TIME-CRITICAL REMOVAL ACTION WORK PLAN
FS 3030 ROAD SITE
PRINCE OF WALES ISLAND, ALASKA

Submitted to:

Western Federal Lands Highway Division, Vancouver, WA

Submitted by:

AMEC Geomatrix, Inc., Seattle, WA

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1.0 PURPOSE

The purpose of this work plan is to describe the time-critical removal action to be completed at the U.S. Forest Service (FS) 3030 Road site located near the city of Coffman Cove on Prince of Wales Island, Alaska. A removal action is deemed necessary as a time-critical removal action (TCRA) to address three locations along FS 3030 Road Site to attempt to control releases of potentially toxic materials to the environment based on previous investigations of the three areas. While the three removal actions are being proposed as a TCRA, other portions of the road alignment are also impacted and could require cleanup. More information will be gathered for the other portions of the road under a non-time-critical removal action (NTCRA).

The TCRA will be conducted with the Western Federal Lands Highway Division (WFLHD) in cooperation with the FS, under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). In addition to the FS, other environmental regulatory agencies will be reviewing the project and providing comments. These agencies include the U.S. Environmental Protection Agency (EPA), the Alaska Department of Environmental Conservation (ADEC), and the Alaska Department of Fish and Game (ADF&G). WFLHD, which designed and managed the construction of FS 3030 Road in partnership with the FS and the Alaska Department of Transportation and Public Facilities (ADOT&PF), is voluntarily proceeding with a TCRA at this point in time to address apparent releases of acid rock drainage into surface water at three road locations along FS 3030 Road. This work plan provides the background, identifies the probable problem, and describes the removal action(s) proposed to be completed in the fall of 2008.

2.0 SITE CONDITIONS, BACKGROUND, AND PROBLEM IDENTIFICATION

FS Road 3030, a portion of Alaska Forest Highway (FH) 44 located on Prince of Wales Island in southeast Alaska (Figure 1). The 31.5-kilometer (19.6-mile) road is the main route linking the city of Coffman Cove to North Prince of Wales Road, and is located within the Tongass National Forest. FS 3030 Road crosses 11 primary watersheds, ranging from 2.4 to 256.6 hectares (6 to 634 acres), and crosses numerous streams and extensive peatlands and wetlands underlain by thick peat (DEA, 2008). The majority of the streams drain to Sweetwater Lake, located west of the road. Streams adjacent to and crossing FS 3030 Road support populations of coho, pink, and chum salmon, as well as populations of sea-run cutthroat trout and Dolly Varden (HEC, 2004).

2.1 PROBLEM DESCRIPTION

Phase II of the FS 3030 Road Reconstruction Project began on May 18, 2006. As part of the reconstruction, WFLHD received a permit to discharge approximately 602,054 cubic meters (787,457 cubic yards) of fill into 8.1 hectares (20.05 acres) of wetlands and water. Rock used during reconstruction of Phase II was obtained from several existing and previously developed rock quarries/borrow pits located along the road alignment, including rock obtained from a widened through-cut designated B-5. Rock from the B-5 cut, referred to as B-5 material, was placed intermittently along an approximately 7.84-kilometer (4.9-mile) segment of FS 3030 Road.

In 2007, water quality issues, specifically low pH and suspected high iron (based on visual observation of orange-colored precipitation and/or colloids in the streams), were detected at several culverts installed along FS 3030 Road in areas where B-5 material was placed. Although this was not realized at the time, the water quality issues suggested a possible release of acid rock drainage (ARD). Subsequent investigations in the spring of 2008 by David Evans and Associates, Inc. (DEA), on behalf of WFLHD indicated that surface waters adjacent to road areas known to be associated with B-5 material tended to contain high concentrations of iron and copper and had pH and dissolved oxygen (DO) values lower than area background conditions. Iron, copper, DO and pH were found to exceed ADEC water quality standards. In addition, a fish and macro invertebrate survey by DEA of Stream 3027 in the ADF&G stream designation and referred to as Stream 3 by DEA, was found to be devoid of both fish and macro invertebrates downstream of the road. Fish avoidance was also documented by ADF&G in the affected creeks. The B-5 material was tested and found to have the potential to be acid producing and was believed by the various regulatory agencies to be the likely source of the exceedances of ADEC water quality standards.

The ADEC water quality standards known to be exceeded in the creeks impacted by the ARD effects of B-5 rock are for pH, iron, copper, and occasionally for dissolved oxygen (DO). None of these constituents or properties is considered a direct threat to human health. The surface water quality standard for copper is based on the toxic effects of copper on aquatic biota including salmonids. High concentrations of iron, extremely low DO, and very low pH can also have an effect on aquatic organisms.

An FS cabin is located on Stream 3027, one of the streams planned for a TCRA. The cabin is located at the point where the stream enters Sweetwater Lake and the cabin could allow recreational users to come in contact with ARD as there is visual evidence of ARD at the stream mouth of the lake. The FS has posted warning signs in and around the cabin and on the FS web site for cabin rentals to warn recreational users of drinking the water from the creek.

2.2 PREVIOUS REPORTS AND ACTIONS

In 2007, WFLHD conducted an investigation of water quality at 15 culverts. One sample of B-5 material was also analyzed. In 2008, DEA conducted an investigation on behalf of WFLHD of nine creeks and 16 culverts along FS 3030 Road in the affected area, as well as of a peatland/wetland and a waste pile containing B-5 rock. A biological survey including a fish trapping study was also conducted. Results of the 2007 WFLHD investigation and the 2008 DEA investigation are included in the Phase 1 Site Characterization Plan and Preliminary Report (DEA, 2008). This report concluded the following.

- Water quality was above ADEC water quality standards in surface waters located near road segments backfilled with B-5 material.

- Culverts associated with the most extensive water quality problems tended to be located in areas where the peat had been deeply excavated.

- Waters associated with peatland/wetlands tend to have variable pH that is frequently lower than Alaska state water quality standards for fresh, fish-bearing waters (6.5 to 8.5). DEA observed pH values as low as 4.0 in unaffected peatlands, while unaffected stream pH values were as low as 6.0 (DEA, 2008).

- Water quality problems were identified in runoff from the D-2 disposal area, which contains a small amount of B-5 material. It is unclear what is the cause of the water quality problems at this location.

- A fish-trapping survey conducted in Stream 3027 (culvert 19+964) indicates that in the area of the stream with diminished water quality, which is downstream of the road and B-5 material, there were no fish and macroinvertebrates present at the time of the survey.

Additional investigations are proposed as part the NTCRA to assess these conclusions and fill in the remaining data gaps.

3.0 PROPOSED ACTIONS

During the week of July 18, 2008, WFLHD, FS, EPA, ADEC, ADOT&PF, ADF&G, and a representative of the Alaska Attorney General's Office met on Prince of Wales Island to tour the impacted portion of the road alignment and to discuss a path forward. At the meeting, the following conditions were determined.

1. The B-5 rock appears to be resulting in potential and confirmed releases of ARD, resulting in the water quality problems in creeks along the road.
2. The exceedances of ADEC water quality criteria appear to correlate most directly to locations where areas of the peat soils were excavated to depth.
3. The water quality in several creeks has apparently resulted in disruptions to aquatic life, including impaired salmon spawning in the affected creeks.
4. Since the water quality is impairing salmon spawning in the creeks, a TCRA in 2008 would be appropriate in an attempt to control the source of the ARD release of toxic constituents to the environment for several of the worst impacted locations. TCRAs are considered under CERCLA as appropriate to address a release of hazardous constituents potentially threatening human health or the environment. It was decided that as many as three TCRAs could potentially be completed within this construction season.
5. Although the placement of B-5 rock correlates with water quality exceedances at a number of locations, at other locations it is not known if the water quality is impacted. As a result, data gaps exist for many portions of the impacted area and need to be filled before decisions on further removal actions can be completed for the entire area of impacted alignment. These data gaps and subsequent removal actions should be completed as an NTCRA.
6. It is unlikely that the potential and/or confirmed releases are a threat to human health through direct contact or consumption of aquatic organisms, but further evaluation is necessary before making a final ruling.

The Superfund Accelerated Cleanup Model (SACM), created in 1992, introduced as a central feature a philosophy to integrate the removal and remediation programs to achieve the greatest human health and environmental protection in the most efficient manner. The increased used of removal actions under the SACM has been highly effective in increasing the pace of site cleanups. In determining the need for TCRAs and NTCRAs, the lead agency must make a determination that a release or threat of release of a hazardous substance into the environment may present an imminent threat to public health or the environment. That determination must consider factors outlined in 40 C.F.R. Section 300.415(b)(2) of the National Contingency Plan (NCP).

For FS 3030 Road, the site assessment conducted by DEA (DEA, 2008) for WFLHD concluded that rock taken from the B-5 quarry and placed along sections of the road as fill is resulting in a release of hazardous substances to the environment, generating acid which is releasing copper, iron, and sulfides to surface water and also resulting in low stream pH. These impacts pose an imminent threat to the aquatic life in the streams and may potentially eliminate or reduce salmon runs in the affected streams. Since the placement of the B-5 rock is relatively recent, the effects of the ARD are relatively rapid, and the cycle of coho salmon spawning runs only three to four years, the need to expedite cleanup of the ARD source material is considered high, thereby meeting the determination of 40 C.F.R. Section 300.415(b)(2). As a result, the FS in a joint decision with WFLHD, EPA, and ADEC elected to pursue cleanup under the Time-Critical and Non-Time-Critical Removal Authority in CERCLA.

This TCRA will be completed in 2008, if possible, to address the source areas that are resulting in ARD impacts on water quality in the most highly affected areas of the road construction project, where confirmed releases constitute the greatest known potential threat to the environment. The identified areas for the TCRA include:

- full removal to the extent practicable of B-5 material from the Stream 3027 road crossing area with disposal of the rock at the associated B-1 consolidation area,
- preparation of the existing B-1 rock borrow pit as a consolidation area for the TCRA and NTCRA responses,
- collection and buffering of groundwater seeps from the B-5 road cut, and
- limestone buffering of ARD symptoms apparently originating from the D-2 soil disposal site.

The proposed TCRAs are discussed in detail in the following sections.

3.1 STREAM 3027 REMOVAL ACTION

Rock and water quality samples and a fish survey conducted at Stream 3027 indicate that this area is adversely affected by B-5 rock. The intent of the Stream 3027 removal action is to restore water quality in Stream 3027 to baseline conditions (to be established by upstream data gathering and other similar creeks not constructed with B5 rock) by removing the B-5 rock. The removal action at Stream 3027 is intended to remove the source of the material believed to be resulting in water quality impairment, but the removal action is not being conducted to meet a specific performance standard. Further actions in this area include monitoring that will be evaluated during the NTCRA.

3.1.1 Proposed Action Description

The Stream 3027 removal action consists of full removal to the extent practicable of B-5 source material from the Stream 3027 area located between stations 19+820 and 20+020. B-5 rock in this location will be excavated to the depth of the original rock placement (roughly 5.5 meters, or 18 feet) as practicable. The 1.8-meter-diameter (5.9-foot-diameter) culvert located at 19+964 will be replaced with a plastic culvert. The excavation will be backfilled with limestone from the B-1 quarry. Because the major source of the water quality impacts will be removed, the limestone may include rock as large as cobbles and boulders or finer grained rock. The grading and compaction of the limestone will meet the construction guidelines used during the road reconstruction so as to match pre-removal conditions. The plan set for the Stream 3027 removal action is included in Appendix A.

The B-5 material removed from Stream 3027 will be placed in a temporary consolidation area in the B-1 quarry as described in Section 3.2. The temporary consolidation area may become the final consolidation area.

3.1.2 Performance Criteria

The goal of the Stream 3027 removal action is to remove as much of the B-5 material from the road fill at this location as is practical. B-5 rock at this location is as deep as 5 meters (16.5 feet) and some of the rock may be compressed into underlying muck. As a result it is possible that not all the B-5 rock can be practically removed, but B-5 rock remaining will be well below the water table and embedded in the organic muck. As a result the planned removal of the B-5 rock should eliminate the source causing water quality impairment at Stream 3027. Water quality is expected to improve over time to conditions considered similar to pre-road-reconstruction water quality. Since water quality prior to road placement is unknown, a background water quality of similar creeks not affected by B-5 material and upstream of the road will be used to compare post-removal-action water quality.

In order to accomplish the removal action goal, B-5 rock will be removed between stations 19+820 and 20+020 to the extent practicable. The extent of the removal is shown in Appendix A. Surface water samples will also be collected prior to the removal action to enable WFLHD in the future as part of the NTCRA to assess the impact the removal action has on water quality. A sample summary is provided in Table 1. The sampling and analyses will be conducted in accordance with the Quality Assurance Project Plan (QAPP), which is currently in production as part of the NTCRA and will be completed prior to the removal action sampling. Because completion of the removal action will not be based on the attainment of cleanup standards, no confirmation samples will be collected; however, long-term monitoring may need to be conducted to ensure that water quality has been restored to acceptable conditions. The decision to monitor, the approach and plan for long-term monitoring, and any further actions at Stream 3027 will be assessed and implemented as part of the NTCRA.

3.1.3 ARARs

The applicable or relevant and appropriate requirements (ARARs) for the Stream 3027 TCRA include:

- ADEC water quality regulations (ADEC, 2003, 2006, and 2008), and
- the Federal Clean Water Act (33 U.S.C. §§ 1341 and 1344) including sections 401 and 404.

WFLHD road construction permits cover the Federal Clean Water Act including the 404 permit for construction within wetlands. During the removal action the standard Federal Highways Administration (FHWA) best management practices (BMPs) for construction and dewatering that were used during road reconstruction will be implemented consistent with the existing permits. A description of the BMPs is located in Appendixes H, I, and J of the Contract Documents for Project AK PFH 44-1(2) (FHWA, 2006).

No confirmation samples will be collected; however, samples will be collected prior to the removal action and long-term water quality monitoring may be conducted. The water produced during the removal action will be discharged onto a jute mat or similar surface to settle out any sand and then discharged directly to Stream 3027. Although the water generated during the removal action will exceed ADEC water quality standards, ADEC has agreed that the water quality is currently degraded and that the removal action will ultimately improve water quality.

The B-5 rock from the Stream 3027 removal action will be placed in the B-1 quarry. The B-1 quarry will initially serve as the consolidation area for rock removed during the TCRA and will be confirmed in future studies as the final consolidation area as part of the NTCRA.

3.2 B-1 CONSOLIDATION AREA

The B-1 borrow pit is a rock quarry that has been developed by the FS and more recently by WFLHD as a rock borrow area for road construction. The rock in the quarry is a limestone containing over 97% calcium carbonate ($CaCO_3$). Since limestone is a natural buffer to ARD, the B-1 borrow pit is considered an ideal location to place any B-5 material resulting from the TCRA and NTCRA. Prior to placing material in the B-1 pit, the site needs to be engineered and developed for a final consolidation area for B-5 rock.

3.2.1 Proposed Action Description

The consolidation area will be placed abutting the headwall of the B-1 quarry wall and will be surveyed and graded, as necessary. The existing footprint of the consolidation area location with the borrow pit will be enlarged as necessary to account for potential maximum material that could be excavated during the TCRA and NTCRA. Enlarging the pit will also be necessary to generate the volume of limestone rock needed to replace the B-5 rock excavated from the existing road bed.

The floor of the consolidation area, which is competent limestone, will be covered with 18 inches of crushed limestone of a maximum diameter of 50 millimeters (mm) (2 inches). The extent of the limestone bedding material will extend at least 3 meters (10 feet) beyond the limits of the consolidation area in the downgradient direction.

For the TCRA, the B-5 material removed from Stream 3027 will be placed over the limestone and temporarily covered with 40-mil high-density polyethylene (HDPE) sheeting to minimize precipitation infiltrating the material. The B-5 material and cover should be sloped to promote natural drainage. The plastic sheets will be placed so that seams have a minimum overlap of 2 meters (approximately 6 feet). Rock (non-B-5) or an equivalent material will be placed over the plastic to hold the HDPE in place for the winter. A geotextile fabric will be placed above and below the HDPE to serve as a cushioning layer to prevent rock from puncturing the plastic. The design of the consolidation area is shown in Appendix A. This area will be our proposed area for further B-5 disposal in 2009 and possibly beyond.

The uphill side of the consolidation area will be prepared to divert surface water from the uphill rock face from flowing into the consolidation area. This will be accomplished by ditching into the rock bottom or placing low-permeability berms (soil, clay, or other low-permeability material) at the top of the slope. For 2008, these surface water diversions can be temporary structures; however, the surface water diversions will be constructed such that no visual seepage enters the containment area and they have a minimum lifespan of 12 months. In addition, a 40-mil HDPE geomembrane will be placed between the B-1 rock face and B-5 material. Geotextile fabric will be laid on each side of the geomembrane to prevent rips and tears. The geomembrane will have a minimum overlap of 2 meters (approximately 6 feet) at the seams.

Prior to placement of B-5 material, monitoring wells or piezometers were installed the week of August 4, 2008, to evaluate rock type and obtain groundwater information. A work plan specific to the peizometer installation is attached to this TCRA work plan as Appendix B. Information related to the installation of these monitoring wells and piezometers will be submitted per the work plan schedule.

3.2.2 Performance Criteria

The portion of the B-1 borrow pit that is being developed into a consolidation area for the placement of the B-5 waste rock was chosen because the rock pit floor is composed of limestone which provides buffering of ARD. There are no specific performance criteria for the consolidation area, but the site is being designed to minimize the potential for ARD generation for the B-5 rock in the short and long term by using design standards consistent with solid waste landfills. The B-5 material will be placed directly on to a 450-mm (18-inch) thick layer of crushed limestone rock which in turn is sitting on limestone bedrock. Drilling was performed by WFLHD on August 7, 2008, to confirm the presence of limestone bedrock to the depth drilled. Visual inspection during drilling indicated the presence of limestone the entire depth drilled which was 9.1 m (30 ft); a field report will be provided by WFLHD at a later date. The bottom layer will serve as a treatment layer for any ARD leachate from the B-5 material as opposed to a low-permeability liner. A low permeability liner could result in long-term maintenance issues and failure, whereas the treatment layer will result in long-term treatment of any leachate generated. The B-5 material will be capped with a low-permeability HDPE membrane to maximize precipitation runoff and prevent infiltration into the B-5 material. As a result very little water can enter the consolidation area, and leachate generation is expected to be minimal and easily handled by the limestone treatment area.

As part of the NTCRA, the B-1 location will be evaluated for use as a long term location for the B-5 material from this removal action and possible future removal actions. To ensure that the B-1 consolidation area is adequately storing the B-5 material without additional water quality impacts, long-term monitoring would need to be conducted. Long-term monitoring will be assessed and implemented as part of the NTCRA. A round of groundwater samples will also be collected prior to B-5 placement to establish a baseline condition.

3.2.3 ARARs

The B-1 pit consolidation area is considered by the FS and EPA to be a potential disposal area. Regulations that apply are:

- ADEC solid waste regulations (ADEC, 2003b), and
- ADEC water quality standards for surface and ground waters (ADEC, 2003, 2006, and 2008).

Consistent with landfill siting regulations, groundwater piezometers will be installed upgradient and downgradient of the consolidation area prior to placing the B-5 rock so that the water table elevations can be identified and the baseline water quality can be established. Should the boring data indicate that this site is not suitable for long-term disposal of B-5 material, the rock will need to be relocated to another location.

The design of the final consolidation area, which will be completed as part of the NTCRA, will be consistent with minimal functional standards for landfills with the exception that a bottom low-permeability liner will not be installed. In its place, a permeable liner to act as a buffering layer will be placed to treat any water seeping through the overlying B-5 rock, thereby maintaining long-term water quality of ground and surface water. The limestone buffering liner will be a minimum of 450 mm (18 inches) in thickness. Once filled and assuming that the site can be used as a long term location, the consolidation area will be closed in place with a low-permeability cover installed to minimize infiltration of surface water into the B-5 rock. Surface water will be directed away from the consolidation area.

A long-term monitoring plan will be developed as part of the NTCRA for the final consolidation area to ensure that the B-5 rock is adequately stored and water quality in that area meets the baseline water quality conditions. The baseline water quality conditions will be established from groundwater samples collected from the piezometers prior to placement of the B-5 rock. A summary of proposed groundwater samples is shown in Table 1.

During this removal action the standard FHWA BMPs for construction that were used during road reconstruction will be implemented. A description of the BMPs is located in Appendixes H, I, and J of the Contract Documents for Project AK PFH 44-1(2) (FHWA, 2006).

3.3 B-5 Cut Collection and Buffering Trench

A portion of FS 3030 Road was laid through an area of bedrock that ultimately became the location of the B-5 through cut quarry. Upon completion of the road, the B-5 pit was backfilled to match the surrounding topography covering the B-5 rock face. The road at this location is a cut section through B-5 rock. The uphill portion of the roadside forms a steep slope; ARD seepage is apparent from this backfilled slope, which appears to be drainage from the bedrock. The seeps drain into the roadside ditch and through a culvert across the road into Stream 3021 (Stream 6). Since this area is cut into the native B-5 bedrock, removal of the bedrock is not feasible; however, seepage off the uphill side of the road can be effectively captured and treated before the ARD enters a stream. Stream 3021 downstream of the road currently is impacted with ARD and treating ARD water in the seep should greatly improve water quality in the stream. Since water quality impacts to the stream could be affecting salmon migration, a TCRA is warranted.

In this location, the removal action includes placing a limestone-filled collection trench along the ditch on the uphill side of the road cut to capture and treat groundwater by buffering the ARD with limestone. The collection and treatment trench will collect groundwater seeping through the B-5 rock, buffer it with limestone, and redirect it downstream.

3.3.1 Proposed Action Description

A collection and treatment trench will be installed parallel to the upgradient (east) side of FS 3030 Road at the B-5 cut. To install the drain a one-meter wide (minimum) trench will be excavated along the road from station 23+300 to station 23+440. The depth of the trench will be approximately 4 meters (13 feet). Type I-A geotextile fabric will be placed in the trench and overlain with 38-mm-minus (1.5-inch-minus) limestone. At station 24+420 the trench will cross the road and enter a naturally occurring low spot, which will be used as a detention pond. The drain will be "field fit" so that the length of the drain extends the total length of the B-5 cut. In addition to placement of the collection and treatment trench, all known B-5 rock will be removed between stations 23+400 and 23+440 and replaced with shot-rock limestone from the B-1 quarry. This rock was placed during construction and is not a part of the original native landscape. The plan set for the B-5 removal action is included in Appendix A.

3.3.2 Performance Criteria

This action should have a rapid effect of eliminating ARD from discharging directly into the creek across the road, which should lead to improvements to surface water quality in Stream 3021. No performance criteria have been developed for this action. Initial seep samples will be collected prior to the removal action to document water quality conditions prior to the removal action. A long-term seep monitoring plan will be developed and conducted during the NTCRA to evaluate the effectiveness of the collection and treatment trench, The need for additional actions will be assessed during the NTCRA. A summary of the initial seep samples is provided in Table 1.

3.3.3 ARARs

The federal and state water quality regulations are the only ARARs for this action and are primarily related to construction stormwater management. During this action the standard FHWA BMPs for construction and dewatering that were used during road reconstruction will be implemented. A description of the BMPs is located in Appendixes H, I, and J of the Contract Documents for Project AK PFH 44-1(2) (FHWA, 2006).

3.4 D-2 Site Drain

An estimated 90,000 cubic meters (117,700 cubic yards) of soil and peat and approximately 1,000 cubic meters (1,308 cubic yards) of B-5 material were disposed of at the D-2 site. The waste soil and peat has retained rainwater, which then drains through the waste to the underlying rock quarry bottom. Alternatively, rainwater may be diverted under the waste through fractures in the bedrock. The quarry rock is similar in characteristics to the B-5 cut and is an extension of the same outcrop as the B-5 rock; as a result the rock outcrop is potentially acid-generating material. Currently, a rock face situated downhill from the disposal area contains a seep that is a known ARD release point. This seep has water low in pH and contains elevated dissolved copper concentrations. The seep drains into a small creek that flows into Stream 3021 (Stream 6), which also has evidence of an ARD release as indicated by low pH and high copper. It is not known at this time if the current ARD issues at this location are a result of the relatively small amount of B-5 rock disposed of at this location or simply the increased presence of water on the rock pit resulting from the soil and peat wastes at this location causing a high retention of water.

Since ARD is occurring and the copper concentrations in the seep from this site are the highest tested to date on the FS 3030 Road site, it was decided that a TCRA is appropriate. Since the volume of waste material at this location is very high and the volume of B-5 rock within this waste is relatively small, it was decided that removal of the waste from this location is not practicable particularly since the cause of the water quality issues are unknown. However, since the ARD is emanating from a single seep location within the pit rock face, buffering of the seep was considered a good approach to address the identified problem in a quick manner consistent with the goals of a TCRA.

The proposed TCRA involves placing a limestone buttress, drain, and detention ponds at the toe of the disposed material to buffer the seepage and reduce downstream impacts. This action will allow the ARD to be evaluated in more detail and monitored as part of the NTCRA process.

3.4.1 Proposed Action Description

Soil, peat, and up to 1,000 cubic meters of B-5 rock were disposed of at the D-2 site. The total area of the disposed material is approximately 13,500 square meters (145,000 square feet). As part of the removal action a limestone drain will be placed to buffer any remaining seepage through the bedrock. At the base of the rock face where the seepage is daylighting, 50-mm-minus (2-inch-minus) limestone will be placed as a buttress. The buttress will extend to a height above the existing seeps and will be placed at a one-to-two slope. A limestone drain will be placed below the buttress. The drain will be approximately 120 meters (394 feet) long, 1 meter (3.3 feet) wide, and 2 meters (6.6 feet) deep, and will be filled with 50 mm (2 inch)-minus limestone. Three detention ponds, each approximately 20 meters (66 feet) long, will be placed in series at the end of the drain and will each have a limestone check dam. The D-2 removal action is shown in Appendix A.

3.4.2 Performance Criteria

The purpose of the TCRA is to buffer the ARD water seep from the rock pit. No performance criteria have been established for this action, but the plan is that buffering the seep will ultimately result in improved water quality downstream and ultimately in Stream 3021

(Stream 6). It is not known whether the ARD is a temporary issue at this location that will attenuate or whether further actions will be necessary in the longer term to eliminate ARD issues at this location. Water quality downstream of the rock pit will need to be monitored to evaluate the effectiveness of the buffering remedy. An initial round of seep samples will be collected prior to the removal action implementation to assess the water quality prior to implementation of the removal action. A sample summary is shown in Table 1. The long-term surface water monitoring will be designed and conducted as part of the NTCRA to evaluate the effectiveness of the limestone drain and buttress and to ensure that water quality improves to acceptable levels. At that time an investigation will also be conducted to determine if the D-2 waste pile is also contributing to poor water quality. Additional actions may be required pending the outcome of the D-2 waste pile investigation.

3.4.3 ARARs

The ARARs applicable to this TCRA are:

- the Clean Water Act, 33 U.S.C. §§ 1341 and 1344), and
- ADEC water quality standards (ADEC, 2003, 2006, and 2008).

The WFLHD 404 existing permit will apply to this action. In addition, seep sampling will be conducted to determine the effectiveness of the D-2 removal action. During this action the standard FHWA BMPs for construction that were used during road reconstruction will be implemented. A description of the BMPs is located in Appendixes H, I, and J of the Contract Documents for Project AK PFH 44-1(2) (FHWA, 2006).

3.5 CONTRIBUTION TO REMEDIAL PERFORMANCE

The actions above define the scope of the TCRA to be completed during the remainder of the 2008 construction season. Other areas of the FS 3030 Road site that are not addressed as part of the TCRA require further investigation to fill data gaps before any removal actions can be evaluated and implemented. The investigations to fill data gaps and complete characterization of the ARD and ultimately the evaluation and implementation of actions for other areas of FS 3030 Road will be completed as part of an NTCRA. The NTCRA data gaps investigation will be completed concurrently with the TCRA. The schedule and scope of work for the NTCRA are described in the Non-Time-Critical Removal Action Work Plan (AMEC Geomatrix, in progress).

3.6 REPORTING

A memorandum documenting the removal actions, including as-builts of the actions, will be completed and submitted to the FS once the removal action is complete. The schedule for submittal of this report is shown in Section 6.0.

4.0 LONG-TERM MONITORING

Long-term monitoring should be conducted to determine the degree of success of each of the removal actions. The long-term monitoring is not a time-critical component of the work and plans will be developed for monitoring and implemented as part of the NTCRA process. The number, location, and frequency of samples will be determined in the NTCRA and implementation will begin with the NTCRA sampling event(s).

5.0 TCRA IMPLEMENTATION

The TCRA work described in this work plan will be performed by WFLHD and its contractors. All work will be conducted under the supervision of a “qualified” objective third party. WFLHD has contracted with AMEC Geomatrix, Inc. (AMEC), of Seattle and Robert Peccia and Associates (RPA) of Helena, Montana, to be the third-party oversight consultant for the TCRA and NTCRA phases of work in 2008 and 2009. AMEC’s and RPA’s qualifications are provided as Appendix C of this document. Surveying, construction management, and geotechnical engineering will be conducted by Federal Highway Administration, resumes of specific staff assigned to this project are also included in Appendix C.

6.0 ESTIMATED COSTS

The estimated costs to implement the TCRAs described in this work plan are as follows.

1. Removal Action at Stream 3027 - $520,000
2. Development of the B-1 Consolidation Area - $110,000
3. Collection and Buffering Trench at B-5 Cut - $200,000
4. Buffering of seep at D-2 Pit - $70,000

The costs of the TCRA are estimated to be $900,000 based on preliminary engineering estimates. WFLHD proposes to negotiate for this work with their existing road contractor to complete this work in September through December of 2008. The actual costs will be dependent on the outcome of negotiating a price with the contractor.

7.0 PROJECT SCHEDULE

The components of the TCRA will be completed based on the following schedule. This schedule assumes that the Action Memorandum will be signed and approved on or before September 5, 2008, and that weather conditions will allow work to continue at least until December 1, 2008. Delays in work plan approval or unfavorable weather conditions will result in schedule delays. The ability to complete all three TCRAs in the 2008 construction season will be dependent on maintaining the schedule. If the schedule is delayed one or more of the actions may not be able to be conducted.

Because they are perceived as the most critical TCRAs, work will begin concurrently at Stream 3027 and the B-1 consolidation area so that these removal actions can be completed during 2008. This removal action is expected to require 30 to 45 days to complete. Once the Stream 3027 and B-1 removal actions are complete, work can begin on the B-5 removal action, which is estimated to take 30 days to complete. If conditions allow, the D-2 removal action will be implemented once the B-5 removal action is complete. Any TCRAs not completed during 2008 will be completed as part of the NTCRAs.

Milestone	Start Date	Completion Date
Action Memorandum approval	Not applicable	September 5, 2008
Stream 3027 and B-1 removal actions (concurrent)	September 15, 2008	45 days from start of work
B-5 removal action	Immediately following Stream 3027 and B-1 removal actions completion	30 days from start of work
D-2 removal action	Immediately following B-5 removal action completion	14 days from start of work
As-built report completion	December 15, 2008	February 28, 2009

8.0 REFERENCES

ADEC (Alaska Department of Environmental Conservation), 2003, Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances, May 15.

ADEC, 2003, Title 18 AAC 60, Solid Waste Management, August 8.

ADEC, 2006, Title 18 AAC 70, Water Quality Standards, December 28.

ADEC, 2008, Title 18 AAC 75, Oil and Other Hazardous Substances Pollution Control, July 1.

DEA (David Evans and Associates, Inc.), 2008, Phase 1 Site Characterization Plan and Preliminary Report – Coffman Cove Road Water Quality Assessment: Prepared for the Federal Highway Administration Western Federal Lands Highway Division, July.

FHWA (Federal Highway Administration), 2006, Contract Documents for Project AK PFH 44-1(2), Coffman Cove Road, Phase II: Prepared by the U.S. Department of Transportation, Federal Highway Administration, Issued March 24.

HEC (Herrera Environmental Consultants, Inc.), 2004, Preliminary Jurisdictional Wetland Determination Report: Prepared for Federal Highway Administration Western Federal Lands Highway Division, January 29.

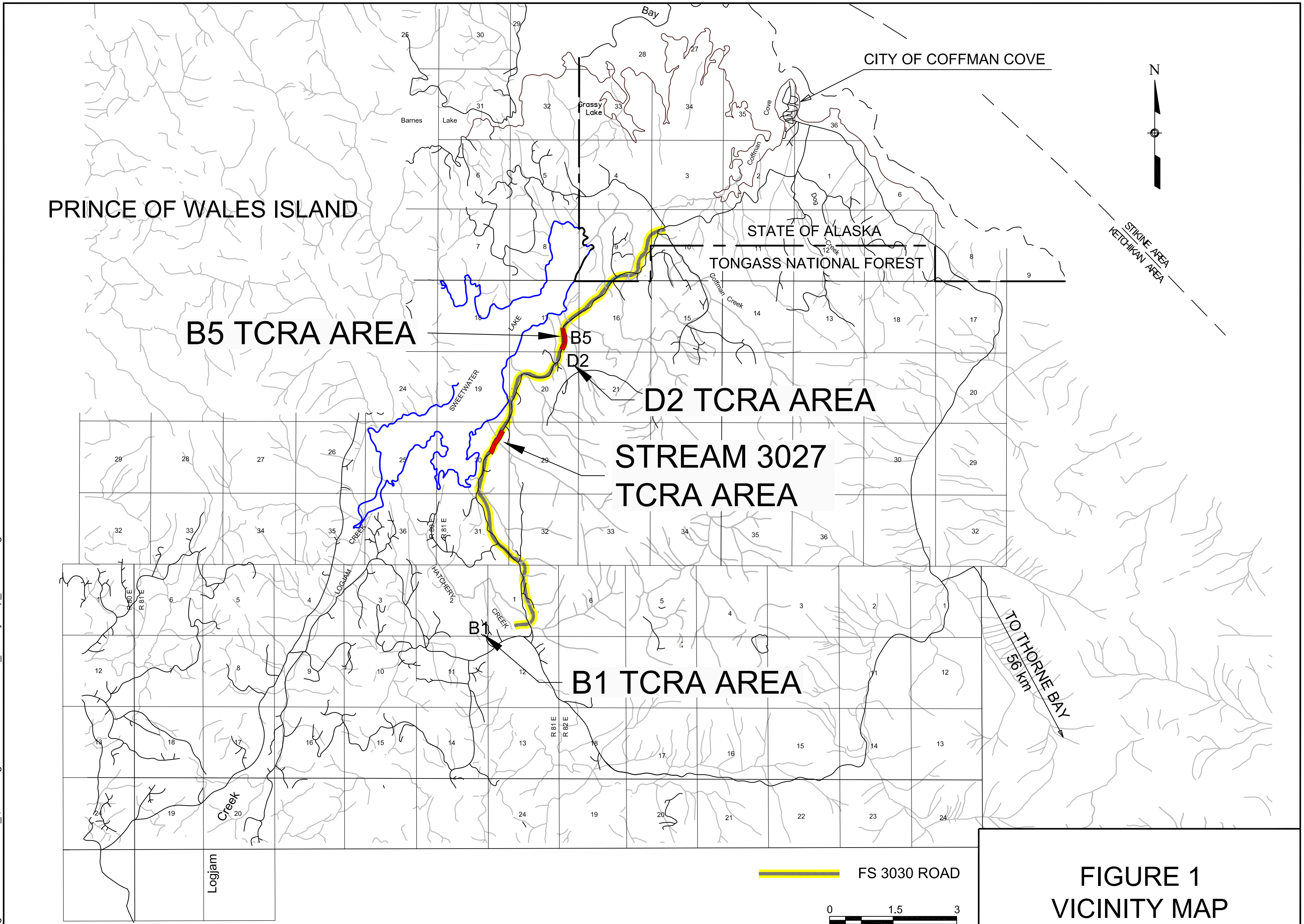
TABLE 1

SAMPLE SUMMARY
FS 3030 Road Site
Prince of Wales Island, Alaska

Removal Action Area	Location	Sample Media	Distance Upstream (-) or Downstream (+) (meters)	pH	Conductivity	DO	Temperature	TDS	Turbidity	ORP	Dissolved Organic Carbon	TOC	Cations and Metals[1]	Ammonia	Nitrate + Nitrite - Nitrogen	Chlorine	Alkalinity (HCO_3, CO_3)	Sulfate
Stream 3027	Culvert 19+887	Surface Water	-150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Culvert 19+887	Surface Water	+1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Culvert 19+887	Surface Water	+150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Culvert 19+964	Surface Water	-150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Culvert 19+964	Surface Water	+1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Culvert 19+964	Surface Water	+150	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Culvert 19+964	Surface Water	+300	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Culvert 19+964	Surface Water	+450	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B-1 Consolidation Area	Piezometer 1	Groundwater	N/A	X	X	X	X	X	X	X			X		X		X	X
	Piezometer 2	Groundwater	N/A	X	X	X	X	X	X	X			X		X		X	X
	Piezometer 3	Groundwater	N/A	X	X	X	X	X	X	X			X		X		X	X
	Piezometer 4	Groundwater	N/A	X	X	X	X	X	X	X			X		X		X	X
	Piezometer 5	Groundwater	N/A	X	X	X	X	X	X	X			X		X		X	X
	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
B-5 Collection and Buffering Trench	Culvert 23+257	Surface Water	+1	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
D-2	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Visible Seep	Seep	N/A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Notes
1. Cations / Metals = aluminum, arsenic, total and dissolved cadmium, calcium, total and dissolved chromium, total and dissolved copper, total and dissolved iron, magnesium, manganese, nickel, potassium, selenium, sodium, and zinc.

Abbreviations
CO_3 = carbonate
DO = Dissolved Oxygen
HCO_3 = bicarbonate
N/A = not applicable
ORP = Oxidation Reduction Potential
TDS = Total Dissolved Solids
TOC = Total Organic Carbon



BASEMAP COURTESY OF ROBERT PECCIA & ASSOCIATES

FIGURE 1
VICINITY MAP

Plot Date: 08/18/08 - 1:12pm, Plotted by: astenberg
Drawing Path: S:\14481\001_\, Drawing Name: Coffman Cove_Vicinity Map_081308.dwg

APPENDIX A

Removal Action Plans Set

A.1

Stream 3027 Site Plans

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	1

Stream 3027 site

TABULATION OF PLAN QUANTITIES				
Item number	Description	Unit	Quantity	
			19+820 TO 20+020	14+200 B1 Material Source and Consolidation Area
15201-0000	Construction Survey and Staking	Lump Sum		
15301-0000	Contractor Quality Control	Lump Sum		
15401-0000	Contractor Testing	Lump Sum		
15705-0100	Soil Erosion control Silt Fence	m	400	
15705-1500	Soil Erosion control Sediment Wattle	m	50	
15801-0000	Watering For Dust Control	m3	30	
20450-1000	Rock Borrow	m3	12000	
	50 mm drain rock, limestone	m3		80
20701-0100	Earthwork Geotextile, Type I-A	m2		242
20701-0700	Earthwork Geotextile, Type II-A	m2		7000
	40 mil HDPE Liner	m2		3500
	Surfacing Removal and Replacement	m3	800	
30101-2000	Aggregate Base Grading D 1/	ton	400	
60201-1500	1500 mm Pipe Culvert, Plastic	m	29	
62201-0200	Dump Truck, 8 Cubic meter minimum capcapacity	Hour		70
62201-0950	Wheel Loader, 3 cubic meter minimum rated capacity	Hour		80
62201-1950	Bulldozer, universal blade, 225kW minimum	Hour		80
62201-2850	Motor Grader, 3.6 m minimum blade	Hour		40
62201-3150	Hydraulic Excavator, crawler mounted 0.7 (m3) minimum capacity with thumb attachment	Hour		40
62301-0000	General Labor	Hour		80

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FOOTNOTE:

1/ Quantity based on estimated 20% loss of Select Topping and Aggregate Base Grading D.

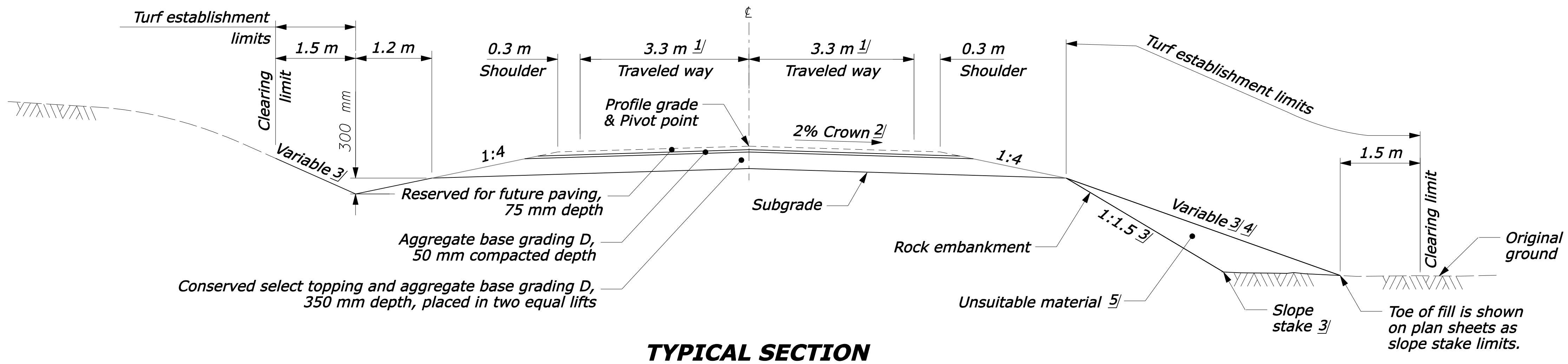
TABULATION OF PLAN QUANTITIES

F:\highways\FHWA\Coffman_paving\08550005_DSDC\Design\Typical Sections\Stream 13-Aug-2008 3:40 Designed by: C. Voermans 8/2008 Checked by: Brian Wacker

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	2

Stream 3027 site

CURVE WIDENING TABLE 1/		
LOCATION	SIDE	ADDITIONAL WIDTH (m)
19+928.45 to 19+942.28	LT.	0.65
19+928.45 to 19+942.28	RT.	0.65



TYPICAL SECTION
FOREST ROAD 3030
19+820 TO 19+880 9/
19+890 TO 20+020 9/

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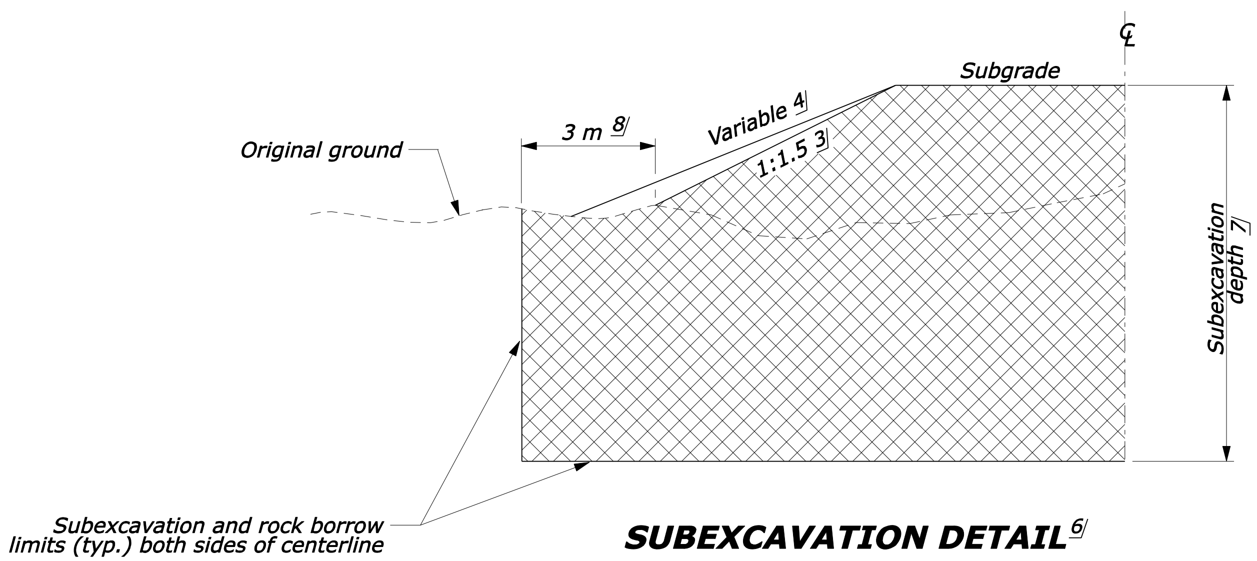

SUBEXCAVATION DETAIL 6/

FOOTNOTE:

1/ Curve widening is distributed equally on each side for spiral curves and only on the inside of the curve for simple curves. Construct curve widening as shown in the Staking Report (See FAR 52.236-4).

2/ Superelevate roadway on curves at the rate "e" as indicated on the plan and profile curve data.

3/ Construct cut and fill slopes as shown on the Staking Report (See FAR 52.236-4).

4/ Construct slopes as shown on plotted cross-sections.

5/ Place a minimum 300 mm of unsuitable material on all fill slopes.

6/ Backfill subexcavation with rock borrow. See sheet 1 for quantities.

7/ See cross sections for estimated subexcavation depths.

8/ Adjust as shown on cross sections and as approved by CO.

9/ Adjust limits as approved by CO to avoid impacts to existing pipe.

TYPICAL SECTION AND SUBEXCAVATION DETAIL

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STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	3

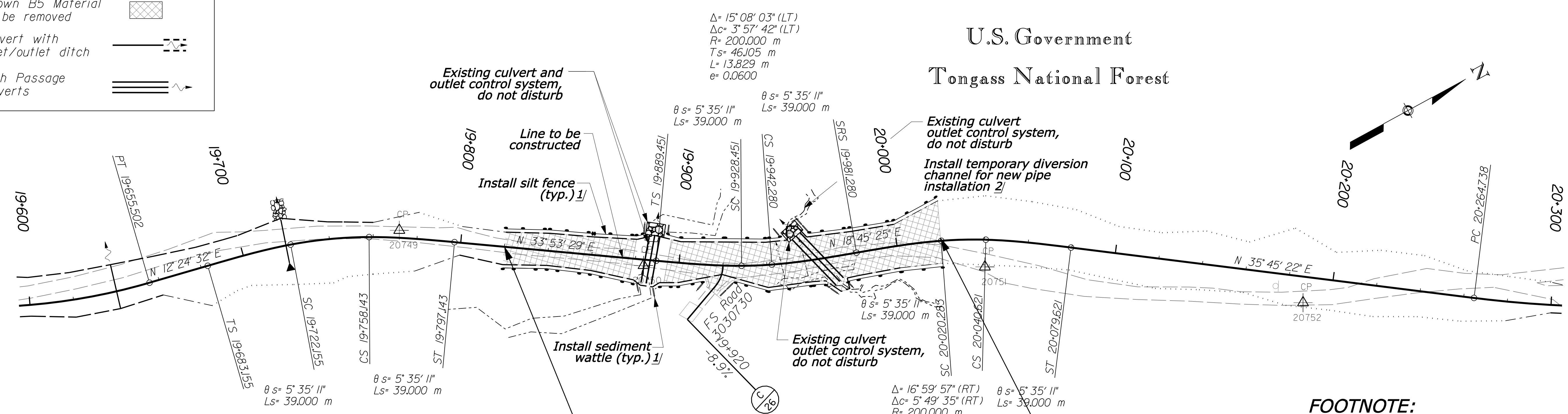
Stream 3027 site

U.S. Government

Tongass National Forest

LEGEND:

- Known B5 Material to be removed
- Culvert with inlet/outlet ditch
- Fish Passage Culverts



CONTROL POINTS

NAME	NORTHING	EASTING	ELEVATION
20-749	458256.509	864450.925	19.207
20-750	458346.529	864518.336	19.412
20-751	458482.774	864593.462	20.315
20-752	458602.229	864677.245	28.979

FOOTNOTE:

1/ Install silt fence and sediment wattles as shown at both the existing and proposed culvert locations. See detail sheets 4 and 5.

2/ See detail sheet 6.

3/ See detail sheet 9.

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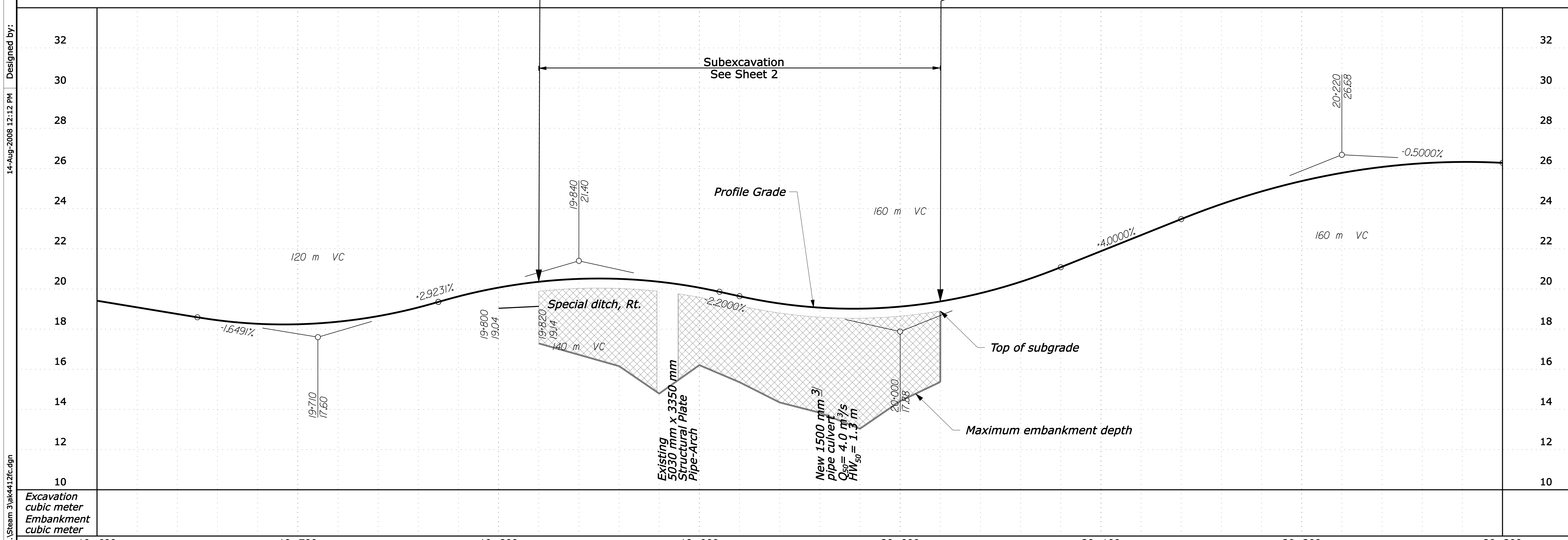

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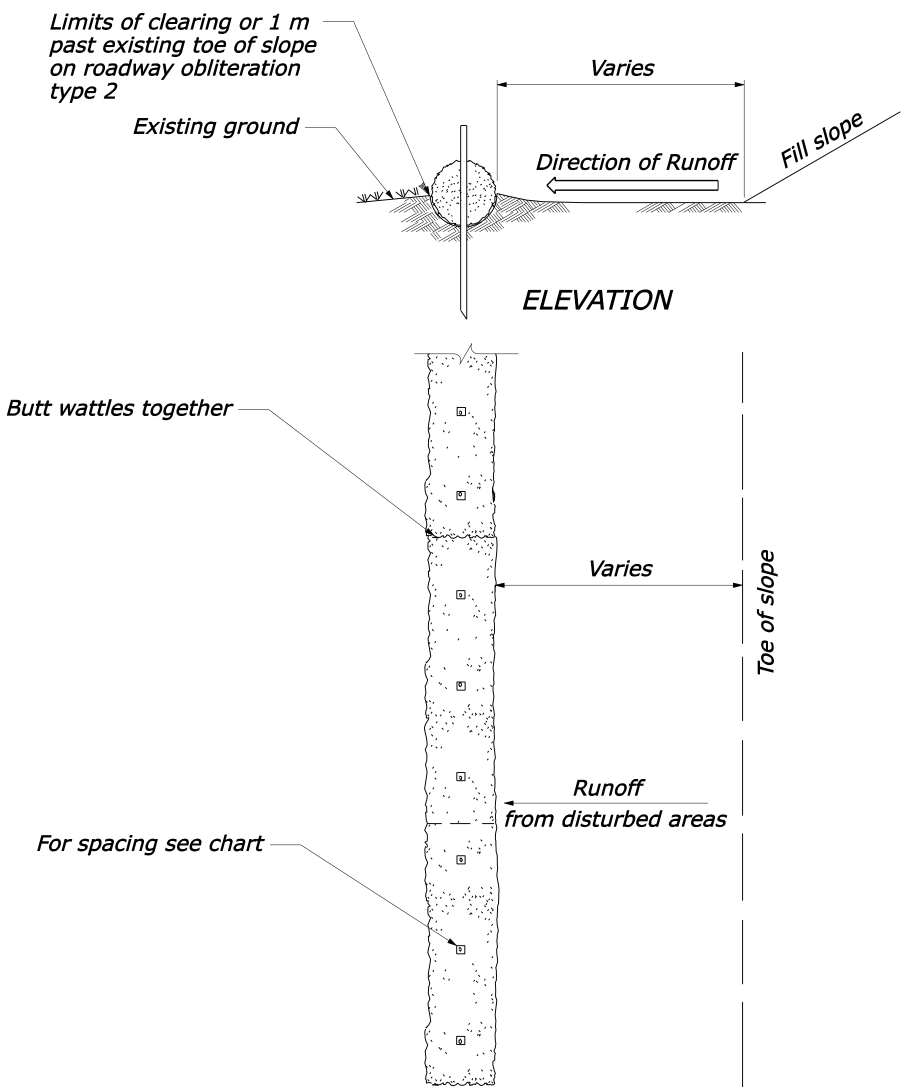
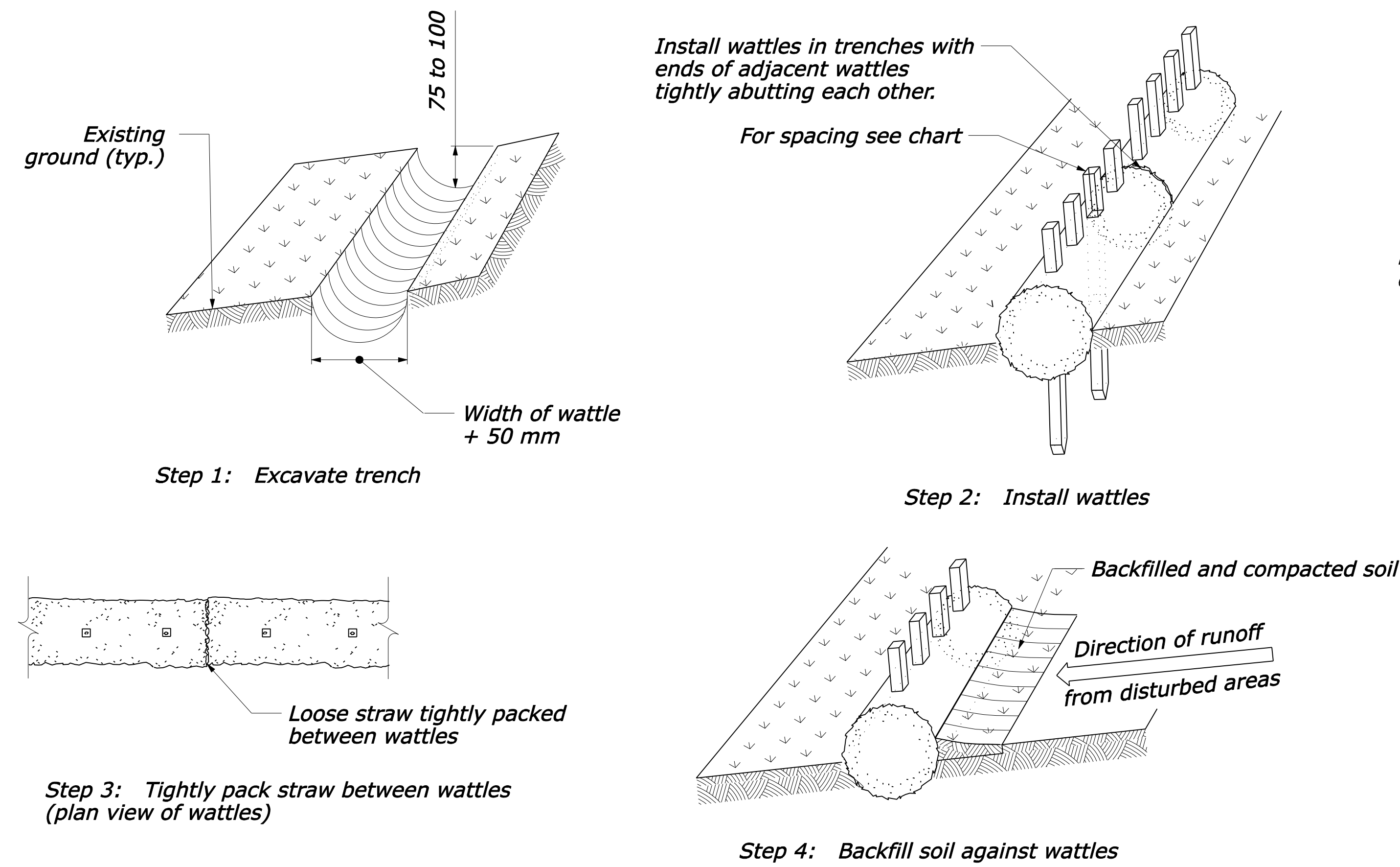
STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	4

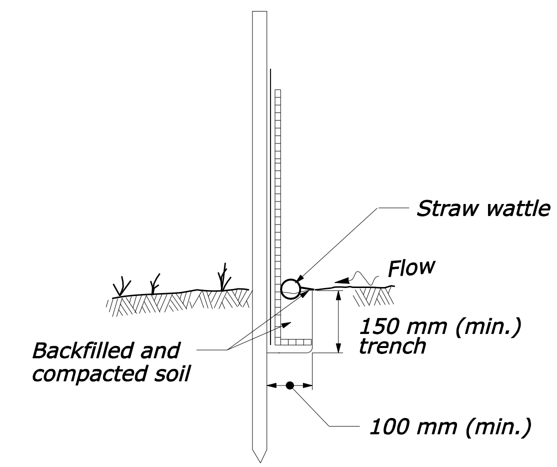
Stream 3027 site



INSTALLATION OF A SEDIMENT WATTLE BARRIER AT TOE OF FILL

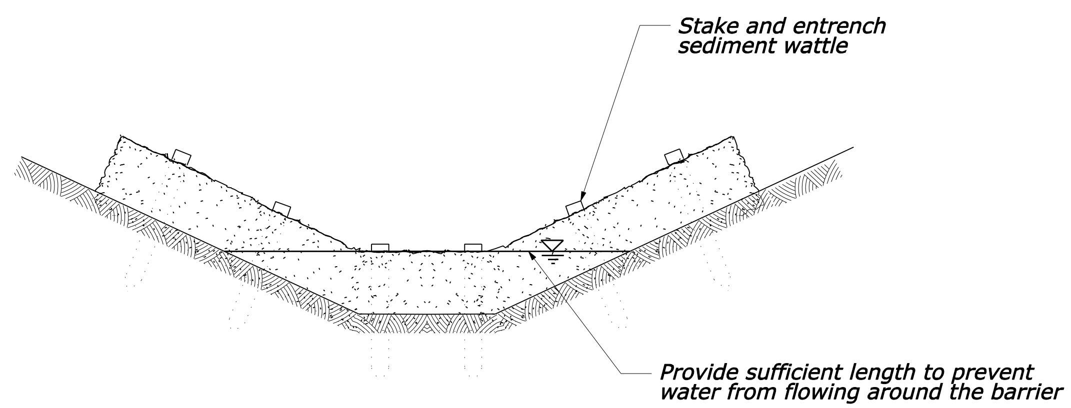


PROPERLY STAKED AND ENTRENCHED SEDIMENT WATTLES

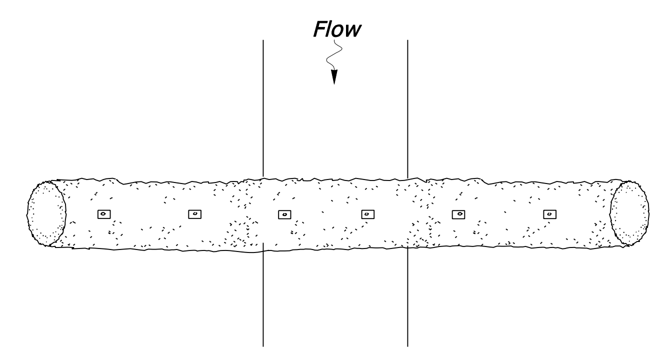


SEDIMENT WATTLE WITH SILT FENCE DETAIL

STAKE SPACING	
Wattle length (m)	No. of stakes (each)
7.5	6
6.0	5
3.7	4



ELEVATION



PLAN

INSTALLATION OF A SEDIMENT WATTLE BARRIER IN DITCH

NOTE:

1. Use sediment wattles in drainage ditches for only low flow conditions.
2. See Sheet 5 for silt fence details.
3. Dimensions not labeled are in millimeters.

