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Geologic Report for Appraisal Assessment – Wymer Dam and Reservoir

A component of
Yakima River Basin Water Storage Feasibility Study, Washington
Technical Series No. TS-YSS-20

Pacific Northwest Region

U.S. Department of the Interior
Bureau of Reclamation
Pacific Northwest Region

January 2008

Cover Photograph – View looking west from the upper left abutment of the proposed Wymer dam towards the Yakima River. Wymer Damsite, Yakima River Basin Water Storage Feasibility Study, Washington – Bureau of Reclamation photograph by D. Stelma, April 11, 2007.

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prepared by

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Bureau of Reclamation
Pacific Northwest Region
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Boise, Idaho

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Mission Statements

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian Tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Preface

Section 214 of the Act of February 20, 2003, P.L. 108-7, authorized the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) to conduct a feasibility study of options for additional water storage in the Yakima River Basin, Washington, with emphasis on the feasibility of storing Columbia River water in the potential off-stream Black Rock reservoir. In 2004 Reclamation completed their appraisal assessment of likely configurations, sizes, and costs of Black Rock Project facilities needed to pump, store, and deliver water to willing exchange participants in the Yakima Basin. In 2006, Reclamation prepared an appraisal assessment of three other alternatives: the Bumping Lake enlargement; Wymer dam and reservoir; and Keechelus-to-Kachess pipeline. Conclusions reached in these two appraisal assessments were that the Black Rock and Wymer alternatives should be included in the plan formulation phase of the Storage Study. Reclamation's Upper Columbia Area Office in Yakima, Washington, is managing and directing the Storage Study.

This technical document, prepared by Reclamation's Pacific Northwest (PN) Regional Geology, Exploration & Instrumentation Group, Boise, Idaho, is a component of the assessment reporting on preliminary geologic investigations conducted at the Wymer dam and reservoir site in 2007.

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33-100-5869	Wymer Dam and Reservoir – Geologic Plan Map, Locations of Explorations and Geologic Sections, General Geologic Legend, Explanation and Notes (2007)
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Summary and Conclusions

Geologic investigations were performed in 2007 to assist engineers in preparing appraisal-level designs and cost estimates for the proposed Wymer dam and reservoir sites. The sites were initially investigated by Reclamation in 1984 and 1985 as part of the Yakima River Basin Water Enhancement Project. The earlier investigations focused on an upper damsite, as well as the lower damsite and saddle dike, which are addressed in this report.

The 2007 investigation included drilling exploratory drilling at the lower dam and saddle dike sites, and at the proposed pumping plant site near the Yakima River. The investigations were conducted to determine the depth to bedrock, obtain core samples of the bedrock, perform constant-head hydraulic conductivity tests, compile geologic maps, and complete a reconnaissance survey for borrow materials.

Exploratory holes drilled on upper left abutments at the dam and saddle dike sites indicated shallow bedrock depths with variable rock quality and permeability characteristics for each of the three bedrock units encountered.

The bedrock units at the site are part of the Columbia River Basalt Group, consisting of (from youngest to oldest) the Frenchman Spring Basalt (Tfs) of the Wanapum Formation, the Vantage Sandstone (Tv) of the Ellensburg Formation, and the Grande Ronde Basalt (Tgr) of the Grande Ronde Formation. The Frenchman Springs Basalt (Tfs), the uppermost unit, is of generally poor quality and has high hydraulic conductivity. This material would likely require extensive foundation treatment (grouting). The underlying bedrock, the Vantage Sandstone (Tv) and Grande Ronde Basalt (Tgr), are more competent and have generally low to moderate hydraulic conductivity.

Several potential landslide areas have been identified. One landslide area is located downstream of the left abutment at the damsite and three small slides are located upstream from the damsite in the reservoir basin. A third landslide area is larger and is located in Scorpion Coulee. Although a thorough field reconnaissance and geologic evaluation of potential landslides have not been conducted, a cursory visual assessment made during the current study indicates that the landslides are not clearly defined and there is no indication of recent movement of these slides.

The pumping plant foundation is composed of Yakima River alluvial (Qal) deposits overlying Grande Ronde Basalt (Tgr). The alluvium is primarily fine- to coarse-grained gravel with cobbles, and occasional beds and lenses of silty sand. The underlying basalt is dense, hard, and intensely to moderately fractured. The alluvium is expected to have high permeability due to the abundance of coarse-grained material. Dewatering may be necessary in the alluvium to provide stable slopes during excavation. The alluvium and basaltic bedrock should provide adequate foundations for the pumping plant structure.

Construction materials needed for the dam, saddle dike, and associated features include impervious fill, rockfill, processed material for filter and drain elements, cement, and concrete aggregate and sand. These can likely be obtained from both developed and undeveloped land within approximately 17 miles of the site. It is common practice to obtain material from the reservoir basin during construction of large embankment dams. The Lmuma Creek valley, Scorpion Coulee, and uplands northeast of the reservoir basin are potential sources for earthfill for the embankment. In order to meet gradation requirements for filter, drain, and concrete aggregate, washing and screening of raw material will be necessary. The nearest potential sources of relatively clean material include Yakima River alluvial deposits from commercial sites in either Yakima or Ellensburg, Washington.

Introduction

The Yakima River Basin Water Enhancement study conducted in the 1980's identified Wymer dam and reservoir as a potential off-stream storage site within the Yakima River Basin. In 2004, Reclamation completed an appraisal assessment of the Black Rock Project facilities as an option to provide water to the Yakima Basin. In 2006, Reclamation prepared an additional assessment of several other storage alternatives, including the Wymer dam and reservoir. The 2006 assessment report concluded the Black Rock and Wymer Alternatives should advance to the next level of the storage study. The purpose of the reservoirs is to store water that could be made available for irrigation, instream flow enhancement, and municipal purposes in the Yakima River Basin during dry years. The present plan for the Wymer dam and reservoir site entails pumping excess water from the Yakima River and storing the water in the off-stream reservoir (Lmuma Creek valley). Field investigations were conducted at the proposed dam, saddle dike, and pumping plant sites from April to June 2007 to obtain geologic and hydrogeologic information for use in preparation of the report entitled, *Yakima River Basin Storage Study, Wymer Dam and Reservoir Appraisal Report, A component of Yakima River Basin Water Storage Study, Washington, Technical Series No. TS-YSS-16* (Bureau of Reclamation, 2007). These investigations were performed by staff of Reclamation's Pacific Northwest (PN) Regional Geology, Exploration & Instrumentation Group, Boise, Idaho.

Purpose

This report summarizes the findings of the exploratory drilling program conducted at the Wymer dam and reservoir site. Data collected were used to assess the suitability of the foundations for the proposed embankments and pumping plant. The field program involved core drilling and conducting constant-head hydraulic conductivity tests at the dam and saddle dike sites, and sampling and core drilling at the pumping plant site. In addition to the drilling program, a reconnaissance-level borrow material investigation was conducted.

Location

The project area is located adjacent to highway 821 approximately 24 miles north of Yakima, Washington. The legal description is Sections 3 and 4, T.15 N., R. 19 E., and Section 33 and 34, T. 16 N., R. 19 E. Refer to Figure 1 for general location.

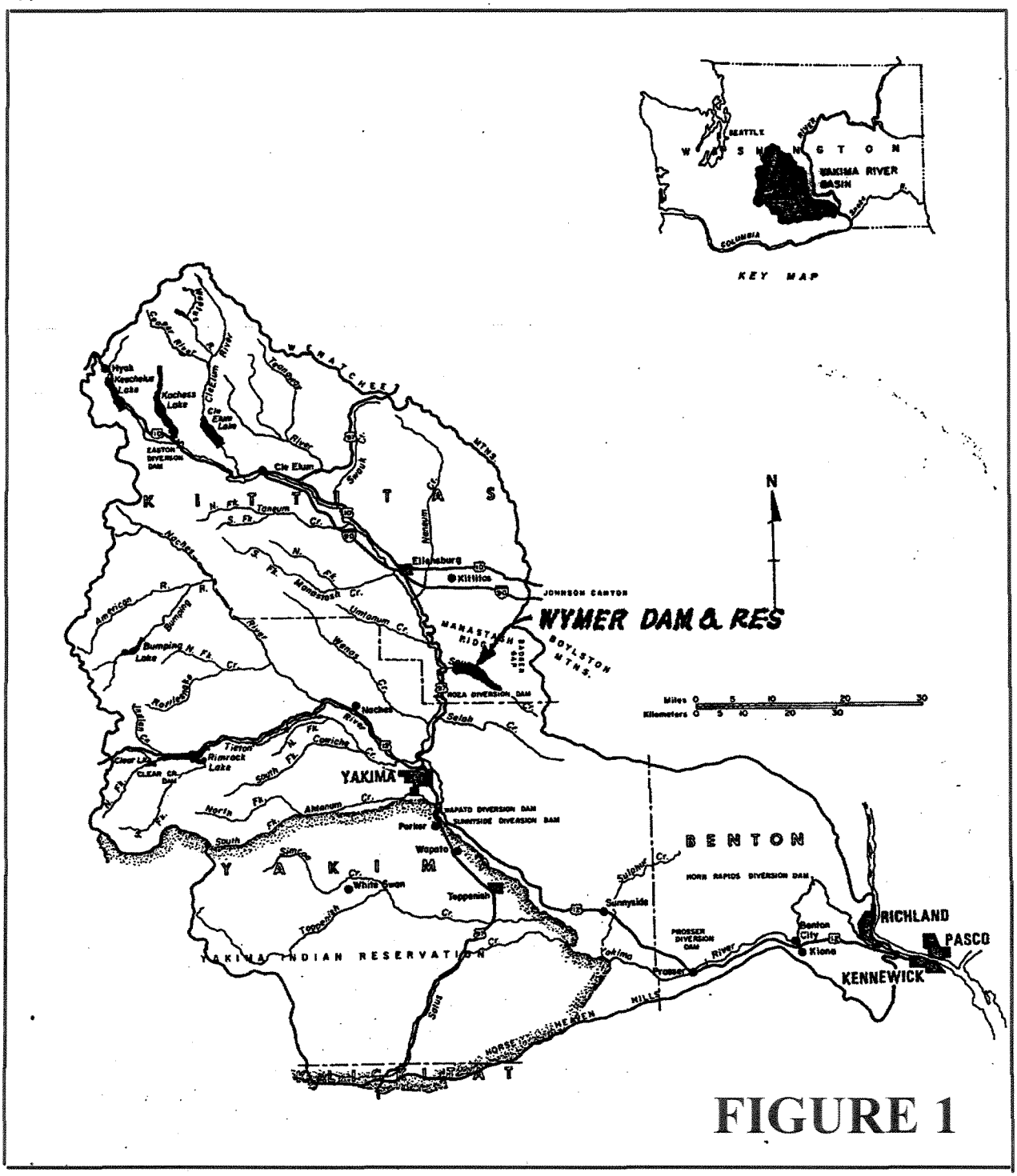


Figure 1 - General Location Map of Study Area

Previous Investigations

Geologic investigations of the Lmuma Creek area were undertaken in 1984 at a proposed Wymer damsite (upper site), located about three-quarters of a mile upstream of the currently proposed damsite (lower site). Investigations at the upper site consisted of geologic mapping, drilling, and identifying potential borrow sources. Drilling consisted of one core hole on each abutment, drill hole DH-84-1 on the right abutment and drill hole DH-84-2 on the left abutment. The holes were drilled to a depth of 174.7 feet and 290.4 feet, respectively. Pressure percolation tests and falling-head tests were conducted in each of the drill holes. Details of these investigations are presented in the report entitled, *Geologic Report, Wymer Damsite, Yakima River Basin Water Enhancement Project, Washington* (Bureau of Reclamation, 1984)

The lower damsite was investigated in 1985 primarily to determine the depth to bedrock along the proposed dam axis, and to define the characteristics of the bedrock and the overburden materials. The drilling program consisted of three drill holes, DH-85-1 through DH-85-3, located in the valley bottom near the dam axis; one drill hole, DH-85-4, located at the proposed saddle dike site; and four shallow, "hand dug" test pits, TP-85-1 through TP-85-4, located on the dam abutments. During this time period no drilling was done at the pumping plant site because of "right-of-way issues." Some additional geologic mapping was accomplished at the dam and dike site areas. The three drill holes in the valley bottom were fairly shallow, with depths ranging from 23.8 to 50.5 feet. Details of these investigations are documented in the report entitled, *Addendum No. 1 Geologic Report, Wymer Damsite, Yakima River Basin Water Enhancement Project, Washington* (Bureau of Reclamation, 1988).

Geologic logs (summary logs) for the 1984 and 1985 explorations are included in Appendix A.

Current Investigation

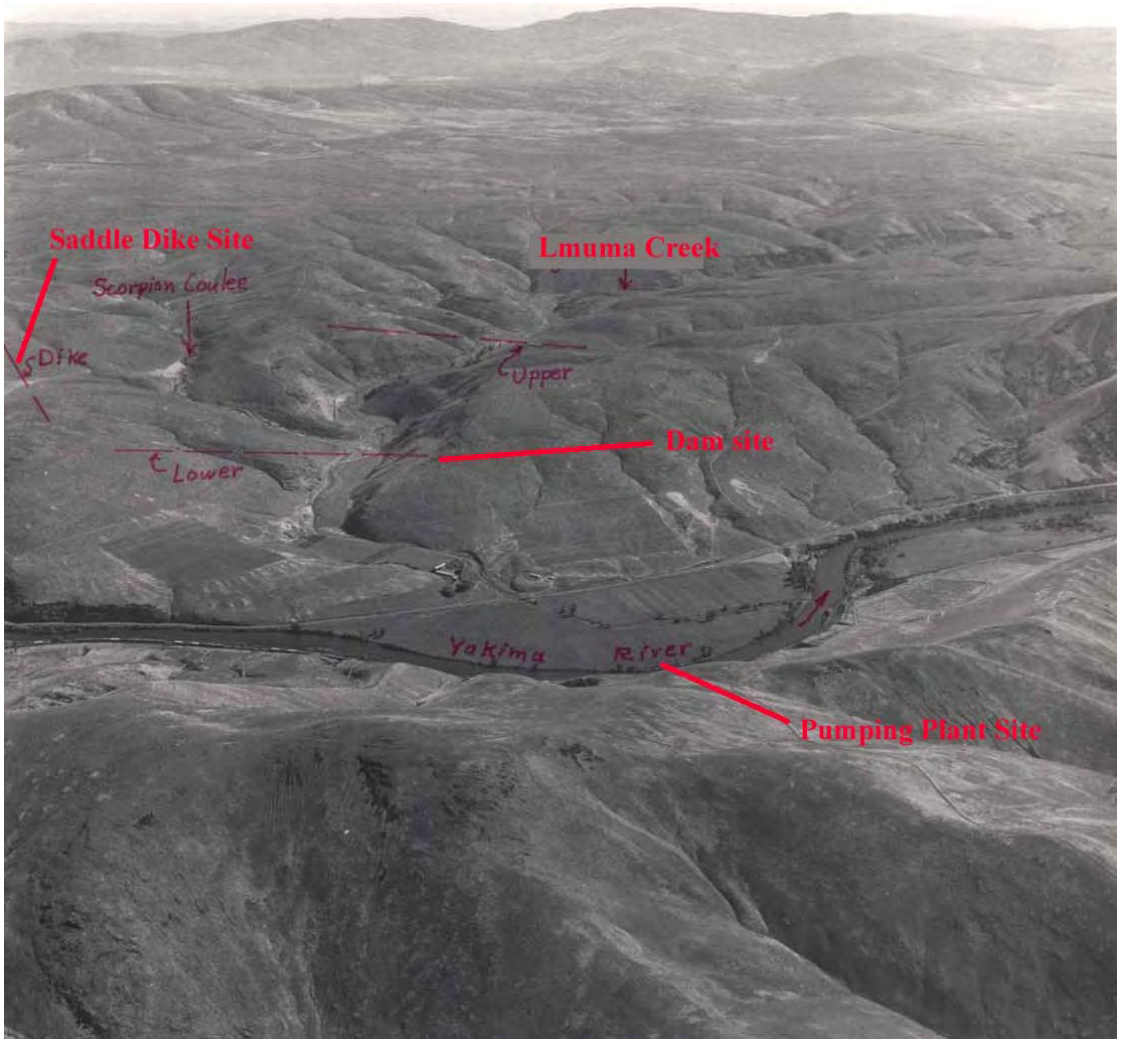
The current investigations included development of an updated topographic base map, drilling exploratory holes at the dam, saddle dike, and pumping plant sites (refer to Photograph No. 1), performing constant-head hydraulic conductivity tests, conducting geologic mapping, and completing a reconnaissance-level borrow investigation.

Topographic Base Map

The topographic base map was generated from the existing U.S.G.S. 10-meter Nation Elevation Data (NED) set. The topography is shown at a scale of 1 inch equals 500 feet and a contour interval of 10 feet. Drill holes were field located by Reclamation's Ephrata Field Office (EFO) survey crew members using global positioning system (GPS) methods. Horizontal control is Washington State Plane Coordinate System South NAD 83 and vertical control is NAVD 29.

Exploratory Drilling and Geologic Mapping

Geologic investigations conducted from April to June 2007 included drilling three core holes; one at the proposed pumping plant site on the east bank of the Yakima River near the mouth of Lmuma Creek; one on the upper left abutment of the dam site; and another on the upper left abutment at the dike site (refer to Drawing 33-100-5869, located in Appendix B). An updated geologic map was produced from a combination of field mapping and a compilation of published geologic maps. Core drilling and testing were performed to determine the engineering characteristics of the overburden and bedrock, and to obtain hydraulic conductivity values for the bedrock units. Drilling was conducted using a 4-inch-diameter casing advancer in the unconsolidated materials and diamond core drilling in the bedrock. Clear water was the primary drilling fluid utilized except in one zone where an additive (diamond seal polymer) was used in an attempt to establish circulation. Down-hole, multi-pressure permeability tests were conducted in drill holes at the dam and saddle dike sites. Geologic logs and core photographs for the 2007 explorations are included in Appendix A.



Photograph No. 1. Oblique aerial view looking eastward at the Lmuma Creek drainage basin and the proposed Wymer dam, saddle dike, and pumping plant sites. Yakima River Basin Water Storage Feasibility Study, Washington – Bureau of Reclamation photograph circa 1984.

Regional Geology

The proposed Wymer dam and reservoir sites are located in the northwest-central portion of the Columbia Basin, a structural and depositional basin that forms much of eastern Washington. The basin is the site of large basaltic flood lava known as the Columbia River Basalt Province. The basalts are derived from volcanic eruptions that occurred between 18 and 6 million years ago from vents near the present boundary between Washington, Oregon, and Idaho. Individual flows were up to 100 feet thick and covered hundreds to thousands of square miles. Extended time periods between eruptions allowed for sediment deposition in interflow zones. Basaltic eruptions over millions of years resulted in a stack of relatively horizontal flows that are referred to as the Miocene-age Columbia River Basalt Group. Locally relatively thin surface deposits of Pleistocene to recent

sediments mantle the bedrock surfaces and along side and main drainages of Lmuma Creek and the Yakima River.

Structure

The western portion of the Columbia Plateau underwent north-south directed compression resulting in faulting and generally east-west trending folds. This zone of deformation is referred to as the Yakima Fold Belt. The anticlinal ridges of the Yakima Fold Belt between Ellensburg and Yakima, Washington are cut through by the south-flowing Yakima River. Lmuma Creek is within a synclinal trough between the Manastash Ridge anticline to the northeast and the Umtanum Ridge anticline to the southwest. Based on basaltic flow and sedimentary interbed elevations from drill hole data, the bedrock in the study area strikes approximately N70°W and dip approximately 2° to 3° southwest (refer to Drawing 33-100-5870, Geologic Sections A-A' and B-B', located in Appendix B).

