by the Government and new means and methods are considered necessary, then the Contractor must repeat the test section, in a new location directed by the Contracting Officer, and submit a new report and drawings.]

]1.15 PERMITS, CERTIFICATIONS, AND LICENSES

****

NOTE: The designer should add any known permits, certifications, and or licenses known to be required to perform the work. These could include: water

withdrawal permit, city business permit, noise permit, etc. The designer should contact the city or county and state to determine if any permits are required.

****

Submit all permits, certifications, and licenses required for the work.

[

Known permits requirements are: [_____]]

[1.16 LABORATORY ACCREDITATION

****

NOTE: This requirement is for all USACE contracts. Non-USACE can delete this paragraph.

****

All laboratories submitting testing results for this Contract must be accredited in accordance with ER 1110-1-8100. Submit written proof of accreditation for each laboratory utilized. If the accreditation expires during the Contract period, the accreditation renewal must be submitted prior to the expiration. Each laboratory will be submitted separately.

]PART 2 PRODUCTS

2.1 DELIVERY, STORAGE, AND HANDLING

Transport and store cements in accordance with manufacturer's recommendations and as required herein. Store enough cement, and constituent components of grout, at or near the site to ensure grouting operations are not delayed by shortages. If cement is found to contain lumps or contaminants that may be deleterious to the grouting operation, screen the cement through a standard No. 16 mesh screen, or else replace the cement. No payment is made for such screening or replacement. Adequately protect all materials from inclement weather - including rain, snow, and freezing conditions. Provide suitable enclosures to prevent the degradation of the various materials prior to use.

2.2 GROUTING MATERIAL

****

NOTE: Provisions are made for the use of a sanded grout. Sanded grout is used for large void filling and plugging holes. The use of sanded grout should generally be limited to formations and conditions where solution features and cavities are anticipated that may require hole plugging and split spacing due to the inability to build up to the target pressure or exceeding the injected grout volume threshold for the stage. This should be defined in the DIPP. The use of sanded grout can damage high mobility grouting equipment more quickly than sand-free grouts. Modern grouting operations should allow the cement/bentonite blended grout to be batched separately with the sand added to the mix in a secondary mixing unit before being transferred to the grout cart.

The use of calcium carbonate (limestone) as a filler

may be a better choice than sand to limit the potential for damage to equipment.

For USACE, all laboratory testing must be completed by a USACE validated laboratory in accordance with Engineering Regulation ER 1110-1-8100.

****

Provide grout composed of water and cement[, supplementary cementitious materials, pozzolans, admixtures, fillers, and pigment]. Store enough cement, water, and ancillary grout mix components at or near the site of the work to ensure that grouting operations are not delayed by shortage of grout materials or water. Design grout mixes that are varied to meet the characteristics of each hole, as determined by conditions encountered. Submit grout mixes in the Grout Mix Design and Trial Batches submittal.

All materials must conform to the basic specifications listed in the paragraphs below, and include test results in the GROUT MATERIALS TEST REPORTS submittal. Ensure all grouting materials are compatible. Any material found to be incompatible must be replaced at no expense to the Government. Testing of the replacement material and revised grout mixes must be approved by the Contracting officer in writing prior to use. No additional payment will be made for replacement material or testing.

2.2.1 Grout Materials Test Reports

****

NOTE: The intent of this requirement is for the grout material information provided with each significant delivery of grouting material to include manufacture site, batch number, and any test results provided for the material. An example would be the manufacturer's data that comes with a batch of Portland cement.

****

Submit material test reports showing that all grouting materials listed in this specification, or proposed substitutions, meet the quality and soundness requirements specified. Submit the material test reports no later than 1 week after receipt. If any materials received onsite fail quality testing or any specification requirements, do not use those materials, and notify the Contracting Officer immediately.

2.2.2 Water for Grout

****

NOTE: The designer needs to determine if either potable or non-potable water is readily available. If neither is readily available, water will have to be trucked in at a considerable expense. This must be addressed in the paragraph, DESCRIPTION OF WORK.

The specification allows for one of four conditions: 1) Potable water to be provided by the contractor, 2) Potable water on-site and provided by the government, 3) non-potable water is utilized for grouting, 4) no water is available onsite, 5) water will need to be trucked in. Choose the appropriate paragraph(s) and delete the non-applicable

paragraphs.

In high sulfate environments, such as those found in foundations with gypsum and annhydrite deposits, high levels of sulfate can be found in potable water which may be deleterious to grout setting. In these instances, water testing of potable water supplies may be warranted.

****

[Water is not available on-site. Provide[potable] water for grout including transportation of water to the site.][Commercial water trucking companies are present in [_____] county, bidders are encouraged to price the cost of the needed quantity of water prior to bidding. The closest potable water source is [_____] kilometers miles away at [_____]. The closest non-potable water source is [_____] kilometers miles away at [_____].][Potable water is provided by the Government. Provide any necessary connections and extensions to the provided supply line.][Withdrawing water from the [lake][river] requires a permit from the [_____].][Potable water does not need to be tested.]

[

If non-potable water is utilized for the grouting, conduct testing [quarterly][_____] and submit mixing water test reports in accordance with ASTM C1602/C1602M and ASTM C1603, and then submit Mixing Water Test Reports to the Contracting Officer within 72 hours of ASTM test completion. Begin sampling no later than 7 days after Notice to Proceed is given. Perform testing of samples within ASTM time requirements for the sample, or 24 hours of sampling, whichever is less.]

2.2.3 Cements

****

NOTE: The specification has a requirement that the grout mix contain 30 percent portland cement by dry weight. That is due to problems on some projects where contractors have proposed 85 percent slag with poor results. Therefore, a minimum cement dosage is included in this specification as a precaution. A waiver of this requirement should be considered if the contractor is able to satisfactorily demonstrate performance of an alternative mix design. Note that cement grout not containing sufficient portland cement may be erodible when subjected to a differential head and flowing conditions. Strength requirements must consider the stress condition present at the depth of grouting. This requirement is in partnership with the compressive strength requirement. The designer must ensure the mix design (including the water chemistry of available water) and performance are adequate for the subsurface conditions at the site.

****

The grout mixes must contain at least [30][_____] percent Portland Cement by dry weight of the mixture.

2.2.3.1 Portland Cement

****

NOTE: Type III cement has advantages for some grouting due to the fineness of the cement particles, which applies primarily to jobs with the need for a very tight curtain. Type V cement has high sulfate resistance for environments with the potential for chemical attack by hydrogen sulfide, which can be present in seepage through high-head dams. Some cement types are not locally available. Availability must be confirmed prior to specifying.

On USACE jobs, and especially on high-head dams, it is recommended (by materials engineers) to require 2 years of mill certificates for Portland Cements, but this may not apply to smaller jobs.

****

Cement used in grout mus be in accordance with ASTM C150/C150M Type [I,][II,][III,][IV,][or V]. The use of bulk cement is permitted provided methods of handling, transporting, and storage that are satisfactory to the Contracting Officer are employed. Otherwise, only cement provided in fabric or paper bags is acceptable for use in the work.[The GROUTING MATERIAL Submittal must include the source[s] of cement,[[6 month][1 year][2 years] of mill tests,] and an ASTM C150/C150M compliance certificate.] Storage of cement must be in accordance with paragraph DELIVERY, STORAGE, AND HANDLING.

2.2.3.2 Blended Hydraulic Cement

****

NOTE: Although blended hydraulic cements were not commonly used for cement grouting prior to the 2020's, they must be included as an option in all new specifications. They can be utilized for grouting. Blended cement may become what is available or affordable. The designer is recommended to perform market studies and determine the best alternative (straight portland or blended cement) based on price and availability. Technical requirements, market conditions, and local practice will govern selection of cement types.

This paragraph should never be deleted, even where the designer would prefer a pure portland cement for grout, due to the potential for the non-availability of pure portland cement.

Type IT(PX)(PY)X is a secondary component and Y is a tertiary component.

****

Blended Hydraulic Cement is a combination of Portland cement and one or more Supplementary Cementitious Materials (SCM's)/pozzolans or limestone. Blended Hydraulic Cements must be in accordance with ASTM C595/C595M. ASTM C595/C595M recognizes four types of blended cements: Type IS (X), Type IP (X), Type IL (X), and Type IT. The "X" in the name refers to the percentage of secondary ingredient in the blend. Type IS (X) has slag as

the secondary component, Type IP (X) has Pozzolan, typically fly ash, as the secondary component. Type IL Cement has limestone as the secondary component, and Type IT(PX)(PY) has two types of pozzolans. For example, Type IP (15) would contain 15 percent pozzolan. All four types of blended cements are permissible for use in grout.[Verify fresh and hardened grout properties through trial batching and field demonstrations.] Test Blended Cement with Limestone using ASTM C1797 to determine the chemical composition of the lime.

The use of bulk cement is permitted provided methods of handling, transporting, and storage that are satisfactory to the Contracting Officer are employed. Otherwise, only cement provided in fabric or paper bags is acceptable for use in the work. The GROUTING MATERIAL submittal must include the source[s] of cement, [6 month][1 year][2 years] of mill tests, and a certificate of compliance in accordance with ASTM C595/C595M. Store cement in accordance with paragraph DELIVERY, STORAGE, AND HANDLING.

2.2.4 Supplementary Cementitious Materials (SCM's) and Pozzolans

2.2.4.1 Fly Ash

****
NOTE: Fly ash is typically used as an inexpensive filler. It has slight pozzolanic properties. It also increases pressure filtration resistance. As a waste product, the properties vary.
****

If used, fly ash[or other raw or calcined natural pozzolans] must cbe in accordance with ASTM C618. Fly Ash may be provided in paper sacks or in bulk. Transport, handle, and store so as to avoid damage, waste, or absorption of moisture. Use of reclaimed ash and alternatives to Class F and Class C ash are not permitted.

2.2.4.2 Ground-Granulated Blast Furnace Slag

****
NOTE: GGBF is a byproduct of iron and steel making. It increases durability and strength, lowers head of hydration, decreases ASR reactions, and decreases the chance of chemical attack.
****

Ground-Granulated Blast Furnace Slag (GGBF), if used, must be in accordance with ASTM C989/C989M, [grade 100][grade 120]. Transport, handle, and store so as to avoid damage, waste, or absorption of moisture.

2.2.4.3 Silica Fume

****
NOTE: Silica fume is very fine, with a maximum particle size of 1 micron. It improves pressure filtration resistance, reduces bleed, improves water repellency, and increases grout strength.
****

If used, Silica Fume must be in accordance with ASTM C1240. Use of Pelletized Silica Fume is not permitted. Transport, handle, and store so as to avoid damage, waste, or absorption of moisture.

2.2.4.4 Hydrated Lime

****
NOTE: Hydrated lime can be used a pozzolan. It is found in some blended cement. It should not be confused with calcium carbonate (limestone), which is not pozzolanic. Hydrated Lime is created by powdering limestone and heating it to 900 C1650 F and then adding water.
****

Hydrated Lime, also called 'Lime', is calcium oxide or calcium hydroxide that has pozzolanic properties. If used, hydrated lime must be in accordance with ASTM C207.

2.2.5 Admixtures

****
NOTE: Refer to USACE's Engineering Manual (EM)1110-2-3506, "Grouting Technology", for discussions of properties, characteristics and limitations for principal admixture and filler materials.
****

Provide admixtures in adequate containers of suitable volume to allow measurement and dispensing on a production basis without delay or error. Allowed additives include, but are not limited to, the following: [[superplasticizers,][water reducing admixtures,][viscosity modifiers,][and anti-washout admixtures,]]. If use of an additive that is not specified is desired, propose the additive in writing to the Contracting Officer and include in the proposal material quality and property data, and applicable literature. Use of any unspecified admixture must be approved in writing by the Contracting Officer prior to use. No time extension will be allowed for the time required for Government review and approval of substituted or alternative materials. Provide certification from the manufacturer for all admixtures. When multiple admixtures are used in a grout mix, all of the admixtures must be demonstrated to be compatible with each other and the other ingredients in the mix by testing and other applicable data.

Ship, handle, and store admixtures in such a way as to prevent deterioration, contamination, damage, or waste. Storage vats must contain paddle type agitators and the entire admixture dispensing system must be protected from extreme temperatures and conditions. Reject and replace any admixtures subject to freezing, and replace them at no additional cost to the Government.

2.2.5.1 Superplasticizer

****
NOTE: Superplasticizers reduce the amount of water needed for mixes and reduces viscosity and cohesion. It does this by overprinting solid particles with a charge and making them repel each other.

Previous versions of this specification required the

use of super-plasticizer, and zero-bleed mixes require their use in 2023. However, technology changes and the use of superplastizer must not be absolutely required, since a new material may fill the same purpose in the future.

****

A superplasticizer is a high-range water reducer possessing characteristics that reduce the water demand by at least 12 percent. If used, a superplasticizer must meet the requirements of ASTM C494/C494M, type F.[Naphthalene sulphonate or polycarboxylate with the ability to coat grout particles in the suspension with a film having a negative charge must be used.]

2.2.5.2 Water-Reducing Admixture

If used, Water Reducing Admixtures must be in accordance with ASTM C494/C494M, type A.

2.2.5.3 Viscosity Modifier

****

NOTE: Gums, specifically diutan gum and welan gum, have been used as viscosity modifiers in the past. The gums reduce bleed, resist pressure filtration, and make the grout more water repellant. See Chapter 7 of USACE's Engineering Manual EM 1110-2-3506, entitled 'Grouting Technology' for more details.

****

If used, the Viscosity Modifier will be a[natural,] soluble, copolymer having a high molecular weight which enhances the stability of the suspension grouts. Viscosity Modifiers must be in accordance with ASTM C494/C494M, Type S.

2.2.5.4 Fluidifier

If used, the Fluidifier must be a compound possessing characteristics which increase the flowability of the mixture, assist in dispersal of the cement grains, and neutralize the setting shrinkage of the grout. The quality of the material must be in accordance with ASTM C937.

2.2.5.5 Anti-Washout Admixture

****

NOTE: Anti-washout admixture was designed to be used for underwater concrete placement, such as in rivers or ponds. It helps keep the concrete from disintegrating in the presence of water, especially flowing water.

Anti-washout admixture can help cement grouts achieve the same ends. Post-grout coring and televiewer images prove that anti-washout admixture is not needed for typical grout holes, but can be a tool in the toolbox to use if flowing water is encountered or for larger voids.

Anti-washout admixtures are cellulose based and may

have compatibility issues with other admixtures. Consultation with the supplier is recommended before use, along with additional mix design testing.

Anti-washout admixture is expensive and usually requires more than an order-of-magnitude greater cleanup time than 'normal' cement grout mixes. Designers should not be surprised to see much greater costs for the anti-washout grout mix.

****

If used, Anti-washout admixtures must be in accordance with ASTM C494/C494M, Type S, and COE CRD-C 661. Consult with the anti-washout admixture manufacturer to ensure compatibility with the other grout mix components. Provide documentation of admixture compatibility to the Government in the Mix Design submittal.

2.2.5.6 Retarder

****

NOTE: Retarders delay the set-up time of grout. Set times can be delayed from hours to days.

****

If used, Retarders must be in accordance with ASTM C494/C494M, Type B.

2.2.5.7 Other Chemical Admixture

Submit a written request to the Contracting Officer to use any Other Chemical Admixtures in accordance with ASTM C494/C494M. Include a detailed written justification, and supporting data. Use of any Other Chemical Admixtures must be approved in writing by the Contracting Officer prior to use.

2.2.6 Fillers

2.2.6.1 Bentonite

****

NOTE: Bentonite (a mined clay) reduces bleed and increases pressure filtration resistance. It increases viscosity and cohesion. It also makes grout weaker.

****

If used, Bentonite must be sodium (Na) cation. Add powdered montmorillonite to the cement grout at a ratio between [2][_____] to [8][_____] percent by weight of cement. Adjust the percentage as directed by the Contracting Officer, based on the Contractor's mix design. Use a separate colloidal bentonite mixer to mix the bentonite and water to ensure the bentonite is fully dispersed and hydrated before adding to the grout mixer. Handle and store the bentonite to avoid absorption of moisture, damage, or waste. Reject any bentonite which has become caked due to moisture absorption. Store enough bentonite at or near the site of the work to ensure that grouting operations are not delayed by a shortage of bentonite.

[2.2.6.2 Sand

****

NOTE: Sand damages the flow meters and pressure transducers used in computer grouting. The use of sand should be limited to applications where grout flows beyond 40 liters per minute 10 gallons per minute are expected. The actual use of sand should be limited to large voids, karst, and holes that fail to refuse in a time effective manner.

Lime is a less-damaging filler that should be considered over sand.

NOTE: Sand properties for local sources need to be evaluated prior to setting sand requirements, including the gradations.

****

[a. Sand for grout must be clean and consist of hard, tough, durable, uncoated particles with no more than [5][_____] percent passing the 0.075 mm No. 200 sieve in accordance with ASTM C117. The shape of the particles must be generally rounded or cubical[and must not contain more than [_____] percent of flat or elongated pieces having a maximum dimension in excess of three times the minimum dimension]. When coarse sand is used, the sand must be well graded from fine to coarse in accordance with ASTM C136/C136M with 100 percent passing the 2.36 mm No. 8 sieve.]