SEDIMENT WATTLES

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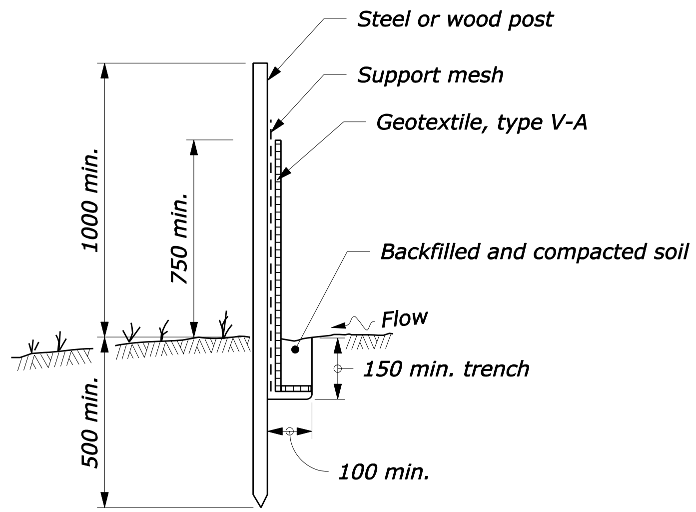
Designed by: C. VOERMANS 07/2007

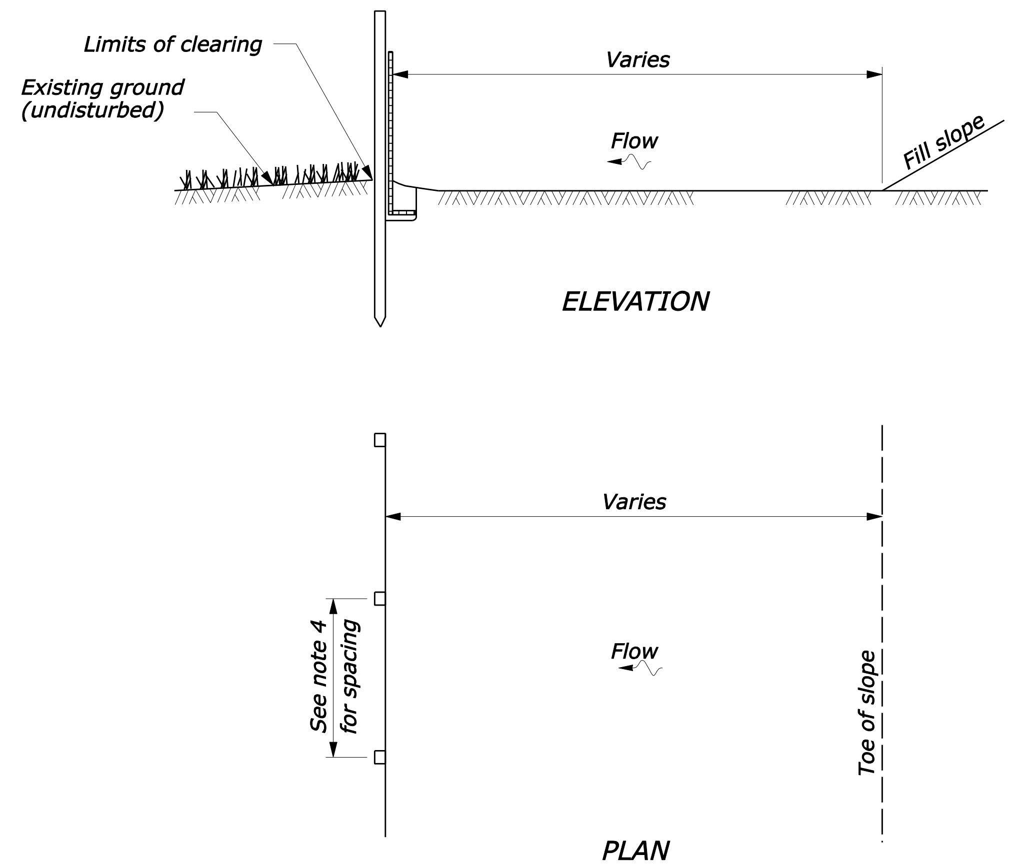
Checked by: B. WACKER 07/2007

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	5

Stream 3027 site



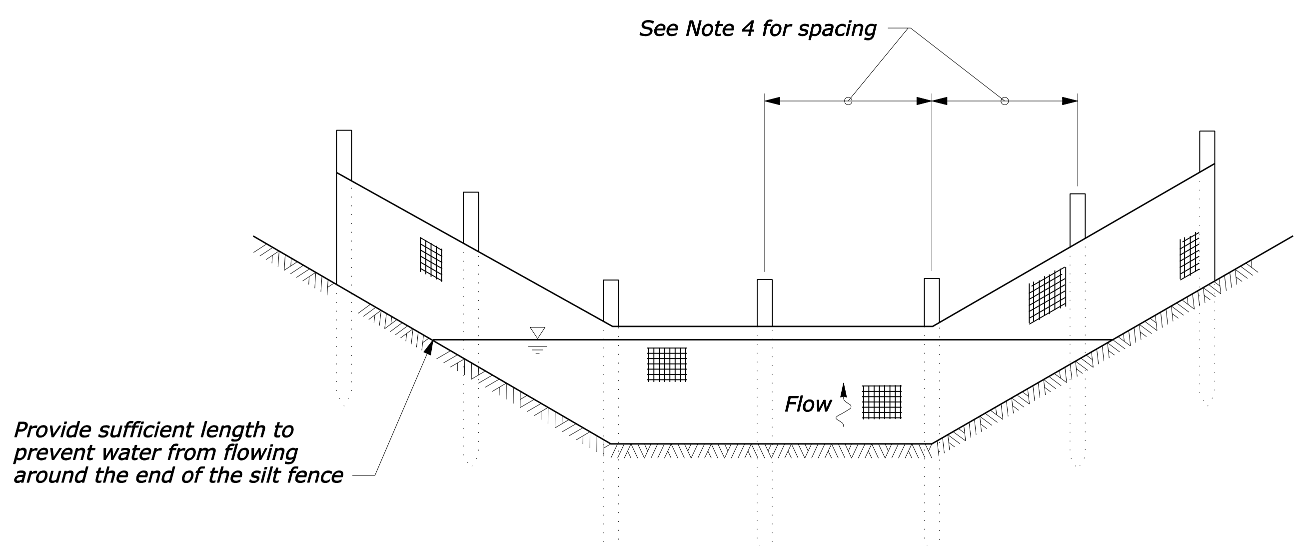
POST AND GEOTEXTILE INSTALLATION DETAIL



SILT FENCE INSTALLATION AT TOE OF FILL

NOTE:

1. Use drainage ditch installation for low flow conditions only when specified on Erosion Control Plan.
2. Alternate preassembled silt fence options (geotextile, type V-B) will be allowed as long as specified dimensions are satisfied. Follow manufacturer's recommendations for installation procedures. All types must ensure silt fence remains attached to, and does not slide down, supporting posts.
3. Install silt fence along ground contours. Curve ends of silt fence upgrade to prevent water from running around the ends.
4. 3.0 m (max.) spacing with fence support. 1.8 m (max.) spacing without fence support.
5. Dimensions without units are millimeters.



SILT FENCE INSTALLATION IN A DRAINAGE DITCH
See Note 1

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

METRIC STANDARD

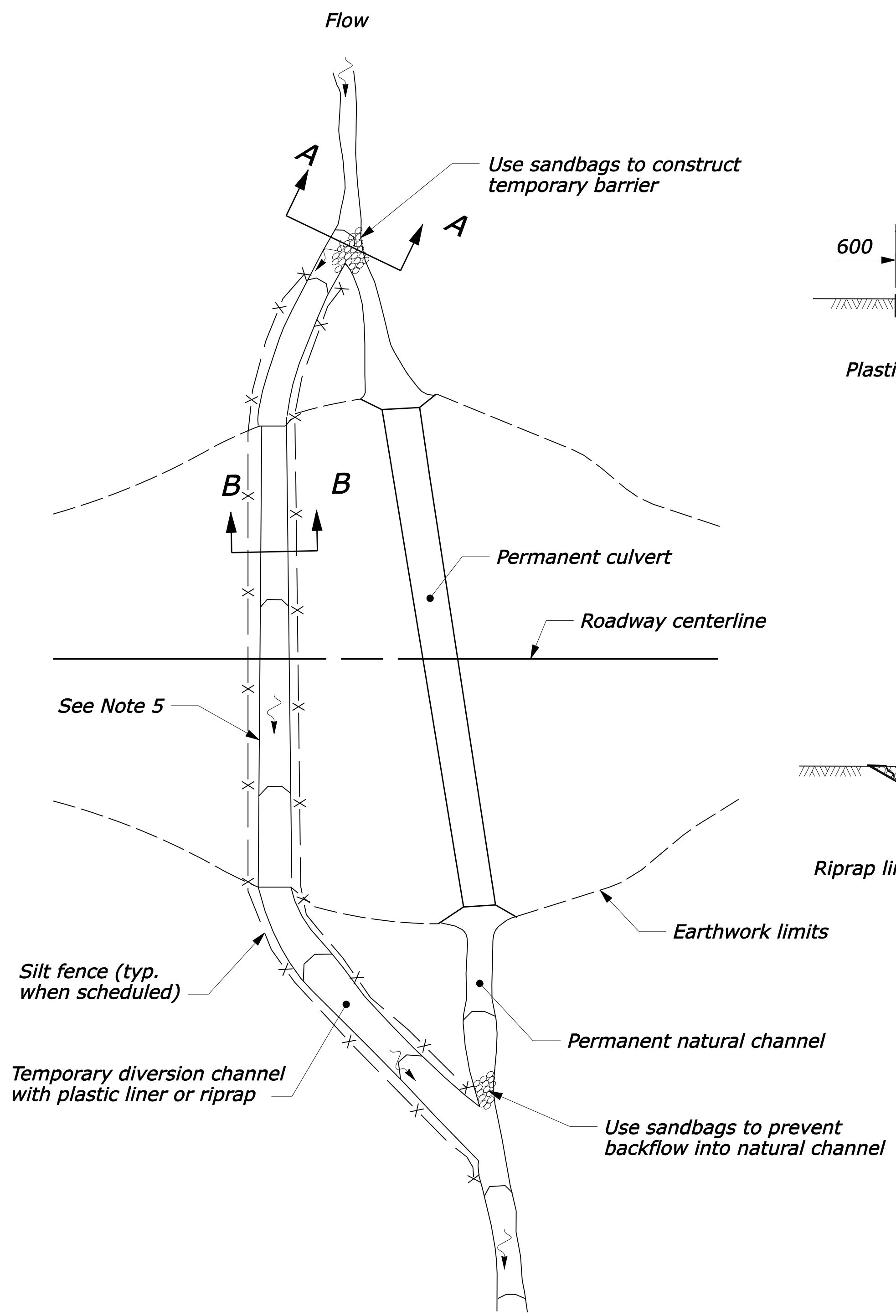
SILT FENCE

STANDARD APPROVED FOR USE 3/1996
REVISED: 6/1997 6/2005 6/2007

STANDARD
M157-1

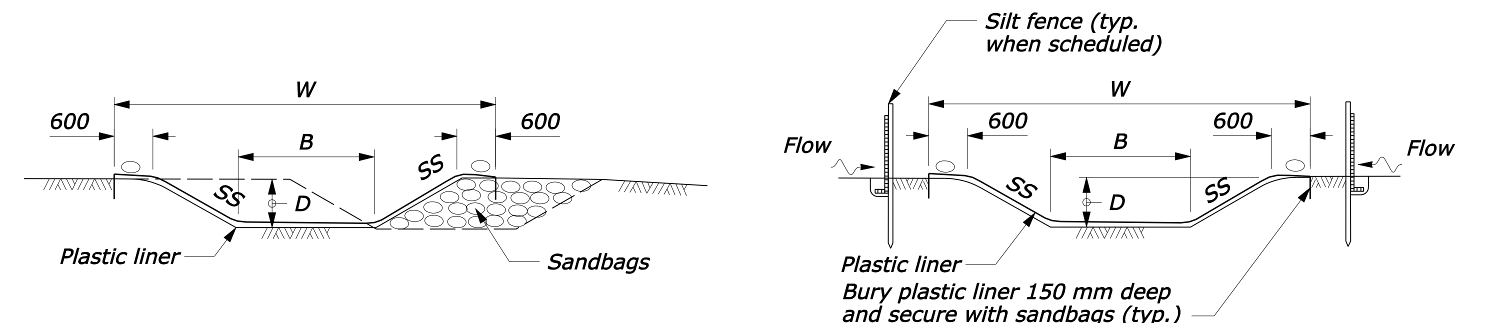
STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	6

Stream 3027 site



PLAN

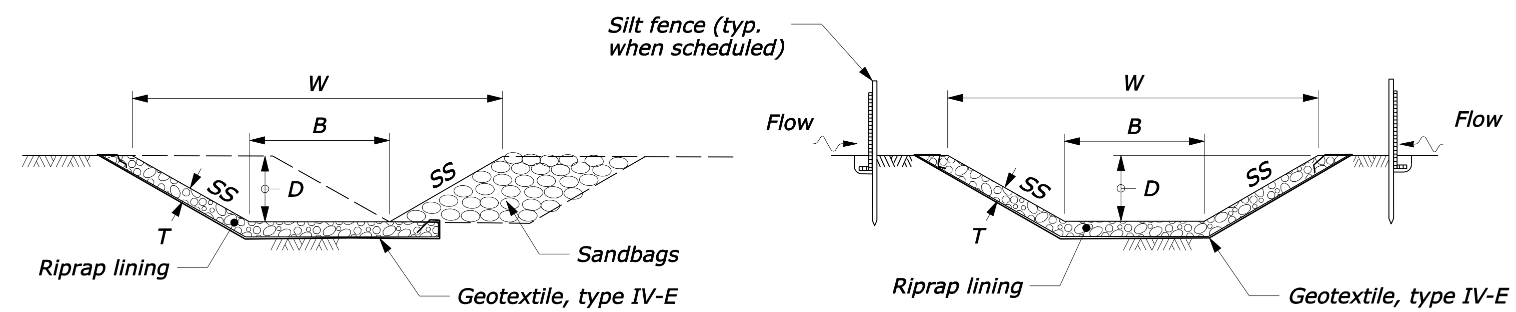
DIVERSION CHANNEL



SECTION A-A

SECTION B-B

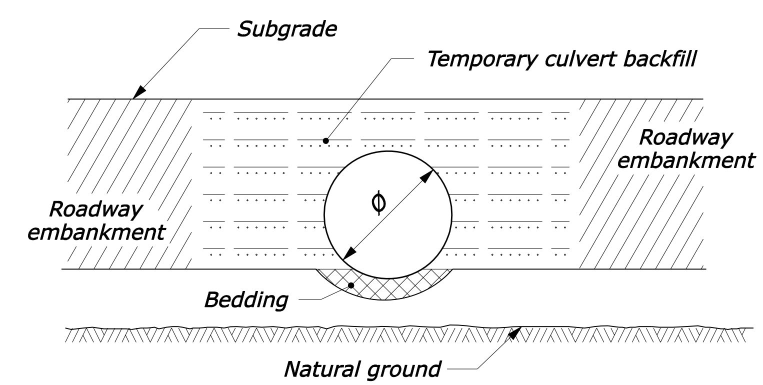
PLASTIC LINED DIVERSION CHANNEL



SECTION A-A

SECTION B-B

RIPRAP LINED DIVERSION CHANNEL



SECTION B-B

TEMPORARY CULVERT

NOTE:

1. See Erosion Control Section for temporary culvert diameter, riprap class, channel dimensions and quantities.
2. Use plastic liner or riprap along the entire length and width of the temporary diversion channel.
3. Construct channel at a minimum grade of 0.5 percent.
4. Do not construct with longitudinal joints if using a plastic liner. Bury the upstream edge of the liner a minimum of 150 mm deep and secure with riprap or sandbags.
5. When specified replace the portion of the diversion channel through the roadway embankment with temporary culvert. Compact temporary culvert backfill using one of the methods listed in Subsection 204.11(a).
6. Dimensions without units are millimeters.

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NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

METRIC STANDARD

TEMPORARY DIVERSION CHANNELS

STANDARD APPROVED FOR USE 3/1996

REVISED: 6/1997 12/1998 6/2005 6/2007

STANDARD M157-5

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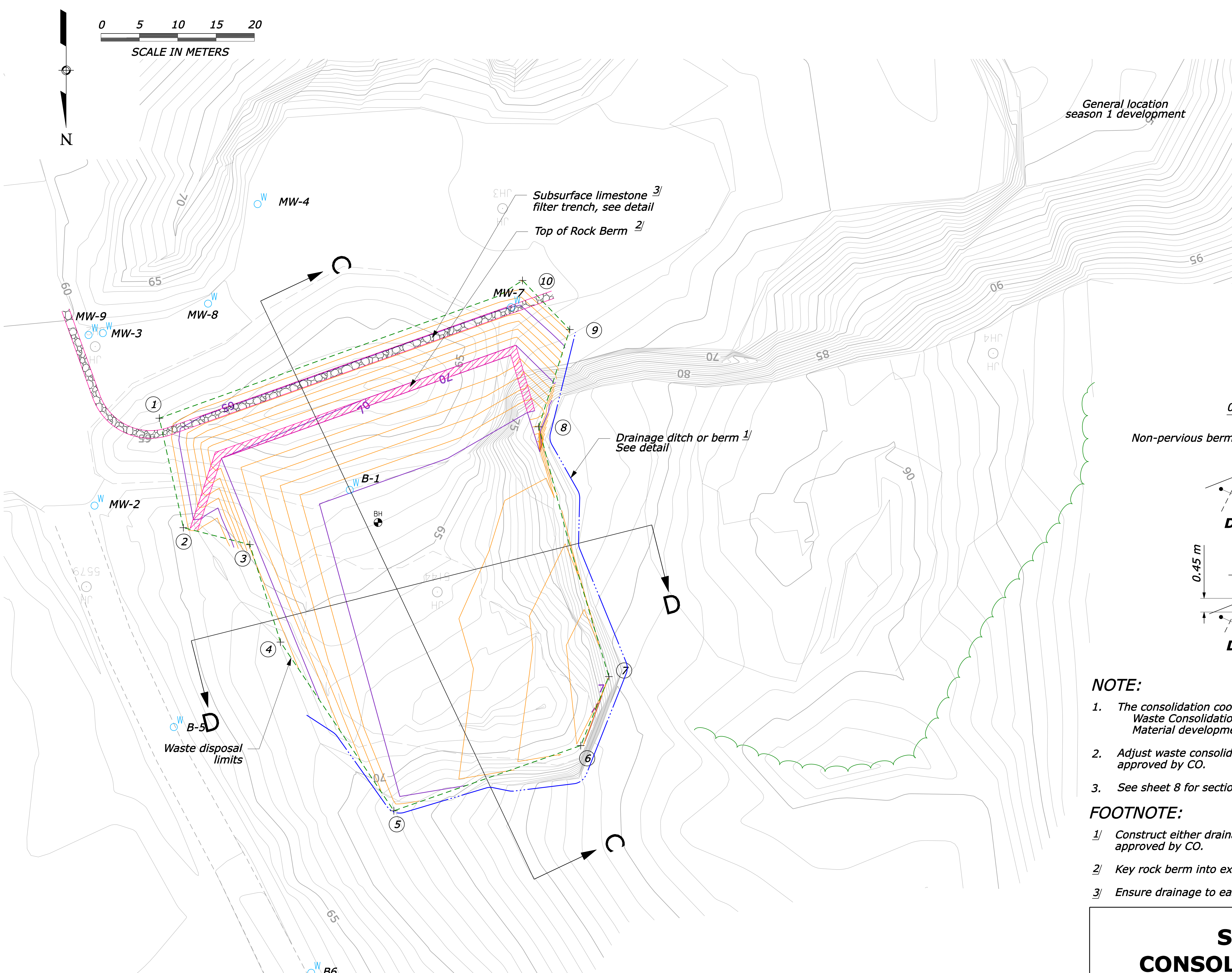
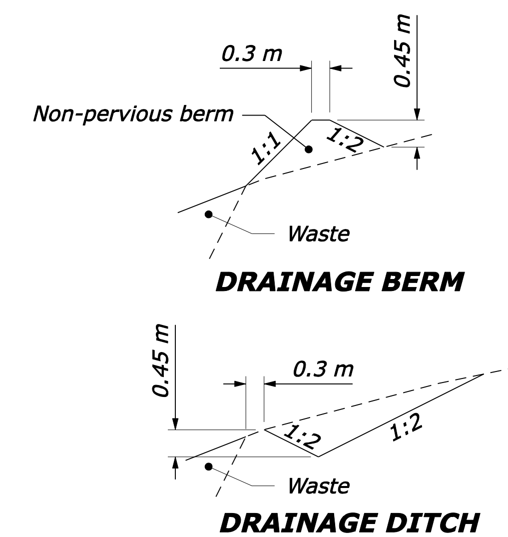
STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	7

Stream 3027 site



BORROW DEVELOPMENT COORDINATE TABLE		
P#	NORTHING	EASTING
1	453 873.847	864 590.947
2	453 888.118	864 587.816
3	453 890.328	864 579.162
4	453 903.033	864 575.157
5	453 925.015	864 560.380
6	453 916.521	864 536.028
7	453 907.533	864 532.368
8	453 874.975	864 541.506
9	453 862.293	864 537.455
10	453 855.894	864 543.623



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NOTE:

1. The consolidation coordinates are based on the following:
   Waste Consolidation 18 200 m3
   Material development 17 400 m3
2. Adjust waste consolidation based on field conditions as approved by CO.
3. See sheet 8 for sections.

FOOTNOTE:

1/ Construct either drainage ditch or berm as approved by CO.

2/ Key rock berm into existing rock wall.

3/ Ensure drainage to east.

SEASON 1 CONSOLIDATION PLAN

08/2008
B. WACKER
Checked by:
08/2008
M. JOHNSON
Designed by:
13-Aug-2008 05:22 PM
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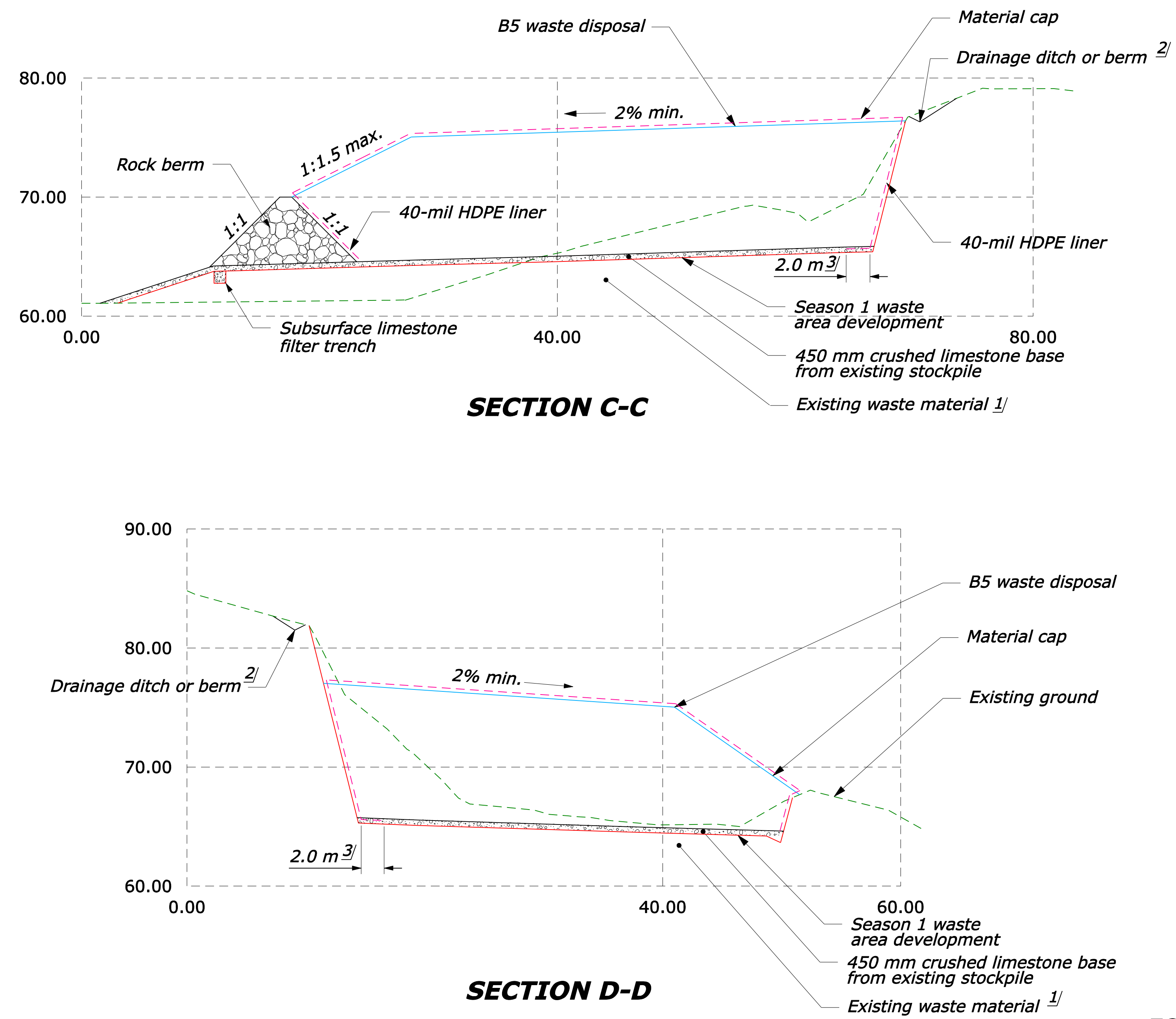

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FOOTNOTE:

1/ *Level existing waste material and prep for 450 mm crushed limestone base.*

2/ *See sheet 7.*

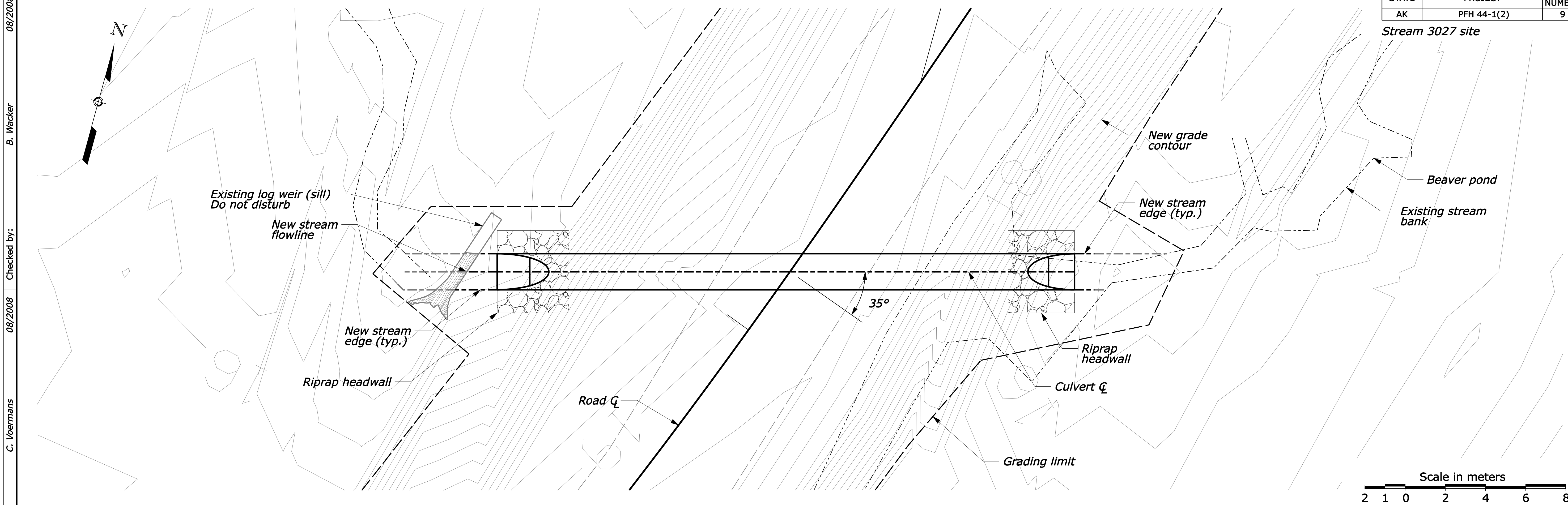
3/ *Key 40-mil HDPE liner and earthwork geotextile type II-A into crushed limestone base.*

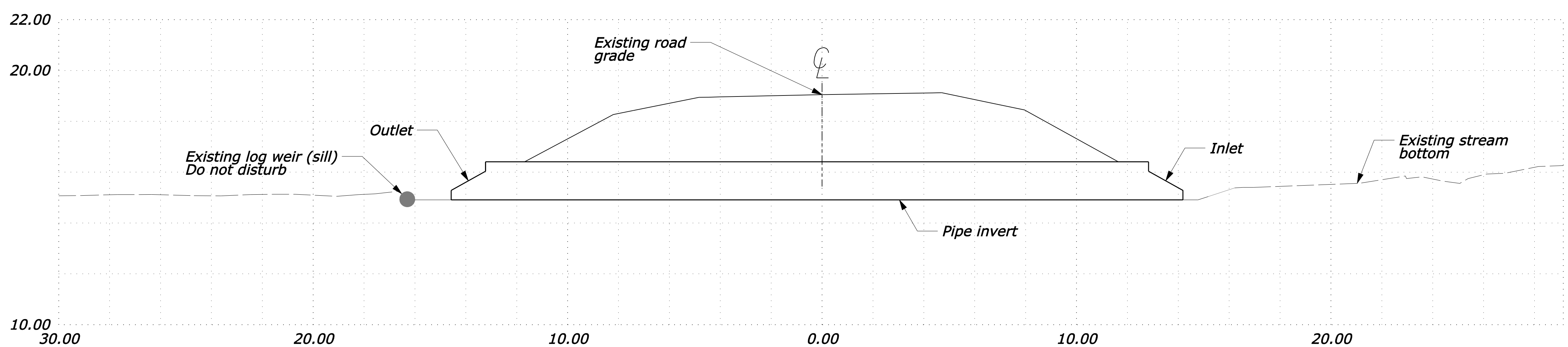
SEASON 1 CONSOLIDATION SECTIONS

08/2008 B. WACKER Checked by: 08/2008 M. JOHNSON Designed by: 14-Aug-2008 01:39 PM ...\ak4412md.dgn

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	9

Stream 3027 site





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08/2008 B. Wacker Checked by:
08/2008 C. Voermans Designed by:
14-Aug-2008 12:19 PM
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NOTE:

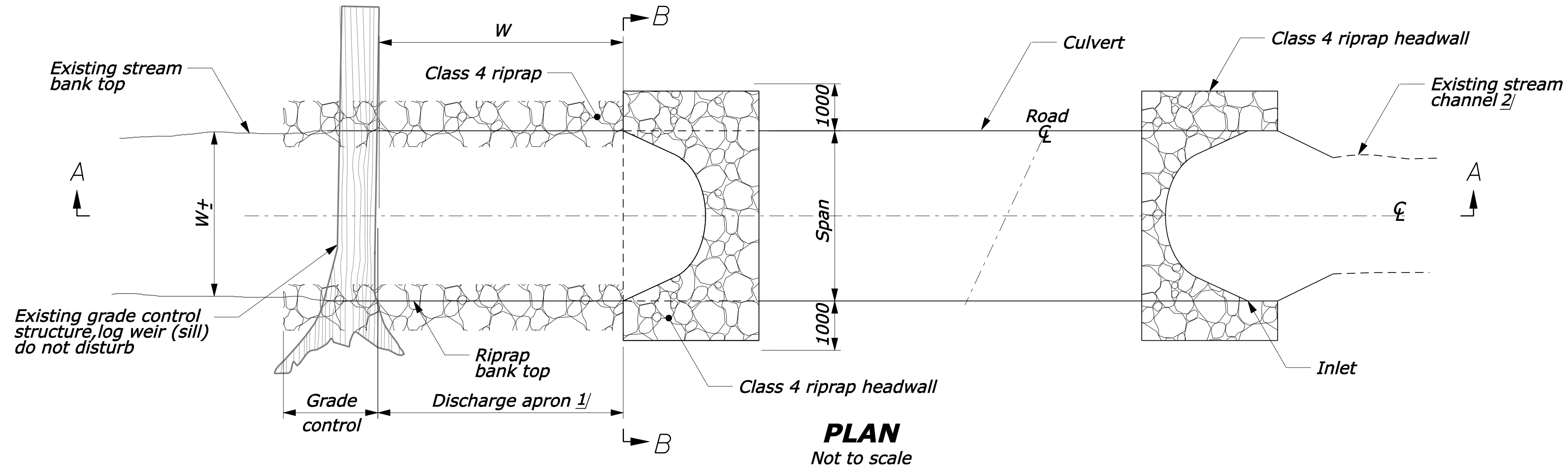
1. See sheet 10 for details.

HYDRAULIC INFORMATION	PIPE	INLET	OUTLET
Q_2: 1.4 m3/s OHW: 0.3 m	TYPE: PLASTIC ROUND PIPE	FLOWLINE EL: NA	FLOWLINE EL: NA
Q_{50}: 4.0 m3/s HW_{50}: 1.3 m	DIA: 1500 LENGTH: 28.7 m +/-1 m WALL THICK.:	EMBEDMENT DEPTH: 0.5 m	EMBEDMENT DEPTH: 0.3 m
FISH SPECIES: coho salmon	PIPE SLOPE: 0.000 m/m +/-1%	HEAD WALL: CLASS 4 RIPRAP	HEAD WALL: CLASS 4 RIPRAP
INSTREAM WORK WINDOW: 6/15to9/01	FLOWLINE SLOPE: NA	BEVEL: STEP 1.5(h):1(V)	BEVEL: STEP 1.5(h):1(V)
ACTIVE CHANNEL WIDTH: 1.8 m	INFILL TYPE: NONE SBM TYPE: NONE	LOWER BEVEL STEP HEIGHT: 0.375 m	LOWER BEVEL STEP HEIGHT: 0.375 m

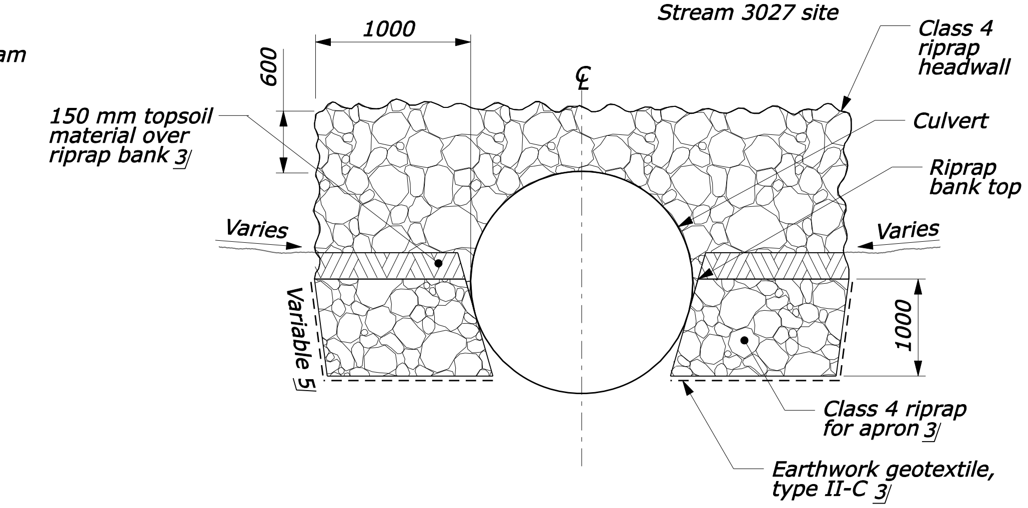
19+964
FISH PASSAGE CULVERT

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	10

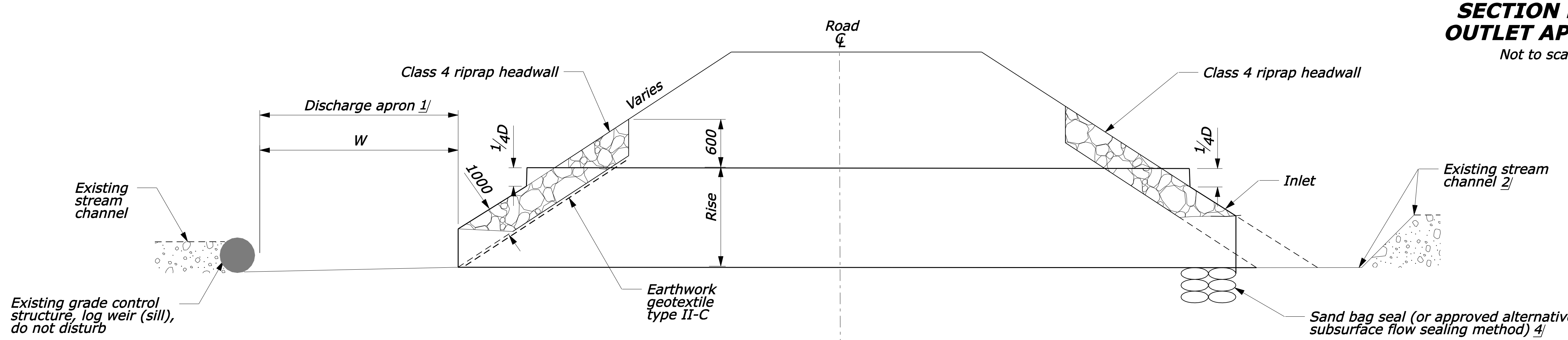
Stream 3027 site



PLAN
Not to scale



SECTION B-B
OUTLET APRON
Not to scale



SECTION A-A
Not to scale

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NOTE:

1. Dimensions not labeled are in millimeters.

FOOTNOTE:

1/ Reconstruct disturbed discharge apron as approved by CO. Do not disturb log weir sill.

2/ Reconstruct disturbed stream channel to its original configuration (elevation, width, side slopes) as approved by CO.

3/ Reconstruct disturbed riprap bank alignment as needed to transition outlet area to match existing stream. Replace Earthwork Geotextile as required.Conserve a minimum of 150 mm topsoil to be placed over disturbed areas as approved by CO.

4/ Sand bag seal: Place sand-filled sand bags beneath culvert completely across excavation and up around culvert to bottom of culvert bevel.

5/ Minimize slope according to field conditions.

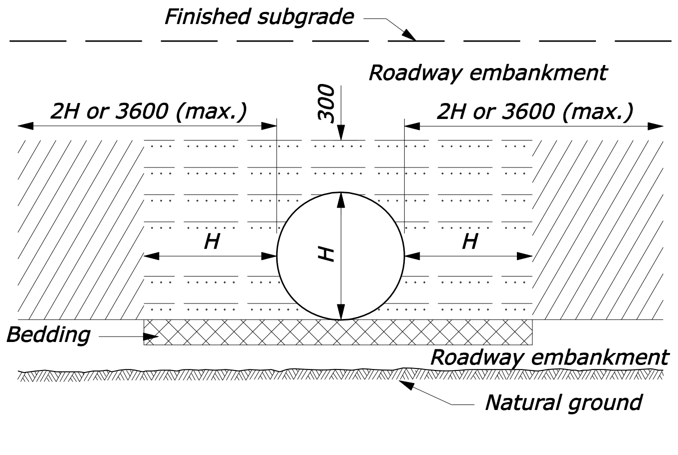
INFORMATION ONLY				
CULVERT OUTLET CONTROL SYSTEM				RIPRAP HEADWALL
LOCATION	W (m)	P (mm)	GRADE CONTROL STRUCTURE	GEOTEXTILE TYPE II-C AREA (m2)
19+964	1.8		Log weir (sill)	27.2

RIPRAP HEADWALL AND DISCHARGE APRON DETAILS

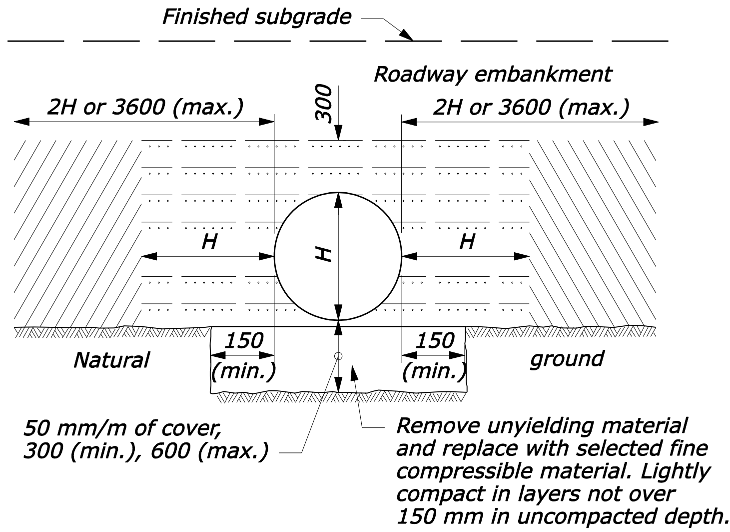
...\Drainage\Stream 3\ak4412er.dgn | 13-Aug-2008 05:25 PM | Designed by: C. Voermans 08/2008 | Checked by: B. Wacker 08/2008

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	11

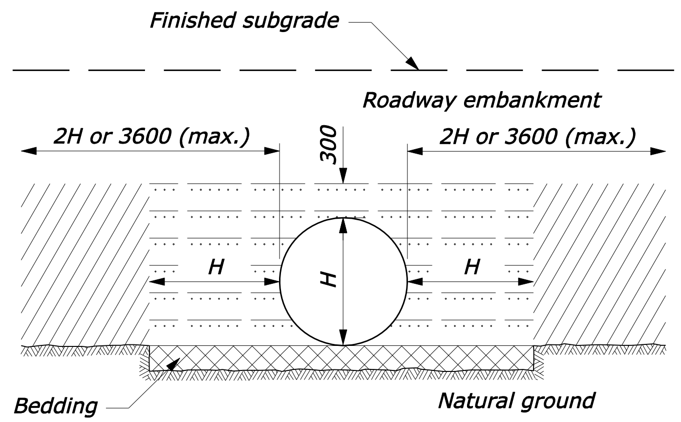
Stream 3027 site



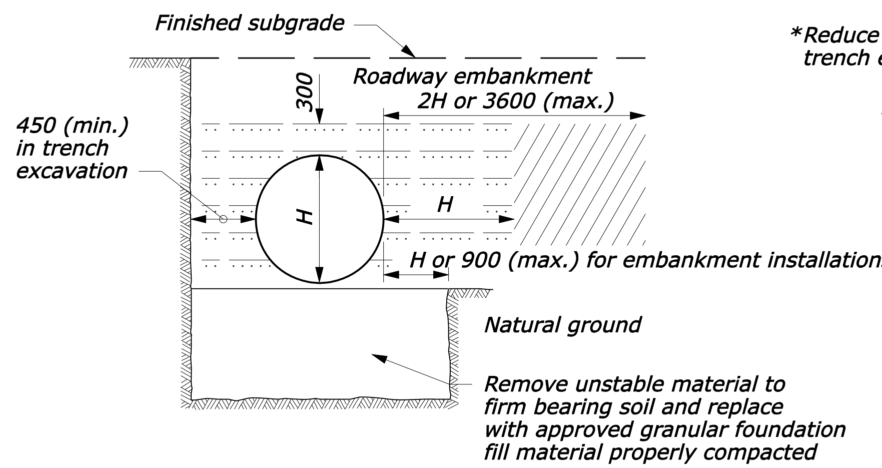
ABOVE NATURAL GROUND



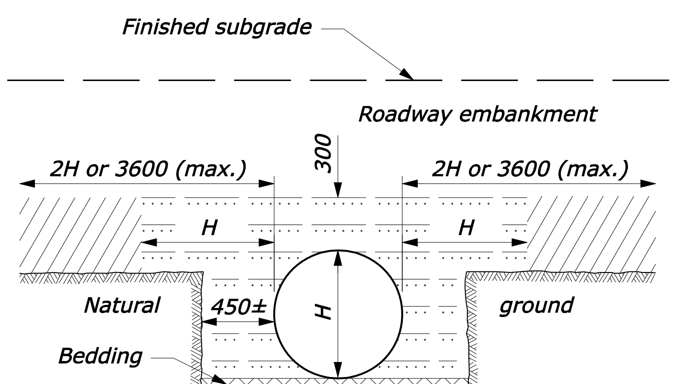
ON UNYIELDING MATERIAL



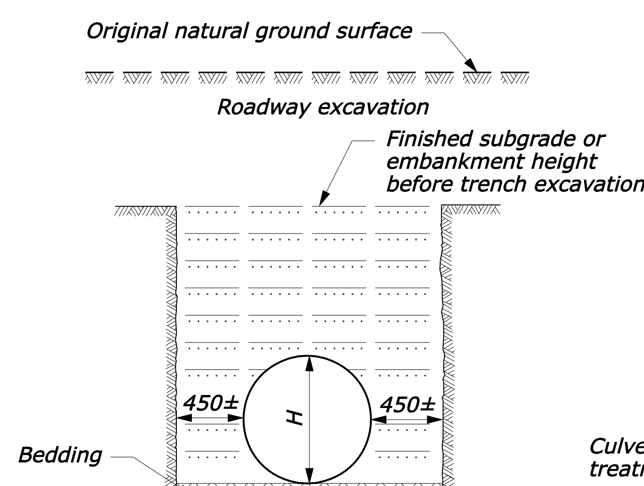
ON NATURAL GROUND



ON UNSTABLE MATERIAL



ABOVE AND BELOW NATURAL GROUND



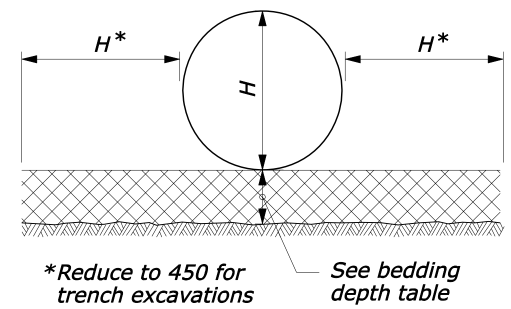
BELOW NATURAL GROUND OR TRENCH EXCAVATION IN EMBANKMENT

Bedding material (uncompacted)

Embankment material placed in layers not exceeding 150 mm compacted depth.

Compacted backfill material placed in layers not exceeding 150 mm compacted depth meeting the following:
Metal Pipe: Maximum particle size = 75 mm
Soil classification: A-1, A-2, or A-3
Plastic Pipe: Maximum particle size: 37.5 mm
Soil classification: A-1, A-2-4, A-2-5, or A-3
Or lean concrete backfill in accordance with Section 614.

BEDDING DEPTH	
PIPE SIZE (H)	DEPTH
300 to 1350	100
> 1350	150

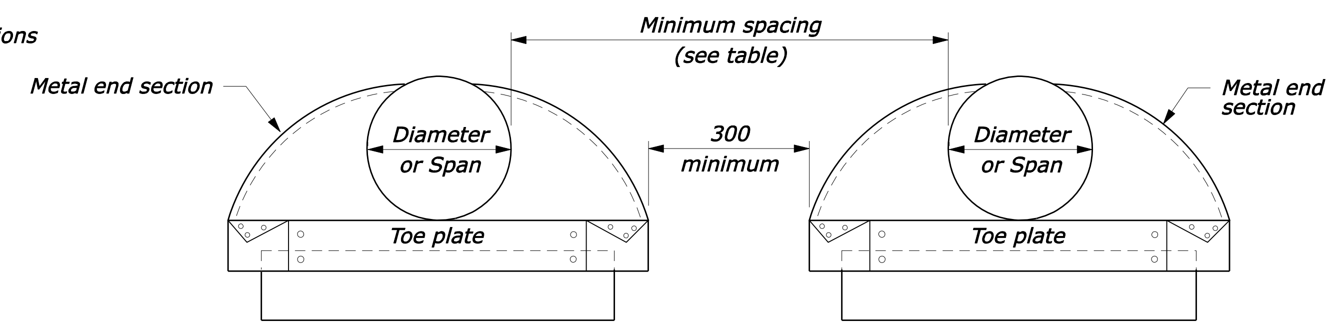


PIPE BEDDING

NOTE:

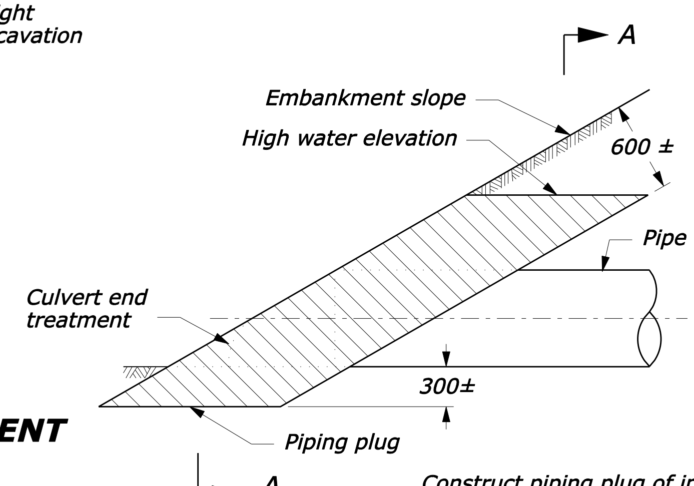
1. When directed, camber pipe culverts upward from a chord through the inlet and outlet inverts an ordinate amount equal to 1% of the pipe length. Develop camber on a parabolic curve. If the midpoint elevation on the parabolic curve as designed exceeds the elevation of the inlet invert, reduce the amount of camber or increase the pipe culvert gradient.
2. H equals the diameter of all round pipe culverts or the rise dimension of all pipe arch culverts.
3. Dimensions without units are millimeters.

MINIMUM SPACING	
DIAMETER or SPAN	SPACING
UP to 1200	610
1200 and UP	Half diameter or span OR 900 whichever is less



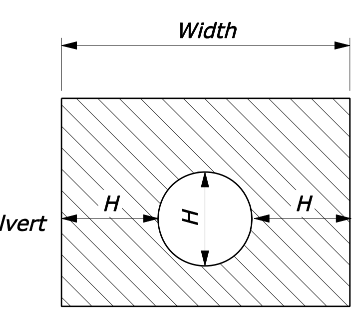
ELEVATION

MULTIPLE PIPE INSTALLATION



Construct piping plug of impermeable backfill material at the pipe culvert inlet where granular material is used for backfill. Width may be adjusted to tie into impervious material.