Seismicity

The seismic hazard assessment presented in the following section is based on the probabilistic seismic hazard assessment (PSHA) that was conducted for the Black Rock Dam and discussed in the Wymer dam and reservoir appraisal report entitled, *Yakima River Basin Storage Study, Wymer Dam and Reservoir Appraisal Report, A component of Yakima River Basin Water Storage Study, Washington, Technical Series No. TS-YSS-16* (Bureau of Reclamation, 2007). The Black Rock dam PSHA is based on limited data from existing studies and preliminary evaluation of that data and may overstate the seismic hazard at the proposed Wymer damsite. Reclamation typically designs its power and pumping facilities for earthquakes having a return period of 2,500 years, and dams for earthquakes having a return period of 10,000 years. For the Wymer area, an earthquake having a return period of 2,500 years has an estimated total Peak Horizontal Acceleration (PHA) of about 0.50g, and at a return period of 10,000 years, the total PHA is about 0.95g.

Site Geology

The geology and stratigraphy described here is based on exploratory drilling performed at the pumping plant and damsites, and from interpretations of foundation geology presented in the reports documenting the 1984 and 1985 geologic investigations for Wymer damsite (Bureau of Reclamation, 1984 and 1988). Also referenced is *Open File Report 94-12, Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington* (Schuster, 1994)

The surface geologic materials include fill (F), river and stream alluvium (Qal), slopewash (Qsw), loess (Ql), and landslide (Qls) deposits. The bedrock units are part of the Columbia River Basalt Group, consisting of the Wanapum Basalt Formation, which include the Roza (Trz) and Frenchman Springs (Tfs) Basalt Members, and the Grande Ronde Basalt Formation (Tgr). The period between eruption of the Wanapum and Grande Ronde basaltic flows allowed for the deposition of sediments. The sediments are known as the Ellensburg Formation and include the Vantage Sandstone Sedimentary Interbed (Tv). The main geologic units are shown on the generalized stratigraphic section (refer to Figure 2) and are described in the flowing sections from youngest (recent) to oldest. For locations of these materials and the geologic explanation, refer to Drawings 33-100-5869 and -5870, located in Appendix B.

The nomenclature of the Columbia River Basalt Group currently used is slightly different than the nomenclature used in 1984 and 1988 geologic reports (Bureau of Reclamation, 1984 and 1988). The Columbia River Basalt Group was referred to as the "Yakima basalts." The Yakima basalt was divided into "post-Vantage" and "pre-Vantage," based on position above or below the prominent Vantage Sandstone interflow or interbed. These are now referred to as the Wanapum and Grande Ronde Formations. Individual basaltic members within these formations have essentially remained unchanged.

Surface Units

The surface geologic units include fill (F), river and stream alluvium (Qal), slopewash (Qsw), alluvial fan (Qaf), loess (Ql), and landslide (Qls) deposits (refer to Figure 2). The surface deposits form a relatively thin cover over shallow bedrock surfaces. The Yakima River alluvium and alluvial fan deposits at the mouths of the side canyons west of the river may have somewhat thicker sediment accumulations.

Fill (F)

Road base and surfacing materials are composed of gravel, sand, fines, cobbles, and asphalt used to construct State Highway 821 (refer to Drawing 33-100-5869 and Drawing 33-100-5870, Geologic Section C-C').

Quaternary Alluvium (Qal)

Yakima River and Lmuma Creek alluvial deposits consist of gravel, sand, and fines with cobbles. The alluvium overlies the bedrock in the valley section of the dam foundation along Lmuma Creek (refer to Geologic Section A-A', Drawing 33-100-5870) and adjacent to the Yakima River in the pumping plant area (refer to Geologic Section C-C', Drawing 33-100-5870).

Period	Epoch	Group	Formation	Member	Age (*)	Thickness (ft)	Graphic	Symbol
Quaternary	Recent/Pleistocene		Yakima R. & Lumna Ck. Alluvium Slopewash Alluvial Fan Loess Landslide Debris (?)	---	Varies	Varies		Qal Qsw Qaf Ql Qls
Tertiary	Miocene	Columbia River Basalt Group	Wanapum Basalt	Roza	14.5–15.3	---		Trz
				Frenchman Springs	15.3–15.5	60–280		Tfs
			Ellensburg	Vantage	15.6	Appr. 70		Tv
			Grande Ronde	Grande Ronde (Undifferentiated)	15.6–16.5	Unknown		Tgr

Recent alluvium, slopewash and landslide deposits

Sedimentary Interbeds

Columbia River Basalt Group Lava Flows

(*) Isotopic age from reference [3]

FIGURE 2 – GENERALIZED STRATIGRAPHY – WYMER DAM AND RESERVOIR AREA

Quaternary Slopewash (Qsw)

Soil and weathered rock deposits on slopes and within small side drainages cover most surfaces throughout the study area and consist of gravel, and sand and fines with cobbles and scattered boulders, including talus deposits. Slopewash was encountered in most of the holes drilled at the dam and saddle dike and was sampled in hand-dug test pits at the damsite (refer to Sections A-A' and B-B', Drawing 33-100-5870).

Quaternary Alluvial Fan (Qaf)

The alluvial fan deposits consist of a variable mixture of fines, sand, gravel, and oversized materials that are well developed at the bases of drainages on the west side of the Yakima River (refer to Drawing 33-100-5869). The unit was not encountered in explorations at the dam, saddle dike, or pumping plant sites, but large ancient alluvial fan deposits northeast of the project area are considered a potential source for construction materials.

Quaternary Loess (Ql)

Windblown silt and fine sand deposits blanket the lower slopes and terraces east of the Yakima River at the mouth of Lmuma Creek (refer to Drawing 33-100-5869 and Section C-C', Drawing 33-100-5870).

Quaternary Landslide (Qls)

Landslide deposits consist of clay, silt, sand, and gravel. These are generally associated with failure of the Vantage Sandstone (Tv) sedimentary interbed. Several small landslide areas have been identified upstream of the damsite along Lmuna Creek, and a large slide was mapped near the upper portion of Scorpion Coulee (refer to Drawing 33-100-5869).

Bedrock Units

Bedrock underlying the Wymer Dam and Reservoir area is composed of volcanic rocks of the Columbia River Basalt Group (refer to Figure 2). The units are the Roza and Frenchman Springs Members of the Wanapum Formation, underlain by the Grande Ronde Basalt Formation. The Vantage Member of the Ellensburg Formation is sedimentary unit that separates the Wanapum and Grande Ronde Formations.

Roza Basalt (Trz)

The Roza Member (Trz) is the uppermost member in the Wanapum Basalt Formation exposed at the site (refer to Figure 2). The Roza Member is gray to black, reddish-brown weathered, fine- to medium-grained basalt with plagioclase phenocrysts, often with well developed colonnade with columns up to 1 meter in diameter. The Roza was not noted to be in foundations at any of the sites, but is exposed in outcrops near drill hole DH-84-2 southeast of the upper left abutment of the dam (refer to Drawing 33-100-5869).

Frenchman Springs Basalt (Tfs)

The Frenchman Springs Member (Tf) is the lowest flow in the Wanapum Basalt Formation (refer to Figure 2). The Frenchman Springs Basalt is dark gray, fine- to medium-grained, and porphyritic. The Frenchman Springs was encountered in drill holes on the upper left abutment at the dam (DH-07-2) site, the upper left abutment at the saddle dike (DH-07-3), and in drill holes on the upper abutments at the upper damsite (DH-84-1 and -2). The unit is composed of multiple flows and is highly permeable based on drilling fluid losses and constant-head water tests. The unit ranges from approximately 60 to 280 feet thick in the Lmuma Creek area and tends to thicken to the south, likely due to erosion or thinning associated with uplift of the Manastash Ridge to the north (refer to Geologic Sections A-A' and B-B', Drawing 33-100-5870).

Vantage Sandstone (Tv)

The Vantage Sandstone interbed occurs stratigraphically between the Frenchman Springs and Grande Ronde basaltic units (refer to Figure 2). The Vantage is composed of tan to gray, medium- to fine-grained, moderately soft, tuffaceous sandstone with interbedded siltstone and claystone. Based on constant-head water tests conducted in drill holes, the Vantage has low permeability. The interbed is present near the middle left abutment (DH-07-2) and upper right abutment at the damsite, near the upper left abutment (DH-07-3) at the dike site, and in drill holes on the upper abutments at the upper damsite (DH-84-1 and -2). The Vantage has a relatively uniform thickness ranging from approximately 63 to 73 feet in the foundations of the dam and saddle dike (refer to Sections A-A' and B-B', Drawing 33-100-5870).

Grande Ronde Basalt (Tgr)

The Grande Ronde is the most voluminous unit of the Columbia River Basalt Group (Carson, et al., 1987). The basalt is black or dark gray, and fine-grained to aphanitic, hard to very hard, slightly weathered, and slightly fractured. Hackly jointing is common and columns are typically smaller than in the Frenchman Springs and Roza Members. Based on constant-head water tests conducted in drill holes, the Grande Ronde has low permeability. The Grande Ronde Basalt underlies the alluvium adjacent to the Yakima River at the pumping plant site (DH-07-1) (refer to Geologic Section C-C', Drawing 33-100-5870), and forms the lower abutments and valley sections at the dam (DH-07-2 and DH-85-1) (refer to Geologic Section C-C', Drawing 33-100-5870) and saddle dike (DH-07-3 and DH-85-4) (refer to Geologic Section C-C', Drawing 33-100-5870) sites. The unit was also encountered in drill holes at the upper damsite (DH-85-1 and -2).

Engineering Geology

The following sections address the findings of drilling, sampling, and constant-head hydraulic conductivity testing conducted at the proposed Wymer dam, saddle dike, and pumping plant sites. Portions of the following geologic discussions are taken from the 2007 Wymer dam and reservoir appraisal report (Bureau of Reclamation, 2007).

Pumping Plant Site

The proposed pumping plant is located on the inside of a broad meander of the Yakima River approximately 4,000 feet southwest of the damsite (refer to Drawing 33-100-5869). Drill hole DH-07-1, located about 350 feet east of the Yakima River, encountered 24.7 feet of alluvium (Qal) overlying Grande Ronde Basalt (Tgr) (refer to Geologic Section C-C', Drawing 33-100-5870).

The Yakima River alluvium (Qal) consists of undifferentiated gravel, sand, and fines with cobbles. Poorly graded gravel (GP) was the predominant soil type encountered in this hole; however, a 5-foot zone of loose, silty sand with gravel (SM)g was encountered from about 16 to 21 feet deep. Sample recovery was generally poor within the alluvium. Therefore, soil descriptions and estimates of cobble content are often based on drilling conditions and cuttings. Sample recovery was fairly good at 71 percent in the lower portion of the alluvium, from 21.2 to 24.7 feet. Within this zone, cobbles are estimated to comprise about 30 percent of the total sample. The cobbles are mostly 3 to 5 inches in size and are composed of hard, subrounded basaltic clasts with lesser amounts of granitic material.

Although down-hole permeability tests were not performed in drill hole DH-07-1, the alluvium can be expected to have high to very high permeability due to the abundance of poorly graded gravel with low fines content. Excavations in the alluvium should be stable on 2:1 slopes provided dewatering has been accomplished first.

Grande Ronde Basalt (Tgr) was encountered in drill hole DH-07-1 from 24.7 to 49.2 feet. The basalt is black to gray, fine-grained to aphanitic, hard, slightly vesicular to dense, slightly weathered, and intensely to moderately fractured. The joints are generally subhorizontal; however, some subvertical joints were also encountered in specific core intervals. Joint surfaces are generally slightly rough. Rock quality designation (RQD) ranged from 33 to 68 percent.

Clear water was used as the drilling fluid throughout the entire drill hole. Fluid return (during drilling) ranged from 50 to 100 percent in the alluvium, and 40 to 60 percent in the bedrock. The depth to ground-water level, measured in the hole upon completion of drilling, was 10.6 feet (elevation 1276.6).

Damsite

The proposed damsite is located in the lower portion of the Lmuma Creek Canyon just downstream of the confluence with Scorpion Creek (refer to Drawing 33-100-5869). The dam axis spans a relatively flat-lying valley bottom, a fairly steep left abutment, and a gentler right abutment (refer to Geologic Section A-A', Drawing 33-100-5870). Two basaltic flow units and a sandstone interflow unit will provide the foundation bedrock for the dam structure. These units dip gently southwestward (from the right to left abutment).

Except for sporadic outcrops of bedrock, the abutments are covered with a surficial layer of slopewash and talus. The 1985 test pits, located on the abutments, encountered between 1.5 and 5.0 feet of slopewash (Qsw) overlying the bedrock. Description of the local geology in the 1984 geologic report states that "talus and slopewash cover much of the valley sides from a few feet up to an estimated 10 feet deep" (Bureau of Reclamation, 1984). The three 1985 drill holes completed within the valley bottom encountered about 20 feet of alluvium (Qal) overlying basalt of Grande Ronde Basalt (Tgr). Summary logs of these holes describe the alluvium as "mostly sand, gravel, and cobbles." No other characteristics of the alluvium are provided on these logs.

Drill hole DH-07-2 is located on the upper left abutment area of the proposed dam. The drill hole encountered bedrock from 2.8 feet to the bottom of the hole at 402.2 feet. The bedrock consists of Frenchman Springs Basalt (Tfs) from 2.8 to 237.6 feet, Vantage Sandstone (Tv) from the 237.6 to 310.7 feet, and Grande Ronde Basalt (Tgr) from 310.7 to 404.2 feet (refer to Geologic Section A-A', Drawing 33-100-5870).

The Frenchman Springs Member (Tfs) of the Wanapum Basalt Formation is the uppermost bedrock unit on both abutments. Based on drill hole DH-07-2 the rock consists of black to gray, fine-grained, hard, dense to slightly vesicular, slightly to moderately weathered basalt. Core recovered from this drill hole ranged from slightly to moderately fractured in some intervals, to intensely and very intensely fractured in other intervals. The joints are generally subhorizontal with slightly rough surfaces. However, scattered vertical fractures (probably representing columnar joints) were also observed. Core recovery in the basalt was good, with RQD values ranging from 0 to 100 percent, with an average range from about 42 to 76. All drilling fluid was lost (i.e., zero drill fluid return) below a depth of 28.3 feet, indicating that many of the joints are open. Constant-head hydraulic conductivity and gravity permeability tests in the Frenchman Springs units were

attempted, but in all cases no back pressure or water level could be established, which indicate that this bedrock has very high hydraulic conductivity (refer to *Permeability Tests* section).

The Vantage Sandstone (Tv) interflow unit is about 70 feet thick. Although poorly exposed, it was mapped on the left abutment between elevations 1509 and 1572, and on the right abutment between elevations1608 and 1680. This unit is described as consisting of "low strength sandstones, siltstones, and claystones" (Bureau of Reclamation, 1984). Due to the limited exposure, the Vantage Sandstone description is based primarily on published information, but was recognized on the aerial photographs and in the field by "light-colored, sandy slopes that, in some places, support vegetation growth." Seeps and springs appeared at the lower contact of the Vantage Sandstone unit, and along the canyon walls, some small landslides occur in this unit.

Based on drill hole DH-07-2 the Vantage consists of brown to dark gray, fine-grained, well indurated, moderately soft, slightly weathered sandstone with interbedded siltstone and claystone. Core recovered from this drill hole ranged from slightly to moderately fractured in some intervals, to intensely fractured in other intervals. The joints are generally subhorizontal with slightly rough surfaces. RQD ranged from 20 to 70 percent. Poor drill fluid returns noted in the Vantage are attributed to losses through the joints in the overlying Frenchman Springs Basalt. Pressure permeability tests indicate the unit has low to moderate hydraulic conductivity (refer to *Permeability Tests* section).

The Grande Ronde Basalt Member will provide the foundation for the dam across the valley section and up the majority of both abutments (refer to Geologic Section A-A', Drawing 33-100-5870). This is the same basaltic unit encountered in the drill hole at the pumping plant site. Based on drill hole DH-07-2, the rock consists of black to gray, fine-grained, aphanitic, very hard, slightly vesicular to dense, slightly to moderately weathered basalt. Core recovered from this drill hole ranged from moderately to slightly fractured. RQD ranged from 59 to 66 percent. The joints are generally randomly oriented with smooth surfaces. However, scattered vertical fractures (probably representing columnar joints) were also recovered.

Two of the 1985 drill holes in the valley section encountered artesian water that flowed at the surface at a rate of about 20 gallons per minute (gal/min). The artesian water was encountered in the basalt at a depth of about 35 feet. Poor drill fluid returns noted in drill hole DH-07-2 in the Grande Ronde unit are attributed to losses through the joints in the Frenchman Springs Basalt near the upper section of the drill hole. Pressure permeability tests indicate the unit has low to moderate hydraulic conductivity (refer to *Permeability Tests* section).

Oblique aerial photographs indicated the possibility of a landslide covering portions of the left abutment area of the proposed damsite (Bureau of Reclamation, 1988). Although a thorough field reconnaissance and geologic evaluation of this potential landslide have not yet taken place, a cursory visual assessment made during the current study indicates that a landslide on the left abutment is not clearly defined. If a landslide does exist, it does not appear to be a deep-seated feature. The appraisal study team determined that the dam axis should not be relocated due to the potential slide, and that any slide material encountered during dam construction would be excavated and potentially used for the rockfill structure. It was also noted during the site visit that bedrock is exposed on the left abutment upstream of the 1985 axis, if shifting the axis becomes a consideration in the future.

Saddle Dike Site

The site for the dike is in the broad, low saddle on the right canyon side about 2,000 feet northeast from the right abutment of the damsite (refer to Drawing 33-100-5869). Geologic mapping and drilling performed in 1985 and 2007 indicate that the saddle dike foundation will have similar geologic conditions as the damsite. Two basaltic flow units and a sandstone interflow unit will provide the foundation bedrock for the saddle dike structure. These units dip gently southwestward (from the right to left abutment).

Except for sporadic outcrops of bedrock, the abutments are covered with a surficial layer of slopewash and talus. Description of the local geology in the 1988 addendum geologic report states that "talus and slopewash cover much of the valley sides from a few feet up to an estimated 10 feet deep" (Bureau of Reclamation, 1988). The bottom of the saddle area is about 1,300 feet wide at the site. Drill hole DH-85-4 was completed near the axis in the lowest part of the saddle (refer to Geologic Section B-B', Drawing 33-100-5870). The log of this hole indicates slopewash from 0.0 to13.8 feet; highly altered and fractured basalt from 13.8 to 20.0 feet; and alternating soft to hard, altered scoriaceous to vesicular basaltic rock from 20.0 to 42.9 feet. This occurrence of poor quality bedrock in the pre-Vantage Basalt is anomalous to the basalt seen in drill holes and outcrops at the damsite and is probably only a local deviation of the mostly hard, competent rock seen elsewhere. Another interpretation offered in the 1988 addendum geologic report is that the materials in the upper 20 feet of the drill hole may be part of the Vantage Sandstone interflow unit (Bureau of Reclamation, 1988).

Drill hole DH-07-3 is located on the upper left abutment area of the proposed saddle dike. The drill hole encountered bedrock from ground surface to the bottom of the hole at 201.2 feet. The bedrock consists of Frenchman Springs Basalt (Tfs) from 0.0 to 62.6 feet, Vantage Sandstone (Tv) from 62.6 to 126.1 feet, and Grande Ronde Basalt (Tgr) from 126.1 to 201.2 feet (refer to Geologic Section B-B', Drawing 33-100-5870).

The Frenchman Springs Basalt (Tfs) forms the uppermost bedrock unit on the upper left abutment and, based on the upward sloping bedrock surface, the unit projects above the crest of the proposed dike on the right abutment (refer to Geologic Section B-B', Drawing 33-100-5870). Based on core samples from drill hole DH-07-3, the rock consists of black to gray, fine-grained, moderately hard to hard, dense to slightly vesicular, intensely to slightly weathered basalt. Core recovered from this drill hole ranged from intensely to moderately fractured in some intervals, to intensely fractured in other intervals. The joints were generally randomly oriented with slightly rough surfaces. However, scattered subvertical fractures (probably representing columnar joints) were also noted. RQD ranged from 0 to 84 percent, with an average range of about 16 to 63 percent.