[b. The sand must be tested at no additional expense to the Government as necessary to determine its acceptability. Perform all sampling of sand in accordance with the applicable sampling provisions in accordance with COE CRD-C 100, or as directed. Test the sand as follows:]

[(1) Table 1: Sand Properties

Property	Standard	Criteria
Specific Gravity	ASTM C128	greater or equal to 2.55
Absorption	ASTM C128	less than or equal to 2.0
Flat and Elongated	COE CRD-C 120	less than 25 percent
Clay Lumps and Friable Particles	ASTM C142/C142M	less than 1%
Organic Impurities	ASTM C40/C40M and if fails then ASTM C87/C87M	3 maximum or minimum, 95 percent strength retention

]

[c. Determine the percentage of surface moisture in terms of the saturated surface-dried sand in accordance with ASTM C70, ASTM C566, COE CRD-C 112, or other method giving comparable results.]

[d. Store sand in such a manner as to avoid the inclusion of any foreign materials in the grout. Keep all sand in free draining storage for at least 72 hours prior to use.]

[
e. The GROUTING MATERIAL submittal must include the source(s) of sand and all required test results.]

][2.2.6.3 Calcium Carbonate

****

NOTE: This specification allows for the calcium carbonate to have a maximum grain size, as determined by the Blaine fineness test. The designer should add the following in the English values tags: <ENG>(There is no English equivalent for the Blaine fineness test, it is only performed using the metric system)</ENG>. If there is no need for small grain sizes, such as when the calcium carbonate is used instead of sand, then the size requirement can be eliminated.

****

If used, Calcium Carbonate must be limestone or dolostone,[ground to a Blaine fineness of [_____] cme-per-gram][ground to the same Blaine fineness as the cement used]. Test lime in accordance with ASTM C1797.[Test Blaine fineness in accordance with ASTM C204.]

][2.2.7 Pigment

****

NOTE: Pigment can be used to differentiate between historic and current grouting, or between different grout lines. Pigment will complicate wastewater treatment, so it should be used judiciously. If used, the overall cost of pigment in grout is low.

If pigment is used, all applicable environmental regulations should be followed, and consideration should be made for adding the wastewater treatment system cost line item (CLIN) from Specification Section 31 43 13.13 CONCRETE PRESSURE GROUTING. See that specification spec for details.

****

Pigment (also known as dye or colorant) must be in accordance with ASTM C979/C979M.

]2.3 OVERBURDEN/ROCK INTERFACE TREATMENT MATERIALS

2.3.1 PVC Casing

****

NOTE: When drilling through overburden, PVC pipe is utilized to act as a permanent casing through the overburden, which protects the overburden from subsequent rock drilling fluid pressures. For PVC casing to be effective, it must be embedded and grouted into bedrock. This is especially important in dams and levees. PVC pipe can also be used when drilling directly on bedrock or concrete.

****

All PVC pipe must be in accordance with ASTM D1785. Each pipe must be free from contamination by dirt, mud, oil, or any other substance.[Glue for use during the assembly of the pipe must be as recommended by the manufacturer.]

2.3.2 Sleeve Port Pipe

****

NOTE: Sleeve port pipe is used when drilling overburden to allow the annular space between the borehole wall and the casing to be backfilled from the bottom. It also allows repeated attempts at grouting, if one attempt cannot fill the annular space. A single packer is used to push grout through the sleeve port hole. A significant advantage of sleeve port pipe is that the inside of the pipe will not be filled with grout, except the very bottom meter or two few feet. This saves on both extraneous grout costs and redrilling costs

Sleeve port casing while drilling angled holes is especially useful in preventing upward migration of grout when soil collapses occur. It is also very useful when trying to case through a karstic cavity.

Sleeve port pipe is created when holes are drilled through the PVC casing. Rubber sleeves cover the hole and act as one-way valves. Depending on the applied pressures, sleeve-port pipe casing can be constructed of either plastic or steel. Steel is most appropriate for very high pressure applications, while plastic is often selected to reduce cost, or where other drilling or excavation activities would be adversely impacted by a steel obstruction. Sleeves can be spaced at any interval, however, sleeve spacing of 0.5 to 3 meters 2 to 5 feet are common in practice.

There are very limited cases where sleeve port pipe could be replaced by a simple notched open pipe, but it is only recommended in very thin overburden situations (i.e., 4 meters 12 feet). The disadvantages are: 1) It will fill both the annular space outside the pipe, and the interior of the pipe, so it requires twice the grout volume, and 2) The contractor is forced to redrill the hardened grout inside the pipe.

****

Sleeve port pipe must be made of PVC or a Contracting Officer-approved equivalent. Space sleeves at [_____] meters feet. Every Sleeve port hole must be at least [20] mm [_____] inches in diameter.

2.3.3 Barrier Bag Equipment

Materials used in barrier bags include specialty fabric (geotextile) and attachment materials.

2.3.4 Other Casing Barrier System Materials

Other barrier systems have been utilized to separate overburden or embankments from underlying rock with potential flaws. If barrier systems outside of sleeve port pipe or barrier bags are proposed, provide details of the materials and the application for which they were used. Include details of previous experience with the proposed system[s].

[2.4 CORE BOXES

****
NOTE: If coring is not required by this specification section, then this sub-section should be deleted. Note that there are measurement and payment paragraphs, as well as equipment and procedures in part 3, for coring, that need to be utilized if coring is required.

For USACE jobs, Engineering Regulation ER 1110-1901, page 6-7, requires the retention of all cores until release of claim on the construction job, unless borehole camera images exist, in which case only representative cores need to be retained. In addition, representative cores need to be retrained for 5 years after final project completion in case unforeseen foundation conditions develop.

The designer will need to choose between wooden and corrugated plastic core boxes. The appropriate paragraph will be chosen and the non-chosen type paragraph deleted.
****

Box all rock core and concrete core drilled at the site. Make core boxes out of [wood][corrugated plastic].

[
Supply wooden core boxes built using plywood and dressed lumber, having longitudinal partitions, a hinged top, and spacer blocks.[Make core boxes lockable.] Construct wooden core boxes using [screws][staples][nails].
][
Supply Plastic Corrugated core boxes with longitudinal partitions, a removable lid, and spacer blocks.[Provide rubber band(s) to keep the lid on each box.]]

]PART 3 EXECUTION

3.1 EQUIPMENT

****
NOTE: During design, pump test data should be used to determine minimum grout pumping specifications. Include considerations for multiple simultaneous operations and contingencies.
****

3.1.1 General

Use drilling,[washing,] water pressure testing, and grouting equipment of

a type, capacity, and mechanical condition suitable to perform the work including but not limited to the desired depths, angles, diameters, pressures, and volumes as determined and approved by the Contracting Officer. The power, equipment, and layout are required to meet all applicable local, State, and Federal regulations and codes, both safety and otherwise.

3.1.1.1 Equipment Arrangement and Operation

Regardless of grout take, grouting equipment arrangement is required to provide a continuous circulation of grout throughout the system, and to permit accurate pressure control by operation of a valve on the grout return line. Prevent equipment and lines from becoming fouled by maintaining the constant circulation of grout, and by performing the periodic flushing out of the system with water. Complete flushing with the grout intake valve closed, the water supply valve open, and the pump running at full speed.

3.1.2 Drilling Rigs and Equipment

****
NOTE: Floating needle pressure gauges record the highest pressure until reset. These can be specified if there is concern for excess pressure, but are not necessary on all jobs.
****

The drilling equipment must be capable of drilling a borehole at the required angle from vertical, to the required drill depth, and produce grout hole suitable for accepting grout. The power, equipment, and layout must meet all applicable requirements of local, State, and Federal regulations and codes, both safety and otherwise. Supplies include all coring and non-coring bits, drill rods, tools, core barrels, casing, piping, pumps, other equipment, water, and power to accomplish the required drilling. All drilling rigs and pumps must be equipped with[pressure gauges][floating needle pressure gauges].[The use of air as circulating medium is prohibited.] All drilling equipment used must be of a type, capacity, and mechanical condition suitable for performing the work, as determined by the Contracting Officer. Provide all relevant documentation which demonstrates equipment meets these stated requirements.

3.1.2.1 Soil Drilling Equipment

****
NOTE: Delete if no soil is present.
****

Submit the proposed drilling equipment to include: 1) manufacturer and model number of the drill rig, 2) the manufacturer, model, designation, and diameter[s] of the drill rods, and 3) the bit type, bit manufacturer, bit model, and diameter, proposed for overburden drilling.

Drill dam embankment and underlying overburden with[[resonant sonic drills,][hollow stem augers,][other]]. Drilling in the dam embankment with air or water circulation down the hole is not permitted. Displacement bits are not permitted for drilling holes in the embankment.

3.1.2.2 Rock Drilling Equipment

****

NOTE: Please note that no sample or core is required for rock drilling equipment as written. Destructive drilling is cheaper than core drilling and is recommended for heavy production work in conjunction with downhole cameras. Coring should be considered for all exploratory holes and for all verification holes.

Air is compressible and can damage foundations through hydrofracture and/or jacking. In addition, air can clog fractures with moist cuttings. Air should be avoided where there is concern about nearby structures or overburden. Regardless of structure type, sensitive structures should consider adherence to USACE's Engineering Regulation ER 1110-1-1807.

If measurement while drilling (MWD) is required, include the bracketed section for MWD in addition to the rock drilling section.

****

Perform grout hole drilling in rock with water-actuated down-the-hole hammers, top-hole hammers, or standard rotary drills. Submit the proposed drilling equipment to include: 1) manufacturer and model number of the drill rig, 2) the manufacturer, model, designation, and diameter(s) of the drill rods, and 3) the bit type, bit manufacturer, bit model, and diameter, proposed for the drilling of rock. Air drilling of the rock is prohibited.[The rock drill rig must utilize Measurement-While-Drilling (MWD) recording.] Use [water][air] for removing cuttings from the hole during drilling operations.

[3.1.2.3 Measurement While Drilling (MWD)

Utilize a measurement while drilling system that develops specific energy plots capable of discerning between soil, fractured rock, and intact rock. Equipment must measure and record drilling parameters including, but not limited to, bit load, rate of penetration, flush pressure, revolutions per minute (rpm), rotation pressure, specific energy, and water inflow and outflow in real-time. Allow the Government real-time access to specified input and output data in [_____], and Microsoft Excel format during production, and at the end of each day. All generated input and output data is the property of the Government. Perform all required record keeping regardless of Government activities.

Submit an example of the digital output of the MWD system in the Drilling and Grouting Work Plan. Provide a table listing each column (field) of the example table along with a description of the field (e.g., definitions of any acronyms, English translations of any non-English terms). Specify the units of any numerical field. If the format of this table is changed during the project, submit an updated example table and definitions table prior to changing the formats. Include all calculations used to produce numeric values, and define all variables and constants. The digital output of the MWD system is required to be uploaded to the secure file sharing site[by end of shift,][within 1 hr,][within 4 hr,][of hole completion].

]3.1.2.4 Rock Coring Equipment

****

NOTE: Rock Coring is not strictly necessary for grouting jobs, unless core samples are required for laboratory testing. It is cheaper to drill a destructive hole and perform a televiewer survey (Add the 'Downhole Surveys-Imaging' tailoring option to utilize this method.) However, the designer may decide that they want rock coring, and then this item must be added. The designer should determine the core size/diameter: 2-inch for NQ, 2.5-inch for HQ, or 3.3-inch for PQ. Choose either double-tube or triple tube: 1) for rock that is partially or all soft, a triple-tube coring system is recommended; 2) for hard rock, a double-tube coring system could suffice. The triple tube system has a second inner barrel that is split, allowing the core not be disturbed during removal. Spilt barrel may be considered for the double-tube to improve recovery of material that may be substandard. See EM 1110-1-1804, or other standards, on geotechnical investigations for more information on rock coring equipment and uses.

MWD is typically not used for rock coring, so judgment should be utilized before adding this requirement.

****

Utilize standard [triple-tube][double-tube] rock coring equipment for rock coring. The core size is required to be [_____]. Submit the proposed drilling equipment to be used in the Drill Rigs and Equipment submittal. Include the following information : 1) Manufacturer and model number of the drill rig, 2) The manufacturer, model, designation, and diameter(s) of the drill rods, and 3) The bit type, bit manufacturer, bit model, and diameter, proposed for rock coring. Perform rock coring using fresh water as the drilling fluid, with no air utilized.[The rock core drill rig is required to utilize Measurement-While-Drilling (MWD) recording.]

3.1.2.5 [Reinforced]Concrete Drilling Equipment

****

NOTE: This is for jobs where small amounts of reinforced concretes are present. If extensive concrete is to be drilled through, or more than a few locations drilled that have reinforced concrete, use Section 31 43 13.13 CONCRETE PRESSURE GROUTING instead and delete this section.

For small amounts of concrete, the designer should do one of the following 1) Delet this paragraph because no concrete needs to be drilled, 2) Keep this paragraph with no mention of reinforcement because none of the concrete is reinforced, or 3) Keep this paragraph with the word reinforced in

the title and discuss the reinforcement present.

Reinforced concrete require rock coring diamond bits (either providing a core sample or 'full face diamond bits' that do not create samples) are the only known bits that can reliably drill through reinforced concrete.

The designer needs to add the details of the reinforcing steel. These details will help guide the contractor in the selection of their equipment.

****

Utilize coring equipment appropriate for drilling [reinforced]concrete. [To utilize alternative equipment, submit written documentation and data demonstrating the successful use of non-coring equipment for drilling through reinforced concrete in the Drill Rigs and Equipment submittal. Alternative equipment must be approved in writing by the Contracting Officer prior to use.][Coring bits or 'full face diamond-coring bits'] [_____] are acceptable. Submit the proposed drilling equipment to include: 1) manufacturer and model number of the drill rig, 2) the manufacturer, model, designation, and diameter[s] of the drill rods, and 3) the bit type, bit manufacturer, bit model, and diameter, proposed for reinforced concrete. Air drilling of the concrete is prohibited.

[

The details of the reinforcing steel present are [_____].]

[3.1.3 Pressure Washing Equipment

****

NOTE: Using hole washing as a separate step is recommended where discontinuities are infilled with soil-type materials. This sub-section is recommended to be added in that case.

****

Provide a separate piece of equipment that is used for washing the grout hole. The equipment must be capable of spraying the hole in 360-degrees through[spiral] holes that are required to emit a pressure no less than [_____] kPa psi and no more than [_____] kPa psi, measured at a distance from the nozzle to the diameter of the hole.[The tooling must employ centralizers to keep it in the center of the hole.] The equipment must provide a way of determining the depth of the tooling from the surface. Submittal photos of the hole pressure washing equipment, manufacturer cut sheets[if applicable] or design details[if custom made], as well as output and pressures.

]3.1.4 Grouting Equipment

****

NOTE: Recommendations for a typical grout job include: Minimum capacity of 57 lpm 15 gpm, max pressure 1400 kPa 200 psi per active hole. The number of simultaneous holes will vary by job from one, to as many as needed.

****

The grout plant must be capable of supplying, mixing, stirring, and pumping the grout and additives to the satisfaction of the Contracting

Officer. Submit a detailed plan showing equipment and grout plant layout proposed for mixing and placing grout. The plant must have a minimum capacity of [[_____] mL/s] [[_____] cm3/s] [[_____] gpm] [[_____] cfm] of grout injected at a pressure no greater than [_____] kPa psi. The plant must be well-maintained. Redrill and replace at no additional cost to the Government any grout hole that is lost or damaged due to mechanical failure of equipment or inadequacy of grout supply. The amount of grouting equipment must be sufficient to perform the work specified herein and must include the following:

****

NOTE: Progressive cavity pumps provide a constant output pressure. This makes them superior to piston pumps, which have variable output pressures. Pumps are addressed in USACE's Engineering Manual EM 1110-2-3506 "Grouting Technology" in section 10-5, on pages 10-7 to 10-8, and in the book "Dam Foundation Grouting" by Bruce and Weaver (2007) in section 9.3 on pages 274-276. The use of piston pumps are predominately excluded from this specification. There may be limited circumstances where piston pumps are needed or preferred by the Contractor, such as when grouting at high pressures in tight formations. Pistom pumps may also be advantageous for pumping sanded grout mixes. For other applications, dampers are required to reduce pressure spikes and risk for harm to the foundation materials. A test section will likely be required.

For dams or levees, piston pumps should generally not be permitted due to risks for hydrofracture and foundation damage.

****

a. A progressive cavity pump capable of passing particles up to a top size of [_____] mm inches, generating pressures up to [_____] kPa psi and pumping a maximum of [[_____] mL/s] [[_____] cm^3/s] [[_____] gpm] [[_____] cfm]. In no case must the distance from the grout pump to the grout header exceed the capabilities of the equipment to deliver grout to the hole.[Do not exceed [100][200][_____] meters [300][500][_____] feet of grout line from the header of a hole being grouted.] Where grout lines are more than [200][_____] meters [500][_____] feet long, an additional pump is required to be placed in the line. Alternate configurations and distances may be submit and demonstrated, but are subject to approval by the Contracting Officer.

****

NOTE: Colloidal mixers are vastly superior to paddle mixers for mixing grout. Colloidal mixers have been in use for nearly a century as of 2023. The use of paddle mixers for mixing grout on grouting jobs is no longer acceptable.

****

b. A colloidal type grout mixer having a minimum drum capacity of approximately 0.3 cubic meters 10 cubic feet. Mixing time is required to be approximately [_____] seconds per batch. The diffuser-type centrifugal mixing pump must operate at 1,500 to 2,000 rpm during mixing and delivery. The grout mixers must be equipped with a

tangential return line and capable of effectively mixing grout having water to cement ratios of 0.5 to 2 measured by weight.

c. If using bentonite, a separate colloidal mixer for mixing and hydrating bentonite.