PIPING PLUG



SECTION A-A

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

METRIC STANDARD

METAL AND PLASTIC PIPE CULVERT BEDDING

STANDARD APPROVED FOR USE 3/1996
REVISED: 12/1998 6/2005

STANDARD M602-3

13-Aug-2008 05:25 PM

...\Drainage\Stream 3\st60203.dgn

A.2

B-5 Site Plans

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	1

B-5 Borrow Source Site

Item number	Description	Unit	Quantity 23+285.00 TO 23+439.00
15201-0000	Construction Survey and Staking	Lump Sum	
15301-0000	Contractor Quality Control	Lump Sum	
15401-0000	Contractor Testing	Lump Sum	
15705-0100	Soil Erosion control Silt Fence	m	50
15705-1500	Soil Erosion control Sediment Wattle	m	50
15801-0000	Watering For Dust Control	m3	30
20450-1000	Rock borrow, limestone, B1 material source	m3	2800
	38 mm drain rock, limestone	m3	1400
20501-0000	Controlled blast hole	m	135
20701-0100	Earthwork Geotextile Type I-A	m2	2150
	Surfacing Removal and Replacement	m3	200
30101-2000	Aggregate Base Grading D 1/	ton	80

DRAFT

FOOTNOTE:

1/ *Quantity based on estimated 20% loss of Select Topping and Aggregate Base Grading D.*

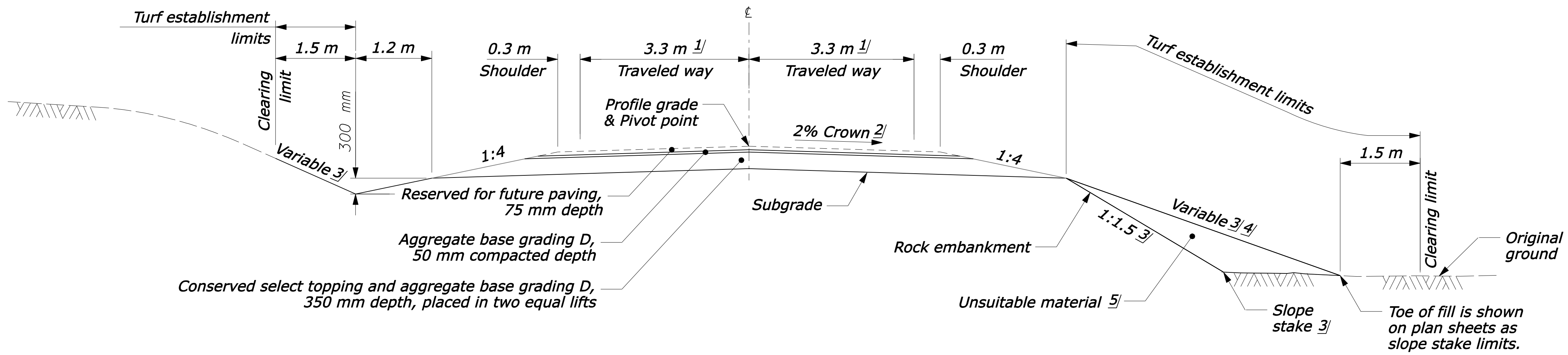
TABULATION OF PLAN QUANTITIES

F:\highways\FHWA\Coffman_paving\08550005_DSDC\Design\Typical Sections\B- 13-Aug-2008 3:49 Designed by: C. Voermans 8/2008 Checked by: Brian Wacker 8/2008

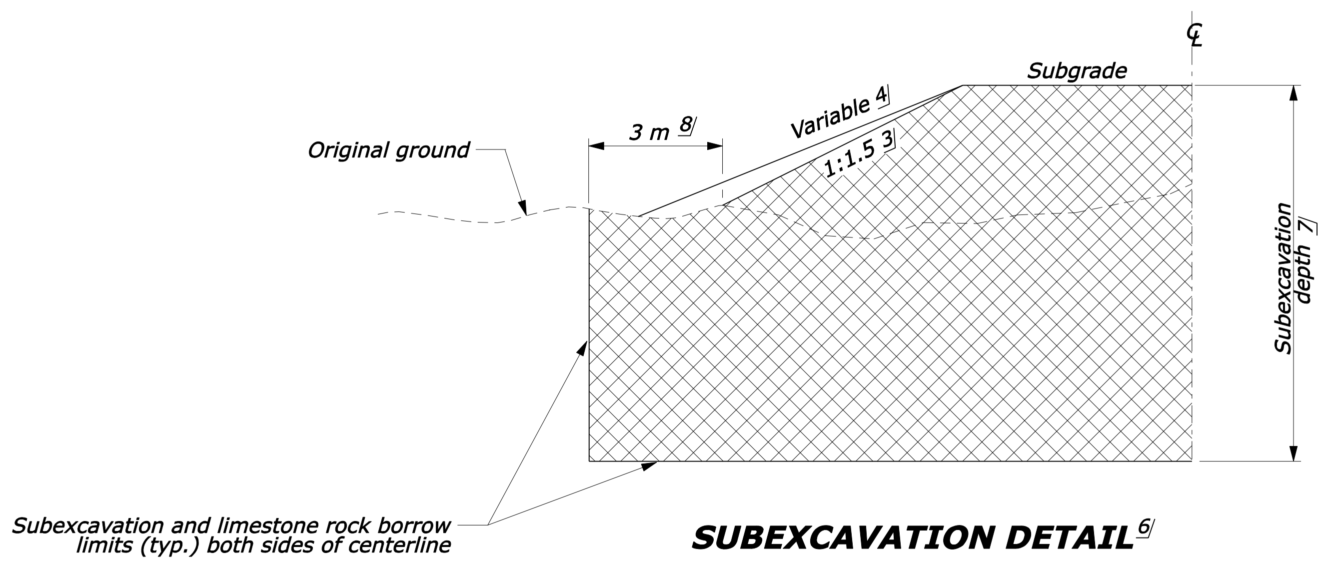
STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	2

B5 Borrow site

CURVE WIDENING TABLE 1/		
LOCATION	SIDE	ADDITIONAL WIDTH (m)
23+097.96 to 23+552.65	RT.	0.8



TYPICAL SECTION
FOREST ROAD 3030
23+400 TO 23+439 9/



SUBEXCAVATION DETAIL 6/

DRAFT

FOOTNOTE:

1/ Curve widening is distributed equally on each side for spiral curves and only on the inside of the curve for simple curves. Construct curve widening as shown in the Staking Report (See FAR 52.236-4).

2/ Superelevate roadway on curves at the rate "e" as indicated on the plan and profile curve data.

3/ Construct cut and fill slopes as shown on the Staking Report (See FAR 52.236-4).

4/ Construct slopes as shown on plotted cross-sections.

5/ Place a minimum 300 mm of unsuitable material on all fill slopes.

6/ Backfill subexcavation with rock borrow. See sheet 1 for quantities.

7/ See cross sections for estimated subexcavation depths.

8/ Adjust as shown on cross sections and as approved by CO.

9/ Adjust limits as approved by CO to avoid impacts to existing pipe.

TYPICAL SECTION AND SUBEXCAVATION DETAIL

08/2008 B. WACKER Checked by:
08/2008 C. VOERMANS Designed by:
13-Aug-2008 03:53 PM
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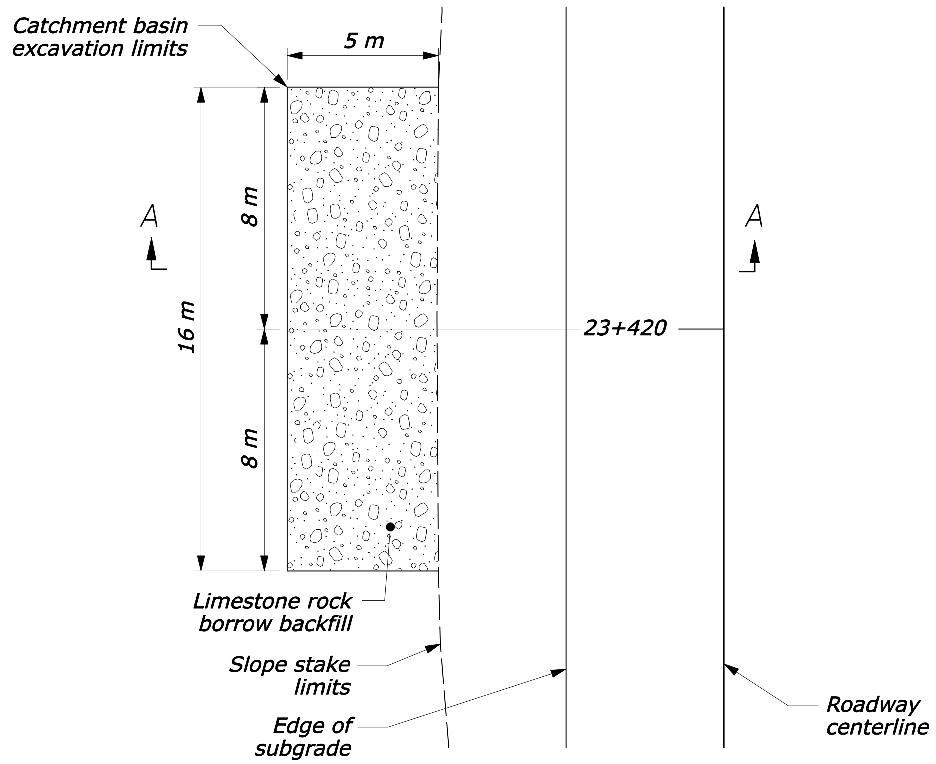
STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	3

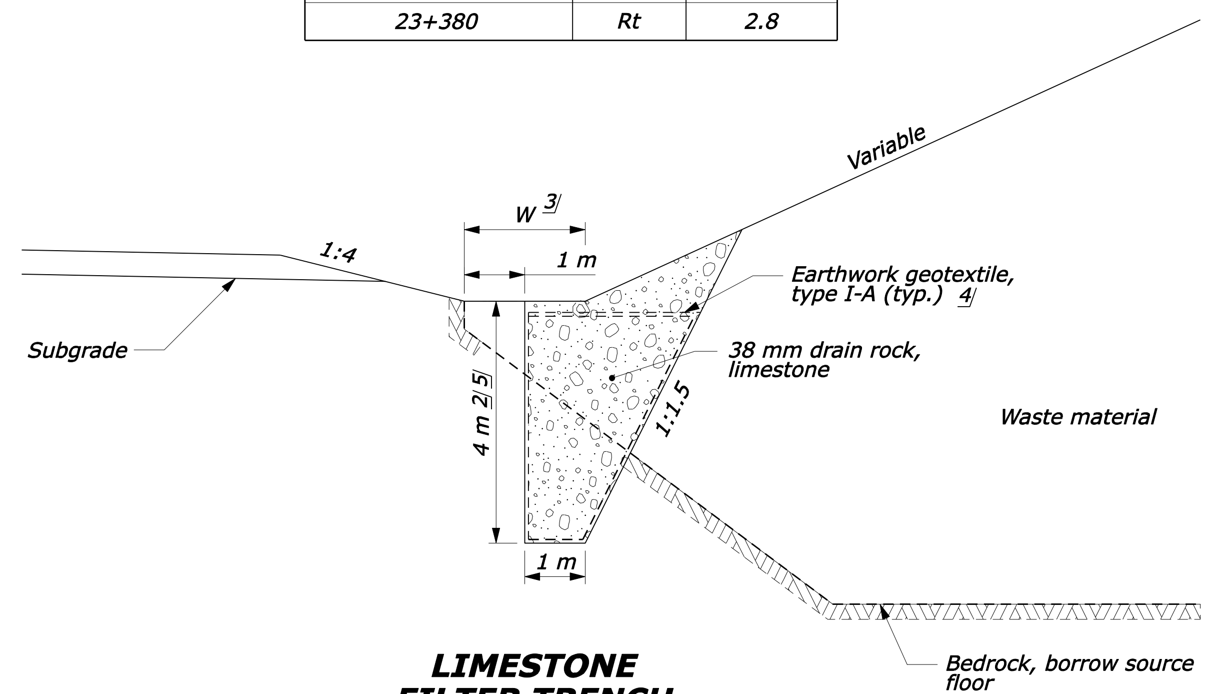
B5 Borrow site



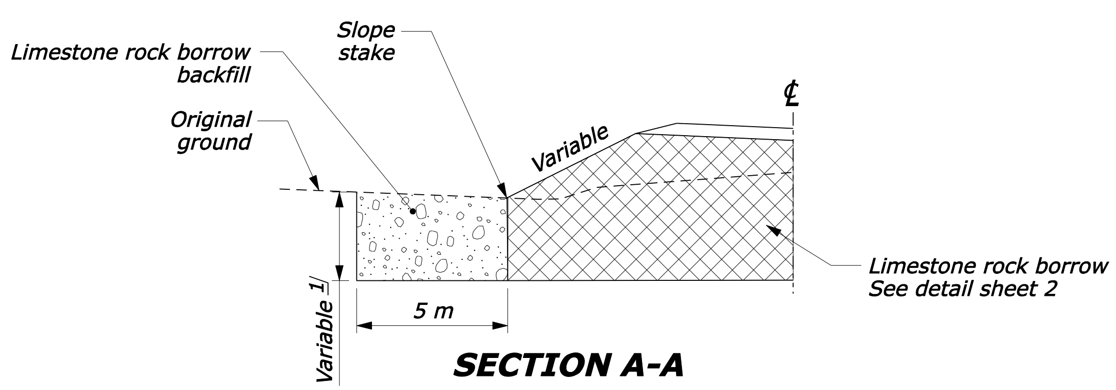
CATCHMENT BASIN DETAIL

EXISTING DITCH LOCATIONS

LOCATION	SIDE	W FLAT BOTTOM DITCH (m)
23+300	Rt	2.8
23+320 to 23+360	Rt	4.8
23+380	Rt	2.8



LIMESTONE FILTER TRENCH DETAIL 23+285 TO 23+420 RT



SECTION A-A

DRAFT

NOTE:

1. Construct cut and fill slopes as shown on the Staking Report (See FAR 52.236-4).

FOOTNOTE:

1/ Excavate catchment basin to a depth of 3 m or as approved by CO.

2/ Excavate limestone filter trench to the limits shown or to borrow source floor, whichever is greater.

3/ Restore flat bottom ditch to dimensions indicated in table.

4/ Lap geotextile full width of trench, 150 mm below existing ditch elevation.

5/ Adjust trench cut slope for stability as approved by the CO.

TYPICAL SECTION DETAILS

08/2008 B. WACKER Checked by:

08/2008 C. VOERMANS Designed by:

14-Aug-2008 12:32 PM

...\B-5\ak4412ca.dgn

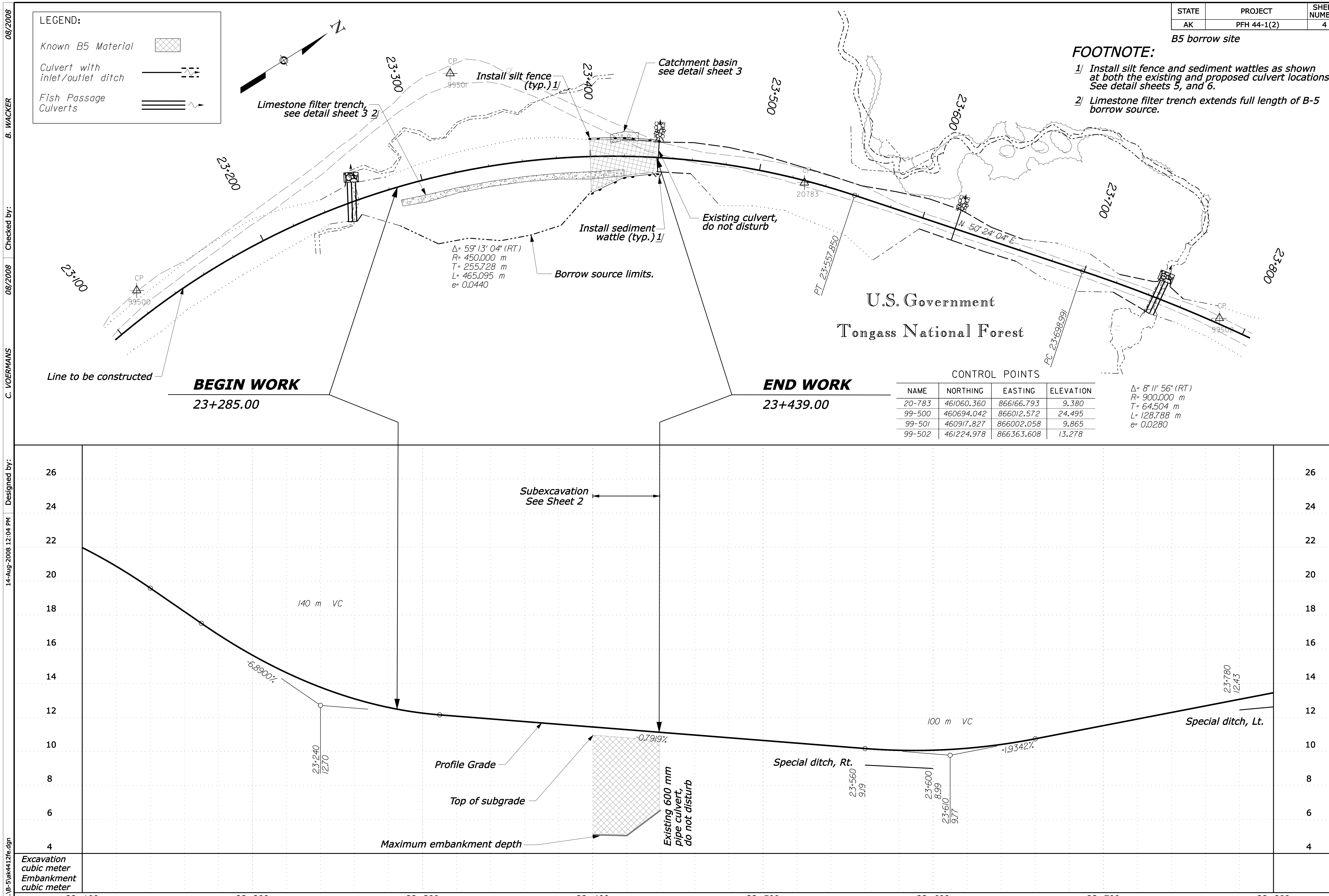
STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	4

B5 borrow site

FOOTNOTE:

1/ Install silt fence and sediment wattles as shown at both the existing and proposed culvert locations. See detail sheets 5, and 6.

2/ Limestone filter trench extends full length of B-5 borrow source.



CONTROL POINTS

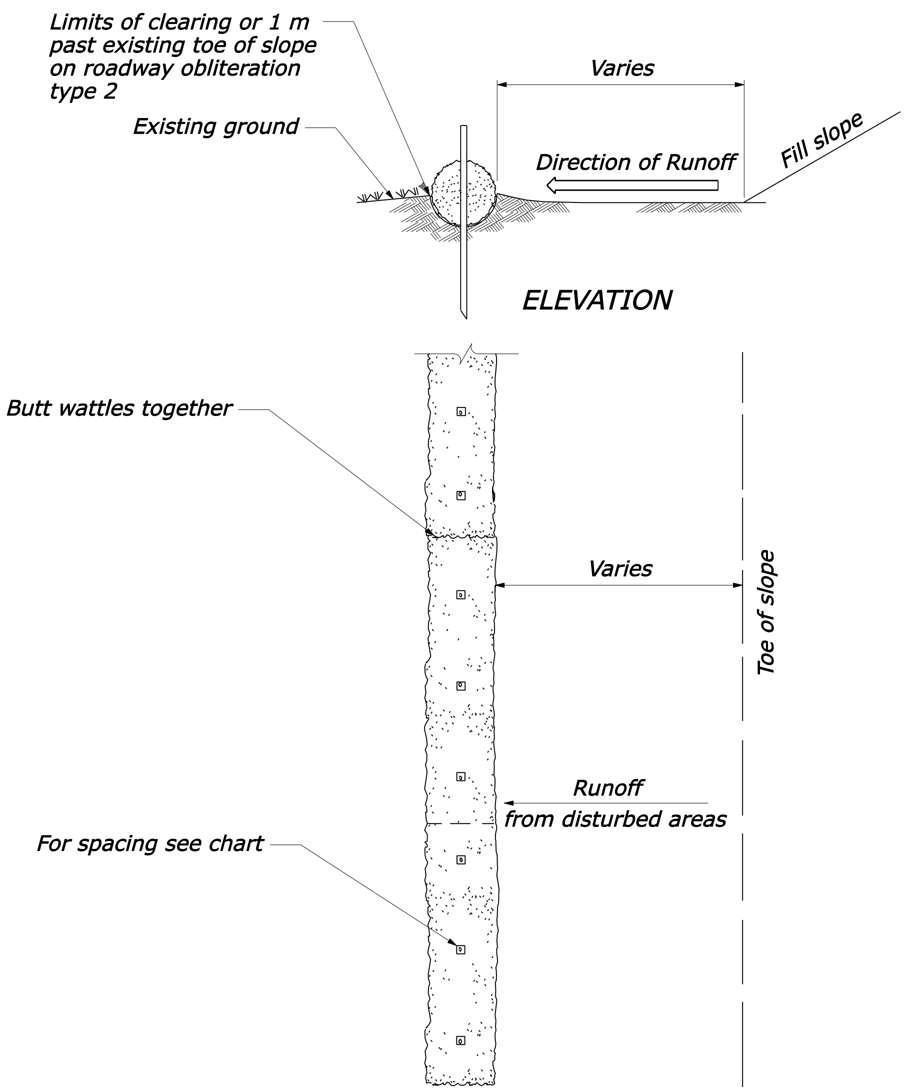
NAME	NORTHING	EASTING	ELEVATION
20-783	461060.360	866166.793	9.380
99-500	460694.042	866012.572	24.495
99-501	460917.827	866002.058	9.865
99-502	461224.978	866363.608	13.278

DRAFT

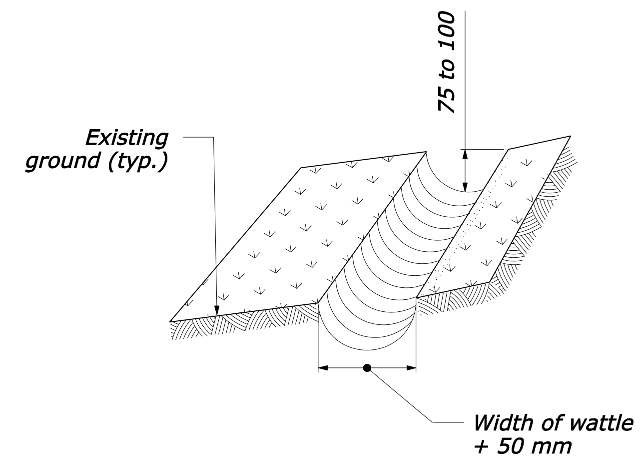
08/2008 B. WACKER Checked by: 08/2008 C. VOERMANS Designed by: 14-Aug-2008 12:04 PM ...\B-5\ak4412fe.dgn

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	5

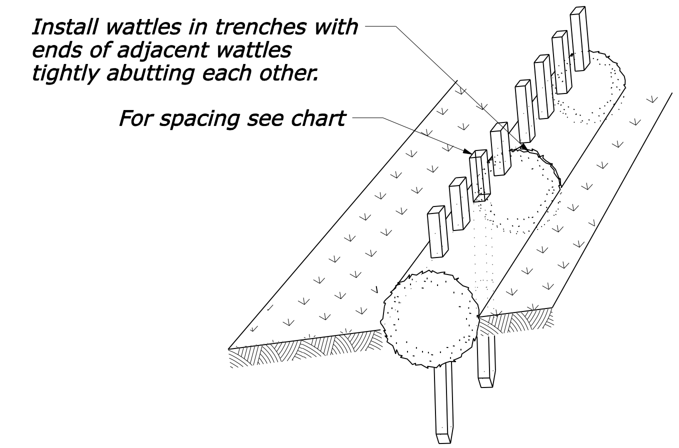
B5 Borrow site



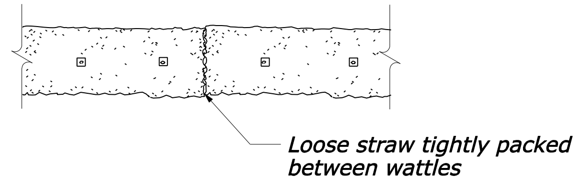
INSTALLATION OF A SEDIMENT WATTLE BARRIER AT TOE OF FILL



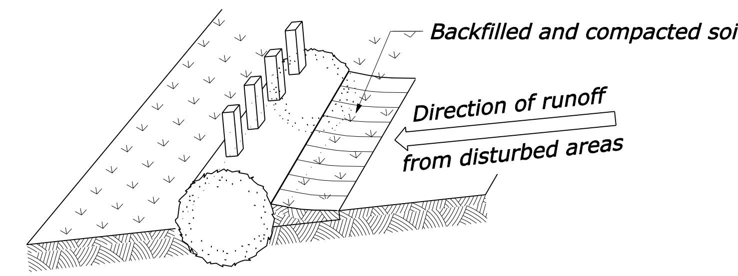
Step 1: Excavate trench



Step 2: Install wattles

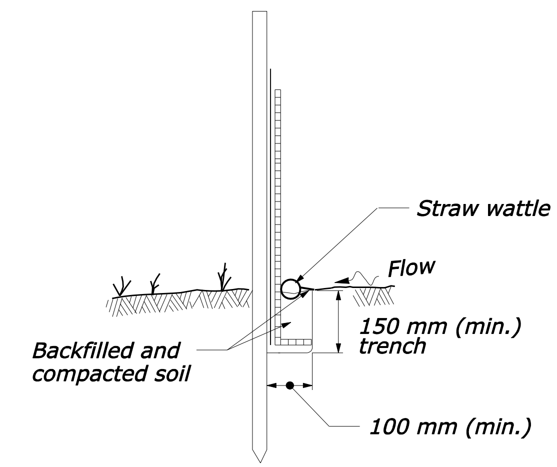


Step 3: Tightly pack straw between wattles (plan view of wattles)



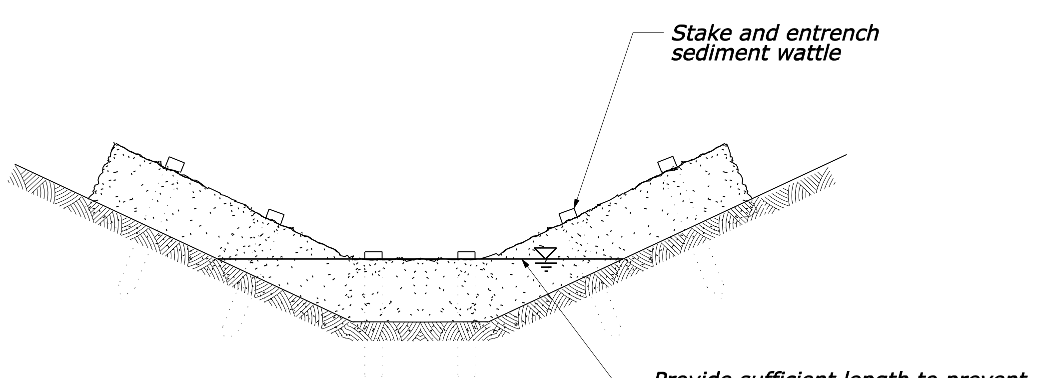
Step 4: Backfill soil against wattles

PROPERLY STAKED AND ENTRENCHED SEDIMENT WATTLES

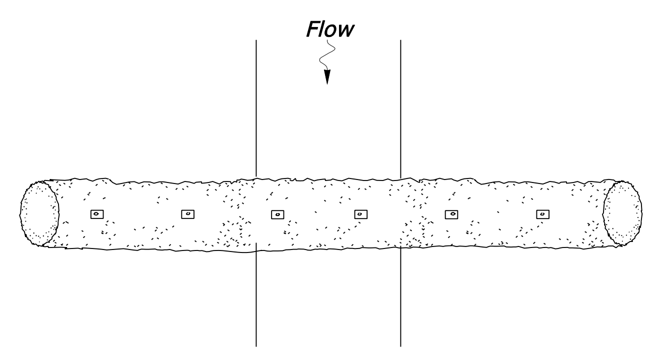


SEDIMENT WATTLE WITH SILT FENCE DETAIL

STAKE SPACING	
Wattle length (m)	No. of stakes (each)
7.5	6
6.0	5
3.7	4



ELEVATION



PLAN

INSTALLATION OF A SEDIMENT WATTLE BARRIER IN DITCH

NOTE:

1. Use sediment wattles in drainage ditches for only low flow conditions.
2. See Sheet 6 for silt fence details.
3. Dimensions not labeled are in millimeters.

SEDIMENT WATTLES

DRAFT

07/2007 B. WACKER Checked by: 07/2007 C. VOERMANS Designed by: 08-Aug-2008 11:24 AM

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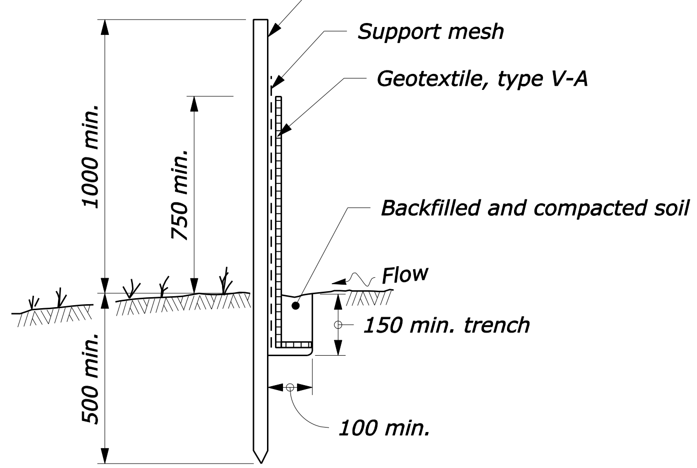
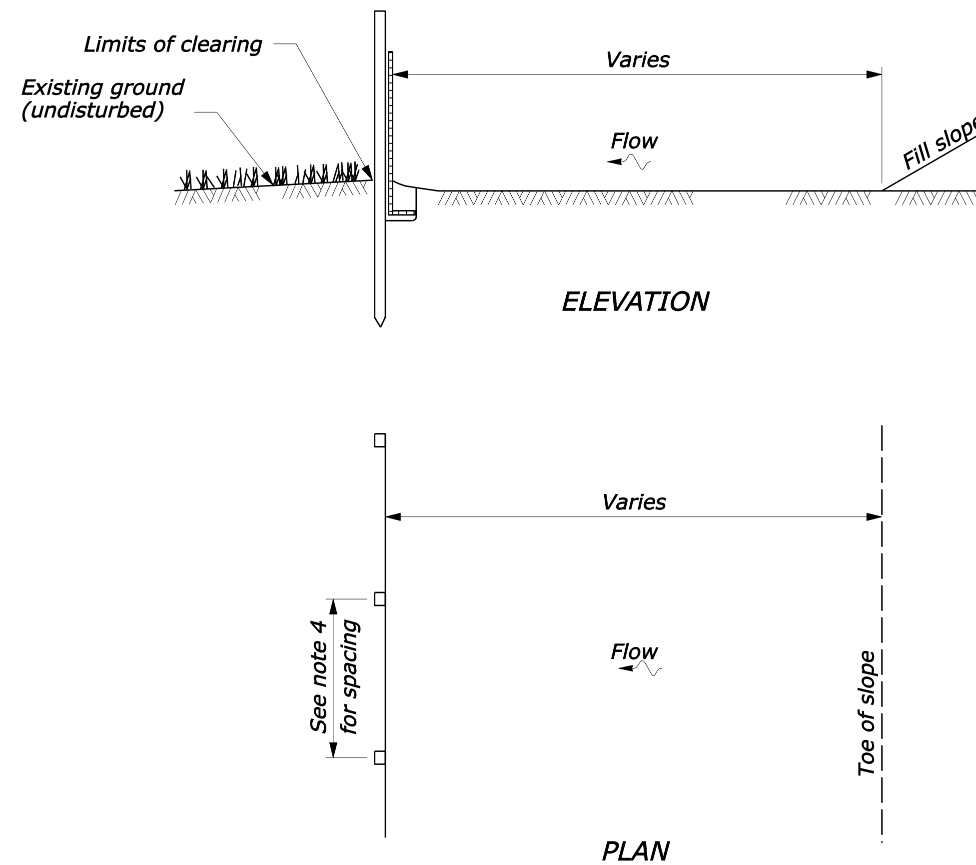
STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	6

B5 Borrow site



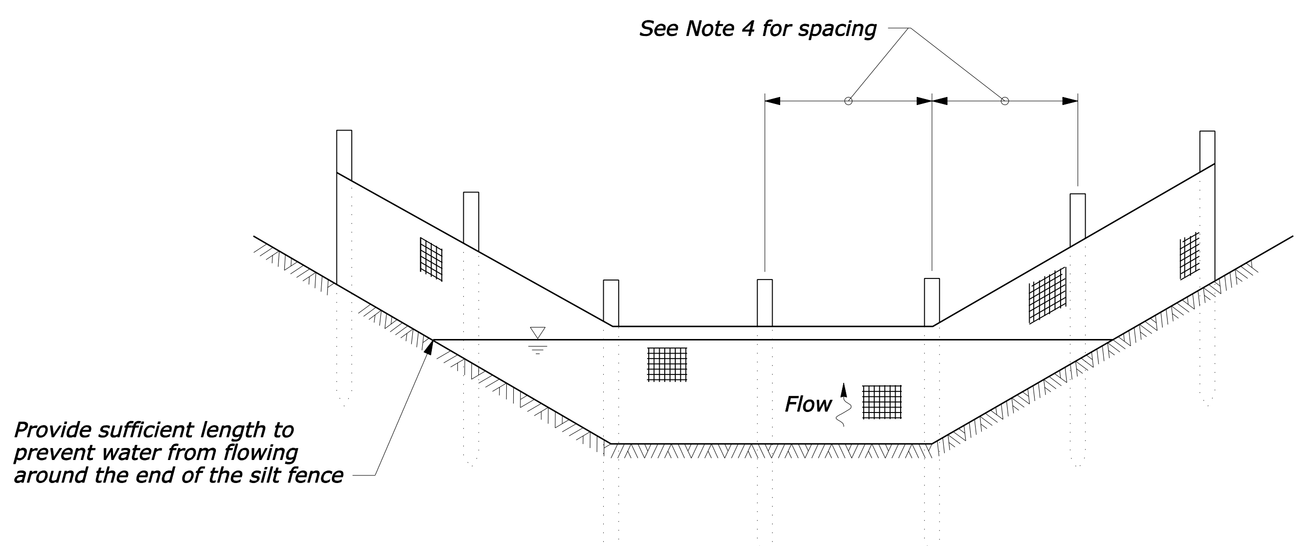
POST AND GEOTEXTILE INSTALLATION DETAIL



SILT FENCE INSTALLATION AT TOE OF FILL

NOTE:

1. Use drainage ditch installation for low flow conditions only when specified on Erosion Control Plan.
2. Alternate preassembled silt fence options (geotextile, type V-B) will be allowed as long as specified dimensions are satisfied. Follow manufacturer's recommendations for installation procedures. All types must ensure silt fence remains attached to, and does not slide down, supporting posts.
3. Install silt fence along ground contours. Curve ends of silt fence upgrade to prevent water from running around the ends.
4. 3.0 m (max.) spacing with fence support.
   1.8 m (max.) spacing without fence support.
5. Dimensions without units are millimeters.



SILT FENCE INSTALLATION IN A DRAINAGE DITCH

See Note 1

DRAFT

NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

METRIC STANDARD

SILT FENCE

STANDARD APPROVED FOR USE 3/1996
REVISED: 6/1997 6/2005 6/2007

STANDARD M157-1

A.3

D-2 Site Plans

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	1

D-2 Disposal Site

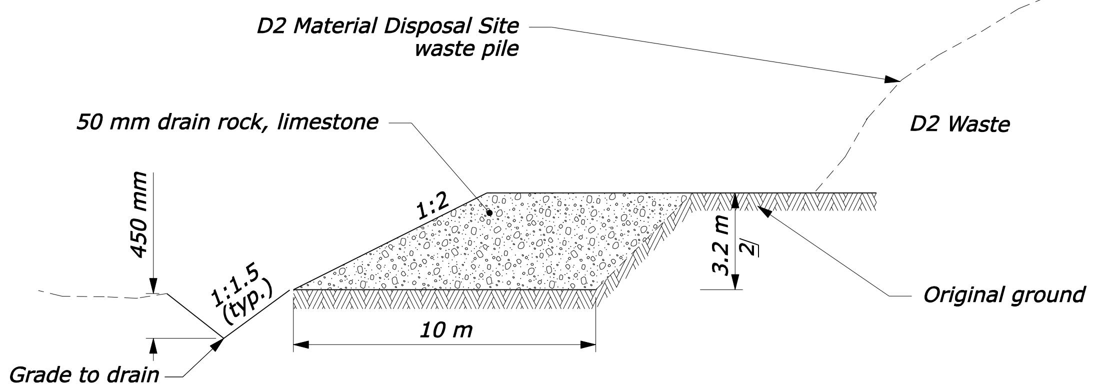
Item number	Description	Unit	Quantity
			D2 Disposal Site
15201-0000	Construction Survey and Staking	Lump Sum	
15301-0000	Contractor Quality Control	Lump Sum	
15401-0000	Contractor Testing	Lump Sum	
15706-0200	Check Dam, Riprap	each	3
15801-0000	Watering For Dust Control	m3	30
	50 mm drain rock, limestone, B-1 material source	m3	1100
20701-0100	Earthwork Geotextile Type I-A	m2	600

DRAFT

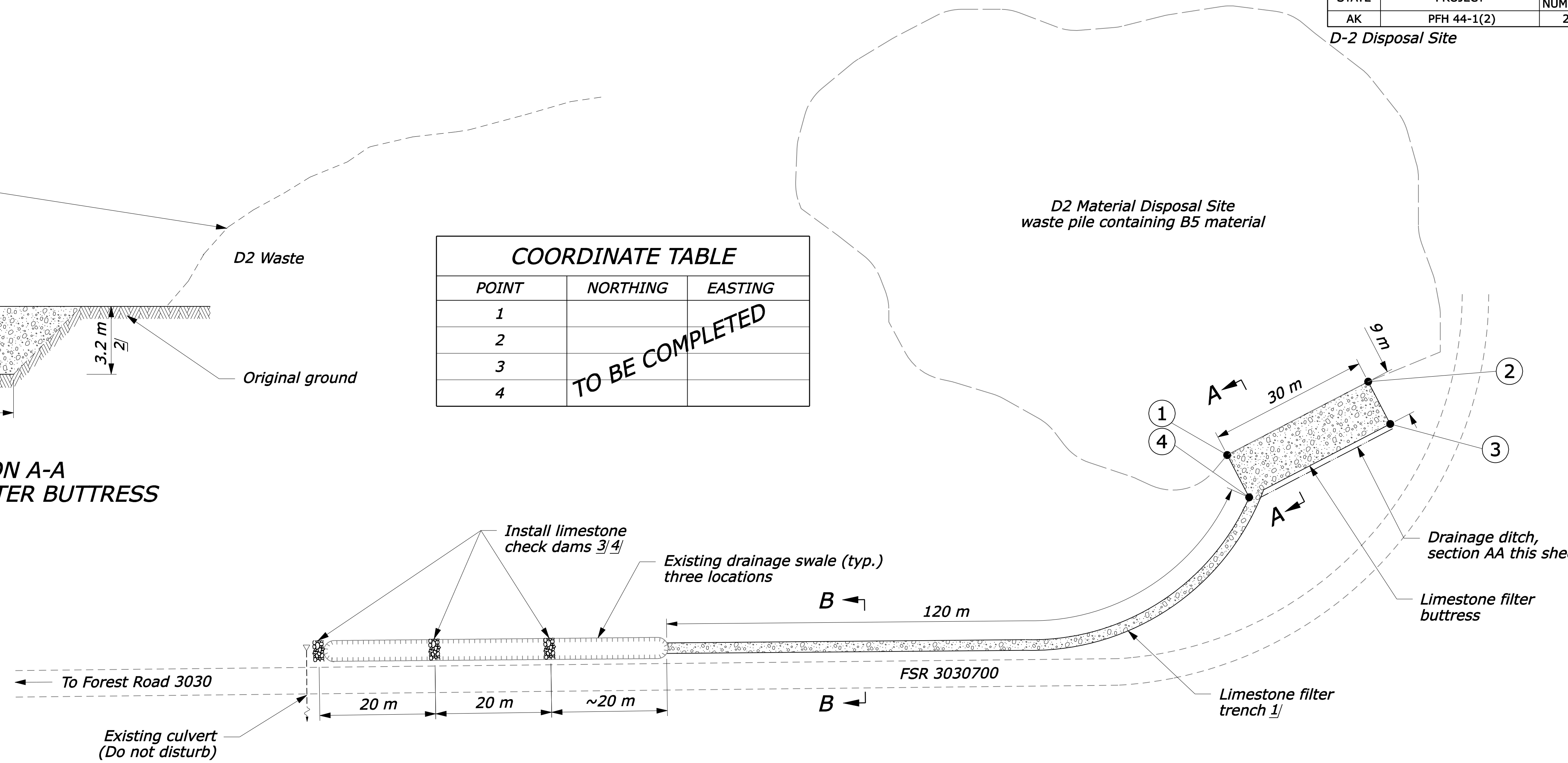
TABULATION OF PLAN QUANTITIES

F:\highways\FHWA\Coffman_paving\08550005_DSDC\Design\Plan and Profile\D- 13-Aug-2008 4:12 Designed by: C. Voermans 8/2008 Checked by: Brian Wacker 8/2008

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	2



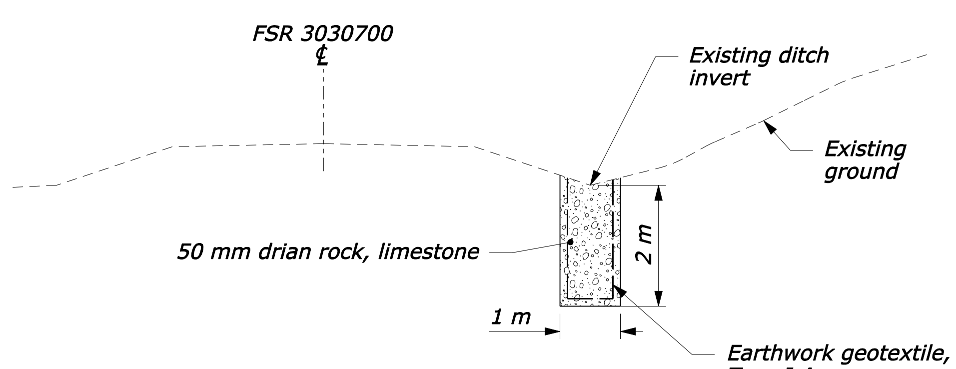
SECTION A-A
LIMESTONE FILTER BUTTRESS



COORDINATE TABLE

POINT	NORTHING	EASTING
1		
2		
3		
4		

TO BE COMPLETED



SECTION B-B
LIMESTONE FILTER TRENCH

NOTE:

1. Dimensions and distances shown are estimates for informational purposes only. Adjust to meet field conditions as approved by CO.
2. See sheet 1 for quantities.

FOOTNOTE:

1/ Ensure positive drainage from limestone filter buttress to existing drainage swale.

2/ Ensure 50 mm minus crushed limestone extends above elevation of existing seeps.

3/ See sheet 3.

4/ Install check dams prior to all other ground disturbing activities.

D2 MATERIAL DISPOSAL SITE MITIGATION DETAILS

DRAFT

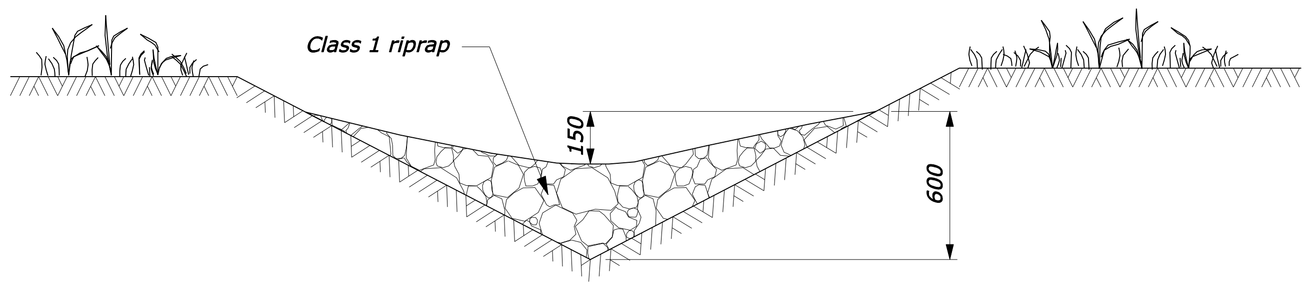
08/2008 B. Wacker Checked by: 08/2008 C. Voermans Designed by: 13-Aug-2008 04:13 PM ...\D-2\ak4412_D2_mitigation.dgn

STATE	PROJECT	SHEET NUMBER
AK	PFH 44-1(2)	3

D-2 Disposal Site

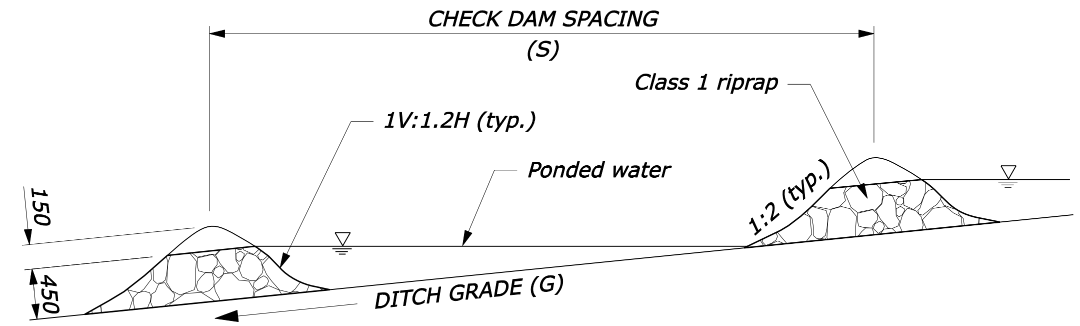
NOTE:

1. *Dimensions without units are millimeters.*



CROSS SECTION

V DITCH

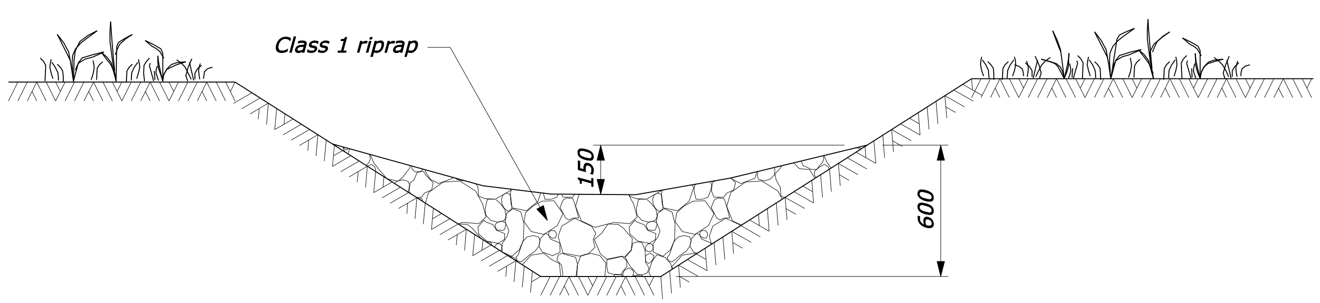


PROFILE VIEW

DITCH

*DITCH GRADE * (G)*	*CHECK DAM SPACING S (m)*
2%	*23*
3%	*15*
4%	*12*
5%	*9*
6%	*7.5*

** Do not use Check Dams below 2% or above 6% ditch grades*



CROSS SECTION

TRAPEZOIDAL DITCH

08-Aug-2008 11:16 AM

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NO SCALE

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION
FEDERAL LANDS HIGHWAY

METRIC STANDARD

CHECK DAM

STANDARD APPROVED FOR USE 3/1996

REVISED: 6/2005 6/2007

STANDARD M157-6

APPENDIX B

Draft Coffman Cove B1 Pit Air Track Hole Installation and Ground Water Measurement Device Installation Work Plan and Approval Letter

Draft

USFS 3030 B1 Pit Air Track Hole Installation and Ground Water Measurement Device Installation Work Plan

The purpose of this work will be to confirm the presence of lime stone bedrock in the B-1 quarry on the Coffman Cove roadway project and to install open standpipe piezometers. This work will be done in accordance with the FLH project development design manual (PDDM) Chapter 6 geotechnical section and FHWA Publication – FHWA NHI-01-031 Subsurface Investigations – Geotechnical Site Characterization Reference Manual, and Alaska Department of Environmental Conservation (DEC) Recommended Practices for Monitoring Well Design, Installation, and Decommissioning (April 1992).

The work plan is as follows:

1. **Surface Conditions**
   The existing conditions of the pit will be documented based on visual observations and incorporated into a B-1 Investigation and Piezometer Installation memorandum. In addition all relevant available information on the B-1 pit will be recorded. This information should include:
   - **a.** When the pit was first established
   - **b.** Approximately how much material has already been removed
   - **c.** Ground treatment performed to access the pit.

2. **Drilling Plan**
   Six air-track installed 4" diameter boreholes are proposed (see attached Drawing). The depth of all borings is anticipated to be 30 feet. However, the final depth could change based on field observations during drilling.

3. **Drilling Schedule**
   - **a.** Start Date: August 7th, 2008
   - b. Completion date: August 8th, 2008

4. **Logging and Sampling Procedures of Proposed Holes**
   Field logs will be generated based on drill cutting color, texture, presence of water, and driller's comments. Whenever possible, the cuttings will be collected (at a minimum of 5-foot intervals, or at every change of formation) for future review and/or testing. Quality control practices for logging and sampling will be employed per FHWA NHI-01-031.

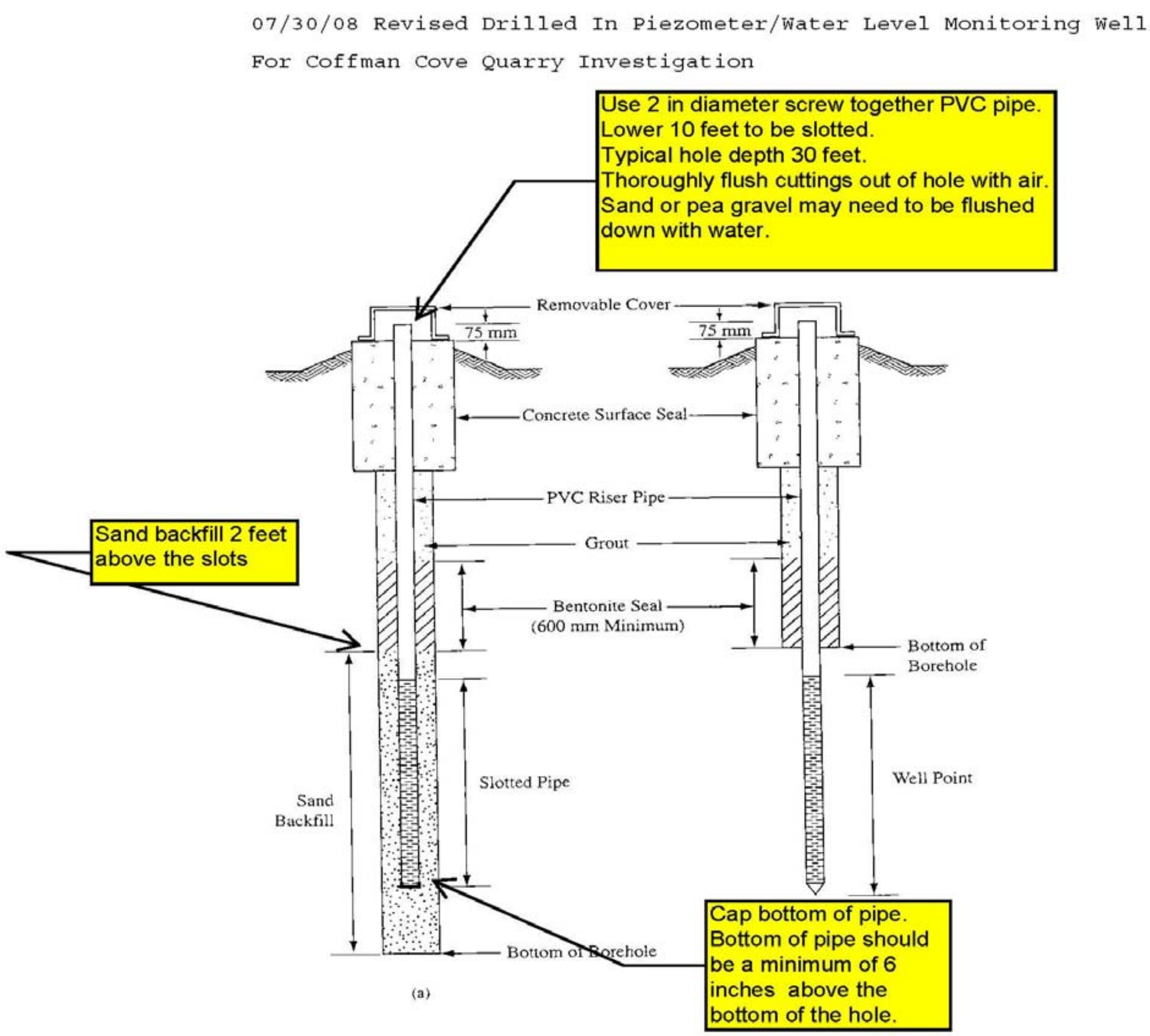
5. **Staff on site for logging of holes**
   A WFLHD geotechnical engineer and a USFS geologist will be on site to log the holes.

6. **Determination of Ground Water Levels**
   Piezometers will be surveyed after installation by a WFLHD surveyor prior to measuring water levels. Ground water levels will be measured using the top of the

stand pipe as a reference with an electronic water level meter in accordance with FHWA NHI-01-031. The electronic water level meter consists of a weighted electric probe attached to the lower end of a length of electrical cable that is marked at intervals to indicate the depth. When the probe reaches the water a circuit is completed and this is registered by a meter mounted on the cable reel.

7. Installation Procedures for Piezometers

A WFLHD geotechnical engineer will assist with the installation of the installation of proposed 5 to 6 piezometers. Again this work will be performed in accordance with FHWA NHI-01-031.



- If any borehole is drilled deeper than the well to be completed in the borehole, the borehole will be sealed with bentonite or cement/bentonite grout to within one foot of the bottom of the completed interval. The seal should be allowed sufficient time to set or hydrate before completing the well in the borehole above the seal.