Drill fluid (water) returns ranged from 25 to 80 percent from 0.0 to 62.6 feet, with significant losses in the very intensely fractured rock from approximately 38.2 to 46.4 feet and near the contact with the underlying Vantage Sandstone (Tv). Results of pressure permeability tests performed indicate this bedrock unit has moderate to high hydraulic conductivity (refer to *Permeability Tests* section).

The Vantage Standstone (Tv) unit was encountered on the left abutment in drill hole DH-07-3 between about 62.6 and 126.1 feet and, owing to the upward trend of the bedrock surface to the north, the unit is at or slightly above the dam foundation on the right abutment (refer to Geologic Section B-B', Drawing 33-100-5870). The Vantage Sandstone (Tv) recovered in DH-07-3 consists of greenish gray, fine-grained, well indurated, moderately soft, moderately weathered sandstone with interbedded siltstone and claystone. Core recovered from this drill hole was mostly intensely to moderately fractured. The joints were generally subhorizontal with slightly rough surfaces. RQD ranged from 23 to 91 percent, with an average range of about 44 to 76 percent. Poor drill fluid returns noted in the sandstone are attributed to losses through the joints in the overlying Frenchman Springs Basalt. Pressure permeability tests indicate that the unit has low to moderate hydraulic conductivity (refer to *Permeability Tests* section).

The Grande Ronde Basalt Member will provide the majority of the foundation for the Saddle Dike, extending across the valley section and up both abutments (refer to Geologic Section B-B', Drawing 33-100-5870). Based on drill hole DH-07-3, the rock consists of black to gray, fine-grained, aphanitic, very hard, slightly vesicular to dense, slightly to moderately weathered basalt. Core recovered from this drill hole ranged from moderately to slightly fractured. The joints were generally randomly oriented with smooth surfaces. However, scattered vertical fractures (probably representing columnar joints) were also recovered. RQD ranged from 38 to 100 percent, with an average of about 80 percent. Pressure permeability tests indicate the unit has low to moderate hydraulic conductivity (refer to *Permeability Tests* section).

Reservoir Basin

The geology of the reservoir basin is mostly flat-lying lava flows exposed in a steep, narrow canyon that extends upstream for about six miles on Lmuma Creek, and about two miles upstream in the broader canyon of Scorpion Creek (Bureau of Reclamation, 1984). The Vantage Sandstone interflow zone is present on both canyon sides and will be within the reservoir pool in most of the reservoir basin. Under a reservoir condition, the interflow zone will be subject to some small landslides as the pool fluctuates. The slopewash deposits along the canyon sides will also be subject to sloughing and minor sliding along the reservoir shoreline.

The potential reservoir seepage losses are judged to be inconsequential for the major, upstream part of the reservoir (Bureau of Reclamation, 1984). However, near the damsite and dike site, the potential for reservoir seepage becomes more of a concern given the fractured nature of the Frenchman Springs Basalt (Tfs) that forms the upper abutment foundations and the steep gradient from a full reservoir across relatively narrow reservoir rims to deep adjacent, dry drainages.

Permeability Tests

Multi-pressure permeability tests were conducted in two bore holes drilled between April and June 2007 at the proposed damsite (refer to Drawing 33-100-5869). Packer tests were conducted in the drill holes as they were advanced through the basalt and sedimentary interbeds of the Columbia River Basalt Group (see drill logs for DH-07-2 and DH-07-3). Each of the holes encountered the following units (described in order from the ground surface): the Frenchman Springs Member of the Wanapum Basalt Formation; the Vantage Sandstone Member of the Ellensburg Formation; and the upper Grande Ronde Basalt Formation. All of the tests were conducted in the vadose zone, above the water table. Water was supplied for the injection tests by truck, which was filled from Lmuma Creek near the Eaton farmstead.

The upper Frenchman Springs Basalt in drill hole DH-07-02 was so intensely fractured and pervious that all of the drilling fluid was lost at a depth of about 28 feet and the addition of "stop-loss" material did not increase fluid return. Permeability tests were unsuccessful because pressure could not be established while injecting water at the capacity of the pump (50 to 60 gal/min). The drill hole was repeatedly filled with cement grout then re-drilled to limit fluid losses through the upper section while advancing the hole. Hydraulic conductivity values in the upper basalts at this location are presumed to be very high, which may require extensive grouting in the dam abutments and upper reservoir rim to limit seepage losses.

Permeability tests in the Vantage Sandstone were more successful and indicate low to moderate hydraulic conductivity values, less than 200 feet per year (see Table 1). The upper Grande Ronde Basalt also appears to have low to moderate hydraulic conductivity in this area. The Grande Ronde hosts a confined aquifer at depth and previous investigations at the site indicate artesian levels above the valley bottom (Bureau of Reclamation, 1988). The current testing, in drill holes located at the upper abutments, did not encounter the deeper members of the Grande Ronde that host the artesian aquifer.

The methods used to calculate hydraulic conductivity are detailed in the *Ground Water Manual* (Bureau of Reclamation, 1995). All of the tested intervals were above the water table and met the conditions of "zone 1", which indicates a deep water table relative to the test interval.

The following equation was used to calculate hydraulic conductivity (K):

$$K = \frac{Q}{Cu\ r\ H}$$

where:

Q = steady inflow into well [cubic feet per second (ft^3/s)]
Cu = conductivity coefficient for unsaturated materials
r = radius of drill hole [feet (ft)]
H = effective head (ft)

Results of the packer tests and a description of the test intervals are listed in Table 1. The parameters used for the test analyses are listed in Tables 2 and 3.

Table 1 – Results of drill hole permeability testing, Wymer dam and dike sites.

Drill Hole	Test Depth Interval (ft)	Geologic Description of Test Interval	Hydraulic Conductivity (K) ft/yr
DH-07-2	43.2-67.0	Frenchman Springs member (Tfs) of Wanapum Basalt Formation Very intensely fractured to slightly fractured	Very high
	79.0-84.6	Frenchman Springs member (Tfs), very intensely to intensely fractured basalt	Very high
	178.1-191.0	Frenchman Springs member (Tfs), moderately to slightly fractured basalt	Very high
	247.3-262.6	Vantage Sandstone member (Tv) of Ellensburg Formation, sandstone and siltstone, intensely to slightly fractured, moderately soft	15.9-53.7
	279.0-295.0	Vantage Sandstone member (Tv) of Ellensburg Formation, sandstone and siltstone, well indurated with pumice and ash.	123.5-149.2
	311.0-325.3	Grande Ronde Basalt Formation (Tgr), basaltic breccia, moderately to slightly fractured	95.7-130.9
	388.0-402.2	Grande Ronde Basalt Formation (Tgr), slightly fractured basalt	Very low
DH-07-3	17.0-27.6	Frenchman Springs member (Tfs) of Wanapum Basalt Formation, intensely to moderately fractured	2351.3-2658.8
	47.0-57.6	Frenchman Springs member (Tfs), very intensely to moderately fractured basalt	1713.2-1902.8
	67.0-77.6	Vantage Sandstone member (Tv) of Ellensburg Formation, sandstone, intensely fractured, moderately soft	162.8-1478.5
	87.0-97.6	Vantage Sandstone member (Tv) of Ellensburg Formation, sandstone and siltstone, intensely to moderately fractured, moderately soft	348.9-612.2
	117.0-127.2	Vantage Sandstone member (Tv) of Ellensburg Formation and top of Grande Ronde Basalt (contact logged at 126.1 feet), claystone and siltstone, intensely to moderately fractured, basalt is intensely to moderately fractured	5.7-22.7
	132.0-142.6	Grande Ronde Basalt Formation (Tgr), slightly to very slightly fractured basalt	Very low
	152.0-167.6	Grande Ronde Basalt Formation (Tgr), slightly to very slightly fractured basalt	4.1-11.3
	191.0-201.2	Grande Ronde Basalt Formation (Tgr), slightly fractured basalt	Very low

Table 2 - Pertinent test parameters used to determine hydraulic conductivity values for pressure permeability tests in drill hole DH-07-2.

Drill Hole	Test Depth Interval (ft)	Test Parameters							Hydraulic Conductivity (K) ft/yr
		R Ft	A ft	H ft	Q ft^3/s	Tu ft	h_2 lb/in^2	Cu	
DH-07-2	43.2-67.0	Could not build pressure or fill hole with water at capacity of pump (60 gal/min)							Very high
DH-07-2	79.0-84.6	Could not build pressure or fill hole with water at capacity of pump (60 gal/min)							Very high
DH-07-2	178.1-191.0	Could not build pressure or fill hole with water at capacity of pump (60 gal/min)							Very high
DH-07-2	247.3-262.6	0.104	15.3	312.2	.005	535.6	20	300	15.9
	247.3-262.6	0.104	15.3	351.9	.019	575.3	40	300	53.7
	247.3-262.6	0.104	15.3	312.2	.009	535.6	20	300	28.1
DH-07-2	279.0-295.0	0.104	16.0	328.2	.04	519.22	22	300	123.5
	279.0-295.0	0.104	16.0	374.4	.053	565.4	42	300	144.3
	279.0-295.0	0.104	16.0	325.9	.048	516.9	21	300	149.2
DH-07-2	311.0-325.3	0.104	14.3	353.9	0.036	514.6	20	300	101.8
	311.0-325.3	0.104	14.3	400.1	0.038	560.8	40	300	95.7
	311.0-325.3	0.104	14.3	436.3	0.053	597.0	60	300	123.8
	311.0-325.3	0.104	14.3	343.9	0.045	504.6	20	300	130.9
DH-07-2	388.0-402.2	0.104	14.2	-	0	-	20	-	Very low

Table 3 - Pertinent test parameters used to determine hydraulic conductivity values for pressure permeability tests in drill hole DH-07-3.

Drill Hole	Test Depth Interval (ft)	Test Parameters							Hydraulic Conductivity (K) ft/yr
		R Ft	A ft	H ft	Q ft^3/s	Tu ft	h_2 lb/in^2	Cu	
DH-07-3	17.0-27.6	0.104	10.6	50.8	0.089	517.2	10	200	2658.8
		0.104	10.6	70.6	0.120	537.0	20	200	2582.8
		0.104	10.6	51.7	0.08	518.1	10	200	2351.3
DH-07-3	47.0-57.6	0.104	10.6	74.9	0.085	511.3	10	200	1713.2
		0.104	10.6	91.0	0.113	527.4	20	200	1877.6
		0.104	10.6	74.0	0.093	510.4	10	200	1902.8
DH-07-3	67.0-77.6	0.104	10.6	102.7	0.012	519.1	10	210	162.8
		0.104	10.6	105.3	0.107	521.7	20	210	1472.1
		0.104	10.6	90.9	0.089	507.3	10	200	1478.5
DH-07-3	87.0-97.6	0.104	10.6	120.0	0.028	516.4	10	200	348.9
		0.104	10.6	137.9	0.056	534.3	20	200	612.2
		0.104	10.6	117.4	0.04	513.8	10	200	512.0
DH-07-3	117.0-127.2	0.104	10.2	153.9	0.001	520.7	10	200	5.7
		0.104	10.2	177.0	0.001	543.8	20	200	9.5
		0.104	10.2	223.2	0.003	590.0	40	200	22.7
		0.104	10.2	177.0	0.002	543.8	20	200	17.2
		0.104	10.2	153.9	0.002	520.7	10	200	17.6
DH-07-3	132.0-142.6	0.104	10.2	169.3	0.0	520.7	10	200	Very low
	152.0-167.6	0.104	15.6	217.4	0.001	543.8	20	300	4.1
		0.104	15.6	263.6	0.001	590.0	40	200	6.4
		0.104	15.6	309.8	0.001	636.2	60	200	5.4
		0.104	15.6	263.6	0.002	590.0	40	200	11.3
		0.104	15.6	217.4	0.002	543.8	20	300	8.2
	191.0-201.2	0.104	10.2	252.0	0	544.8	20	200	Very low
		0.104	10.2	298.2	0	591.0	40	200	Very low
		0.104	10.2	344.4	0	637.2	60	100	0.00
		0.104	10.2	298.2	0	591.0	40	200	Very low
		0.104	10.2	252.0	0	544.8	20	200	Very low

Nomenclature:
r = radius of test section
A = length of test section
H = effective head (distance between gage and hole bottom + applied pressure - head loss due to friction)
h2 = applied pressure
Tu = distance from water surface in well to (projected) water table
Q = steady flow into well
Cu = conductivity coefficient
K = hydraulic conductivity

Construction Materials

The pumping plant, dam, and dike will require materials consisting of concrete products, processed filter and drain materials, rockfill, riprap, and semi-pervious fill. Table 4 provides a summary of the availability of these materials showing approximate haul distances that were used to develop costs for this study.

Construction materials for the dam and associated structures can be obtained from both developed and undeveloped land within approximately 17 miles of the site. Geologically, the sources consist of recent Yakima River alluvium, post-Yakima Fold Belt alluvium, Ellensburg Formation sediments, and Columbia River basalt. The main material types for the dam include impervious fill, rockfill, processed material for filter and drain elements, and concrete aggregate and sand. It is common practice to obtain material from the reservoir basin during construction of large embankment dams. The Lmuma Creek Valley, Scorpion Coulee, and uplands northeast of the reservoir basin are potential sources for zoned earthfill for the embankment.

In order to meet gradation requirements for filter, drain, and concrete aggregate, washing and screening of raw material will be necessary. The nearest potential sources of relatively clean material include Yakima River alluvial deposits from commercial sites in either Yakima or Ellensburg, Washington.

Table 4 - Summary of construction materials - haul distances.

Site	Concrete Products (cement, sand, and aggregate)[1]	Processed Filter/Drain Materials[1]	Rockfill[2]	Riprap[2]	Semi-pervious Fill[3]
	Approximate Haul Distance (miles)[4]	Approximate Haul Distance (miles)[4]	Approximate Haul distance (miles)[4]	Approximate Haul Distance (miles)[4]	Approximate Haul Distance (miles)[4]
Pumping plant	16	16	3	3	N/A
Main dam	17	17	2	2	5
Dike	18	18	3	3	5

Notes:
[1] The nearest commercial sources of natural material are in Yakima, Selah, or Ellensburg, Washington. All are about the same distance from the project site. Quarry rock within the reservoir basin could be processed (crushed, graded, and washed) for filter drain material if acceptable.
[2] Potential borrow sites are within the reservoir basin (from Bureau of Reclamation, 1984).
[3] Potential borrow sites include mining and blending basalt and sedimentary rock from exposures of Vantage Sandstone (siltstone, claystone) near the upper end of the Scorpion Creek, and/or mining and blending basalt and alluvial fan deposits from uplands near Interstate 82 at the head of Scorpion Creek (from Schuster, 1994).
[4] Haul distances shown are one-way.

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Appendices

Appendix A

Summary of Drilling and Geologic Logs

Summary of Drilling – 2007 Geologic Explorations for Proposed Wymer Reservoir and Pumping Plant Sites (includes data on 1984 and 1985 drill holes and test pits)
Geologic Log of Drill Hole No. DH-07-1
Photographs of Core – 3.1 to 49.2 feet
Geologic Log of Drill Hole No. DH-07-2
Photographs of Core – 2.8 to 156.1 feet and 189.4 to 402.2 feet
Geologic Log of Drill Hole No. DH-07-3
Photographs of Core – 3.6 to 201.2 feet
Geologic (Summary) Logs of Drill Holes DH-84-1 through DH-84-2 (1984)
Geologic (Summary) Logs of Drill Holes DH-85-1 through DH-85-4 (1985)
Geologic (Summary) Logs of Test Pits TP-85-1 through TP-85-4 (1985)

Summary of Drilling

2007 Geologic Explorations for Proposed Wymer Reservoir and Pumping Plant Sites
(includes data on 1984 and 1985 drill holes and test pits)
Yakima River Basin Water Storage Feasibility Study, Washington

HOLE NUMBER	LOCATION STATION/OFFSET	COORD. NORTH	COORD. EAST	ELEV.	HOLE DEPTH	COMP. DATE	WATER SURFACE ELEV/DATE	REMARKS
DH-07-1	Pumping Plant	541705.4	1650841.8	1287.2	49.2’	04-13-07	1276.6 / 04-12-07	
DH-07-2	Lower Damsite – Left Abutment	542904.6	1654187.9	1786.1	402.2’	05-30-07	Dry	
DH-07-3	Lower Damsite – Right Abutment	546991.9	1654050.1	1794.3	201.2	06-21-07	Dry	
DH-84-1	Upper Damsite – Right Abutment	546656.1	1659033.6	1901.6	174.7	05-18-84	Not Measured	
DH-84-2	Upper Damsite – Left Abutment	541015.8	1657357.5	1853.4	290.4	06-14-84	Dry / 06-14-84	
DH-85-1	Lower Damsite – Right Valley Bottom	544045	1653675	1323	50.5’	08-01-85	Artesian / 08-01-85	
DH-85-2	Lower Damsite – Left Valley Bottom	543978.9	1654521.9	1334.5	34.6’	08-06-85	Artesian / 05-01-07	
DH-85-3	Lower Damsite – Right Valley Bottom	544079.3	1654470.7	1339.1	23.8’	08-08-85	1332.1 / 08-08-85	
DH-85-4	Saddle Damsite – Middle Valley Bottom	547894	1654973	1604.5	42.9’	08-10-85	Dry	
TP-85-1	Lower Damsite – Left Abutment	543535	1653943	1490	5.0’	08-07-85	Dry	
TP-85-2	Lower Damsite – Right Abutment	544863	1653264	1545	2.0’	08-07-85	Dry	
TP-85-3	Lower Damsite – Right Abutment	545123	1653163	1610	3.0’	08-07-85	Dry	
TP-85-4	Lower Damsite – Right Abutment	545270	1653222	1630	1.5’	08-07-85	Dry	

Note: Survey Data: NAD83/NAVD29

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-1

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Proposed Pumping Plant Site
COORDINATES: N 541,705 E 1,650,842
GROUND ELEVATION: 1287.2 ft. above sea level
BEGUN: 4/10/2007 FINISHED: 4/13/2007
TOTAL DEPTH: 49.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: 10.6 ft. (1276.6)
DEPTH TO BEDROCK: 24.7 ft.
HOLE LOGGED BY: D. Stelma
WATER DEPTH MEASURED ON: 4/12/2007
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES

PURPOSE OF HOLE:

Determine engineering properties of the bedrock and overburden in the vicinity of the proposed pumping plant and intake areas.

DRILLED BY:

Pacific Northwest Regional Drill Crew: Chris Peterson, driller, Ben Horton, helper.

DRILL EQUIPMENT:

CME Model 75 track-mounted rotary drill rig with casing advancer and HQ wire line coring system with a diamond impregnated bit.

DRILLING METHOD:

0.0 to 3.1': Advanced 4-inch I.D. surface casing using a casing advancer (wireline rockbit) using clear water as circulating fluid.

3.1-11.2': Advanced hole with HQ coring system using clear water as circulating fluid. Installed 4-inch I.D. surface casing using a casing advancer (wireline rockbit) and clear water as circulating fluid following coring.

11.2 to 49.2': Advanced hole with HQ coring system using clear water as circulating fluid.

DRILLER NOTES:

0.0 to 3.1': Slow and moderately rough using casing advancer with rockbit.

3.1 to 14.0': Slow and rough using casing advancer and HQ coring system.

14.0-21.2': Fast and smooth to moderately rough using HQ coring system.