****

NOTE: After the grout is mixed in the colloidal mixer, it is transferred to the distribution tank. This tank contains paddle agitators and is connected to the pump for distribution out the grout header. Grout that is not injected into the hole is returned to the distribution tank in the grout 'loop'.

****

d. Grout distribution tanks that have paddles capable of rotating at a minimum of 100 rpm and be properly baffled to prevent vortex formation. Equip each tank with two 0.45 mm No. 16 screens such that all grout arriving from the mixer and returning from the grout hole return line is screened. A mechanically agitated sump having a minimum capacity of [_____] cubic meters feet.

e. A water storage tank or suitable source of clean auxiliary water for use in washing, water pressure testing, and flushing operations.

f. If bentonite is used, separate tanks are required for hydrating bentonite, and storing hydrated bentonite. Fit the tanks with agitators to prevent settlement or separation.

****

NOTE: Experts have noted that water meters by weight are more accurate than by volume. Batching components are specified by weight. Remain consistent.

****

g. Utilize either: 1) A water meter graduated in cubic meters feet to tenths, employing a direct reading totalizer, and capable of conveniently resetting to zero, or 2) A water scale measuring in kilograms pounds with tenths and hundredths.

h. Valves, packers, pressure gauges[with gauge savers], pressure hose, supply lines, and small tools as are necessary to provide a continuous supply of grout at accurately controlled pressures as specified. The inside diameter of the pressure hose and grout supply line of not less than 25 mm 1 inch. Utilize an accurately NIST-calibrated, high precision pressure gauge to check the accuracy of all gauges used in the grouting. Check gauges at least once every 24 hours, or more frequently if quality issues are noted, and as required by the Contracting Officer. The minimum gauge accuracy is two percent over the range of the gauge. When defects are found, stop grouting operations until gauges have been calibrated to within the acceptable range. Maintain a ready supply of pneumatic packers and other accessories for water pressure testing. Provide a sufficient supply of mechanical packers for the purpose of preventing debris from entering, or grout escaping the grout holes, and to stop grout or water from flowing between holes that are hydraulically connected.

i. A means of measuring quantities of all materials used in grouting

operations, including components of grout injected and wasted.

j. A sheltered space and equipment for conducting Quality Control tests on the grout. Provide the Government space and separate equipment of equal grade, quality, precision, and accuracy as used for QC activities to conduct Quality Assurance testing of the grout.

3.1.4.1 Grout Plant

Include the technical specifications of equipment to be utilized in accordance with paragraph GROUTING EQUIPMENT, in the Grout Equipment submittal. Also include the setup configuration of the grout equipment in relation to each other in the submittal.

3.1.4.2 Grout Header[s]

****

NOTE: For low flow rates, the inner diameter of the hoses will need to be reduced. If piston pumps are proposed by the Contractor, a return circuit is not required.

****

Each grout header must have two valves that control flow both 1) Down the hole, and 2) Back to the grout plant. These valves must be capable of being controlled by hand. Each grout header must have a sufficient length of hose to reach the bottom of the deepest hole in the work area.

Hose inner diameters are not permitted to be smaller than 2.5 cm 1 inch. The hose must be marked minimally every 1-meter (with no English markings) 5-feet, in feet (with no metric markings). Do not wrap hoses more tightly than [30][_____]-degrees per 1/3-meter foot. Each hose must be supplied with, and be capable of rapidly attaching, either a single-packer or double-packer. Fit each grout header with a pressure transducer, and a flow meter; each of which must produce an electronic signal for the Automated Grouting Data Collection System. Each pressure transducer and flow meter must have a readout that is visible at the header itself. Each grout header is required to have a visible air pressure gauge for inflation of the packer[s]. Each grout header must be capable of having a reference pressure gauge and reference flow meter attached to it for calibration. Grout headers must be capable of using all mixes submitted; if thick mixes require larger diameter hoses and a separate grout cart, provide them for that setup at no additional cost to the Government.

3.1.4.2.1 Grout Cart

A grout cart is a self-propelled entity that contains a grout header and associated equipment. Grout carts are not required, but they may prove optimal for the efficient and timely completion of work.

[3.1.4.2.2 Instrumented Packer Equipment

****

NOTE: Instrumented packers must be used on USACE Embankment Dams and Levees and should be combined with the use of an AGDCS. The 2 percent accuracy listed below may not be appropriate for all situations, especially where pressures are relatively low (2 percent of 10 psi is 0.2 psi).

For lower-risk or low-pressure situations, it may make sense to decrease the accuracy requirement (to 6 percent).

****

Procure instrumented packer systems in both single packer and double packer configurations. The Instrumented packer must measure the fluid pressure below the packer seal, or between the packers for a double-packer assembly. Packer diameters must be compatible with borehole diameters drilled. Use pressure transducers with a pressure range appropriate for the pressures encountered, accurate to plus or minus 2 percent. The sensor must work in temperatures between 1 to 32 degrees Celsius 33 to 90 degrees Fahrenheit. Procure a length of casing, here referred to as "calibration casing", with an external and replaceable pressure gauge that senses the inside of the casing. This external pressure gauge must allow comparison with the instrumented packer pressure gauge. The calibration casing external gauge must be a test gauge accurate to plus or minus 0.25 percent full scale or better with NIST certificate, and a sensitivity, range, and scale appropriate for anticipated pressure during operations. The calibration casing and pressure gauge location must be compatible for either single or double packer assemblies, and the calibration casing must have a minimum burst strength of 5500 kPa 800 psi. Metal is recommended for the calibration casing, but not required.

[The systems must include all items required for monitoring and data collection during production pressure grouting. Devise a system such that the down hole sensor is readable in real-time within the AGDCS. Procure sufficient extra packers, pressure sensors, accessories, and spare parts as not to cause delays. The system must include the wiring, wireless-or-wired transmitter and receiver, [processor][computer], and display monitor necessary to show the data in real-time, and record the data for record. Calibration is required weekly or more frequently when anomalous readings are observed.][Perform operator's checks on equipment at the beginning of each shift of operation to verify gauges are reading zero during no pressure and no flow conditions. Conduct a check of manually measured flow and pressure versus equipment readout daily, or at any time as directed by the Contracting Officer. Record these checks in QC documentation.]

]3.1.5 Downhole Survey Tools

3.1.5.1 Optical Televiewer Equipment

****

NOTE: Downhole cameras have become a relatively cheap and effective means of borehole evaluation that do not hamper the rate of production as much as core recovery. They create a 360-degree view of the entire borehole depth, with printouts for permanent record. They have an added advantage over coring because they never miss a single inch of hole. It is usually cheaper to drill destructively and perform a camera survey than to core a hole, but coring is still necessary for lab testing of rock samples.

****

Utilize Optical Televiewer Equipment that meets the following minimum requirements:

a. Submersible, high definition, color, 360-degree side-view optical televiewer capable of generating a permanent high-resolution, visual true color, archival quality record (30 fps or better) of the entire borehole under naturally occurring external wall pressure inside the borings. Televiewer must be capable of viewing borehole over 360 degrees in horizontal plane of rotation, along with side-view orientation of the borehole angled a maximum of 30 degrees from vertical.

b. The equipment must incorporate an electrically powered winching system with depth encoder and LCD depth display integrated into the winching system. The winching and OPTV/ATV equipment must be capable of operation in a submerged condition in up to 50 meters 170 feet of water and at temperatures up to 60 degrees C for eight (8) hours of continuous operation.

c. All imaging equipment functions including focus, iris, orientation, and lighting intensity (minimum variable lighting of 20 lux at one meter) must be controllable from the surface, both manually and automatically.

d. Color image compliant with[HDTV format (1080i)], with at least [90][_____] minutes of continuous recording capabilities.

e. Televiewer must have built-in magnetic compass (azimuth) and inclination measurement capabilities, which have the following minimum specifications:

(1) Noise level Magnetometer 5 x 10-6 G
(2) Noise level Accelerometer 2 x 10-4
(3) Gee Linearity plus or minus 0.1 percent FS

(4) Angular accuracy:
(5) Roll and pitch plus or minus 0.5 degree
(6) Azimuth plus or minus 1.0 degree
(7) Axis alignment plus or minus 0.2 degree
(8) Alignment of axes with plus or minus 0.2 degree package reference frame

f. Able to measure and record borehole deviations including azimuth and inclination, relative to compass direction, and in relation to intended alignment.

g. Minimum azimuthal resolution must be [900][_____] pixels and maximum vertical resolution must be [2][_____] millimeters.

h. The borehole imaging device(s) must fit within the drilled hole with all equipment being able to pass through the entire length of the hole.

i. Supply a high-resolution color video monitor, with a minimum screen size of [24][_____] inches, at the surface which is integrated into the imaging equipment system for real-time viewing by the Government. Supplement the imaging equipment with a device to check the calibration in the field of all the on-board instrumentation of the camera based on the manufacturer's recommendations.

3.1.5.2 Acoustic Televiewer Equipment

Provide a high resolution, side viewing acoustic televiewer, which obtain oriented, virtual survey of the entire length of the uncased boring. Specific grout holes in rock, as directed by the Contracting Officer, must be thoroughly washed and documented by a submersible acoustic televiewer. The camera must be available whenever required on-site, and no separate mobilization must be paid for having the acoustic televiewer on-site.

Utilize Acoustical Televiewer Equipment that meets the following minimum requirements:

Acoustic Televiewer Requirements
Acoustic Sensor: Fixed transducer, rotating focusing mirror
Focus Optimized For: 15.2 cm 6 in borehole
Frequency: 1.2 MHz
Acoustic Beam Width: 1.5 mm .060 in focal distance
Rotation Speed: Up to 35 revolutions/sec.
Samples per Rev.: 72, 144, 216, 288, and 360
Measurement Ranges: Standard ABI-2G or ABI40-GR: 5 to 51 cm 2 to 20 inch open or cased borehole
QL40-ABI-VLB: 25 to 76 cm 10 to 30 inch in a cased borehole, minimum thickness 5 mm .20 in
Caliper Resolution: 0.08 mm .003 in
Orientation Sensor: APS 544, 3-Axis Magnetometer and Accelerometer
Inclination Accuracy: plus or minus 0.5 degrees
Azimuth Accuracy: plus or minus 1.2 degree

[3.1.5.3 Borehole Deviation Equipment

****

NOTE: Borehole Deviation/Alignment devices have matured and can now pinpoint a hole's true position in 3-D space. This is especially useful in drilling holes in locks, concrete dams, or other locations with tight tolerances, or when fan drilling.

The presence of metal adjacent to the hole can cause problems with some alignment devices that use magnetic north for reference; but non-magnetic deviation survey equipment is also available. Be sure to note the presence of metal.

****

The Downhole Deviation (Alignment) Device must have built-in magnetic compass (azimuth) and inclination measurement capabilities, which have the following minimum specifications:

Noise level Magnetometer 5 x 10-6 G
Noise level Accelerometer 2 x 10-4 Gee
Linearity plus or minus 0.1 percent FS

Angular accuracy:
Roll and pitch plus or minus 0.5 degree
Azimuth plus or minus 1.0 degree
Axis alignment plus or minus 0.2 degree
Alignment of axes with plus or minus 0.2 degree

Some televiewer equipment also have built-in deviation equipment. It is

not necessary to have separate devices if one device can fulfill both requirements.

[
Steel or Iron is anticipated in the vicinity of[some of] the boreholes, therefore, a downhole deviation device that is non-magnetic is required. A combination of non-magnetic and magnetic devices is also acceptable.]

][3.1.5.4 Mechanical Caliper Equipment

The mechanical caliper must be capable of producing a survey that meets the requirements of ASTM D6167. The mechanical caliper must have at least [3][_____] arms.

][3.1.5.5 Other Downhole Survey Tooling Equipment

Other downhole survey tooling could be used for geophysical surveys or other downhole surveys. The tooling must conform to manufacture requirements and applicable ASTM specifications

]3.1.6 Automated Grouting Data Collection System (AGDCS)

Provide, set up, maintain, and operate the AGDCS. Utilize the system during all grouting operations, which includes water pressure testing, pressure grouting, interface treatment, sealing casing into rock, and backfilling or topping off both grout and verification holes. Provide the Government unlimited access to the system for monitoring purposes. Include in the AGDCS all necessary equipment, materials, computer hardware, and software to direct grouting operations in accordance with these specifications and collect and display digital data in real-time. Ensure the system is capable of producing data in hard copy and digital formats.

3.1.6.1 AGDCS Equipment Capabilities

The AGDCS must have the following capabilities:

a. Monitor and record all water pressure testing including but not limited to pressures, flow rates, and lugeon values.

b. Monitor and record all grouting including but not limited to mix type, [line losses], target pressure, gauge pressure, total volume, flow rates, and apparent lugeon values at the midpoint of each stage.

c. Calculated maximum total pressures from the specified pressure criteria.

****
NOTE: Please ensure that only one of the two choices for paragraph "d" below are picked, depending upon whether the designer is specifying instrumented packers or not. The second choice of 'd' is for use with instrumented packers.
****

[d. Downhole effective grouting pressure must be calculated based on pressures measured at the grout header, considering in-situ water pressure, weight of grout column, and estimated head losses.]

[
d. Measure effective pressure in the ground with an instrumented

packer. Calculate effective grouting pressure based on 1) pressures readings from the grout stage, from the instrumented packer, minus 2) the pressure provided by the local water table.]

e. The automated system must have the ability to continuously monitor the grouting operation without interference or interruption to the grout injection process while grouting a stage when a mix change is warranted.

f. List of cumulative drilling and grouting issues including but not limited to broken PVC, tooling lost in the dam, hole communications, rod drops, and fluid loss.

g. Correct and reduce the collected data to account for correction factors and field parameters including pressure head losses, pressure measurements, actual depth of the stage being grouted, groundwater influence, and mix batching/cycling.

h. Export raw data files into a non-proprietary file format and produce tabular digital records as specified in section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION, paragraph "DATA REQUIREMENTS".

i. Capable of producing graphs in [Excel 360] format. Use of othere formats must be proposed and approved within this submittal.

j. Graphically display in real-time, the following at a minimum:

1) Total volume of grout or water placed in the stage;
2) Gauge pressure, [total pressure,] and [effective pressures,] [and measured total pressure from the instrumented packer,] at active zone being grouted.
3) Start and stop times of grout injection;
4) A continuous dotted line showing the target pressure;
5) Rate of injection (volume per time);
6) Apparent Lugeon value;
7) The time, type and volume of a particular grout mix for the full duration of the grouting;
[8) Plots for Time History of flow, pressure, Apparent Lugeon.]
9) The entire grouting record for the stage versus time;
[10) Do not distort the time axis on real-time plots;]

3.1.6.2 Automated Grouting Data Collection System (AGDCS) Submittal

Include the following information about the automated grouting data collection program in the submittal:

a. System name and manufacturer.
b. The calculations for producing effective pressure.
c. Describe the process for data input to the system.
d. Describe the process for data storage for all generated data, including but not limited to grouting, testing, or other required processes.
e. Describe the data visualization, including but not limited to, GIS mapping, CAD profiles, and plots used, and methodology - including any data transformations or binning.
f. Describe methodology used for export of data to [Excel Spreadsheets] [Enterprise Database].
g. Capability to backup data to ensure no data loss occurs.

h. Screenshots of raw data format and typical plots.
i. Example normal water-pressure-testing log.
j. Example step water-pressure-testing log.
k. Example grout log with a change in mix type.

3.2 HOLE SEQUENCES

****
NOTE: Edit the following sections to clarify prescribed hole sequences. It is recommended to sequence the grouting procedures in the order you intend for work to progress during production. Include sequences for grouting multiple stages, zones, grout lines, sections, verification, and exploratory holes as required to complete the scope.

For typical grouting, most holes will be upstage grouted unless caving holes, fluid loss, or other geologic conditions necessitate the need for downstage grouting. Clarify what conditions may necessitate downstage grouting. For example, if drilling in dams or levees, the Drilling Program Plan may prescribe (dependent on agency regulation) the designer to prescribe downstaging for the soil/bedrock contact and upper 10-15 feet of the grout hole.
****

3.2.1 Sequence of Grout Lines

****
NOTE: The book entitled 'Dam Foundation Grouting' by Bruce and Weaver (2007), paragraph 11.2.2, 'Multiple Row Curtains', page 323, states: "Grouting of multiple row grout curtains should always and without exception begin with the downstream row." This is applicable when the foundation is exposed to flowing or differential head conditions. The downstream grout line will somewhat disrupt flowing conditions and also provide confinement for the upstream grout line. Overall, this approach will increase the grouting effectiveness for the grouting program. If the foundation is not subject to these conditions, other factors may influence the decision on whether to start with the upstream or downstream grout lines at the designer's discretion.
****

Perform drilling and grouting in [a single line][multiple lines] as shown. Drill and grout the[downstream] line first, followed by the[upstream] line.[The middle grout line must be sequenced last.]

Perform drilling and the grouting by stages, using the[split spacing, downstage grouting method][split spacing, upstage grouting method] as described herein. The maximum water pressure testing and grout stage length is [6][9] meters [20][30] feet.

3.2.2 Sequence of Grout Zones

****

NOTE: Generally, the time between grouting one hole and working on a nearby hole should be equal to the final set time of the grout utilized. However, on a constrained worksite, where this restriction will have a significant schedule impact, a less restrictive time based on initial set time plus some additional time (2-8 hours) may be appropriate.

The most common method of grouting is to complete holes using the upstage method. If return fluid is lost during drilling, then the interval where return fluid was lost must be downstage grouted. Sensitive projects may define zones where the upper portion of the hole is downstage grouted before drilling and upstage grouting the remaining hole.

