United States Department of the Interior

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In Reply Refer To:

18 FEB 2010

3000 (920) (P)

Memorandum

To: Eagle Lake Field Manager

From: Acting Deputy State Director, Energy and Minerals

Subject: Eagle Lake Water Budget

At your request, I have completed the analysis of the water budget for Eagle Lake. My report of this analysis is attached.

Please do not hesitate to contact me if you have any questions or need additional information.

Attachment: Eagle Lake Water Budget Report (14 pages)

Eagle Lake Water Budget

The Eagle Lake Field Manager has requested a water budget analysis of Eagle Lake relative to surface and subsurface water inflow and outflow. The purpose of this analysis is to provide a hydrologic analysis of Eagle Lake and the Bly Tunnel that may assist the field office in determining the disposition of water flow through an 8-inch diameter outlet pipe built into the concrete plug located in the Bly Tunnel. In preparation for this analysis, I reviewed available information and reports regarding Eagle Lake and the Bly Tunnel and made a site visit to Eagle Lake and the Bly Tunnel with field office staff on November 2 and 3, 2009. No specific field measurements were made as part of this evaluation. Specific references and/or reports used in this analysis are listed at the end of this report.

PHYSICAL SETTING

Eagle Lake is located in northeastern California about 16 miles north of Susanville. Since the lake sits in a closed drainage basin that has no surface outlet with limited surface water flowing into it, the surface area and lake level of the lake fluctuates with seasonal and annual variations in precipitation. Generally the lake covers roughly 16,000-29,000 acres and has over 100 miles of shoreline. Recent lake levels measured by Lassen County Public Works in October, 2009 indicated a lake elevation of 5096 feet. At this elevation, the surface area of the lake is approximately 21,500 acres.

The Bly Tunnel was constructed in 1923 to divert water from Eagle Lake for irrigation in the Honey Lake Valley area. The tunnel is 7,300 feet long, extending from the inlet point near Miner's Point on Eagle Lake in a southeasterly direction to the outlet portal at Murrers Upper Meadow and Willow Creek. The tunnel construction details are described in previous reports, including the 1972 California Department of Water Resources report, the 1974 BLM EA (EA # CA-026-06), and the 1983 BLM geologic report on the tunnel. Details of previous water diversions through the tunnel and water appropriations associated with the tunnel are discussed in the State Water Resources Control Board letter dated June 1, 2009. It is important to note that during original tunnel construction, a zone of excessive subsurface seepage was encountered at about 300 feet from Eagle Lake; and may be the current source of seepage into the tunnel. This condition caused a modification of the original tunnel construction to the portion adjacent to Eagle Lake, involving an increase in the inclination of the tunnel, lining the tunnel with a 60-inch corrugated metal pipe, and raising the final elevation so as to have the tunnel inlet near the lake surface at the time. In the 1980's the BLM constructed a permanent concrete plug at the approximate half-way point in the tunnel. An outlet pipe (8-inches in diameter) was built into the concrete plug to accommodate existing private water rights, as stated in the California State Water Resources Control Board letter dated June 1, 2009. The outlet pipe has a valve than can be opened or closed.

REGIONAL AND LOCAL GEOLOGY

Eagle Lake is in an area between geomorphic provinces considered to have physical characteristics most similar to the volcanic Modoc Plateau, merging with the Basin and Range Province on the east, and the Cascade Province on the west and the Sierra Nevada on the south.

The principal rock units at Eagle Lake and the surrounding area are Quaternary age sedimentary lake deposits consisting of thin-bedded clay, silt, and sand material deposited by sedimentation in Eagle Lake; and Recent to Pliocene age volcanic rocks consisting basalts, and layered pyroclastic rocks (volcanic ash and tuff). Details of the geology of the Eagle Lake basin and the Bly Tunnel are adequately described in a number of reports referenced at the end of this report. It is important to note the following information relative to this analysis.