21.2-24.7': Slow and rough using HQ coring

DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION
0	1287.2	SM						50		
								0		
5		GP						29		
10	Qal							0		
		GP						20		
15										
		SMg						20		
20										
		GPc						71		
	1262.5									
25								100	32	
30								100	53	
35	Tgr	Basalt	FD6	H3	W3			95	39	
40								100	68	
45								100	33	
	1238									

END OF HOLE. Total Depth = 49.2 Feet

CLASSIFICATION AND SAMPLE DESCRIPTION

0.0-24.7': **QUATERNARY ALLUVIUM DEPOSITS (Qal).** Yakima River alluvial deposits consisting of undifferentiated gravel, sand and fines with cobbles, composed of primarily of basaltic clasts with lesser amounts of granitic material. Description is based on HQ-size core samples, drilling conditons and cuttings returned.

0.0-1.0': SILTY SAND WITH GRAVEL (SM)g. About 60% medium to fine, hard, subrounded sand; about 20% nonplastic fines; about 20% coarse to fine, hard, subrounded to rounded gravel; moist, dark brown, abundant organics (roots), homogenous.

1.0-3.1': GRAVEL AND SAND WITH COBBLES. Description based on drilling conditions and cuttings returned.

3.1-8.2': POORLY GRADED GRAVEL (GP). About 100% mostly coarse, hard, subrounded gravel.

8.2-11.2': GRAVEL AND SAND WITH COBBLES. Description based on drilling conditions and cuttings returned.

11.2-16.2': POORLY GRADED GRAVEL (GP). About 100% mostly coarse, hard, subrounded gravel.

16.2-21.2': SILTY SAND WITH GRAVEL (SM)g. About 40% medium to fine, hard, subangular sand; about 30% fines with low plasticity; about 30% fine to coarse, hard, subrounded gravel; moist to wet, light brown.

21.2-24.7': POORLY GRADED GRAVEL (GP). About 100% mostly coarse, hard, subrounded gravel.

TOTAL SAMPLE (BY VOLUME): About 30% 3- to 5-inch, hard, subrounded cobbles; remainder minus 3 inch; maximum dimension, 125 mm.

24.7-49.2': **GRANDE RONDE MEMBER (Tgr)** of the Grande Ronde Basalt Formation, Miocene Columbia River Basalt Group (CRB). Black to gray, hard, fine grained-aphanitic dense basalt. Descriptions are based on HQ-size core samples.

24.7-49.2': BASALT. Black to gray, fine grained dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces, vesicles contain minor amouts of yellowish palagonite. Hard (H3). Core can be scratched with knife with heavy pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.9', mostly less than 0.3', the joints are generally subhorizontal with slightly rough surfaces. Two continuous subvertical joints were noted from 27.3-31.2' and 37.9-38.9'.

49.2': BOTTOM OF HOLE

STRATIGRAPHY:

0.0 to 24.7 QUATERNARY ALLUVIUM DEPOSITS (Qal)
24.7 to 49.2 GRANDE RONDE MEMBER (Tgr)

COMMENTS:

Stratigraphy based on data from: Schuster, J.E., 1994, Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-12.

Soil and bedrock descriptions based on BOR Enginering Geology Field Manual, 2nd Ed., Vol.

Abbreviations:

Rb - Rock Bit

NENAHNEZAD WYMER.GPJ NENAHNEZAD.GDT 1/16/08

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-1

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Proposed Pumping Plant Site
COORDINATES: N 541,705 E 1,650,842
GROUND ELEVATION: 1287.2 ft. above sea level
BEGUN: 4/10/2007 FINISHED: 4/13/2007
TOTAL DEPTH: 49.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: 10.6 ft. (1276.6)
DEPTH TO BEDROCK: 24.7 ft.
HOLE LOGGED BY: D. Stelma
WATER DEPTH MEASURED ON: 4/12/2007
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES	DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION	CLASSIFICATION AND SAMPLE DESCRIPTION

system.
24.7-49.2': Slow and rough with frequent blocking using HQ coring system through basalt.

DRILLING FLUID:

0.0 to 49.2': Water

DRILL FLUID RETURN:

0.0 to 8.2': 100%
8.2 to 21.2': 70%
21.2 to 31.2: 50%
31.2 to 36.5': 40%
36.5 to 45.2': 50%
45.2 to 49.2': 60%

DRILL FLUID COLOR:

0.0 to 11.2': Brown to grayish brown
11.2 to 49.2': Gray

WATER LEVELS:

Water Level	Date
10.6	04/12/2007

CASING RECORD:

*Casing Depth	Interval Drilled
11.2'	0.0-26.2'
11.5'	26.2-49.2'

* 4-inch diameter steel casing (threaded)

TESTING & SAMPLING:
N/A

HOLE COMPLETION:

Pulled drill rods and backfilled hole with bentonite (swell plug).


WYMER RESERVOIR & PUMPING PLANT SITES
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-1
FROM 3' to 49.2'

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-2

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Wymer Damsite
COORDINATES: N 542,905 E 1,654,188
GROUND ELEVATION: 1786.1 ft. above sea level
BEGUN: 4/14/2007 FINISHED: 5/30/2007
TOTAL DEPTH: 402.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 2.8 ft.
HOLE LOGGED BY: D. Stelma/S. Acree
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES

PURPOSE OF HOLE:

Determine engineering properties of the left abutment bedrock at the proposed Wymer Damsite.

DRILLED BY:

Pacific Northwest Regional Drill Crew: Chris Peterson, driller, Ben Horton and Dick Stienke, helpers.

DRILL EQUIPMENT:

CME Model 75 track-mounted rotary drill rig with casing advancer and HQ and NQ wire line coring systems with diamond impregnated bits.

DRILLING METHOD:

0.0-2.8': Advanced 4-inch I.D. surface casing using a casing advancer (wireline rockbit) using clear water as circulating fluid.

2.8-62.6': Advanced hole with HQ coring system using clear water as circulating fluid. Lost all circulation at about 28.3'. Attemped pressure permeability test from 43.3 to 61.0', pumped 50 gallons per minute but could not establish back pressure. Pulled drill rods and backfilled hole with 5 bags of cement grout, filled hole to 45.0'. Reamed hole (drilled through cement grout) to 48.0' using drilling fluid (Diamond Seal) but did not establish circulation. Pulled rods and backfilled with 20 bags of cement grout, filled hole to 16.0'. Reamed hole (drilled through cement grout) to 62.0' using clear water as circulating fluid, lost circulation at 62.0'.

62.6-92.6': Advanced hole with HQ coring system using clear water

DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION
0	1786.1	GMsc								
50	Tfs	Basalt	FD5	H3	W3	See Notes		100	67	
			FD3					100	77	
			FD8		W5			100	0	
			FD3		W3			100	85	
			FD8		W5	See Notes		30	0	
95			FD3		W3			75	58	

0.0-2.8': **QUATERNARY SLOPEWASH (Qsw).** Surficial deposits consisting of undifferentiated gravel, sand and fines with cobbles. Description is based drilling conditons and cuttings returned.

2.8-237.6': **FRENCHMAN SPRINGS MEMBER (Tfs)** of the Wanapum Basalt Formation, Miocene Columbia River Basalt Group (CRB). Black to gray, hard, fine grained to slightly porphyritic, slightly vesicular to dense basalt. Descriptions are based on HQ-size core samples.

2.8-24.6': BASALT. Black to gray, fine grained slightly vesicular basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces, vesicles contain small amouts of yellowish palagonite. Hard (H3). Core can be scratched with knife with heavy pressure. Moderately Fractured (FD5). Core recovered in lengths from fragments to 1.1', mostly about 0.5', the joints are generally subhorizontal with slightly rough surfaces.

24.6-51.0': BASALT. Black to gray, fine grained dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces, vesicles contain small amouts of yellowish palagonite. Hard (H3). Core can be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from fragments to 4.0', the joints are generally subhorizontal with slightly rough surfaces.

51.0-61.0': BASALT. Black to gray, fine grained dense basalt. Moderately Weathered (W5). Oxidation (iron and manganese) covers all fracture surfaces, moderately altered plagioclase minerals throughout. Hard (H3). Core can be scratched with knife with heavy pressure. Very Intensely to Intensely Fractured (FD8). Core recovered mostly as fragments, closely spaced joints are primarily subhorizontal with scattered vertical fractures, joint surfces are the slightly rough.

61.0-77.0': BASALT. Black to gray, fine grained dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Hard (H3). Core can be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from 1.3' to 3.7', joints are generally subhorizontal with slightly rough surfaces. Two continuous vertical joints were noted from 65.0-68.0' and 70.0-71.6'.

77.0-86.2': BASALT. Black to gray, fine grained dense basalt. Moderately Weathered (W5). Oxidation (iron and manganese) covers all fracture surfaces, moderately altered plagioclase minerals and traces of palagonite throughout. Hard (H3). Core can be scratched with knife with heavy pressure. Very Intensely to Intensely Fractured (FD8). Core recovered mostly as fragments, closely spaced the joints are primarily subhorizontal with scattered vertical fractures, joint surfces are the slightly rough.

Drillers Note: Void or soft zone from 79.0-82.6' based on drilling conditions.

86.2-99.3': BASALT. Black to gray, fine grained, slightly porphyritic, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Hard (H3). Core can be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from 0.4' to 2.4', joints are generally subhorizontal with slightly rough surfaces.

99.3-123.4': BASALT. Black to gray, fine grained dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) covers all fracture surfaces, moderately altered plagioclase minerals and

CLASSIFICATION AND SAMPLE DESCRIPTION

COMMENTS:

Stratigraphy based on data from: Schuster, J.E., 1994, Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-12.

Soil and bedrock descriptions based on BOR Enginering Geology Field Manual, 2nd Ed., Vol.

Abbreviations:

Rb - Rock Bit
psi - Pounds per square inch
gpm - Gallons per minute
K - Permeability expressed in feet per year

NENAHNEZAD WYMER.GPJ NENAHNEZAD.GDT 1/16/08

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-2

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Wymer Damsite
COORDINATES: N 542,905 E 1,654,188
GROUND ELEVATION: 1786.1 ft. above sea level
BEGUN: 4/14/2007 FINISHED: 5/30/2007
TOTAL DEPTH: 402.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 2.8 ft.
HOLE LOGGED BY: D. Stelma/S. Acree
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES	DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION	CLASSIFICATION AND SAMPLE DESCRIPTION
as drilling fluid. Drill rods advanced without resistance from about 79.0 to 82.6'. Lost core sample from the interval between 86.2 and 92.6. Pulled drill rods and retrieved about 0.8' of sample. Drill hole caved to 84.6'. Attemped gravity permeability test at bottom of hole, pumped 70 gallons per minute without establishing a measurable water level, pumped approximately 2500 gallons. Backfilled hole with 38 bags of cement grout, filled hole to 82.5'. Reamed hole (drilled through cement grout) to 92.6' using clear water as circulating fluid. 92.6-276.1': Advanced hole with HQ coring system using clear water, added small amount of polymer through casing to minimize rod chatter. 276.1-402.2': Advanced hole with NQ coring system using clear water, added small amount of polymer through casing to minimize rod chatter. **DRILLER NOTES:** 0.0-2.8: Hard and slow using casing advancer with rockbit. 2.8-51.8': Slow and rough using HQ coring system. 51.8-61.0': Slow and very rough using HQ coring system. 61.0-82.6': Slow and moderately rough using HQ coring system. 82.6-86.2': Slow and very rough with frequent blocking using HQ coring system through basalt. 86.2-166.1': Slow and moderately rough using HQ coring system. 166.1-222.8': Slow and slightly rough using HQ coring system. 222.8-237.6': Slow and moderately rough using HQ coring system. 237.6-276.1': Slow and slightly rough with occassional blocking using HQ coring system. 276.1-402.2': Moderately slow with NQ coring system. **DRILLING FLUID:** 0.0-92.6': Water. 92.6-402.2': Water with	105 110 115 120 125 130 135 140 145 150 155 160 165 170 175 180 185 190 195 200 205 210 215	Tfs	Basalt	FD6 FD7 FD5 FD4 FD4 FD4 FD4 FD3 FD4 FD5 FD4 FD5 FD5	H3 H4 H3 H2 H3 H2	W3 W6 W3 W3 W4 W4 W3	See Notes		100 100 100 100 100 100 100 100 100 100 100 100 100	23 40 41 48 39 79 90 100 93 76 100 82 88 100 50 100		traces of palagonite throughout. Hard (H3). Core can be scratched with knife with heavy pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to1.0', joints are primarily subhorizontal with slightly rough surfaces. Continuous, moderately wide (0.5") vertical joint was noted from 109.0-119.0'. 123.4-138.8': BASALT. Black to gray, fine grained vesicular basalt. Intensely to Moderately Weathered (W6). Abundant oxidation (iron and manganese) on fracture surfaces, body of rock oxidized with scattered cindery zones. Moderately hard (H4). Core can be scratched with knife with moderate pressure. Moderately Fractured (FD6). Core recovered in lengths from fragments to1.0' with most lengths from 0.4' to 0.5', joints are primarily subhorizontal with slightly rough surfaces. Continuous vertical joint was noted from 126.4-127.6'. 138.8-156.1': BASALT. Black to gray, fine grained, slightly porphyritic (1-2mm rectangular phenocrys), dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces, moderately altered plagioclase minerals and traces of palagonite throughout. Hard (H3). Core can be scratched with knife with heavy pressure. Moderately Fractured (FD6). Core recovered in lengths from fragments to 2.0' with most lengths around 0.4', joints are randomly oriented with slightly rough surfaces. Continuous vertical joint was noted from 150.5-152.6'. 156.1-161.1': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) on all fracture surfaces, two small palagonitic zones (0.3') were noted. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from 0.3 to 0.4, joints are equally subhorizontal and subvertical with slightly rough surfaces. Joints are tight to moderately open. 161.1-166.1': BASALT. Black to gray, fine grained, moderately vesicular basalt. Moderately to Slightly Weathered (W4). Oxidation (iron and manganese) on most fracture surfaces, vesicles range from 3 to 8 mm and have palagonitic infillings. Hard (H3). Core can be scratched with knife with heavy pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.3', joints are equally subhorizontal and subvertical with slightly rough surfaces. 166.1-171.1': BASALT. Black to gray, fine grained, moderately vesicular basalt. Moderately to Slightly Weathered (W4). Oxidation (iron and manganese) on most fracture surfaces, most vesicles have palagonitic infillings. Hard (H3). Core can be scratched with knife with heavy pressure. Moderately Fractured (FD5). Core recovered in lengths from 0.3' to 0.5', joints are equally subhorizontal and subvertical with slightly rough surfaces. 171.1-176.1': BASALT. Black to gray, fine grained, slightly vesicular basalt. Vesicles are up to 3 mm in diameter. Slightly Weathered (W3). Oxidation (iron and manganese) on most fracture surfaces, vesicles have minor palagonite infillings. Hard (H3). Core can be scratched with knife with heavy pressure. Moderately to Slightly Fractured (FD4). Core recovered mostly in 1.0' lengths, joints are generally subhorizontal. 176.1-180.8': BASALT. Black to gray, fine grained, slightly vesicular basalt. Vesicles range from 1 to 10 mm in diameter. Slightly Weathered (W3). Oxidation (iron and manganese) on most fracture surfaces, vesicles range from 1 to 10 mm with minor palagonite infillings. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Moderately to Slightly Fractured (FD4). Core recovered mostly in 1.0' lengths or greater, joints are generally subhorizontal. 180.8-186.0': BASALT. Black to gray, fine grained, slightly vesicular basalt. Vesicles range from 1 to 5 mm in diameter. Slightly Weathered (W3). Oxidation (iron and manganese) on most fracture surfaces, vesicles have minor palagonite infillings. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Moderately to Slightly Fractured (FD4). Core recovered mostly in 2.0' lengths or greater, joints are generally subhorizontal.

NENAHNEZAD WYMER.GPJ NENAHNEZAD.GDT 1/16/08

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-2

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Wymer Damsite
COORDINATES: N 542,905 E 1,654,188
GROUND ELEVATION: 1786.1 ft. above sea level
BEGUN: 4/14/2007 FINISHED: 5/30/2007
TOTAL DEPTH: 402.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 2.8 ft.
HOLE LOGGED BY: D. Stelma/S. Acree
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES

small amount of polymer added to minimize rod chatter.

DRILL FLUID RETURN:

0.0-2.8': 100%
2.8-7.6': 40%
7.6-28.3': 80%
28.3-276.1': 0%
276.1-280.3': 5%
280.3-280.6': 0%
280.6-285.3': 5%
285.3-402.2': 0%

DRILL FLUID COLOR:

0.0-28.3': Gray
28.3-276.1': No return.
276.1-285.3': Brown.
285.3-402.2': No return.

WATER LEVELS:

Date	Hole Depth	*Water Level
4/15	2.8'	Dry
4/16	32.6'	29.3'
4/18	61.0'	Dry
4/29	92.6'	Dry
5/02	120.0'	Dry
5/09	127.6'	127.2'
5/10	156.1'	154.5'
5/11	180.0'	Dry
5/12	201.0'	200.5'
5/13	220.8'	215.2'
5/14	242.6'	230.6'
5/15	245.3'	230.6'
5/24	276.6'	262.8'
5/25	290.3'	283.6'
5/26	320.3'	>300.0'
5/27	339.9'	>300.0'
5/28	379.5'	>300.0'
5/29	402.2'	>300.0'

* Drilling fluid (water)

CASING RECORD:

Casing Depth	Interval Drilled
2.8'(4")	0.0-276.1'
276.6'(3")	276.1-402.2'

TESTING & SAMPLING:
Constant Head Permeability Test Intervals:

43.0-67.0': Could not build pressure

79.0-84.6': Gravity injection test, took capacity of pump, 60 gpm

178.1-191.0': Could not build pressure

247.3-262.6': 8.4 gpm at 40 psi (K=54 ft/yr)

279.0-295.0': 21.6 gpm at 20 psi (K=149 ft/yr)

DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION	CLASSIFICATION AND SAMPLE DESCRIPTION
220			FD5					100	100		186.0-191.0': BASALT. Black to gray, fine grained, slightly vesicular basalt. Vesicles range from 1 to 5 mm in diameter. Slightly Weathered (W3). Oxidation (iron and manganese) on most fracture surfaces, vesicles have minor palagonite infillings. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from 0.5' to 0.8', joints are generally subhorizontal. Very Intensely to Intensely Fractured (FD8) from 186.7-188.4', core recovered mostly as fragments.
225			FD5	H2	W3			100	45		
			FD7								
			FD7					100	42		
230	Tfs	Basalt	FD8	H3	W5			78	10		
			FD9	H7	W9			95	0		
235			FD7	H2	W3			100	33		
	1548.5										
			FD7								191.0-196.0': BASALT. Black to gray, fine grained, slightly vesicular basalt. Vesicles mostly 1 mm in diameter. Slightly Weathered (W3). Vesicles have minor palagonite infillings. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from 0.7' to 0.8' with a single core length of 3.0', joints are generally subhorizontal.
240			FD6					92	64		
			FD7					100	69		
245											196.0-201.0': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from 0.4' to 0.7', joints are equally subhorizontal and subvertical with slightly rough surfaces, some of the subhorizontal joints are rehealed.
250			FD4			54		97	70		
255											
260											
265			FD7					100	48		201.0-206.0': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to fracture surfaces. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Moderately Fractured (FD5). Core recovered in lengths from 0.5' to 0.7', joints are equally subhorizontal and subvertical with slightly rough surfaces.
270			FD4					90	70		206.0-211.0': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to staining on fracture surfaces. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths of about 1.0', joints are mostly subhorizontal with slightly rough surfaces.
275	Tv	Sediments	FD7	H5	W3			90	49		
280											211.0-216.0': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to staining on fracture surfaces. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Moderately Fractured (FD5). Core recovered in lengths from 0.5' to 0.7', joints are mostly subhorizontal with slightly rough surfaces.
			FD6			149					
285			FD7								
290			FD5					83	20		216.0-220.8': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to staining on fracture surfaces. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Moderately Fractured (FD5). Core recovered in lengths from 0.6' to 1.0', joints are mostly subhorizontal with slightly rough surfaces.
295											
300			FD7								220.8-222.5': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to staining on fracture surfaces. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Intensely to Moderately Fractured (FD5). Core recovered mostly in 0.2' lengths, most joint surfaces are near verticle with scattered subhorizontal joints.
305											
310	1475.4										222.5-225.2': BASALT. Black to gray, fine grained, slightly vesicular basalt. Vesicles range from 1 to 10 mm in diameter. Moderately Weathered (W5). Oxidation (iron and manganese) and palagonite cover fracture surfaces. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Intensely Fractured (FD7). Core recovered mostly as fragments.
315			FD4		W5	131					
320											225.2-227.6': BASALT. Black to gray, fine grained, slightly vesicular basalt. Moderately Weathered (W5). Oxidation (iron and manganese) limited to staining on fracture surfaces. Palagonite up to 2 mm thick present between fractures and infilling vesicles. Hard (H3). Core can be scratched with knife with heavy pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.3', joints are mostly subhorizontal with slightly rough surfaces.
325	Tgr	Basalt		H2				100	59		
330			FD3		W3						
335											227.6-232.6': BASALT. Black to gray, fine grained, slightly vesicular basalt. Moderately Weathered (W5). Oxidation (iron and manganese) limited to staining on fracture surfaces.