The designer must tailor the following sections for to their scope. Army projects in earth dams and levees must downstage grout the first two zones.

****

[Execute all planned holes by series using[upstage grouting for the entire borehole][downstage grouting for the entire borehole][downstage grouting the first zone then upstage [drilling][grouting] the remaining hole].][Execute all primary holes to full depth before starting secondary holes, and follow the same procedure for each successive series.] Do not perform any rock [drilling][coring] and water pressure testing adjacent to any hole where grouting is ongoing until[after grout stage has reached the final set time][after the grout stage has set for a period of 24 hours.][Isolate the [soil][bedrock] contact for the entire section before downstage pressure grouting.]

3.2.3 Upstage Grouting Sequence

Upstage grouting is a method where each hole is drilled to a final depth in one step, and then grouted by stages through an expansion plug or packer which is set at successively shallower depths, starting at the bottom and working upward. Drill and grout in accordance with the following procedures and sequence:

a. Drill hole to the full depth and wash in accordance with paragraph DRILLING PROCEDURES.

b. As directed, flush[, pressure wash] and water pressure test drill holes in accordance with paragraphs GROUT HOLE WASHING PROCEDURES and WATER PRESSURE TESTING PROCEDURES.

c. Place the packer in the hole at the top of the stage to be grouted, blocking off the higher portion of the hole, and grout the deepest stage. Complete this for all stages in the upstage grouting zone. The deepest grout stage is restricted to a depth of between [_____] meters feet and [_____] meters feet.

[

d. After placing the grout at the pressure and mix directed by the Contracting Officer, leave the expansion plug, or packer, in place until the grout pressure drops to the pressure required for the next

higher stop, or as directed by the Contracting Officer.]

e. Move the packer to the next higher stop and place grout at the target pressure pressure for that stage, as directed by the Contracting Officer.

f. Repeat procedures described in subparagraph[s "d" and] "e" above until grouting of the hole is complete.

g. After the primary holes in the first zone have been completed in any section as specified above, grout the second and succeeding series of holes as determined by the "split spacing method", in like manner until all zones of that section are completely grouted.

h. Grout othere sections along the grout curtain using the same procedure until grouting of the foundation is completed to the satisfaction of the Contracting Officer.

i. As the drilling and grouting work progresses, additional split-spacing may be required in some sections to reach closure.

3.2.4 Downstage Grouting Sequence

****

NOTE: There are essentially three ways to grout using downstaging. Select and tailor the scenario that best fits your project scope.

1. If drilling fluid it lost, that individual stage can be downstage grouted. This frequently applies to situations where upstage grouting was planned.

2. Start and finish the first grout zones on all scheduled holes for a section before deepening any of the holes to the second grout stage. The second grout zone on all scheduled holes in a section is then started and completed. The benefit of completing all the planned grout holes for the upper zones is to create a 'grout cap' that should help to (sometimes) prevent lower/later grout stages from having grout flow upwards.

3. Downstage each complete hole series individually, where every primary hole is completed before starting the secondary holes.

The first section applies to all general grouting projects in the event drilling fluid is lost - regardless of whether upstage or downstage grouting is prescribed. Use the subsections that follow only if prescribed downstage grouting is required. Delete subsections for prescribed downstage grouting as appropriate.

****

Downstage grout any drilled hole in bedrock that loses [100 percent] drilling fluid, at the target pressure for that depth. The general procedure for downstage grouting in this instance is as follows:

a. Flush[, pressure wash,]and then grout the stage at target pressure until refusal occurs.

****
NOTE: In the paragraph below, the first bracketed text, would only apply where there is an over-tremie or other problem.
****

b. Prevent excess grout from filling the hole above the grouted stage. The Government will not make any additional payments for placing or removing excess grout. Do not proceed to the next lower stage until previously placed grout has[reached measured final set time][set for a period of [24][_____] hours].

c. Drill, flush,[pressure wash,][water pressure test][complete downhole imaging] and grout the next lower stage at the target pressure until refusal occurs. The grout within the hole must be removed as described above.

d. Proceed with upstage drilling and grouting until additional loss of drilling fluid occurs, then repeat this process.

[3.2.4.1 Downstage Grouting for the First and Second Zone

****
NOTE: Downstage grouting can be utilized as a method to limit upward communication of pressurized drilling fluids into the overburden. Sensitive projects will need methods to comply with the Drilling and Invasive Activities Plan (DIPP). Typically, the first zone is the first stage below the bottom of the casing. Flush, wash, and water pressure test (if required) the first zone. Grout the first zone to the target pressure. After the grout in the first zone sets, the grout creates a "cap" preventing the upward migration of pressurized fluids. Drill the second zone after the first zone has reached the required set time. The second zone will generally be a medium to long grout stage. For USACE Dams and Levees, this stage may utilize lower pressure to comply with the DIPP. Once both the first and second zones have been downstage grouted, proceed with upstage drilling and grouting for the entire length of the grout hole in bedrock.
****

a. Flush[, pressure wash,] and then grout the first zone at gravity pressure until refusal occurs. Do not proceed to the next lower stage until previously placed grout has[reached measured final set time][set for a period of [24][_____] hours].

b. Begin the second zone drilling and grouting by coring or drilling through the first grouted zone and proceeding an additional [3][5][8] meters [10][15][20] feet to the bottom of the second zone. Flush, [pressure wash,][water pressure test] the second zone and then grout the second zone at[gravity pressure][target pressure] until refusal. The grout within the hole must be removed as described

above. Do not proceed to the next lower stage until previously placed grout has[reached measured final set time][set for a period of [24][_____] hours].

c. Drill, flush,[pressure wash,][water pressure test][complete downhole imaging] and grout the next lower stage at the target pressure until refusal. The grout within the hole must be drilled through as described above.

d. Adjacent holes within the same series may be advanced concurrently, provided the holes are over 13 meters 40 feet apart.

e. After all Primary hole first and second zone grouting is completed for a section, drill the remainder of the grout hole full depth and proceed with upstage grouting in stages.

[

f. Move to the next succeeding series following the same process as required in the project scope or per Split Spacing Criteria.]

][3.2.4.2 Downstage Grouting Entire Boreholes

When downstage grouted is required for an entire borehole, use the following procedure and sequence:

a. Flush[, pressure wash,] and then grout the first zone at[gravity pressure][target pressure] until refusal occurs. Do not proceed to the next lower stage until previously placed grout has[reached measured final set time][set for a period of [24][_____] hours].

b. Begin the second zone drilling and grouting by coring or drilling through the first grouted zone and proceeding an additional [3][5][8] meters [10][15][20] feet to the bottom of the second zone. Flush, [pressure wash,][water pressure test] the second zone and then grout the second zone at[gravity pressure][target pressure] until refusal. The grout within the hole must be removed as described above. Do not proceed to the next lower stage until previously placed grout has[reached measured final set time][set for a period of [24][_____] hours].

c. Perform downstage drilling and grouting of progressively deeper zones in successive operations at [_____] meters [_____] foot stage increments until the hole is completed. Drill, flush,[pressure wash,][water pressure test][complete downhole imaging] and grout each successive lower stage at the target pressure until refusal.[When water pressure testing indicates relatively tight grout stages in sequence, the Contracting Officer may direct multiple grout stages to be combined into a single grout zone, provided grouting pressures do not exceed target thresholds for the overall length of the combined grout stages.]

d. Adjacent holes within the same series may be advanced concurrently, provided the holes are over 13 meters 40 feet apart.[For a given series, completely drill, wash, and flush the two nearest holes to the same stage before grouting to facilitate flushing of infilled discontinuities.]

e. Move to the next succeeding series following the same process as required in the project scope or per Split Spacing Criteria.

]3.2.5 Hole Series Sequence

****

NOTE: Engineering and geologic judgment is required to establish the designed spacing between grout holes, which partially depends upon the discontinuity spacing. For example, a foundation with fracture spacing of 30 centimeters 1 foot may need more closely spaced grout holes than a foundation with fracture spacing of 2 meters 6 feet.

There should also be thought given to the desired primary hole spacing. "Typical" primary spacing is 6 meters 20 feet. Permeable horizontal discontinuities usually provide the means for hole-to-hole hydraulic connections. In general, two adjacent primary holes should not be drilled and grouted concurrently. All grout should be set before drilling the adjacent hole. Consider adding a sequence requirement for adjacent holes in karst and very pervious foundations. This can be reduced (but not eliminated) by imposing a minimum space restriction for the prevailing series being advanced. As an extreme example would not allow primary holes to be completed within, 24-meter 80-feet until after the grout is set and cured to limit the potential for hole-to-hole hydraulic connections.

It is recommended that the orientation, spacing, and depth of primary grout holes be indicated in the plans. Depths for secondary and tertiary holes may be adjusted to shallower depths to target specific stages for treatment

****

3.2.5.1 Exploratory Holes

The spacing of the exploratory holes must correlate to the spacing of [_____] primary holes.

3.2.5.2 Primary Holes

Drill primary holes for foundation grouting to the bottom of the deepest [stage][zone]. The depths are governed by the foundation conditions.

3.2.5.3 Secondary Holes

After the primary holes are completed,[in one section,][for the grout line,] complete the secondary grout holes next.

3.2.5.4 Tertiary Holes

After the secondary grout holes are completed,[in a particular section,][for the grout line,] complete the tertiary grout holes next if required in the base scope, or if required due to split spacing criteria.[Complete all tertiary holes on each grout line.]

3.2.5.5 Succeeding Series

Utilize the following nomenclature for succeeding series: 'Quaternary' for fourth order holes, 'Quinary' for fifth-order holes, 'Senary' for sixth-order holes, 'Septenary' for seventh order holes, and 'Octonary' for eight-order holes.

3.3 DRILLING PROCEDURES

****

NOTE: Tailor the following sections based on the project scope. Clarify the hole depth, geometries, and tolerances. Include provisions for overburden, concrete, or exposed rock as anticipated to exist at your grouting location. Describe requirements for exploratory and verification holes, if needed. Verification holes should be included for most projects.

****

3.3.1 Grout Hole Depths, Inclinations,[and Tolerances] [and Oversight]

****

NOTE: Oversight is defined for Dams and Levees in ER 1110-1-1807, with the requirement included in the tailoring option here. For drilling in other than dams and levees, the designer may wish to add an oversight requirement, depending upon the construction risk of the job.

The angle of the boreholes from vertical (batter) should be specified to intercept both fractures and bedding planes (or cleavage and fractures for metamorphic rock). For flat-lying sedimentary rock with vertical fractures, angled holes are a necessity for quality. Battered holes cost more than vertical holes. Battered angles of 15-degrees and 20-degrees are common for rock grouting, shallower angles than that are more costly. For some unusual rock geometries, vertical holes may make sense. Where valley stress relief may be present, holes should be battered towards the abutments (not upstream-downstream).

****

Drill all holes for grouting, drainage or exploration at the locations, in the direction,[vertical,][degrees,]and to the depths indicated, or as directed by the Contracting Officer.[The maximum tolerance for deviation in angle and direction is [_____].] Drill and grout the first series of holes at [7][_____] meter [20][_____] foot intervals and referred to as primary holes. Determine the location of and addition of secondary, and succeeding series holes by the split spacing method, in accordance with paragraph REFUSAL, SPLIT-SPACING, AND CLOSURE. Increase the number of grout holes progressively by the split spacing method as deemed necessary by the Contracting Officer until closure criteria is achieved. Protect holes from becoming clogged or obstructed by means of a cap, or other suitable device on the collar. Any hole that becomes clogged or obstructed before completion of operations by a failure to prevent clogging must be cleaned out or replaced as directed by the Contracting

Officer. No additional payment will be made for cleaning or replacement of clogged holes.

All holes drilled in Dams or Levees must be drilled by a driller that has been approved in a "Drill Rig Operator Qualifications" submittal, logged by a logger that has been approved in a "Drill Inspector Qualifications" submittal, and have the drilling overseen continuously in the field by a Licensed Geologist or Licensed Geotechnical (Civil) Engineer that has been approved in the "Field Supervisor qualifications" submittal.

3.3.2 Grout Hole Overburden [Fill][Embankment] Drilling and Casing Installation

****

NOTE: When drilling into an earth dam or levee, adherence to ER 1110-1-1807 is required. This ER has very specific requirements for this special overburden drilling designed to prevent damage to embankments. If not drilling in an earth dam or levee, reference to this ER is not necessary.

****

Perform overburden drilling in[, fill][, embankment] using methods, equipment, and tooling approved by the Contracting Officer in the Drilling and Grouting Work Plan. Drilling methods must be in accordance with ER 1110-1-1807. Minimal water use requires the approval of the Contracting Officer. Drilling operations must not subject the overburden materials to circulating fluids whether water or air. Equipment must be capable of maintaining the correct orientation, and permit subsequent rock drilling to proceed within specified tolerances. Overburden drilling must maintain orientation tolerances through materials including, but not limited to, clay, silt, sand, gravel, cobbles, and boulders. Install PVC Casing through the overburden, and grout the annular space between the casing and the wall of the hole. Grout the casing [_____] meters feet into bedrock, or as directed by the Contracting Officer.[Verify the seal of the casing by taking water level readings[, falling head tests][, packer checks using instrumented packer][or other method], as submitted and approved in the Drilling and Grouting Work Plan.]

Utilize standard wall thickness pipe for all pipe and fittings used to construct grout holes. Clean the pipe and fittings thoroughly of all dirt, grease, oil, grout, and mortar immediately before embedment. Make all joints snug, and the ensure the assembly is held firmly in position, and protected from damage or displacement while the casing is being placed. Take all necessary precautions to prevent any pipe from becoming clogged, collapsed, or obstructed from any cause, or else replace pipe at no expense to the Government. The presence of tramp metal such as nails, wire, bolts, nuts, and other foreign material in the pipes through drilled holes are considered obstructions.[Paint the top 6-inches of the casings for primary holes red, secondary holes blue, tertiary holes white, and quaternary holes yellow.][Each casing must have a non-deteriorating tag attached showing the hole number.] Leave PVC casing in place after completion of grout curtain installation. Cut or remove the top of the PVC casing at a joint 1-foot below ground surface, and fill the void, as directed by the Contracting Officer.[Utilize sleeve port casing for all overburden drilling on the Contract.] Place a minimum of two pairs of ports in the lowest 3 meters 10 feet of casing, and the bottom of the casing must be capped to allow pressure to build in the sleeves.[In addition, one pair of sleeve port holes must be placed every [6][9] meters

[20][30] feet along the length of the casing to the surface.]

3.3.3 Overburden-Rock Interface Special Procedures

****

NOTE: The USACE ER 1110-1-1807 requires consideration to grout the rock socket separately from the casing annular space. For USACE Dams and Levees, this submittal is strongly encouraged; but may be situationally waived based on prevailing geologic conditions where low permeability rock exists at the soil bedrock contact. For such instances, it may be appropriate to delete the entire section that follows. Otherwise, tailor the brackets to the requirements of your site, including consideration for any planned exploratory drilling/grouting. In the first paragraph, use the first bracketed sentence where special procedures will be used for exploratory holes as a trial. Use the second bracketed sentence where special procedures will be prescribed across the entire jobsite. The second bracketed paragraph provides an example for how a prescribed paragraph may be written.

****

Include procedures to isolate the rock socket from the overlying material in this submittal. Acceptable methods include the use of geotextile barrier bags, inverted cones, or as submitted and demonstrated to be meet the requirements of the DIPP.[Utilize exploratory holes to determine what special procedures are required for treatment of the overburden-rock interface.][Grouting of the standpipe casing annulus space must be isolated from grouting of the [soil][rock] interface and the uppermost portions of bedrock.]

[

Use geotextile barrier bags in addition to the sleeve port pipe to protect the soil-bedrock contact. Use multiple port sleeve pipes (MPSPs) and equip with geotextile barrier bags, or other approved barrier systems to isolate the interface for treatment. Utilize a double packer to isolate the port with the barrier bag. Position the barrier bag to isolate the embankment from the bedrock. Once the MPSP casing is seated into rock the required distance, extract the inner drill steel, and locate a barrier bag no more than 1 foot above the top of rock. Inflate with grout at[equivalent gravity pressure][90 percent of the theoretical hydrofracture pressure][as demonstrated in the field to be] in compliance with the DIPP.

]

3.3.4 Exploratory Hole Drilling

****

Note: The designer must choose between rock coring and destructive drilling for exploratory holes. If strength testing is not needed, the exploratory holes can be drilled destructively and imaged and the "Downhole Imaging" tailoring option is chosen. If the "downhole imaging" tailoring option is excluded, or if strength testing is desired, then coring with recovery should be chosen.

The intent of this guide specification is to use existing cost line items for exploratory holes.

As an example, on a 300 meter-long 1000 foot-long dam, exploratory holes could be drilled on 30 meter-long 100 foot-long spacing ahead of production grouting, providing a preview of the foundation to the Contractor.

****

a. Perform such exploratory drilling as directed by the Contracting Offer to determine the condition of the rock prior to grouting. Perform all exploratory drilling with rotary drilling equipment. Drill all holes to full depth in a single setup unless conditions are so poor that drilling cannot continue. The loss of drilling water returns alone does not justify stopping drilling exploratory holes.[Use Rock Coring on exploratory holes.][Exploratory holes will be paid under existing cost line items.]

b. The exploratory holes may be required to be drilled to varying depths, with a maximum depth of [_____] meters feet. Do not drill exploratory holes at an angle greater than [_____] degrees measured from the vertical.