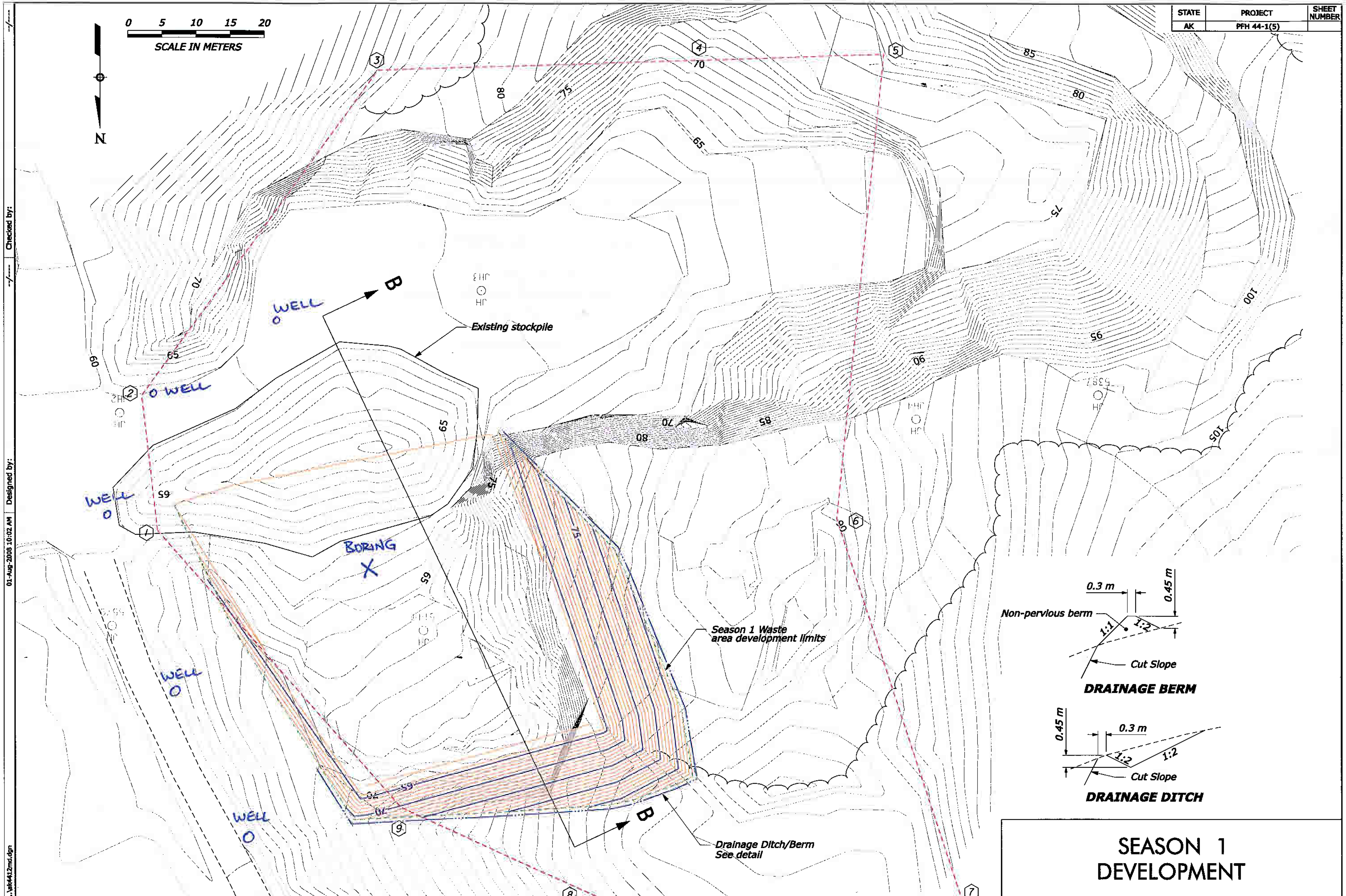
- The bottom of the 2” diameter Schedule 40 pipe is machine-slotted to #10 slot and capped, and the annular space around the slotted pipe is backfilled with clean sand. Screens will not be hand-slotted.
- Joints, caps, and end caps will be watertight and secured by threads. Solvents, glues, or adhesives will not be used.
- Boreholes will have a minimum inside diameter at least 2 inches larger (due to current equipment availability) than the maximum outside diameter of the riser pipe and screen to ensure an adequate annular seal.
- Filter pack will consist of clean, chemically inert, well-rounded, siliceous, medium or coarse sand or gravel. The filter pack should extend one foot below the bottom of the well end cap, and two feet above the top of the screen interval.
- The area above the sand is sealed with bentonite, and the remaining annulus is filled with grout, concrete, or soil cuttings. If bentonite slurry is used for the seal, then the top six inches of the filter pack should be fine-grained sand. If bentonite pellets or chips are used above the water table, they should be hydrated by pouring water down the borehole after placing each 1-foot lift.
- If slurry or grout is used above the bentonite seal, there should be a 24-hour period between the time the seal is installed and the time the protective cover pipe is installed. Any settling in the annular space seal should be filled before the protective cover pipe is installed.
- A surface seal, which is sloped away from the pipe, is commonly formed with concrete in order to prevent the entrance of surface water. The surface seal will extend down to a minimum of 60 inches below the land surface.
- The top of the pipe will also be capped to prevent the entrance of foreign material; a small vent hole should be placed in the top cap.
- A locking well cover or a metal pipe with a wrench tightened screw on cap will also be installed.
- Will develop a FHWA site identification number for each piezometer.

8. Piezometer Development

Piezometers will be developed by hand bailing.

9. Final Reporting

A B-1 Investigation and Piezometer Installation memorandum will be developed that summarizes the results of this work. The memorandum will include final boring logs for the proposed six holes, as well as site photographs, and a plan figure of well locations. Initial water level readings will also be presented. The memorandum will be provided to FS, EPA, and ADEC within 30 days of piezometer installation. Copies of all borehole and well completion logs will be sent to the Division of Geological and Geophysical Surveys, DNR.



STATE
AK
PROJECT
PFH 44-1(5)
SHEET NUMBER
0 5 10 15 20
SCALE IN METERS
N
B
WELL
WELL
WELL
WELL
WELL
BORING
X
Existing stockpile
Season 1 Waste area development limits
Drainage Ditch/Berm See detail
0.3 m
0.45 m
Non-pervious berm
1:1
1:2
Cut Slope
DRAINAGE BERM
0.45 m
0.3 m
1:2
1:2
Cut Slope
DRAINAGE DITCH
Checked by:
Designed by:
01-Aug-2008 10:02 AM
SEASON 1
DEVELOPMENT

U.S. Department
of Transportation
**Federal Highway
Administration**

**Publication No. FHWA NHI-01-031
May 2002**

NHI Course No. 132031

Subsurface Investigations
— Geotechnical Site Characterization

Reference Manual






National Highway Institute

CHAPTER 4.0

BORING LOG PREPARATION

4.1 GENERAL

The boring log is the basic record of almost every geotechnical exploration and provides a detailed record of the work performed and the findings of the investigation. The field log should be written or printed legibly, and should be kept as clean as is practical. All appropriate portions of the logs should be completed in the field prior to completion of the field exploration.

A wide variety of drilling forms are used by various agencies. The specific forms to be used for a given type of boring will depend on local practice. Typical boring log, core boring log and test pit log forms endorsed by the ASCE Soil Mechanics & Foundations Engineering Committee are presented in Figures 4-1 through 4-3, respectively. A proposed legend for soil boring logs is given in Figure 4-4 and for core boring logs in Figure 4-5. This chapter presents guidelines for completion of the boring log forms, preparation of soil descriptions and classifications, and preparation of rock descriptions and classifications.

A boring log is a description of exploration procedures and subsurface conditions encountered during drilling, sampling and coring. Following is a brief list of items which should be included in the logs. These items are discussed in detail in subsequent sections:

- Topographic survey data including boring location and surface elevation, and bench mark location and datum, if available.
- An accurate record of any deviation in the planned boring locations.
- Identification of the subsoils and bedrock including density, consistency, color, moisture, structure, geologic origin.
- The depths of the various generalized soil and rock strata encountered.
- Sampler type, depth, penetration, and recovery.
- Sampling resistance in terms of hydraulic pressure or blows per depth of sampler penetration. Size and type of hammer. Height of drop.
- Soil sampling interval and recovery.
- Rock core run numbers, depths & lengths, core recovery, and Rock Quality Designation (RQD)
- Type of drilling operation used to advance and stabilize the hole.
- Comparative resistance to drilling.
- Loss of drilling fluid.
- Water level observations with remarks on possible variations due to tides and river levels.

Project: Project Location: Project Number:	**Log of Boring ___** Sheet 1 of ___

Date(s) Drilled	Logged By	Checked By
Drilling Method	Drill Bit Size/Type	Total Depth Drilled (meters)
Drill Rig Type	Drilled By	Hammer Weight/ Drop (N/m)
Apparent Groundwater Depth ____ m ATD ____ m after ___ hrs ____ m after ___ hrs		Surface Elevation (meters)
Comments	Borehole Backfill	Elevation Datum

Depth, meters	SAMPLES				MATERIAL DESCRIPTION and other remarks	Elevation, meters	Pocket Pen., kPa	Water Content, %	Liquid Limit	Plasticity Index	Other Tests
	Location	Type	Number	Sampling Resistance							
0											
1											
2											
3											
4											

Template: Proj ID: Printed:

Figure 4-1. Representative Boring Log Form.

Project: **Project Location:** **Project Number:**	**Log of Core Boring ___** Sheet 1 of ___

Date(s) Drilled	Logged By	Checked By
Drilling Method	Drill Bit Size/Type	Total Depth Drilled (meters)
Drill Rig Type	Drilled By	Inclination from Vertical/Bearing
Apparent Groundwater Depth ___ m ATD ___ m after ___ hrs	___ m after ___ hrs	Approx. Surface Elevation (meters)
Comments		Borehole Backfill

Depth, meters	Elevation, meters	ROCK CORE							MATERIAL DESCRIPTION	Packer Tests	Laboratory Tests	Drill Rate, meters/hour	FIELD NOTES
		Run No.	Box No.	Recovery, %	Frac. Freq.	R Q D, %	Fracture Drawing/ Number	Lithology					
0													
1													

Template: Proj ID: Printed:

Figure 4-2. Representative Core Boring Log.

Project: Project Location: Project Number:	**Log of Exploration Pit ___**

Date(s) Excavated	Logged By	Checked By
Approximate Length (meters)	Approximate Width (meters)	Approximate Depth (meters)
Excavation Equipment	Excavation Contractor	Approximate Pit Trend
Groundwater Level (meters)	Date Measured	Approx. Surface Elevation (meters)
Comments		

Depth, meters	Elevation, meters	Sample Type	and Number	Pocket Pen., kPa	Graphic Log	**MATERIAL DESCRIPTION** and other remarks	Water Content, %	Other Tests
0								
1								
2								
3								
4								

Template: Proj ID: Printed:

Figure 4-3. Representative Exploration Pit Log.

Project:	Key to Soil Symbols and Terms
Project Location:	Sheet 1 of 2
Project Number:	

Depth, meters	SAMPLES Location	Type	Number	Sampling Resistance	MATERIAL DESCRIPTION and other remarks	Elevation, meters	Pocket Pen., kPa	Water Content, %	Liquid Limit	Plasticity Index	Other Tests
0					**DESCRIPTIONS OF SAMPLER AND FIELD TEST CODES**						
		S	1	15	The number of blows (15) of a 63.6 Kgr hammer falling 750 mm used to drive a 50 mm O.D. split-barrel sampler for the last 300 mm of penetration.						
1											
		S	2	50/150	Number of blows (50) used to drive the split-barrel a certain number of millimeters (150).						
2		P	3	1724	Thin-wall tube pushed hydraulically, using a certain pressure (1,724 kPa) to push the last 150 mm.						
					SAMPLER CODES						
3		A	4		P - Thin-wall tube sample. C - Denison or Pitcher-type core-barrel sample. Ps - Piston sample. A - Auger sample. BS - Bulk sample. SS - Standard spoon sample. CL - California liner sample.						
4		NX - 65	5	40	BX - Rock cored with BX core barrel, which obtains a 41 mm-diameter core. NX - Rock cored with NX core barrel, which obtains a 53 mm-diameter core. 65 - Percentage (65) of rock core recovered. 40 - Rock Quality Designation (RQD) percentage (40).						
5		S			Sample recovered: indicated by blackened box in "Location" column.						
6		NR			Sample not recovered: indicated by vertical bar in "Location" column and "NR" (no recovery) in "Type" column.						
7					**OTHER FIELD TEST DESIGNATIONS** FV - Field vane shear test. PMT - Pressuremeter test. DMT - Dilatometer test. BHS - Borehole shear test.						

ABBREVIATIONS FOR "OTHER TESTS" COLUMN

- C - Consolidation and specific gravity tests.
- D - Maximum and minimum density.
- DS - Direct shear test.
- G - Specific gravity test.
- K - Permeability test.
- M - Mechanical (sieve or hydrometer) analysis.
- T - Triaxial compression test.
- TV - Torvane shear test.
- U - Unconfined compression test.
- W - Unit weight and natural moisture content.
- X - Special tests performed - see laboratory test results.

Template: MS9K Proj ID: KEY Point ID: MS9K Printed: MAY 28 97

Figure 4-4. Proposed Key to Boring Log (Continued on Page 4-6).

Project: Project Location: Project Number:	**Key to Soil Symbols and Terms** Sheet 2 of 2

TERMS DESCRIBING CONSISTENCY OR CONDITION

COARSE-GRAINED SOILS (major portion retained on No. 200 sieve): includes (1) clean gravels and sands and (2) silty or clayey gravels and sands. Condition is rated according to relative density as determined by laboratory tests or standard penetration resistance tests.

Descriptive Term	Relative Density	SPT Blow Count
Very loose	0 to 15%	< 4
Loose	15 to 35%	4 to 10
Medium dense	35 to 65%	10 to 30
Dense	65 to 85%	30 to 50
Very dense	85 to 100%	> 50

FINE-GRAINED SOILS (major portion passing on No. 200 sieve): includes (1) inorganic and organic silts and clays, (2) gravelly, sandy, or silty clays, and (3) clayey silts. Consistency is rated according to shearing strength, as indicated by penetrometer readings, SPT blow count, or unconfined compression tests.

Descriptive Term	Unconfined Compressive Strength, kPa	SPT Blow Count
Very soft	< 25	< 2
Soft	25 to 50	2 to 4
Medium stiff	50 to 100	4 to 8
Stiff	100 to 200	8 to 15
Very stiff	200 to 400	15 to 30
Hard	> 400	> 30

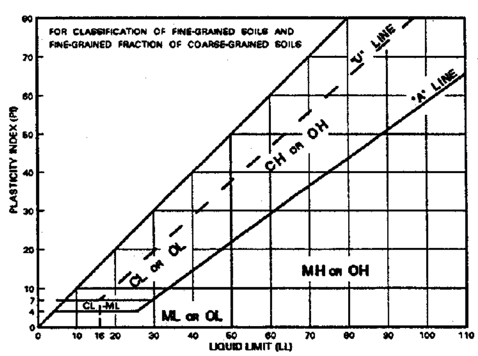
GENERAL NOTES

1. Classifications are based on the Unified Soil Classification System and include consistency, moisture, and color. Field descriptions have been modified to reflect results of laboratory tests where deemed appropriate.

2. Surface elevations are based on topographic maps and estimated locations.

3. Descriptions on these boring logs apply only at the specific boring locations and at the time the borings were made. They are not warranted to be representative of subsurface conditions at other locations or times.

Major Divisions			Group Symbols	Typical Names	Laboratory Classification Criteria		
Coarse-Grained Soils (More than half of material is larger than No. 200 sieve size)	Gravels (More than half of coarse fraction is larger than No. 4 sieve size)	Clean gravels (Little or no fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines	Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve) coarse-grained soils are classified as follows: Less than 5 percent ...... GW, GP, SW, SP; More than 12 percent ...... GM, GC, SM, SC; 5 to 12 percent ...... Borderline cases requiring dual symbols **	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines		Not meeting all gradation requirements for GW	
		Gravels with fines (Appreciable amount of fines)	GM* d / u	Silty gravels, gravel-sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			GC	Clayey gravels, gravel-sand-silt mixtures		Atterberg limits above "A" line or P.I. greater than 7	
	Sands (More than half of coarse fraction is smaller than No. 4 sieve size)	Clean sands (Little or no fines)	SW	Well-graded sands, gravelly sands, little or no fines		$C_u = \frac{D_{60}}{D_{10}}$ greater than 6; $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 and 3	
			SP	Poorly-graded sands, gravelly sands, little or no fines		Not meeting all gradation requirements for SW	
		Sands with fines (Appreciable amount of fines)	SM* d / u	Silty sands, sand-silt mixtures		Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols
			SC	Clayey sands, sand-clay mixtures		Atterberg limits above "A" line or P.I. greater than 7	
Fine-Grained Soils (More than half of material is smaller than No. 200 sieve size)	Silts and Clays (Liquid limit less than 50)		ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity	Plasticity Chart		
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays			
			OL	Organic silts and organic silty clays of low plasticity			
	Silts and Clays (Liquid limit greater than 50)		MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts			
			CH	Inorganic clays of high plasticity, fat clays			
			OH	Organic clays of medium to high plasticity, organic silts			
	Highly Organic Soils		Pt	Peat and other highly organic soils			



Plasticity Chart

Material		Particle Size: mm	Particle Size: Sieve size
Silt or clay		< 0.074	< #200
Sand	Fine	0.074 to 0.42	#200 to #40
	Medium	0.42 to 2.00	#40 to #10
	Coarse	2.00 to 4.76	#10 to #4

Material		Particle Size: mm	Particle Size: Sieve
Gravel	Fine	4.76 to 19.1	#4 to 3/4 in.
	Coarse	19.1 to 76.2	3/4 in. to 3 in.
Cobbles		76.2 to 304.8	3 in. to 12 in.
Boulders		304.8 to 914.4	12 in. to 36 in.

* Division of GM and SM groups into subdivisions of d and u are for roads and airfields only. Subdivision is based on Atterberg Limits: suffix d used when L.L. is 28 or less and the P.I. is 6 or less; the suffix u used when L.L. is greater than 28.

** Borderline classifications, used for soils possessing characteristics of two groups, are designated by combinations of group symbols. For example: GW-GC, well-graded gravel-sand mixture with clay binder.

Figure 4-4. Proposed Key for Final Boring Log (continued).

Project:
Project Location:
Project Number:

Key to Rock Core Log

Sheet 1 of 2

Depth, meters	Elevation, meters	ROCK CORE: Run No.	Box No.	Recovery, %	Frac. Freq.	R Q D, %	Fracture Drawing/Number		Lithology	MATERIAL DESCRIPTION	Packer Tests	Laboratory Tests	Drill Rate, meters/hour	FIELD NOTES
0 [1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11] META-ARKOSE, light gray, moderately weathered, moderately strong.	[13]	[14]	[15]	[16]
2		1	1	100	1	80				[12] [a][b][c][d][e][f][g][h]				Slow drilling
					0			1		1: 75, J, VN, Fe, Su, Pl, S, VC				
4								M		M: Mechanical Breakage				

1	**Depth:**	Distance (in meters) from the collar of the borehole.
2	**Elevation:**	Elevation (in meters) from the collar of the borehole.
3	**Run No.:**	Number of the individual coring interval, starting at the top of bedrock.
4	**Box No.:**	Number of the core box which contains core from the corresponding run.
5	**Recovery:**	Amount (in percent) of core recovered from the coring interval; calculated as the length of core recovered divided by the length of the run.
6	**Frac. Freq.:**	(Fracture Frequency) The number of naturally occurring fractures in each foot of core; does not include mechanical breaks, which are considered to be induced by drilling.
7	**R Q D:**	(Rock Quality Designation) Amount (in percent) of intact core (pieces of sound core greater than 100 mm in length) in each coring interval; calculated as the sum of the lengths of intact core divided by the length of the core run.
8	**Fracture Drawing:**	Sketch of the naturally occurring fractures and mechanical breaks, showing the angle of the fractures relative to the cross-sectional axis of the core. "NR" indicates no recovery.
9	**Fracture Number:**	Location of each naturally occurring fracture (numbered) and mechanical break (labeled "M"). Naturally occurring fractures are described in Column 11 (keyed by number) using descriptive terms defined on the following page (Items a - h).
10	**Lithology:**	A graphic log presentation using symbols to represent differing rock types.
11	**Description:**	Lithologic description in this order: rock type, color, texture, grain size, foliation, weathering, strength, and other features; descriptive terms are defined on the following page. A detailed descriptive log of overburden materials is not necessarily provided.
12	**Discontinuity Description:**	Abbreviated description of fracture corresponding to number of naturally occurring fracture in Column 9 using terms defined on the following page (Items a - h).
13	**Packer Tests:**	A vertical line depicts the interval over which a packer test is performed.
14	**Laboratory Tests:**	A vertical line depicts the interval over which core has been removed for laboratory testing. Laboratory tests performed are indicated in Column 16.
15	**Drill Rate:**	Rate (in meters per hour) of penetration of drilling. "N/O" indicates rate not observed.
16	**Field Notes:**	Comments on drilling, including water loss, reasons for core loss, and use of drilling mud; also, laboratory tests performed on core.

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Figure 4-5. Proposed Key to Core Boring Log (Continued on Page 4-8).

Project: **Project Location:** **Project Number:**	**Key to Rock Core Log** Sheet 2 of 2

Depth, meters	Elevation, meters	ROCK CORE: Run No.	Box No.	Recovery, %	Frac. Freq.	R Q D, %	Fracture Drawing/ Number	Lithology	MATERIAL DESCRIPTION	Packer Tests	Laboratory Tests	Drill Rate, meters/hour	FIELD NOTES

KEY TO DESCRIPTIVE TERMS USED ON CORE LOGS

DISCONTINUITY DESCRIPTORS

a Dip of fracture surface measured relative to horizontal

b **Discontinuity Type:**
- F - Fault
- J - Joint
- Sh - Shear
- Fo - Foliation
- V - Vein
- B - Bedding

c **Discontinuity Width (millimeters):**
- W - Wide (12.5-50)
- MW - Moderately Wide (2.5-12.5)
- N - Narrow (1.25-2.5)
- VN - Very Narrow (<1.25)
- T - Tight (0)

d **Type of Infilling:**
- Cl - Clay
- Ca - Calcite
- Ch - Chlorite
- Fe - Iron Oxide
- Gy - Gypsum/Talc
- H - Healed
- No - None
- Py - Pyrite
- Qz - Quartz
- Sd - Sand

e **Amount of Infilling:**
- Su - Surface Stain
- Sp - Spotty
- Pa - Partially Filled
- Fi - Filled
- No - None

f **Surface Shape of Joint:**
- Wa - Wavy
- Pl - Planar
- St - Stepped
- Ir - Irregular

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

h **Discontinuity Spacing (meters):**
- EW - Extremely Wide (>20)
- W - Wide (7-20)
- M - Moderate (2.5-7)
- C - Close (0.7-2.5)
- VC - Very Close (<0.7)

ROCK WEATHERING / ALTERATION

Description	Recognition
Residual Soil	Original minerals of rock have been entirely decomposed to secondary minerals, and original rock fabric is not apparent; material can be easily broken by hand
Completely Weathered/Altered	Original minerals of rock have been almost entirely decomposed to secondary minerals, minerals, although original fabric may be intact; material can be granulated by hand
Highly Weathered/Altered	More than half of the rock is decomposed; rock is weakened so that a minimum 50-mm-diameter sample can be broken readily by hand across rock fabric
Moderately Weathered/Altered	Rock is discolored and noticeably weakened, but less than half is decomposed; a minimum 50-mm-diameter sample cannot be broken readily by hand across rock fabric
Slightly Weathered/Altered	Rock is slightly discolored, but not noticeably lower in strength than fresh rock
Fresh	Rock shows no discoloration, loss of strength, or other effect of weathering/alteration

ROCK STRENGTH

Description	Recognition	Approximate Uniaxial Compressive Strength (kPa)
Extremely Weak Rock	Can be indented by thumbnail	250 - 1,000
Very Weak Rock	Can be peeled by pocket knife	1,000 - 5,000
Weak Rock	Can be peeled with difficulty by pocket knife	5,000 - 25,000
Medium Strong Rock	Can be indented 5 mm with sharp end of pick	25,000 - 50,000
Strong Rock	Requires one hammer blow to fracture	50,000 - 100,000
Very Strong Rock	Requires many hammer blows to fracture	100,000 - 250,000
Extremely Strong Rock	Can only be chipped with hammer blows	> 250,000

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Figure 4-5. Proposed Key to Core Boring (continued).

- C The date and time that the borings are started, completed, and of water level measurements.
- C Closure of borings.

Boring logs provide the basic information for the selection of test specimens. They provide background data on the natural condition of the formation, on the ground water elevation, appearance of the samples, and the soil or rock stratigraphy at the boring location, as well as areal extent of various deposits or formations. Data from the boring logs are combined with laboratory test results to identify subgrade profiles showing the extent and depth of various materials at the subject site. Soil profiles showing the depth and the location of various types of materials and ground water elevations are plotted for inclusion in the geotechnical engineer's final report and in the plans and specifications. Detailed boring logs including the results of laboratory tests are included in the text of the report.

4.2 PROJECT INFORMATION

The top of each boring log provides a space for project specific information: name or number of the project, location of the project, drilling contractor (if drilling is contracted out), type of drilling equipment, date and time of work, drilling methods, hammer weight and fall, name of personnel logging the boring, and weather information. All information should be provided on the first sheet of each boring log.

4.3 BORING LOCATIONS AND ELEVATIONS

The boring location (coordinates and/or station and offset) and ground surface elevation (with datum) must be recorded on each boring log. Procedures discussed in Section 2.5.3 should be used for determining the location and elevation for each boring site.

4.4 STRATIGRAPHY IDENTIFICATION

The subsurface conditions observed in the soil samples and drill cuttings or perceived through the performance of the drill rig (for example, rig chatter in gravel, or sampler rebounding on a cobble during driving) should be described in the wide central column on the log labeled "Material Description", or in the remarks column, if available. The driller's comments are valuable and should be considered as the boring log is prepared. In addition to the description of individual samples, the boring log should also describe various strata. The record should include a description of each soil layer, with solid horizontal lines drawn to separate adjacent layers. It is important that a detailed description of subsurface conditions be provided on the field logs at the time of drilling. Completing descriptions in the laboratory is not an acceptable practice. Stratification lines should be drawn where two or more items in the description change, i.e., change from firm to stiff and low to high plasticity. Minor variations can be described using the term 'becoming'. A stratification line should be drawn where the geological origin of the material changes and the origin (if determined) should be designated in the material description or remarks column of the log. Dashed lines should be avoided.

The stratigraphy observations should include identification of existing fill, topsoil, and pavement sections. Careful observation and special sampling intervals may be needed to identify the presence and thickness of these strata. The presence of these materials can have a significant impact on the conclusions and recommendations of the geotechnical studies.

Individual strata should be marked midway between samples unless the boundary is encountered in a sample or special measurements are available to better define the position of the boundary.

4.5 SAMPLE INFORMATION

Information regarding the sampler types, date & time of sampling, sample type, sample depth, and recovery should be shown on each log form using notations and a graphical system or an abbreviation system as designated in Figures 4-4 and 4-5. Each sample attempt should be given a sequential number marked in the sample number column. If the sampler is driven, the driving resistance should be recorded at the specified intervals and marked in the sampling resistance column. The percent recovery should be designated as the length of the recovered sample referenced to the length of the sample attempt (example 550/610 mm).

4.6 SOIL DESCRIPTION AND SOIL CLASSIFICATION

Soil description/identification is the systematic, precise, and complete naming of individual soils in both written and spoken forms (ASTM D-2488, AASHTO M 145), while soil classification is the grouping of the soil with similar engineering properties into a category based on index test results; e.g., group name and symbol (ASTM D-2487, AASHTO M 145). It is important to distinguish between visual identification and classification to minimize conflicts between general visual evaluation of soil samples in the field verses a more precise laboratory evaluation supported by index tests. During progression of a boring, the field personnel should only describe the soils encountered. Group symbols associated with classification should not be used in the field. Visual descriptions in the field is often subjected to outdoor elements, which may influence results. It is important to send the soil samples to a laboratory for accurate visual identification by a technician experienced in soils work, as this single operation will provide the basis for later testing and soil profile development. Classification tests can be performed by the laboratory on representative samples to verify identification and assign appropriate group symbols. If possible, the moisture content of every sample should be performed.

4.6.1 Soil Description

The soil's description should include as a minimum:

- Apparent consistency (for fine-grained soils) or density adjective (for coarse-grained soils)
- Water content condition adjective (e.g., dry, damp, moist, wet)
- Color description
- Minor soil type name with "y" added if fine-grained minor component is less than 30 percent but greater than 12 percent or coarse-grained minor component is 30 percent or more.
- Descriptive adjective for main soil type
- Particle-size distribution adjective for gravel and sand
- Plasticity adjective and soil texture (silty or clayey) for inorganic and organic silts or clays
- Main soil type name (all capital letters)

- C Descriptive adjective "with" for the fine-grained minor soil type if 5 to 12 percent or for the coarse-grained minor soil type if less than 30 percent but 15 percent or more (note some practices use the descriptive adjectives "some" and "trace" for minor components).

- C Descriptive term for minor type(s) of soil

- C Inclusions (e.g., concretions, cementation)

- C Geological name (e.g., Holocene, Eocene, Pleistocene, Cretaceous), if known, (in parenthesis or in notes column)

The various elements of the soil description should generally be stated in the order given above. For example:

Fine-grained soils: Soft, wet, gray, high plasticity CLAY, with f. Sand; (Alluvium)

Coarse-grained soils: Dense, moist, brown, silty m-f SAND, with f. Gravel to c. Sand; (Alluvium)

When changes occur within the same soil layer, such as change in apparent density, the log should indicate a description of the change, such as "same, except very dense".

Consistency and Apparent Density

The consistency of fine-grained soils and apparent density of coarse-grained soils are estimated from the blow count (*N*-value) obtained from Standard Penetration Tests (AASHTO T-206, ASTM D 1586). The consistency of clays and silts varies from soft to firm to stiff to hard. The apparent density of coarse-grained soil ranges from very loose to firm to dense and very dense Suggested guidelines in Tables 4-1 and 4-2 are given for estimating the in-place consistency or apparent density of soils from N-values.

The apparent density or consistency of the soil formation can vary from these empirical correlations for a variety of reasons. Judgment remains an important part of the visual identification process. Mechanical tools such as the pocket (hand) penetrometer, and field index tests (smear test, dried strength test, thread test) are suggested as aids in estimating the consistency of fine grained soils.

In some cases the sampler may pass from one layer into another of markedly different properties; for example, from a dense sand into a soft clay. In attempting to identify apparent density, an assessment should be made as to what part of the blow count corresponds to each layer; realizing that the sampler begins to reflect the presence of the lower layer before it reaches it.

The N-values in all soil types should be corrected for energy efficiency, if possible (ASTM D 4633). An energy efficiency of 60% is considered the reference in the U.S. In certain geotechnical evaluations of coarse-grained soil behavior (relative density, friction angle, liquefaction potential), the blow count (N-value) should be normalized to a reference stress of one atmosphere, as discussed in Chapters 5 and 9.
Note that N-values should <u>not</u> be used to determine the design strength of fine grained soils.

Water Content (Moisture)

The amount of water present in the soil sample or its water content adjective should be described as dry, moist, or wet as indicated in Table 4-3.

Color

The color should be described when the sample is first retrieved at the soil's as-sampled water content (the color will change with water content). Primary colors should be used (brown, gray, black, green, white, yellow, red). Soils with different shades or tints of basic colors are described by using two basic colors; e.g., gray-green. Note that some agencies may require Munsell color and carry no inferences of texture designations. When the soil is marked with spots of color, the term "mottled" can be applied. Soils with a homogeneous texture but having color patterns which change and are not considered mottled can be described as "streaked".

TABLE 4-1.

EVALUATION OF THE APPARENT DENSITY OF COARSE-GRAINED SOILS

Measured N-value	Apparent Density	Behavior of 13 mm Diameter Probe Rod	Relative Density, %
0 - 4	Very loose	Easily penetrated by hand	0 - 20
> 4 - 10	Loose	Firmly penetrated when pushed by hand	20 - 40
>10 - 30	Firm	Easily penetrated when driven with 2 kg. hammer	40 - 70
>30 - 50	Dense	A few centimeters penetration by 2 kg. hammer	70 - 85
>50	Very Dense	Only a few millimeters penetration when driven with 2 kg. hammer	85 - 100

TABLE 4-2.

EVALUATION OF THE CONSISTENCY OF FINE-GRAINED SOILS

Uncorrected N-value	Consistency	Unconfined Compressive Strength, q_u, kPa	Results Of Manual Manipulation
<2	Very soft	<25	Specimen (height = twice the diameter) sags under its own weight; extrudes between fingers when squeezed.
2 - 4	Soft	25 - 50	Specimen can be pinched in two between the thumb and forefinger; remolded by light finger pressure.
4 - 8	Firm	50 - 100	Can be imprinted easily with fingers; remolded by strong finger pressure.
8 - 15	Stiff	100 - 200	Can be imprinted with considerable pressure from fingers or indented by thumbnail.
15 - 30	Very stiff	200 - 400	Can barely be imprinted by pressure from fingers or indented by thumbnail.
>30	Hard	>400	Cannot be imprinted by fingers or difficult to indent by thumbnail.

TABLE 4-3.
ADJECTIVES TO DESCRIBE WATER CONTENT OF SOILS

Description	Conditions
Dry	No sign of water and soil dry to touch
Moist	Signs of water and soil is relatively dry to touch
Wet	Signs of water and soil wet to touch; granular soil exhibits some free water when densified

Type of Soil

The constituent parts of a given soil type are defined on the basis of texture in accordance with particle-size designators separating the soil into coarse-grained, fine-grained, and highly organic designations. Soil with more than 50 percent of the particles larger than the (U.S. Standard) No. 200 sieve (0.075 mm) is designated coarse-grained. Soil (inorganic and organic) with 50 percent or more of the particles finer than the No. 200 sieve is designated fine-grained. Soil primarily consisting of less than 50 percent by volume of organic matter, dark in color, and with an organic odor is designated as organic soil. Soil with organic content more than 50 percent is designated as peat. The soil type designations follow ASTM D 2487; i.e., gravel, sand, clay, silt, organic clay, organic silt, and peat.

Coarse-Grained Soils (Gravel and Sand)

Coarse-grained soils consist of gravel, sand, and fine-grained soil, whether separately or in combination, and in which more than 50 percent of the soil is retained on the No. 200 sieve. The gravel and sand components are defined on the basis of particle size as indicated in Table 4-4.

The particle-size distribution is identified as well graded or poorly graded. Well graded coarse-grained soil contains a good representation of all particle sizes from largest to smallest. Poorly graded coarse-grained soil is uniformly graded with most particles about the same size or lacking one or more intermediate sizes.

Gravels and sands may be described by adding particle-size distribution adjectives in front of the soil type following the criteria given in Table 4-5. Based on correlation with laboratory tests, the following simple field identification tests can be used as an aid in identifying granular soils.

Feel and Smear Tests: A pinch of soil is handled lightly between the thumb and fingers to obtain an impression of the grittiness or of the softness of the constituent particles. Thereafter, a pinch of soil is smeared with considerable pressure between the thumb and forefinger to determine the degrees of roughness and grittiness, or the softness and smoothness of the soil. Following guidelines may be used:

- Coarse- to medium-grained sand typically exhibits a very harsh and gritty feel and smear.
- Coarse- to fine-grained sand has a less harsh feel, but exhibits a very gritty smear.
- Medium- to fine-grained sand exhibits a less gritty feel and smear which becomes softer and less gritty with an increase in the fine sand fraction.
- Fine-grained sand exhibits a relatively soft feel and a much less gritty smear than the coarser sand components.
- Silt components less than about 10 percent of the total weight can be identified by a slight discoloration of the fingers after smear of a moist sample. Increasing silt increases discoloration and softens the smear.

Sedimentation Test: A small sample of the soil is shaken in a test tube filled with water and allowed to settle. The time required for the particles to fall a distance of 100 mm is about 1/2 minute for particle sizes coarser than silt. About 50 minutes would be required for particles of .005 mm or smaller (often defined as "clay size") to settle out.

For sands and gravels containing more than 5 percent fines, the type of inorganic fines (silt or clay) can be identified by performing a shaking/dilatancy test. See fine-grained soils section.

Visual Characteristics: Sand and gravel particles can be readily identified visually but silt particles are generally indistinguishable to the eye. With an increasing silt component, individual sand grains become obscured, and when silt exceeds about 12 percent, it masks almost entirely the sand component from visual separation. Note that gray fine-grained sand visually appears siltier than the actual silt content.

TABLE 4-4.
PARTICLE SIZE DEFINITION FOR GRAVELS AND SANDS

Soil Component	Grain Size	Determination
Boulders*	300 mm +	Measurable
Cobbles*	300 mm to 75 mm	Measurable
Gravel		
Coarse	75 mm to 19 mm	Measurable
Fine	19 mm to #4 sieve (4.75 mm)	Measurable
Sand		
Coarse	#4 to #10 sieve	Measurable and visible to eye
Medium	#10 to #40 sieve	Measurable and visible to eye
Fine	#40 to #200 sieve	Measurable and barely discernible to the eye

*Boulders and cobbles are not considered soil or part of the soil's classification or description, except under miscellaneous description; i.e., with cobbles at about 5 percent (volume).

TABLE 4-5.
ADJECTIVES FOR DESCRIBING SIZE DISTRIBUTION FOR SANDS AND GRAVELS

Particle-Size Adjective	Abbreviation	Size Requirement
Coarse	c.	< 30% m-f sand or < 12% f. gravel
Coarse to medium	c-m	< 12% f. sand
Medium to fine	m-f	< 12% c. sand and > 30% m. sand
Fine	f.	< 30% m. sand or < 12% c. gravel
Coarse to fine	c-f	> 12% of each size[1]

[1] 12% and 30% criteria can be modified depending on fines content. The key is the shape of the particle-size distribution curve. If the curve is relatively straight or dished down, and coarse sand is present, use c-f, also use m-f sand if a moderate amount of m. sand is present. If one has any doubts, determine the above percentages based on the amount of sand or gravel present.

Fine-Grained Soils

Fine-grained soils are those in which 50 percent or more pass the No. 200 sieve (fines) and the fines are inorganic or organic silts and clays. To describe the fine-grained soil types, plasticity adjectives, and soil types as adjectives should be used to further define the soil type's texture and plasticity. Based on correlations and laboratory tests, the following simple field identification tests can be used to estimate the degree of plasticity of fine-grained soils.

Shaking (Dilatancy) Test: Water is dropped or sprayed on a part of basically fine-grained soil mixed and held in the palm of the hand until it shows a wet surface appearance when shaken or bounced lightly in the hand or a sticky nature when touched. The test involves lightly squeezing the soil pat between the thumb and forefinger and releasing it alternatively to observe its reaction and the speed of the response. Soils which are predominantly silty (nonplastic to low plasticity) will show a dull dry surface upon squeezing and a glassy wet surface immediately upon releasing of the pressure. With increasing fineness (plasticity) and the related decreasing dilatancy, this phenomenon becomes less and less pronounced.

Dry Strength Test: A portion of the sample is allowed to dry out and a fragment of the dried soil is pressed between the fingers. Fragments which cannot be crumbled or broken are characteristic of clays with high plasticity. Fragments which can be disintegrated with gentle finger pressure are characteristic of silty materials of low plasticity. Thus, materials with great dry strength are clays of high plasticity and those with little dry strength are predominantly silts.

Thread Test: (After Burmister, 1970) Moisture is added or worked out of a small ball (about 40 mm diameter) and the ball kneaded until its consistency approaches medium stiff to stiff (compressive strength of about 100 KPa), it breaks, or crumbles. A thread is then rolled out to the smallest diameter possible before disintegration. The smaller the thread achieved, the higher the plasticity of the soil. Fine-grained soils of high plasticity will have threads smaller than 3/4 mm in diameter. Soils with low plasticity will have threads larger than 3 mm in diameter.

Smear Test: A fragment of soil smeared between the thumb and forefinger or drawn across the thumbnail will, by the smoothness and sheen of the smear surface, indicate the plasticity of the soil. A soil of low plasticity will exhibit a rough textured, dull smear while a soil of high plasticity will exhibit a slick, waxy smear surface.

Table 4-6 identifies field methods to approximate the plasticity range for the dry strength, thread, and smear tests.

Highly Organic Soils

Colloidal and amorphous organic materials finer than the No. 200 sieve are identified and classified in accordance with their drop in plasticity upon oven drying (ASTM D 2487). Additional identification markers are:

1. dark gray and black and sometimes dark brown colors, although not all dark colored soils are organic;
2. most organic soils will oxidize when exposed to air and change from a dark gray/black color to a lighter brown; i.e., the exposed surface is brownish, but when the sample is pulled apart the freshly exposed surface is dark gray/black;

TABLE 4-6.

FIELD METHODS TO DESCRIBE PLASTICITY

Plasticity Range	Adjective	Dry Strength	Smear Test	Thread Smallest Diameter, mm
0	nonplastic	none - crumbles into powder with mere pressure	gritty or rough	ball cracks
1 - 10	low plasticity	low - crumbles into powder with some finger pressure	rough to smooth	6 to 3
>10 - 20	medium plasticity	medium - breaks into pieces or crumbles with considerable finger pressure	smooth and dull	1-1/2
>20 - 40	high plasticity	high - cannot be broken with finger pressure; spec. will break into pieces between thumb and a hard surface	shiny	3/4
>40	very plastic	very high - can't be broken between thumb and a hard surface	very shiny and waxy	½

3. fresh organic soils usually have a characteristic odor which can be recognized, particularly when the soil is heated;
4. compared to non-organic soils, less effort is typically required to pull the material apart and a friable break is usually formed with a fine granular or silty texture and appearance;
5. their workability at the plastic limit is weaker and spongier than an equivalent non-organic soil;
6. the smear, although generally smooth, is usually duller and appears more silty; and
7. the organic content of these soils can also be determined by combustion test method (AASHTO T 267, ASTM D 2974).

Fine-grained soils, where the organic content appears to be less than 50 percent of the volume (about 22 percent by weight) should be described as soils with organic material or as organic soils such as clay with organic material or organic clays etc. If the soil appears to have an organic content higher than 50 percent by volume it should be described as peat. The engineering behavior of soils below and above the 50 percent dividing line presented here is entirely different. It is therefore critical that the organic content of soils be determined both in the field and in the laboratory (AASHTO T 267, ASTM D 2974). Simple field or visual laboratory identification of soils as organic or peat is neither advisable nor acceptable.

It is very important not to confuse topsoil with organic soils or peat. Topsoil is the thin layer of deposit found on the surface composed of partially decomposed organic materials, such as leaves, grass, small roots etc. It contains many nutrients that sustain plant and insect life. These should not be classified as organic soils or peat and should not be used in engineered structures.

Minor Soil Type(s)

In many soil formations, two or more soil types are present. When the percentage of the fine-grained minor soil type is less than 30 percent but greater than 12 percent or the total sample or the coarse-grained minor component is 30 percent or more of the total sample, the minor soil type is indicated by adding a "y" to its name (i.e., f. gravelly, c-f. sandy, silty, clayey, organic). Note the gradation adjectives are given for granular soils, while the plasticity adjective is omitted for the fine-grained soils.)

When the percentage of the fine-grained minor soil type if 5 to 12 percent or for the coarse-grained minor soil type if less than 30 percent but 15 percent or more of the total sample, the minor soil type is indicated by adding the descriptive adjective “with” to the group name (i.e., with clay, with silt, with sand, with gravel, and/or with cobbles).

Some local practices use the descriptive adjectives “some” and “trace” for minor components.
- "trace" when the percentage is between 1 and 12 percent of the total sample; or
- "some" when the percentage is greater than 12 percent and less than 30 percent of the total sample.

Inclusions

Additional inclusions or characteristics of the sample can be described by using "with" and the descriptions described above. Examples are given below:

- with petroleum odor
- with organic matter
- with foreign matter (roots, brick, etc.)
- with shell fragments
- with mica
- with parting(s), seam(s), etc. of (give soils complete description)

Layered Soils

Soils of different types can be found in repeating layers of various thickness. It is important that all such formations and their thicknesses are noted. Each layer is described as if it is a nonlayered soil using the sequence for soil descriptions discussed above. The thickness and shape of layers and the geological type of layering are noted using the descriptive terms presented in Table 4-7. Place the thickness designation before the type of layer, or at the end of each description and in parentheses, whichever is more appropriate.

Examples of descriptions for layered soils are:

- Medium stiff, moist to wet 5 to 20 mm interbedded seams and layers of: gray, medium plastic, silty CLAY; and lt. gray, low plasticity SILT; (Alluvium).

- Soft moist to wet varved layers of: gray-brown, high plasticity CLAY (5 to 20 mm); and nonplastic SILT, trace f. sand (10 to 15 mm); (Alluvium).

TABLE 4-7.

DESCRIPTIVE TERMS FOR LAYERED SOILS

Type Of Layer	Thickness	Occurrence
Parting	< 1.5 mm	
Seam	10 to 1.5 mm	
Layer	300 to 10 mm	
Stratum	>300 mm	
Pocket		Small erratic deposit
Lens		Lenticular deposit
Varved (also layered)		Alternating seams or layers of silt and/or clay and sometimes fine sand
Occasional		One or less per 0.3 m of thickness or laboratory sample inspected
Frequent		More than one per 0.3 m of thickness or laboratory

Geological Name

The soil description should include the field supervisor's assessment of the origin of the soil unit and the geologic name, if known, placed in parentheses or brackets at the end of the soil description or in the field notes column of the boring log. Some examples include:

a. *Washington, D.C.* - Cretaceous Age Material with SPT-N values between 30 and 100 bpf:
Very hard gray-blue silty CLAY (CH), damp **[Potomac Group Formation]**
b. *Newport News, VA* - Miocene Age Marine Deposit with SPT- N values around 10 to 15 bpf:
Stiff green sandy CLAY (CL) with shell fragments, calcareous **[Yorktown Formation].**

4.6.2 Soil Classification

As previously indicated, final identification with classification is best performed in the laboratory. This will lead to more consistent final boring logs and avoid conflicts with field descriptions. The Unified Soil Classification System (USCS) Group Name and Symbol (in parenthesis)appropriate for the soil type in accordance with AASHTO M 145, ASTM D 3282, or ASTM D 2487 is the most commonly used system in geotechnical work and is covered in this section. For classification of highway subgrade material, the AASHTO classification system (see Section 4.6.3) is used and is also based on grain size and plasticity.

The Unified Classification System

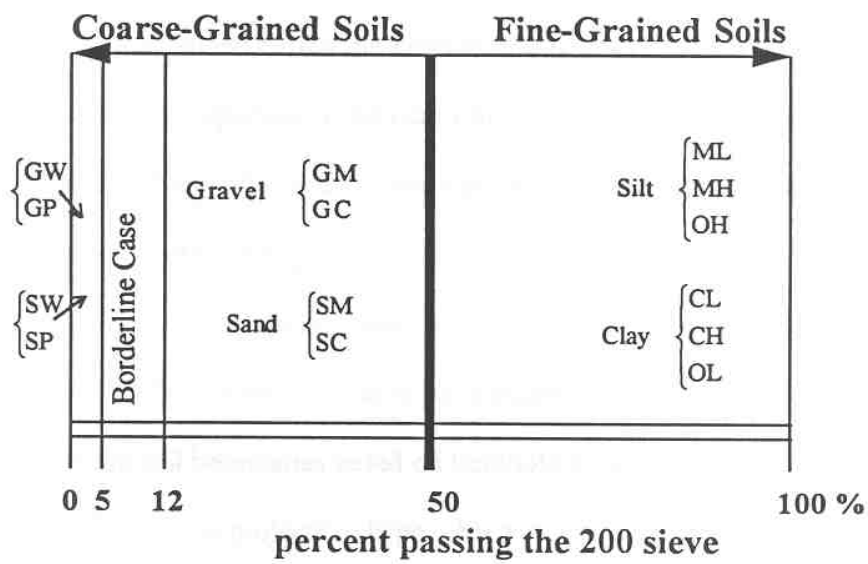
The Unified Classification System (ASTM D 2487) groups soils with similar engineering properties into categories base on grain size, gradation and plasticity. Table 4-8 provides a simplification of the group breakdown and Table 4-9 provides an outline of the complete laboratory classification method. Following are the procedures along with charts and tables for classifying coarse-grained and fine-grained soils.

Classification of Coarse-Grained Soils

The flow chart to determine the group symbol and group name for coarse-grained soils, those in which 50 percent or more are retained on the No. 200 sieve (0.075 mm) is given in Figure 4-6. This figure is identical to that of Figure 2 in ASTM D 2487 except for the recommendation to capitalize the primary soil type; i.e., GRAVEL.

TABLE 4-8.

THE UNIFIED CLASSIFICATION SYSTEM



Soil Type: G = Gravel S = Sand M = Silt
C = Clay O = Organics

Soil Gradation: determined on dis-aggregated specimen forced through nested sieves
W = Well Graded P = Poorly Graded
C_u > 4 (GW) to 6 (SW) **C_u < 4 (GP) to 6(SP)**

Plasticity: determined on remolded specimens
H = High Plasticity L = Low Plasticity
LL > 50 **LL< 50**

TABLE 4-9.

SOIL CLASSIFICATION CHART (LABORATORY METHOD)

Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[a]			Soil Classification: Group Symbol	Soil Classification: Group Name[b]
GRAVELS	CLEAN GRAVELS	C_U $4 and 1#$C_C$ #3[e]	GW	Well-graded Gravel
More than 50% of coarse	Less than 5% fines	C_U #4 and 1$$C_C$ $3[e]	GP	Poorly-graded Gravel[f]
Fraction retained on No. 4	GRAVELS WITH FINES	Fines classify as ML or MH	GM	Silty Gravel[f,g,h]
Sieve	More than 12% of fines[c]	Fines classify as CL or CH	GC	Clayey Gravel[f,g,h]
SANDS	CLEAN SANDS	$C_U$$6 and 1#C_C #3[e]	SW	Well-graded Sand[i]
50% or more of coarse	Less than 5% fines[d]	C_U #6 and 1$$C_C$ $3[e]	SP	Poorly-graded Sand[i]
Fraction retained on No. 4	SANDS WITH FINES	Fines classify as ML or MH	SM	Silty Sand[g,h,i]
Sieve	More than 12% fines[d]	Fines classify as CL or CH	SC	Clayey Sand[g,h,i]
SILTS AND CLAYS	Inorganic	PI > 7 and plots on or above "A" line[j]	CL	Lean Clay[k,l,m]
Liquid limit less than 50%		PI < 4 or plots below "A" line[j]	ML	Silt[k,l,m]
	Organic	$\frac{\text{Liquid limit - ovendried}}{\text{Liquid limit - not dried}} < 0.75$	OL	Organic Clay[k,l,m,n]
				Organic Silt[k,l,m,o]
SILTS AND CLAYS	Inorganic	Pl plots on or above "A" line	CH	Fat Clay[k,l,m]
Liquid limit more than 50%		Pl plots below "A" line	MH	Elastic Silt[k,l,m]
	Organic	$\frac{\text{Liquid limit - ovendried}}{\text{Liquid limit - not dried}} < 0.75$	OH	Organic Silt[k,l,m,p]
				Organic Silt[k,l,m,q]
Highly fibrous organic soils	Primary organic matter, dark in color, and organic odor		Pt	Peat and Muskeg

TABLE 4-9. (Continued)

SOIL CLASSIFICATION CHART (LABORATORY METHOD)

NOTES:

a Based on the material passing the 75-mm sieve.

b If field sample contained cobbles and/or boulders, add “with cobbles and/or boulders” to group name.

c Gravels with 5 to 12% fines require dual symbols:
GW-GM well-graded gravel with silt
GW-GC well-graded gravel with clay
GP-GM poorly graded gravel with silt
GP-GC poorly graded gravel with clay

d Sands with 5 to 12% fines require dual symbols:
SW-SM well-graded sand with silt
SW-SC well-graded sand with clay
SP-SM poorly graded sand with silt
SP-SC poorly graded sand with clay

e
$$C_U = \frac{D_{60}}{D_{10}} = Uniformity\ Coefficient\ (also\ UC)$$

$$C_C = \frac{(D_{30})^2}{(D_{10})(D_{60})} = Coefficient\ of\ Curvature$$

f If soil contains $ 15% sand, add “with sand” to group name.

g If fines classify as CL-ML, use dual symbol GC-GM, SC-SM.

h If fines are organic, add “with organic fines” to group name.

i If soil contains $ 15% gravel, add “with gravel” to group name.

j If the liquid limit and plasticity index plot in hatched area on plasticity chart, soil is a CL-ML, silty clay.

k If soil contains 15 to 29% plus No. 200, add “with sand” or “with gravel”, whichever is predominant.

l If soil contains $ 30% plus No. 200, predominantly sand, add “sandy” to group name.

m If soil contains $ 30% plus No. 200, predominantly gravel, add “gravelly” to group name.

n Pl $ 4 and plots on or above “A” line.

o Pl < 4 or plots below “A” line.

p Pl plots on or above “A” line.

q Pl plots below “A” line.

FINE-GRAINED SOILS (clays & silts): 50% or more passes the No. 200 sieve

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COARSE-GRAINED SOILS (sands & gravels): more than 50% retained on No. 200 sieve

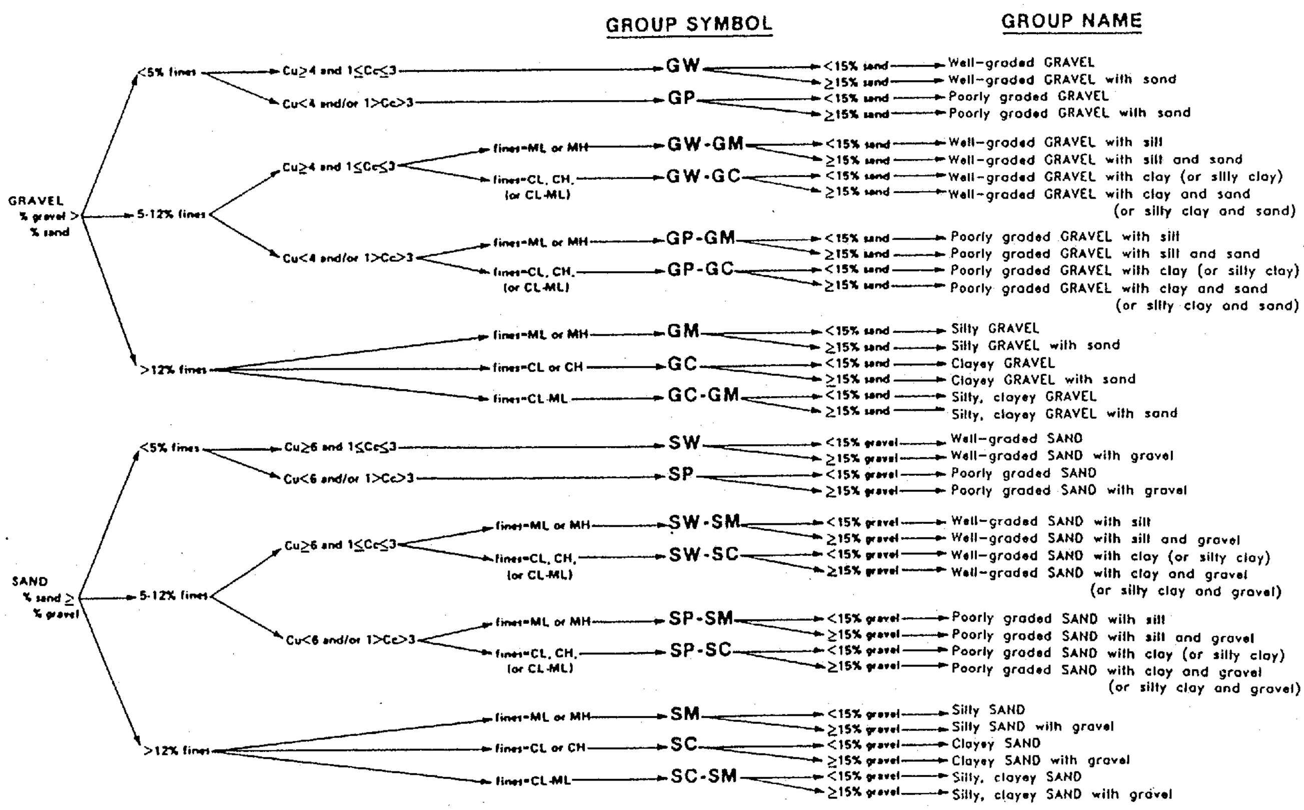

Figure 4-6. Flow Chart to Determine the Group Symbol and Group Name for Coarse-grained Soils. (From U.S. Bureau of Reclamation Soil Classification Handbook, 1960)

Classification of Fine-Grained Soils

Fine-grained soils, those in which 50 percent or more pass the No. 200 sieve (fines), are defined by the plasticity chart (Figure 4-7) and, for organic soils, the decrease in liquid limit (LL) upon oven drying (Table 4-9). Inorganic silts and clays are those which do not meet the organic criteria as given in Table 4-9. The flow charts to determine the group symbol and group name for fine-grained soils are given in Figure 4-8a and b. These figures are identical to Figures 1a and 1b in ASTM D 2487 except that they are modified to show the soil type capitalized; i.e., CLAY. Dual symbols are used to indicate the organic silts and clays that are above the "A"-line. For example, CL/OL instead of OL and CH/OH instead of OH. To describe the fine-grained soil types, plasticity adjectives, and soil types as adjectives should be used to further define the soil type's texture , plasticity, and location on the plasticity chart; see Table 4-10. Examples using Table 4-10 are given in Table 4-11.