NENAHNEZAD WYMER.GPJ NENAHNEZAD.GDT 1/16/08

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-2

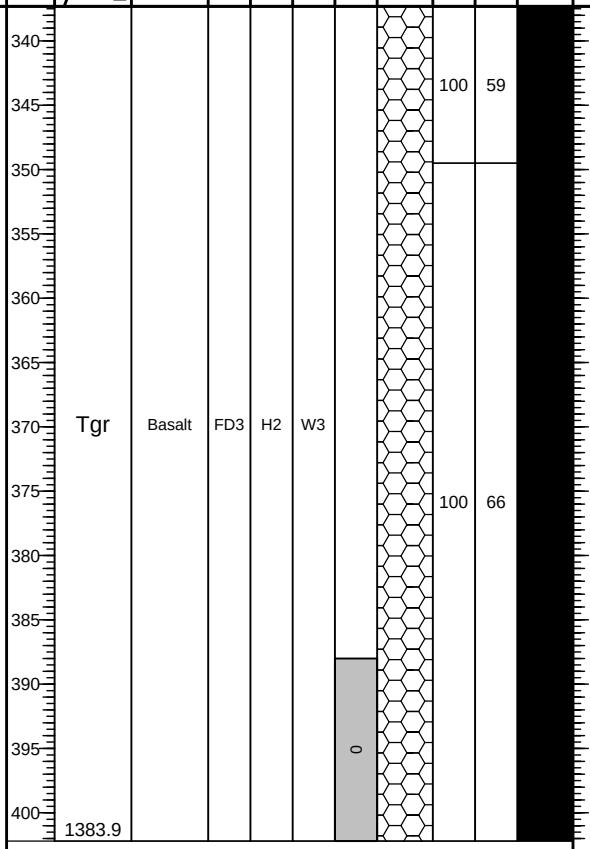
FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Wymer Damsite
COORDINATES: N 542,905 E 1,654,188
GROUND ELEVATION: 1786.1 ft. above sea level
BEGUN: 4/14/2007 FINISHED: 5/30/2007
TOTAL DEPTH: 402.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 2.8 ft.
HOLE LOGGED BY: D. Stelma/S. Acree
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES

311.0-325.3': 20 gpm at 20 psi (K=131 ft/yr)

388.0-402.2': No water take at 20 or 60 psi (K= 0 ft/yr)

HOLE COMPLETION: Pulled drill rods and backfilled hole with bentonite (swell plug).



END OF HOLE. Total Depth = 402.2 Feet

CLASSIFICATION AND SAMPLE DESCRIPTION

Palagonite up to 3 mm thick present between fractures and infilling vesicles. Hard (H3). Core can be scratched with knife with heavy pressure. Very Intensely to Intensely Fractured (FD8). Core recovered in lengths from fragments to 0.3', joints are mostly subhorizontal with slightly rough surfaces.

232.6-234.6': PALAGONITE BRECCIA. Altered (oxidixed and devitrifed) basalt consisting of Clayey Sand with Gravel (SM)g. About 45% fine to medium, predominantly coarse, hard, angular to subangular sand; about 35% fines with medium plasticity, high dry strength and no dliatancy; about 20% coarse to fine, predominantly coarse, hard, angular to subangular gravel; maximum size, 45 mm; no reaction with HCl; wet, reddish brown.

234.6-237.6': BASALT. Black to gray, fine grained, dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited to staining on fracture surfaces, some thin palagonite coatings. Very Hard (H2). Core cannot be scratched with knife with heavy pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.3', joints are mostly subhorizontal with slightly rough surfaces.

237.6-310.7': **VANTAGE SANDSTONE (Tv)** of the Miocene Ellensburg Formation. Tan to gray, moderately soft, medium to fine grained sandstone with interbedded siltstone and claystone. Descriptions are based on HQ-size core samples.

237.6-239.6': SILTSTONE. Fine grained, brown, heterogenous, well indurated silt-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.3', joints are mostly subhorizontal with slightly rough surfaces.

239.6-242.2': SANDSTONE. Fine to medium grained, reddish brown, well indurated sand and silt-size lithic fragments with pumice and ash. Moderately to Slightly Weathered (W3). Oxidation (iron and manganese) and palagonite up to 1 mm thick coat fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely to Moderately Fractured (FD7). Core recovered in 0.5' lengths, joints are mostly subhorizontal with slightly rough surfaces.

242.2-247.6': SILTSTONE. Fine grained, brown, heterogenous, well indurated silt-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely to Moderately Fractured (FD7). Core recovered in lengths from fragments to 0.3', joints are mostly dipping about 45 degrees with slightly rough surfaces.

247.6-248.8': SILTSTONE. Fine grained, brown, heterogenous, well indurated silt-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from 0.4' to 1.3, joints are mostly subhorizontal with slightly rough surfaces.

248.8-253.7': SANDSTONE. Medium grained, gray to dark brown, well indurated sand-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from 0.5' to 1.0, joints are mostly subhorizontal with slightly rough surfaces.

253.7-260.4': SILTSTONE. Fine grained, brown, heterogenous, well indurated silt-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from 0.4' to 1.0, joints are mostly subhorizontal with slightly rough surfaces. Joint at 259.9' dipping about 45 degrees with smooth straited (slickensides) surface.

260.4-262.6': SANDSTONE. Medium to fine grained, gray to

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-2

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Wymer Damsite
COORDINATES: N 542,905 E 1,654,188
GROUND ELEVATION: 1786.1 ft. above sea level
BEGUN: 4/14/2007 FINISHED: 5/30/2007
TOTAL DEPTH: 402.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 2.8 ft.
HOLE LOGGED BY: D. Stelma/S. Acree
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES	DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION	CLASSIFICATION AND SAMPLE DESCRIPTION

greenish gray, well indurated sand-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from 0.5' to 2.7, joints are mostly subhorizontal with slightly rough surfaces.

262.6-267.6': SANDSTONE. Medium to fine grained, gray to greenish gray, well indurated sand-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 1.5, joints are mostly subhorizontal with slightly rough surfaces.

267.6-272.6': SANDSTONE. Medium to fine grained, gray to greenish gray, well indurated sand-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from fragments to 3.2', joints are mostly subhorizontal with slightly rough surfaces.

272.6-273.5': CLAYSTONE. Very fine grained, greensih gray to tan, heterogenous, well indurated clay-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 1.7', joints are mostly subhorizontal with slightly rough surfaces.

272.6-276.1': SANDSTONE. Medium grained, greenish gray to tan, well indurated sand-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 1.0', joints are mostly subhorizontal with slightly rough surfaces.

276.1-278.5': SILTSTONE. Fine grained, white, well indurated silt-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from 0.2' to 0.4', joints are mostly subhorizontal with slightly rough surfaces.

278.5-281.8': SANDSTONE. Medium grained, gray, well indurated sand-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.1', joints are mostly subhorizontal with slightly rough surfaces.

281.8-285.6': SILTSTONE. Fine grained, tan to white, well indurated silt-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from 0.3' to 0.6', joints are mostly subhorizontal with slightly rough surfaces.

285.6-290.3': SANDSTONE. Medium to coarse grained, dark gray, well indurated sand-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.3', joints are mostly subhorizontal with slightly rough surfaces.

290.3-296.0': SILTSTONE. Fine grained, light gray, well indurated silt-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately Fractured

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-2

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Wymer Damsite
COORDINATES: N 542,905 E 1,654,188
GROUND ELEVATION: 1786.1 ft. above sea level
BEGUN: 4/14/2007 FINISHED: 5/30/2007
TOTAL DEPTH: 402.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 2.8 ft.
HOLE LOGGED BY: D. Stelma/S. Acree
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES	DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION	CLASSIFICATION AND SAMPLE DESCRIPTION

(FD5). Core recovered in lengths from 0.2' to 1.0', joints are mostly subhorizontal with slightly rough surfaces.

296.0-310.7': SANDSTONE. Medium to coarse grained, dark gray, well indurated sand-size lithic fragments with pumice and ash. Slightly Weathered (W3). Oxidation (iron and manganese) limited to thin staining on fracture surfaces. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from 0.1' to 0.4', joints are mostly subhorizontal with slightly rough surfaces.

310.7-402.2': **GRANDE RONDE MEMBER (Tgr)** of the Grande Ronde Basalt Formation, Miocene Columbia River Basalt Group (CRB). Black to gray, very hard, fine grained, aphanitic, slightly vesicular to dense basalt. Descriptions are based on NQ-size core samples.

310.7-320.3': BASALT BRECCIA. Brownish black fragments of vesicular basalt in a pumice and ash matrix. Moderately Weathered (W5). Extensive oxidation (iron and manganese) of matrix, vesicles contain small amouts of yellowish palagonite. Very Hard (H2). Core (including matrix) can be scratched with knife with heavy pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from fragments to .9', mostly about 0.4', the joints are randomly oriented with rough surfaces.

320.3-349.5': BASALT. Black to gray, fine grained slightly vesicular basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces, vesicles contain small amouts of yellowish palagonite. Very Hard (H2). Core can be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from fragments to 2.7, the joints are generally subhorizontal to 45 degrees with smooth surfaces.

349.5-402.2': BASALT. Black to gray, fine grained dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from 0.3' to 2.7, the joints are randomly oriented with smooth surfaces.

402.2': BOTTOM OF HOLE

STRATIGRAPHY:

0.0-2.8': SLOPEWASH (Qsw).
2.8-237.6': FRENCHMAN SPRINGS MEMBER (Tfs).
237.6-310.7': VANTAGE SANDSTONE (Tv).
310.7-402.2': GRANDE RONDE MEMBER (Tgr).

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ., WA
DH-07-2
FROM 2.8 to 47.7

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ., WA
DH-07-2
FROM 47' to 58.2


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 58² to 102⁸

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 102.8 to 114.3

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 114 3 to 125 4

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 125± to 136±

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 136º to 146º

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 146.5 to 156.1

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN, STORAGE PROJECT, WA.

DH-07-2

From 189± to 199±

WYMER DH-07-2 189±-209±

189±

189±

196±

201±

206±

209±

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJECT, WA.

DH-07-2

From 189± to 199±

WYMER DH-07-2 189±-209±

189±

196±

199±

201±

206±

209±

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJECT, WA.
DH-07-2
209.6 to 220.8

MAY 2007

WYMER DH-07-2 209.6-233.6

209.6 →

211.2

216.0

220.8

220.8 →

225.1

227.6

232.6

WYMER RESERVOIR SITE, WA
YAKIMA RIVER BASIN STORAGE PROJECT
DH-07-2
233± to 244±

WYMER DH-07-2 233'6"-244'6"

WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ - WA

DH·07·2

FROM [redacted] to

2442 - 2673

BOX 23 OF

2441→


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 267' 3" - 281' 8"
BOX ___ OF ___
YAKIMA
DH-07-2
233' 6"
BOX 21
PROJ. - WA
BOX 22
PROJ.
BOX 24


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 281B - 299G
BOX ___ OF ___


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 299½ - 315⅝
Box ___ of ___
300-1
305-1
310-1
315-1
Box 24
Box 22


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 315 1/8 - 330 1/9
Box ___ of ___
315.8
320.2
325.2
327.5
PROJ. - WA
Box 24 OF
PROJ. - WA
Box 22
PROJ. - WA
Box 23


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 330 1/2 - 345 8/10 Box ___ of ___


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 345 1/2 - 360 1/2
BOX __ OF __
WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE SITE WA.
DH 07-2
FR 330'
TO 345'
BOX 28


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 360½ - 376½
BOX ___ OF ___


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 376 3/4 - 389 1/2
Box __ of __
WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE SITE WA.
DH 07-2
FR 330'
TO 345'


WYMER RESERVOIR SITE
YAKIMA RIVER BASIN STORAGE PROJ. - WA
DH-07-2
FROM 389 9/10 - 402 2/10
Box ___ of ___

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-3

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Saddle Damsite
COORDINATES: N 546,992 E 1,654,050
GROUND ELEVATION: 1794.3 ft. above sea level
BEGUN: 6/7/2007 FINISHED: 6/21/2007
TOTAL DEPTH: 201.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 0.6 ft.
HOLE LOGGED BY: Stelma/Acree/Didricksen
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES

PURPOSE OF HOLE:

Determine engineering properties of the left abutment bedrock at the proposed Saddle Damsite (Wymer Reservoir).

DRILLED BY:

Pacific Northwest Regional Drill Crew: Chris Peterson, driller, Ben Horton and Dick Stienke, helpers.

DRILL EQUIPMENT:

CME Model 75 track-mounted rotary drill rig with casing advancer and HQ wire line coring system with a diamond impregnated bit.

DRILLING METHOD:

0.0-3.6': Advanced 4-inch I.D. surface casing using a casing advancer (wireline rockbit) using clear water as circulating fluid.

3.6-7.6': Drilled with HQ coring system using clear water as circulating fluid, advanced 4-inch casing following coring using a casing advancer (wireline rockbit) and clear water to remove cuttings.

7.6-201.2': Drilled with HQ coring system using clear water as circulating fluid.

DRILLER NOTES:

0.0-3.6: Hard and slow using casing advancer with rockbit.

3.6-62.6': Slow and moderately rough with occassional blocking using HQ coring system.

62.6-82.6': Slow and smooth using HQ coring system.

82.6-88.0': Slow and smooth with occassional blocking using HQ coring system.

88.0-126.1': Slow

DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION
0	1794.3							0		
5			FD8	H4	W5			82	0	
10					W4			92	0	
15			FD7			2659		95	17	
20								98	48	
25				H3				100	20	
30	Tfs	Basalt	FD6					100	10	
35			FD5		W4			100	44	
40			FD6					100	84	
45			FD9					100	82	
50			FD6					100	63	
55			FD6		W5			86	45	
60			FD9					100	14	
65	1731.7		FD7			1903		100	0	
70			FD8	H5	W6			100	0	
75			FD7					100	0	
80				H2				92	16	
85			FD6		W5			100	61	
90			FD6					100	56	
95			FD7		W4	1478		96	40	
100			FD7					100	23	
105	Tv	Sediments	FD6	H5				98	71	
110								100	57	
115					W5			100	88	
120			FD7					100	88	
125						612		100	72	
130			FD6					100	54	
135								100	76	

CLASSIFICATION AND SAMPLE DESCRIPTION

0.0-62.6': **FRENCHMAN SPRINGS MEMBER (Tfs)** of the Wanapum Basalt Formation, Miocene Columbia River Basalt Group (CRB). Black to gray, hard, fine grained to slightly porphyritic, vesicular to dense basalt. Descriptions are based on HQ-size core samples, drilling contions and cuttings returned. .

0.0-3.6': BASALT. Black to gray, fine grained slightly vesicular basalt. Description based on drilling conditions and cuttings returned.

3.6-10.3': BASALT. Black to gray, fine grained slightly vesicular to dense basalt. Moderately Weathered (W5). Oxidation (iron and manganese) extends from fracture surfaces into body of rock. Moderately Hard (H4). Core can be scratched with knife with moderate pressure. Very Intensely to Intensely Fractured (FD8). Core recovered mostly as chips and fragments with scattered short core lengths.

10.3-22.6': BASALT. Black to gray, fine grained moderately to slightly vesicular basalt. Moderately to Slightly Weathered (W4). Oxidation (iron and manganese) limited mainly to fracture surfaces, vesicles contain small amounts of yellowish palagonite. Moderately Hard (H4). Core can be scratched with knife with moderate pressure. Intensely to Moderately (FD6) to Intensely (FD7) Fractured. Core recovered in lengths from fragments to 0.7', mostly 0.2 to 0.4', the joints are generally subhorizontal with slightly rough surfaces.

22.6-41.6': BASALT. Black to gray, fine grained slightly vesicular to dense basalt. Moderately to Slightly Weathered (W4). Oxidation (iron and manganese) limited mainly to fracture surfaces, vesicles contain small amounts of yellowish palagonite. Hard (H3). Core can be scratched with knife with heavy pressure. Moderately (FD5) to Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.6', mostly 0.4 to 0.5', the joints are randomly oriented from subhorizontal to subvertical with slightly rough surfaces. Very Intensely Fractured (FD9) from 38.2-39.2'. Core recovered mostly as fragments.

41.6-52.6': BASALT. Black to gray, fine grained moderately vesicular to dense basalt. Moderately (W5) to Intensely to Moderately Weathered (W6). Oxidation (iron and manganese) on fracture surfaces from 1- to 5mm thick, vesicles infilled and coated with yellowish palagonite. Hard (H3) to Moderately Soft (H5). Core can be scratched with knife with heavy pressure, weathered matrix and joint surfaces scratch with moderate to light knife pressure. Intensely to Moderately Fractured (FD6) to Very Intensely to Intensely Fractured (FD8). Core recovered in lengths from fragments to 0.6', mostly fragments to 0.2', the joints are randomly oriented from subhorizontal to subvertical with moderately rough surfaces. Very Intensely Fractured (FD9) from 38.2-39.2'. Core recovered mostly as fragments.

62.6-126.1': **VANTAGE SANDSTONE (Tv)** of the Miocene Ellensburg Formation. Greenish gray, moderately soft, medium to fine grained sandstone with interbedded siltstone and claystone. Descriptions are based on HQ-size core samples.

62.6-67.6': SANDSTONE. Light greenish gray, coarse to medium grained, well indurated sand size fragments. Moderately to Slightly Weathered (W4). Oxidation (iron) coat fracture surfaces and coarser sand grains. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.9', mostly 0.3' to 0.4', the joints are mostly subhorizontal with slightly rough surfaces.

COMMENTS:

Stratigraphy based on data from: Schuster, J.E., 1994, Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-12.

Soil and bedrock descriptions based on BOR Enginering Geology Field Manual, 2nd Ed., Vol.

Abbreviations:

Rb - Rock Bit
psi - Pounds per square inch
gpm - Gallons per minute
K - Permeability expressed in feet per year

NENAHNEZAD WYMER.GPJ NENAHNEZAD.GDT 1/16/08

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-3

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Saddle Damsite
COORDINATES: N 546,992 E 1,654,050
GROUND ELEVATION: 1794.3 ft. above sea level
BEGUN: 6/7/2007 FINISHED: 6/21/2007
TOTAL DEPTH: 201.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 0.6 ft.
HOLE LOGGED BY: Stelma/Acree/Didricksen
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES

and smooth using HQ coring system.
126.1-201.2': Slow and moderately rough with occassional blocking using HQ coring system.

DRILLING FLUID:

0.0-201.2': Water.