- The volcanic basalt rocks in the area are hard and dense and generally have low porosity and permeability, resulting in limited groundwater flow through the basalt.
- Pyroclastic volcanic rocks, such as ash and tuff layers which are contained within the basalt rocks tend to be more porous and permeable. These rocks have greater porosity and permeability.
- The more recent (10,000-20,000 years before present) near surface basalts and pyroclastic deposits contain significant zones of fractures and joints, which tend to act as pathways for groundwater flow. There does not appear to be any specific pattern, orientation, or trend to the fractures and joints.
- Lava tubes within the basalts have been noted in water well completion reports in the area. These features also act as avenues for groundwater flow.
- Northwest and north trending faults are mapped within the basalt and pyroclastic units. These fault zones can act as either barriers or conduits to groundwater flow. Faults with intense zones of fracturing and fissuring are permeable zones conducive to groundwater flow. Fault zones that offset rock units and contain fractures that are cemented or filled with clay materials create barriers to groundwater flow. Both of these conditions exist in the Eagle Lake area.
- The complex geologic structure, consisting of the varying fracture and jointing patterns, lava tubes, and fault zones make it very difficult to predict the flow and movement of groundwater.
- The geologic conditions described above result in the conclusion that the groundwater and surface water associated with Eagle Lake are probably interconnected. The extent of the direct effect of groundwater on lake level and the amount of water in Eagle Lake is not known due to complex geologic conditions and limited data.

HYDROLOGY OF EAGLE LAKE

The following factors and assumptions pertain to the surface and subsurface hydrology of the lake:

- The surface area of the lake fluctuates between about 16,000 and 24,000 acres, depending upon lake levels.
- The drainage basin is estimated to be about 435 square miles.

- The principal surface water tributary to Eagle Lake is Pine Creek. Minor tributaries are Papoose and Merrill Creeks.
- Estimated average annual surface inflow to Eagle Lake is 11,400 acre feet/year(af/yr) (1960-68 recorded flows primarily from Pine Creek, DWR, 1972)
- Annual precipitation at the lake is an average 18 inches/yr (range = 12-24")(DWR, 1972)
- At 18 inches per year, direct precipitation onto the lake is calculated to be 32,250 af/yr, assuming a 5096 foot lake elevation (18" X 21,500 af) (DWR, 1972)
- Average annual evaporation at the lake is measured to be 42 in/yr (for the period 1875-1970, DWR, 1972)
- At 42 inches per year, evaporation on the lake is estimated to be an average of 75,250 af/yr, assuming a 5096 lake elevation (42" X 21,500 af) (DWR, 1972)
- Groundwater inflow beneath the lake is estimated to be 41,000 af/yr (DWR estimate of Ave. Annual Inflow 1970-75=52,400 af, therefore 52,400 – 11,400 (surface inflow) = 41,000 af/yr, source BLM EA)
- Eagle Lake Groundwater Basin – The principal water bearing units in the groundwater basin are the Quaternary lake deposits and the underlying basalt flows. The basalt units are highly jointed and contain lava tubes. Recharge to the aquifer is percolation of runoff in the uplands to the west into the highly permeable young basalts and related pyroclastic volcanic rocks. The direction of groundwater flow is generally to the east-northeast. (DWR, Bulletin 118)