As an example, the group name and symbol has been added to the example descriptions given in the previous section:

Fine-grained soils: Soft, wet, gray, high plasticity CLAY, with f. Sand; Fat CLAY (CH); (Alluvium)

Coarse-grained soils: Dense, moist, brown, silty m-f SAND, with f. Gravel to c. Sand; Silty SAND (SM); (Alluvium)

Some local practices omit the USCS group symbol (e.g., CL, ML, etc.) but include the group symbol at the end of the description.

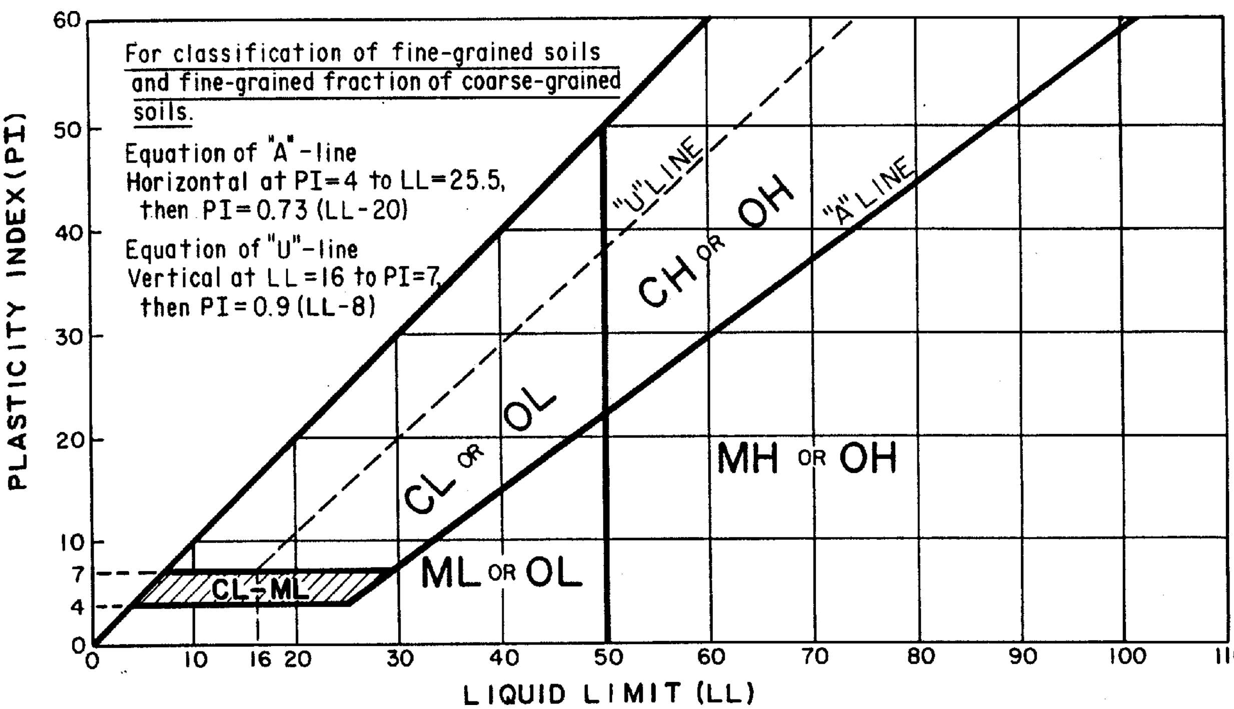

Figure 4-7. Plasticity Chart for Unified Soil Classification System (ASTM D 2488).

TABLE 4-10.

SOIL PLASTICITY DESCRIPTIONS

Plasticity Index Range	Plasticity Adjective	Adjective for Soil Type, Texture, and Plasticity Chart Location		
		ML & MH (Silt)	CL & CH (Clay)	OL & OH (Organic Silt or Clay)[1]
0	nonplastic	-	-	ORGANIC SILT
1 - 10	low plasticity	-	silty	ORGANIC SILT
>10 - 20	medium plasticity	clayey	silty to no adj.	ORGANIC clayey SILT
>20 - 40	high plasticity	clayey	-	ORGANIC silty CLAY
>40	very plastic	clayey	-	ORGANIC CLAY

[1] Soil type is the same for above or below the "A"-line; the dual group symbol (CL/OL or CH/OH) identifies the soil types above the "A"-line.

TABLE 4-11.

EXAMPLES OF DESCRIPTION OF FINE-GRAINED SOILS

Group Symbol	PI	Group Name	Complete Description For Main Soil Type (Fine-Grained Soil)
CL	9	lean CLAY	low plasticity silty CLAY
ML	7	SILT	low plasticity SILT
ML	15	SILT	medium plastic clayey SILT
MH	21	elastic SILT	high plasticity clayey SILT
CH	25	fat CLAY	high plasticity silty CLAY or high plasticity CLAY, depending on smear test (for silty relatively dull and not shiny or just CLAY for shiny, waxy)
OL	8	ORGANIC SILT	low plasticity ORGANIC SILT
OL	19	ORGANIC SILT	medium plastic ORGANIC clayey SILT
CH	>40	fat CLAY	very plastic CLAY

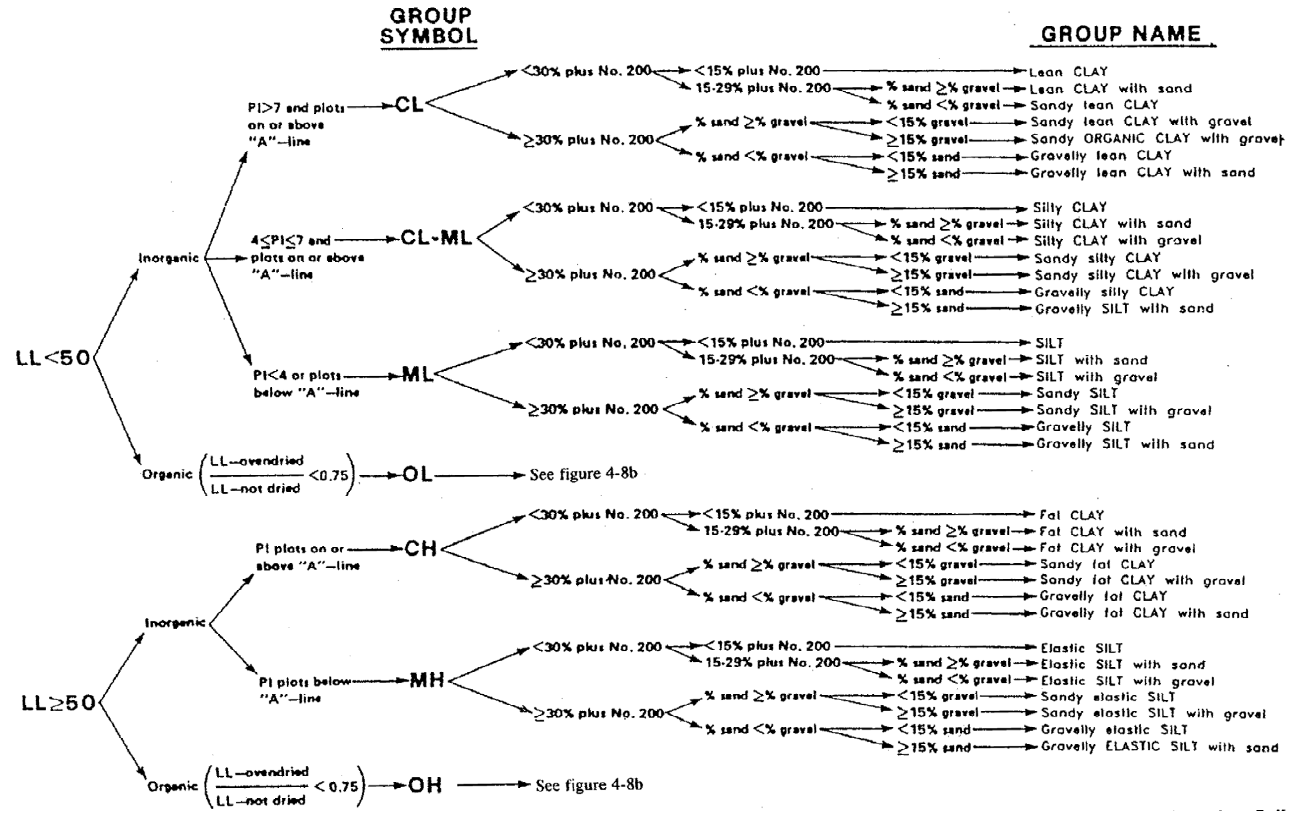

Figure 4-8a. Flow Chart to Determine the Group Symbol and Group Name for Fine-Grained Soils.

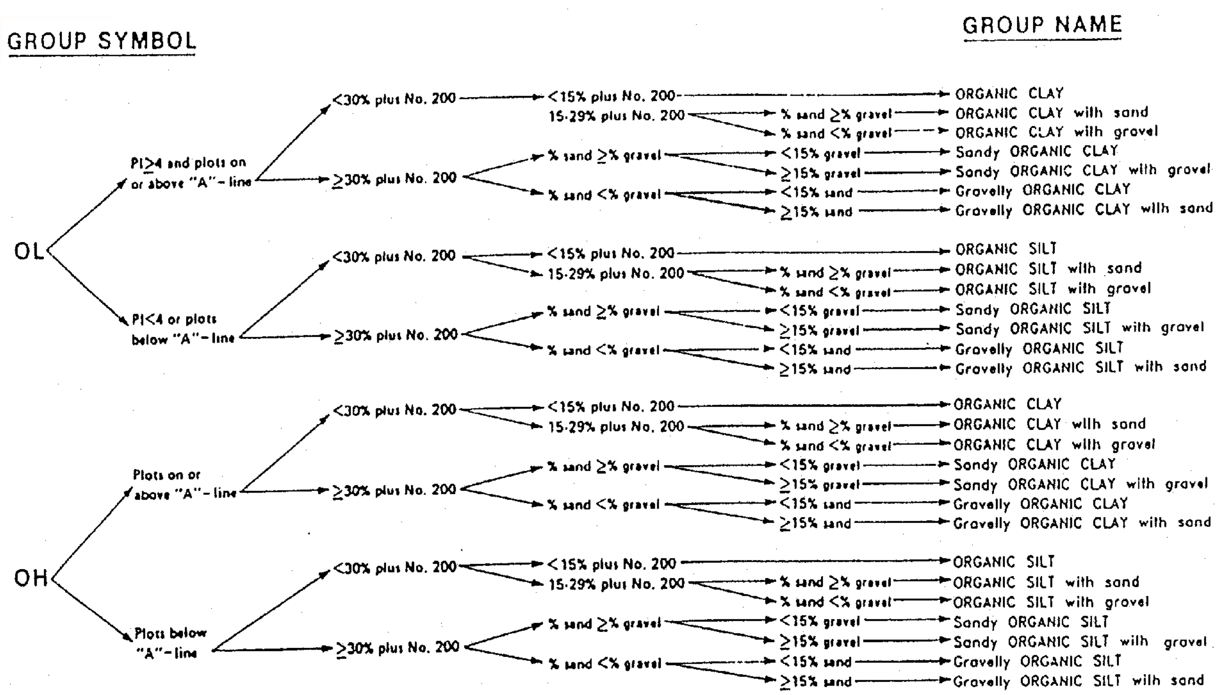

Figure 4-8b. Flow Chart to Determine the Group Symbol and Group Name for Organic Soils.

4.6.3 AASHTO Soil Classification System

The AASHTO soil classification system is shown in Table 4-12. This classification system is useful in determining the relative quality of the soil material for use in earthwork structures, particularly embankments, subgrades, subbases and bases.

According to this system, soil is classified into seven major groups, A-1 through A-7. Soils classified under groups A-1, A-2 and A-3 are granular materials where 35% or less of the particles pass through the No. 200 sieve. Soils where more than 35% pass the No. 200 sieve are classified under groups A-4, A-5, A-6 and A-7. These are mostly silt and clay-type materials. The classification procedure is shown in Table 4-12. The classification system is based on the following criteria:

I. *Grain Size*: The grain size terminology for this classification system is as follows:
   Gravel:fraction passing the 75 mm sieve and retained on the No. 10 (2 mm) sieve.
   Sand:fraction passing the No. 10 (2 mm) sieve and retained on the No. 200 (0.075 mm) sieve
   Silt and clay: fraction passing the No. 200 (0.075 mm) sieve

ii *Plasticity*: The term *silty* is applied when the fine fractions of the soil have a plasticity index of 10 or less. The term *clayey* is applied when the fine fractions have a plasticity index of 11 or more.

iii. If cobbles and boulders (size larger than 75 mm) are encountered they are excluded from the portion of the soil sample on which classification is made. However, the percentage of material is recorded.

To evaluate the quality of a soil as a highway subgrade material, a number called the *group index* (GI) is also incorporated along with the groups and subgroups of the soil. This is written in parenthesis after the group or subgroup designation. The group index is given by the equation

Group Index: $GI=(F-35)[0.2+0.005(LL-40)] + 0.01(F-15)(PI-10)$ (4-1)

where F is the percent passing No. 200 sieve, LL is the liquid limit and PI is the plasticity index. The first term of Eq. 4-1 is the partial group index determined from the liquid limit. The second term is the partial group index determined from the plasticity index. Following are some rules for determining group index:

- If Eq. 4-1 yields a negative value for GI, it is taken as zero.
- The group index calculated from Eq. 4-1 is rounded off to the nearest whole number, e.g., GI=3.4 is rounded off to 3; GI=3.5 is rounded off to 4.
- There is no upper limit for the group index.
- The group index of soils belonging to groups A-1-a, A-1-b, A-2-4, A-2-5, and A-3 will always be zero.
- When calculating the group index for soils belonging to groups A-2-6 and A-2-7, the partial group index for PI should be used, or

$$GI=0.01(F-15)(PI-10) \quad (4-2)$$

In general, the quality of performance of a soil as a subgrade material is inversely proportional to the group index.

TABLE 4-12.

AASHTO SOIL CLASSIFICATION SYSTEM (AASHTO M 145, 1995)

GENERAL CLASSIFICATION	GRANULAR MATERIALS (35 percent or less of total sample passing No. 200)							SILT-CLAY MATERIALS (More than 35 percent of total sample passing No. 200)			
GROUP CLASSIFICATION	A-1		A-3	A-2				A-4	A-5	A-6	A-7
	A-1-a	A-1-b		A-2-4	A-2-5	A-2-6	A-2-7				A-7-5, A-7-6
Sieve analysis, percent passing: 2 mm (No. 10) 0.425 mm (No. 40) 0.075 mm (No. 200)	 50 max. 30 max. 15 max.	 50 max. 25 max.	 51 min. 10 max.	35 max.	35 max.	35 max.	35 max.	36 min.	36 min.	36 min.	36 min.
Characteristics of fraction passing 0.425 mm (No. 40) Liquid limit Plasticity index	 6 max.		 NP	40 max. 10 max.	41 min. 10 max.	40 max. 11 min.	41 min. 11 min.	40 max. 10 max.	41 min. 10 max.	40 max. 11 min.	41 min. 11 min.*
Usual significant constituent materials	Stone fragments, gravel and sand		Fine sand	Silty or clayey gravel and sand				Silty soils		Clayey soils	
Group Index**	0		0	0		4 max.		8 max.	12 max.	16 max.	20 max.

Classification procedure: With required test data available, proceed from left to right on chart; correct group will be found by process of elimination. The first group from left into which the test data will fit is the correct classification.

*Plasticity Index of A-7-5 subgroup is equal to or less than LL minus 30. Plasticity Index of A-7-6 subgroup is greater than LL minus 30 (see Fig 4-9).

**See group index formula (Eq. 4-1) Group index should be shown in parentheses after group symbol as: A-2-6(3), A-4(5), A-6(12), A-7-5(17), etc.

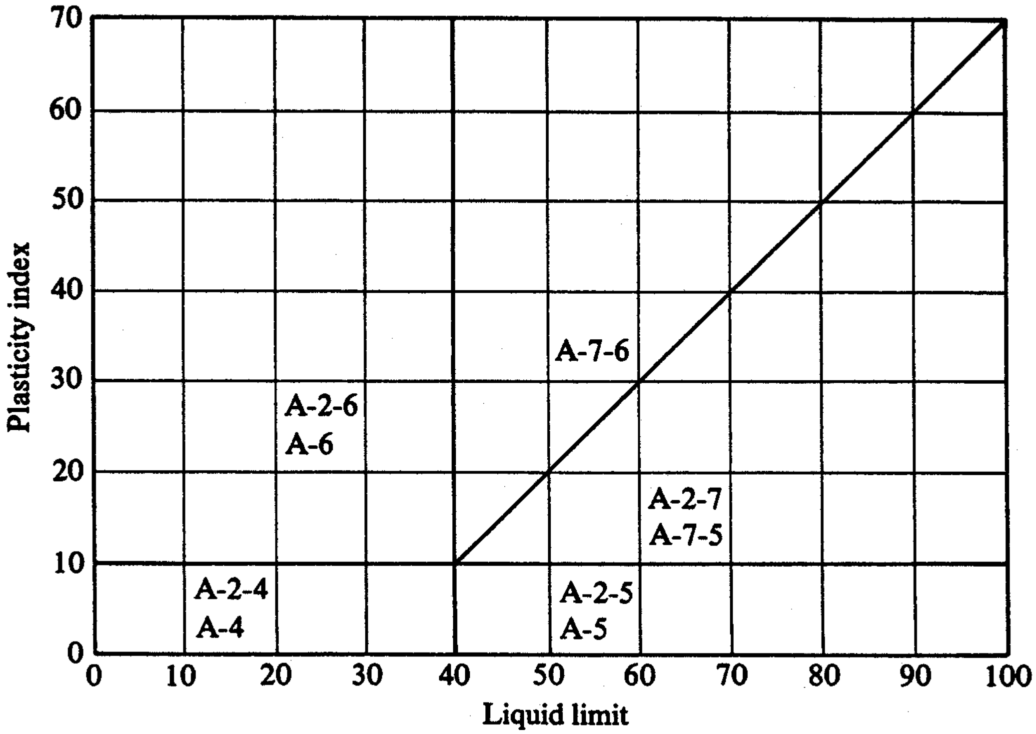

Figure 4-9. Range of Liquid Limit and Plasticity Indices for Soils in Soil Classification Groups A-2, A-4, A-5, A-6 and A-7 (AASHTO Standard M 145, 1995).

4.7 LOGGING PROCEDURES FOR CORE DRILLING

As with soil boring logs, rock or core boring logs should be as comprehensive as possible under field conditions, yet be terse and precise. The level of detail should be keyed to the purpose of the exploration as well as to the intended user of the prepared logs. Although the same basic information should be presented on all rock boring logs, the appropriate level of detail should be determined by the geotechnical engineer and/or the geologist based on project needs. Borings for a bridge foundation may require more detail concerning degree of weathering than rock structure features. For a proposed tunnel excavation, the opposite might be true. Extremely detailed descriptions of rock mineralogy may mask features significant to an engineer, but may be critical for a geologist.

4.7.1 Description of Rock

Rock descriptions should use technically correct geological terms, although local terms in common use may be acceptable if they help describe distinctive characteristics. Rock cores should be logged when wet for consistency of color description and greater visibility of rock features. The guidelines presented in the "International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests" (1978, 1981), should be reviewed for additional information regarding logging procedures for core drilling.

The rock's lithologic description should include as a minimum the following items:

- Rock type
- Color
- Grain size and shape
- Texture (stratification/foliation)
- Mineral composition
- Weathering and alteration
- Strength
- Other relevant notes

The various elements of the rock's description should be stated in the order listed above. For example:

"Limestone, light gray, very fine-grained, thin-bedded, unweathered, strong"

The rock description should include identification of discontinuities and fractures. The description should include a drawing of the naturally occurring fractures and mechanical breaks.

4.7.2 Rock Type

Rocks are classified according to origin into three major divisions: igneous, sedimentary, and metamorphic, see Table 4-13. These three groups are subdivided into types according to mineral and chemical composition, texture, and internal structure. For some projects a library of hand samples and photographs representing lithologic rock types present in the project area should be maintained.

4.7.3 Color

Colors should be consistent with a Munsell Color Chart and recorded for both wet and dry conditions as appropriate.

4.7.4 Grain Size and Shape

The grain size description should be classified using the terms presented in Table 4-14. Table 4-15 is used to further classify the shape of the grains.

4.7.5 Stratification/Foliation

Significant nonfracture structural features should be described. The thickness should be described using the terms in Table 4-16. The orientation of the bedding/foliation should be measured from the horizontal with a protractor.

TABLE 4-13.

ROCK GROUPS AND TYPES

IGNEOUS

Intrusive (Coarse Grained)	***Extrusive (Fine Grained)***	***Pyroclastic***
Granite	Rhyolite	Obsidian
Syenite	Trachyte	Pumice
Diorite	Andesite	Tuff
Diabase	Basalt	
Gabbro		
Peridotite		
Pegmatite		

SEDIMENTARY

Clastic (Sediment)	***Chemically Formed***	***Organic Remains***
Shale	Limestone	Chalk
Mudstone	Dolomite	Coquina
Claystone	Gypsum	Lignite
Siltstone	Halite	Coal
Sandstone		
Conglomerate		
Limestone, oolitic		

METAMORPHIC

Foliated	***Nonfoliated***
Slate	Quartzite
Phyllite	Amphibolite
Schist	Marble
Gneiss	Hornfels

TABLE 4-14.

TERMS TO DESCRIBE GRAIN SIZE OF (TYPICALLY FOR) SEDIMENTARY ROCKS

Description	Diameter (mm)	Characteristic
Very coarse grained	> 4.75	Grains sizes are greater than popcorn kernels
Coarse grained	2.00 -4.75	Individual grains can be easily distinguished by eye
Medium grained	0.425 -2.00	Individual grains can be distinguished by eye
Fine grained	0.075-0.425	Individual size grains can be distinguished with difficulty
Very fine grained	< 0.075	Individual grains cannot be distinguished by unaided eye

TABLE 4-15.

TERMS TO DESCRIBE GRAIN SHAPE (FOR SEDIMENTARY ROCKS)

Description	Characteristic
Angular	Showing very little evidence of wear. Grain edges and corners are sharp. Secondary corners are numerous and sharp.
Subangular	Showing definite effects of wear. Grain edges and corners are slightly rounded off. Secondary corners are slightly less numerous and slightly less sharp than in angular grains.
Subrounded	Showing considerable wear. Grain edges and corners are rounded to smooth curves. Secondary corners are reduced greatly in number and highly rounded.
Rounded	Showing extreme wear. Grain edges and corners are smoothed off to broad curves. Secondary corners are few in number and rounded.
Well-rounded	Completely worn. Grain edges or corners are not present. No secondary edges or corners are present.

TABLE 4-16.

TERMS TO DESCRIBE STRATUM THICKNESS

Descriptive Term	Stratum Thickness
Very Thickly bedded	> 1 m
Thickly bedded	0.5 to 1.0 m
Thinly bedded	50 mm to 500 mm
Very Thinly bedded	10 mm to 50 mm
Laminated	2.5 mm to 10 mm
Thinly Laminated	< 2.5 mm

4.7.6 Mineral Composition

The mineral composition should be identified by a geologist based on experience and the use of appropriate references. The most abundant mineral should be listed first, followed by minerals in decreasing order of abundance. For some common rock types, mineral composition need not be specified (e.g. dolomite, limestone).

4.7.7 Weathering and Alteration

Weathering as defined here is due to physical disintegration of the minerals in the rock by atmospheric processes while alteration is defined here as due to geothermal processes. Terms and abbreviations used to describe weathering or alteration are presented in Figure 4-5.

4.7.8 Strength

The point load test, described in Section 8.2.1, is recommended for the measurement of sample strength in the field. The point-load index (I_s) may be converted to an equivalent uniaxial compressive strength and noted as such on the records. Various categories and terminology recommended for describing rock strength based on the point load test are presented in Figure 4-5. Figure 4-5 also presents guidelines for common qualitative assessment of strength while mapping or during primary logging of core at the rig site by using a geological hammer and pocket knife. The field estimates should be confirmed where appropriate by comparison with selected laboratory tests.

4.7.9 Hardness

Hardness is commonly assessed by the scratch test. Descriptions and abbreviations used to describe rock hardness are presented in Table 4-17.

TABLE 4-17.

TERMS TO DESCRIBE ROCK HARDNESS

Description (Abbr)	Characteristic
Soft (S)	Reserved for plastic material alone.
Friable (F)	Easily crumbled by hand, pulverized or reduced to powder and is too soft to be cut with a pocket knife.
Low Hardness (LH)	Can be gouged deeply or carved with a pocket knife.
Moderately Hard (MH)	Can be readily scratched by a knife blade; scratch leaves a heavy trace of dust and scratch is readily visible after the powder has been blown away.
Hard (H)	Can be scratched with difficulty; scratch produces little powder and is often faintly visible; traces of the knife steel may be visible.
Very Hard (VH)	Cannot be scratched with pocket knife. Leave knife steel marks on surface.

4.7.10 Rock Discontinuity

Discontinuity is the general term for any mechanical crack or fissure in a rock mass having zero or low tensile strength. It is the collective term for most types of joints, weak bedding planes, weak schistosity planes, weakness zones, and faults. The symbols recommended for the type of rock mass discontinuities are listed in Figure 4-5.

The spacing of discontinuities is the perpendicular distance between adjacent discontinuities. The spacing should be measured in centimeters or millimeters, perpendicular to the planes in the set. Figure 4-5 presents guidelines to describe discontinuity spacing.

The discontinuities should be described as closed, open, or filled. Aperture is used to describe the perpendicular distance separating the adjacent rock walls of an open discontinuity in which the intervening space is air or water filled. Width is used to describe the distance separating the adjacent rock walls of filled discontinuities. The terms presented in Table 4-18 should be used to describe apertures.

Terms such as "wide", "narrow" and "tight" are used to describe the width of discontinuities such as thickness of veins, fault gouge filling, or joints openings. Guidelines for use of such terms are presented in Figure 4-5.

For the faults or shears that are not thick enough to be represented on the boring log, the measured thickness is recorded numerically in millimeters.

In addition to the above characterization, discontinuities are further characterized by the surface shape of the joint and the roughness of its surface. Refer to Figure 4-5 for guidelines to characterize these features.

Filling is the term for material separating the adjacent rock walls of discontinuities. Filling is characterized by its type, amount, width (i.e., perpendicular distance between adjacent rock walls) and strength. Figure 4-5 presents guidelines for characterizing the amount and width of filling. The strength of any filling material along discontinuity surfaces can be assessed by the guidelines for soil presented in the last three columns of Table 4-2. For non-cohesive fillings, then identify the filling qualitatively (e.g., fine sand).

TABLE 4-18.
TERMS TO CLASSIFY DISCONTINUITIES BASED ON APERTURE SIZE

Aperture	Description	
<0.1 mm 0.1 - 0.25 mm 0.25 - 0.5 mm	Very tight Tight Partly open	"Closed Features"
0.5 - 2.5 mm 2.5 - 10 mm > 10 mm	Open Moderately open Wide	"Gapped Features"
1-10 cm 10-100 cm >1 m	Very wide Extremely wide Cavernous	"Open Features"

4.7.11 Fracture Description

The location of each naturally occurring fracture and mechanical break is shown in the fracture column of the rock core log. The naturally occurring fractures are numbered and described using the terminology described above for discontinuities.

The naturally occurring fractures and mechanical breaks are sketched in the drawing column. Dip angles of fractures should be measured using a protractor and marked on the log. For nonvertical borings, the angle should be measured and marked as if the boring was vertical. If the rock is broken into many pieces less than 25 mm long, the log may be crosshatched in that interval, or the fracture may be shown schematically.

The number of naturally occurring fractures observed in each 0.5 m of core should be recorded in the fracture frequency column. Mechanical breaks, thought to have occurred due to drilling, are not counted. The following criteria can be used to identify natural breaks:

1. A rough brittle surface with fresh cleavage planes in individual rock minerals indicates an artificial fracture.
2. A generally smooth or somewhat weathered surface with soft coating or infilling materials, such as talc, gypsum, chlorite, mica, or calcite obviously indicates a natural discontinuity.
3. In rocks showing foliation, cleavage or bedding it may be difficult to distinguish between natural discontinuities and artificial fractures when these are parallel with the incipient weakness planes. If drilling has been carried out carefully then the questionable breaks should be counted as natural features, to be on the conservative side.
4. Depending upon the drilling equipment, part of the length of core being drilled may occasionally rotate with the inner barrels in such a way that grinding of the surfaces of discontinuities and fractures occurs. In weak rock types it may be very difficult to decide if the resulting rounded surfaces represent natural or artificial features. When in doubt, the conservative assumption should be made; i.e., assume that they are natural.

The results of core logging (frequency and RQD) can be strongly time dependent and moisture content dependent in the case of certain varieties of shales and mudstones having relatively weakly developed diagenetic bonds. A not infrequent problem is "discing", in which an initially intact core separates into discs on incipient planes, the process becoming noticeable perhaps within minutes of core recovery. The phenomena are experienced in several different forms:

1. Stress relief cracking (and swelling) by the initially rapid release of strain energy in cores recovered from areas of high stress, especially in the case of shaley rocks.
2. Dehydration cracking experienced in the weaker mudstones and shales which may reduce RQD from 100 percent to 0 percent in a matter of minutes, the initial integrity possibly being due to negative pore pressure.
3. Slaking cracking experienced by some of the weaker mudstones and shales when subjected to wetting and drying.

All these phenomena may make core logging of fracture frequency and RQD unreliable. Whenever such conditions are anticipated, core should be logged by an engineering geologist as it is recovered and at subsequent intervals until the phenomenon is predictable. An added advantage is that the engineering geologist can perform mechanical index tests, such as the point load index or Schmidt hammer test (see Chapter 8), while the core is still in a saturated state.

CHAPTER 6.0

GROUNDWATER INVESTIGATIONS

6.1 GENERAL

Groundwater conditions and the potential for groundwater seepage are fundamental factors in virtually all geotechnical analyses and design studies. Accordingly, the evaluation of groundwater conditions is a basic element of almost all geotechnical investigation programs. Groundwater investigations are of two types as follows:

- Determination of groundwater levels and pressures and
- Measurement of the permeability of the subsurface materials.

Determination of groundwater levels and pressures includes measurements of the elevation of the groundwater surface or water table and its variation with the season of the year; the location of perched water tables; the location of aquifers (geological units which yield economically significant amounts of water to a well); and the presence of artesian pressures. Water levels and pressures may be measured in existing wells, in boreholes and in specially-installed observation wells. Piezometers are used where the measurement of the ground water pressures are specifically required (i.e. to determine excess hydrostatic pressures, or the progress of primary consolidation).

Determination of the permeability of soil or rock strata is needed in connection with surface water and groundwater studies involving seepage through earth dams, yield of wells, infiltration, excavations and basements, construction dewatering, contaminant migration from hazardous waste spills, landfill assessment, and other problems involving flow. Permeability is determined by means of various types of seepage, pressure, pumping, and flow tests.

6.2 DETERMINATION OF GROUNDWATER LEVELS AND PRESSURES

Observations of the groundwater level and pressure are an important part of all geotechnical explorations, and the identification of groundwater conditions should receive the same level of care given to soil descriptions and samples. Measurements of water entry during drilling and measurements of the groundwater level at least once following drilling should be considered a minimum effort to obtain water level data, unless alternate methods, such as installation of observation wells, are defined by the geotechnical engineer. Detailed information regarding groundwater observations can be obtained from ASTM D 4750, "Standard Test Method For Determining Subsurface Liquid Levels in a Borehole or Monitoring Well" and ASTM D 5092 "Design and Installation of Groundwater Wells in Aquifers".

6.2.1 Information on Existing Wells

Many states require the drillers of water wells to file logs of the wells. These are good sources of information of the materials encountered and water levels recorded during well installation. The well owners, both public and private, may have records of the water levels after installation which may provide extensive information on fluctuations of the water level. This information may be available at state agencies regulating the drilling and installation of water wells, such as the Department of Transportation, the Department of Natural Resources, State Geologist, Hydrology Departments, and Division of Water Resources.

6.2.2 Open Borings

The water level in open borings should be measured after any prolonged interruption in drilling, at the completion of each boring, and at least 12 hours (preferably 24 hours) after completion of drilling. Additional water level measurements should be obtained at the completion of the field exploration and at other times designated by the engineer. The date and time of each observation should be recorded.

If the borehole has caved, the depth to the collapsed region should be recorded and reported on the boring record as this may have been caused by groundwater conditions. Perhaps, the elevations of the caved depths of certain borings may be consistent with groundwater table elevations at the site and this may become apparent once the subsurface profile is constructed (see Chapter 11).

Drilling mud obscures observations of the groundwater level owing to filter cake action and the higher specific gravity of the drilling mud compared to that of the water. If drilling fluids are used to advance the borings, the drill crew should be instructed to bail the hole prior to making groundwater observations.

6.2.3 Observation Wells

The observation well, also referred to as piezometer, is the fundamental means for measuring water head in an aquifer and for evaluating the performance of dewatering systems. In theory, a "piezometer" measures the pressure in a confined aquifer or at a specific horizon of the geologic profile, while an "observation well" measures the level in a water table aquifer (Powers, 1992). In practice, however, the two terms are at times used interchangeably to describe any device for determining water head.

The term "observation well" is applied to any well or drilled hole used for the purpose of long-term studies of groundwater levels and pressures. Existing wells and bore holes in which casing is left in place are often used to observe groundwater levels. These, however, are not considered to be as satisfactory as wells constructed specifically for the purpose. The latter may consist of a standpipe installed in a previously drilled exploratory hole or a hole drilled solely for use as an observation well.

Details of typical observation well installations are shown in Figure 6-1. The simplest type of observation well is formed by a small-diameter polyvinyl chloride (PVC) pipe set in an open hole. The bottom of the pipe is slotted and capped, and the annular space around the slotted pipe is backfilled with clean sand. The area above the sand is sealed with bentonite, and the remaining annulus is filled with grout, concrete, or soil cuttings. A surface seal, which is sloped away from the pipe, is commonly formed with concrete in order to prevent the entrance of surface water. The top of the pipe should also be capped to prevent the entrance of foreign material; a small vent hole should be placed in the top cap. In some localities, regulatory agencies may stipulate the manner for installation and closure of observation wells.

Driven or pushed-in well points are another common type for use in granular soil formations and very soft clay (Figure 6-1b). The well is formed by a stainless steel or brass well point threaded to a galvanized steel pipe (see Dunnicliff, 1988 for equipment variations). In granular soils, an open boring or rotary wash boring is advanced to a point several centimeters above the measurement depth and the well point is driven to the desired depth. A seal is commonly required in the boring above the well point with a surface seal at the ground surface. Note that observation wells may require development (see ASTM D 5092) to minimize the effects of installation, drilling fluids, etc. Minimum pipe diameters should allow introduction of a bailer or other pumping apparatus to remove fine-grained materials in the well to improve the response time.

Local or state jurisdictions may impose specific requirements on "permanent"observation wells, including closure and special reporting of the location and construction that must be considered in the planning and installation. Licensed drillers and special fees also may be required.

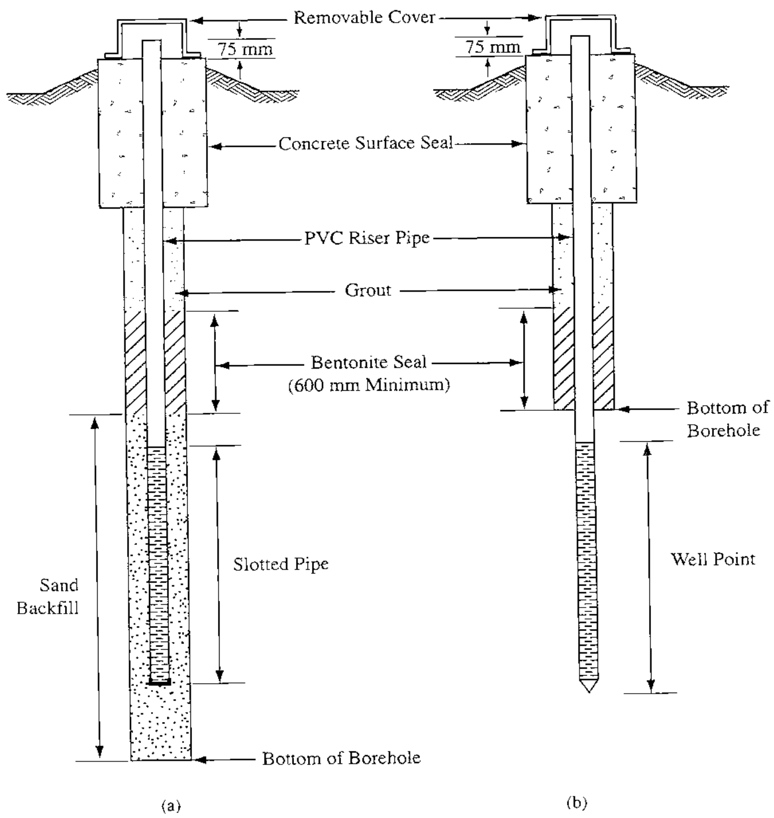

Figure 6-1. Representative Details of Observation Well Installations. (a) Drilled-in-place Stand-Pipe Piezometer, (b) Driven Well Point.

Piezometers are available in a number of designs. Commonly used piezometers are of the pneumatic and the vibrating wire type. Interested readers are directed to Course Module No. 11 (Instrumentation) or Dunnicliff (1988) for a detailed discussion of the various types of piezometers.

6.2.4 Water Level Measurements

A number of devices have been developed for sensing or measuring the water level in observation wells. Following is a brief presentation of the three common methods that are used to measure the depth to groundwater. In general, common practice is to measure the depth to the water surface using the top of the casing as a reference, with the reference point at a common orientation (often north) marked or notched on the well casing.

Chalked Tape

In this method a short section at the lower end of a metal tape is chalked. The tape with a weight attached to its end is then lowered until the chalked section has passed slightly below the water surface. The depth to the water is determined by subtracting the depth of penetration of the line into water, as measured by the water line in the chalked section, from the total depth from the top of casing. This is probably the most accurate method, and the accuracy is useful in pump tests where very small drawdowns are significant. The method is cumbersome, however, when taking a series of rapid readings, since the tape must be fully removed each time. An enameled tape is not suitable unless it is roughened with sandpaper so it will accept chalk. The weight on the end of the tape should be small in volume so it does not displace enough water to create an error.

Tape with a Float

In this method, a tape with a flat-bottomed float attached to its end is lowered until the float hits the water surface and the tape goes slack. The tape is then lifted until the float is felt to touch the water surface and it is just taut; the depth is then measured. With practice this method can give rough measurements, but its accuracy is poor. A refinement is to mount a heavy whistle, open at the bottom, on a tape. When it sinks in the water, the whistle will give an audible beep as the air within it is displaced.

Electric Water-Level Indicator

This battery operated indicator consists of a weighted electric probe attached to the lower end of a length of electrical cable that is marked at intervals to indicate the depth. When the probe reaches the water a circuit is completed and this is registered by a meter mounted on the cable reel. Various manufacturers produce the instrument, utilizing as the signaling device a neon lamp, a horn, or an ammeter. The electric indicator has the advantage that it may be used in extremely small holes.

The instrument should be ruggedly built, since some degree of rough handling can be expected. The distance markings must be securely fastened to the cable. Some models are available in which the cable itself is manufactured as a measuring tape. The sensing probe should be shielded to prevent shorting out against metal risers. When the water is highly conductive, erratic readings can develop in the moist air above the actual water level. Sometimes careful attention to the intensity of the neon lamp or the pitch of the horn will enable the reader to distinguish the true level. A sensitivity adjustment on the instrument can be useful. If oil or iron sludge has accumulated in the observation well, the electric probe will give unreliable readings.

Data Loggers

When timed and frequent water level measurements are required, as for a pump test or slug test, data loggers are useful. Data loggers are in the form of an electric transducer near the bottom of the well which senses changes in water level as changes in pressure. A data acquisition system is used to acquire and store the readings. A data logger can eliminate the need for onsite technicians on night shifts during an extended field permeability test. A further significant saving is in the technician's time back in the office. The preferred models of the data logger not only record the water level readings but permit the data to be downloaded into a personal computer and, with appropriate software, to be quickly reduced and plotted. These devices are also extremely useful for cases where measurement of artesian pressures is required or where data for tidal corrections during field permeability tests is necessary.

6.3 FIELD MEASUREMENT OF PERMEABILITY

The permeability (k) is a measure of how easily water and other fluids are transmitted through the geomaterial and thus represents a flow property. In addition to groundwater related issues, it is of particular concern in geoenvironmental problems. The parameter k is closely related to the coefficient of consolidation (c_v) since time rate of settlement is controlled by the permeability. In geotechnical engineering, we designate small k = coefficient of permeability or hydraulic conductivity (units of cm/sec), which follows Darcy's law:

$$q = k \cdot i \cdot A \qquad (6\text{-}1)$$

where q = flow (cm^3/sec), i = dh/dx = hydraulic gradient, and A = cross-sectional area of flow.

Laboratory permeability tests may be conducted on undisturbed samples of natural soils or rocks, or on reconstituted specimens of soil that will be used as controlled fill in embankments and earthen dams. Field permeability tests may be conducted on natural soils (and rocks) by a number of methods, including simple falling head, packer (pressurized tests), pumping (drawdown), slug tests (dynamic impulse), and dissipation tests. A brief listing of the field permeability methods is given in Table 6-1.

The hydraulic conductivity (k) is related to the specific (or absolute) permeability, K (cm^2) by:

$$K = k\mu/\gamma_w \qquad (6\text{-}2)$$

where μ = fluid viscosity and γ_w = unit weight of the fluid (i.e., water). For fresh water at T = 20°C, μ = $1.005 \cdot$E-06 kN-sec/m^2 and γ_w = 9.80 kN/m^3. Note that K may be given in units of darcies (1 darcy = $9.87 \cdot$E-09 cm^2). Also, please note that groundwater hydrologists have confusingly interchanged k $\equiv$ K in their nomenclature and this conflict resides within the various ASTM standards. The rate at which water is transmitted through a unit width of an aquifer under a hydraulic gradient i = 1 is defined as the transmissivity (T) of the formation, given by:

$$T = k \cdot b \qquad (6\text{-}3)$$

where b = aquifer thickness.

The coefficient of consolidation (c_v for vertical direction) is related to the coefficient of permeability by the expression:

$$c_v = k \cdot D'/\gamma_w \qquad (6\text{-}4)$$

where D' = (1/m_v) = constrained modulus obtained from one-dimensional oedometer tests (i.e., in lieu of the well-known e-log σ_v' curve, the constrained modulus is simply D = $\Delta\sigma_v'/\Delta\varepsilon_v$). In conventional one-dimensional vertical compression, c_v is often determined from the time rate of consolidation:

$$c_v = T H^2/t \qquad (6\text{-}5)$$

where T = time factor (from Terzaghi theory), H = drainage path length, and t = measured time. For field permeability, it may be desirable to distinguish between vertical (c_v) and horizontal consolidation (c_h).

TABLE 6-1.

FIELD METHODS FOR MEASUREMENT OF PERMEABILITY

Test Method	***Applicable Soils***	***Reference***
Various Field Methods	Soil & Rock Aquifers	ASTM D 4043
Pumping tests	Drawdown in soils	ASTM D 4050
Double-ring infiltrometer	Surface fill soils	ASTM D 3385
Infiltrometer with sealed ring	Surface soils	ASTM D 5093
Various field methods	Soils in vadose zone	ASTM D 5126
Slug tests.	Soils at depth	ASTM D 4044
Hydraulic fracturing	Rock in-situ	ASTM D 4645
Constant head injection	Low-permeability rocks	ASTM D 4630
Pressure pulse technique	Low-permeability rocks	ASTM D 4630
Piezocone dissipation	Low to medium k soils	Houlsby & Teh (1988)
Dilatometer dissipation	Low to medium k soils	Robertson et al. (1988)
Falling head tests	Cased borehole in soils	Lambe & Whitman (1979)

6.3.1 Seepage Tests

Seepage tests in boreholes constitute one means of determining the in-situ permeability. They are valuable in the case of materials such as sands or gravels because undisturbed samples of these materials for laboratory permeability testing are difficult or impossible to obtain. Three types of tests are in common use: falling head, rising head, and constant water level methods.

In general, either the rising or the falling level methods should be used if the permeability is low enough to permit accurate determination of the water level. In the falling level test, the flow is from the hole to the surrounding soil and there is danger of clogging of the soil pores by sediment in the test water used. This danger does not exist in the rising level test, where water flows from the surrounding soil to the hole, but there is the danger of the soil at the bottom of the hole becoming loosened or quick if too great a gradient is imposed at the bottom of the hole. If the rising level is used, the test should be followed by sounding of the base of the hole with drill rods to determine whether heaving of the bottom has occurred. The rising level test is the preferred test. In those cases where the permeability is so high as to preclude accurate measurement of the rising or falling water level, the constant level test is used.

Holes in which seepage tests are to be performed should be drilled using only clear water as the drilling fluid. This precludes the formation of a mud cake on the walls of the hole or clogging of the pores of the soil by drilling mud. The tests are performed intermittently as the borehole is advanced. When the hole reaches the level at which a test is desired, the hole is cleaned and flushed using clear water pumped through a drill tool with shielded or upward-deflected jets. Flushing is continued until a clean surface of undisturbed material exists at the bottom of the hole. The permeability is then determined by one of the procedures given below. Specifications sometimes require a limited advancement of the borehole without casing upon completion of the first test at a given level, followed by cleaning, flushing, and repeat testing. The difficulty of obtaining satisfactory in situ permeability measurements makes this requirement a desirable feature since it permits verification of the test results.

Data which must be recorded for each test regardless of the type of test performed include:

1. Depth from the ground surface to groundwater surface both before and after the test,
2. Inside diameter of the casing,
3. Height of the casing above the ground surface,
4. Length of casing at the test section,
5. Diameter of the borehole below the casing,
6. Depth to the bottom of the boring from the top of the casing,
7. Depth to the standing water level from the top of the casing, and
8. A description of the material tested.

Falling Water Level Method

In this test, the casing is filled with water, which is then allowed to seep into the soil. The rate of drop of the water surface in the casing is observed by measuring the depth of the water surface below the top of the casing at 1, 2 and 5 minutes after the start of the test and at 5-minute intervals thereafter. These observations are made until the rate of drop becomes negligible or until sufficient readings have been obtained to satisfactorily determine the permeability. Other required observations are listed above.

Rising Water Level Method

This method, most commonly referred to as the "time lag method" (US Army Corps of Engineers, 1951), consists of bailing the water out of the casing and observing the rate of rise of the water level in the casing at intervals until the rise in the water level becomes negligible. The rate is observed by measuring the elapsed time and the depth of the water surface below the top of the casing. The intervals at which the readings are required will vary somewhat with the permeability of the soil. The readings should be frequent enough to establish the equalization diagram. In no case should the total elapsed time for the readings be less than 5 minutes. As noted above, a rising level test should always be followed by a sounding of the bottom of the hole to determine whether the test created a quick condition.

Constant Water Level Method

In this method water is added to the casing at a rate sufficient to maintain a constant water level at or near the top of the casing for a period of not less than 10 minutes. The water may be added by pouring from calibrated containers or by pumping through a water meter. In addition to the data listed in the above general discussion, the data recorded should consist of the amount of water added to the casing at 5 minutes after the start of the test, and at 5-minute intervals thereafter until the amount of added water becomes constant.

6.3.2 Pressure ("Packer") Test

A test in which water is forced under pressure into rock through the walls of a borehole provides a means of determining the apparent permeability of the rock, and yields information regarding its soundness. The information thus obtained is used primarily in seepage studies. It is also frequently used as a qualitative measure of the grouting required for reducing the permeability of rock or strengthening it. Pressure tests should be performed only in holes that have been drilled with clear water.

The apparatus used for pressure tests in rock is illustrated schematically in Figure 6-2a. It comprises a water pump, a manually-adjusted automatic pressure relief valve, pressure gages, a water meter, and a packer assembly. The packer assembly, shown in Figure 6-2b, consists of a system of piping to which two expandable cylindrical rubber sleeves, called packers, are attached. The packers, which provide a means of sealing off a limited section of borehole for testing, should have a length at least five times the diameter of the hole. They may be of the pneumatically, hydraulically, or mechanically expandable type.

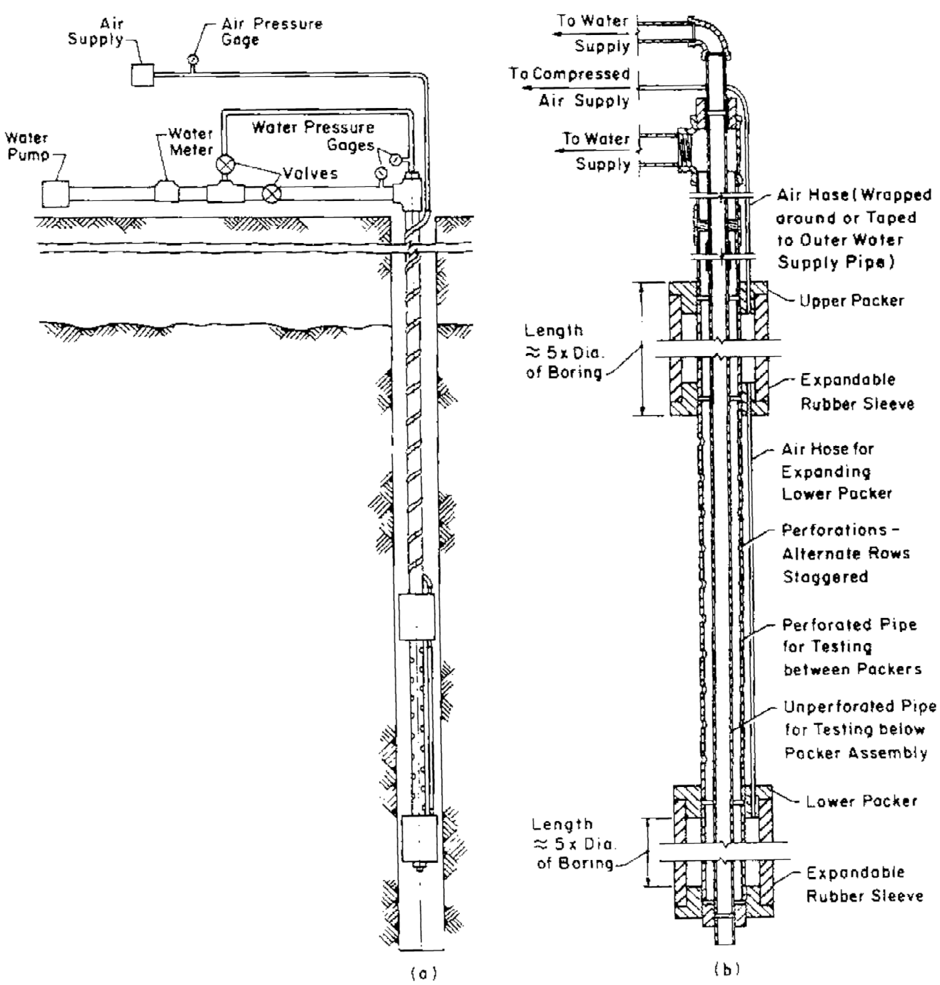

Figure 6-2. Packer-Type Pressure-Test Apparatus for Determining the Permeability of Rock. (a) Schematic Diagram; (b) Detail of Packer Unit. (Lowe and Zaccheo, 1991)

Pneumatic or hydraulic packers are preferred since they adapt to an oversized hole whereas mechanical packers may not. However, when pneumatic/hydraulic packers are used, the test apparatus must also include an air or water supply connected, through a pressure gage, to the packers by means of a high-pressure hose as shown in Figure 6-2a. The piping of the packer assembly is designed to permit testing of either the portion of the hole between the packers or the portion below the lower packer. Flow to the section below the lower packer is through the interior pipe; flow to the section between the packers is provided by perforations in the outer pipe, which have an outlet area two or more times the cross-sectional area of the pipe. The packers are normally set 0.6, 1.5 or 3 m apart and it is common to provide flexibility in testing by having assemblies with different packer spacing available, thereby permitting the testing of different lengths of the hole. The wider spacings are used for rock that is more uniform; the short spacing is used to test individual joints that may be the cause of high water loss in otherwise tight strata.

The test procedure used depends upon the condition of rock. In rock that is not subject to cave-in, the following method is in general use. After the borehole has been completed it is filled with clear water, surged, and washed out. The test apparatus is then inserted into the hole until the top packer is at the top of the rock. Both packers are then expanded and water under pressure is introduced into the hole, first between the packers and then below the lower packer. Observations of the elapsed time and the volume of water pumped at different pressures are recorded as detailed in the paragraph below. Upon completion of the test, the apparatus is lowered a distance equal to the space between the packers and the test is repeated. This procedure is continued until the entire length of the hole has been tested or until there is no measurable loss of water in the hole below the lower packer. If the rock in which the hole is being drilled is subject to cave-in, the pressure test is conducted after each advance of the hole for a length equal to the maximum permissible unsupported length of the hole or the distance between the packers, whichever is less. In this case, the test is limited, of course, to the zone between the packers.

The magnitudes of these test pressures are commonly 100, 200 and 300 kPa above the natural piezometric level. However, in no case should the excess pressure above the natural piezometric level be greater than 23 kPa per meter of soil and rock overburden above the upper packer. This limitation is imposed to insure against possible heaving and damage to the foundation. In general, each of the above pressures should be maintained for 10 minutes or until a uniform rate of flow is attained, whichever is longer. If a uniform rate of flow is not reached in a reasonable time, the engineer must use his/her discretion in terminating the test. The quantity of flow for each pressure should be recorded at 1, 2 and 5 minutes and for each 5-minute interval thereafter. Upon completion of the tests at 100, 200 and 300 kPa the pressure should be reduced to 200 and 100 kPa, respectively, and the rate of flow and elapsed time should once more be recorded in a similar manner.

Observation of the water take with increasing and decreasing pressure permits evaluation of the nature of the openings in the rock. For example, a linear variation of flow with pressure indicates an opening that neither increases nor decreases in size. If the curve of flow versus pressure is concave upward it indicates that the openings are enlarging; if convex, the openings are becoming plugged. Detailed discussion for interpretation of pressure tests is presented by Cambefort (1964). Additional data required for each test are as follows:

1. Depth of the hole at the time of each test,
2. Depth to the bottom of the top packer,
3. Depth to the top of the bottom packer,
4. Depth to the water level in the borehole at frequent intervals (this is important since a rise in water level in the borehole may indicate leakage around the top packer. Leakage around the bottom packer would be indicated by water rising in the inner pipe).

5. Elevation of the piezometric level,
6. Length of the test section,
7. Radius of the hole,
8. Length of the packer,
9. Height of the pressure gage above the ground surface,
10. Height of the water swivel above the ground surface, and
11. A description of the material tested.