DRILL FLUID RETURN:

0.0-7.6': 25%
7.6-22.6': 90%
22.6-36.6': 80%
36.6-41.6': 60%
41.6-46.4': 5%
46.4-49.3': 50%
49.3-52.6': 40%
52.6-57.6': 30%
57.6-62.6': 5%
62.6-67.6': 20%
67.6-72.6': 5%
72.6-201.2': 0%

DRILL FLUID COLOR:

0.0-62.6': Gray.
62.6-72.6': Tan.
72.6-201.2': No return.

WATER LEVELS:

Date 2007	Hole Depth	Water Level
6/07	3.6'	2.8'
6/08	17.6'	Dry
6/09	46.4'	Dry
6/10	67.6'	55.5'
6/11	92.6'	Dry
6/12	117.6'	106.1'
6/13	132.6'	125.7'
6/20	157.6'	145.9'
6/21	182.6'	Dry
6/22	201.2'	183.5'

CASING RECORD:

*Casing Depth	Interval Drilled
7.6'	0.0-201.2'

* 4-inch diameter steel casing (threaded)

TESTING & SAMPLING:

Constant Head Permeability Test Intervals:

17.0 - 27.6': 40 gpm at 10 psi (K=2659 ft/yr)

47.0 - 57.6': 38 gpm at 10 psi (K=1713 ft/yr)

67.0 - 77.6': 39.8 gpm at 10 psi (K=1478 ft/yr)

87.0 - 97.6': 25 gpm at 20 psi (K=612 ft/yr)

117.0 - 127.2': 1.5 gpm at 40 psi (K=22.7

DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION
105			FD6					100	76	
110			FD5					100	61	
115	Tv	Sediments		H5	W5			100	91	
120			FD4					94	74	
125	1668.2		FD6			22.7		74	44	
			FD6					100	68	
130			FD6		W5			100	60	
135			FD3					100	100	
140			FD2		W3	0		100	100	
145			FD5					100	80	
150			FD5		W4			100	82	
155			FD3					100	68	
160								100	76	
165	Tgr	Basalt	FD2	H2				100	100	
170								100	80	
175			FD6		W3			100	40	
180								100	38	
185			FD5					100	56	
190			FD7					100	57	
195			FD3					98	42	
200	1593.1							100	94	
								100	65	

END OF HOLE. Total Depth = 201.2 Feet

CLASSIFICATION AND SAMPLE DESCRIPTION

67.6-77.6': SANDSTONE. Dark greenish gray, coarse grained, well indurated sand size fragments. Moderately to Slightly Weathered (W4) to Moderately Weathered (W5). Oxidation (iron) coat fracture surfaces and coarser sand grains. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely Fractured (FD7). Core recovered in lengths from fragments to 0.5', mostly 0.2' to 0.3', the joints are randomly oriented from subhorizontal to subvertical with slightly rough surfaces.

77.6-92.6': SANDSTONE AND SILTSTONE. Light greenish gray to Dark greenish gray, well indurated medium grained sand to silt size particles. Moderately Weathered (W5). Oxidation (iron) coat fracture surfaces and some minerals altered to clay. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately (FD5) to Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.9', mostly 0.4' to 0.6', the joints are mostly subhorizontal with slightly rough surfaces. Intensely Fractured (FD7) from 88.0-89.1'. Core recovered mostly as fragments.

92.6-97.6': SANDSTONE. Dark greenish gray, coarse grained, well indurated sand size fragments. Moderately Weathered (W5). Oxidation (iron) coat fracture surfaces and coarser sand grains. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from 0.2' to 0.6', the joints are mostly subhorizontal slightly rough surfaces.

97.6-112.6': SANDSTONE AND SILTSTONE. Light greenish gray to dark greenish gray, well indurated medium grained sand to silt size particles. Moderately Weathered (W5). Oxidation (iron) coat fracture surfaces and some minerals altered to clay. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately (FD5) to Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.8', mostly 0.2' to 0.6', the joints are randomly oriented ranging from subhorizontal to subvertical with slightly rough surfaces.

112.6-117.1': SANDSTONE. Light greenish gray, medium grained, well indurated sand size fragments. Moderately Weathered (W5). Oxidation (iron) mostly on fracture surfaces with minor oxidation of coarser sand grains. Moderately Soft (H5). Core scratches with moderate knife pressure. Moderately to Slightly Fractured (FD4). Core recovered in lengths from 0.1' to 2.7', the joints are mostly subhorizontal slightly rough surfaces.

117.1-123.3': CLAYSTONE. Light greenish gray, well indurated clay size fragments. Moderately Weathered (W5). Oxidation (iron) mostly on fracture surfaces with minor oxidation of body of rock. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 1.0', the joints are mostly subhorizontal slightly rough surfaces.

123.3-126.1': SILTSTONE. Light greenish gray to dark reddish brown, thinly bedded to laminated, well indurated silt size fragments. Moderately Weathered (W5). Oxidation (iron) mostly on fracture surfaces with minor oxidation of body of rock. Moderately Soft (H5). Core scratches with moderate knife pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.5', the joints are mostly subhorizontal slightly rough surfaces.

126.1-201.2': **GRANDE RONDE MEMBER (Tgr)**of the Grande Ronde Basalt Formation, Miocene Columbia River Basalt Group (CRB). Black to bluish gray, very hard, fine grained, aphanitic, slightly vesicular to dense basalt. Descriptions are based on HQ-size core samples.

126.1-129.7': BASALT. Black to gray, fine grained vesicular basalt. Moderately Weathered (W5). Oxidation (iron and manganese) limited mainly to fracture surfaces, vesicles contain small amouts of yellowish palagonite. Very Hard (H2). Core can be scratched with knife with heavy pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from fragments to 0.4', the joints are generally subhorizontal with moderately rough surfaces.

129.7-134.3': BASALT. Black to gray, fine grained vesicular basalt. Slightly Weathered (W3). Oxidation (iron and

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-3

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Saddle Damsite
COORDINATES: N 546,992 E 1,654,050
GROUND ELEVATION: 1794.3 ft. above sea level
BEGUN: 6/7/2007 FINISHED: 6/21/2007
TOTAL DEPTH: 201.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 0.6 ft.
HOLE LOGGED BY: Stelma/Acree/Didricksen
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES	DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION	CLASSIFICATION AND SAMPLE DESCRIPTION

ft/yr)

132.0 - 142.6': No water take at 10, 20 or 40 psi (K= 0 ft/yr)

HOLE COMPLETION: Pulled drill rods and backfilled hole with bentonite (swell plug).

manganese) limited mainly to fracture surfaces, vesicles contain small amouts of yellowish palagonite. Very Hard (H2). Core can be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from 0.3' to 4.7', the joints are generally subhorizontal with moderately rough surfaces.

134.3-142.6': BASALT. Black to gray, fine grained dense to slightly vesicular basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Slightly to Very Slightly Fractured (FD2). Core recovered in lengths from 0.6' to 4.7', the joints are generally subhorizontal with slightly rough surfaces.

142.6-147.2': BASALT. Black to gray, fine grained slightly vesicular basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Moderately Fractured (FD5). Core recovered in lengths from 0.1' to 1.4', the joints are generally subhorizontal with slightly rough surfaces. Basalt Breccia from 146.3-146.5'. Angular sand-size (5 mm) basalt fragments in a hard green (clorite) matrix.

147.2-150.6': BASALT. Black to gray, fine grained vesicular basalt. Moderately to Slightly Weathered (W4). Oxidation (iron and manganese) limited mainly to fracture surfaces with scattered thin soil zones. Very Hard (H2). Core can be scratched with knife with heavy pressure. Moderately Fractured (FD5). Core recovered in lengths from fragments to 0.8', the joints are randomly oriented with slightly rough surfaces.

150.6-157.6': BASALT. Black to gray, fine grained slightly vesicular basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from 0.3' to 2.2', the joints are randomly oriented with slightly rough surfaces.

157.6-168.2': BASALT. Black to gray, fine grained dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Slightly to Very Slightly Fractured (FD2). Core recovered in lengths from 0.3' to 2.2', the joints are randomly oriented with slightly rough surfaces.

168.2-178.6': BASALT. Black to gray, fine grained dense to slightly vesicular basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Intensely to Moderately Fractured (FD6). Core recovered in lengths from 0.1' to 0.5', mostly less than 0.3', the joints are randomly oriented with slightly rough surfaces.

178.6-186.0': BASALT. Black to gray, fine grained dense to slightly vesicular basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Moderately Fractured (FD5). Core recovered in lengths from 0.1' to 1.2', the joints are randomly oriented with slightly rough surfaces.

186.0-191.2': BASALT. Black to gray, fine grained dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Moderately Fractured (FD7). Core recovered in lengths from 0.1' to 0.5', the joints are generally subhorizontal with slightly rough surfaces.

191.2-201.2': BASALT. Black to gray, fine grained dense basalt. Slightly Weathered (W3). Oxidation (iron and manganese) limited mainly to fracture surfaces. Very Hard (H2). Core can be scratched with knife with heavy pressure. Slightly Fractured (FD3). Core recovered in lengths from 0.2' to 3.4', the joints are mostly subhorizontal to approximately 45 degrees with slightly rough surfaces.

201.2': BOTTOM OF HOLE

STRATIGRAPHY:

GEOLOGIC LOG OF DRILL HOLE NO. DH-07-3

FEATURE: Wymer Reservoir and Pumping Plant Sites
PROJECT: Yakima R. Basin Water Storage Feasibility Study
STATE: Washington
LOCATION: Upper Left Abutment - Saddle Damsite
COORDINATES: N 546,992 E 1,654,050
GROUND ELEVATION: 1794.3 ft. above sea level
BEGUN: 6/7/2007 FINISHED: 6/21/2007
TOTAL DEPTH: 201.2 ft.
ANGLE FROM HORIZONTAL: -90°
DEPTH TO WATER & ELEVATION: Not encountered
DEPTH TO BEDROCK: 0.6 ft.
HOLE LOGGED BY: Stelma/Acree/Didricksen
TOP OF CASING ELEVATION: N/A
REVIEWED BY: D. Bennett

NOTES	DEPTH	GEOLOGIC UNIT / ELEVATION	ROCK TYPE	ENGINEERING PROPERTIES: Fracture Density	Hardness	Weathering	Permeability (Feet/Year)	GRAPHIC	% RECOVERY	RQD	HOLE COMPLETION	CLASSIFICATION AND SAMPLE DESCRIPTION
												0.0-62.6': FRENCHMAN SPRINGS MEMBER (Tfs). 62.6-126.1': VANTAGE SANDSTONE (Tv). 126.1-201.2': GRANDE RONDE MEMBER (Tgr).

WYMER DAM & RESERVOIR SITE
YAKIMA RIVER STORAGE SITE, WA
DH-07-3
3' to 36'
6-12-07

WYMER DAM & RESERVOIR

YAKIMA RIVER STORAGE SITE, WA.

DH-07-3

6-12-07

36.6 to 59.0

wymer Reservoir Site

WYMER DAM & RESERVOIR

YAKIMA RIVER STORAGE SITE, WA.

DH-07-3

59° to 81½

6-12-07

WYMER Reservoir Site

WYMER DAM & RESERVOIR SITE
YAKIMA RIVER STORAGE SITE, WA
DH-07-3
81 4/5 to 114 5/5
6-13-07


WYMER RESERVOIR SITE
YAKIMA RIVER STORAGE SITE WA.
DH07-3
FR 114 5/
TO 126 3/
DH-07-3 114 5/ - 126 3/


WYMER RESERVOIR SITE
YAKIMA RIVER STORAGE SITE WA
DH 07-3
FR 126 3/
TO 137 1/
DH-07-3 126 3/ - 137 1/


WYMER RESERVOIR SITE
YAKIMA RIVER STORAGE SITE WASH.
DH07-3
DH-07-3 137½-147⅔


WYMER RESERVOIR SITE
YAKIMA RIVER STORAGE SITE WA.
DH07-3.
FR 147 2/3 TO 157 6/6
DH-07-3 147 2/3 - 157 6/6


WYMER RESERVOIR SITE
YAKIMA RIVER STORAGE SITE WA
DH07-3
EX 157½ to 168½
BOX 15 of
DH-07-3 157⅙-168⅔


WYMER Reservoir Site
YAKIMA RIVER STORAGE SITE WDA.
DH 07-3
FR 168 2/ to 178 6/
DH-07-3 168 2/ - 178 6/


WYMER Reservoir Site
YAKIma RIVER Storage SITE WA.
DH07-3
FR 178 6/
TO
DH-07-3 178 6 - 190 2
BOX 17


WYMER Reservoir site
YAKIMA River Storage Site WA.
DH 07-3
FR 190 Z To 201 Z
DH-07-3 190Z-201Z
07 18

DH-84-1 Sheet 1 of 3

WYMER DAMSITE
Yakima Enhancement Project, Washington

SUMMARY LOG

Drill Hole No. DH-84-1 Location Right Abutment Elevation 1901.6

Total Depth 174.7' Water Table 138.6', 6-14-84

Log:

0.0-0.5': SLOPEWASH. Silty sand with basalt fragments.
0.5-96.5': MIOCENE FRENCHMAN SPRINGS BASALT MEMBER.
0.5-4.0': Basalt. Dark gray, stained with limonite, moderately hard, intensely fractured, some fractures filled with up to 1/16" thick silt.
4.0-14.2': Basalt. Dark gray, moderately vesicular, moderately hard, recovered in pieces from fragments up to 1.0', average 0.3' (moderately fractured). Major fractures dip 20-30° and are filled with up to 1/4" of brown-orange palagonite. Vesicles are also filled with palagonite.
14.2-21.5': Basalt. Dark gray with iron and manganese staining, nonvesicular, moderately hard, moderately fractured at all angles, however, prominent fractures dip 30° and are filled with up to 1/4" of soft, brown and white palagonite.
21.5-28.0': Basalt. Similar to 4.0-14.2' section.
28.0-35.4': Basalt and Basalt Breccia. Intensely fractured, altered with breccia intermixed with soft, white to yellow palagonite. Individual basalt fragments are moderately hard but core can easily be broken in hands. Recovered in fragments up to core pieces 0.1', random fractures.
35.4-37.2': Basalt. Light gray to red, intensely fractured, soft.
37.2-51.6': Basalt. Dark gray, moderately vesicular with vesicles up to 1/2", most filled with palagonite. Intensely fractured from fragments up to 0.5', average 0.1'. Random fracturing but some prominent fractures dip 20-30°, most fractures filled with up to 1/8" palagonite. There is some infilling of brown chalcedony up to 1" thick. Moderately soft, can be broken with light hammer blow.
51.6-71.0': Basalt. Dark gray, slightly vesicular, lightly weathered, moderately fractured, mostly random but prominent fractures dip 30-45° and are filled with up to 1/2" of white and yellow, soft palagonite, recovered in pieces from 0.1' to 1.0', mostly 0.3'. Moderately hard to moderately soft requiring light hammer blow to break.
71.0-79.0': Basalt. Dark gray, moderately vesicular and amygdaloidal with fillings of soft, brown, yellow, and white palagonite. Core contains some scattered sections of basalt breccia-angular basalt fragments in a palagonite matrix. Moderately fractured, fracture spacing from 0.1' to 0.4', mostly random but major fractures 10-45°. Moderately hard.

79.0-96.5': Basalt and Basaslt Breccia. Gray to brown, slightly vesicular. Intensely fractured from fragments up to 0.5', averaging 0.1', random fractures but major fractures dip 30-45° and are filled with up to 1/4" of palagonite. Palagonite breccia sections of core predominant 80.0-80.5' 83.6-84.0' and 94.0-94.4'. Lost all drill water at 83.5' in prominent, open, iron and manganese stained fracture with dip of about 45°.

96.5-167.3': MIOCENE VANTAGE SANDSTONE MEMBER

96.5-99.0': Tuff. White to yellow. Intensely fractured from fragments up to 0.2', random fractures mostly filled with palagonite up to 1/8", soft to very soft.

99.0-105.0': Sandstone. Light to dark gray, fine to medium grained. Friable, can easily be broken in the hands. Contains some organic material.

105.0-121.0': Claystone. Mostly light gray with some iron staining, faint stratification normal to core, moderately soft to soft, can be scratched with fingernail. Contains twigs and other organic matter.

121.0-126.5': Sandstone. Medium grained, light gray, friable, can be broken in hands. Faint stratification normal to core.

126.5-136.0': Claystone and Siltstone. Moderately soft to soft.

136.0-143.0': Sandstone. Medium grained, dark gray to brown, contains some claystone. Soft to moderately soft.

143.0-152.5'; Siltstone and Claystone. Dark gray to black. Soft to moderately soft, carbonaceous.

152.5-167.3': Siltstone. Dark gray to black, carbonaceous (resembles low grade coal, leaves oily residue on hands), slacks, soft to moderately soft.

167.3-174.7': MIOCENE MUSEUM BASALT MEMBER. Dark gray, moderately vesicular, hard, fresh, moderately fractured.

Water Return

0.0- 8.3	100%
8.3-23.8	90%
23.8-28.0	50%
28.0-33.5	40%
33.5-44.7	20%
44.7-64.7	0%
64.7-69.2	80%
69.2-74.1	30%
74.1-79.0	75%
79.0-81.1	60%
81.0-174.5	0%

Depth to Water

Depth of Hole	Depth of Casing	Depth of Water
28.0	1.2	Dry
49.2	1.2	Dry
64.7	1.2	41.9
64.7	25.0	48.2
65.1	58.0	45.9
79.0	58.0	48.4
98.8	58.0	87.0
151.1	58.0	122.8
174.7	58.0	139.0
174.7	0.0	138.6

DH-84-1 Sheet 3 of 3

Percolation Tests

Depth	Pressure	Loss GPM
0.0-49.0	G	22.0
0.0-64.7	G	23.0
60.9-69.2	32	1.75
	42	1.75
68.5-79.0	28	1.8
	50	5.3
75.4-85.9	0	35.0
95.8-161.1	Falling Head Test	
	Minutes	Depth
	0	61.0
	2' 8"	83.0
	2' 18"	83.0
	3' 18"	83.3
	9' 0"	84.2
	14' 0"	86.3

DH-84-2 Sheet 1 of 2

WYMER DAMSITE
Yakima Enhancement Project, Washington

SUMMARY LOG

Drill Hole No. DH-84-2 Location Left Abutment Elevation 1856.3

Total Depth 290.4'

Log:

0.0-3.8': SLOPEWASH. Silty sand with basalt fragments.
3.8-290.4': MIOCENE FRENCHMAN SPRINGS MEMBER
3.8-79.0': Basalt. Gray-brown, lightly to highly vesicular up to 1/2", some vesicles filled with yellow and brown palagonite. Intensely to moderately fractured at random orientation, but major joints are high angle and filled with palagonite up to 1/8". Moderately hard.
79.0-10.7': Basalt. Light gray-brown. Intensely fractured in all directions but prominent fractures are normal to core. Most fractures are filled with palagonite up to 1/8" thick. Moderately hard.
108.7-154.4': Basalt. Gray-brown. Moderately fractured, most fractures are stained with Fe and Mn oxides. Moderately hard.
154.4-164.6': Basalt. Dark gray, fairly fresh appearing. Moderately fractured, most fractures dip 30^{0} and 60^{0} and are stained with Fe and Mn oxides and some palagonite. Mostly hard.
164.6-167.0': Agglomerate. Cinder-like material in brown tuff matrix. Intensely fractured, moderately soft.
167.0-172.4'; Basalt. Similar to section from 154.4-164.6'.
172.4-173.6': Agglomerate. Similar to 164.6-167.0' section.
173.6-181.5': Basalt. Dark gray to black, fresh, hard, moderately fractured, fractures at all angles but prominent fractures 60^{0} dip.
181.5-222.4': Basalt. Dark gray to reddish gray, lightly to moderately vesicular. Moderately fractured with Fe and Mn oxide staining in fractures. Hard to moderately hard.
222.4-266.0': Basalt. Dark gray, scattered vesicles up to 1/4" across. Moderately to locally intensely factured, most fractures are stained with Fe and Mn oxides and some are filled with palagonite up to 1/4". Hard to moderately hard.
266.0-273.6': Basalt Breccia. Dark gray vesicular basalt fragments in matrix of reddish brown palagonite. Moderately fractured, moderately soft.
273.6-290.4': Basalt. Dark gray to black, nonvesicular, intensely fractured, moderately hard.