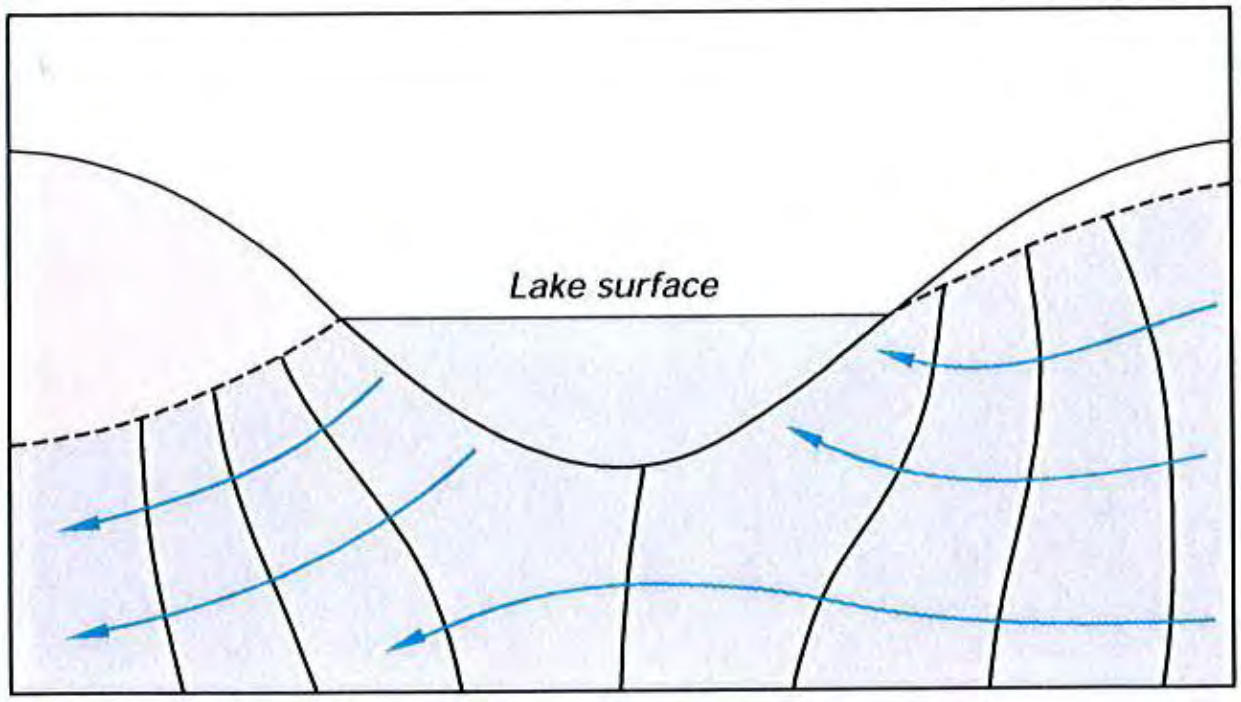


Figure A – Generalized diagram of the lake-groundwater model for Eagle Lake. Arrows indicate the direction of groundwater flow. (Source, USGS Circular # 1139)

- Figure A represents a possible model of surface water-groundwater interaction at Eagle Lake. Generally, the lake receives groundwater flows through the lakebed, and has seepage loss to groundwater in other sections of the lakebed. Groundwater enters the lake from upland area sources within fractured and fissured basalt flows generally from the west. Groundwater seepage flows out of the lake through fractured volcanic rocks and fault zones generally on the east side.
- Average annual consumption from water wells located in the Eagle Lake Groundwater Basin (Source: DWR, Bulletin 118, California's Groundwater, 2003) is 837 af/yr.
- Calculated(estimated) natural groundwater outflow beneath lake is 8563 af/yr:

  total inflow - evaporation – groundwater consumption = groundwater outflow

  84650 af/yr – 75250 af/yr – 837 af/yr = 8563 af/yr.
- The Lassen County Public Works Department has periodically measured Eagle Lake levels at the Gallatin Marina Gauging Station since 1990. The department also maintains historic lake level data back to 1916. This data was reviewed on a graph (dated June 17, 2009) prepared by the County. This data indicates that lake level fluctuations generally coincide with historic California drought periods identified as follows. Thus, there appears to be a correlative relationship between drought periods and lake levels.

  1918-1920 3 years

  1922-1924 3 years

  1929-1934 6 years

  1947-1950 4 years

  1959-1961 3 years

  1976-1977 2 years

  1987-1992 6 years

  2007-2009 2 years +

  Source: California Dept. of Water Resources, Drought Preparedness

Bly Tunnel Hydrology

- Outflow through the 8-inch pipe at the plug in Bly Tunnel – Varies from 1.5 cfs up to 10 cfs – Annual flows are estimated varying from 1086 af/yr @ 1.5cfs to 7240 af/yr @ 10cfs. These flows depend on variations in water pressure that builds up behind the tunnel plug.
- When groundwater percolation increases within the upper sections of the tunnel, the water pressure builds up at the plug, thus increasing the flow through the 8-inch pipe.

- Visual measurement made on Nov. 3, 2009 of outflow through the 8-inch pipe = 1040 gpm (measured 20 inches horizontal distance at a 12 in drop, assume a full 8-inch pipe; using a pipe flow measurement chart in the Johnson Well Handbook) (1 cubic foot per second = 449 gallons per minute, therefore, 1040 gpm = 2.3 cfs = 1665 af/yr)
- The current low level of Eagle Lake and the blocked condition at the tunnel inlet portal eliminates the possibility that surface water from Eagle Lake is directly flowing into the tunnel. Thus, there currently is no lake water directly entering the Bly Tunnel.
- The Bly Tunnel most likely taps groundwater flows, as shown on Figure A, above. Due to a lack of data and direct observation, it is difficult to determine the amount of groundwater that originates from Eagle Lake, the Eagle Lake groundwater basin, or other sources.
- The tunnel acts as a horizontal water well intersecting groundwater within the fractured and faulted basalts along the unlined sections at the upper end of the tunnel.