The formulas used to compute the permeability from pressure tests data are (from *Earth Manual*, US Bureau of Reclamation, 1960):

$$k = \frac{Q}{2\pi\, LH} \ln\left(\frac{L}{r}\right) \quad for\ L \geq 10r \tag{6a}$$

$$k = \frac{Q}{2\pi\, LH} \sinh^{-1}\left(\frac{L}{2r}\right) \quad for\ 10r > L > r \tag{6b}$$

where, k is the apparent permeability, Q is the constant rate of flow into the hole, L is the length of the test section, H is the differential head on the test section, and r is the radius of the borehole.

The formulas provide only approximate values of k since they are based on several simplifying assumptions and do not take into account the flow of water from the test section back to the borehole. However, they give values of the correct magnitude and are suitable for practical purposes.

6.3.3 Pumping Tests

Continuous pumping tests are used to determine the water yield of individual wells and the permeability of subsurface materials in situ. The data provided by such tests are used to determine the potential for leakage through the foundations of water-retaining structures and the requirements for construction dewatering systems for excavations.

The test consists of pumping water from a well or borehole and observing the effect on the water table by measuring the water levels in the hole being pumped and in an array of observation wells. The observation wells should be of the piezometer type. The depth of the test well will depend on the depth and thickness of the strata to be tested. The number, location, and depth of the observation wells or piezometers will depend on the estimated shape of the groundwater surface after drawdown. Figure 6-3 shows a typical layout of piezometers for a pumping test. As shown in Figure 6-3, the wells should be located on the radial lines passing through the test well. Along each of the radial lines there should be a minimum of four wells, the innermost of which should be within 7.5 m of the test well; The outermost should be located near the limits of the effect of drawdown, and the middle wells should be located to give the best definition of the drawdown curve based on its estimated shape.

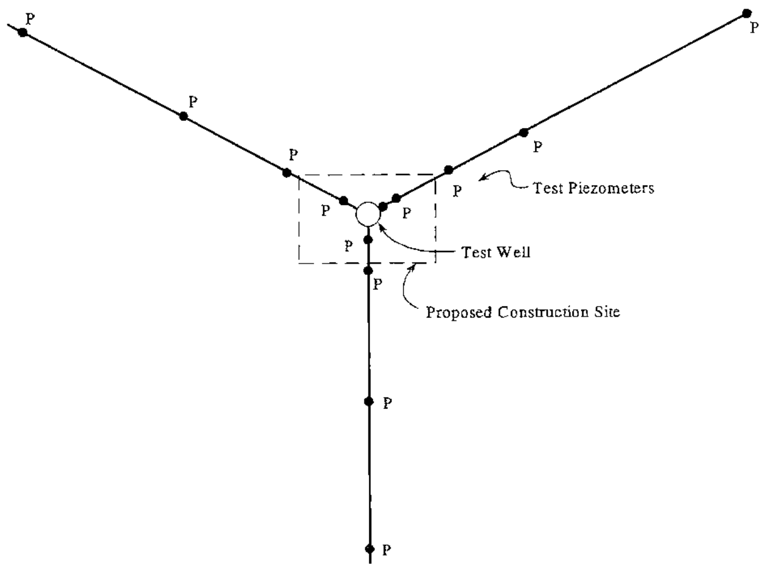

Figure 6-3. A General Configuration and Layout of Piezometers for a Pumping Test.

The pump used for these tests should have a capacity of 1.5 to 2 times the maximum anticipated flow and should have a discharge line sufficiently long to obviate the possibility of the discharge water recharging the strata being tested. Auxiliary equipment required include an air line to measure the water level in the test well, a flow meter, and measuring devices to determine the depth to water in the observation well. The air line, complete with pressure gage, hand pump, and check valve, should be securely fastened to the pumping level but in no case closer than 0.6 m beyond the end of the suction line. The flow meter should be of the visual type, such as an orifice. The depth-measuring device for the observation well may be any of the types described in Section 6.2.

The test procedure for field pumping tests is as follows: Upon completion of the well or borehole, the hole is cleaned and flushed, the depth of the well is accurately measured, the pump is installed, and the well is developed. The well is then tested at 1/3, 2/3 and full capacity. Full capacity is defined as the maximum discharge attainable with the water levels in the test and observation wells stabilized. Each of the discharge rates is maintained for 4 hours after further drawdown in the test and observation well has ceased, or for a maximum of 48 hours, whichever occurs first. The discharge must be maintained constant during each of the three stages of the test and interruptions of pumping are not permitted. If pumping should accidentally be interrupted, the water level should be permitted to return to its full non-pumping level before pumping is resumed. Upon completion of the drawdown test, the pump is shut off and the rate of recovery is observed.

The basic test well data which must be recorded are:

1. Location, top elevation and depth of the well,
2. The size and length of all blank casing in the well,
3. Diameter, length, and location of all screen casing used; also the type and size of the screen opening and the material of which the screen is made,
4. Type of filter pack used, if any,
5. The water elevation in the well prior to testing, and
6. Location of the bottom of the air line.

Information required for each observation well are:

1. Location, top elevation, and depth of the well,
2. The size and elevation of the bottom of the casing (after installation of the well),
3. Location of all blank casing sections,
4. Manufacturer, type, and size of the pipes etc.
5. Depth and elevation of the well and
6. Water level in the well prior to testing.

Pump data required include the manufacturer's model designation, pump type, maximum capacity, and capacity at 1800 rpm. The drawdown test data recorded for each discharge rate consist of the discharge and drawdowns of the test well and each observation well at the time intervals shown in Table 6-1.

TABLE 6-2.

TIME INTERVALS FOR READING DURING PUMPING TEST

Elapsed Time	Time Interval for Readings
0-10 min	0.5 min
10-60 min	2.0 min
1-6 hour	15.0 min
6-9 hour	30.0 min
9-24 hour	1.0 hour
24-48 hour	3.0 hour
>48 hour	6.0 hour

The required recovery curve data consist of readings of the depth to water at the test location and observation wells at the same time intervals given in Table 6-2. Readings are continued until the water level returns to the prepumping level or until adequate data have been obtained. A typical time-drawdown curve is shown in Figure 6-4. Generally, the time-drawdown curve becomes straight after the first few minutes of pumping. If true equilibrium conditions are established, the drawdown curve will become horizontal.

Field drawdown tests may be conducted using 2 or more cased wells and measuring the drop in head with time. A submersible pump at a central well is used for the drawdown and the head loss at two radial distances may be measured manually or automated via pore pressure transducers. Sowers (1979) discusses the details briefly for two cases: (1) an unconfined aquifer over an impervious layer and (2) artesian aquifer. If the gradient of the drawdown is not too great (< 25° slope), then the head loss in the drawdown well may be used itself (r_1 = well radius) and only two cased wells are necessary.

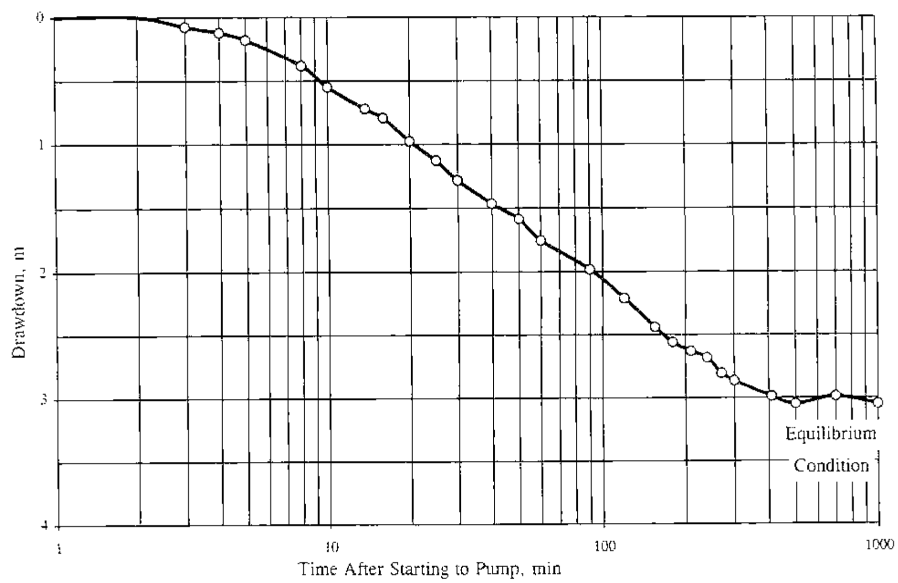

Figure 6-4. Drawdown in an Observation Well Versus Pumping Time (Logarithmic Scale).

For the case of measured drawdown pressures in an unconfined aquifer (shown in Figure 6-5), the permeability (k in cm/s) of the transmitting medium is given by:

Unconfined:

$$k = \frac{q \ln(r_2/r_1)}{\pi\,[(h_2)^2-(h_1)^2]} \qquad (6\text{-}7)$$

where q = measured flow with time (cm^3/s), r = radial distance (cm), and h = height of water above the reference elevation (cm).

For a confined aquifer where an impervious clay aquiclude caps the permeable aquifer, the permeability is determined from:

Confined:

$$k = \frac{q \ln(r_2/r_1)}{2\pi b\,(h_2-h_1)} \qquad (6\text{-}8)$$

where b = thickness of the aquifer (Figure 6-6).

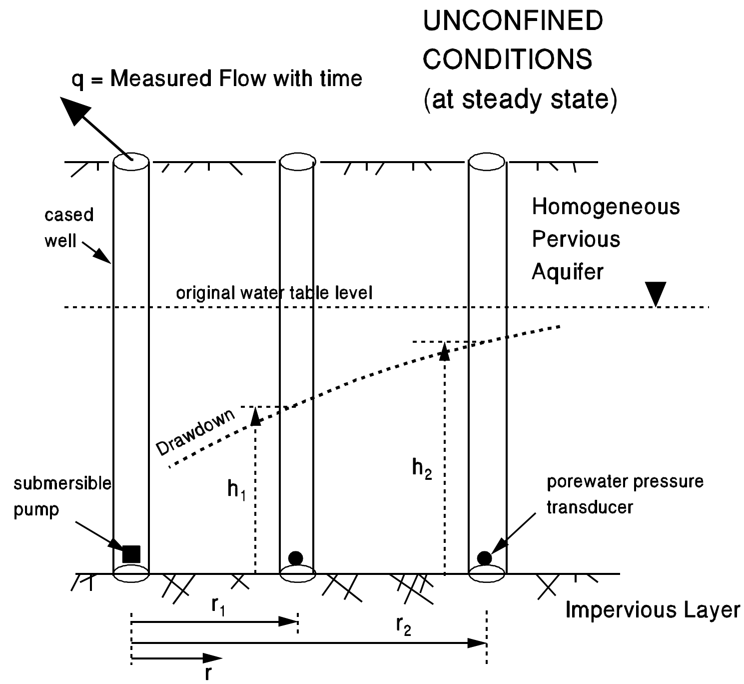

Figure 6-5. Definitions of Terms in Pumping Test Within an Unconfined Aquifer.

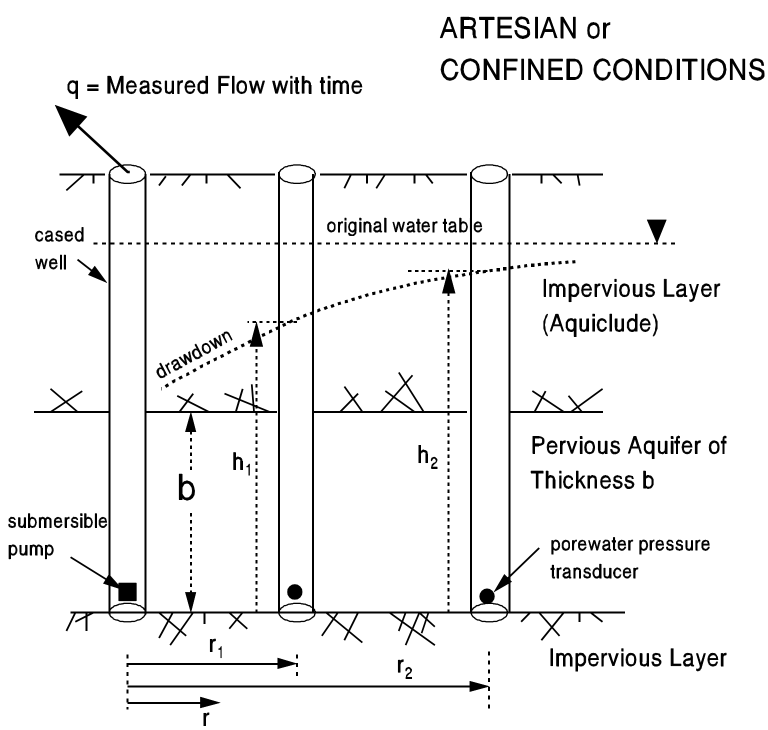

Figure 6-6. Definitions of Terms in Pumping Test Within a Confined Aquifer System.

6.3.4 Slug Tests

Using mechanical slug tests (ASTM 4044) in which a solid object is used to displace water and induce a sudden change of head in a well to determine permeability has become common in environmental investigations. Figure 6-7 presents the slug test procedure. It is conducted in a borehole in which a screened (slotted) pipe is installed. The solid object, called a "slug", often consists of a weighted plastic cylinder. The slug is submerged below the water table until equilibrium has been established; then the slug is removed suddenly, causing an "instantaneous" lowering of the water level within the observation well. Finally, as the well gradually fills up with water, the refill rate is recorded. This is termed the "slug out" procedure.

The permeability, k, is then determined from the refill rate. In general, the more rapid the refill rate, the higher the k value of the screened sediments.

It is also possible to run a "slug in" test. This is similar to the slug out test, except the plastic slug is suddenly dropped into the water, causing an "instantaneous" water level rise. The decay of this water level back to static is then used to compute the permeability. A slug in and slug out test can be performed on the same well.

Alternatively, instead of using a plastic slug, it is possible to lower the water level in the well using compressed air (or raising it using a vacuum) and then suddenly restore atmospheric pressure by opening a quick-release valve.

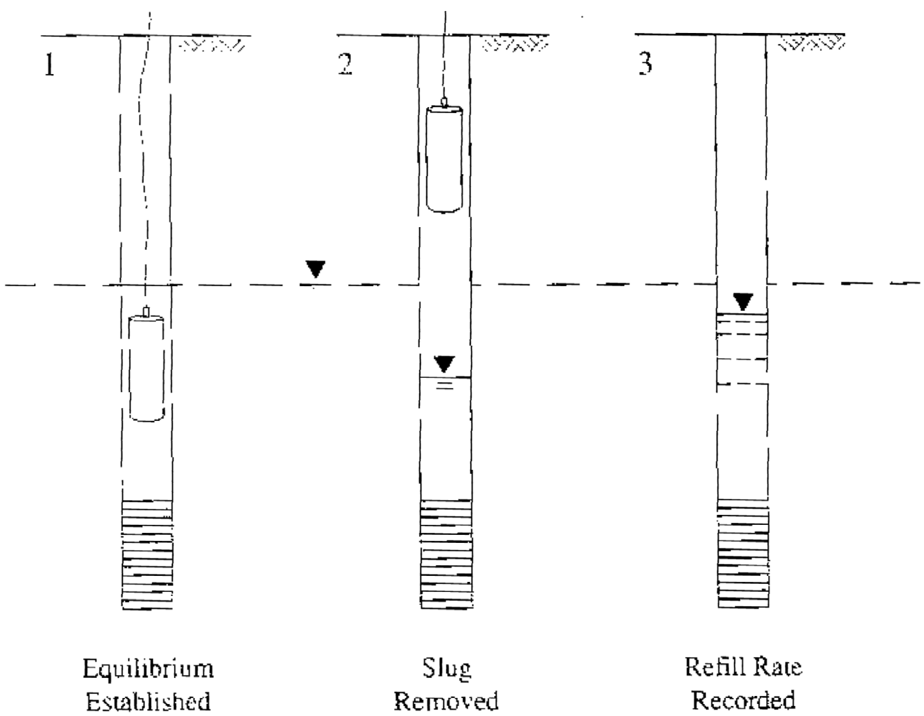

Figure 6-7. General Procedure for Slug Test in as Screened Borehole.

With either method, a pressure transducer and data logger are used to record time and water levels. In instances where water-level recovery is slow enough, hand-measured water levels (see Section 6.2) are adequate. Once, the data have been collected, drawdown is graphed versus time, and various equations and/or curve-matching techniques are used to compute permeability.

Much of the popularity of these tests results from the ease and low cost of conducting them. Unfortunately, however, slug tests are not very reliable. They can give wrong answers, lead to misinterpretation of aquifer characteristics, and ultimately, improper design of dewatering or remediation systems. Several shortcomings of the slug tests may be summarized as follows (Driscoll, 1986):

1. Variable accuracy: Slug tests may be accurate or may underestimate permeability by one or two orders or magnitude. The test data will provide no clue as to the accuracy of the computed value unless a pumping test is done in conjunction with slug tests.
2. Small zone of investigation: Because slug tests are of short duration, the data they provide reflect aquifer properties of just those sediments very near the well intake. Thus, a single slug test does not effectively integrate aquifer properties over a broad area.
3. Slug tests cannot predict the storage capacity of an aquifer.
4. It is difficult to analyze data from wells screened across the water table.
5. Rapid slug removal often causes pressure transients that can obscure some of the early test data.
6. If the true static water level is not determined with great precision, large errors can result in the computed permeability values.

Therefore, it is crucial that a qualified hydrogeologist assesses the results of the slug tests and ensures that they are properly applied and that data from them are not misused. Although the absolute magnitude of the permeability value obtained from slug tests may not be accurate, a comparison of values obtained from tests in holes judiciously located throughout a site being investigated can be used to establish the relative permeability of various portions of the site.

6.3.5 Piezocone Dissipation Tests

In a CPT test performed in saturated clays and silts, large excess porewater pressures (Δu) are generated during penetration of the piezocone. Soft to firm intact clays will exhibit measured penetration porewater pressures which are 3 to 6 times greater than the hydrostatic water pressure, while values of 10 to 20 times greater than the hydrostatic water pressure will typically be measured in stiff to hard intact clays. In fissured materials, zero or negative porewater pressures will be recorded. Regardless, once penetration is stopped, these excess pressures will decay with time and eventually reach equilibrium conditions which correspond to hydrostatic values. In essence, this is analogous to a push-in type piezometer. In addition to piezometers and piezocones, excess pressures occur during the driving of pile foundations, installation of displacement devices such as vibroflots for stone columns and mandrels for vertical wick-drains, as well as insertion of other in-situ tests including dilatometer, full-displacement pressuremeter, and field vane. How quickly the porewater pressures decay depends on the permeability of the surrounding medium (k), as well as the horizontal coefficient of consolidation (c_h), as per equation 6-4. In clean sands and gravels that are pervious, essentially drained response is observed at the time of penetration and the measured porewater pressures are hydrostatic. In most other cases, an initial undrained response occurs that is followed by drainage. For example, in silty sands, generated excess pressures can dissipate in 1 to 2 minutes, while in contrast, fat plastic clays may require 2 to 3 days for complete equalization.

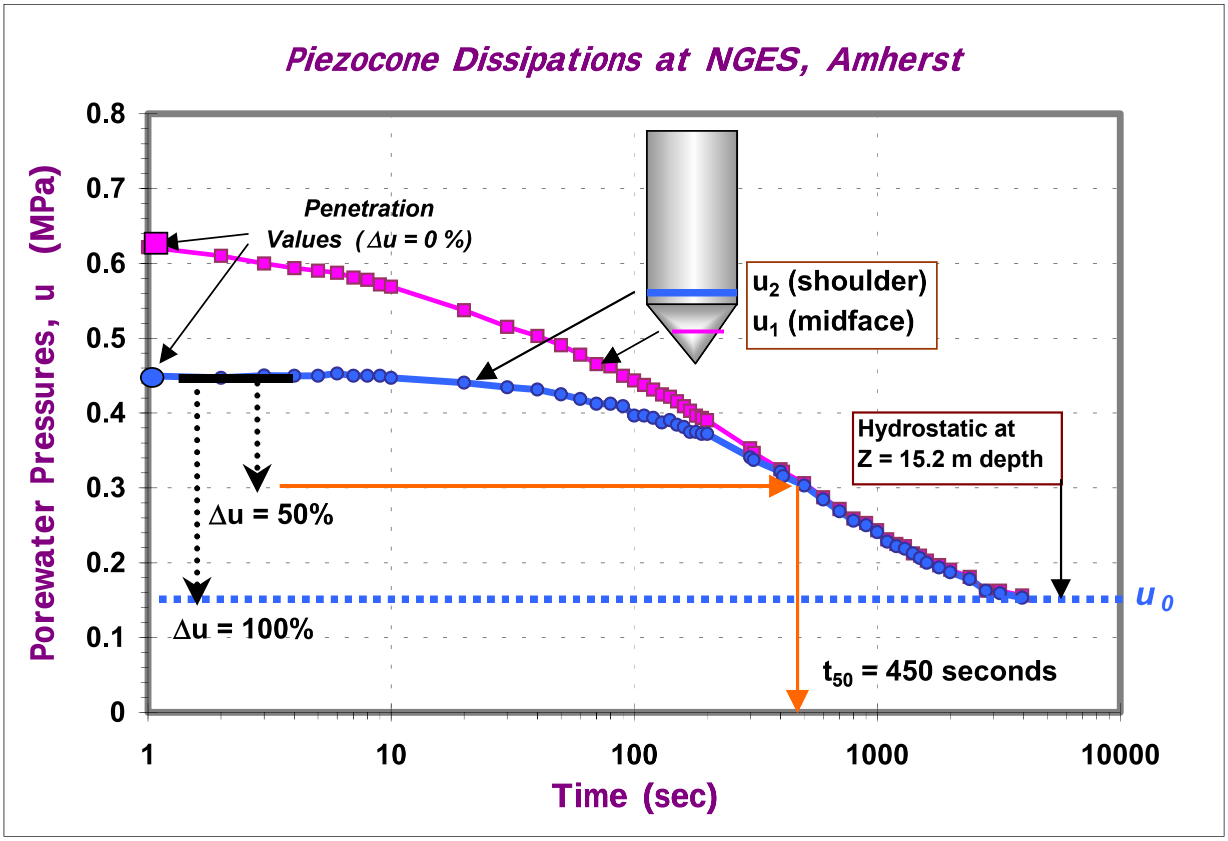

Figure 6-8. Porewater Pressure Dissipation Response in Soft Varved Clay at Amherst NGES. (Procedure for t_{50} determination using U_2 readings shown)

Representative dissipation curves from two types of piezocone elements (midface and shoulder) are presented in Figure 6-8. These data were recorded at a depth of 15.2 meters in a deposit of soft varved silty clay at the National Geotechnical Experimentation Site (NGES) in Amherst, MA. Full equalization to hydrostatic conditions is reached in about 1 hour (3600 s). In routine testing, data are recorded to just 50 percent consolidation in order to maintain productivity. In this case, the initial penetration pressures correspond to 0 percent decay and a calculated hydrostatic value (u_0) based on groundwater levels represents the 100 percent completion. Figure 6-8 illustrates the procedure to obtain the time to 50 percent completion (t_{50}).

The aforementioned approach applies to soils that exhibit monotonic decay of porewater pressures with logarithm of time. For cases involving heavily overconsolidated and fissured geomaterials, a dilatory response can occur whereby the porewater pressures initially rise with time, reach a peak value, and then subsequently decrease with time.

For type 2 piezocones with shoulder filter elements, the t_{50} reading from monotonic responses can be used to evaluate the permeability according to the chart provided in Figure 6-9. The average relationship may be approximately expressed by:

$$k\ (cm/s) \approx \left(\frac{1}{251 \cdot t_{50}}\right)^{1.25} \tag{6-9}$$

where t_{50} is given in seconds. The interpretation of the coefficient of consolidation from dissipation test data is discussed in Chapter 9 and includes a procedure for both monotonic and dilatory porewater pressure behavior.

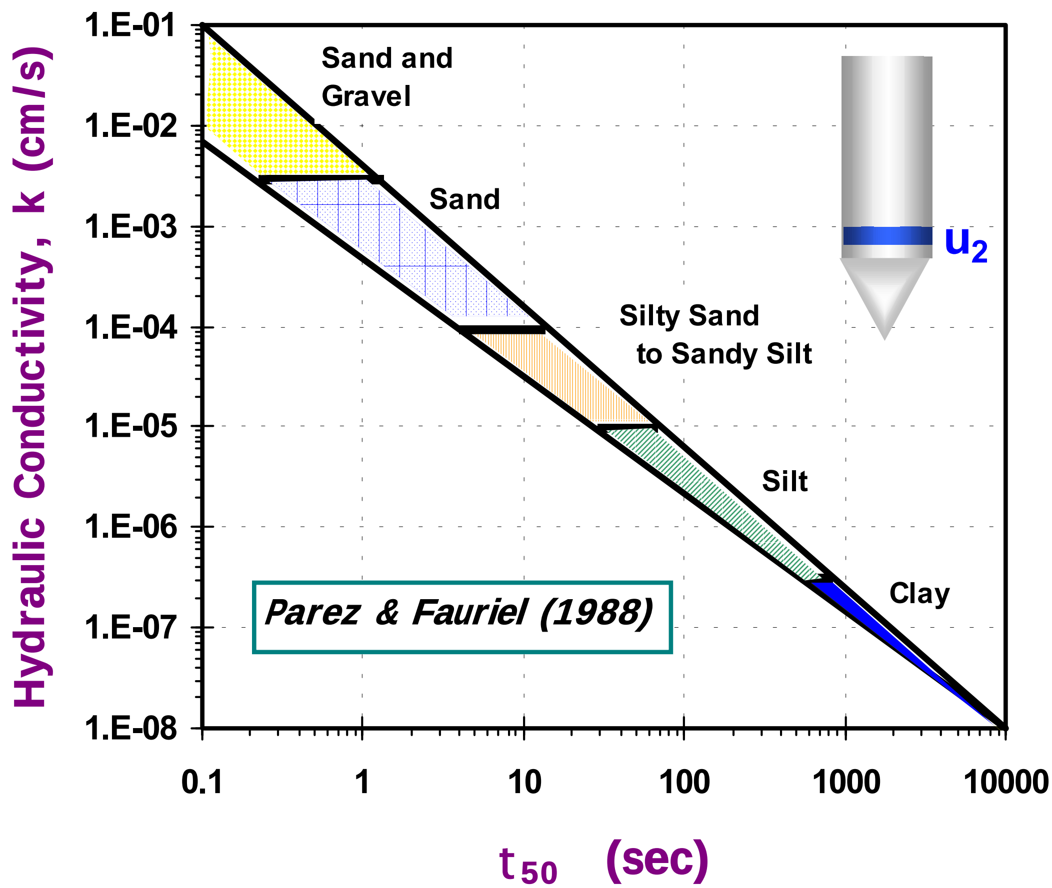

Figure 6-9. Coefficient of Permeability (k = Hydraulic Conductivity) from Measured Time to 50% Consolidation (t_{50}) for Monotonic Type 2 Piezocone Dissipation Tests
(from Parez & Fauriel, 1988).

- Prepare a safety plan for use by field staff, including unique safety practices that apply to specific projects or are required by partner agencies, emergency contact information, and considerations for first aid in the event of an injury.

- Plan appropriate traffic control, consistent with road/traffic conditions, partner agency requirements, the MUTCD and local codes.

- Provide training and other means to provide safe working conditions. Drilling safety procedures can be found in the *National Drilling Association (NDA) Drilling Safety Guide.*

- Arrange for utility locates to identify probable locations of buried utilities that could potentially create hazards to subsurface explorations. Identify overhead power lines. Guidance on safety as related to utility location is in TGM Section 3.1.3.

- Follow applicable state and federal safety regulations pertaining to job site safety and management of hazardous materials. On-site safety requirements are defined in OSHA Section 29.

> Refer to TGM Section 3.1.3 for guidance on safety.
>
> The primary sources supporting safety standards and guidance are NDA for drilling and MUTCD for traffic. Secondary sources are BOR Drillers Safety, USACE EM 1110-1-1804, and FHWA-CFL/TD-05-00.

6.3.2 METHODS AND PRACTICE

FLH standard practice is to use appropriate methods for recovering physical samples of soil and rock strata for testing, and for characterizing subsurface materials and conditions in-situ. This means that multiple methods of investigation and sampling are generally needed for each project. This section presents standard methods and practices for:

- Surface and subsurface exploration;
- Logging and sampling;
- Laboratory and in-situ testing; and
- Instrumentation and monitoring.

6.3.2.1 Preliminary Study and Reconnaissance

After the preliminary planning described in Section 6.3.1, it is standard practice for the Geotechnical Discipline to perform a preliminary study and reconnaissance to identify and preliminarily address geotechnical issues, hazards, risks, and project constraints. Base the site study and reconnaissance on a clear understanding of project goals, objectives, constraints, values and criteria. Perform tasks to the extent necessary to disclose the probable materials and conditions to be encountered. Include an assessment of risk and uncertainty associated with each of the preliminarily recommended design options. Multiple design alternatives are often advanced at this stage.

> Refer to TGM Section 3.2.1 for guidance on preliminary study and reconnaissance.
>
> The primary supporting sources are NHI 132031 for office and field work, and FHWA-ED-88-053 for reporting. Secondary sources are AASHTO MSI-1 and USACE EM 1110-1-1804.

6.3.2.2 Surface Exploration Methods

Use appropriate surface exploration methods corresponding with project needs and goals. Standard surface exploration methods include field reconnaissance, wherein visual observations are recorded according to stationing, mile post or other location information such as GPS coordinates. Geologic mapping is standard where preliminary study indicates geologic features and rock units have direct bearing on project design or construction, and suitable geologic mapping does not already exist. Field-developed sketched cross sections or digital photographs are standard at locations of explorations and key features.

> Refer to TGM Section 3.2.2 for guidance on surface exploration methods.
>
> The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and NHI 132035.

6.3.2.3 Subsurface Exploration Methods

Subsurface investigation methods most commonly include drilled borings, and/or excavated test pits and trenches. Drilling is the standard and preferred method for subsurface exploration and sampling. Use the appropriate exploration methods for the anticipated ground conditions to optimize surface and subsurface characterization and sample recovery for roadway and structure design.

6.3.2.3.1 Geotechnical Equipment

FLH standard practice is to use equipment that is most advantageous to the project. This may be in-house drilling or geophysics equipment, or it may require rental of equipment or contract of equipment and services.

Guidance for selection of the applicable exploration methods is tabulated in Exhibit 6.3–A (borings) and Exhibit 6.3–B (probes, test pits, trenches and shafts). FLH standards on these methods and the steps of subsurface investigation are in the following subsections. Additional guidance on methods is in TGM Section 3.2.4.

Exhibit 6.3–A TEST BORINGS: TYPES AND APPLICATION

Boring Method	Procedure Utilized	Applicability
Auger Boring (AASHTO T203)	Hand or power operated augering with periodic removal of material. In some cases continuous auger may be used requiring only one withdrawal. Stratum changes indicated by examination of material removed.	Probe investigations to bedrock and shallow disturbed soil samples, typically less than 6 m [20 ft] in depth. <u>Typical Uses</u> Disturbed soil sampling. Determine overburden depth.
Hollow-Stem Auger (AASHTO T251)	Power operated augering. Hollow stem serves as casing.	General purpose drilling method for soil and very weak rock locations requiring a cased hole. <u>Typical Uses</u> Disturbed/undisturbed soil sampling. In situ testing. Foundation investigations.
Rotary Drilling (AASHTO T225)	Power rotation of drilling bit as circulating fluid removes cuttings from hole. Stratum changes indicated by rate of progress, action of drilling tools, and examination of cuttings in drilling fluid. Casing usually not required, except near surface.	Relatively fast and economical method to advance borings through wide variety of materials, including large boulders and broken rock. <u>Typical Uses</u> Obtaining rock cores. Probe drilling. Instrumentation installation. Foundation, landslide, and rock cut investigations.
Wire-Line Drilling	Rotary-type drilling method where coring device is integral part of drill rod string, which also serves as casing. Core samples obtained by removing inner barrel assembly from core barrel portion of drill rod. Inner barrel is released by retriever lowered by wire-line through the drilling rod.	Efficient method for recovering quality core samples of rock. <u>Typical Uses</u> General rock coring applications. Foundation, landslide, rock cut, and material source investigations.

Boring Method	Procedure Utilized	Applicability
Air Drilling	Uses compressed air to remove cuttings from the borehole as drilling advances. Both rotary and percussion techniques can be used with either open-hole (rotary reverse circulation) or under-reamed casing advancement (ODEX). SPT samples possible; however, materials between samples are highly disturbed.	This type of drilling is generally fast, but expensive. <u>Typical Uses</u> Deep holes in dense gravels and boulders where Hollow Stem Auger and Rotary methods cannot drill or sample effectively. Fast-moving landslides. Rock anchor drilling.

Exhibit 6.3–B USE OF PROBES, TEST PITS, TRENCHES AND SHAFTS

Exploration Method	General Use	Advantages and Capabilities	Limitations
Hand Auger Probes	Bulk sampling. Visual inspection. Depth of shallow soft deposits and top of shallow bedrock.	Useful in difficult access areas. Results in minor ground disturbance. Rapid, cost-effective exploration. Good for shallow deposits (< 5 m [15 ft] deep).	Difficult to advance in rocky or dense materials.
Hand-Excavated Test Pits and Shafts	Bulk sampling. Visual inspection. In situ testing. Depth of shallow bedrock and groundwater.	Useful in difficult access areas. Results in less disturbance of surrounding ground.	Relatively time-consuming and expensive. Limited to depths above groundwater level.
Backhoe-Excavated Test Pits and Trenches	Bulk sampling. Visual inspection. In situ testing. Rapid excavation rates. Depth of shallow bedrock and groundwater.	Rapid, cost-effective exploration. Depths up to 6 m [20 ft] can be explored.	Limited equipment access. Generally limited to depths above groundwater level. Limited undisturbed sampling. Significant surrounding ground disturbance.

Exploration Method	General Use	Advantages and Capabilities	Limitations
Drilled Shafts	Bulk sampling. Visual inspection. In situ testing. Depth of bedrock and groundwater. Pre-excavation for piles and shafts. Landslide investigations. Drainage wells.	Rapid, cost-effective exploration (compared to hand methods). Minimum 0.75 m [2.5 ft] to maximum 2 m [6 ft] diameter.	Limited equipment access. Costly mobilization. Visual inspection possibly obscured by casing. Limited undisturbed sampling. Significant surrounding ground disturbance.
Dozer Cuts	Bulk sampling. Visual inspection. In situ testing. Rapid excavation rates. Depth of shallow bedrock and groundwater. Rippability determinations. Increase backhoe depth capabilities. Provide access for other exploration equipment.	Rapid, cost-effective exploration (compared to hand methods). Provides exposures for geologic mapping.	Limited equipment access. Generally limited to depths above groundwater level. Limited undisturbed sampling. Significant surrounding ground disturbance.

6.3.2.3.2 Geophysical Methods

Evaluate the potential use of geophysical methods and the value they might add in terms of improved understanding of subsurface conditions, lower impact and/or cost, etc. Though geophysics may be used under other circumstances, standard practice is to incorporate geophysical methods where they are likely to lead to lower overall investigation, design and/or construction costs. Multi-channel seismic refraction with a sledge hammer source is the standard method used to help identify depth to bedrock and excavation requirements (e.g. rippability), and to extrapolate between borings. Other methods may be more appropriate for specific projects or other project needs.

Refer to TGM Section 3.2.3.2 for guidance on geophysical methods.

The primary source supporting the guidance is FHWA-Geophysical. Secondary sources are NHI 132031 and USACE EM 1110-1-1802.

6.3.2.3.3 Drilling and Soil Sampling

Drilling and sampling is the most common means of subsurface exploration. Standards are presented in Exhibit 6.3–C for boring layout and depth with respect to structure types, locations and sizes, and proposed earthwork. Standard drilling methods include hollow-stem auger in soils and wire-line core drilling in rock. Rotary-wash, casing advancer, solid-stem auger and other methods are also used to fulfill specific project needs.

Exhibit 6.3–C STANDARDS FOR BORING LAYOUT AND DEPTH

Geotechnical Feature	Minimum Boring Layout	Minimum Boring Depth
Structure Foundation	A minimum of two borings for piers or abutments over 30 m [100 ft] wide. A minimum of one boring for piers or abutments under 30 m [100 ft] wide. Provide additional borings in areas with erratic subsurface conditions.	All borings extend below estimated scour. Spread Footings (on soil) 2B where L < 2B; 4B where L > 5B; and Interpolate between 2B and 4B when 2B ≤ L ≤ 5B. (L is footing breadth and B is footing width.) Deep Foundations In soil, 6 m [20 ft] below tip elevation or twice maximum pile group dimension, whichever is greater. For piles on rock, 3 m [10 ft] into bedrock below tip elevation. For shafts on rock, extend borings below tip elevation 3 m [10 ft] into bedrock or 3D into bedrock for isolated shafts or twice the maximum shaft group dimension into bedrock, whichever is greater. (D is shaft diameter.)
Retaining Structures	A minimum of one boring for each retaining structure. Space borings every 30 m [100 ft] to 60 m [200 ft]. Characterize wall toe and anchorage zones with additional borings, as needed.	Extend borings 0.75 to 1.5 times the retaining structure height. When stratum indicates potential deep stability or settlement problem, extend borings to hard stratum. For deep foundations, use Structure Foundation criteria above.

Geotechnical Feature	Minimum Boring Layout	Minimum Boring Depth
Cuts and Embankments	A minimum of one boring per cut slope. Space borings every 60 m [200 ft] (erratic conditions) to 120 m [400 ft] (uniform conditions), with one boring per landform. Place borings in high cuts and fills perpendicular to the roadway to establish geologic cross-sections. Use additional shallow explorations to determine depth and extent of topsoil and/or unsuitable surface soils.	Cuts: In stable materials, 5 m [15 ft] below depth of cut at the ditch line. In weak materials, extend borings to firm materials or twice the cut depth, whichever is less. Embankments: Extend borings to a firm stratum or to a depth twice the embankment height, whichever is less.
Landslides	Place borings perpendicular to the roadway to establish geologic cross-sections for analysis. Locate at least one boring above the sliding area.	Extend borings below failure surface into firm stratum, or to a depth which failure is unlikely. Extend inclinometers below the base of the slide.
Culverts	A minimum of one boring per major culvert. Perform additional borings for long culverts or in areas of erratic subsurface conditions.	Use criteria presented above for embankments.
Material Sources	Space borings every 30 m [100 ft] to 60 m [200 ft].	Extend borings 1.5 m [5 ft] beyond the base of the deposit or depth required to provide needed quantity.

Note: Table is modified from FHWA Geotechnical Checklist and Guidelines (FHWA-ED-88-053) as discussed in TGM Section 3.2.3.3.

Select the most appropriate drilling technique to achieve the project specific information and sampling requirements. Do not use equipment design for other site conditions or purposes and expect to get adequate subsurface characterization and sample recovery. Sampling type and frequency is dependent upon both the type of material encountered and the purpose of the investigation. Disturbed and undisturbed samples can be obtained with a number of different sampling devices. The split barrel from the Standard Penetration Test (SPT) is the standard disturbed soil sampling method. Minimum disturbed and undisturbed soil and rock sampling standards are presented in Exhibit 6.3–D.

Exhibit 6.3–D MINIMUM STANDARDS FOR SAMPLING AND TESTING FROM BORINGS

Material	Sampling and Testing Criteria
Sand-Gravel Soils	• Obtain SPT (split-spoon) samples at 1.5 m [5 ft] intervals, or at significant changes in soil strata. • Continuous SPT samples are obtained in the top 4.5 m [15 ft] of borings at locations where spread footings may be placed in natural soils. • Submit representative SPT jar or bag samples to the lab for classification testing and verification of field visual soil identification.
Silt-Clay Soils	• Obtain SPT and undisturbed thin-wall tube samples at 1.5 m [5 ft] intervals or at significant changes in strata. Obtain a sufficient number of samples, suitable for the types of testing intended, within each soil layer. • Take alternate SPT and tube samples in the same boring, or take tube samples in separate undisturbed boring. • Submit representative SPT jar or bag samples to the lab for classification testing and verification of field visual soil identification. • Submit representative tube samples to the lab for consolidation testing (for settlement analyses) and strength testing (for slope stability and foundation bearing capacity analyses).
Rock	• Obtain continuous cores using double or triple tube core barrels. Photograph rock core as soon as possible after being taken from the boring and before shipping core boxes. • For structural foundation investigations, core a minimum of 3 m [10 ft] into rock to ensure it is bedrock and not a boulder. • Determine percent core recovery and Rock Quality Designation (RQD) in the field for each core run, and record on the boring log. • Submit representative core samples to the lab for unconfined compressive strength testing (foundation bearing capacity analyses, rock mass classification, and modulus estimation).
Groundwater	• Record water level encountered during drilling, at completion of boring, and (if boring remains open) 24 hours after completion of boring. • In low permeability soils, such as silts and clays, a false indication of the water level may be obtained when water is used as the drilling fluid and adequate time is not permitted after hole completion for the water level to stabilize (more than one week may be required). In such soils and where water level is critical to design, install a plastic standpipe observation well to allow monitoring of the water level over a period of time. • Determine seasonal fluctuation of the water table where such fluctuation will have a significant impact on design or construction (e.g., borrow sources, footing excavation, excavations at toe of landslide, etc.). • Measure and record zones of artesian water and seepage.

Material	Sampling and Testing Criteria
Soil Borrow Sources	• Use backhoes, dozers, or large diameter augers where possible for exploration above the water table. • Use borings for exploration extending below the water table. Obtain SPT (split-spoon) samples at 1.5 m [5 ft] intervals, or at significant changes in soil strata. • Submit representative SPT jar or bag samples to the lab for classification testing and verification of field visual soil identification. • Record groundwater levels. Install piezometers or observation wells to monitor water levels where significant seasonal fluctuation is anticipated.
Rock Quarry Sources	• Utilize rock coring to explore new quarry sites. Use double or triple tube core barrels to maximize core recovery. • For riprap source, measure rock mass fracture spacing to assess riprap sizes that can be produced by blasting. • For aggregate sources, note the amount and type of joint in-filling. • Base source assessment on exposed quarry face only if exposures are large relative to required quantities and quality is apparently very good with respect to requirements; otherwise augment with coring or geophysical techniques to verify that the nature of the rock does not change behind the face or at depth. • Submit representative core samples to the lab for rock quality tests to determine suitability for riprap or aggregates.

Note: Table is modified from FHWA Geotechnical Checklist and Guidelines (FHWA-ED-88-053) as discussed in TGM Section 3.2.3.3.

Refer to TGM Section 3.2.3.3 for guidance on drilling and sampling.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

6.3.2.3.4 Rock Coring

Use rock coring techniques to explore and sample bedrock, and to confirm bedrock locations beneath structures. Use double or triple tube core barrels to minimize disturbance. Measure and record percent recovery and Rock Quality Designation (RQD) as soon as the core is recovered, and classify the rock according to Exhibit 6.3–F. Log rock coring in accordance with the standards in Section 6.3.2.5.

Refer to TGM Section 3.2.3.4 for guidance on rock coring.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

6.3.2.3.5 Test Pits, Trenches, and Surface Exposures

Use surface exposures, test pits and trenches in lieu of drilling to quickly and cost-effectively investigate soils and highly weathered rock masses when shallow explorations (< 5 m [15 ft] deep) are planned. Use test pits and trenches only when the impact to the site is acceptable. Follow safety standards in Section 6.3.1.2.

Bulk disturbed soil samples are collected from distinct material types in test pits, trenches and exposures. Where practical obtain samples large enough to include representative gradation. Otherwise, note that this was not done and describe presence of larger particles. Tube samples and plastic bags of smaller samples are collected for in-situ water content and density when this information might be representative and useful.

Standard rock sampling includes "grab" samples obtained from outcrops or test pits. Obtain sample sizes small enough to carry, but large enough to be tested in a point load device or used as hand specimens. Label grab samples with the location where they were obtained and identify the location on a site map.

Refer to TGM Section 3.2.3.5 for guidance on various explorations and sampling.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and CalTrans 2001.

6.3.2.3.6 Boring and Test Pit Closure

Backfill and/or seal abandoned boreholes in consideration of guidelines for boring closure in TGM Section 3.2.3.6. Minimum standard practice is to backfill and compact all test pits to match original grade and replace conserved topsoil or revegetate with an owner-approved mulch/seed mix. Minimum standard practice for borings is use of cuttings, bentonite or grout in consideration of the guidelines in the TGM. Borings through asphalt pavement are covered with asphalt cold patch.

Refer to TGM Section 3.2.3.6 for guidance on closing exploration sites.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are NCHRP RR 378 and AASHTO R 22-97.

6.3.2.3.7 Care and Retention of Samples

Collect, transport, and store rock and soil samples in a manner suitable for maintaining sample integrity prior to testing, and for maintaining the character and integrity of the sample for review by engineers and contractors. Retain representative soil samples and all untested rock core samples until the construction contract is awarded, or longer if Division or project-specific requirements are set.

Refer to TGM Section 3.2.3.7 for guidance on care and retention of samples.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

6.3.2.4 Soil and Rock Classification

FLH standard practice is to classify soils in accordance with the ASTM Unified Soil Classification System (USCS) and/or the AASHTO Soil Classification System (NHI 132031). Field classification of soil and rock follow the standards presented in Exhibit 6.3–E and Exhibit 6.3–F, respectively. Rock and rock mass descriptions and classification follow the ISRM classification system presented in GEC-5.

Refer to TGM Section 3.2.4 for guidance on soil and rock classification.

The primary source supporting the standards and guidance is NHI 132031 and the secondary source is GEC-5.

6.3.2.5 Exploration Logs

FLH standard practice is to prepare exploration logs within the gINT™ boring/test pit log platform, though a variety of presentation formats may be used to best represent the field data. Use standardized logging and data collection forms for all field measurements to ensure accurate, concise, and consistent data management. Collect data during the field work on a field log and revise this log later to be a final log by including laboratory test data. The log is a record of factual data and observations, interpretations are generally not included and if they are they are explicitly identified as such.

Logs have a heading that identifies who did what, when, where and how. Otherwise they are a factual record of materials encountered versus depth using a consistent description format that is explained either on the log or on an attached legend sheet. Logs include sample types and locations, and also include other observations such as progress, water, and remarks by drillers. FLH does not have a standard format but uses the example in NHI 132031 for reference.

Refer to TGM Section 3.2.5 for guidance on exploration logging.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and GEC-5.

Exhibit 6.3–E FIELD CLASSIFICATIONS FOR SOIL

Particle Size Limits of Soils Constituents[1]		Cohesive Soils[2]			Granular Soils[2]	
Constituent	Sieve Size	Consistency	Field Identification	SPT Resistance	Relative Density	SPT Resistance
Boulder (BLDR)	305 mm +	Very Soft	Easily penetrated 100-150 mm by fist.	0-1	Very Loose	0-4
Cobble (COBB)	75 to 305 mm	Soft	Easily penetrated 50-75 mm by thumb.	2-4	Loose	5-10
Gravel (GR)	4.75 to 75 mm	Firm	Penetrated 50-75 mm by thumb with moderate effort.	5-8	Medium Dense	11-30
Sand (SA)	0.075 to 4.75 mm	Stiff	Readily indented by thumb, but penetrated only with great effort.	9-15	Dense	31-50
Silt (SL)	0.002 to 0.075 mm	Very Stiff	Readily indented by thumb.	16-30	Very Dense	50+
Clay (CL)	Less than 0.002 mm	Hard	Indented with difficulty by thumbnail.	31-60		
		Very Hard	Cannot be indented by thumbnail.	>60		

[1] *ASTM D653.*
[2] *N' from Standard Penetration Test, AASHTO T-206-87(2000)*

6.3.2.6 In Situ Testing

The Standard Penetration Test (SPT) is the standard in situ test for FLH site investigations and is performed whenever subsurface conditions and drilling methods allow the use of this test. Automatic hammers are preferred to the “cathead” method. N-values and N-values corrected for energy ratio and overburden are used to evaluate soil variability and to estimate soil density and shear strength parameters.

Refer to TGM Section 3.2.6 for guidance on applying the SPT and other in-situ testing.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are FHWA-SA-91-043 and FHWA-SA-91-044.

Exhibit 6.3–F FIELD CLASSIFICATIONS FOR ROCK

Rock Strength			Rock Quality		Weathering	
Description (Grade)	**Field Identification**	**Uniaxial Compressive Strength (MPa)**	**Structural Quality**	**RQD[1]**	**Description (Grade)**	**Field Identification**
Extremely Weak (R0)	Indented by thumbnail.	0.25-1.0	Very Poor	0-25%	Fresh (I)	No visible sign of weathering. Slight discoloration on major discontinuity surface possible.
Very Weak (R1)	Crumples under firm blows with point of geologist pick. Can be peeled by pocket knife.	1.0-5.0	Poor	25-50%	Slightly Weathered (II)	Rock discolored by weathering, and external surface somewhat weaker than in its fresh condition.
Weak (R2)	Can be peeled by a pocket knife with difficulty. Shallow indentations made by firm blow of point on geologists pick.	5.0-25	Fair	50-75%	Moderately Weathered (III)	Less than half of the rock is decomposed and/or disintegrated to soil. Fresh or discolored rock present as discontinuous framework/corestones.
Medium Strong (R3)	Cannot be scraped or peeled with a pocket knife. Specimen can be fractured with single firm blow of hammer end of geologist pick.	25-50	Good	75-90%	Highly Weathered (IV)	More than half of rock is decomposed and / or disintegrated to soil. Fresh or discolored rock present as discontinuous framework / corestones.
Strong (R4)	Specimen requires more than one blow with hammer end of geologist pick to cause fractures.	50-100	Excellent	90-100%	Completely Weathered (V)	All rock is decomposed and / or disintegrated to soil. Original mass structure is still largely intact.

Rock Strength			Rock Quality		Weathering	
Description (Grade)	Field Identification	Uniaxial Compressive Strength (MPa)	Structural Quality	RQD[1]	Description (Grade)	Field Identification
Very Strong (R5)	Specimen requires many blows of the hammer end of geologist pick to cause fractures.	100-250			Residual Soil (VI)	All rock material is converted to soil. Mass structure and fabric are destroyed, but apparent structure remains intact. May be a in change in volume, but soil has not been significantly transported.
Extremely Strong (R6)	Specimen can only be chipped with geologist pick	>250				

Note: Modified from Evaluation of Soil and Rock Properties, GEC-5.
[1] *"Rock Quality Designation"*

6.3.2.7 Laboratory Testing

FLH standard practice is to routinely perform laboratory and index property tests to verify field classifications and quantify material properties. Appropriate testing methods are dependent on materials encountered and on project requirements so they are not standardized. A laboratory testing plan is developed prior to exploration based on anticipated sample recovery and materials. The plan is finalized after exploration and sampling to best use the recovered materials to find the material properties and parameters needed for design and construction. Standard practice is to conduct relatively few complex tests, such as tests for shear strength or compressibility, and to use index tests to extrapolate their results to the extent practical.

Minimum testing standards are defined in Exhibit 6.3–D. Whenever possible, laboratory tests are performed according to standards of AASHTO. ASTM Standards are followed if AASHTO does not have an appropriate standard. Tests that are not standards of AASHTO and ASTM are seldom used and if they are specific laboratory procedures are included with laboratory reporting.

Refer to TGM Section 3.2.7 for guidance on laboratory testing.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and AASHTO Stds HM-25-M.

6.3.2.8 Instrumentation and Monitoring

Install and monitor instrumentation where necessary to answer specific critical questions relevant to project features and designs. Instrumentation is commonly used to measure water table depth and fluctuation, and/or slope movement. Standard instruments are standpipe piezometers, slope inclinometers and surface monuments. Prepare an instrumentation and monitoring plan to include: (1) the safety or economic justification for instruments and monitoring, (2) the timely monitoring of instrumentation to capture seasonal or other expected variations in ground conditions and displacements, (3) detailed and standardized data collection and record keeping processes, and (4) timely communication of findings to the design team members.

It is standard practice to install groundwater and ground deformation instrumentation at major landslides potentially impacting planned roadway construction. Locate deformation instrumentation within the slide in a manner supportive of slope and structure analyses, and install as early in the roadway design process as possible to maximize the monitoring period. Even though design and construction decisions will have been made, continue monitoring through design, and construction, if practicable. Convey results to Cross Functional Team and Project Manager with geotechnical interpretation of observations.

Refer to TGM Section 3.2.8 for guidance on instrumentation and monitoring.

The primary source supporting the standards and guidance is NHI 132031. Secondary sources are AASHTO MSI-1 and NHI 132012.

STATE OF ALASKA

SARAH PALIN, GOVERNOR

DEPT. OF ENVIRONMENTAL CONSERVATION

DIVISION OF SPILL PREVENTION AND RESPONSE
CONTAMINATED SITES PROGRAM

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File No: 1503.38.004
CS Database Reckey
No: 2007130935501

August 7, 2008

Michael S. Traffalis
Western Federal Lands Highway Div.
Federal Highway Administration
610 East Fifth Street
Vancouver, WA 98661-3801

Mr. Forrest Cole, Supervisor
U.S. Forest Service Tongass National Forest
Federal Building
648 Mission Street
Ketchikan, AK 99901

RE: Comment Resolution for B-1 Piezometer Installation Work Plan rev 080508

Dear Messrs. Traffalis and Cole;

The Alaska Department of Environmental Conservation (ADEC) held a conference call with Mr. Michael S. Traffalis, Federal Highway Administration on August 7, 2008. The purpose of call was to resolve comments ADEC had on the work plan submitted by the Federal Highway Administration. The purpose of the plan is to install piezometers to determine ground water levels and the geology at the B-1 quarry.

Based on the discussion among project managers during the call, it appears that ADEC concerns regarding the proposed work have been addressed and the work plan is approved. Please note that ADEC review and approval of this specific work plan is to ensure that the work is done in accordance with State of Alaska Environmental Conservation laws and regulations. While ADEC may comment on other state and federal laws and regulations, our approval on the plan does not relieve responsible persons from the need to comply with other applicable laws and regulations.

If you have any questions concerning this matter, please contact me at (907) 269-7552 or the other field operation project manager, Bruce Wanstall at (907) 465-5210.

Sincerely,

Louis Howard
Project Manager

cc: Michelle Powdrill, Alaska Department of Law, via email
Jenn Currie, Alaska Department of Law, via email
Bruce Wanstall, ADEC CS Programs via email.
Veris Lunasin, SPAR Accountant, via email

APPENDIX C

Statement of Qualifications

C.1

AMEC Geomatrix, Inc.

amec

STATEMENT OF QUALIFICATIONS
FOR ENVIRONMENTAL SERVICES

Submitted to:

Western Federal Lands Highway Division, Vancouver, WA

Submitted by:

AMEC Geomatrix, Inc., Seattle, WA

August 2008

Project No. 14481

AMEC Geomatrix

STATEMENT OF QUALIFICATIONS
FOR ENVIRONMENTAL SERVICES

AMEC Geomatrix, Inc. (AMEC), is a subsidiary of AMEC Earth and Environmental, a publicly owned firm of consulting engineers and scientists that is part of the AMEC company based in London, England. AMEC's capabilities include environmental engineering, mining engineering, chemical and process engineering, air quality and toxicology, risk assessment, decision analysis, geotechnical engineering, biological sciences, and applied environmental and earth sciences.

AMEC has offices located throughout North America and overseas. From these offices, AMEC staff of more than 3,500 technical and support professionals lead projects ranging from individual consulting assignments to multidisciplinary team efforts.

AMEC projects span the globe. We have worked throughout North America and in more than 120 countries worldwide—on projects ranging from port facilities and railyards to landfills and hydrocarbon investigations. Our clients include Fortune 500 firms, businesses from major industries, service-sector organizations, and government entities at federal, state/provincial, and local levels.