DH-84-2 Sheet 2 of 2

Water Return

0.0- 8.8'	100%
8.8-23.3'	90%
23.3-47.0'	80%
47.0-56.0'	85%
56.0-86.3'	90%
86.3-100.2'	95%
100.2-112.9'	85%
112.9-138.3'	90%
138.3-146.9'	80%
146.9-195.5'	75%
195.5-210.1'	70%
210.1-227.4'	75%
227.4-265.7'	80%
265.7-280.5'	75%
280.5-290.4'	0%

Depth to Water

Depth of Hole	Depth of Casing	Depth of Water
8.8	3.8	Dry
37.7	3.8	Dry
65.1	3.8	46.0
81.6	3.8	76.2
108.7	3.8	96.4
131.4	3.8	118.1
143.6	3.8	Dry
155.4	3.8	154.7
173.6	3.8	167.6
195.5	3.8	183.6
210.1	3.8	187.6
227.4	3.8	208.9
256.1	3.8	254.7
265.7	3.8	235.7
287.0	3.8	Dry
287.0	0.0	Dry

Percolation Tests

Depth	Pressure	Loss GPM
5.1-18.7	25	11.6
17.5-33.0	40	2.1
31.5-47.0	25	1.6
	50	7.1
46.8-65.1	25	2.1
	50	5.5
65.0-81.6	50	2.6
	75	4.2
81.0-100.2	50	4.8
	75	10.0
99.4-117.6	60	1.3
	100	2.6
117.5-138.3	70	39.6
137.2-155.4	45	29.0
	95	44.9
150.9-173.6	50	5.0
	85	30.3
73.0-195.5	G	5.2
154.3-225.7	50	6.3
	78	13.2
	90	31.7
225.0-256.1	G	8.7

Falling Head Test

Time	Depth
0	280.6
1 min	280.9
2 min	281.6
3 min	281.6
4 min	282.0
6 min	282.3
12 min	282.8

WYMER DAMSITE
YAKIMA RIVER BASIN WATER ENHANCEMENT PROJECT
WASHINGTON

SUMMARY LOG

Drill Holes

Drill Hole DH-85-1

Location: Right valley bottom on axis
Coordinates: N13,600 AND E11,000
Elevation: 1323 feet
Water Table: Artesian water of about 20 gal/min encountered at about 39.8-48.7'

Log:
0.0-18.7': ALLUVIUM. Mostly sand, gravel and cobbles.
18.7-50.5': MIOCENE MUSEUM BASALT MEMBER.
- 18.7-34.0': Basalt. Dark gray, hard, moderately vesicular, intensely to moderately fractured, moderately weathered.
- 34.0-50.5': Basalt. Black, Very hard, dense, lightly fractured.

Drill Hole DH-85-2

Location: Left valley bottom, 760 ft. upstream of axis
Coordinates: N13,535 and E11,850
Elevation: 1335 feet
Water Table: Artesian water of about 23 gal/min encountered at about 30.6-34.8'

Log:
0.0-19.4': ALLUVIUM. Mostly sand, gravel and cobbles.
19.4-34.6': MIOCENE MUSEUM BASALT MEMBER.
- 19.4-26.7': Basalt. Dark gray, hard, slightly vesicular, moderately fractured, tightly to moderately weathered.
- 26.7-34.6': Basalt. Dark gray to black, hard, dense, moderately to lightly fractured.

Drill Hole DH-85-3

Location: Right valley bottom, 760 ft. upstream of axis
Coordinates: N13,650 and E11,800
Elevation: 1336 feet
Water Table: 7.0 ft.

Log:
0.0-18.6': ALLUVIUM. Mostly sand, gravel and cobbles.
18.6-23.8': MIOCENE MUSEUM BASALT MEMBER.
- 18.6-23.8': Basalt. Black, very hard, dense, lightly weathered to fresh, lightly to moderately fractured.

Drill Hole DH-85-4

Location: Middle of saddle at dike site.
Coordinates: N17,450 and E12,300
Elevation: 1604.5 feet
Water Table: Dry

Log:
0.0-13.8': SLOPEWASH. Mostly angular basaltic fragments of sand, gravel, and cobble size.
13.8-42.9': MIOCENE MUSEUM BASALT MEMBER
- 13.8-20.0': Basalt. Dark gray to brown, fairly hard, intensely fractured, moderately weathered.
- 20.0-24.8': Basalt. Gray-brown, moderately to intensely weathered, scoriaceous, fragmental.
- 24.8-27.5': Tuff. Brown, soft to medium.
- 27.5-35.0': Basalt. Dark gray, mostly hard, vesicular to locally scoriaceous, moderately to intensely fractured.
- 35.0-42.9': Basalt. Dark gray, medium to moderately hard, slightly vesicular, moderately fractured.

TP-85-1, TP-85-2, TP-85-3 and TP-85-4 Sheet 1 of 1

Test Pits

Test Pit TP-85-1 (Hand Dug)

Location: Left abutment
Coordinates: N13,090 and E11,270
Elevation: 1490 feet

Log:
0.0-5.0': SLOPEWASH. Gravel size fragments of basalt in a silty soil matrix. Stopped on hard, platy basalt.

Test Pit TP-85-2 (Hand Dug)

Location: Right abutment
Coordinates: N14,420 and E10,590
Elevation: 1545 feet

Log:
0.0-2.0': SLOPEWASH. Silty sand, gravel and cobbles, probably derived from the Vantage sandstone member.

Test Pit TP-85-3 (Hand Dug)

Location: Right abutment
Coordinates: N14,680 and E10,490
Elevation: 1610 feet

Log:
0.0-3.0': SLOPEWASH. Silty sand, gravel and cobbles, probably derived from the Vantage sandstone member.

Test Pit TP-85-4 (Hand Dug)

Location: Right abutment
Coordinates: N14,825 and E10,550
Elevation: 1630 feet

Log:
0.0-1.5': SLOPEWASH. Cobble size fragments of angular basalt, stopped on basalt bedrock

Appendix B

Drawings

33-100-5869	Wymer Dam and Reservoir – Geologic Plan Map, Locations of Explorations and Geologic Sections, General Geologic Legend, Explanation and Notes (2007)
33-100-5870	Wymer Dam and Reservoir – Geologic Sections A-A', B-B' and C-C' (2007)
40-D-7022	Geology for Design & Specifications - Standard Descriptors and Descriptive Criteria for Rock
40-D-7023	Geology for Design & Specifications - Standard Descriptors and Descriptive Criteria for Discontinuities

Notes:

1. Topography generated from U.S.G.S. 10 meter NED (National Elevation Data) set.

2. Drill holes were located by the Ephrata Field Office survey crew using global positioning system (GPS) methods. Horizontal control is Washington State Plane Coordinate System NAD83. Vertical control is NAVD29

3. All locations, distances and measurements are approximate.

4. For geologic sections refer to drawing 33-100-5870.

5. Surface geology, stratigraphy and geologic unit descriptions based partially on interpretations presented in the following reports:

Schuster, J.E., 1994, Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington, Washington Division of Geology and Earth Open file Report 94-12, Olympia, WA.

Magleby, D.N., 1958, Addendum No. 1, Geologic report for Wymer Damsite, Yakima River Basin Water enhancement Project, Washington , U.S.D.I., U.S.B.R., Pacific Northwest Region, Division of Geology and Construction, Geology Branch, Boise, ID.

Magleby, D.N., 1954, Geologic report for Wymer Damsite, Yakima River Basin Water enhancement Project, Washington , U.S.D.I., U.S.B.R., Pacific Northwest Region, Division of Geology and Construction, Geology Branch, Boise, ID.

GENERAL GEOLOGIC LEGEND

F — Road Fill. Undifferentiated gravel, sand, fines and cobbles, and asphalt surfacing that forms State Highway 821.

Qal — Quaternary Alluvium. Yakima River and Limuma Creek alluvial deposits consisting of gravel, sand and fines with cobbles. The alluvium overlies the bedrock adjacent to the Yakima River in the pumping plant area (DH-07-1) and in the valley section of the dam along Limuma Creek (DH-85-4).

Qsw — Quaternary Slopewash. Surface materials (not shown) mantling the bedrock. Consists of soil and weathered rock deposits on slopes and within small side drainages, covers most surfaces throughout the study area, consists of gravel sand and fines with cobbles and scattered boulders. Includes talus deposits. Slopewash was encountered in most of the holes drilled at the dam and dike sites, and was sampled in hand-dug test pits (TP-85-1 thru 4) at the dam site.

Qaf — Quaternary Alluvial Fan. Alluvial deposits consisting of sand and gravel at the bases of drainages on the west side of the Yakima River.

Ql — Quaternary Loess. Windblown silty sand deposits blanketing the lower slopes and terraces east of the Yakima River at the mouth of Limuma Creek.

Qls — Landslides. Landslide deposits consisting of clay, silt, sand and gravel generally associated with failure of lower strength sedimentary interbeds.

Tertiary Columbia River Basalt Group – Wanapum Formation

Trz — Ross Basalt. Gray to black, reddish brown weathered, fine to medium grained basalt with plagioclase phenocrysts, often well developed colonnade with columns up to 1 meter in diameter. The Ross was not encountered in drill holes, but is exposed in outcrops near DH-84-2, about 2700 southeast of the upper left abutment of the dam.

Tfs — Frenchman Springs Basalt. Black to gray, fine grained, aphanitic, very hard (N12), jointing is variable, but the core generally ranged from intensely (FI37) to moderately fractured (FI25), and moderately (WS) to slightly weathered (W3). The Frenchman springs is composed of multiple flows is highly permeable based on drilling fluid losses and constant head water tests. The unit was encountered in drill holes on the upper left abutment at the dam (DH-07-2) site, the upper left abutment at the dike (DH-07-3), and in drill holes on the upper abutments at the upper dam site (DH-85-1 and -2).

Ellensburg Formation

Tv — Vantage Sandstone. Tan to gray, medium to fine grained, moderately soft (N5), tuffaceous (ash and pumice) sandstone with interbedded siltstone and claystone. The Vantage interbed occurs stratigraphically between the Frenchman Springs and Grande Ronde Basalt units. Based on constant head water tests conducted in drill holes the Vantage has low permeability. The interbed is present near the middle left abutment (DH-07-2) and upper right abutment at the dam site, near the upper left abutment (DH-07-3) at the dike site, and in drill holes on the upper abutments at the upper dam site (DH-85-1 and -2).

Tertiary Columbia River Basalt Group – Grande Ronde Formation

Tgr — Grande Ronde Basalt. Black to gray, fine grained, hard (N3) to very hard (N2), mostly slightly fractured (FI13), and slightly weathered (W3). Based on constant head water tests conducted in drill holes the Grande Ronde has low permeability. The Grande Ronde basalt underlies the alluvium adjacent to the Yakima River at the pumping plant site (DH-07-1), and forms the lower abutments and valley sections of the dam (DH-07-2 and DH-85-1) and dike (DH-07-3 and DH-85-4) sites. The unit was also encountered in drill holes at the upper dam site (DH-85-1 and -2).

GENERAL GEOLOGIC EXPLANATION

- Approximate geologic contact
- DH-07-2 — Drill hole location and designation.
- TP-85-2 — Test pit location and designation.
- A — A' — Geologic section location and designation.
- DH-07-2 — Drill hole designation.
- El. 1788.1 — Elevation of ground surface.
- (Proj. 17 NE) — Distance and direction of projection (if projected)
- Tfs
- 237.5 — Depth to geologic contact.
- Tv
- 310.7
- Tgr — Geologic unit.
- 402.2 — Total depth of drill hole.

N

500 0 500 1000 1500

SCALE OF FEET

Contour Interval = 10 feet

Notes:

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN STORAGE STUDY – WASHINGTON

WYMER DAM AND RESERVOIR
GEOLOGIC PLAN MAP,
LOCATIONS OF EXPLORATIONS AND GEOLOGIC SECTIONS, GENERAL GEOLOGIC LEGEND, EXPLANATION AND NOTES

GEOLOGY D.MAGLEBY, D.STELMA CHECKED

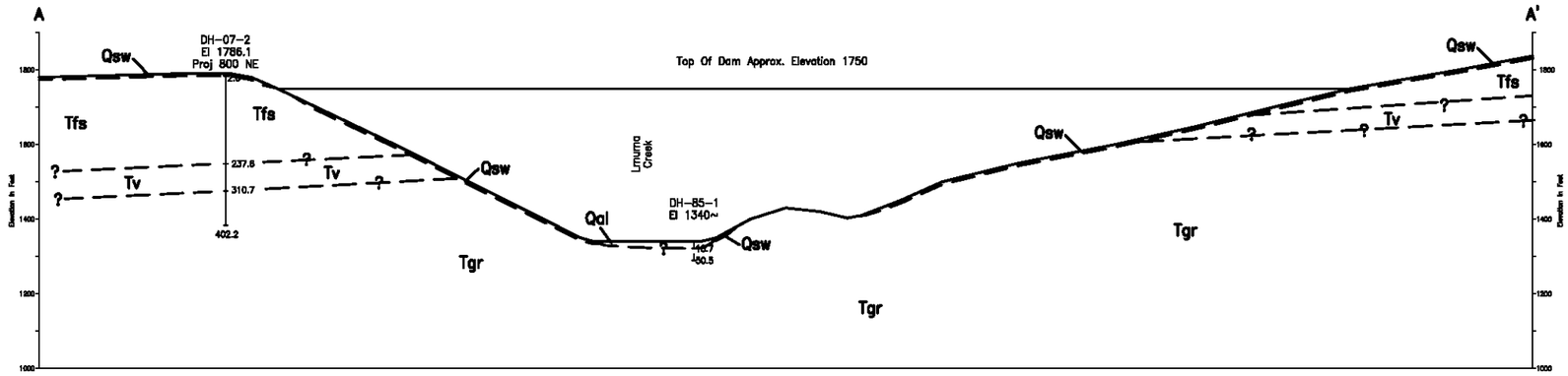
DRAWN T.ENGLAND, D.STELMA TECH. APPR.

APPROVED
PEER REVIEWER – REGIONAL GEOLOGIST

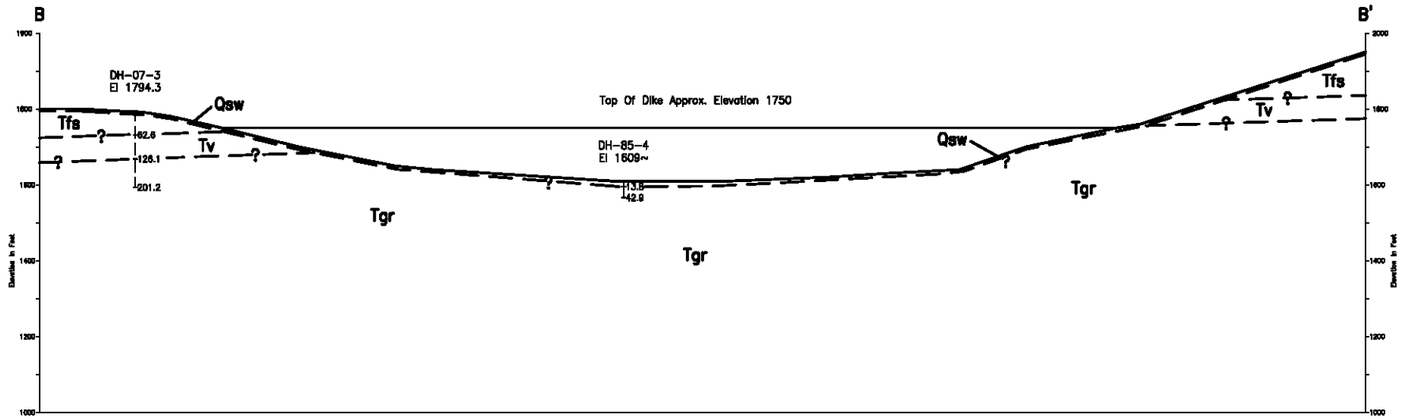
CAD SYSTEM ACAD 2008 | geo\wymer\dwgs\33-100-5869

BOISE, IDAHO SHEET 1 OF 1 2007, OCTOBER 26

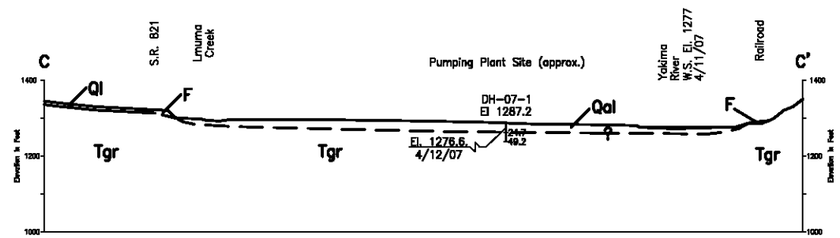
33-100-5869



GEOLOGIC SECTION A–A' – DAM



GEOLOGIC SECTION B–B' – DIKE



GEOLOGIC SECTION C–C' – PUMPING PLANT

Notes:

1. Drill holes were located by the Ephrata Field Office survey crew using global positioning system (GPS) methods. Horizontal control is Washington State Plane Coordinate System NAD83. Vertical control is NAVD29
2. For locations of geologic sections refer to drawing 33–100–5869.
3. For geologic explanation refer to drawing 33–100–5869.
5. Stratigraphy and geologic unit descriptions based partially on interpretations presented in the following reports:

Schuster, J.E., 1994, Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington, Washington Division of Geology and Earth Open File Report 94–12, Olympia, WA.

Mogleby, D.N., 1988, Addendum No. 1, Geologic report for Wymer Damsite, Yakima River Basin Water enhancement Project, Washington , U.S.D.I., U.S.B.R., Pacific Northwest Region, Division of Geology and Construction, Geology Branch, Boise, ID.

Mogleby, D.N., 1984, Geologic report for Wymer Damsite, Yakima River Basin Water enhancement Project, Washington , U.S.D.I, U.S.B.R., Pacific Northwest Region, Division of Geology and Construction, Geology Branch, Boise, ID.

200 0 200 400 600
SCALE OF FEET

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DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
YAKIMA RIVER BASIN STORAGE STUDY – WASHINGTON

WYMER DAM AND RESERVOIR

GEOLOGIC SECTIONS A–A', B–B' AND C–C'

GEOLOGY D.STELMA CHECKED
DRAWN T.ENGLAND, D.STELMA TECH. APPR.
APPROVED
FIELD REVIEWER – REGIONAL GEOLOGIST

CAD SYSTEM ACAD 2008 | geo\wymer\dwgs\33-100-5870
BOISE, IDAHO SHEET 1 OF 1 2007, OCTOBER 26 | 33-100-5870

WEATHERING

FRESH (W1): Body of rock is not oxidized or discolored; fracture surfaces are not oxidized or discolored*; no separation of grain boundaries; no change of texture and no solutioning. Hammer rings when crystalline rocks are struck.

SLIGHTLY WEATHERED TO FRESH (W2): **

SLIGHTLY WEATHERED (W3): Discoloration or oxidation is limited to surface of, or short distance from fractures; some feldspar crystals are dull; fracture surfaces have minor to complete discoloration or oxidation; no visible separation of grain boundaries; texture preserved and minor leaching of soluble minerals may be present. Hammer rings when crystalline rocks are struck, body of rock is not weakened by weathering.

MODERATELY TO SLIGHTLY WEATHERED (W4): **

MODERATELY WEATHERED (W5): Discoloration or oxidation extends from fractures, usually throughout body of rock; ferromagnesian minerals are "rusty", feldspar crystals are "cloudy"; all fracture surfaces are discolored or oxidized; partial opening of grain boundaries visible; texture generally preserved, but soluble minerals may be mostly leached. Hammer does not ring when rock is struck, body of rock is slightly weakened.