****

NOTE: Keep these 4 paragraphs (below) when coring is utilized, otherwise delete.

****

[c. Exercise special care, including the utilization of proper drilling equipment, tooling, rates of advancement, rotation speed of the drill, water discharge rates, rapid logging, and climate-controlled core storage to obtain cores in optimal condition.]

[

d. Exercise special care to obtain cores in as good condition as possible. In a manner satisfactory to the Contracting Officer, keep an accurate Drill Log of all exploratory holes drilled. The log must include a geotechnical description of all materials encountered in the drilling, their location in the holes, and the location of special features such as discontinuities, solution features, soft, broken, or weathered rock, depths of abnormal loss or gain of drill water, rod drops, tooling loss, intersected metals, and any other items of interest in connection with the purpose of the exploratory drilling.]

****

NOTE: The location where the core boxes will be delivered should be specified. It could be an on-site location, a nearby location, or a more distant location. If not on-site, the distance between the jobsite and the delivery location should be listed for biddability purposes.

****

[e. [Provide [wooden][corrugated plastic] core boxes][The Government will provide core boxes]. Place the cores in the boxes in the correct sequence, and separate accurately by wooden blocks, according to the measured distances in the hole. No box can contain cores from more than one hole. Fasten the covers securely to the core boxes and deliver to [_____] as directed.]

[
f. Photograph all exploratory rock cores with a solid background, both for each core run, and each core box. In addition, all exploratory core boxes will be handled, moved, and stored with care to preserve the integrity of the samples.]

g. Water pressure test exploratory holes as described in paragraph WATER PRESSURE TESTING PROCEDURES, using the [normal method][step method]..

****

NOTE: Exploratory holes should be pressure grouted, rather than gravity (tremie) backfilled. Follow the same procedures as any other grout hole.

****

h. Utilize pressure grouting as described in paragraph GROUTING PROCEDURES on all exploratory holes.

i. Survey all exploratory holes with a downhole camera for the entire length of the hole.

3.3.5 Grout Hole Rock[Concrete] Drilling

****

NOTE: If downhole surveys are planned or possible, then the hole diameter should be large enough to accommodate the survey equipment. Optical Televiewers are commonly at least 40 mm 1.6 inches. Some are 46 mm 1.8 inches, so ensure the hole is at least that large with room to travel down the hole.

****

a. Drill grout holes with standard rotary[or percussion] drilling equipment.[No drilling equipment using air will be permitted.] No core recovery is required. The type bit used is optional.[The hole must be of sufficient diameter to allow use of an expansion plug or packer with an effective inside diameter of not less than 13 mm 1/2 inch]. The minimum diameter of hole must be [46][_____] mm [1 7/8][_____] inches at the point of maximum penetration. Do not drill grout holes at an angle greater than [_____] degrees measured from the vertical. Do not drill grout holes to a depth greater than [_____] meters feet measured from the collar of the hole.

b. Perform drilling in accordance with the applicable grouting method described in this paragraph. Whenever as much as [_____] percent of the drill water is lost, or the cumulative total of successive water losses is estimated to amount to [_____] percent loss, or artesian flow is encountered, stop drilling operations and perform downstage grouting prior to resuming operations. This includes washing, pressure testing, then grouting of the [stage][hole]. Allow injected grout to reach the pre-determined final set time before re-drilling the grout, then attempt to drill to the bottom of the hole again. Upon completion of drilling of any hole and prior to water pressure testing, all drill cuttings and slurry must be removed by applying water to the bottom of the hole[through the end of drill rods] and returning the wash water through the hole to the surfaces until the return water is clear.

3.3.6 Verification Hole Drilling

****

NOTE: Verification holes are a necessary part of a grouting job and will vary by job.

The designer must choose between rock coring and destructive drilling for verification holes. If strength testing is not needed, and the "Downhole Imaging" tailoring option is chosen, then the holes can be drilled destructively and imaged. If the "downhole imaging" tailoring option is excluded, or if strength testing is desired, then coring should be chosen.

The author should consider defining special drilling conditions and add specific drilling requirements, (see special care in c. below) depending on quality of core recovery needed by the designer. E.g., drilling rates or core recovery lengths.

The intent of this guide specification is to use existing cost line items for verification holes.

****

a. Perform verification drilling as directed by the Contracting Officer. Perform all verification drilling with[rotary drilling equipment using coring type bits][any method of drilling used for grouting holes, including destructive drilling].[Since the maximum recovery of unpredictable, soft, or friable materials is of prime importance, make every effort to recover 100 percent of the core using appropriate equipment and drilling procedures.] Verification holes will be paid under existing cost line items.

b. Drill verification holes to varying depths as directed by the Contracting Officer, with a maximum depth of [_____] meters feet. Do not drill verification holes at an angle greater than [_____] degrees measured from the vertical.

****

NOTE: Keep these 4 paragraphs (below) when coring is utilized, otherwise delete.

****

[c. Exercise special care, including the utilization of proper drilling equipment, tooling, rates of advancement, rotation speed of the drill, water discharge rates, rapid logging, and climate-controlled core storage to obtain cores in as good condition as possible.]

[

d. Keep accurate Drill Logs of all verification holes drilled. The log must include a geotechnical description of all materials and formations encountered in the drilling, material contact elevation in the holes, and the elevation of special features such as discontinuities, solution features, soft, broken, or weathered rock, depths of abnormal loss or gain of drill water, rod drops, and any other items of interest in connection with the purpose of the verification drilling.[Log the hole in decimal feet to tenth foot precision.][Log the hole in meters to [centimeter][decimeter] precision.]]

****
NOTE: NOTE: Specify the location where core boxes will be delivered. It could be an on-site location, a nearby location, or a regional office. The distance from the jobsite to the location may need to be included for biddability purposes.
****

[e. [Provide [Wooden][Corrugated Plastic] core boxes.][The Government will provide core boxes]. Place the cores in the boxes in the correct sequence and separated accurately by wooden blocks, according to the measured distances in the hole. No box can contain cores from more than one hole. Fasten the covers securely to the core boxes and deliver to [_____] as directed.]

[

f. Photograph all verification rock cores with a solid background, including each core run, and each core box. Handle, move, and store all verification core boxes with care to preserve the integrity of the samples.]

g. Water pressure test all verification holes in accordance with paragraph WATER PRESSURE TESTING PROCEDURES.

h. Grout verification holes under pressure by stage grouting per the requirements of the production holes nearby. Backfill holes in accordance with paragraph BACKFILLING OF OVERBURDEN CASINGS.

i. Survey all verification holes with a downhole camera for the entire length of the hole.

3.3.7 Drill Logging Procedures

****
NOTE: The drill logging procedures here utilize USACE references. Substitute agency-specific forms and guidance for non-USACE work.
****

Drill logs must use the USACE Form 1836 and 1836 Continuation Form. Complete drill logging in accordance with EM 1110-1-1804. The Government may choose to log holes in parallel, however, complete drill logging as specified is still required. Logging may be performed on paper logs or, if approved in writing by the Contracting Officer in advance, using a digital device such as a tablet. If any data associated with a hole is lost through no fault of the Government, the log must be reproduced from core, or the entire zone where data is missing must be redrilled and logged, at no cost to the Government.

3.3.7.1 Paper Logging

If using a paper form, then the logger must keep no separate log. The log must contain all relevant information collected, including any verbal comments made by the driller. The paper log must be legible, and available for a quality assurance check by any Government representative at any time. Photograph or scan paper logs at the end of each day, and back up electronically[in accordance with Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION].

3.3.7.2 Digital Logging

If using a digital logging device such as a tablet[, the program utilized must be approved in advance by the Contracting Officer, and] it must produce a[USACE Form 1836] formatted drill log. Back up the logging data via cloud synchornization at the conclusion of every run while drilling. In remote sites without Internet connectivity, use device and external storage in tandem as redundant backups to protect against data losses. Print any drill log or partial drill log within 1 hour of any Contracting Officer request.

[3.3.7.3 OpenGround Cloud

****
NOTE: OpenGround Cloud is the authoritative data source location for all USACE boring data. This section should be used by all USACE projects where recovered core is logged. Other agencies can delete this section. If used, verify that this language is up to date with the HQUSACE OpennGround Cloud point of contact.
****

Provide all drilling data in OpenGround Cloud configured for the [_____] project. The Government will provide necessary permissions to enter data. Provide a list of users with name and emails for the Government to grant access. OpenGround Cloud (OGC) named user or concurrent licensing are required for use. For data entry into OGC, utilize fields with dropdown lists where applicable. Only use additional descriptions for text entry of data when a dropdown list for that feature does not exist. Verify there is no applicable field for a feature before using the [Comments][Remarks] fields in any table to enter material classification.

The field geologist who logged the core must perform the data entry of the log into OGC. A separate geologist must perform a 100 percent QC check of the data entered into OGC. Enter logs into OGC within 48 hours of hole completion, or as directed by the Contracting Officer. Complete QC of the log entry to OGC within 72 hours of hole completion.

]3.4 GROUT HOLE WASHING PROCEDURES

****
NOTE: Pressure washing of boreholes has created controversy for a long period of time. It has previously been included as a) both incidental to drilling and b) a separate cost item.

The two (2) ways to wash holes are 1) cleaning hole with extra water pumped through the drill rods, and 2) using a separate tool as a separate step. An effective separate washing tool produces jets of water in a 360-degree spiral pattern at moderate pressure and is raised or lowered (or both) through the hole at a moderate speed.

While pumping water through the drill rods (i.e., "flushing the hole") can be made incidental to drilling, separate hole washing should be a separate line item or incidental to water pressure testing.

Select the appropriate brackets based on your scope of work and anticipated geologic conditions. Hole washing using the drill tooling and separate equipment may also be selected.

****

Wash the hole thoroughly with clean water under pressure after completion of drilling[and][before the injection of grout] for any hole drilled. [Also][Wash the hole with separate hole washing equipment [fitted with brushes] immediately before grout injection.] Perform all hole washing[for [10][15] minutes][until the return water runs clear]. The maximum pressure at which air and water are introduced for hole washing must be less than the pressures required to complete[water pressure testing][grouting operations].[Document the hole washing with a washing log. See the paragraph HOLE WASHING LOG for details.]

3.5 WATER PRESSURE TESTING PROCEDURES

****

NOTE: Water Pressure Testing of all grout hole stages is not required, but it does build a database of knowledge about the foundation that can be displayed in cross-section format and easily understood by personnel not in the field. The designer should determine how many stages should be water pressure tested and adjust bid item quantities appropriately.

Water pressure testing of all primary holes provides a good "pre-grouting" estimation of the foundation permeability. In general, a basic scope should require all exploratory and verification holes for every stage to be water pressure tested.

If eliminating water pressure testing, intermediate holes (usually secondary holes) should be the first eliminated.

Pressure grouting of all planned final series holes (e.g., tertiary holes) provides an as-built foundation permeability. These should be the last series to be eliminated because of their importance in providing the as-built record.

For Dam foundations, pressure testing must be performed on all exploratory holes, primary holes, all planned final series holes, all split-spaced holes, and all verification holes.

There may be occasions to increase the duration of a water pressure test if there is communication between two boreholes and dirty water is coming out the second borehole. Measurement of water pressure testing by time allows the Contracting Officer to extend the duration of the water pressure test by a reasonable amount.

****

Prior to the pressure grouting operation, perform water pressure testing on selected holes. The Contracting Officer assigns stages, zones, grout holes, or a series of grout holes for water pressure testing. Do not exceed the maximum grouting pressure, as directed. Test directed grout holes with clean water under continuous pressure up to the maximum grouting pressure as directed by the Contracting Officer. Water pressure testing intervals must not exceed [3][9] meters [10][30] feet in length, unless directed by the Contracting Officer.[Set packers in rock not in the PVC casing.] The stage may be adjusted up to 1 meter 3 feet based on the drilling records to facilitate packer setting. The Contracting Officer may adjust stages and zone interval assignments within a grout hole as needed.

Provide plots in electronic and paper format along with the tabular water pressure testing data. In addition, record the summary data from the water pressure test in the "Database of Water Pressure Testing and Pressure Grouting Results". If the result of the water pressure testing suggests that hydro-fracture occurred, notify the Contracting Officer immediately.

3.5.1 Normal Water Pressure Testing Method

****

NOTE: The normal water pressure test method is used for normal/production grout holes. The method reaches (or attempts to reach) a specific target pressure, at which it measures the steady-state flow rate of the hole, allowing calculations for a lugeon value, which is a permeability measurement.

If pressure testing is paid by each (not recommended and not present in this guide spec), then the sentence starting with "Continuation of water pressure testing" needs to be deleted.

****

Test grout holes until the stage has reached target effective pressure and the rate of take and permeability has stabilized for at least two minutes. If the rate of take and the permeability do not stabilize, pressure test the hole for five minutes. Continuation of water pressure testing, for longer periods of time, may be requested by the Contracting Officer at any time. Measure all pressures by a pressure transducer and gauge. Readout at the top of the hole and at the Automated Grouting Data Collection System. For each packer setting, the target effective pressure must be 12 kPa per meter 0.5 psi per foot of depth of overburden, and 24 kPa per meter 1.0 psi to per foot of [rock][concrete]. Exceedance of this target pressure by up to 10 percent of the effective pressure is permitted. If the effective pressure is exceeded by more than 10 percent, take all necessary measures, up to deflating the packer, to keep the pressure from increasing. If it appears that hydrofracturing may have occurred, notify the Contracting Officer immediately. Compute the lugeon values for each test, and submit this data with the water pressure testing data in paper and electronic[Microsoft Excel] format. After completion of water pressure testing, cap and seal the holes temporarily to prevent material or debris from entering the holes prior to grouting. Utilize the Automated Grouting Data Collection System to collect and record data, and calculate and display the: 1) gauge pressure, 2) effective pressure, 3) flow, and 4) the Lugeon value in real-time during testing.

[3.5.2 Varied (Step) Water Pressure Test Method

****

NOTE: The varied/step water pressure test is utilized to determine the permeability characteristics of the stage under differing pressures. It is commonly referenced in grouting textbooks. It should not be utilized for each stage on a job, but is appropriate for exploratory and verification holes. On small jobs, it could be deleted.

****

For every[fourth,][third,] primary hole[designated exploratory or verification hole,] or as directed by the Contracting Officer, perform water pressure testing in two 3-meter 10-foot intervals using "The Varied Pressure Test Method", in the following order:

a. Apply water at a low pressure for a maximum of 5 minutes, or until there is no change in lugeon value over a 2-minute period. This is followed immediately by b.

b. A moderate pressure for the next 5 minutes (maximum) or until there is no change in lugeon value over a 2-minute period.

c. A peak pressure for the next 5 minutes (maximum) or until there is no change in lugeon value over a 2-minute period.

d. A moderate pressure again for the next 5 minutes (maximum) or until there is no change in lugeon value over a 2-minute period, then-

e. Low pressure for the final 5 minutes (maximum) or until there is no change in lugeon value over a 2-minute period.

Compute the varied pressure as follows: For each packer setting, the low effective pressure must be 12 kPa per meter 0.5 psi per foot of depth of overburden and 12 kPa per meter 0.5 psi per foot of [rock][concrete]. The moderate effective pressure must be 12 kPa per meter 0.5 psi per foot of depth of overburden and 18 kPa per meter 0.75 psi per foot of [rock][concrete]. The PEAK effective pressures must be 12 kPa per meter 0.5 psi per foot of depth of overburden and 24 kPa per meter 1.0 psi per foot of rock. This pressure may be exceeded by 10 percent of the effective pressure. However, if the applied pressure exceeds the effective pressure plus 10 percent, take all measures, including deflating the packer, to stop the pressure from increasing further. Compute the lugeon values for each varied test and determine their interpretation of whether the collective values indicate erosion, dilation, hydro-fracture, void-filling, no flow, laminar flow, or turbulent flow. Submit this data and interpretation with the water pressure testing data in paper and electronic [Microsoft Excel] format. The reported Lugeon value for a varied test for as-built drawings must be the highest Lugeon value measured after achieving at least low pressure. Exercise care during the testing to assure that joint dilation, and hydrofracturing of the rock is not occurring (especially at the highest pressures). Plot pressure versus Lugeon value data to assess the rock response during testing.

]3.6 GROUTING PROCEDURES

3.6.1 Protection to Work and Cleanup

Except as otherwise specified, no grouting is permitted within [_____] meters feet of installed perforated pipe or gravel filters for foundation drains. Monitor water flow through drains for early indications of communication. In case leakage of grout into drains does occur, immediately stop the grouting operations, and remove all grout from the drains affected by washing to the satisfaction of the Contracting Officer. During grouting operations, take all necessary precautions to prevent drill cuttings, equipment exhaust oil, equipment hydraulic oil, wash water, and grout, from defacing or damaging the permanent structure. Perform daily maintenance along grout lines to facilitate inspection of interconnected holes and breakouts. Provide any pumps and ponding equipment necessary to care for wastewater and grout from these operations, and to be in compliance with all applicable environmental regulations. Upon completion of these operations, clean up all resulting waste that is unsightly, creates a safety hazard, impedes transportation, or would interfere with the efficient operation of the project as designed.

During grouting operations, keep the work area clean, and continually clean any areas where grout is placed on permanent project features. Repair any damage to project features from drilling and grouting operations. No additional payment will be made for cleanup or repair.

3.6.2 Grout Mix Requirements

****

NOTE: This specification requires that all grout be batched and injected between 10 to 32 degrees C 50 to 90 degrees F. Storage of the grouting materials should be at temperatures above freezing.