FULL-SERVICE CAPABILITIES

ENVIRONMENTAL SCIENCES AND ENGINEERING

Soil and Groundwater

- Site assessments for property transactions
- Process engineering/system optimization
- Soil and groundwater quality investigations
- Hydrogeologic studies
- Modeling and analysis of groundwater and vapor flow
- Remediation design and construction
- Innovative remediation technologies
- Assessment and closure of storage tanks
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigations and feasibility studies

- CERCLA time-critical and non-time-critical removal actions
- Resource Conservation and Recovery Act (RCRA) corrective action
- Toxicology and risk assessment

Air Quality Management

- Support for Clean Air Act Amendment; air permitting
- Emission inventories
- Assessment and control of air emissions
- Air toxics
- Indoor air quality (Sick Building Syndrome)

Water Resources Management

- Groundwater resource evaluation
- Well design, installation, and testing
- Identification of aquifer parameters
- Analysis of contaminant and radionuclide transport
- Analytical/numerical modeling of groundwater systems

Monitoring and Evaluation of Water Quality

- Statistical analysis of monitoring data

Hazardous Materials Program

- RCRA compliance and waste evaluation
- Superfund Amendments and Reauthorization Act (SARA) Title III inventories
- Process safety
- Spill control plans
- Risk management prevention plans

Environmental Compliance

- Support for multimedia permits

- Environmental audits and training
- Waste minimization
- Facility closure plans and implementation
- Stormwater permits, monitoring plans, implementation training

Environmental Management

- Environmental management systems
- ISO 14000 compliance
- Resource optimization
- Information technology
- Waste economics
- Natural resources
- Biological surveys
- Archeological surveys
- Wetlands delineation
- Fisheries studies
- Sediments investigations and cleanup

LICENSING AND REGULATORY INTERACTION

- Safety analysis reports
- Interaction with regulatory agencies
- Representation at governmental reviews/public hearings
- Program planning and technical review

GEOTECHNICAL ENGINEERING

Geotechnical and Foundation Engineering

- Foundation engineering
- Earth dams and embankments
- Retaining structures

- Landslide investigations; hillside stabilization
- Geomarine and coastal engineering

Engineering Geology

- Site reconnaissance and field exploration
- Geologic mapping/aerial photo interpretation
- Quarry evaluation and investigation
- Fault studies
- Landslide evaluation
- Land use and environmental planning
- Hazard assessment studies

EARTHQUAKE-RELATED SERVICES

Seismotectonic Evaluation/Seismic Geology

- Site selection/evaluation studies
- Analysis of remote sensing data
- Photogeologic interpretation
- Earthquake hazards assessment
- Fault activity assessment
- Earthquake recurrence assessment

Earthquake Engineering

- Assessment of dynamic soil properties
- Evaluation of earthquake ground motions
- Development of seismic design criteria
- Evaluation of soil liquefaction/site stability

Evaluation of Landslide and Slope Stability

- Seismic evaluation of dam stability
- Geophysics

DECISION ANALYSIS AND PERFORMANCE ASSESSMENT

Design Applications

- Probabilistic hazard analysis
- Logic tree uncertainty analysis
- Development of design criteria
- Decision and priority analysis

Environmental Applications

- Probabilistic modeling of groundwater flow and transport
- Reliability analyses of natural systems
- Total system performance assessments
- Cost/benefit analyses
- Site strategic planning

INFORMATION SERVICES/GEOGRAPHIC INFORMATION SYSTEMS (GIS)

- Intergraph GIS (AutoCAD, Microstation, ClarisCAD)
- Windows NT and Novell Network Systems

LEGAL SUPPORT

- Pre-trial research, investigation, and analysis
- Litigation support
- Expert witness and neutral expert

ENVIRONMENTAL QUALIFICATIONS

- Site characterization
- Remediation design
- Remediation construction
- Health risk assessment and toxicology
- Site assessments for property transactions
- Environmental compliance and facility audits

- Industrial resource conservation
- Assessment and closure of storage tanks
- Assessment and control of air emissions
- Litigation support
- Groundwater resources management
- Modeling and analysis of groundwater and vapor flow
- Graphic and geographic information systems

AMEC's expertise is described in further detail in the following sections.

SITE CHARACTERIZATION

AMEC characterizes sites to identify and assess the nature and distribution of chemicals in soil and groundwater. We begin a site characterization by investigating site history and reviewing available information regarding site conditions. If additional site investigation is called for, we work with our client to develop a field program that considers the technical, regulatory, and financial aspects of the project, and that addresses client concerns and goals for the site. The field program may include evaluating the site's geologic and hydrogeologic setting, performing reconnaissance soil and groundwater quality surveys, installing monitoring wells, and/or performing aquifer and plume characterization studies.

During field programs, our professional staff collect soil and water samples for physical and/or chemical testing. Our sampling experience covers a range of media—rock, soil, sediments, surface water, groundwater, biota, and air—and a variety of investigative methods. Methods include advancing borings, conducting continuous-core drilling and sampling, performing cone penetration tests, installing water and soil gas sampling probes, and applying specialized techniques for sampling wetlands soils. We design monitoring networks to assess soil, vadose zone, and groundwater quality; evaluate the performance of groundwater pumping and drainage systems; and assess hydraulic gradients within an aquifer. Monitoring networks range in complexity from conventional wells for measuring water levels and sampling water quality in the saturated zone, to devices for measuring liquids and gases in the unsaturated zone.

In performing site characterization studies, AMEC has pioneered several field techniques. Our use of innovative data collection methods has provided our clients with substantial savings in cost and time. Typically, before installing a monitoring well network, AMEC staff use various screening methods to define the lateral and vertical extent of chemicals in the subsurface.

This approach requires the fewest monitoring wells, reducing both the short-term costs of characterization and the long-term costs of monitoring.

Project Example

AMEC was asked to define the lateral and vertical extent of trichloroethene and chromium in groundwater in a hydrogeologically complex area having a depth to groundwater greater than 300 feet.

Value-added solutions: To minimize the high cost of installing wells to these depths, AMEC developed a discrete-depth groundwater sampling method to characterize groundwater quality using a minimum number of wells. The plume of affected groundwater was determined to be approximately 2 miles long and to extend to a depth of 550 feet. Because of our innovative reconnaissance sampling method, the regulatory agencies approved a monitoring network of only nine wells for the off-site part of this extensive plume. Estimated cost savings to our client exceeded $8 million.

REMEDIATION DESIGN

AMEC designs remediation schemes that provide cost-effective solutions to meet cleanup goals. Our first step in evaluating site remediation alternatives is to understand our client's needs and goals, considering technical, financial, regulatory, and strategic factors. We then identify feasible remediation alternatives for achieving cleanup goals; we often develop net present value comparisons to evaluate the short- and long-term costs of each alternative. Our evaluations, which are structured to facilitate decision making and design, generally include the following steps.

- Identify remediation goals and strategy based on client needs and regulatory requirements.
- Develop criteria for selecting remediation alternatives.
- Identify feasible alternatives; perform cost/benefit analyses.
- Recommend the best remediation alternative based on all factors.
- Prepare a detailed cost estimate and schedule.
- Design the remediation system.

AMEC creatively applies both innovative and established remediation technologies to solve straightforward or complex environmental projects. Projects have involved removing chemical mass through groundwater extraction and treatment, free-phase product removal, and vapor extraction and treatment; soil excavation and disposal; construction of engineered containment systems such as slurry cutoff walls, geotextiles, and caps; and/or applying in situ and ex situ treatment techniques such as chemical fixation, bioremediation, and bioventing. We design innovative technologies, such as in situ permeable treatment walls, when creative solutions will meet project and client goals more effectively than existing technologies.

Project Example

AMEC was retained to investigate soil and groundwater quality and develop a remediation action plan after solvents were identified beneath leased property. The property had been the site of semiconductor manufacturing. We characterized the hydrogeology, defined the extent of chemicals in soil and groundwater, evaluated pathways of chemical migration, and assessed potential human health risks in order to design a final site remedy. Soil in suspected source areas was excavated, and an interim groundwater extraction/treatment program was implemented to contain affected groundwater.

Value-added solution: Although the pump-and-treat system would have been acceptable to regulatory agencies as a final site remedy, we proposed an innovative, passive subsurface groundwater treatment wall composed of granular iron. This technique reduced total project costs by several million dollars, eliminated the need for an aboveground treatment system, and produced minimal impact on the property's future use. AMEC obtained regulatory approval to install the innovative treatment wall as a final remedy. This approach allowed removal of the pump-and-treat system, successful treatment of chemicals in groundwater as confirmed by follow-up sampling and testing, and economic use of the site.

REMEDIATION CONSTRUCTION

AMEC provides construction services for implementing the selected remediation design. We can act as general contractor in constructing the remediation system or provide construction management and support services. We have performed construction management for a variety of projects, including soil excavation, on-site treatment, and disposal. We have also engineered removal of underground and aboveground storage tanks, as well as containment systems such as slurry walls and caps, storm drain systems, large-scale groundwater extraction wells, pilot- and large-scale groundwater and vapor treatment plants, and small- and large-scale pipelines. We implement remediation programs that incorporate innovative and emerging technologies such as bioventing, soil fixation, iron-reduction treatment walls, and in situ bioremediation. We have designed and are patenting a state-of-the-art, portable, combustion-engine-driven vapor extraction system. It quickly and cost-effectively removes organic vapors and free-phase product from sites containing petroleum hydrocarbons.

Our professional staff can implement and oversee all aspects of construction, such as:

- permitting,
- preparing construction plans and specifications and contract documents,
- evaluating bids and making recommendations for qualified contractors,
- overseeing implementation,
- preparing implementation reports,
- administering construction contracts,
- providing system startup and monitoring,
- performing operation and maintenance functions,
- interfacing with regulatory agencies/facilitating approval processes, and
- assisting with community relations.

Geomatrix controls remediation costs through efficient planning and organization, effective contractor negotiation and contracting, and quality assurance/control programs during construction. We optimize system operations by tracking performance closely and developing improvement programs for established treatment systems. Once remediation is complete, we prepare the appropriate documentation to demonstrate that remediation goals have been met, and work closely with regulatory agencies to obtain final site closure.

MODELING AND ANALYSIS OF GROUNDWATER AND VAPOR FLOW

Analytical and numerical models are powerful tools for evaluating groundwater flow, soil vapor flow, aqueous geochemistry, and solute transport. AMEC maintains an up-to-date library of computer software to model hydrogeologic processes that range from relatively straightforward, two-dimensional flow to complex, three-dimensional solute transport. At the outset of a project, hydrogeologists work closely with the client to identify the specific objectives of the hydrogeologic analysis. Based on these goals and the available data, project budget, and schedule constraints, a hydrogeologist develops a scope of work and selects the appropriate computer code(s) to accomplish project objectives.

Our professionals keep abreast of developments in modeling techniques and regularly update our computer library with new codes and upgrades. Our quantitative hydrogeologic evaluations typically apply one or more of the following tools.

- Vapor flow analysis - MODFLOW
- Aquifer test analysis - AQTESLOV

- Groundwater flow - MODFLOW, FLOWPATH, RESSQ, AQUIFEMN
- Particle tracking - MODPATH, MODFLOW
- Solute transport - MT3D, MOC, SUTRA, AQUIFEMN
- Aqueous geochemistry - WATEQF, PHREEQE, NETPATH.

Continuing advances in computer software have reduced dramatically the cost of sophisticated groundwater modeling. However, the professional hydrogeologist's technical judgment and insight still largely control the usefulness and validity of groundwater models. The cumulative breadth of AMEC's knowledge and experience in hydrogeologic analysis brings to any project the resources needed to develop practical, cost-effective solutions.

GEOTECHNICAL ENGINEERING QUALIFICATIONS

AMEC maintains capabilities in geotechnical engineering and engineering geology, skills required for siting facilities, landfills, and public works; evaluating geologic hazards; and designing infrastructure projects, critical structures, and storage and supply systems.

Our engineers are thoroughly familiar with sites containing difficult soil and rock conditions, including sites underlain by debris, fine silt, or garbage fill. Foundation systems devised for structures underlain by soft soils or heterogeneous fill materials have included driven piles, drilled piers, and spread footings bearing on compacted fill or improved soil. Methods for soil improvement have included stone columns, grouting, and vibro-compaction.

AMEC provides the following geotechnical services.

- Site selection, exploration, and evaluation
- Evaluation of geologic hazards, flooding, and scour
- Evaluation of and recommendations for foundation alternatives
- Development of foundation design criteria
- Stipulations for retaining structures, subsurface drainage, and temporary excavation support
- Assessment of slope stability, creep, and erosion
- Development of recommendations for site preparation and earthwork
- Preparation of specifications and guidelines for grading, compaction, backfilling, and other earthwork

- Procurement and installation of instrumentation; collection, processing, and analysis of data

- Consultation in preparing and evaluating construction bid packages

- Construction observation and soils testing

AMEC STAFF AND PROJECT TEAM

AMEC's professional personnel offer considerable breadth and experience. Senior staff members are widely recognized experts in their respective disciplines. AMEC's experience and know-how regarding complex situations that require a thorough understanding of air, soil, water, and contaminant interdynamics allow us to develop innovative and cost-effective solutions to our clients' most challenging problems.

AMEC clients, their legal counsel, and the numerous regulatory agencies we interact with respect the depth of our expertise, the quality of our technical products, and our ability to communicate that work. Senior professionals at AMEC have 15 to 35 years of experience in their respective fields; 75 percent have advanced degrees. We have a mix of geologists, engineers, biologists, and environmental scientists.

We have earned a reputation for providing clients with innovative solutions that minimize project costs. This reputation is maintained by the personal commitment of each of our professional specialists.

Outlined below is the project team for the U.S. Forest Service (USFS) Road 3030 project at Coffman Cove, Alaska.

Gary Dupuy, LHG (WA), will serve as the project manager for AMEC. Mr. Dupuy has over 30 years of engineering geology and hydrogeology experience related to investigation and cleanup of hazardous materials releases throughout the U.S. and Canada. He has worked extensively in southeast Alaska on projects for Ketchikan Pulp related to the closure of their pulp mill, two sawmills, and several logging camps, including Thorne Bay, Coffman Cove, and Naukati on Prince of Wales Island. He also managed the closure of the Thorne Bay Landfill as a CERCLA time-critical action under the oversight of the USFS. This included managing the construction phase of the landfill closure.

Bruce Wielinga, PhD Geochemist, will provide geochemistry support to the project. Dr. Wielinga has more than 14 years of experience solving problems related to environmental and industrial microbiology, acid mine drainage, and water quality analysis. His primary focus is on the geochemical processes consequential to the mining industry. He has been involved in the design and testing of water treatment systems for transformation and removal of heavy metals and metalloids, acid rock drainage issues, radionuclides, inorganic anions, and organic contaminants. Dr. Wielinga has diverse experience that includes site investigations and assessments, remedial investigation, feasibility studies, bench-scale and pilot testing, and design and implementation of treatment systems.

Dave Haddock, RG (AK), is a principal hydrogeologist and senior consultant in the Seattle office of AMEC. His responsibilities include planning, budgeting, and implementing environmental projects, as well as providing oversight and quality assurance. Mr. Haddock is an experienced program manager and director with 25 years of experience in the environmental field and more than 18 years of experience conducting and managing environmental projects in the Pacific Northwest.

Stephen Dailey, PE (AK), Project Civil Engineer, is a civil engineer with more than 13 years of environmental and civil engineering experience encompassing regulatory remediation system design, installation, and operation; site characterization; remedial action plan development; regulatory compliance; and construction management. Mr. Dailey is experienced in field operations including geotechnical and environmental site investigations, well installation, and remediation system installation, operation, and maintenance. He has designed, implemented, and managed various soil and groundwater remediation technologies including biostimulation, bioaugmentation, peroxide injection, groundwater pump-and-treat, air stripping, vapor extraction, catalytic oxidation, and carbon adsorption.

Abigail Bazin, Project Engineer, is an environmental engineer with four years of experience in sampling of various environmental media, project management, cost estimation, engineering evaluation/cost analysis (EE/CA) preparation, construction management, and contracts administration. She has a strong understanding of water quality/chemistry and has worked on several abandoned mine site cleanups and acid rock drainage problems.

Naila Moreira, PhD Staff Geochemist, has more than six years of experience in water and sediment geochemical characterization and in hydrogeologic investigations. She has worked on projects examining microbial metabolism, soil and groundwater contamination and remediation, contaminant chemistry, and mineral authigenesis on field sites on Cape Cod, in Brazil, and throughout the Pacific Northwest. Dr. Moreira's field work has included sediment coring in freshwater and marine environments; sampling of pore, ground, and surface waters; and installation of groundwater wells. She has worked extensively with a variety of chemical contaminants and constituents, such as phosphate, arsenic, petroleum by-products, chlorinated compounds, and carbonate waters. Her analytical expertise includes sediment and water quality measurement, including specific conductivity, pH and salinity, wet chemical techniques, ion chromatography, inductively coupled plasma emission spectrophotometry, X-ray diffractometry, dissolved inorganic carbon (DIC) and dissolved organic carbon (DOC) analysis, scanning electron microscopy, and other methods.

Resumes of the project team are attached.

RESUMES

GARY DUPUY, LG, PG

VICE PRESIDENT AND PRINCIPAL HYDROGEOLOGIST

EDUCATION

University of Alberta, Edmonton, Canada: B.S., Geology, 1975

REGISTRATION

Licensed Geologist, Washington, 2003

Registered Geologist, California, No. 5745, 1993

Professional Geologist, Alberta, Canada, 1982

AFFILIATIONS

- Remediation of Chlor-Alkali Facilities
- Remediation of Chlorinated Solvent Sites
- Coordinated Remediation for Shoreline/Uplands/Sediments
- Experience at Former OCC Facility
- Brownfields Redevelopment
- Third-Party Cleanup
- Northwest Hydrogeology

Mr. Dupuy applies his knowledge of hydrology, hydrogeology, and engineering geology to environmental cleanup projects. His broad experience encompasses evaluation/remediation of manufacturing facilities, landfills, Port areas, and chemical plants under MTCA, RCRA and CERCLA. Mr. Dupuy's strengths include providing technical strategy for complex projects such as remediation of chlorinated solvent sites, chemical plants, and redevelopment of brownfield sites. He has led innovative remedies for projects such as deep soil mixing. He is also highly skilled at interaction and negotiation with agencies at federal, state, and local levels. Specific project experience includes:

Thorne Bay and Ward Cove Landfill Closures, *Ketchikan Pulp Company, southeast Alaska.* Project manager for the closure and expansion of two landfills. Project included development of conceptual closure and landfill expansion alternatives, design, seismic and static slope stability analyses, drawings, specifications, and construction engineering support. Regrading plans were prepared during construction to optimize soil balance and minimize waste relocation. This project was performed under a design/build contract, and construction was completed within 9 months of initial conceptual designs. Total project costs were approximately $14 Million.

Standard Steel Superfund RI/FS, *Chugach Electric, Anchorage, AK.* Project director for conducting an RI/FS of the Standard Steel Superfund site. The site, a former transformer storage yard and scrap metal recycling operation, has soil contaminated with lead and PCBs. The RI was completed in 1994 for the site and indicates groundwater has not been impacted, but that approximately 11,000 cubic yards of soil are impacted with lead and/or PCB. The feasibility study included bench scale testing of soil washing and stabilization. A soil washing pilot scale study was performed in the field in 1995. The EPA prepared a Record of Decision, directing remediation of the site soils by stabilization/solidification. Stabilization was the preferred alternative for the PRP group as it was shown in the FS to be effective, readily implemented in Alaska, cost effective, and will allow reuse of the site for industrial purposes.

Alberta Wetlands Inventory, *Alberta Environment, Alberta, Canada.* Project manager for a wetlands inventory encompassing three sub-basin areas in Alberta, Canada. Study involved detailed environmental assessment of soils, geology, hydrogeology, and hydrology of three mini-basins. Evaluated potential runoff characteristics, floodplain area, and drainage control. Assessed impacts of agricultural chemicals (particularly herbicides, pesticides, and fertilizers) on surface water quality during maximum and minimum flow periods.

Hydraulic Control Interim Measure, *Former Rhone Poulenc RCRA site, Container Properties, L.L.C., Tukwila, WA.* Project Director for RCRA Corrective Actions and site redevelopment of former chemical manufacturing facility on the Duwamish. Managed all work and conducted all agency negotiations since 2001, including design and construction of a barrier wall interim measure, final corrective measures on a portion of the property to allow sale to the Museum of Flight, multi-incremental soil sampling for metals, removal of affected soils, and negotiating with EPA on final corrective measures, including remediation of sediments and nearshore habitat restoration.

Sitewide RI/FS, *Boeing Renton Facility, Renton, WA.* Principal-in-charge for environmental cleanup program at this active 150-acre industrial facility located on the Cedar River and Lake Washington. Tasks have included remediation costs estimates, remediation design, remediation planning and permitting, negotiation with Ecology, and corrective actions at 10 areas of concern affected by chlorinated solvents and other VOCs, fuels, and metals.

Southwest Harbor Project RI/FS, *Port of Seattle, Seattle, WA.* Senior technical reviewer for RI/FS of Remedial Area 3 of the Southwest Harbor Project cleanup. The site is located within the tidally influenced fill materials along Elliott Bay and encompasses a former municipal landfill and disposal areas for treated pond and treated wood wastes, construction debris, and slag.

BRUCE WIELINGA, PhD

SENIOR GEOCHEMIST

EDUCATION

Ph.D., Biochemistry/ Microbiology, University of Montana, Missoula, MT, 1997

B.S., Microbiology/ Chemistry, University of Montana, Missoula, MT, 1992

AFFILIATIONS

American Society for Microbiology

American Chemical Society

Soil Science Society of America

CERTIFICATIONS

API – LNAPL Training Workshop

MSHA New Surface Miner Training

40-hour OSHA Hazardous Material Training

Dr. Wielinga has more than 14 years of experience solving problems related to environmental and industrial microbiology, Acid Mine Drainage, and water quality analysis. His primary focus is on the biogeochemical processes consequential to contaminant transport, as well as, the chemical and biological transformation and/or biodegradation of inorganic and organic contaminants. He has been involved in the design and testing of water treatment systems for transformation and removal of heavy metals and metalloids, radionuclides, inorganic anions, and organic contaminants. Bruce has diverse experience, which includes site investigations & assessments, remedial investigation, feasibility studies, bench-scale and pilot testing, and design and implementation of treatment systems. These systems include horizontal well systems for in situ remediation of hydrocarbons, passive and active systems designed for in situ and/or ex situ treatment of ground water, and the chemical and/or biological treatment of sediments and soils. His relevant experience in the mining industry includes:

In Situ Uranium Treatment. Technical lead in conducting field demonstration of in situ biological treatment to remove uranium, and nitrate from groundwater at a uranium milling facility.

Uranium Mine Refill Water. Project manager and technical lead in conducting pilot studies testing the feasibility of using in situ biological treatment to remove uranium and molybdenum from mine refill water.

Mine Pit Lake Geochemistry. Technical lead modeling the geochemical evolution of a mine pit lake using dynamic systems modeling to evaluate long-term trends in radium, selenium, and uranium concentrations. Conducted bench-scale studies to evaluate the feasibility of using in situ bioremediation for removing selenium and uranium from the reservoir.

Passive In Situ Groundwater Treatment. Technical lead in design of large-scale column studies to demonstrate the feasibility for removing uranium, nitrate and sulfate from groundwater adjacent to a Title II uranium milling facility.

ARD Treatment System. Laboratory evaluation of a 4-stage water treatment reactor for removing iron, manganese, arsenic, zinc and sulfate from ARD leachate.

Arsenic Treatment. Designed and initiated pilot scale studies that demonstrated that readily available agricultural waste products could be used to successfully remove arsenic and sulfate from pit lake water.

ARD Water Treatment. Project included: Pit neutralization with hydrated lime using the Neutra-Mill technology followed by organic addition; and participation in developing an engineering evaluation and cost analysis (EECA) for evaluating treatment alternatives for an ARD impacted pit lake and river system associated with historic copper mining.

Title II Uranium Millsites. Biogeochemical evaluation and characterization of several Title II uranium milling sites pursuant to NRC regulations for site decommissioning.

Mine Water Treatment. Designed and evaluated treatability alternatives for several mine sites. These include both passive and active treatment technologies.

Chromium and Radionuclide Remediation, *U.S. Department of Energy, Hanford, WA.* Member of technical advisory team for U.S. Department of Energy to evaluate proposals for intercepting/remediating contaminant plumes containing chromium, strontium, and/or uranium thereby protecting the Columbia River adjacent to the Hanford reservation.

Chromium Biogeochemistry and Remediation, *U.S. Department of Energy*. Extensive experience conducting basic/applied research and providing consulting services on various projects involving chromium contamination. Including: Applied research conducted under the U.S. DOE, Natural and Accelerated Bioremediation Research (NABIR) Program pertaining to chromium biogeochemical reactions and in situ chromium remediation. The work resulted in several publications and numerous presentations at national meetings. Also, served as the technical lead evaluating in situ stabilization of chromium contaminated sludge and the in situ treatment of soils and ground water with elevated concentrations of chromium and nitrate.

LNAPL Soil and Ground Water Remediation. Technical lead evaluating remedial action alternatives at rail yard contaminated with diesel oil, gasoline, and kerosene. Systems evaluations included free-product recovery, air-sparge/soil vapor extraction, and biosparging. Supported design and implementation of a horizontal well biosparge system pilot test.

Mixed DNAPL/LNAPL Remediation. Technical advisor for site assessment and remedial alternative evaluation for industrial property contaminated with mixed organic wastes.

Aquatic Nutrient Cycling. Project manager/technical lead evaluating nitrogen, carbon, and phosphate dynamics in treatment wetland and riparian zone, focused on potential controls on unionized ammonia discharge to river.

Selenium Biogeochemistry. Member of technical advisory team evaluating selenium biogeochemistry in mine waste units as related to methods for assessing potential environmental impacts, and possible chemical and biological attenuation mechanisms.

In Situ Chromate Treatment, *U.S. Department of Energy, Hanford, WA.* Member of technical advisory team evaluating in situ treatment options for large chromate plume within the U.S. Department of Energy, Hanford Site.

DAVE HADDOCK

PRINCIPAL HYDROGEOLOGIST

EDUCATION:

Colorado State University, Fort Collins, CO, M.S. Geology, 1978

Colorado State University, Fort Collins, CO, B.S. Geology, 1975

REGISTRATIONS/LICENSES:

Licensed Geologist, Hydrogeologist, Engineering Geologist, Washington, No. 1790, 2002

Registered Professional Geologist, Oregon, No. G960, 1986

Registered Professional Geologist, Alaska, No. 4982, 1984

Mr. Haddock is a principal hydrogeologist with more than 25 years of experience implementing geotechnical, hydrologic, and environmental projects, as well as providing oversight and quality assurance. Mr. Haddock has supervised a broad range of multi-disciplinary projects at solid waste landfills, including design and evaluation of closure plans, monitoring systems, groundwater extraction and monitoring programs, landfill gas and leachate collection systems, and remediation plans. Mr. Haddock has worked as the Project Manager evaluating environmental management systems at more than 10 solid waste landfills in the Northwest under either WAC 173-304 or WAC 173-351, as well as contaminated site cleanup actions under the Model Toxics Control Act (MTCA). He is currently managing the evaluation of potential improvements to environmental management systems, including the groundwater and landfill gas collection and treatment systems, at closed areas of the Cedar Hills Regional Landfill under King County Contract E53019E. For the Puyallup/Kit Corner Landfill he developed an innovative “sweep well” approach to dealing with LFG-contaminated groundwater. For the Cedar Hills Landfill he also managed the design and construction of dual-phase extraction wells to minimize potential migration of VOCs to groundwater under the unlined Southeast Pit. He managed the feasibility study, Agreed Order negotiations, landfill closure design, and construction management services for the Greenacres Landfill in Spokane County, a project with a construction cost of over $4 million. Many of these projects involved overseeing and coordinating the work of consultant teams involving multiple subcontractors and changing scopes of work.

Related Project Experience

Landfill Siting Study, *Intalco Aluminum Corporation, Ferndale, WA.* Project hydrogeologist for a landfill siting study to determine the placement for new state-of-the-art design industrial landfills. Also prepared the groundwater-monitoring plan for the completed landfills considering state Minimum Functional Standards (MFS) monitoring requirements.

National Environmental Policy Act Environmental Impact Statements, *Wesco Resources, MT.* As project hydrogeologist, Mr. Haddock contributed to NEPA EISs for two proposed coal mines and a proposed railroad in southeastern Montana. He attended public meetings on behalf of the proponents and presented information on the baseline geology and groundwater of the proposed areas. The EISs were subsequently accepted by the lead agency, the Montana Department of State Lands.

Regulatory Analysis, *Kennecott Minerals Company, southern OR.* As project manager, Mr. Haddock performed an analysis of regulatory requirements for an underground mine proposed for southern Oregon. This analysis evaluated air, water, and mining permits necessary for the proposed facility. In addition, he prepared a conceptual baseline groundwater monitoring program for the facility, including implementation schedules and cost estimates.

Abandoned Mined Land Investigations, *Various Clients, MT.* Mr. Haddock has been project manager responsible for the investigation of over 30 abandoned mined land (AML) sites throughout eastern and southeastern Montana. He researched courthouse records, interviewed landowners, and conducted detailed site evaluations. He performed geophysical surveys for some subsidence prone sites to determine the extent of old underground workings. To compare and rank reclamation alternatives for sites, he prepared hydrologic and hydrogeologic calculations. He attended public meetings and gave presentations on behalf of the Montana Department of State Lands. The end result of these studies are reclamation plans, engineering plans and drawings, and construction bidding packages that have been utilized to abate the AML related hazards. Designs were based on recharge elimination and included surface seals, groundwater interception and drainage, and channelization of surface water.

Landfill Gas Header Systems, *Cedar Hills Regional Landfill, Issaquah, WA.* Telephone: As Project Manager, Mr. Haddock was responsible for preparing design documents including drawings, specifications, and cost estimates for the installation of new landfill gas headers, laterals, and condensate recovery piping. He oversaw multiple consultants and staff.

Environmental Management Systems Improvements, Cedar Hills Regional Landfill, Issaquah, WA. As Project Manager for the client, King County Solid Waste Division, Mr. Haddock and his team are currently evaluating the environmental control systems for the closed portions of this 940-acre landfill in rural King County. The primary goal of the project is to evaluate these systems and to effect improvements that will result in better containment, treatment, and/or control of landfill gas (LFG), leachate, and stormwater management systems, if needed. Preliminary investigations and work plans have been completed and improvements are being implemented for LFG, leachate, and groundwater extraction systems.

STEPHEN M. DAILEY, PE
PROJECT ENGINEER

EDUCATION
B.S. Civil Engineering, University of Washington, Seattle, WA, 1995

REGISTRATION
Professional Civil Engineer, Washington No. 36481, 2000
Professional Engineer, Oregon No. 66816PE, 2001
Professional Engineer, Montana No. 15588PE, 2002
Professional Civil Engineer, California No. C66370, 2003
Professional Civil Engineer, Arizona No. 41755, 2004
Professional Civil Engineer Alaska No. 11419, 2006

AFFILIATIONS
- Remediation of Chlorinated Solvent Sites
- Northwest Hydrogeology

Mr. Dailey has more than 13 years of environmental and civil engineering experience specializing in regulatory remediation system design, installation, and operation, site characterization, remedial action plan development, regulatory compliance, and construction management. Mr. Dailey is experienced in field operations including geotechnical site investigations, environmental site investigations, well installation, remediation system installation, and remediation system operation and maintenance. He has designed, implemented and managed various soil and groundwater remediation technologies, including biostimulation, bioaugmentation, peroxide injection, groundwater pump-and-treat, air stripping, vapor extraction, catalytic oxidation, and carbon adsorption. His construction management experience includes preparing designs and specifications, selecting contractors and vendors, managing costs and schedules, and representing clients on site.

REPRESENTATIVE PROJECTS

Vapor Extraction Pilot Testing at Military Site, *SUBASE Bangor, Kitsap County, WA*. Project engineer and field supervisor for pilot test at military facility with commingled fuel and chlorinated solvent groundwater plumes. Designed and specified pilot test equipment, instrumentation, and procedures. Managed sample collection and conducted data quality assurance review.

Remediation System Optimization, Operations, and Maintenance at Former Dry Cleaner, *Everett, WA.* Served as project manager for remediation system refurbishment, optimization, and operation and maintenance at a former dry cleaner in Everett, Washington, where chlorinated solvents (PCE and breakdown products) were present in groundwater. Monitored carbon loading to ensure adequate treatment of extracted soil vapor. Evaluated changes in groundwater concentrations to optimize system flows. Conducted periodic reporting to agencies as required.

Site Characterization and Remediation System Design and Installation at Former Gasoline Service Station*, ExxonMobil, Seattle, WA*. Project Manager and Construction manager for site characterization, remediation system design, installation, and demolition, and remedial excavation design, at a former gasoline service station where gasoline-range petroleum, including separate-phase hydrocarbons, was present in soil and groundwater. Conducted dual-phase extraction pilot test, designed extraction and sparge well networks and piping, and specified equipment. Designed equipment enclosure to meet stringent sound level requirements resulting from the site's location in a residential neighborhood and current use as a medical office building. Managed contractors, budget, and schedule during system installation in close quarters with limited maneuverability for construction traffic, and also during system and building demolition when owner redeveloped property. Calculated quantities and costs to dispose of impacted soils during owner-directed redevelopment.

Site Characterization and Remediation System Design and Installation at Former Gasoline Service Station*, ExxonMobil, Portland, OR.* Project Manager and Construction Manager for site characterization, remediation system design, installation, and operation at former gasoline service station where gasoline-range petroleum impact was present in soil. Designed extraction well network and piping, specified and selected vendor for equipment, and solicited and evaluated contractors' bids. Managed contractors, budget, and schedule for system construction. Reevaluated vapor treatment technology options when hydrocarbon concentrations in soil vapor were greater than expected. Oversaw installation of a catalytic oxidizer to replace original vapor-phase carbon canisters, including specifying and ordering new equipment and managing electrical service upgrade and equipment installation.

ABIGAIL BAZIN
PROJECT ENGINEER

EDUCATION
M.S., Civil and Environmental Engineering, Stanford University, Stanford, CA, 2004
B.S., Chemistry, Minor in Environmental Science, Colorado School of Mines, Golden, CO, 2003

REGISTRATION
E.I.T., WA No. 26890, 2005

Ms. Bazin has more than 4 years of experience specializing in the assessment of abandoned mine lands and acid rock drainage, site characterization, project management, cost estimation, and contractor oversight. She has a strong understanding of water quality/chemistry as well as experience with remediation system design, installation, and operation. Representative projects include:

Josephine Mill #2, *Bureau of Land Management*, Pend *Oreille County, WA.* Staff Engineer in conducting a detailed investigation of the Josephine Mine site. Helped to complete the preliminary design, costing, and assessment of remedial alternatives for the Engineering Evaluation/Cost Analysis as part of a non-time critical removal action.

Abandoned Mined Land Investigations, *Washington Department of Ecology, WA.* Staff Engineer investigating abandoned mined lands (AML) at remote sites throughout Washington State. Interviewed landowners and conducted detailed site evaluations to compare and rank sites. The sites were evaluated using the Washington Ranking Method.

Holden Mine Site, *US Forest Service*, *Okanogan-Wenatchee National Forest, WA.* Staff Engineer developing cost estimates for 11 remedial alternatives for the feasibility study at an inactive mine in central Washington contaminated with metals and petroleum. Cost estimating included the preliminary design of a tailings landfill and a remote, low-energy water treatment plant.

Groundwater Remediation at Wood Treatment Plant, *J.H. Baxter, Arlington, WA.* Project engineer for the installation of a groundwater remediation system for treatment of penta-chlorophenol plume at an active wood treatment facility. The groundwater treatment system consisted of extraction wells and a bioremediation infiltration gallery.

Former Scott Paper Company Site, *MJB, Anacortes, WA.* Project Engineer developing remedial alternatives and cost estimates for the Feasibility Study at a former Scott Paper Company site. Alternatives included soil homogenization to permanently reduce the risk to terrestrial ecological receptors due to metals contamination.

Site Investigation at Aircraft Parts Fabricating Facility *Confidential Client, Renton, WA.* Project Engineer installing and sampling groundwater monitoring wells and injection wells, and advancing more than 25 push probe borings to collect soil and groundwater samples. The investigation assessed current site conditions and chemical-specific cleanup levels prior to initiating the cleanup action plan. Provided support in evaluating potential cleanup recommendations, including excavation of contaminated soils, soil vapor extraction, electron-donor injection, and natural monitored attenuation.

NAILA FIN MOREIRA, PHD

STAFF GEOLOGIST

EDUCATION

Ph.D., Geology, University of Michigan, Ann Arbor, 2006

B.A., Geology, Magna Cum Laude, Amherst College, Amherst, MA, 2000

AFFILIATIONS

American Geophysical Union

National Association of Science Writers

Society of Environmental Journalists

Dr. Moreira has had over 6 years of experience in water and sediment geochemical characterization and in hydrogeologic investigations. She has worked on projects examining microbial metabolism, soil and groundwater contamination and remediation, contaminant chemistry, and mineral authigenesis on field sites on Cape Cod, in Brazil, and throughout the Pacific Northwest.

Dr. Moreira's field work has included sediment coring in freshwater and marine environments, sampling of pore, ground and surface waters, and installation of groundwater wells. She has worked extensively with a variety of chemical contaminants and constituents, such as phosphate, arsenic, petroleum by-products, chlorinated compounds, and carbonate waters. Her analytical expertise includes sediment and water quality measurement, including specific conductivity, pH and salinity, wet chemical techniques, ion chromatography, inductively coupled plasma emission spectrophotometry, X-ray diffractometry, dissolved inorganic carbon (DIC) and dissolved organic carbon (DOC) analysis, scanning electron microscopy, and other methods. Representative projects include:

Former J.H. Baxter Log Treating Facility, *J.H. Baxter, Arlington, WA*. As Staff Geologist, Dr. Moreira, supervised the installation of more than 25 extraction, recovery, and monitoring wells at a wood preservation facility contaminated with pentachlorophenol and diesel compounds. Wells were constructed as part of a pilot-scale test for in situ bioremediation extraction/infiltration system and passive LNAPL recovery system, both designed by Geomatrix Consultants, Inc.

121 N.W. Everett Phase I Environmental Site Assessment, *Washington Holdings, Portland, OR.* As Staff Geologist, she conducted site walk-through, record review, and contributed to final report for a Phase I environmental site assessment for a property in downtown Portland to facilitate site purchase by the client. Assessed potential environmental liabilities and identified recognized environmental conditions (RECs) following ASTM Standard E 1527-05. Analyzed and interpreted historical data sources, including historical topographic maps, historical aerial photographs, regulatory agency records, public safety records, and other historical data sources to document site history and identify potential environmental issues. Identified legacy environmental concerns associated with a former gas manufacturing facility at the site and other neighboring industrial properties. Prepared reports under tight budgets and short deadlines.

Lagoon Sedimentation and Chemistry Investigation, *University of Michigan, Cabo Frio, Brazil.* Lead research assistant for project characterizing waters and sediments from coastal lagoons near Rio de Janeiro, Brazil. Examined the influence of bacterial metabolism on mineral formation, sediment chemistry, and water chemistry in the lagoons. Planned research field trip to Brazil and organized international collaboration between researchers at the University of Michigan and ETH-Zurich in Switzerland. Coupled field work with detailed laboratory analysis to establish the fundamental role of sulfide-oxidizing bacteria and fluid transport in promoting dolomite formation in the lagoons, leading to Ph.D. dissertation.

Otis Air Force Base Groundwater Contamination Study, *U.S. Geological Survey, Massachusetts Military Reservation, MA.* As Hydrologic Technician, Dr. Moreira, collected field samples and investigated the fate of contaminants in a sand and gravel aquifer that provides drinking water to Cape Cod. Project involved cleanup efforts for more than a dozen plumes of contamination at the site for more than 20 years. She measured water quality parameters and collected samples from multilevel monitoring wells to assess natural attenuation in a sewage-contaminated plume, and to determine the effectiveness of an iron reactive wall remediation system at containing a separate plume of perchlorate and explosive compounds. Also, assisted in installation of passive volatile gas samplers in the bottom of a groundwater-fed contaminated kettle pond. Pursued further research through senior honors thesis at Amherst College, examining isotopic markers of microbial metabolism of phosphate within the sewage plume. Organized scientific collaboration between researchers at Amherst College, Yale University, and the USGS to establish, through thesis work, that microbes can produce a measurable and significant oxygen-isotope signature in phosphate in natural groundwater environments.

ROBERT E. STUART, FP-C
SENIOR SCIENTIST

EDUCATION
M.S., Fisheries Science, Oregon State University, Corvallis, OR, 1981
B.A., Chemistry, Arizona State University, Tempe, AZ, 1975
B.S., Zoology, Arizona State University, Tempe, AZ, 1973

AFFILIATIONS
American Fisheries Society

Mr. Stuart is a certified fisheries biologist with 28 years of experience in fisheries, environmental assessment, environmental chemistry and toxicology, aquatic ecological risk assessment, and project management. His project experience encompasses marine, estuarine, and freshwater habitats. He has studied aquatic habitat degradation from physical and chemical impacts, as well as ecological and toxicological issues associated with bioaccumulation of organic chemicals and inorganic substances in fish and aquatic invertebrates. As a habitat-assessment-team member, Mr. Stuart has applied his training in fisheries, chemistry, and toxicology to a variety of projects. He specializes in assessing risks to aquatic receptors and their habitat from physical and chemical stressors. He has 15 years of experience in providing technical support to NOAA's Coastal Resource Coordination Branch assessing habitat degradation in marine, estuarine, and freshwater environments at over 100 sites throughout the United States and its territories. Mr. Stuart is also listed by the Washington State Department of Transportation (WSDOT) as a qualified senior writer to prepare biological assessments.

Mr. Stuart has conducted aquatic ecological risk assessments in both freshwater and marine environments using computer models to describe the transport and fate of organic chemicals and trace metals in freshwater habitats. He has also used probabilistic computer models in quantitative risk assessments. He has been involved in all aspects of the habitat-assessment process, from developing initial conceptual models to preparing final characterizations. Representative projects include:

Aquatic Resource Baseline Studies, Ahafo Stage 2 Project, *Newmont Ghana Gold Ltd., Accra, Ghana.* Project Aquatic Scientist. Conducted baseline aquatic resource studies in the Tano River Basin near Sunyani, Ghana. Conducted field studies for stream and riparian habitat, fisheries, and aquatic macroinvertebrate resources at 18 study sites in the Tano River and its tributaries in the vicinity of the proposed project. Collected data during both the wet season and dry season to assess seasonal variation in fish usage and other aquatic resources in this West African tropical river basin. Assisted in activities of our local subcontractor from the University of Cape Coast, Ghana. Conducted data analysis and coauthored the baseline data report.

Aquatic Resource Baseline Studies, Akyem Gold Project, *Golden Ridge Resources Ltd., Accra, Ghana.* Lead Aquatic Scientist. Conducted baseline aquatic resource studies in the Pra River Basin near Afosu, Ghana. Conducted field studies for fisheries, fish tissue contamination, ecological risk, and aquatic macroinvertebrate resources at 13 study sites in the Pra River and its tributaries in the vicinity of the proposed project. There is concern with contamination of fish with mercury from historic and continuing small-scale mining operations in the Pra River Basin. We are collecting data during both the wet season and dry season to assess seasonal variation in fish usage and other aquatic resources in this West African tropical river basin. Assisted in activities of our local subcontractor from the University of Cape Coast, Ghana.

Environmental Assessment Study, *Cominco Alaska, Inc., Red Dog and Ikalukrok Creeks, AK*. Project Scientist. Assessed potential impacts on anadromous salmonids in creeks exposed to high concentrations of trace elements (cadmium, lead, and zinc) caused by passage of Red Dog Creek through exposed ore deposits. The primary objective of the project was to evaluate effects of mining and effluent from a mine-tailings pond on habitat for migratory salmon and char. An extensive study evaluated data collected over a decade.

Biological Assessment for Puyallup River Outfall Permitting, *Cascade Pole and Lumber Company, Tacoma, WA.* Project Scientist. Managed wetland delineation and conducted a Biological Assessment (BA) to assess potential impacts on Chinook and coho salmon and bull trout from construction of a stormwater diffuser pipe in the Puyallup River. Installation of the diffuser pipe involved trenching through a small wetland area and extending the trench into the streambed of the Puyallup River. The BA examined possible impacts on salmonids from resuspension of sediments, exposure to stormwater contaminants, and construction. The BA also examined potential impacts of the diffuser-pipe installation on migratory behavior of salmon using the Puyallup River system, an issue of concern to the Puyallup Tribe which fishes the river commercially.

Biological Evaluation (BE) for a National Pollutant Discharge Elimination System (NPDES) Permit for Discharges from the Teck Cominco Port Site Facility, Alaska, EPA Region 10, *U.S. Environmental Protection Agency, Region 10, Seattle, WA.* Project Scientist. Prepared a BE evaluating the protectiveness and potential effects of a proposed NPDES permit authorizing waste water discharges from Teck Cominco's Port Site facility located on the Chukchi Sea, Alaska. The BE addressed the potential for take of listed avian and mammalian species in the Chukchi Sea adjacent to the Teck Cominco Port Site facility. The BE was submitted to the EPA for review by the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) in compliance with Sections 2(c) and 7(a)(2) of the Endangered Species Act.

Biological Evaluation for a National Pollutant Discharge Elimination System General Permit for the Discharge of Hydrostatic Test Waters from Vessels Used for the Storage and Transport of Water, *U.S. Environmental Protection Agency, Region 10, State of AK.* Project Scientist. Prepared a BE evaluating the protectiveness and potential effects of a proposed NPDES general permit for discharges of hydrostatic test waters from vessels used for the storage and transport of water in the State of Alaska. The BE addressed the potential for take of listed fish, avian, and mammalian species throughout the State of Alaska. The BE was submitted to the EPA for review by the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) in compliance with Sections 2(c) and 7(a)(2) of the Endangered Species Act.

Biological Evaluation for Promulgation of Revised Water Quality Standards for the State of Alaska, EPA Region 10, *U.S. Environmental Protection Agency, Region 10, Seattle, WA.* Project Scientist. Prepared a BE evaluating the protectiveness and potential effects of proposed revisions to selected water quality criteria for the State of Alaska. The BE addresses potential effects of the proposed criteria changes to listed marine mammals, sea birds, and three evolutionarily significant units of Pacific salmon that are found in Alaskan waters. The BE was submitted to the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) in compliance with Sections 2(c) and 7(a)(2) of the Endangered Species Act.

C.2

Robert Peccia and Associates

ROBERT PECCIA AND ASSOCIATES – THE COMPANY

In business for over a quarter of a century, **Robert Peccia and Associates (RPA)** first opened its doors in 1978 with twelve employees. The respected civil engineering firm now employs nearly 60 individuals and has built its national award-winning reputation by providing solid technical skills in a professional, ethical and trustworthy manner.

Headquartered in **Helena, Montana,** with two branch offices located in **Kalispell** and **Butte Montana,** our employee-owned civil engineering firm has served federal, state, and municipal clients as well as private organizations throughout 28 states, the District of Columbia, Puerto Rico, and Costa Rica.

Civil Engineering Disciplines

Robert Peccia and Associates manages projects in a variety of civil engineering disciplines:

- Water Systems
- Wastewater Systems
- Site Development
- Storm Drainage
- Natural Resources
- Highways and Urban Streets
- Traffic and Transportation
- Airports
- Environmental Documents
- Land Surveying
- Subsurface Utility Engineering (SUE)
- Graphic Design

Consistent Professional Service

The profession of engineering is one of problem solving. Although most civil engineering firms offer their clients technical solutions for their projects, Robert Peccia and Associates prides itself on finding the most appropriate solution for any given challenge, and in providing continuing support long after the project is completed. To identify the most appropriate solution, we work hand-in-hand with our clients to match project alternatives with available budgets.

We provide clients with a fresh, enthusiastic approach to each new project, and we view each client's problem as an opportunity to assist with finding the correct solution. In 30 years of business operations, RPA has never had a professional liability claim filed on any project. Even when unexpected problems arise on a project, which they sometimes do, RPA is known for standing side-by-side with clients until a resolution is found. Part of the reason for our unblemished professional liability record is due in part to our strictly enforced in-house Quality Assurance / Quality Control program. At RPA, we believe in the old-fashioned measure of providing quality and value for every dollar you spend.

A National Award-Winning Team

Since 2001, ***CE News Magazine*** has consistently ranked Robert Peccia and Associates as one of the top civil engineering firms to work for in the United States! This prestigious honor has been annually awarded to the company based on the firm's commitment to providing its employees with an outstanding work environment. As an employee-owned company, these awards are a direct reflection on all employees and have given them a sense of pride in their work. This pride is extended to clients through the services provided.

Our Employees

The most valuable resource of RPA is its employees. Individual qualities that the company looks for are self-motivation, intelligence, common sense, industriousness, and the ability to communicate and work with people. This commitment to excellence is reflected in our finished product and we believe these attributes are important to our clients!

RPA's staff consists of a team of professional engineers, surveyors, scientists, planners, accountants, graphic designers, drafting technicians, and administrative assistants. Every employee provides an important function in the overall efficient operation of the firm.

Project Management

Every project undertaken at RPA is completed under the direction of a project manager who serves as the main contact person between our clients and the firm. Project managers are involved from project start-up to closeout and beyond. They serve as the team leader and will draw upon the firm's other employees as needed to best meet the needs of our client's project.

Our younger employees turn to their project manager for advice and guidance, and all employees receive mentoring through the vision and wisdom of our senior managers. Because of our management style and structure, our employee turnover rate is uncommonly low - if a client enjoyed working with an individual or individuals on a previous project, there is an excellent chance that those same employees will be available on the client's next project. This is an important aspect of our business because we are able to build long-term professional relationships and personal friendships with our clients.

Scheduling and Workload Assessments

Robert Peccia and Associates fully understands that timeliness and budget restraints are of prime importance to our clients. We are especially aware that this is often a concern on analysis and design projects due to project complexity and funding constraints.

In order to minimize scheduling conflicts, we have implemented in-house procedures to maximize our productivity and responsiveness to clients. Our project managers have instant access to budgeting information to ensure their projects stay on track.

Office and Facilities

RPA is headquartered in **Helena, Montana, at 825 Custer Avenue, (406-447-5000).** The company has a **Flathead Valley branch office** at **102 Cooperative Way, Suite 300, Kalispell, Montana 59903 (406-752-5025)** and a second branch office at **65 East Broadway, Butte, Montana 59701 (406-533-6770).** All three offices have a layout that provides individual offices for most employees. Guests are greeted in a large reception area, and conference rooms and efficient document production rooms complete the design. The facilities provide employees with a comfortable working environment to successfully perform their duties. The firm maintains a fleet of vehicles for employee use, including a Cessna 172 that several of our employee-pilots utilize for quicker access to projects and meetings with our clients.

Our networked computer system and all drafting and design software packages are constantly updated in accordance with our Computer Systems Manager's recommendations. Our firm has a high-speed wireless Internet connection, with a Web site **(www.rpa-hln.com)**, and an FTP site to provide information and data transfer services for our staff, subconsultants, and clients.

RPA's surveying equipment includes **three Trimble 5700 GPS System, 5800 GPS System, Geodimeter 610 Robotic Total Station,** and **Trimble 5603 Robotic Total Station.** This remarkable equipment allows for either one-person or two-person field crews to gather information quickly and with complete accuracy. The firm also has two standard total station electronic distance-measuring instruments, Tripod Data System (TDS) data collection devices, and several Lietz automatic levels. The surveyors operating the equipment are trained extensively in its use and attend continuing education classes to bring the most efficient and accurate methods to the field.

The Subsurface Utility Engineering (S.U.E.) Division uses **Metrotech 850 and 960 audio frequency line tracing instruments** to determine the exact location of underground utilities for utility mapping purposes. Our S.U.E. Division utilizes a **Vacmaster "Vac-n-Dig" multipurpose vacuum excavator** to pothole the exact depth of utilities, in a non-destructive manner.

Field services equipment includes five Troxler nuclear densometer gauges for verifying soil compaction efforts on construction projects, water quality testing equipment, and hazardous waste protective clothing and associated equipment.

Professional, Trustworthy, and Ethical

We stand committed to our clients. We care, and we maintain respect for traditional engineering principles. Our service is focused on technical excellence, with a commitment to tailor solutions to fit individual challenges.

RPA

Neal Bell, E.I.

Engineering Designer/Construction Technician

EDUCATION
Bachelor of Science with High Honors, Civil Engineering, 2006, Montana State University.

REGISTRATION
Engineer Intern, Montana

Specialties

- Streets and Highways Engineering Design
- Construction Observation and Administration
- Data Collection and Analysis

Experience

Mr. Bell graduated with high honors from Montana State University in December of 2006 and holds a Bachelor of Science degree in Civil Engineering. Prior to joining Robert Peccia and Associates (RPA), Mr. Bell worked for the Montana State University/Montana Department of Transportation (MDT) Design Unit. He gained valuable experience in MDT road design and construction methods, and was trained to use MicroStation and GEOPAK design software. Mr. Bell also worked extensively on designs to upgrade existing pedestrian facilities to meet the American with Disabilities Act (ADA) regulations.

Since joining the Streets and Highways Division at RPA, Mr. Bell has worked on a variety of Federal Highway Administration (FHWA) and MDT projects. Mr. Bell's involvement on the projects listed below included road design, as well as erosion control and lighting design.

- **Southeast Alaska Mid-Region Access Road,** feasibility analysis of a 150-mile corridor connecting southeast Alaska to Canada's Cassiar Highway, Wrangell, AK (FHWA).
- **Four Corners – North,** Widening and reconstruction of 3 miles of Jackrabbit Lane, Bozeman, MT (MDT).
- **Camp Grisdale Road**, 18 miles of roadway reconstruction on the Olympic Peninsula along the Washington Coast, Montesano, WA (FHWA).
- **Beartooth Highway**, 9 miles of highway reconstruction and facility enhancement at the northeast entrance to Yellowstone National Park, Cooke City, MT (FHWA).

In addition to the projects listed above, Mr. Bell has worked on a road condition assessment project for the Bureau of Land Management (BLM). This project involved field work to determine the condition of existing roads providing access to BLM recreation sites. The road conditions were analyzed and reports were developed to propose potential road improvements.

Mr. Bell is skilled in AutoCAD, MicroStation, HEC-RAS, and Microsoft Office applications. He is preparing to undergo the NRC recognized training course for the safe operation of nuclear density gauges.

(Rev. 02/08)

Donna Deutsch

CADD Technician

EDUCATION
University of Akron
Akron, Ohio

Specialties

- Plans Package Preparation
- Drawings, Maps, and Graphics
- MicroStation
- AutoCAD

Experience

Ms. Deutsch works as a Technician in RPA's CADD Division. Her responsibilities include the creation of working drawings, maps, and graphics using AutoCAD and MicroStation. Prior to joining RPA, Ms. Deutsch worked for other Montana and Ohio firms using MicroStation and AutoCAD. She has prepared construction drawings, plans for road and bridge projects, right-of-way plans and performed quantity calculations for culvert replacements and bridges. Ms. Deutsch has also worked on architectural and structural drafting for site development projects, electrical drawings, and GIS mapping of survey data.

Since joining RPA, Ms. Deutsch has worked on projects for the Federal Highway Administration (FHWA) and the Montana Department of Transportation (MDT). Some of the major projects are listed below.