INTENSELY TO MODERATELY WEATHERED (W6): **

INTENSELY WEATHERED (W7): Body of rock is discolored or oxidized throughout; all feldspars and ferromagnesian minerals are altered to clay to some extent. All fracture surfaces are discolored or oxidized, and friable; partial separation of grain boundaries, rock is friable; in situ disaggregation of granitics common in semi-arid regions; texture altered and leaching of soluble minerals may be complete. Rock has dull sound when struck with hammer; rock is weakened, usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness.

VERY INTENSELY WEATHERED (W8): **

DECOMPOSED (W9): Body of rock is discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspars and ferro-magnesian minerals are completely altered to clay; complete separation of grain boundaries (disaggregated), partial or complete remnant rock structure may be preserved, but resembles a soil.

NOTE: Weathering categories are established primarily for crystalline rocks and those with ferromagnesian minerals, weathering in various sedimentary rocks will not always fit the categories established - weathering categories may be modified for particular site conditions or alteration such as hydrothermal alteration. Where modified criteria are established, they should be identified and described.

* Characteristics of fracture surfaces do not include directional weathering along shears or faults and their associated fracture zones; for example a shear that carries weathering to great depths in a fresh rock mass would not require the whole rock mass to be classified as weathered.

** Combination descriptors are used when equal distribution of both weathering characteristics are present over significant intervals or where characteristics noted are "in between" the diagnostic characteristics.

DURABILITY INDEX

DURABILITY DESCRIPTOR	DESCRIPTIVE CRITERIA
DI0/	Rock specimen or exposure remains intact with no deleterious cracking after exposure longer than 1 year.
DI1	Rock specimen or exposure develops hairline cracking on surfaces within 1 month, but no disaggregation within 1 year of exposure.
DI2	Rock specimen or exposure develops hairline cracking on surfaces within 1 week, and/or disaggregation within 1 month of exposure.
DI3	Specimen or exposure may develop hairline cracks in 1 day and displays pronounced separation of bedding and/or disaggregation within 1 week of exposure.
DI4	Specimen or exposure displays pronounced cracking and disaggregation within 1 day (24 hours) of exposure. Generally ravels and degrades to small fragments.

COLOR

The Munsell color system (Geologic Society of America Rock Color Chart) should be used. This system defines wet color by its hue, value, and chroma. Color symbols used (i.e., 5 YR 5/6 may be included).

SEDIMENTARY AND PYROCLASTIC ROCK PARTICLE SIZES

Size in mm	Sedimentary Rounded, subrounded, subangular		Pyroclastic	
	Particle or fragment	Lithified product	Fragment	Lithified product
256	Boulder	Boulder conglomerate	Block[a] or Bomb[b]	Volcanic[a] breccia or Volcanic[b] agglomerate
64	Cobble	Cobble conglomerate		
4	Pebble	Pebble conglomerate	Lapilli	Lapillistone and Lapilli tuff
2	Granule	Granule conglomerate		
1	Very coarse sand	Sandstone (Very coarse, coarse, medium, fine, or very fine)	Coarse ash	Coarse tuff
0.5	Coarse sand			
0.25	Medium sand			
0.125	Fine sand			
0.0625	Very fine sand			
0.00391	Silt	Siltstone/ Shale	Fine ash	Fine tuff
	Clay	Claystone Shale		

(a) Broken from previous igneous rock, block shaped (angular to subangular).
(b) Solidified from plastic material while in flight, rounded clasts.

IGNEOUS AND METAMORPHIC ROCK TEXTURE

TEXTURE DESCRIPTOR	AVERAGE GRAIN DIAMETER
VERY COARSE GRAINED OR PEGMATITIC	>10 mm [>3/8 in]
COARSE GRAINED	5-10 mm [3/16 -3/8 in]
MEDIUM GRAINED	1-5 mm [1/32 -3/16 in]
FINE GRAINED	0.1-1 mm [0.004 - 1/32 in]
APHANITIC (Cannot be seen with the unaided eye)	<0.1 mm [<0.004 in]

ADDITIONAL TEXTURAL ADJECTIVES

PIT (pitted) - pinhole to 0.03 ft [3/8 in] (<1 to 10 mm) openings.

VUG (vuggy) - Small openings (usually lined with crystals) ranging in diameter from 0.03 ft [3/8 in] to 0.33 ft [4 in] (10 to 100 mm).

CAVITY - An opening larger than 0.33 ft [4 in] (100 mm), size descriptions are required, and adjectives such as small, large, etc., may be used.

HONEYCOMBED - If numerous enough that only thin walls separate individual pits or vugs, this term further describes the preceding nomenclature to indicate cell-like form.

VESICLE (vesicular) - Small openings in volcanic rocks of variable shape and size formed by entrapped gas bubbles during solidification.

BEDDING FOLIATION OR FLOW TEXTURE

DESCRIPTORS	THICKNESS/SPACING
MASSIVE	Greater than 10 ft (>3 m)
VERY THICKLY (bedded, foliated or banded)	3 to 10 ft (1 to 3 m)
THICKLY	1 to 3 ft (300 mm to 1 m)
MODERATELY	0.3 to 1 ft (100 to 300 mm)
THINLY	0.1 to 0.3 ft (30 to 100 mm)
VERY THINLY	0.03 [3/8 in] to 0.1 ft (10 to 30 mm)
LAMINATED (intensely foliated or banded)	Less than 0.03 ft [3/8 in] (<10 mm)

BEDROCK HARDNESS/STRENGTH

EXTREMELY HARD (H1): Core, fragment or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.

VERY HARD (H2): Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.

HARD (H3): Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.

MODERATELY HARD (H4): Can be scratched with knife or sharp pick with light or moderate pressure. Core or fragment breaks with moderate hammer blow.

MODERATELY SOFT (H5): Can be grooved 1/16 inch (2 mm) deep by knife or sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.

SOFT (H6): Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.

VERY SOFT (H7): Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.

Any bedrock unit softer than H7, Very Soft, is to be described using USBR 5005-86 (visual classification of soils) consistency characteristics.

REV NO.	DATE / BY	DESCRIPTION
1	3-8-00 D - P. M. R.	CONVERTED ORIGINAL DRAWING 40-D-8483 TO ACAD, CHANGED DWG. NO., MINOR REVISIONS.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY FOR DESIGN & SPECIFICATIONS

STANDARD DESCRIPTORS AND DESCRIPTIVE CRITERIA FOR ROCK

GEOLOGY NOMENCLATURE COMMITTEE — CHECKED CHUCK SULLIVAN
DRAWN MARSHALL MONSON — TECH. APPROVAL PETER M. ROHRER
APPROVED MARK McKEOWN
FROM RETRIEVED

CADD SYSTEM	CADD FILENAME	DATE AND TIME PLOTTED
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40-D-7022

DISCONTINUITY TERMINOLOGY

DISCONTINUITY – A collective term used for all structural breaks in geologic materials which usually are unhealed and have zero or low tensile strength. Discontinuities also may be healed and exhibit high tensile strength. Discontinuities comprise fractures (including joints), planes of weakness, shears/faults, and shear/fault zones. Contacts between various units also may be considered discontinuities.

FRACTURE – A term used to describe any natural break in geologic material excluding shears and shear zones. Additional fracture terminology is provided below.

SHEAR – A structural break where differential movement has taken place along a surface or zone of failure by shear; characterized by striations, slickensides, gouge, breccia, mylonite, or any combination of these. Often direction, amount of displacement, and continuity may not be known because of limited exposures or observations.

FAULT – A shear with significant continuity which can be correlated between observations; occurs over a significant portion of a given site, foundation area, or region; or is a segment of a fault or fault zone defined in the literature. The designation of a shear as a fault or fault zone is a site-specific determination.

SHEAR/FAULT ZONE – A shear that is expressed in relative terms of width. The zone may consist of gouge, breccia, or many related faults or shears together with fractured and crushed rock between the shears and faults, or any combination of these. In the literature many fault zones simply are referred to as faults.

SHEAR-/FAULT-DISTURBED ZONE – An associated zone of fractures and/or folds adjacent to a shear or shear zone where the country rock has been subjected to only minor cataclastic action and may be mineralized. If adjacent to a fault or fault zone, the term is fault-disturbed zone. Occurrence, orientation, and areal extent of these phenomena depend upon depth of burial (pressure and temperature) during shearing, brittleness of materials, and the stress envelope.

FRACTURE TERMINOLOGY

EXAMPLES SHOWN FOR CORE, BUT APPLICABLE TO ANY OBSERVATION

JOINT (JT) – A relatively planar fracture along which there has been little or no shearing displacement.

FOLIATION JOINT (FJ) OR BEDDING JOINT (BJ) – a relatively planar fracture which is parallel to foliation or bedding along which there has been little or no shearing displacement.

BEDDING PLANE SEPARATION – A separation along bedding after extraction or exposure due to stress relief or slaking.

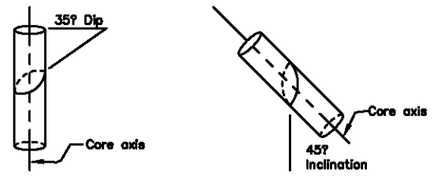
INCIPIENT JOINT (IJ) OR INCIPIENT FRACTURE (IF) – A joint or fracture which does not continue through the specimen or at least is not seen with the naked eye. However, when the specimen is wetted, and then allowed to dry, the joint or fracture trace is evident. When core is broken, it breaks along an existing plane.

RANDOM FRACTURE (RF) – A natural break which does not belong to a joint set, and which exhibits a generally rough, very irregular, nonplanar surface.

MECHANICAL BREAK (MB) – A break due to drilling, blasting, or handling. Mechanical breaks parallel to bedding or foliation are called Bedding Breaks (BB) or Foliation Breaks (FB), respectively. Recognizing mechanical breaks may be difficult. The absence of oxidation, staining, or mineral fillings, and often a hackly or irregular surface are clues for recognition.

FRACTURE ZONE (FZ) – Numerous, very closely spaced intersecting fractures. Often fragmented core cannot be fitted together.

METHOD OF MEASURING DIP OF PLANAR DISCONTINUITIES, FOLIATION, AND BEDDING IN CORE

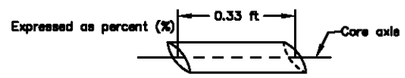


1. Vertical hole – true dip is measured and reported.
2. Angle hole – true dip usually not known; angle is measured from core axis and is called inclination.

ROCK QUALITY DESIGNATION (RQD)

EXAMPLE SHOWN FOR CORE, BUT APPLICABLE TO ANY LINEAR OBSERVATION

$$RQD = \frac{\text{Sum of length of solid core pieces} > 0.33 \text{ ft [4 in] (100 mm) long}}{\text{Length of the run in feet (mm)}} \times 100$$



FRACTURE FREQUENCY

FRACTURE FREQUENCY – The number of natural fractures occurring within a base length or core run. The number of fractures is divided by the length and is reported as fractures per foot or fractures per meter. Expressed as 3/m or 6/ft.

FRACTURE DENSITY

FRACTURE DENSITY – Based on the spacing of all natural fractures in an exposure or core recovery lengths in boreholes; excludes mechanical breaks, shears, and shear zones; however, shear-disturbed zones (fracturing outside the shear) are included. Descriptors for fracture density apply to all rock exposures such as tunnel walls, dozer trenches, outcrops, or foundation cut slopes and inverts, as well as boreholes. Descriptive criteria presented below are based on borehole cores where lengths are measured along the core axis. For other exposures the criterium is distance measured between fractures (size of blocks).

UNFRACTURED (FD0): No fractures.

VERY SLIGHTLY FRACTURED (FD1): Core recovered mostly in lengths greater than 3 feet (1 m).

SLIGHTLY TO VERY SLIGHTLY FRACTURED (FD2) *

SLIGHTLY FRACTURED (FD3): Core recovered mostly in lengths from 1 to 3 feet (300 to 1000 mm) with few scattered lengths less than 1 foot (300 mm) or greater than 3 feet (1000 mm).

MODERATELY TO SLIGHTLY FRACTURED (FD4) *

MODERATELY FRACTURED (FD5): Core recovered mostly in 0.3- to 1.0-foot (100- to 300-mm) lengths with most lengths about 0.6 foot (200 mm).

INTENSELY TO MODERATELY FRACTURED (FD6) *

INTENSELY FRACTURED (FD7): Lengths average from 0.1 to 0.3 foot (30 to 100 mm) with scattered fragmented intervals. Core recovered mostly in lengths less than 0.3 foot (100 mm).

VERY INTENSELY TO INTENSELY FRACTURED (FD8) *

VERY INTENSELY FRACTURED (FD9): Core recovered mostly as chips and fragments with a few scattered short core lengths.

* Combinations of fracture densities (e.g., Very Intensely to Intensely Fractured or Moderately to Slightly Fractured) are used where equal distribution of both fracture density characteristics are present over a significant interval or exposure, or where characteristics are "in between" the descriptor definitions.

FRACTURE SPACING

JOINT SET, OR FRACTURE SPACING DESCRIPTOR	TRUE SPACING
EXTREMELY WIDELY SPACED (SP1)	Greater than 10 ft (>3 m)
VERY WIDELY SPACED (SP2)	3 to 10 ft (1 to 3 m)
WIDELY SPACED (SP3)	1 to 3 ft (300 mm to 1 m)
MODERATELY SPACED (SP4)	0.3 to 1 m (100 to 300 mm)
CLOSELY SPACED (SP5)	0.1 to 0.3 ft (30 to 100 mm)
VERY CLOSELY SPACED (SP6)	less than 0.1 ft (<30 mm)

FRACTURE CONTINUITY

CONTINUITY DESCRIPTOR	DISCONTINUITY LENGTH
DISCONTINUOUS (C1)	Less than 3 ft (<1 m)
SLIGHTLY CONTINUOUS (C2)	3 to 10 ft (1 to 3 m)
MODERATELY CONTINUOUS (C3)	10 to 30 ft (3 to 10 m)
HIGHLY CONTINUOUS (C4)	30 to 100 ft (10 to 30 m)
VERY CONTINUOUS (C5)	Greater than 100 ft (>30 m)

FRACTURE ENDS (JOINT SURVEYS)

FRACTURE ENDS DESCRIPTOR	DESCRIPTIVE CRITERIA
E0	Zero ends leave the exposure (both ends can be seen).
E1	One end of the fracture terminates in the exposure (one end can be seen).
E2	Neither fracture end terminates in the exposure (neither end can be seen).

FRACTURE OPENNESS OR FILLING THICKNESS

FILLING THICKNESS DESCRIPTOR	THICKNESS/OPENNESS	OPENNESS DESCRIPTOR
CLEAN (T0)	No film or coating.	
	No visible separation.	TIGHT (O0)
VERY THIN (T1)	Less than 0.003 ft [1/32 in] (<1 mm).	SLIGHTLY OPEN (O1)
MODERATELY THIN (T2)	0.003 to 0.01 ft [1/32 to 1/8 in] (1 to 3 mm).	MODERATELY OPEN (O2)
THIN (T3)	0.01 to 0.03 ft [1/8 to 3/8 in] (3 to 10 mm).	OPEN (O3)
MODERATELY THICK (T4)	0.03 ft [3/8 in] to 0.1 ft (10 to 30 mm).	MODERATELY WIDE (O4)
THICK (T5)	Greater than 0.1 ft (>30 mm) Actual thickness or openings recorded.	WIDE (O5)

FRACTURE MOISTURE CONDITIONS

MOISTURE DESCRIPTOR	DESCRIPTIVE CRITERIA
M1	The fracture is dry. It is tight or filling (where present) is of sufficient density or composition to impede waterflow. Waterflow along the fracture does not appear possible.
M2	The fracture is dry with no evidence of previous waterflow. Waterflow appears possible.
M3	The fracture is dry, but shows evidence of waterflow such as staining, leaching and/or vegetation.
M4	The fracture or filling (where present) is damp, but no free water is present.
M5	The fracture shows seepage. It is wet with occasional drops of water.
M6	The fracture emits a continuous flow (estimate flow rate) under low pressure. Filling materials (where present) may show signs of leaching or piping.
M7	The fracture emits a continuous flow (estimate flow rate) under moderate to high pressure. Water is squirting and/or filling material (where present) may be substantially washed out.

FRACTURE ROUGHNESS

Refers to small-scale asperities of surfaces, not large-scale undulations or waviness.

STEPPED (R1): Near-normal steps and ridges occur on the fracture surface.
ROUGH (R2): Large, angular asperities can be seen.
MODERATELY ROUGH (R3): Asperities are clearly visible and fracture surface feels abrasive.
SLIGHTLY ROUGH (R4): Small asperities on the fracture surface are visible and can be felt.
SMOOTH (R5): No asperities, smooth to the touch.
POLISHED (R6): Extremely smooth and shiny.

FRACTURE SURFACE AND/OR FILLING ALTERATION AND HARDNESS

Descriptors for weathering or alteration of fracture surfaces and fracture fillings (excluding soil materials) are the same as those used for weathering and alteration of rock.

Descriptors for hardness/strength of fillings and/or fracture surfaces are the same as those presented for hardness of rock and consistency of soils.

DISCONTINUITY HEALING

TOTALLY HEALED (HL1) – All fragments bonded, discontinuity is completely healed or recemented to a degree at least as hard as surrounding rock.

MODERATELY HEALED (HL3) – Greater than 50 percent of fractured or sheared material, discontinuity surfaces or filling is healed or recemented; and/or strength of healing agent is less hard than surrounding rock.

PARTLY HEALED (HL5) – Less than 50 percent of fractured or sheared material, discontinuity surface or filling is healed or recemented.

NOT HEALED (HL6) – Discontinuity surface, fractured zone, sheared material or filling is not healed or recemented, rock fragments or filling (if present) held in place by their own angularity and/or cohesiveness.

SHEAR/FAULT DESCRIPTORS

SHEAR/FAULT GOUGE CONSISTENCY

DESCRIPTOR	DESCRIPTIVE CRITERIA (similar to consistency of soils)
VERY HARD	Gouge cannot be broken with finger pressure; cannot be indented with fingernail.
HARD	Gouge can be broken with firm finger pressure; can be indented with fingernail; cannot be indented with thumb.
FIRM	Gouge can be easily crumbled; can be indented with thumb 1 to 5 mm.
SOFT	Gouge can be easily molded; can be penetrated with thumb 5 to 25 mm.
VERY SOFT	Gouge can be penetrated with thumb more than 25 mm.

SHEAR/FAULT MOISTURE DESCRIPTORS

The apparent moisture content of gouge is described as WET (visible free water); MOIST (damp, but no visible water); and DRY (absence of moisture, dusty, dry to the touch). Moisture descriptors M1 through M7 may be used to describe the shear or shear zone.

BRECCIA SHAPES

Angular . . . . . .
Subangular . . . . . .
Subrounded . . . . . .
Rounded . . . . . .
Platy . . . . . .
Lens-shaped . . . . . .
Wedge-shaped . . . . . .
Contorted . . . . . .

REV NO.	BY	DATE	CHECKED	DESCRIPTION
1	D - P. M. R.	3-8-00		CONVERTED ORIGINAL DRAWING 40-D-8498 TO ACAD, CHANGED DWG. NO., MINOR REVISIONS.

ALWAYS THINK SAFETY

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

GEOLOGY FOR DESIGN & SPECIFICATIONS

STANDARD DESCRIPTORS AND DESCRIPTIVE CRITERIA FOR DISCONTINUITIES

GEOLOGY NOMENCLATURE COMMITTEE — CHECKED CHUCK SULLIVAN
DRAWN MARSHALL MONSON — TECH. APPROVAL PETER M. BOHRER
APPROVED MARK McKENNA, PEER REVIEWER

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