Temperature controls for grouting surface rock should be specified based on specific site conditions anticipated. Insulation, heated enclosures, water heaters, or other equipment or procedures may be required.

Trial batches for USACE projects must be completed by a USACE validated laboratory.

If grouting is anticipated during extreme temperatures, this will require Contractor attention and special precautions. However, methods must be left open for innovation while meeting performance criteria. This may include allowing a higher maximum temperature for the grout mix, up to 38 degrees Celsius 100 degrees Fahrenheit.

In arid environments, moisture loss must also be considered.

****

3.6.2.1 Grout Mix Design and Trial Batches

Provide the grout mix designs for the grout mixes on Tables 2 and 3 below, and laboratory test results, and physical samples of the trial batches for

each grout mix.

At least 30 days prior to production grouting, submit a minimum of [3][4][5][6][7] proposed grout mixes. Perform mix variation and characterization testing for approval in advance of production grouting. For different types of mixers, slightly different formulations are required to obtain the desired theological characteristics. Consequently, adjustments to the base formulations are anticipated following the series of mix variation and characterization testing. During the performance of these mix tests, develop and submit the following test data for each proposed balanced-stabilized grout mix, and for each of the subsequent mix variations developed:

Table 2: Foundation Grout Mix Consistent Requirements

Table 3: Foundation Grout Mix Variable Requirements

Mix Name	Grout Mix Viscosity Value	Method: Marsh or Flow Cone	Standard Reference
A	[<40 Seconds] Marsh	Marsh Funnel	ASTM D6910/D6910M
B	[40-55 Seconds] Marsh	Marsh Funnel	ASTM D6910/D6910M
C	[55-70 Seconds] Marsh	Marsh Funnel	ASTM D6910/D6910M

Table 3: Foundation Grout Mix Variable Requirements			
Mix Name	Grout Mix Viscosity Value	Method: Marsh or Flow Cone	Standard Reference
D	[Slower than Mix C, (> 70 seconds) with Marsh, and faster than mix E with Flow cone.]	[Marsh Funnel] [Flow Cone]	ASTM D6910/D6910M ASTM C939/C939M
E	[Slower than Mix D measured by flow cone. 20-35 seconds]	Flow Cone	ASTM C939/C939M
F (sand mix)	[35-50 Seconds] Flow Cone	Flow Cone	ASTM C939/C939M
G (Sand Mix with Anti-Washout Admixture)	[35-50 Seconds] Flow Cone	Flow Cone	ASTM C939/C939M

3.6.2.2 Field Testing Procedures and Standards for Mixed Grout

a. Grout temperature must be between 10 and 32 degrees Celsius 50 and 90 degrees Fahrenheit at all times from the end of mixing to injection (measured at the header) in accordance with ASTM C1064/C1064M.

b. Measure specific gravity using a mud balance. Perform specific gravity tests in accordance with the ASTM D4380.

c. Measure viscosity using a Marsh Funnel or Flow Cone. Perform Marsh Funnel testing in accordance with ASTM D6910/D6910M. Conduct Flow Cone testing in accordance with ASTM C939/C939M. Viscosity requirements are shown in Table 3.

d. Perform Bleed tests in accordance with ASTM C940. Grout bleed must not exceed [2][1][3] percent.

e. Conduct pressure filtration testing in accordance with API Method API RP 13B-1, low-pressure/low-temperature, and then calculate the pressure filtration coefficient (Kpf). The API standard addresses the test method, then the calculation method for pressure filtration coefficient (Kpf) is defined in EM 1110-2-3506. The pressure filtration coefficient (Kpf) must not exceed [0.05][0.10].

****

NOTE: USACE Engineering Manual EM 1110-2-3506 entitled "Grouting Technology", on section 7.7.i, on page 7-26 states: "A suite of mix designs for grouting fractured rock might have initial set times of 10–16 hrs and final set times of 12–20 hrs. The

set time can be varied, depending on the purpose of the grouting program, by using admixtures such as retarders or accelerators." Also see the book "Dam Foundation Grouting" by Bruce and Weaver (2007), section 5.2.8, pages 162-163 for more details.

****

f. Final set must not exceed [14][16][18][_____] hours for the thickest mix, and [24][_____] hours for the thinnest mix. Determine set time in accordance with ASTM C191, Method A. Measure initial set for information only, in accordance with ASTM C191, Method A.

g. Perform Unconfined Compressive Strength sample collection and curing in accordance with ASTM C31/C31M.

3.6.2.3 Laboratory Testing Procedures and Standards for Mixed Grout

****

NOTE: USACE jobs require that all laboratory testing be done at a USACE-validated lab. Delete this requirement for non-USACE jobs.

****

Grout strength samples are collected in the field, and are tested in the laboratory. Select either grout cubes or grout cylinders for unconfined compressive strength testing, and do not change the type of sample (cube or cylinder) without the prior written approval of the Contracting Officer. Submit QC verified test data to the Contracting Officer within 96 hours of test completion. Submit the results of all laboratory testing of mixed grout as part of the Weekly Grout Test Results submittal. Adhere to the following requirements as applicable:

a. For grout cubes, perform unconfined compressive strength testing in accordance with ASTM C109/C109M.

b. For grout cylinders, perform unconfined compressive strength testing in accordance with: 1) ASTM D4832 for grout cylinders less than ~8400 kPa1200 psi, or 2) ASTM C39/C39M for grout cylinders greater than ~ 8400 kPa1200 psi.

c. Perform unconfined compressive strength testing for test batches on full-size concrete cylinders (containing grout) in accordance with ASTM C39/C39M.

d. All labs must be in accordance with ASTM C1077.[All laboratory testing must be performed by a USACE validated laboratory in accordance with ER 1110-1-8100 for each test.]

3.6.2.4 Consequences for Failing Grout Tests

Grout failing the viscosity, specific gravity, or temperature quality control criteria must be wasted. When mixes fail bleed, pressure filtration, initial set time, final set time, or unconfined compressive strength tests, notify the Contracting Officer immediately. When any grout fails these tests, resume 100-percent testing until that property has passed [6][_____] tests in a row. If QC test failures continue for more than [3][7][14] days, submit a written plan to bring grout quality and material properties back into specification compliance. Grout mixes that fail any quality control test are subject to wasting and replacement

at no additional cost to the Government.

3.6.3 Grout Testing Frequency

3.6.3.1 Trial Mix Testing Frequency Requirements

Trial Mixes are batched for the grout mix design submittals prior to the field portion of the work. Trial mixes have greater testing requirements than production grout. Trial mixes are not billed by quantity or time.

Perform the following field tests at the intervals specified:

a. Temperature (Trial Batches). Test all trial batches for temperature 5 minutes after mixing and 30 minutes after mixing.

b. Viscosity (Trial Batches). Test all trial batches for viscosity using a marsh funnel or flow cone within 10 minutes of mixing for each batch.

c. Specific Gravity (Trial Batches). Test all trial batches for specific gravity using a mud balance.

d. Bleed (Trial Batches). Perform grout bleed weekly for each mix type used that week.

e. Pressure Filtration (Trial Batches). Perform pressure filtration for each mix type used that week.

f. Setting time (Trial Batches). Perform setting time testing on each mix, obtaining both initial set and final set.

g. Grout strength sample collection (Trial Batches). Prepare a minimum of 12 grout cubes or 12 grout cylinders for each mix type. Also prepare a minimum of two standard concrete cylinders for each mix type.

Perform the following laboratory tests at the intervals specified:

h. Test grout strength samples, Cylinders or Cubes (Trial Batches). Perform unconfined compressive (UC) strength testing for all trial batches at time intervals of 3, 7, 14, and 28 days. Break three samples for each time interval tested. Break the two standard concrete cylinders for UC Strength at 28 days.

3.6.3.2 Production Grout Frequency Testing Requirements

****

NOTE: The following text can be used on larger or high-risk jobs. Ensure any conflicting language is deleted. The designer must consider what statistical method (e.g, regression, ANOVA, T-test, or other methods) would be best for the job and specify the statistical method.

****

[

Perform 100 percent quality control testing of the grout mixes for temperature, viscosity, specific gravity, bleed, pressure filtration, initial set, final set, and 28-day unconfined compressive strength, on every shift for at least [75][_____] of each test being performed. Afterward, perform 3 tests on each mix per shift if the analysis shows the process to be in statistical control. If the process is not in control or

has greater than or equal to 10 percent failure, then resume 100 percent testing until it can be proven the batching process is under statistical control. If a process that was formerly under good control becomes out of control, or has greater than or equal to 10 percent failure rate for any test, resume 100 percent testing until the process is again under statistical control.[Utilize the [_____] statistical method to establish statistical control of batch quality and consistency][Submit the statistical method to be used to establish statistical control in the Grout Mix Design and Trial Batches submittal].

]

****

NOTE: In choosing between frequency of testing for the language below, it will depend upon the amount of grout planned to be mixed, and the job risk level. More frequent grout testing is warranted in higher production environments. For example, testing twice per shift is justified when thousands of gallons of grout are produced daily, but not if only a few batches are produced daily.

****

Production Grout is the grout that is mixed onsite for project use. Production grout is billed by quantity. Perform the following tests at the intervals specified:

a. Temperature (production grout). Test grout for temperature at least [once][twice][four times][hourly] per shift, and in tandem with all other field testing. Test each mix type utilized on that shift the first time that mix type is batched.

b. Viscosity (production grout). Test [once][twice] per shift on each mix type utilized that shift.

c. Specific Gravity (production grout). Test [once][twice] per shift on each mix type utilized that shift.

d. Bleed (production grout). Perform grout bleed once per week on each mix type utilized that week.

e. Pressure Filtration (production grout). Perform pressure filtration once per week on each mix type utilized that week.

f. Setting time (production grout). Perform setting time testing, obtaining both initial set and final set,[once per month] on each mix type utilized that month.

g. Grout strength sample collection (production). Collect cubes or cylinders [once][twice] [per week], with every mix type utilized collected at least once a month. A minimum of [4][8][12] cylinders or cubes must be prepared each time. For each testing interval, prepare at least [2][3] samples.

****

NOTE: Testing at 28 days is necessary, other intervals are optional. While it is traditional to test grout samples for strength at 3, 7, and 14 days, those tests are typically 'for information only', and may not always be necessary. Only 28 day samples are typically used for acceptance at final

strength. However, on some projects it could make sense to test at 3 days to ensure proper initial set.

Typically, 2 samples are prepared for each time interval, but 3 samples could be utilized if lesser amounts of testing will be performed.

****

h. Break production grout samples at 28 days.[In addition, samples must be tested at [3][7][14] days[for information only].] The average strength of [two][three] breaks at 28 days will be used for acceptance.

3.6.4 Mixing Procedures for Grouts

****

NOTE: If mixes with sand are being specified, then the bracketed language should be included. If sand mixes are being excluded, then delete the bracketed text.

****

Follow these procedures explicitly, unless otherwise directed by the Contracting Officer. Mix grout in a colloidal mixer[, with the exception of sand mixes]. Mix grout for at least [_____] seconds in the colloidal mixer. Once grout has been mixed, transfer it to a distribution tank to be sent to the header, and then the grout hole. Utilize paddles to continuously agitate the distribution tank.

[

When mixes with sand are utilized, mix all components, except for the sand, in a colloidal mixer. Introduce the sand into a separate paddle mixer with the pre-mixed grout, and then mix for at least [4][_____] minutes before transferring to the header.]

3.6.5 Initial Calibration for AGDCS

****

NOTE: This is one submittal that will need to be reviewed and returned very quickly. Ensure during the preconstruction meeting that the Contractor is aware that this submittal needs to be submitted early. The Government should expedite review.

Consider paying for the installation of a single calibration hole away from sensitive foundations that can be used to calibrate the AGDCS where excessive pressures will not damage the foundation if they occur. Verify in the demonstration section.

****

Prior to production grouting, conduct a test of the automated monitoring and data collection system. The test must be conducted by the operator[s] using the equipment during production grouting to verify the devices and system are functioning properly and that the system is accurately receiving and recording the data. Provide Initial Calibration Reports for AGDCS, and all related equipment, at least 15 calendar days prior to the start of grouting. Provide system calibration reports for the AGDCS and all related equipment at least two business days prior to the start of water pressure testing and or grouting.[For this single submittal, the Government will review within two business days.]

For calibration of the pressure gauge, utilize a NIST "Test" pressure gauge for calibration of the pressure meter in line with the production pressure transducer meter, adjacent to each other. For calibration of the flow meter, utilize a flowmeter purchased new for this Contract and not used for production grouting, and compare values side-by-side with the production flow meter. In addition, use a container of known quantity (greater than 10 liters 5 gallons) to calibrate the flow.

3.6.6 Weekly Calibration for AGDCS

Check and recalibrate the AGDCS at least weekly and as necessary, at no additional cost to the Government. Perform calibrations in conjunction with the Contractor's Quality Control Plan, and at any time during the work as directed by the Contracting Officer. Perform all calibration activities on-site. Calibrate in accordance with section "Initial Calibration for AGDCS".

Check and recalibrate the system at the frequency defined below:

Weekly:
Calibrate the AGDCS at all the following times:

a. After the AGDCS is set up on-site, but before use in a grout hole.
b. Weekly.
c. Whenever the AGDCS output appears unreliable, as determined by the Contracting Officer or the AGDCS operator or Lead Grouting Geologist or Lead Grouting Geotechnical Engineer.
d. When requested by the Contracting Officer.

3.6.7 Grouting Pressures

****

NOTE: Refer to USACE EM 1110-2-3506, "Grouting Technology" for discussions of grouting pressures and selection of allowable pressures under different conditions. When grouting in embankment dams and levees for USACE, DO NOT EXCEED the rule of thumb for grouting pressures indicated in the Grouting EM without advanced lab testing and field demonstrations to verify performance. Consult with the Dam Safety Modification Mandatory Center of Expertise (DSMMCX) and Risk Management Center (RMC) before finalizing design.

****

Grouting pressures employed will vary with hole conditions encountered. Use pressures as directed by the Contracting Officer. It is anticipated that pressures at depth will range from [_____] to [_____] kPa psi. Pressures must not exceed [_____] kPa psi under any circumstances.

3.6.7.1 Holding Pressure

When grouting is complete, shut the valve off above the gauge, and record the rate at which the gauge goes back to zero or stops at a lesser pressure than the grouting pressure. Do not exceed five minutes of holding pressure. Holding may stop when pressure reaches zero, regardless of time.

3.6.8 Grout Injection

Follow these procedures explicitly, unless otherwise directed by the Contracting Officer. Mix grout in a colloidal mixer, with the exception of sand mixes. Mix grout for at least [30][_____] seconds in the colloidal mixer.

a. If pressure tests indicate low Lugeon results, consider executing grouting with the thinnest approved mix. If an open hole condition exists, as determined by loss of drill water or water pressure testing results, start grouting with a thicker mix, as directed by the Contracting Officer.

b. At any time pressure is utilized during the grouting operation, continuously utilize the Automated Grouting Data Collection System to record the operation. Direct the grouting program based on pressure and flow data acquired, recorded, and analyzed from the Automated Grouting Data Collection System. Perform all pressure grouting operations in the presence of the Government, and in accordance with the following. Inject the grout at the directed pressure and mix sequence, and monitor changes in the apparent grout Lugeon value until refusal has been achieved, or until the Contracting Officer directs otherwise. Provide all pressure grouting records to the Government. Do not increase the pressure or rate of pumping suddenly for any reason.

****

NOTE: The refusal criteria can be set at a flow rate (as shown here) or a lugeon value.

****

c. Meet the requirements of paragraph REFUSAL, SPLIT SPACING, AND CLOSURE.

d. Follow the criteria for grout mix thickening:

(1) Start with the thinnest (least viscous) mix on all holes, except as specified in "a" above.

(2) If the gauge pressure is less than 10 percent of target pressure, switch to the next thicker mix after 750 liters 200 gallons.

(3) If the gauge pressure is between 10 percent and 50 percent of target pressure, switch to the next thickest mix after 1500 liters 400 gallons.

(4) If the gauge pressure is between 50 percent and 100 percent of target pressure, switch to the next thicker mix after 2200 liters 600 gallons.

(5) If gauge pressure is at 100 percent of target pressure and flow rate is steadily decreasing, switch to the next thicker mix after 3800 liters 1,000 gallons of each mix. Do not place more than 3800 liters 1,000 gallons of any single mix in a single stage.

(6) Stop and rest stages after [_____] liters [_____] gallons of grout have been pumped into a 3 meter 10 foot stage. Prior to preparing the hole for additional grouting, allow a period of set time equal to the measured final set of the thinnest grout mix

utilized.

e. Tremie the hole with the calculated theoretical volume of each stage using a single packer. During tremie operations, the bottom of the packer discharge must be within 0.67 meters 2 feet of the bottom of the stage, and the packer must be deflated. After the tremie operation is complete, raise the packer to the top of the stage, and then inflate the packer. To ensure accuracy of grout volume records, tremie volumes must be within 15 percent of theoretical stage volume, or the entire stage must be washed clean of grout, and re-tremied before grouting is resumed. The tremie grouting operation is billable, up to 3 minutes, and the raising and inflating of the packer is billable, up to 3 minutes. Once the packer is inflated, begin the pressure grouting operation. Continue until refusal is reached or until grouting of that stage ceases. Increase the flow rate slowly once the packer is fully inflated to avoid hydrofracturing. Continuously record the entire operation with the AGDCS, including the following: tremieing, raising the packer, inflating the packer, and pressure grouting.

f. Suspend grouting of holes that fail to reach the target pressure after the predefined volume of grout has been pumped. [Wash,]Allow the stage to set, and redrill and grout until stage refusal is met.

g. After the grouting of any stage of a hole is finished, maintain the pressure using a stop-cock, or other suitable device, until the grout has set to the extent that it is retained in the hole.

h. Waste any grout that cannot be placed, for any reason, within two hours after mixing. This time may be further reduced based on the characteristics of additives, recommendations of additive manufacturers, or behavior of grout mixes. If such grout is mixed at the direction or with the approval of the Contracting Officer, the wasted grout, except as specified in Section 01 20 00 PRICE AND PAYMENT PROCEDURES, will be paid for at the Contract unit prices for the materials used.