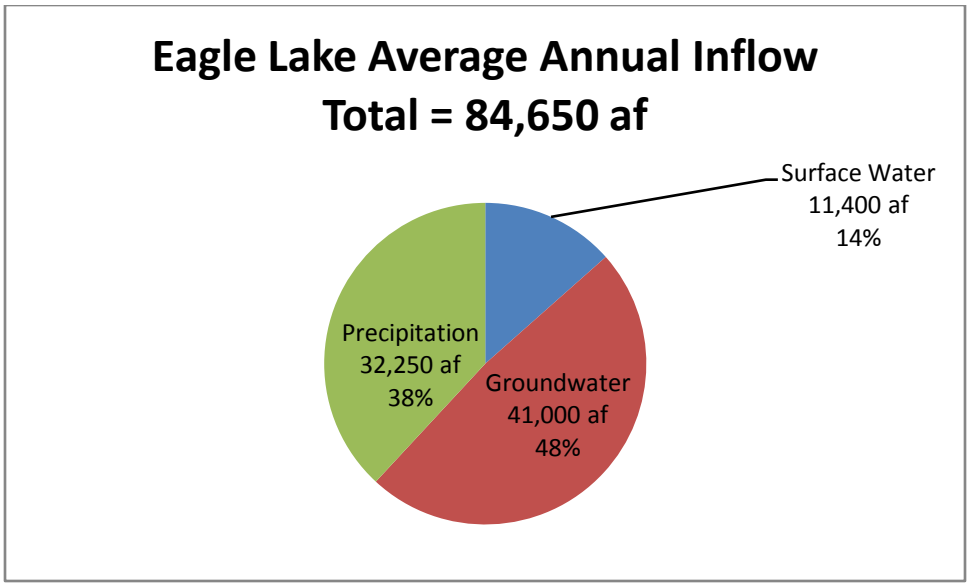
EAGLE LAKE WATER BUDGET

A water budget reflects the relationship between input and output of water for Eagle Lake. This water budget considers both groundwater and surface water. Inflow to the lake includes surface inflow, direct precipitation, and groundwater inflow beneath the lake. Outflow from the lake includes direct evaporation, groundwater usage, groundwater outflow.

The inflow and outflow factors used are average values and include the following assumptions. It should be noted that actual values can vary greatly depending on climatic variations.

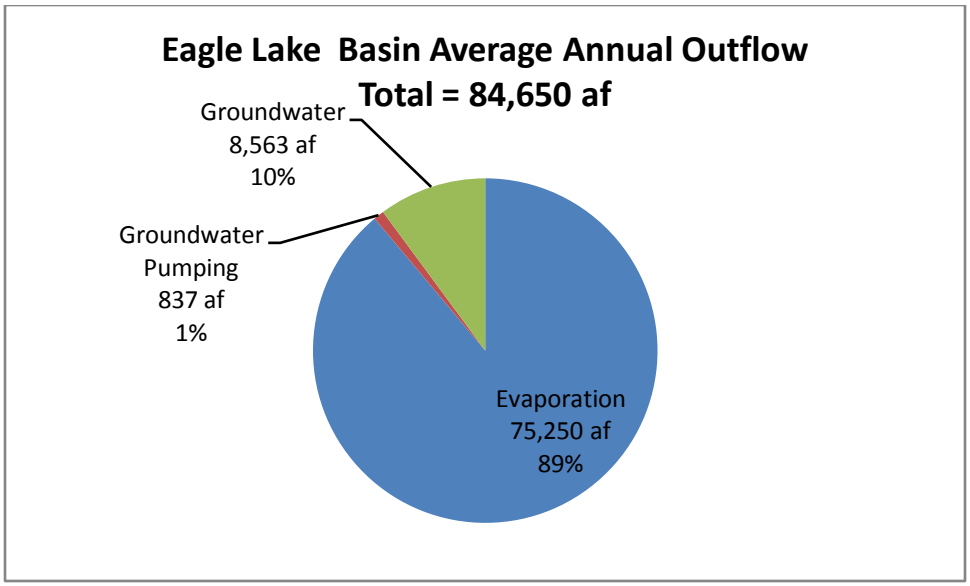
Inflow:

- Surface inflow: Surface inflow is primarily from Pine Creek with minor amounts from Papoose and Merrill Creeks. The value utilized (11,400 af/yr) is an average based on DWR recorded flows over an eight year period 1960-68.
- Direct precipitation: The value is based on an average annual precipitation of 18 inches (DWR, 1972) at the lake. A lake surface area of 21,500 acres was calculated based on Figure 1 in the 1972 DWR report relating Eagle Lake elevations to area and capacity, assuming a lake elevation of 5096 feet.
- Groundwater inflow: This is a calculated estimate. There have been no direct measurements of groundwater inflow into the lake. References report that "underground springs" feed the lake, however, these features have not been observed or measured. Groundwater inflow is calculated by subtracting annual surface inflow from annual total inflow (determined from DWR's estimate of average total inflow from 1970 to 1975). 52,400 af/yr – 11,400 af/yr = 41,000 af/yr



Outflow:

- Direct evaporation – Lake evaporation is an average of 42 inches per year reported by DWR, 1972. The average annual amount of water evaporated from the lake is 75,250 af/yr @ 5096 lake elevation (42" X 21,500 af). Lake evaporation is the largest outflow value in the Eagle Lake water budget, representing an average 89% of the total outflow. Factors affecting evaporation include temperature, wind, and exposed lake surface area.
- Groundwater usage – 837 af/yr, mainly agricultural and municipal water well uses. The source is this data is DWR, Bulletin 118, California's Groundwater.
- Groundwater outflow – This is a calculated estimate of subsurface waters that percolate through the fractured and faulted volcanic rocks. According to Bulletin 118, the groundwater gradient is generally east to northeast, thus it is assumed that groundwater outflow (average = 8563 af/yr) would be toward the east/northeast away from Eagle Lake.
- Bly Tunnel Outflow – A subset of the groundwater outflow is the Bly Tunnel. As indicated previously, the Bly Tunnel acts as a horizontal water well intersecting groundwater within the fractured and faulted basalts along the unlined sections at the upper end of the tunnel. Reports indicate that the flow through rate of the 8-inch pipe located at the plug ranges from 1.5 cfs to 10 cfs. The range of water flowing through the pipe on an annual basis is calculated to be 1,086 af/yr @ 1.5 cfs to 7,240 af/yr @ 10 cfs. This outflow represents 1.3% of the total lake outflow for 1,086 af/yr on the low side of the range and 8.6% of the total lake outflow for 7,240 af/yr on the high side of the range.



EAGLE LAKE – BLY TUNNEL INTERACTION

The water flowing through the Bly Tunnel 8-inch pipe is clearly not directly tapping the surface water in Eagle Lake. The groundwater flowing out of Eagle Lake (see Figure A, above) includes water in Eagle Lake and/or percolating groundwater in the Eagle Lake groundwater basin. The Bly Tunnel intersects this groundwater. It is impossible to calculate the representative amounts of groundwater outflow contributed from Eagle Lake and other subsurface groundwaters.

REFERENCES:

1. Eagle Lake Alternative Plans for Controlling Lake Levels, California Department of Water Resources, Northern Region, November, 1972.

2. Environmental Analysis Record, Eagle Lake Tunnel Hazard Reductions & Seal, BLM, Eagle Lake Field Office, 1973, amended 1985.