Streets and Highways
South Helena Interchange (MDT)
National Wildlife Refuge Roads, Washington/Oregon/Montana (FHWA)
Wisconsin Bike Path, (City of Whitefish, MT.)
Stevens Canyon Road, WA. (FHWA)
Coffman Cove Road, AK. (FHWA)
Bowman's Corner (MDT)
Four Corner's Access Management Plan (MDT), Four Corners – North (MDT)
Townsend Street Improvements (City of Townsend, MT.)
Canyon Ferry Road (MDT)
Seventh Street, Somers Avenue, Second Street, Dakota Avenue, Edgewood Place (Phase I & II), Whitefish Stage Road (City of Whitefish, MT.)
93 North (MDT)
Victor-Florence (MDT)
Meridian Road (MDT)
Dena Mora Rest Area - Interstate 90 (MDT)
Flowery Trail Road, WA. (FHWA)
Milligan Canyon (Jefferson County, MT.)
Claggett Hill (Fergus County, MT.)
Columbia Heights/Hungry Horse (MDT)
Beartooth Highway, MT. (FHWA)
Baxter Meadows Subdivision, Bozeman, MT.
Mount Baker-Snolqualmie Flood Damage Repairs, WA. (FHWA)
Camp Grisdale Road, Montesano, WA. (FHWA)
Mission Ridge Road, Wenatchee, WA. (FHWA)

(Rev02/08)

Mike K. Johnson, P.E.

Project Engineer

EDUCATION
Bachelor of Science, Civil Engineering, 2003, Montana State University

ACCOMPLISHMENTS
Co-authored published article, "Work Zone Safety", *LTAP Matters* (Spring 2004)

REGISTRATION
Professional Engineer, Montana

AFFILITATIONS
Member Chi Epsilon; Civil Engineering Honors Society

Specialties

- Engineering Design
- Road and Street Design
- Hydraulic Design
- Construction Observation and Administration
- Data Collection and Analysis

Experience

Prior to joining Robert Peccia and Associates (RPA), Mr. Johnson worked as a civil engineering specialist for the Montana Department of Transportation (MDT) in Helena. During this time he was involved in the federally funded Hazard Elimination Program, trying to reduce the number and severity of vehicle crashes throughout Montana. While a student at Montana State University (MSU), Mr. Johnson worked for MDT in the MSU Design Unit, where he attained knowledge of road design and hydraulic design as well as the corresponding software.

Since joining RPA in April 2004, Mr. Johnson has worked on Federal Highways Administration (FHWA), MDT, and municipal projects. Mr. Johnson's involvement on the projects below included: signing and striping plans; erosion control plans; utility plans; construction plans; parking facility plans; and hydraulic/hydrologic design.

Canyon Ferry Road (MDT), urban/rural highway and sidewalk improvements along a major arterial including a round-about and traffic signals, Lewis & Clark County, MT.
Coffman Cove (FHWA), 20 miles of roadway realignment and reconstruction on the environmentally sensitive Prince of Wales Island, Craig, AK.
Beartooth Highway (FHWA), 9 miles of highway reconstruction and facility enhancement at the northeast entrance to Yellowstone National Park, Cooke City, MT.
Mission Ridge Road (FHWA), 4 miles of highway reconstruction, Chelan County, WA.
2005 National Wildlife Refuge Road Projects (FHWA), access road, parking area, and facilities improvements at five National Wildlife Refuges throughout Oregon and Washington.
2004 National Wildlife Refuge Road Projects (FHWA), improvements to access roads and parking areas involving four National Wildlife Refuges throughout Montana
Camp Grisdale Road (FHWA), 18 miles of roadway reconstruction on the Olympic Peninsula,Greys Harbor County, WA.

Mr. Johnson is skilled in MicroStation, Geopak, HEC-RAS, HY8 Culvert Modeling software, Word, WordPerfect, and EXCEL software. He has also successfully completed NRC recognized training course for the safe operation of nuclear density gauges.

Bradley A. Thompson, P.E.

Senior Design Team Manager

EDUCATION
Bachelor of Science, Civil Engineering, 1998, Montana State University

REGISTRATION
Professional Engineer - Montana and Alaska

Specialties

- Streets and Highway Design
- Right of Way
- Traffic signal and Lighting Design
- Construction Management

Experience

Prior to joining Robert Peccia and Associates (RPA), Mr. Thompson was employed by the Wyoming Department of Transportation as a field engineer. His experience included design, construction surveying, construction observation, and contract management on a number of highway projects.

Prior to his college graduation from MSU, Mr. Thompson's academic career included an internship with the Lewis and Clark County Planning Office in Helena, Montana. He conducted the County's annual traffic counts, performed cost estimates for sidewalk improvements, and helped draft County commercial and residential approach standards.

While attending classes at MSU, Mr. Thompson participated in class projects that evaluated transportation needs for county roadways in Gallatin County, MT. His senior design project involved a conceptual redesign of the west entrance to Yellowstone National Park.

Since joining RPA in November of 2000, Mr. Thompson has worked on many Federal Highway Administration (FHWA) and Montana Department of Transportation (MDT) projects. Mr. Thompson's involvement on the projects listed below included roadway design, right of way design, as well as signing, delineation, traffic signal, and lighting design.

Camp Grisdale Road, 18 miles of roadway reconstruction on the Olympic Peninsula. (FHWA)
Mission Ridge Road, 4 miles of highway reconstruction in central Washington. (FHWA)
MDT Interstate 15/South Helena Interchange, construction of a new interstate interchange, including a roundabout. (MDT)
U.S. 93/White Coyote Road – South Ravalli, a 7 mile highway reconstruction project on the Flathead Indian Reservation in western Montana, including various wildlife enhancements and cultural preservation improvements, Ravalli, MT (MDT)
Cascade – Warm Lake Road, 24 miles of roadway rehabilitation also resurfacing in central Idaho. (FHWA)
North Meridian Road, reconstruction and widening of Meridian road from U.S. 2 to U.S. 93 in Kalispell, Montana. (MDT)
Huffine Lane Traffic Signal, design and construction, inspection of a new traffic signal on Huffine Lane near Bozeman, MT. (Private Developer)
Bowman's Corner – Augusta, reconstruction and realignment of 17 miles of rural roadway in central Montana.

Bradley A. Thompson, P.E.

Senior Design Team Manager

MDT Victor-Florence, reconstruction of and adding capacity to 14 miles of U.S. Highway 93 in southwest Montana.
Canyon Ferry Road, urban/rural highway and sidewalk improvements along a major arterial including a round-about and traffic signals, Lewis & Clark County, MT
Flowery Trail Road, 20 miles of highway realignment and reconstruction in the pristine National Forests in eastern Washington, including Ski Area access.
Big Sky Access Control, access control plan for MT Highway 64 from U.S. 191 to Big Sky, MT. (MDT)

MDT Right-of-Way Term Contact, 2002 – 2004

- NW Bypass Lighting – Great Falls
- Cut Bank – West
- Powell County Line – North
- Numerous MDT out-sourced Quality Assurance/Quality Control projects

Mr. Thompson is proficient in computer-aided design software packages such as MicroStation and GEOPAK.

(Rev. 02/08)

Cody P. Voermans, P.E.

Hydrology and Hydraulics Project Engineer

EDUCATION
Bachelor of Science, Civil Engineering, 2001, Montana State University

REGISTRATION
Professional Engineer - Montana and Alaska

ACCOMPLISHMENTS
Olympic Exhibition Athlete - 1996 Summer Olympic Games, Atlanta, GA.

Resident Olympic Athlete - 1995 to 1998, U.S. Olympic Training Center.

World Shooting Championships Team Member - 1994 and 1998, Italy and Spain.

Published author in numerous national magazines.

Ambassador for the Olympic Shooting Team for eight years, and motivational speaker to groups of up to 5,000 people with various organizations including Fellowship of Christian Athletes.

Specialties

- Hydrology and Hydraulics
- Engineering Design
- Construction Observation
- Data Collection and Analysis

Experience

Prior to joining the firm, Mr. Voermans worked as a geotechnical and concrete testing technician while attending college. Mr. Voermans also worked for a construction firm installing septic systems, utilities, gravel roads, and small structure foundations.

Upon his graduation, Mr. Voermans joined RPA's Site Development Division, and has since moved into the Streets and Highways Division. Over the last six years Mr. Voermans has worked on over 20 Federal, State and local projects. His skills include hydraulic/hydrologic analysis, roadway drainage and storm drain design, road design, construction plans preparation, and erosion control design. His recent design work includes the following projects.

Coffman Cove Road – Lead designer for the paving of 22 miles of roadway on Prince of Wales Island, AK.
Camp Grisdale Road – Hydrology and Hydraulics designs for 17 miles of roadway in Grays Harbor County, WA.
Wisconsin Avenue Bike/Pedestrian Path – Hydraulic and storm drain design for 3.9 km (2.4 miles) of new shared-use path, Whitefish, MT.
Rookery Road and River Camp Bridge – Lead designer for 5.4 miles of roadway reconstruction in the Little Pend 'Oreille National Wildlife Refuge, Stevens County, WA.
South Helena Interchange – Hydraulics and storm drain design for the Interstate 15 interchange south of Helena, MT.
U.S. Highway S - 430/Canyon Ferry Road – Hydraulics and storm drain design for the reconstruction of approximately 13.2 km (8.2 miles) of Secondary 430 in Lewis & Clark County, MT. Work also included stream and canal design and relocation.
Stevens Canyon Road, Mount Rainier National Park – Hydraulics analysis for 10 miles of roadway in Mount Rainier National Park, WA.
Highway 93 North/Victor Florence – Stream realignment design as part of the reconstruction of 12.3 km (7.6 miles) of U.S. Highway 93 located in Ravalli County, MT.
Fourchette Creek Road – Road design team member for 3.3 miles of roadway reconstruction in the Charles M. Russell National Wildlife Refuge, Phillips County, MT.
USFWS Benton Lake NWR, New Access Road – Lead designer for new access road and parking area, Benton Lake, MT.
University of Montana, South Campus Student Housing – Design team member for water, sewer, storm drainage, sidewalks, and parking lots, Missoula, MT.
SID #343/Kalispell – Construction observation on a site development of 15 acres. It included water, sewer, underground storm drainage detention system, streets, sidewalks, and utility relocations in Kalispell, MT.

Mr. Voermans is skilled in MicroStation, Geopak, HEC-RAS, HY8 Culvert Modeling Software, and Hydro-Cad Water Modeling Software, Word and EXCEL. He has also successfully completed various training courses in HEC-RAS modeling, highway drainage, river engineering for highway encroachments, and Alaska cold regions engineering.

(Rev. 02/08)

Brian G. Wacker, P.E.

Vice President
Streets, Highways and Drainage Division Manager

Specialties

- Project and Construction Management
- Alternative Analysis
- Public Involvement
- Context Sensitive Road and Street Design
- Plans and Bid Package Preparation
- Traffic and Transportation Analysis and Planning

EDUCATION
Bachelor of Science, Civil Engineering, 1990, Montana State University.

AFFILATIONS
American Society of Civil Engineers (ASCE), American Council of Engineering Companies of Montana (ACEC-MT), Rocky Mountain Elk Foundation, and Lewis and Clark County 4H Outdoor Coordinator.

REGISTRATION
Professional Engineer, Montana

Experience

Before joining Robert Peccia and Associates (RPA) in 1996, Mr. Wacker worked for five years with the Federal Highway Administration (FHWA). He managed and coordinated FHWA projects in all phases, from location to final construction, including alignment design and alternative analysis, and assembled plan, specification, and estimate packages. Mr. Wacker was responsible for administering, and supervising personnel for highway construction contracts. He was also a team member for the FHWA's Emergency Relief on Federally Owned Roads projects. This special team developed fast track contract packages for flood damaged roads and bridges throughout the Pacific Northwest.

Since joining RPA, Mr. Wacker has managed projects for federal and state agencies throughout the Northwest, as well as many cities and counties throughout Montana. He is familiar with the standards, policies, and procedures of various federal, state, and local agencies. Mr. Wacker is experienced in coordinating with both in-house staff and with subconsultants necessary to complete complex projects. He has developed, and monitored detailed work plans and schedules. As Manager of RPA's Streets, Highways and Drainage Division, Mr. Wacker provides consultation on all projects, from initial design and through construction management. He is responsible for providing oversight on all projects completed by the Division and serves as the Quality Assurance/Quality Control reviewer.

Various City and County Projects. Mr. Wacker has been involved in the design, management, and overall project oversight of numerous local agency projects. He is knowledgeable in the various funding measures as well as the state and federal regulations. Some of the projects Mr. Wacker has worked on include the following.

Townsend Street Improvements, an Special Improvement District project involving the reconstruction of over 150 blocks of street improvements, including drainage improvements, in the city of Townsend, Montana.
LeGrand Cannon Boulevard, a CTEP/SID project for the city of Helena involving the construction of eight blocks of street. Improvements included waterline upgrades and the addition of a pedestrian/bicycle path.
Whitefish Street Projects, over $4 million of reconstruction and upgrades to several streets in the city of Whitefish. Improvements included drainage improvements, utility upgrades, street lighting, and the addition of sidewalks.
Jim Darcy Bike Path, construction of a CTEP funded bicycle path for Lewis and Clark County, Montana.

Brian G. Wacker, P.E. – *page 2*

Montana Department of Transportation Projects (MDT), Mr. Wacker serves as the primary point of contact with MDT. He is knowledgeable about their procedures and processes. The following are just a few of the MDT projects he has been involved with.

Victor Florence, reconstruction of and adding capacity to 14 miles of U.S. Highway 93 in southwest Montana.
Wisconsin Boulevard, a CTEP funded bicycle path in Whitefish, Montana.
US 93 North, a 7-mile highway reconstruction project on the Flathead Indian Reservation in western Montana, including various wildlife enhancements and cultural preservation improvements.
Columbia Heights – Hungry Horse, 4 miles of urban/rural highway reconstruction and widening on US 2 near Glacier National Park, including an Environmental Impact Statement.
Claggett Hill, a 4-mile-realignment rural highway project accessing the Missouri National Wild and Scenic River area in central Montana; and
Numerous other MDT projects.

Federal Highway Administration Projects (FHWA). Mr. Wacker serves as the Project Coordinator/Contract Administrator for all of the FHWA projects. His years of experience have given him an in-depth understanding of federal standards and funding requirements. He has been the Project Manager on the following projects:

Beartooth Highway, 9 miles of highway reconstruction and facility enhancement at the northeast entrance to Yellowstone National Park.
Montana Refuge Roads, improvements to access roads and parking areas involving four National Wildlife Refuges throughout Montana.
Southeast Alaska Mid Region Access Plan, feasibility analysis of a 150-mile corridor connecting southeast Alaska to Canada's Cassiar Highway.
Stevens Canyon Road, 10 miles of roadway in Mount Rainier National Park.
Coffman Cove Road, 20 miles of roadway realignment and reconstruction on the environmentally sensitive Prince of Wales Island in southeast Alaska.
Camp Grisdale Road, 18 miles of roadway reconstruction on the Olympic Peninsula along the Washington coast.
Mission Ridge Road, 4 miles of highway reconstruction in central Washington.
Oregon/Washington Refuge Roads, access road, parking area, and facilities improvements at five National Wildlife Refuges in Oregon and Washington.
Cascade Warm Lake, 25 miles of improvements on a Forest Highway in southern Idaho.
Flowery Trail Road, 20 miles of highway realignment and reconstruction in the pristine National Forests in eastern Washington, including Ski Area access.
Imnaha River Road, a 24-mile safety project in eastern Oregon.

Other Clients. For years Mr. Wacker has worked with other various public and private sector clients. This broad sector of work has given him a wide range of experience in the assorted Civil Engineering disciplines. These clients include but are not limited to the Bureau of Land Management, United States Fish and Wildlife Service, National Park Service, United States Forest Service, Bureau of Indian Affairs, various State Departments of Transportation, and other government agencies.

(04/08)

C.3

Western Federal Lands Highway Division

Richard James Barrows P.E.

19705 NE 197th Ave, Battle Ground, WA, 98604

Hm (360) 687 – 8971
Cell (360) 624 - 4882
barrows4@netzero.com

Profile

"Hands on" geotechnical engineer with a strong background in innovative problem solving through the use of new techniques and technologies. Have over 15 years experience with the use of geosynthetics on roadway projects. This work has included the use of flexible liner, geotextile, and geogrid materials.

Education

MS Geotechnical Engineering , Portland State University — *April 1993*

B.S. Civil Engineering, Portland State University — *November 1988*

Professional Licensees

State of Oregon Board of Engineering Examiners**,** *License # 14910* — *May 1990*

Career History

FHWA Western Federal Lands Highway Division (WFLHD), *Vancouver, WA* — *March 2002 - Current*

Senior Geotechnical Engineer

- Responsible for the delivery of the WFLHD Geotechnical Projects which consists of roadway project geotechnical designs, and technical outreach functions. In addition I spend 25% of my time as a technical career track (TCT) geotechnical engineer for the FHWA Geotechnical Resource Center. Participate in planning of the National Geotechnical Program and the development and implementation of new geotechnical technologies. Implementation includes demonstrating and marketing these technologies to state DOT's and FHWA geotech's.
- Provide geotechnical support and guidance on policy to the FHWA division offices. Lead state DOT geotechnical program reviews and provide project technical guidance.
- In 2005, the FHWA Montana division office requested that I review major flood damage on the Beartooth Highway. During this review I worked with DOT staff and their consultant on a timely roadway repair plan for thirteen sections of the road. I presented my recommendations to the division office for their consideration. Ultimately, a plan was developed that utilized the majority of my recommendations.

  Manage and teach the NHI course; "Design and Construction of MSE and RSS Structures".

FHWA Western Federal Lands Highway Division*, Vancouver, WA* — *August 2004 - January 2005*

Acting Project Development Engineer

- Over saw the delivery of WFLHD Forest Highway, NPS Roads, Refuge Roads, and ERFO Programs.
- First level supervisor to five project development project managers. Second level supervisor to approx. 35 project designers. Reviewed roadway project design packages and was responsible for final approval signature.
-

Acting Project Development Engineer (Cont'd)

- Worked with the Director of Program Delivery on WFLHD project delivery initiatives.
- Worked with the Director of Project Delivery on identifying the present and future needs of the Project Delivery Branch.
- Served on the Business Planning Team (BPT) and worked on office wide initiatives.
- Attended the annual BPT planning meeting and participated in the review and modification of the divisions business plan, goals, and business measures.
- Occasionally served as both acting Director of Project delivery and Division Engineer.

FHWA Western Federal Lands Highway Division, *Vancouver, WA* *October 1999 – February 2002*

Construction Quality Assurance Engineer

- Shaped and implemented WFLHD's first construction quality assurance (QA) program.
- Performed reviews at specific project design and construction milestones.
- Responsible for the construction branch safety program, which included developing branch training plans and project safety reviews.
- Served as a member of the Construction Home Team (CHT). Worked closely with the construction operation engineers (COE's) and the field pool staff.
- Managed construction equipment budget and procurement. Also managed the contract inspection task order.

FHWA Western Federal Lands Highway Division, *Vancouver, WA* *November 1991 - January 2002*

Geotechnical Engineer

- Developed conventional geotechnical designs for bridge foundations, retaining walls, slide corrections, rock cuts, fill slopes, and pavement structural sections using current state of the art practices. This work has also included special nationally recognized, state of the art, geotechnical designs and approaches.
- To address project environmental needs I played a major role in the design and construction of vegetated faced steep slopes on US Hwy 93. This effort was highlighted in Chapter 3, "Examples of Current Good Practice" in the 1996 National Geotechnical Engineering Improvement Program report.
- During the flooding that occurred in the Northwest from 1996 to 1998 I gained national recognition for work that I did on dozens of urgent projects under the FHWA Emergency Relief for Federally Owned Roads (ERFO) Program. These repairs had short project completion times and required innovative or unconventional contract and design methods. Most of the geotechnical problems that were encountered bordered on extremes. As a result I frequently pursued creative solutions that had often never been used in highway applications.
- Lead geotechnical engineer responding to a gubernatorial inquiry to open the flood damaged Washington State Route 123 road by developing an emergency repair contract and then administering it in the field.

Portland State University, *Portland, OR* — *January 1997 - March 1998*

Lecturer In Civil Engineering (Part Time)

- During winter terms of 1997 and 1998, taught a graduate level retaining wall design course.
- Developed a course curriculum that motivated the students to learn about the design and construction of retaining walls.

Oregon State Department of Transpiration, *Salem, OR* — *February 1987 – October 1991*

Geotechnical Engineer

- Performed geotechnical design and construction support activities. This work included the following:
  Geotechnical site investigations
  Landslide analysis and mitigation
  Bridge foundation design
  Retaining wall design
  Embankment analysis and design

- While with ODOT I participated in FHWA's Demonstration Program Project #66, Oregon Alsea River Bridge Pile load test team. The team consisted of both FHWA and ODOT staff and was responsible for collecting and analyzing pile load test data from two 24 inch, 120 foot long piling.

- Inspected the agencies first Soil Nailed retaining wall on the Swift to Delta Park I-5 interchange.

Professional Publications,

"30 Years of MSE TRB Research Pays Off" - 2007 - Barrows, Alazmora.

"Continuous Recording Landslide Failure-Zone Monitoring Probes" - 2007 North American Landslide Conference, Morehouse, Barrows, Prellwitz.

"Equal and Opposite Technology Transfer", 3rd Qtr 2006 WFLHD Quarterly Report.

"Geotechnics of Our National Parks Preserving In A Setting of Change" - July/August 2005, Geo Strata Magazine, - Barrows, Anderson, Clark.

"Development of Continuous Recording Landslide Failure-Zone Monitoring Probes" - 2001 WFLHD TD White Paper, Barrows, Prellwitz.

“ERFO Repairs” Feb 1999" - FHWA Public Roads Magazine - Hammontree, Barrows, Allen.

“Computer Bits Give Geotechnical Drilling Cutting Edge Technology” -August 1998, FHWA Public Roads Magazine - Barrows, Hay.

Professional Presentations,

“2007 TRB Annual Meeting Extraordinary Repair Solutions for the Glacier National Parks Going To The Sun Road”

"2006 Sculpted Shotcrete For Slope Stabilization" - 2006 NW Northwest Geotechnical Workshop.

"2005 Retaining Wall Selection and Basic Retaining Wall Design" - ASCE Professional Development Training Indiana State DOT.

"2005 Historic Roads Preservation in Glacier and Yellowstone National Park" - 2005 National Preservation Conference.

"2004 Geosynthetic Applications For Low Volume Roads" - Annual BLM Training Conference.

"1999 Innovative Solutions For ERFO Repairs" Western Resource Center Operations Conference.

"1994 Lost Trail Pass Reinforced Slope" - Northwest Geotechnical Workshop.

"1989 Reinforcement of a Failed Embankment Over Slough Mud" - Northwest Geotechnical Workshop.

Professional Publications (Cont'd),

"Lost Trail Pass Reinforced Slope, Using a Non-Woven Geotextile"

1995 Geosynthetics Conference Proceedings - Christopher, Barrows, Wayne, Zornberg.

"Lost Trail Pass Reinforced Slope Using a Non-Woven Geotextile "
1994 Video Production - Barrows, Hammontree.

"Geotextiles and UV Protection" 1993, WFLHD Technology Development Newsletter - Barrows.

"Remote Landslide Monitoring Techniques" 1992,WFLHD Technology Development Newsletter - Barrows.

"Lost Trail Pass Geotextile Durability" 1992, Geosynthetics Magazine - Wayne, Barrows, Christopher.

"Reinforcement of a Failed Embankment Over Slough Mud" 1991, Geosynthetics 1991 Conference - Machan, Barrows.

"Inclinometer Data Electronically Acquired and Logged" June 1987, 12th FHWA Northwest Geotechnical Engineering Workshop, Helena Montana - Long, Barrows, Turner.

"Inclinometer Data Electronically Acquired and Logged" June 1987, Video Production - Long, Barrows, Turner.

Professional Recognition,

2007 FHWA Administrators Award – Strive for Excellence and Innovation

2004 Note of Appreciation from Christine Johnson, Resource Center Director of Field Services, for technical assistance to Arkansas Division Office.

1999 WFLHD Preconstruction Team Award for Customer Satisfaction - Warren-Profile Gap, ERFO project in which I served as project geotechnical engineer.

1998 WFLHD Preconstruction Team Award for Customer Satisfaction - FR-39 North, Gumboot Creek.

1997 Letter of Commendation National Park Service for Triple Arches Temporary Repair.

1997 Best Presenter Northwest Geotechnical Workshop - Innovative Solutions For ERFO Repairs

1997 AASHTO Pathfinder Team Award to WFLHD ERFO Project Delivery Team.

1991 Best Presenter Northwest Geotechnical Workshop - Swift - Delta soil nail wall.

1989 Best Presenter Northwest Geotechnical Workshop - Reinforcement of a Failed Embankment Over Slough Mud.

BRIAN MICHAEL COLLINS, P.E.

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Camas, WA 98607

(360) 619-7657
brian.collins@fhwa.dot.gov

SUMMARY OF QUALIFICATIONS

- Eight years of professional Geotechnical Engineering experience specializing in the Transportation Field
- Expertise includes geosynthetics, subgrade stabilization, foundation design, mechanically stabilized earth walls, reinforced soil slopes, and landslide mitigation

EDUCATION

University of Washington - Master of Science in Civil Engineering — Seattle, Washington
Geotechnical Engineering, 3.67 GPA — August 2004

- Coursework: Seepage and Consolidation, Advanced Laboratory Testing, Shear Strength and Slope Stability, Soil Dynamics, Foundations, Geotechnical Case Histories, Lateral Earth Pressure and Retaining Wall Design, Geotechnical Earthquake Engineering, Foundation Soil Improvement, Design and Construction Law.

North Dakota State University - Bachelor of Science in Civil Engineering — Fargo, North Dakota
Geotechnical and Transportation Engineering, 3.71 GPA — December 1999

- Dean's List-all semesters, graduated with Honors
- Vice President, NDSU Student Chapter of ASCE - 1998, 1999

Continuing Education Courses

- Soils and Foundations Workshop, NHI/FHWA, December 2007 (5 days)
- Earthquake Induced Ground Motions, ASCE, September 2007 (2 days)
- Geotechnical Aspects of Pavement, NHI/FHWA, March 2007 (3 days)
- Value Analysis Workshop, January 2007 (5 days)
- Design of MSE Walls and Reinforced Soils Slopes, October 2006 (3 days)
- LRFD for Highway Bridge Substructure and Earth Retaining Structures, September 2006 (3 days)
- Bridge Seismic Design/Retrofit Workshop, MDT/FHWA, July 2006 (2 days)
- Rock Slopes, NHI/FHWA Design Course, September 2005 (3 days)
- Montana DOT Management Development Program, 2005 (1 year)
- Geosynthetics Engineering Course, NHI/FHWA, April 2005 & March 2004 (3 days)
- Subsurface Investigations Course, NHI/FHWA, March 2005 (3 days)
- Earth Retaining Structures Course, NHI/FHWA, September 2004 (3 days)
- Advances in Ground Improvement Seminars, Seattle ASCE Geotechnical Group, April 2004 (1 day)
- Rockfall Hazard Rating System Course, NHI/FHWA, March 2003 (1 day)
- Ground Improvement Techniques Seminar, NHI/FHWA, September 2002 (3 days)
- Drilled Shaft Inspector's Workshop, ADSC/MDT, August 2002 (3 days)
- Drilled Shaft Design Course, NHI/FHWA, July 2002 (3 days)
- Geotechnical Engineering Conference, University of Minnesota, 2000, 2001, 2002 (1 day)
- Special Inspection and Construction Testing, Technical Excellence Geotechnology, and Risk Management Training Conferences, Braun Intertec Corporation, 2002 (1 day)
- Seepage and Earth Dams, graduate course, University of Idaho Engineering Outreach, Spring 2001 (semester)

COMPUTER SKILLS

- Proficient in Driven, LPILE, GRLWEAP, SHAFT, ReSSA, MSEW, XSTABL, GSTABL, DMM, DigiPro, gINT, Microsoft Excel, Word and PowerPoint
- Developed many Excel spreadsheets to perform geotechnical analyses, design calculations, and to analyze laboratory and field test data

EXPERIENCE

FHWA - Western Federal Lands Highway Division Vancouver, Washington
Geotechnical Engineer April 2008 - present

- Manage geotechnical projects. Provide preliminary geotechnical recommendations for proposed projects. Design subsurface investigation plans and direct field investigations. Perform design calculations for transportation facilities. Conduct slope stability analyses. Prepare geotechnical reports and write supplemental specifications. Attend meetings to discuss and explain geotechnical recommendations. Review plans for constructability and geotechnical design. Provide consultation during construction for geotechnical related issues. Review consultant reports and plans.

Montana Department of Transportation Helena, Montana
District Geotechnical Manager-Geotechnical Section May 2006 – March 2008

- Manage all geotechnical research, analysis, and design activities within the Missoula District and also act as a statewide technical and scientific authority in the areas of geosynthetics, mechanically stabilized earth walls, reinforced soil slopes, and earthquake engineering. Responsible for planning and managing various projects within the District; coordinating with other District and Division managers to plan and administer statewide project priorities, resource allocations, and technical issues; and develop and implement new methods, technologies, and practices into statewide geotechnical operations and practices. Responsible for determining the geotechnical feasibility of proposed projects, supervising or performing geotechnical engineering and report writing, and evaluating compliance with project specifications and contract.

Montana Department of Transportation Helena, Montana
District Geotechnical Engineer-Geotechnical Section May 2002 – June 2003 & June 2004 – May 2006

- Manage geotechnical projects. Provide preliminary geotechnical recommendations for proposed projects. Design subsurface investigation plans and direct field investigations. Perform design calculations for transportation facilities. Review proposed pile driving systems. Conduct slope stability analyses. Prepare geotechnical reports and write supplemental specifications. Attend meetings to discuss and explain geotechnical recommendations. Review plans for constructability and geotechnical design. Provide consultation during construction for geotechnical related issues. Review consultant reports and plans. Write new Standard Specification for Geotextiles.

University of Washington Seattle, Washington
Graduate Research Assistant July 2003 – June 2004

- Research long-term performance of geotextile separators at WSDOT test section constructed in 1991. Coordinate field investigation and supervise excavation of test pits in roadway. Perform in situ testing. Test geotextile and soil samples from field in laboratory. Analyze and compile results of field and laboratory testing. Evaluate results and prepare technical report of findings.

Braun Intertec Corporation Fargo, North Dakota
Staff Engineer January 2000 – April 2002

- Prepare geotechnical evaluation reports and discuss results with clients. Perform geotechnical analysis and design calculations for all types of projects. Work with project engineers to assist in evaluating the suitability of construction materials and practices. Formulate proposals for construction materials testing services and geotechnical evaluations. Manage geotechnical evaluation and construction materials testing projects. Coordinate drill rig schedule. Train interns to perform field and laboratory tests.

Braun Intertec Corporation Fargo, North Dakota
Engineering Intern April 1999 – December 1999

- Perform field and laboratory testing of soils and testing of fresh and hardened concrete.

PUBLICATIONS

- Collins, B.M., and Holtz, R.D. (2005) “Long Term Performance of Geotextile Separators, Bucoda Test Site – Phase III”, Washington State Department of Transportation Research Report No. WA-RD 595.1.
- Collins, B.M., Mahoney, J.P., and Holtz, R.D. (2005) “FWD Analysis of Pavement Sections with Geotextile Separators”, *Proceedings of the Geo-Frontiers 2005 Conference*, Geotechnical Special Publication 130 (CD-ROM), ASCE.
- Collins, B.M. (2004) “Long Term Performance of Geotextile Separators, Bucoda Test Site – Phase III”, MSCE Thesis, University of Washington, Seattle, 194 pp.

Chris Conrad
Property & R/W Coordinator
Federal Highway Administration

Survey Training:

Defense Mapping School
FT Belvoir VA.
Jan 1986 – Aug 1986

Experience:

- Sept. 1986 – Jan. 1992

  Construction Surveyor
  Combat Engineer Platoon
  H&S CO 6th ENGR SPT BN
  USMC/USMCR

- Jan. 1989 – Aug. 1990

  Survey Technician
  Federal Highway Administration
  Western Federal Lands Highway Division
  610 East 5th St
  Vancouver, WA. 98662

- Sept. 1990 – Aug. 1992

  Survey Party Chief
  Federal Highway Administration
  Western Federal Lands Highway Division
  610 East 5th St
  Vancouver, WA. 98662

- Sept. 1992 – Sept. 1993

  Construction Inspector
  Federal Highway Administration
  Western Federal Lands Highway Division
  610 East 5th St
  Vancouver, WA. 98662

- Oct. 1993 – Jan 1998

  Survey Party Chief
  Federal Highway Administration
  Western Federal Lands Highway Division
  610 East 5th St
  Vancouver, WA. 98662

- Feb 1998 – Present

  Property & R/W Coordinator
  Federal Highway Administration
  Western Federal Lands Highway Division
  610 East 5th St
  Vancouver, WA. 98662

Personal Information:

Paul A. Escamilla

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Coffman Cove, AK 99918
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Work (907) 329-2070
paul.escamilla@fhwa.dot.gov

Work Experience

Highway Engineer, FHWA-Western Federal Lands Highway Division, GS-5 thru GS-12,
June 1996-Present, Supervisor: Steve Hinz 360-619-7532

I have spent the last 12 years administering construction contracts for the Federal Highway Administration. During this time, I have worked my way up form the inspector position to the Project Engineer position and worked on several projects in Washington, Idaho, Montana, and Alaska. I have spent the last ten years working in the capacity of the Project Engineer and was responsible for assuring project quality, facilitating field design changes, negotiating costs for construction changes, verifying and approving progress payments, monitoring and controlling contract growth, and training employees. During construction shut down periods, I worked in the design section developing plans, specification, and estimates for highway projects.

Co-op Student Program, FHWA-Western Federal Lands Highway Division, GS-4
June 1994-September 1994 and June 1995-September 1995, Supervisor: Dennis Quarto 360-619-7716

As a co-op, I worked as a construction inspector on several construction projects in Mt. Rainer National Park during the summers of 1994 and 1995.

Education

Oregon Institute of Technology, Klamath Falls, OR 97601, Graduated B.S.E. Civil Engineering Technology June 1996

Other Qualifications:

EIT June 1996 Oregon
PE November 2003 Alaska

Software Proficiency: MSWord, Excel, Microstation, GEOPAK

References:
Brent Coe, FHWA, WFLHD Construction Engineer 360-619-7744
Jane Traffalis, FHWA, WFLHD, Construction QA Engineer, 360-619-7819
Dick Bronder, FHWA, WFLHD, Program Coordinator 360-619-7782

Resume' of
Jeffrey D. Place

B.S. Forest Engineering, 1981, Oregon State University

E.I.T., 1981, State of Oregon
L.S.I.T., 1981, State of Oregon

1998 to Present Survey and Mapping Coordinator
Western Federal Lands Highway Division

Coordinate topographic, cultural, and property surveys and mapping necessary for roadway improvements on federally owned roads within the states of Oregon, Washington, Idaho, Montana, Wyoming, and Alaska.

1990 to 1998 Survey Operations Coordinator
Western Federal Lands Highway Division

Coordinate the operation of survey crews collecting topographic, cultural, and property survey data necessary for roadway improvements on federally owned roads within the states of Oregon, Washington, Idaho, Montana, Wyoming, and Alaska.

1986 to 1990 Highway Engineer
Western Federal Lands Highway Division

Various duties in relation to roadway improvements in the states of Oregon, Idaho, and Montana:

- Survey crew member
- Survey crew party chief
- Road construction quality control inspector
- Highway Designer

1985 to 1986 Transportation Technician
Washington State DOT

Survey and inspection for bridge construction on Interstate 90 near Seattle, Washington.

1981 to 1986 Survey Technician
US Forest Service

Seasonal work on survey crew collecting topographic data for roadway construction projects in the Gifford Pinchot National Forest.

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Evening phone- 360-887-7337
Michael.Traffalis@fhwa.dot.gov

Professional Registrations
California, 1991 (46883); Oregon, 1995 (17771); Idaho; Utah 2002 (5110048-2202);

Work Experience:

- ✓ Federal Highway Administration, Western Federal Land, Vancouver WA (current)
- ✓ Parsons Brinckerhoff Quade and Douglas Inc (previous)
- ✓ California Department of Transportation (previous)

Employer: **Federal Highway Administration, Western Federal Land, Vancouver WA**
Job title **Design Operations Manager/ Project Manager AK/WA**
Started – November 2003 - current
Supervisor- Ted Wood 360-619-7700

Accomplishments with Federal Highway Administration:

Project Manager AK/WA

As a project manager for WFL I am currently managing a diverse array of transportation Studies, Environmental Compliance Processes, Designs, and Design Support during Construction Contracts. I have managed projects across all spectrums of funding WFL currently administrates and have been instrumental in bringing one new funding source to WFL and finding ways to form partnerships leveraging additional funds from BIA funded programs. This diverse array of work experience and the ability to deliver and leverage funding opportunities has enhanced WFL positions as the provider of choice for my geographical coverage area.

Major Projects Managed:

Walden Point Road Project - I am serving as the project manger in coordination with FHWA partner agencies (Alaska DOT, Metlakatla Indian Community, BIA, and US Army and Air Force). The project is located on Annette Island, 15 miles southwest of Ketchikan, Alaska. The Walden Point Road was initially proposed by the Metlakatla Indian Community (MIC) in 1946. In 1954, the Alaska Road Commission recommended it for construction. In 1956, the US Department of Interior surveyed, approved, and recommended the Walden Point Road project to Washington DC for funding. However, rugged terrain, remote location, high construction costs and competition for limited road construction funds all presented significant barriers to building the road. On May 29, 1997, the Federal Highway Administration (FHWA), Department of Defense (DoD), Bureau of Indian Affairs (BIA), Alaska Department of Transportation and Public Facilities (ADOT&PF), and MIC signed a Memorandum of Agreement (MOA) detailing a plan to complete Walden Point Road. Contributions from contributing parties have totaled approximately $110 million from inception of the project through FY2008. Funding needed to complete the project through FY09 is estimated at $15 million.

Bradfield Canal Access/SE Mid Region Access Study - I am serving as the project manger in coordination with FHWA partner agencies (Alaska DOT, City of Wrangell AK, & Tongass National Forest). The project is located in southeast Alaska, beginning roughly 50 miles north of Ketchikan, Alaska, and running easterly for approximately 77 miles along the Bradfield and Craig river valleys in both the United States and Canada. The proposed project is to build a land route from Southeast Alaska to the Canadian road system. I lead efforts to develop a Project Delivery Plan working with US and International Partners to develop a process for an International EIS-US/EA-Canadian environmental process.

Forest Highway Projects

Mission Ridge Road, Grisdale Road, Middle Fork Snoqualmie River Road, Flowery Trail, Coffman Cove Road, Kake to Seal Pt Road

Denali Commission Program

Walden Pt, Kobuk Bridge Replacement, Steven Village Access Study, Kivalina Evacuation Road Study, King Cove City Streets,

Earmark Project:

King Cove City Street Project, Juneau Heliport, Yakataga River Bridge Replacement, Walden Point Road, SE Mid Region Access, Hoonah City Paving,

National Park Projects

Mt Rainier National Park SR 123/410 Reconstruction

Design Operations Engineer AK/WA Team, Western Federal Lands Highway Division- I served to two years as the AK/WA design team supervisor. In that capacity, I manage and supervise a staff of six designers and two environmental specialists. Our team, under my leadership is responsible for delivery of the Forest Highway Road Program, and High Priority Projects Program for AK/WA; while also delivering National Parks Road Program on projects in Mt. Rainer, North Cascades, and Glacier National Parks.

Employer: **Parsons Brinckerhoff Quade and Douglas Inc,**
Job title **Project Manager**
Started - winter 1995 – November 2003
Supervisor- Connie Kratovil 503-274-8772

Accomplishments with Parsons Brinckerhoff:

• Engineering Manager Portland Oregon Office- I served as engineering manager for the PBQD Oregon office. These duties included developing and managing billability goal assessment, setting, tracking, and corrective action plans. Each person had assigned goals/expectation these goals factored training, marketing, functional duties, vacation & sick leave, forecasted project hours. These goals were discussed in-depth with each employee as the office business health was principally governed by this gage. This plan was monitored throughout the year as an engineering discipline, but also will all aspects of serves the Oregon office provided. Adjustments were made individual work plans adjusted to reflect how the office was performing, this could result in extra training or conference when goals exceeded expectation or reflect the urgency to increase billability to increase the overall office projections. Additionally my duties were to perform mid year performance evaluations, year end evaluation, disciplinary actions, furloughing, terminations, bonus assessment, and company stock options offerings.

▪ City of Vancouver Washington, 18th street Environmental Assessment Project. I served as engineering lead for this 5-mile road improvement project. The project construction cost is estimated at 60 million, and will transform an existing unimproved two-lane city street into a five lane principal arterial serving as a major east west street within the City of Vancouver Washington. The road design in being done is support of an environmental assessment conducted under the NEPA guidelines. The design has gone through an extensive public involvement reaching out to over 10 different neighborhood associations, holding 3 different forums of public open houses. These extensive attempts to out reach to the public for input is in an effort to blend transportation needs with community goals. Survey, geotechnical, civil, drainage, bridge, right of way, visual simulation, pedestrian access, and corridor trail development are all activates being performed under my direction.

• Idaho Department of Transportation, Hansen Bridge Rehabilitation over the Snake River in Twin Falls Idaho. I am served as project manager and lead designer for the rehabilitation of Hansen Bridge over the Snake River. The work involves a biological assessment, a letter of no effect to FHWA and other resource agencies, roadway grade increase and overlay, upgrade of substandard highway guard rails, replacement of substandard bridge rails, bridge deck repair, expansion joint replacement, and repair of the twin 300 foot tall bridge piers.

• State Route (SR) 500 At-Grade Intersection Removal, Washington: I served as project manager for the preparation of an environmental assessment (EA) of the removal of three at-grade intersections at St. Johns, 42nd, and 54th Streets with SR 500, all of which have been identified as high accident sites. My responsibilities included overseeing the public involvement process; performing environmental resource studies; preparing National Environmental Policy Act (NEPA) documentation; and performing traffic studies, including forecasts and simulations. I was also technical lead for civil, geotechnical, surveying, bridge and drainage engineering activities. The work is being performed in coordination with the City of Vancouver, Clark County, and Regional Transportation Commission (RTC). The project has gone through an extensive documentation process in order to meet the needs of local agencies, satisfy project goals, incorporate public input and concerns, search out and incorporate input from project stakeholders, and coordinate and implement the use of an early value engineering assessment. Construction cost is anticipated to be over 50 million when all phases are completed.

• SR 35 Columbia Gorge Moveable Bridge Modifications/Replacement Project, Washington: I am served as engineering manager for an environmental impact study to replace the existing Hood River Bridge Oregon/Washington. I am directing civil, structural, and tunnel engineers on alternative development to support the study. This project was conducted in a three-tier process. The first tier developed and narrowed the range of alternatives, the second tier entered into an evaluation based on more defined engineering parameters, and the third tier performed a preliminary type, size, and location study for the preferred alternative. A number of the strategies considered include bored and immersed tunnels, low-level movable bridges, and high-level fixed bridges, and retrofitting the existing 19-foot wide moveable bridge to a fixed span pedestrian bridge. Construction costs are estimate at 160 million for this highway improvement project.

• California Department of Transportation, Sacramento California: I managed PB's design efforts for eight seismic retrofit projects in San Bernardino. The bridges were generally comprised of steel plate girders with cast-in-place decks, founded on reinforced concrete columns with driven pile footings. Seismic analyses were performed, including both linear elastic spectral analyses and non-linear push over analyses. Design forces ranged from 0.3 to 0.9 g. The overall design measures were being implemented to ensure non-collapse of the structure. Retrofit corrective measures were determined and presented to a seismic strategy panel with associated cost breakdowns for design and construction and PS&E were prepared for the approved retrofit schemes.

• FHWA Federal Lands, Various U.S. Locations: I served as project manager for on-call highway and bridge design services with the FHWA staff in both Denver, Colorado and Vancouver, Washington, preparing task orders to perform highway road and structural-related activities. A few of my completed task orders are:
* Harlequin Bridge Replacement: I was project design engineer for the design and completion of a 165-foot (50-meter) weathering steel truss. PB was originally tasked to perform an in-depth inspection on the existing 1940s timber truss of this one-lane Warren truss in North Cascades National Park, but after a failed top chord member was discovered, as well as several other deficiencies, the bridge required replacement.
* Beaver Creek Bridge Repair: The Beaver Creek Bridge project is located in the Mendocino National Forest. A repair project in 1978 replaced the bridge's bearing system with a sliding system that enabled earth movement at the south abutment to occur without damaging Beaver Creek Bridge. The 1978 repairs are currently at the end of

their functional life. Under my direction, PB performed an initial site visit and prepared a site reconnaissance report outlining new repair measures; construction costs, engineering costs, and construction duration. The follow-up phases will be preparing PS&E package for the recommended repairs.
* Gibbon River Type Selection Study for Yellowstone National Park: I led PB's efforts to develop aesthetics design report for Yellowstone National Park. The task entailed walking the site with park personnel to understand the bridge's purpose and needs as well as its natural surroundings. Based on this understanding, my team and I developed a historical perspective of park bridges, assessed the surrounding topography, and developed a range of alternatives. Afterwards, PB held a workshop to develop screening criteria and narrow the field of suitable bridge alternatives. Ultimately, PB developed a decision document for the park to use, documenting the process PB went through to understand, analyze, and determine a preferred bridge option.
* Beryl Springs Bridge Rehabilitation, Yellowstone National Park: I served as project manager for the evaluation and rehabilitation of this historic timber bridge in Yellowstone National Park. PB sent a team to the field to map the deterioration of the timber bridge and to develop repair schemes. The timber bridge crosses a sulfur spring, which has corroded the bridge timbers. PB developed a repair that utilizes high density concrete combined with stainless steel rebar as timber cladding to replace the substructure elements while restoring the visual appearance of the existing bridge.
* Jordon Road Improvement, Jefferson county Oregon. I served as project manager for PB to prepare a concept repair recommendation and developed a work plan for implementation of repairs to two suspension bridges that carry Jordan Road over the Deschutes and Crooked River arms of Lake Billy Chinook in Oregon. Under my direction, PB performed a field investigation and an assessment as to why the bridges were sagging. Under my direction, PB performed the project checklist, biological assessment and public involvement for the roadway and bridge improvements. Environmental tasks consisted of development of a project checklist to determine the level of documentation needed to meet National Environmental Policy Act (NEPA) requirements. The checklist states the purpose and need of the project, addresses the alternative selection process, discusses the affected environmental impacts, and ties the planning and engineering aspects of the project together for the coordinating agencies and jurisdictions. Other environmental tasks included a biological assessment of the impacted species in the area and hosting open houses that allowed the public to become a part of the decision-making process. Two open houses were held locally to provide the public with an opportunity to give input regarding the project's scope, impacts, and need. Roadway design using Geo-Pak software provided widened approach roadways to mitigate the existing tight curved approaches.

• Mill Plain Extension Project, City of Vancouver, Washington: I served as bridge design task leader for a 634-foot (193-meter) continuous precast girder bridge. The plan was prepared in accordance with WSDOT procedures and guidelines. The structure will be founded on drilled shaft foundation and pass over 15 sets of Burlington Northern tracks. Reinforced earth walls contain the approach fills.

Employer: California Department of Transportation,
Job title Senior Bridge Engineer
Started - fall 1988
Ended- Winter 1995
Supervisor- Raymond Zelinski, Retired Caltrans Supervising Engineer, home 916-961-4222

Accomplishments with Caltrans:

• Interstate 280 Retrofit and Reconstruction, San Francisco, California, I served as the design/construction liaison for a $200 million double-deck viaduct retrofit project. I coordinated the designers, specifications writers, and CADD technicians to produce revised plans and specifications for field use. I reviewed consultants' PS&E submittals, guided consultants on Caltrans policies and procedures, developed criteria and guidelines for bridge shoring systems, reviewed contractor value engineering proposals, coordinated shop plan approvals, and designed plans for contract change orders.

• Northridge Earthquake Emergency Repair, Los Angeles, California: I served, as design/construction seismic staff specialist was responsible for preparation of PS&E for 14 Northridge earthquake emergency repair contracts. Site assessments were conducted with FHWA staff, damage assessment reports were completed and final PS&E were prepared in an effort to reopen many of the closed freeways as a result of the Northridge earthquake.

• Van Duzen River Bridge, Bridgeville, California: I served as project engineer involved in redesign of a post-tensioned box girder bridge with 30-degree inclined columns. This bridge replacement project facilitated improved sight distance along Highway 36 from U.S. 101 along the Van Duzen River to I-5. During initial construction phases, shaft installation and removal of material activated a historic landslide. Slope inclinometers were installed and preliminary measurements showed the slope moving 2 inches (0.05 meters) over a 6-week period. I coordinated the design of a whaler tie-back system to permanently secure the slope and was the task leader for redesigning the bridge structure to permit the abutment to move 1 foot (0.3 meters) longitudinally and 6 inches (0.15 meters) transversely (future anticipated movements of the slope) in addition to accommodating Caltrans' 0.7 g seismic design force. Because stream and surrounding sensitive areas dictated construction operations to have minimal impacts, extensive grading and erosion controls had to be taken.

• Century Freeway, Los Angeles, California: as assistant bridge engineer, I was responsible for monitoring contractor's activities during cut-and-fill tunnel construction. I analyzed contractor's falsework designs. I performed bridge alignment surveys, prepared contract change orders, prepared monthly estimates, and monitored activities from initial to final stages including construction of driven pile foundation, drilled shaft foundation, spread footing foundation, reinforced concrete pinned and fixed columns, and concrete superstructure.

Education - College

* University of Colorado at Boulder
Regent Administrative Center 125
552 UCB
Boulder Colorado 80309-0552
303-492-6301
M.S., Civil Engineering 1988

* San Diego State University
5500 Campanile Drive
San Diego California 92182-7455
619-594-6336
B.S., Civil Engineering, 1987

Research/Committee Activities

• Assistant Chairman, Caltrans Approach Slab Committee: served as assistant chair for the Approach Slab Committee. My duties included reviewing approach slab replacement projects, monitoring ongoing temperature effects research, developing new standards to prevent erosion problems, and converting Caltrans standard drawings to metric.
• Contract Monitor, University of California at Irvine Pier Wall and Pin Bottom Column Seismic Research: as part of this Caltrans-sponsored research, I provided oversight functions, consulting with university officials on details, design standards, and current retrofit practices for pier walls. For the pinned bottom column, I assisted the university staff with pin moment and shear capacities before and after plastic rotation had occurred.
• Instructor for the Caltrans Bridge Design Practice Course, Seismic Design Portion: a requirement within the structures group of Caltrans is to have all new employees take the bridge design practice course. This process allows first-time designers to go through entire designs by hand and verify against computer models. As part of this course, I taught the section on seismic retrofit design.
• Seismic Bridge Design Course, University of California at Berkeley: participated in a bridge design course, aiding students with their seismic retrofit projects and serving as instructor's assistant for problem-solving sessions.

Awards/Publication/Certification

• Leadership Development Academy Coach, WFL 2007
Loma Pieta Earthquake Structural Response Team, California Department of Transportation
• Northridge Earthquake Structural Response Team, California Department of Transportation
• Parsons Brinckerhoff, Certified Project Manger

• National Steel Bridge Alliance, Merit Award Winner for the Harlequin Bridge Design, North Cascades National Park, 2002
• Gibbon River Bridge Type Selection, Yellowstone National Park, 2001

References

* Peter Siegenthaler San Francisco Bay Bridge Resident Engineer, California Department of Transportation, work 510-622-5112, home 707-545-9216
* Raymond Zelinski, Retired Caltrans Engineer, home 916-961-4222
* Mike McKinnon, Denali Commission Transportation Director, work-(907) 523-9877
*Andy Hughes, Planning Chief SE Alaska DOT, work 907-465-1776
*Luis Santoyo, Operations Staff Officer, Olympic & Mt Baker National Forest
Work (360) 956-2260

William H. Welton

Education:

Valley High School, Masontown, WV College Prep	HS Diploma	1974
West Virginia University, Morgantown, WV Forest Engineering Fishery Biology Surveying	BS	1979

Work experience:

FHWA
4/02 to present
Projects:

Thorne Bay - NPOW Paving	$ 10,000,000.00
Coffman Cove Road, Phase 1	$ 13,000,000.00
Coffman Cove Road, Phase 2	$ 17,455,000.00
Coffman Cove Road, Phase 4	$ 10,391,000.00
Yakataga Bridge	$ 1,900,000.00
Howling Dog Creek Culvert	$ 793,757.00
Denali Park Road, 4 mi slump	$ 2,772,000.00
Katmai NPS 10,000 Smokes Rd	$ 4,376,000.00

Position: Project Engineer, Assistant Project Engineer, Project Manager
Duties: Administrate FHWA projects, oversee contract employees

South Coast Inc.
10/99 to 4/02
Position: Division Manager
Project: Big Salt Lake Road, FHWA $ 15,000,000.00
Duties: Oversee major Federal Highways project and other projects on Prince of Wales Island

South Coast Inc.
1/99 to 10/99
Position: Division Manager
Projects: Pilot Point Airport; Larsen Bay Harbor
Duties: Oversee all projects in Western Alaska

South Coast Inc.
1993 to 1998
Position: Project Manager
Projects: Chenega Airport; Craig Housing Project; Saxman Housing Project; Metlakatla Housing Project; Wrangell Airport Reconstruction; Klawock Force Main; FHWA Ward Lake Road; Haines Highway; Craig Sewer and Water
Duties: Oversee various projects for Federal Highways; State of Alaska; City; and Regional Housing Authorities.

South Coast Inc.
10/92 to 11/92
Position: Superintendent
Project: Exit Glacier Road Project, FHWA
Duties: Schedule and direct construction activities, deal with FHWA personnel in matters concerning constructions, change orders, traffic control and erosion / pollution control.

South Coast Inc.
9/91 to 10/92
Position: Superintendent
Project: Nome-Council, Mile 32-42, Alaska DOT&PF
Duties: Schedule and direct construction activities. Deal with Alaska State DOT

personnel in all phases of the construction of 10 miles of road. Direct traffic control and erosion / pollution control on the project which ran adjacent to the enviromentally sensitive Solomon River and tributaries.

South Coast Inc.
11/90 to 7/91
Position: Project Engineer
Project: Sandy Beach Road, USFS
Duties: Set all grade stakes and horizontal control. In charge of traffic and erosion / pollution control. Constructed brush barriers, silt fence, sediment ponds, etc.

South Coast Inc.
3/90 to 11/90
Position: Superintendent
Project: Klawock River Bridge, Alaska DOT&PF
Duties: Schedule and direct construction activities during construction of a 320 foot bridge over the Klawock River. The Klawock River is a major salmon hatchery for SE Alaska. Extensive sediment control during the drilling / pile driving activities was required since no sediment was permitted to enter the river.

South Coast Inc.
11/89 to 3/90
Position: Project Engineer
Project: North Prince of Wales Phase 1, FHWA
Duties: Set horizontal and verticle control for 3.5 miles of road on Prince of Wales Island. Also in charge of traffic and erosion / pollution control.

South Coast Inc.
11/86 to 11/89
Position: Project Engineer
Project: Control Lake Phases 1,2 and 3; FHWA
Duties: Set horizontal and vertical control for 18 miles of road on Prince of Wales. Also in charge of traffic and erosion / pollution control. Field directed the following activities: hay bales, silt fence, sediment ponds, rock buttresses, underground (French) drains, brush barriers and more.

State of Alaska Department of Transportation
4/86 to 11/86
Position: Road Inspector
Project: Hollis Highway, Alaska DOT&PF
Supervisor: Tracy Moore
Duties: Inspect construction activities on 11 mile road project. Check grade, specifications and traffic control. Inspect culverts and various erosion / pollution control activities.

South Coast Inc.
4/84 to 4/86
Position: Labor Foreman
Project: USFS Administration Compound, US Forest Service
Duties: Do construction survey and direct site work, underground utilities and building construction for an $11,000,000.00 housing project.

Greg Scheff & Associates
3/83 to 4/84
Position: Survey Party Chief
Duties: Do various road staking, mining claims and other survey work.

Owens Drilling
2/82 to 12/82
Position: Construction Surveyor
Duties: Do horizontal and verticle control for various road and airport projects.

U.S. Forest Service
7/79 to 2/82
Position: Road Inspector / Road Locator
Duties: Ran survey crews, locate / design / inspect Forest Service roads.