3.6.9 Backfilling of Overburden Casings

Backfill PVC Casings with grout proportioned as directed by the Contracting Officer and with a water/cement ratio less than 1.0. Do not commence backfilling until the [rock][concrete] portion of the hole has been pressure grouted and allowed an amount of time equal to the pre-determined final set hours. Perform backfilling by injection of grout through a tremie pipe or hose inserted to the bottom of the casing. When grout vents at the surface, gradually withdraw the tremie, maintaining grout in pipe or hose until completely removed. No separate payment will be made for time involved in backfilling casings; however, grout is paid for at the Contract unit price for the materials used.

3.7 REFUSAL, SPLIT-SPACING, AND CLOSURE

3.7.1 Refusal

The initial refusal criteria for this work is [_____] liters gallons per minute held for [5][10] minutes at the maximum pressure specified (target pressure) for the stage being grouted.[Refusal for gravity grout stages, is defined as maintaining the level of grout (or equivalent grout pressure) at the surface elevation for one hour.] The Contracting Officer

has the right to modify the refusal criteria based on the conditions encountered as the work progresses. The refusal criteria may vary depending on the stage, zone, series, or section that is under consideration. Refusal for each grout stage must be met for the hole to reach refusal. Redrill and regrout[and split space] any stage[hole] that fails to meet refusal.

3.7.2 Split-Spacing Procedures

Complete all succeeding series holes defined in the base project scope. Split-space any final series hole that fails to meet refusal or closure. Drill split-spaced holes to the[full depth][depth of the lowest failed stage] for the previous series.

3.7.3 Closure Criteria

****

NOTE: When water pressure testing is included in the scope of work, closure criteria should be set in Lugeons. If closure is being evaluated based on the results of grouting, closure is determined by apparent lugeons. Water pressure testing is recommended as the preferred method for closure determination.

The height of a dam/structure, perviousness of the foundation, and hydraulic loading considerations are key variables required for selection of the appropriate Lugeon value for closure. The following sections provide best practices in selecting the target permeability value.

Grouting effectiveness is limited for foundations with a permeability less than 1 Lugeon. Weaver and Bruce (2007) state that attempting to grout below one (1) Lugeon is not feasible or practical. One (1) Lugeon is considered nearly impervious.

A value of three (3) Lugeons is recommended by Houlsby (1977) as the minimum foundation permeability to consider grouting. Achieving three (3) Lugeons is considered "tight" (acceptably impervious), and is warranted for consideration at a high hazard dam. Grouting to this level of closure may not be cost effective depending on the application.

A value of five (5) Lugeons is recommended for general applications including lock and dam foundation grouting.

A value of ten (10) Lugeons is considered sufficient for slurry control grouting in advance of a seepage cutoff, including cutoff walls. Such grouting operations are not considered to be final and lasting treatment.

****

All stages must meet the following closure criteria:

a. All holes in the section must reach refusal and satisfy split-spacing criteria.

b. [5][10][_____] Lugeons as calculated by water pressure testing for [production][and] verification holes.

[

c. [5][10][_____] apparent Lugeons as calculated during grouting for production [and][or] verification holes.]

The Contracting Officer reserves the right to change closure criteria. Final closure is determined by the Contracting Officer.

3.8 DOWNHOLE SURVEY METHODS

Perform [optical][acoustic] televiewer surveys[to map the location, aperture and orientation of intersecting fractures, foliations, and lithologic contacts][; grouting verification][;[and]] when directed by the Contracting Officer. If final images or video are of insufficient quality, resulting in inability to identify or measure the features mentioned below based on the preliminary OATV image submittals, the televiewer survey must be conducted again at no expense to the Government.

[

Alternative methods that meet the established requirements and can be printed for archival purposes may be submitted for approval. This includes downhole telemetry that meets the OPTV equipment, method, and product requirements.]

[3.8.1 Optical Televiewer Survey Methods

Perform downhole camera surveys in accordance with ASTM D5753, except as a borehole photo not video, and the following requirements:

a. At the conclusion of drilling, wash the borehole clean and let sit for [12 hours][_____] prior to conducting survey. Allow all fines in the borehole to stabilize through settlement for a period of [24 hours][36 hours][48 hours] [[and][or] the addition of flocculant] to dissipate suspended solids, to the satisfaction of the Contracting Officer. Conduct Optical Televiewer surveys[within all borings as directed by the Contracting Officer].[If utilizing acoustic televiewer, always run the optical and acoustical televiewers in tandem unless otherwise directed by the Contracting Officer. Footage from both survey methods is required.]

b. [Obtain imagery for geologic borings with high flow or which penetrate soft and unstable materials in non-rock intervals.]If the hole falls in, log it to the point of collapse. To view the blockage, perform a traditional borehole camera video; if it does not fall in, log it to the full depth.

c. Capture images at resolution to clearly view and measure the orientation of discontinuities including fractures, bedding planes, voids, changes in lithologies, grout-filled features, and other geologic features[two millimeters] and larger. If final images or videos are of insufficient quality resulting in inability to identify or measure the features mentioned above, run the televiewer survey again at no expense to the Government.

d. Utilize the submitted and approved optical televiewer operator to operate the optical televiewer, capture all data, and ensure that all

information necessary for optimum post-processing is collected and compiled. Only submitted and approved personnel are to perform this work.

e. Supply appropriately positioned lighting (center of the borehole) for optimal image quality, and always utilize a centralizer except where the risk of hole collapse is great enough that the equipment might be lost.

f. Images do not need to be captured while the televiewer is traveling inside the casing. Image capturing must include 0.7 meters 2 feet above tip of casing and down to the bottom of the drill hole.

g. When collecting images and deviation data, move the equipment at a rate of0.5 meters 1.5 feet per minute. There is no maximum speed requirement while the equipment is being moved through the casing.

h. In addition to the images, measure and record all location and positional data, including but not limited to azimuth, depth, borehole inclination, borehole ID, and other data as requested by the Contracting Officer.

i. Measure and record borehole deviations including azimuth and inclination, relative to compass direction and in relation to intended alignment.

j. Develop and employ procedures and equipment which eliminate any impacts or introduced error to the televiewer's magnetic compass.

][3.8.2 Acoustic Televiewer Survey Methods

****

NOTE: An Acoustic Televiewer Survey (ATV) can be run in tandem with, or as an alternative to, the Optical Televiewer Survey (OPTV) if conditions do not allow for OPTV. There are two major drawbacks to the acoustic televiewer surveys. First, the survey has reduced utility (versus an optical televiewer) because it is not a picture. Use is limited to the identification of fractures and voids. Second, it requires a fluid-filled hole, which can be problematic in holes with water losses. Contractors often prefer acoustic televiewer surveys because they can be used in holes with cloudy fluid, and survey preparation requires less work. Therefore, if optical televiewer surveys are preferred, ensure the specification for optical televiewer survey requirement is sufficiently rigorous that the contractor will not simply default to acoustic surveys to reduce their workload or speed their schedule.

****

The acoustic televiewer requires a fluid-filled hole. Perform downhole acoustic surveys in accordance with ASTM D5753 (except as a static printed readout, not video) and the following requirements:

a. At the conclusion of drilling, wash the borehole clean, top off the hole to the surface with clean water, and let the hole sit for [two

hours][_____] prior to conducting survey. Conduct acoustic televiewer surveys[within borings as directed by the Contracting Officer].

b. [Obtain acoustic view for geologic borings with high flow or which penetrate soft and unstable materials in non-rock intervals.]In the event of a partial hole collapse, log the hole to the point of collapse. To view blockage, perform a traditional borehole camera video. In the case of no hole collapse, log the hole to the full depth.

c. Survey capture must be of required resolution to view and measure the orientation of discontinuities including fractures, bedding planes, voids, changes in lithologies, grout-filled features, and other geologic features [two millimeters][_____] or larger. If final surveys are of insufficient quality, resulting in inability to identify or measure the features mentioned above, run the acoustic televiewer survey again at no expense to the Government.

d. Utilize the submitted and approved televiewer operator to operate the acoustic televiewer, capture all data pertinent to the operation, and ensure that all information necessary for optimum post-processing is collected and compiled.

e. Always utilize a centralizer except where the risk of hole collapse is great enough that the equipment might be lost.

f. Develop and employ procedures and equipment which eliminate any impacts or introduced error to the televiewer's magnetic compass.

]3.8.3 Borehole Deviation Survey Methods

Perform borehole surveys in accordance with ASTM D5753. Borehole deviation requirements may be demonstrated via the optical televiewer surveys to satisfy this requirement. Perform surveys on [all][every fourth primary] hole[s].

Provide the following data within [24 hours][48 hours] of hole completion:

a) Original raw deviation data in ASCII readable format or .csv.
b) Deviation data in Microsoft Excel format.
c) A paper copy of the report with a one-page summary table of the deviation data.
d) Three plots
    i. One plan view with compass rose.
    ii. Two section views, perpendicular to each other.

[3.8.4 Mechanical Caliper Survey Methods

Perform mechanical caliper surveys in accordance with ASTM D6167. Perform mechanical caliper surveys on holes that have reached full design depth only, unless specifically directed by the Contracting Officer. Perform surveys on [all][primary][every fourth primary] hole[s] [up to [_____] times as determined by the Contracting Officer].

Provide the following data within [24 hours][48 hours] of hole completion:

a) A report for each hole displaying the results in Metric English units.
b) The original raw survey data in ASCII readable format or .csv (if

digital format), or paper field log (if analog format).
c) Caliper survey data in Microsoft Excel format.

][3.8.5 Other Downhole Survey Methods

****
NOTE: The most likely 'Other Downhole Survey' would be either be a downhole flowmeter or a downhole geophysical survey. However, other surveys should not be added by default. Specific types of downhole surveys should be intentionally selected because of their appropriateness to the aplication. The designer should consult with a downhole geophysical survey specialist to aid in selection if these types are desirable for use.

If geophysical surveys are to be used, the add the description here. Reference the applicable ASTM standards, including the 'generic' ASTM for downhole geophysics, which is ASTM D5753, and any specific ASTM standards specific to the type of geophysical survey. Ensure any equipment specifications, methodology requirements, and final output requirements are captured to ensure quality, resolution, and delivery of final data and outputs.
****

[ADD TEXT HERE]

]3.9 VERIFICATION HOLE PROCEDURES

****
NOTE: The purpose of a verification hole is to verify that the goals of the grouting program have been met. Typically on a two-line grout program, the verification hole is drilled between the two grout lines. Verification holes can be cored and are typically subject to materials testing, water pressure testing, and are required to have downhole optical surveys. Verification holes should utilize existing measurement and payment items.

As part of the verification program, closure of a section will be verified by permeability testing at each verification hole. The designer must consider the goal of the grouting job and local geologic conditions to determine closure criteria. The specification for closure should be adjusted to each job and site specific requirements.
****

Drill and pressure test grouting verification holes within the completed grout curtains to verify that the curtain meets the specified permeability requirements. The Contracting Officer determines locations for verification holes, which may be along the grout line(s) or between successive grout lines.[For bidding purposes, assume a quantity of [_____] verification holes[of which [_____] hole must be angled at [_____] degrees from vertical,][and [_____] holes must be vertical].] Utilize the same drilling, washing, and grouting procedures as production

grout holes.[Use the [typical][varied-step] method for water pressure testing.] There may be differences with the length of water pressure testing intervals, or length of grouting intervals.

The Government reserves the right to add additional verification holes at locations and depths determined by the Contracting Officer to ensure closure has been achieved. Based on In-situ ground conditions encountered, the Contracting Officer reserves the right to require additional grout holes including but not limited to changing spacing, offsets, drilling angles, sequence, staging, mix designs, pressures, and volumes as needed to achieve closure criteria.

3.10 HOLE RECORDS

Submit raw data records within [one][two] days of hole completion. All record keeping and submission is incidental to the work. No additional payment will be made for keeping or providing records. Provide records within the stated turnover times, and provide digital records within [six][_____] hours of a request by the Contracting Officer.

3.10.1 Drill Logs

****
NOTE: USACE uses USACE Form 1836 and 1836 Continuation Form. For other agencies, utilize the agency-specific drilling form.
****

Log boreholes in accordance with paragraph DRILL LOGGING PROCEDURES. If the hole was logged using a paper log, submit the original paper log at[the completion of each borehole][the completion of each working day]. Keep a high-quality scan[and a physical copy] on file.[In addition, submit digital data in [OpenGround][Plog][GIS][MicroStation][Autodesk] format.] If the drill log was completed using a tablet, submit two digital files: 1) a PDF version of the log 2) the original electronic ASCII or Excel-readable file exported from the program utilized for logging.

[3.10.2 Pressure Washing Log

Submit a pressure wash log detailing the tool used for washing, the date and time of washing, the discharge rate, the pressure used, the total amount of water used, the color of discharge water, and any field notes. Submit final records within [seven][_____] calendar days of completion.

]3.10.3 Water Pressure Testing Reports

Provide a separate water pressure testing report for each water pressure test. The report must include: stage information including time history, packer air pressure, water inflow, flow versus time, pressure versus time (including target pressure), any communication between stages or instrumentation, any observed new water flow at the surface, Lugeon value versus time, and any comments [recorded][requested] by the Contracting Officer. For step water pressure testing only, include lugeon values for each step. Provide the report in .doc or .docx format readable by the Microsoft word processing software, and in Adobe PDF formats. Submit final records within [seven][_____] calendar days of stage completion.

3.10.4 Grouting Reports

Provide a separate grouting report for each grout stage. Include in the report: stage information (including time history), packer air pressure, water inflow, flow versus time, pressure versus time (including target pressure), grout mix(es), apparent lugeon value versus time. In addition, the cumulative flow, interpreted single lugeon value, and any comments by the [Contracting Officer][Contractor] recorded, including any communication between stages or instruments, or observed grout at the surface. The comments must include any comment directed to be added to that specific stage report by a Contracting Officer. Provide the report in .doc or .docx format readable by the Microsoft word processing software, and in Adobe PDF formats. Submit final records within [seven][_____] calendar days of stage completion.

[3.10.5 Backfill of Overburden Casing Report

****
NOTE: Use this paragraph and submittal only if there is concern for voids or other flaws in the overburden material.
****

Submit a backfill report of the record of backfilling the cased, non-rock portion of the hole. Required information includes the [date][time], grout volume, and any comments. Submit final records within [seven][_____] calendar days of completion of the hole.

]3.10.6 Downhole Survey Reports

The required downhole survey reports include reports for Optical Televiewer Survey Records, Acoustic Televiewer Survey Records, Borehole Deviation Survey Records, Mechanical Caliper Survey Records, or any other hole-specific survey. Complete each report for each hole.

These reports must include all associated digital deliverables including the original digital file, worksheets of values in [.XLS][or][.XLSX] format, separate image files for picture surveys in .tiff format, and PDFs. Submission of only a PDF file is unacceptable. Submit final records within [7][14] calendar days of survey completion.

[3.10.6.1 Optical Televiewer Survey Records

Submit the records for the optical televiewer survey. Records must include the original digital file, an image file or files in .tiff or other lossless format (no more than [five][_____] image files per hole), and a full resolution pdf file.

][3.10.6.2 Acoustic Televiewer Survey Records

Submit the records for the acoustic televiewer survey. Records must include the original digital file, an image file or files (no more than [five][_____] image files per hole) in .tiff or other lossless file format, and a full resolution pdf file.

][3.10.6.3 Borehole Deviation Survey Records

Submit the records for the Borehole Deviation Survey. Records must include the original digital file, the tabular deviation data versus depth

in Microsoft Excel format, and a pdf file.

][3.10.6.4 Mechanical Caliper Survey Records

Submit the records for the Mechanical Caliper Survey. Records must include the original digital file, the tabular diameter data versus depth in Microsoft Excel format, and a pdf file.

][3.10.6.5 Other Downhole Survey Records

****
NOTE: If another downhole survey method has been utilized, change the title to the survey method, and include what is required to be submitted.
****

Submit the records of the [_____] downhole survey method. Include[native digital file,] ASCII or .CSV export of the native digital file,[tabular data][full resolution imagery in [_____] format,] and a PDF showing the results.

]3.10.7 AGDCS Records

****
NOTE: If this tailoring option is used, delete select sections from above if recorded using AGDCS records.
****

The AGDCS must be capable of producing outputs that include the following information:

a) Type of data (Grouting versus Water-Pressure-Testing)
b) Hole stations and Northing Easting coordinates;
c) Testing interval or stage data (as appropriate)including depth, and elevation.
d) Initial water pressure and calculation for each stage;
e) Water pressure testing results from each stage/zone in Lugeons/modified Lugeons.
f) Grout takes for each mix used in each stage.
g) Grouting time for each stage (hr:min:sec);
h) Graphs displaying injection rates, all pressures, and apparent Lugeon values from the grouting.
i) The system must be able to reduce monitoring data to account for correction factors and field parameters, such as pressure head losses, actual depth of the stage being grouted, and pressure measurements.
j) Show time horizontally on graphs.
k) Produce separate graphs for pressures, flow, lugeon, and (for grouting only) mix-type all measured on the vertical axis.