3. Geology of the Eagle Lake Tunnel, by Ron Smith, Susanville District Geologist, dated May 3, 1983.

4. California State Water Resources Control Board, Division of Water Rights, letter dated June 1, 2009.

5. California's Groundwater, Department of Water Resources Bulletin 118, 2003.

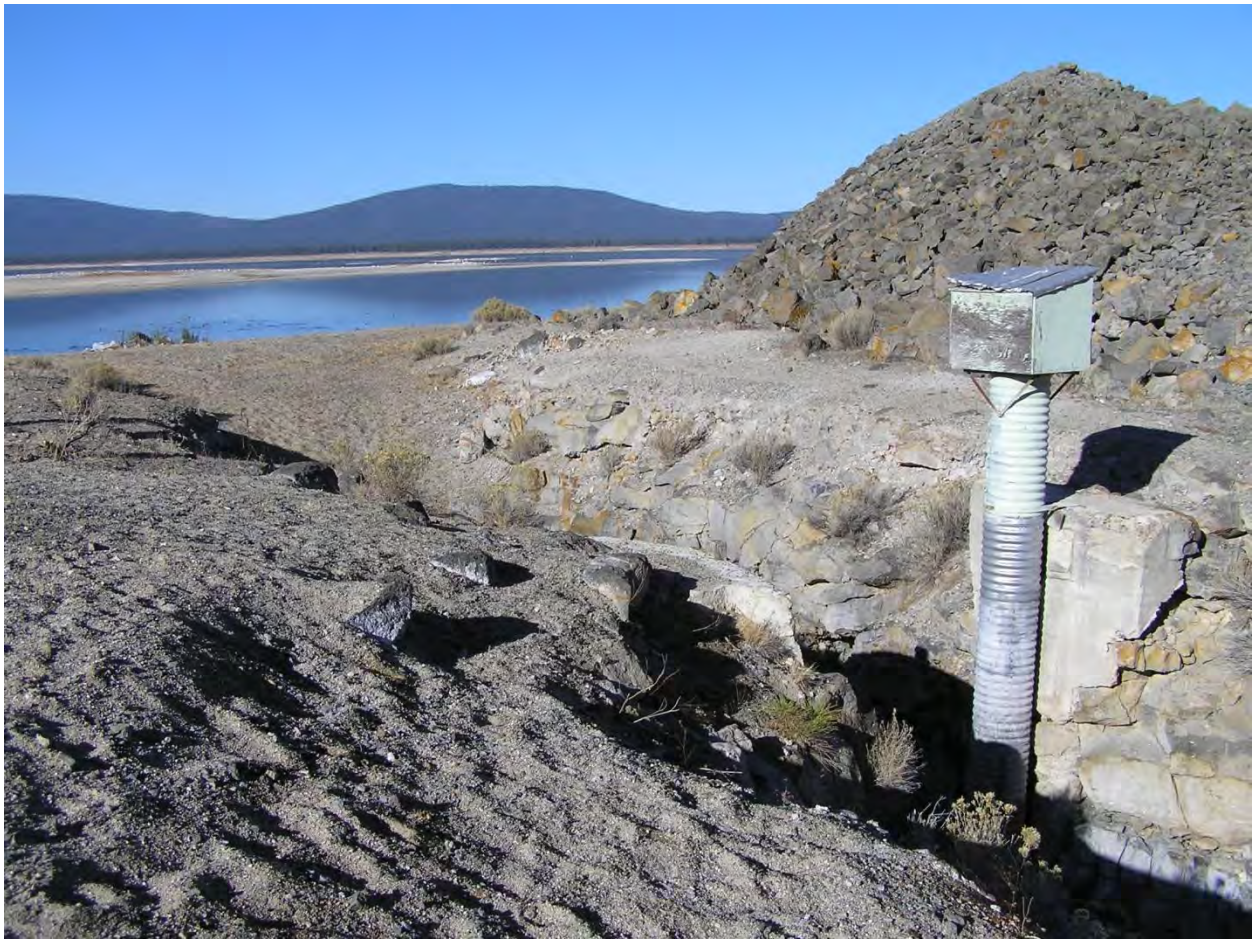
6. Fishes of Bly Tunnel, Lassen County, CA, by P.B. Moyle, T. Kennedy, D. Kuda, L. Martin, and G. Grant; in Great Basin Naturalist, 1991.

7. Lassen County Groundwater Management Plan, by Brown and Caldwell, June, 2007.

8. Groundwater and Surface Water A Single Resource, USGS Circular # 1139, by T.C. Winter, J.W. Harvey, O.L.Franke, and W.M. Alley, May, 2008.

Eagle Lake/Bly Tunnel

Eagle Lake/Bly Tunnel



November 3, 2009 - View facing west of Eagle Lake and Bly Tunnel Inlet Trench

November 3, 2009 – View into blocked Bly Tunnel inlet adjacent to Eagle Lake.

November 3, 2009 – Bly Tunnel Adit Fence

November 3, 2009 – View of Bly Tunnel Outlet, facing northwest, Eagle Lake Field Office staff in background.

November 3, 2009 – View of Murrers Upper Meadow, facing north. Water in foreground is flowing from left to right originating from Bly Tunnel outlet, which is located to the left of photo.