[3.11 TEST SECTION RECORDS

****
NOTE: Typically, a test section will not be required, but it may be necessary in some cases. When a test section is utilized, use the requirements below. If not, delete these paragraphs.

Designers should be aware that use of a test section

may cause a pause in work. Designers should have a plan to minimize delays between a test section and production.

Previously, there has been a disconnect between government and contractor on the need to conduct a second test section if significant changes are made because of problems in (the first) test section. The designers should consider and specify how they will approach this problem, and ensure the language is consistent and enforceable.

****

[3.11.1 Drilling and Grouting Test Section Report

Prepare and submit a drilling and grouting test section report that covers all the test section activities. Submit the complete report with [three][five] hard copies and a digital copy of the report including but not limited to: forms, sketches, drawings, tables, graphs, and color photographs as necessary to provide a full understanding of how the work was accomplished and any difficulties, problems, or unusual conditions which were encountered. The report must 'standalone' and not simply reference other material to the extent as possible without including the language of the reference, with the sole exception of the As-Built drilling and grouting drawings.

Submit the test section report no later than [20 days] [40 days] after grouting the final test section hole. The report must contain the following minimum information:

a. Average drilling time and drilling depths of holes broken down into overburden,[concrete,] and bedrock.

b. Drilling records including depths and locations of holes.

c. A list of all drilling, water pressure testing, and grouting equipment used on the project, type of equipment used on each element, and depth of excavation for each type.

d. A minimum of [12] annotated color photographs of all phases of construction and equipment.

e. A discussion of the grout mix(es) used and quality control procedures for maintaining the grout mix(es).

f. A descriptive list of any lost tooling including type of tooling, length, depth, batter, and location (station and offset, northing and easting, depth, and elevation).

g. Discussion of any deviations from the Work Plan submittals.

h. Discussion of the closure analysis and any stages that were not closed by the split-spacing method.

i. Discussion of all water-pressure-testing stage(s) or grouting stage(s) that appeared to have induced either dilation or hydro-fracture based upon the trend plots. Include the specific trend plots in the report.

j. Instantaneous and Industrial Production rates for drilling, water

pressure testing, camera surveys and grouting. Compare production rates achieved with the production rates forecast in the baseline schedule; note any actual rate 25 percent different of that forecast in the baseline schedule and develop an interpretation of why.

k. Summary statistics of each test for each grout mix during the Contract period. Include: Mean, Median, Mode, Standard Deviation, and 95 percent Confidence limit. Limit the statistics to the data available at the time of report writing.

l. For compressive strength data, only evaluate a Contractor-selected strength testing interval (e.g., 7 days, 14 days, or 28 days). Also plot each test, for each mix, showing results versus time, with specifications limits clearly delineated.

m. Add a table of downhole surveys performed, as well as two examples of each type of downhole surveys as figures, if available. Include a discussion of any problems encountered with downhole surveys and the solutions implemented.

n. A discussion of the Computer Grouting System to include the formulas used for calculating effective pressure of water testing and grouting.

[

o. A discussion of the instrumented packer to include calibration procedures, any problems encountered, and a comparison with calculated effective pressure versus measured total pressure for, to include at least two examples of water pressure testing stages and two examples of grouting stages.]

[

p. If additional test sections are required, submit a new Drilling and Grouting Test Section Report with items A through O, and any additional updates, listed in the list above.]

][3.11.2 Drilling and Grouting Test Section Drawings

Show the drilling, water pressure testing, and grouting for each grout line on separate drawings for each. The color and binning symbology for pressure, grout volume, and drilling issues will be provided by the Government. Make changes to symbology, binning, and color representations at any time as directed by the Contracting Officer.

a. On the drilling view, show the ground surface, top-of-rock surface, an interpreted continuous top-of-rock surface, locations of any concrete, any voids, any lost steel, and any other drilling irregularities. Represent each grout hole as a line.

b. On the water pressure testing view, show the separate water pressure testing stages with color-coding of water pressure testing results for each stage, reported in Lugeons. Represent each grout hole as a line.

c. On the grouting view, show the separate grouting stages with color-coding of grout stage volumes in [liters] [gallons]. Represent each grout hole as a line.

]]3.12 PERIODIC RECORDS

****

NOTE: Depending on the needs of the project, the designer may change frequency of reporting periods

listed.
****

3.12.1 Weekly Grouting Progress Drawings

Provide updated grouting progress drawings weekly. Reduce, correct, and interpret, all grouting data and display in an approved format. Include grout volumes and pressures for each incremental grout injection on progress drawings. Perform quality control review - conducted by the lead grouting geologist or geotechnical engineer - on all drawings for accuracy and completeness prior to submittal. Record the name of the reviewer and the date of the review on the submittal. These drawings are used by the Government to make split-spacing determinations. The Government will not make any additional payment for work or cost resulting from errors in the progress drawings, including, but not limited to, additional drilling, water-pressure-testing, downhole camera surveying, deviation surveying, grouting the theoretical hole volume of any hole, any Contract time associated with drilling, grouting, setups, and associated work on the split-spaced hole, and must not be cause for extending the Contract period. The Government is not responsible for the grout time and grout materials, using Contract quantities, associated with the grout takes over the theoretical volume of the hole on holes that would not have been split-spaced without erroneous data.

Produce drawings at scale of 1:250 or larger (e.g., 1:150), and that are completely legible at that scale. Provide separate sheets: for 1) plan view, 2) [section][profile] view[s] of drilling including lost tooling and interpretive geology, 3) [section][profile] view[s] of pressure testing results, 4) [section][profile] view[s] of grouting results[and 5) [section] [profile] view[s] of projected downhole camera records]. Submit records in [hard copy (two copies),][electronic format on CD or DVD,] and in native file formats and .pdf on the project SFTP site.[Drawing views that are unchanged from the previous week do not need to be submitted in hard copy, but the electronic copy must still be submitted.]

3.12.2 Weekly Grout Test Results

On a weekly basis, submit a project-cumulative table with all daily, weekly, and monthly Contractor Quality Control field and laboratory grout tests in electronic[EXCEL360] spreadsheet. Submit the spreadsheet starting the week after the first test is conducted.

Display each batch as separate records, and test results as fields. Display all testing records. The spreadsheet must contain the following columns: batch date, batch time, combined batch date and time, test date, test time, which batch plant the sample was taken from, ASTM standard utilized, Pass/Fail (with 0 and 1 used for pass and fail, respectively), and each test title (e.g., Viscosity, Density, etc.). The actual numerical test result must be posted; "Passed" or "Within Spec" or "<0.09" are unacceptable. Include all failing and passing tests.

3.12.3 Monthly Grouting Red Line Drawings

****
NOTE: If grouting is part of a larger project, then this submittal need not be required every month, only months that work is occurring. On grouting-only jobs, delete the last paragraph.
****

Prepare red-line drawings each month, with red-lines showing changes from the award drawings, and as many new drawings as necessary showing the drilling, water pressure testing, and grouting work completed to date. Include all of the grout holes authorized to date in plan (map) view. The drawings must be in [MicroStation][AutoCAD][GIS] format.

[
Monthly Grouting Red Line Drawings need only be submitted when drilling or grouting work is underway or when [drilling][grouting] information is still being processed after completion.]

[3.12.4 Monthly Drilling and Grouting Photographs

Provide a set of at least [ten][_____] photographs showing the operation of drilling and grouting. All photographs must be a minimum of[10 megabytes][10 pixels per inch]. Include photograph digital files in a lossless image format, and in annotated PDFs describing the date, location, orientation, and feature of work in the photo.

][3.12.5 Closure Analysis for [_____] Line

****
NOTE: For jobs with multiple grout lines, the designer may wish to add a requirement to submit a closure analysis for each completed line, at a reasonable number of days after completing the lines, rather than wait until the end of the job. For a single line curtain, this requirement should be deleted.
****

No later than [10 days][20 days][30 days] days following the completion of the [upstream][downstream][center] line, submit a closure analysis for the line. Perform the closure analysis by grout line, geological formation with elevation limits, and [stationing][length] for grout take and lugeon values. The closure analysis must be in accordance with the stated closure criteria, including units for Lugeon[and][Apparent Lugeon], as well as calculated permeabilities in cm/s and ft/s. Complete closure analyses in accordance with paragraph REFUSAL, SPLIT-SPACING, AND CLOSURE. The closure analysis must include: [mean][average], median, minimum, maximum, first quartile or 25 percentile, third quartile or 75th percentile values. Provide box-and-whisker plots for each data group, other graphs as appropriate, and raw data of these analyses.

Provide graphs and raw data of these analyses for both the entire length of the job, for every [3] meters [10] feet in elevation, for every geological formation, as well as separately for each [30] meter [100] foot length. Submit the Closure Analysis in Microsoft EXCEL format. Include in the submittal a narrative description of the closure analysis with summary information in a word processing format.

]3.13 DRILLING AND GROUTING CLOSEOUT RECORDS

3.13.1 As-Built Drilling and Grouting Drawings

Provide As-Built drawings in accordance with Section 01 78 00 CLOSEOUT SUBMITTALS. As-Built drawings are not limited to the sheets in the Contract drawings. Add as many sheets as necessary to show the work completed. Include the three new views for the entire grouting work. The

color and binning symbology for pressure, grout volume, and drilling issues will be provided by the Government. Make changes to symbology, binning, and color representations as directed by the Contracting Officer.

a. The first view is drilling results. Include every grout hole as a line, with the ground surface and top-of-rock noted for each hole. Display voids, an interpreted top-of-rock line, and interpreted connections between voids. Show any lost tooling at the presumed lost depth. Show all casings with top and bottom depth.

b. The second view is water pressure testing results. Show each grout hole as a line, with each water pressure testing stage depicted by a color-coded box with the Lugeon value printed on it.[The Government will provide color symbol binning for Lugeons.]

c. The third view is grout volumes. Show each grout hole as a line, with each grouting stage shown with a color-coded box with the grout volume printed on it. Depict annular-space grout volumes for overburden stages separately.

3.13.2 Database of Water Pressure Testing and Pressure Grouting Results

****

NOTE: A database is an essential tool for analysis and quality assurance review by engineering for grouting projects. The database will facilitate data research, analysis, and visualization. It can be incorporated into a project Geographic Information System (GIS) - including profile views of the grout lines. For all dam safety or large-scale grouting jobs, an enterprise database is recommended. Smaller projects could utilize a Microsoft Access database. It is a best practice to develop the database format based on the project quality management and reporting requirements and provide this to the Contractor. Alternatively, the Contractor could propose a format for approval by th project's data manager in conjunction with the grouting engineer. Projects should ensure data requirements are complete enough that they facilitate needed reporting and evaluation required throughout the contract

For any database utilized, it is imperative that all values have a content definition and that any calculations, variables and constants involved in creating values reported in the database are clearly defined in human-readable database documentation.

For all geospatial and database regulations and best practices, refer to applicable guidance. For USACE this includes Engineering Manual 1110-1-2909 Geospatial Data and Systems.

For all data products, ensure minimum data quality, turnover time, and format requirements from UFGS 01 31 20 "Project Technical Data Management and Visualization" are included in that section.

.

****

Develop an [Enterprise][Microsoft Access] database in accordance with Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION that contains all data generated over the course of the project - including but not limited to drilling, grouting, water pressure testing, and verification drilling and testing. Minimum data requirements include but are not limited to:

a. Hole ID
b. Hole surface northing and easting
c. Hole surface station and offset
d. Hole series
e. Hole top (ground surface) elevation
f. Hole bottom elevation
g. Hole inclination (vertical =90, non-vertical as built)
h. Hole azimuth (999 for vertical, as measured for non-vertical)
i. Hole total grout volume for the hole
j. Hole top-of-rock elevation
k. Hole top elevation of casing (if applicable)
l. Hole bottom elevation of casing (if applicable)
m. Hole drilling issues including hole collapse, voids, drill water communication, etc.
n. Stage ID
p. Stage top elevation
p. Stage top station
q. Stage top offset
r. Stage bottom elevation
s. Stage bottom station
t. Stage bottom offset
u. Stage Lugeon value
v. Stage grout volume in [gallons][liters] of each mix
w. Stage geologic formation
x. Stage target effective pressure
y. Stage target gauge pressure
z. Stage grouting issues including communication, bypass of packer, water loss, or others as requested by the Government.
aa. Hole ID of corresponding communicating hole
bb. Stage ID of corresponding communicating stage
cc. Comments

A data dictionary detailing the specific data tables, fields, and relationships of the database required for use[is provided as an addendum to the Contract][will be provided by the Government upon issuance of the notice to proceed]. See Section 01 31 20 PROJECT TECHNICAL DATA MANAGEMENT AND VISUALIZATION for additional database requirements.[The database must contain metadata in accordance with ISO 19115 standards.][The database must be in accordance with SDSFIE Standards.]

3.13.3 Final Closure Analysis

Perform a closure analysis by series, geological formation, stage, and [stationing][length] for both grout take and lugeon values for all grout line(s). Produce separate closure analysis for water-pressure-testing and grouting results. The closure analysis must provide: mean/average, median, minimum, maximum, first quartile or 25th percentile, third quartile or 75th percentile values. Provide box-and-whisker plots for each data group, other graphs as appropriate (or as requested by the Contracting Officer), and raw data of these analyses.

Submit the Final Closure Analysis using the Microsoft Office Suite including but not limited to EXCEL format[and in accordance with data management requirements]. Include a narrative description of the Final Closure Analysis with summary information in the submittal. Submit the Final Closure Analysis no later than 60 days after grouting the final hole. Include database tables of the final closure analysis.

3.13.4 Drilling and Grouting Final Report

****

NOTE: The final report is a necessary submittal and provides the government a thorough and useful final record of the contractor's work that will provide critical information to meet the requirements of completion reports (For USACE, see Engineering Regulation (ER) 1110-2-1901).

The requirement to reduce references without full-text incorporation is necessary to prevent submission of final reports of an inferior quality and detail. Reports which simply reference job submittals and do not present a final aggregate record with digestible analytical findings, and supporting data should be avoided. Utilize specific and descriptive language that is enforceable to get the desired final product.

****

Prior to the Contract completion, prepare and submit a drilling and grouting final report that describes all activities throughout construction in detail. Include any narrative about issues encountered and technical resolution. Submit the complete report with [three][five] hard copies and a digital copy of the report including but not limited to: forms, sketches, drawings, tables, graphs, and color photographs as necessary to provide a full understanding of how the work was accomplished and any difficulties, problems, or unusual conditions which were encountered. The report must 'standalone' and not reference other material to the maximum extent as possible, except for the As-Built drilling and grouting drawings.

Submit the final report no later than [30][60] days after completion of grouting of the final hole.[Submit an outline of the report for approval when 50 percent of the construction is completed.] The report must contain the following minimum content:

a. Average drilling time and drilling depths of holes broken down into overburden[, concrete,] and bedrock.

b. Drilling records including depths and locations of holes.

c. A list of all drilling, water pressure testing, and grouting equipment used on the project, type of equipment used on each element, and depth of excavation for each type.

d. A minimum of [25][_____] annotated color photographs of all phases of construction and equipment.

e. A discussion of the grout mix[es] used and quality control procedures

for maintaining the grout mix[es].

f. A descriptive list of any lost tooling including type of tooling, length, depth, batter, and location (station and offset).

g. Discussion of any deviations from the Work Plan submittals.

h. Discussion of the closure analysis and any stages that were not closed by the split-spacing method.

i. Discussion of all water-pressure-testing stage(s) or grouting stage(s) that appeared to have induced either dilation or hydro-fracture based upon the trend plots. The specific trend plots must be included in the report.

j. Instantaneous and Industrial Production rates for drilling, water pressure testing, camera surveys and grouting. Compare production rates achieved with the production rates forecast in the baseline schedule; note any actual rate that is 25 percent different from the forecast in the baseline schedule. Include an interpretation of why forecast and actual were different.

k. Summary statistics of each test for each grout mix during the Contract period. Include: Mean, Median, Mode, Standard Deviation, and 95-percent Confidence limit.

l. For compressive strength data, only evaluate the 28-day strength. Include plots of tests for each mix, showing results versus time, with specifications limits clearly delineated.

m. A discussion of issues encountered, including but not limited to, cross hole communication, water losses, excessive takes, surface grout emergence, hole collapses, excessive infill materials encountered leading to hole stability problems, signs of vertical connectivity such as leaky packers, instrumentation responses, any signs of structural distress that appeared or changed during grouting - related to the area grouted at the time.

n. A table of downhole surveys performed, and two examples of each type of downhole surveys as figures. Include a discussion of any problems encountered with downhole surveys and the solutions implemented.

o. A discussion of the Computer Grouting System to include the formulas used for calculating effective pressure of water testing and grouting.

[p. A discussion of the instrumented packer to include calibration procedures, any problems encountered, and a comparison with calculated effective pressure versus measured total pressure for, to include at least two examples of water pressure testing stages and two examples of grouting stages.]

[3.14 COMMUNICATIONS

Install a communications system that links (at a minimum) the grout plants, grout injection stations, water-pressure-testing stations, the Automated Grouting Data Collection System and all other operations on-site as necessary.[Provide two devices per shift to the Contracting Officer that communicate on the Contractor's frequency or line for monitoring and coordination of grouting operations. These devices will be returned to the

Contractor at the end of grouting operations, subject to normal wear and tear.]

] -- End of Section --