## VIII. Fuse Plug Design, Construction and Activation

### A. Fuse Plug Design.

The MWH Design Report dated March 2002 provided design data for the Silver Lake fuse plug. Items of design data were extracted from the Design Report for presentation and discussion in this Section. Applicable comments and findings are incorporated with the design items

The Design Report Introduction states that, “The new fuse plug will replace an existing dike (Dike 2) and will be used to release flood water during a Probable Maximum Flood (PMF) event.” This statement indicates that when there is a rare event flood such as the PMF, the fuse plug is intended to supplement the existing spillway capacity.

Section 4.7 Project Operations, states, “The wooden stoplogs at the fourth bay in the spillway from the left are removed during periods of high water or when large flows are expected.” Our recent research into written UPPCO operations procedures for Silver Lake did not find any planned procedures for removing the stoplogs. Discussions with UPPCO management and operator personnel indicate that the stop logs in the fourth bay have always remained in the fourth bay year around and have never been pulled for any expected high water events.

Section 5.5 Velocity at Entrance of Emergency Spillway Channel (found below) presents discussion on the expected velocities at the entrance of the fuse plug channel versus permissible velocities in support for using a grass lined channel for the fuse plug site. The last sentence of Section 5.5 is a reminder that the emergency channel is designed for the PMF event. This is another indicator that the design intent of the fuse plug is for it to be activated only on a very rare event such as the PMF.

> “It can be seen in Figure 7 that the maximum entrance velocity is approximately 9.1 ft/sec and occurs at hour 43. The guidelines established by the Natural Resources Conservation Services indicate that the permissible velocity for a grassed channel with easily erodible bed materials is 6.0 ft/sec. This permissible velocity can be increased by 25 percent for a flood event with occurrence frequency less than once in 100 years. Therefore, the permissible velocity can be increased to 7.5 ft/sec. Based on Figure 7, the duration of an entrance velocity exceeding 6.0 ft/sec is approximately 8.5 hours and the duration for an entrance velocity exceeding 7.5 ft/sec is approximately 4.4 hours. It should be noted that the emergency channel is designed for the PMF event.”

Section 6.4.2 Dike Materials and Zonation provides a general description of the design of the fuse plug. The fuse plug was designed using the USBR 1985 standards in REC-ERC-85-6. Details of the fuse plug design are shown on MWH drawing 20895-C6.

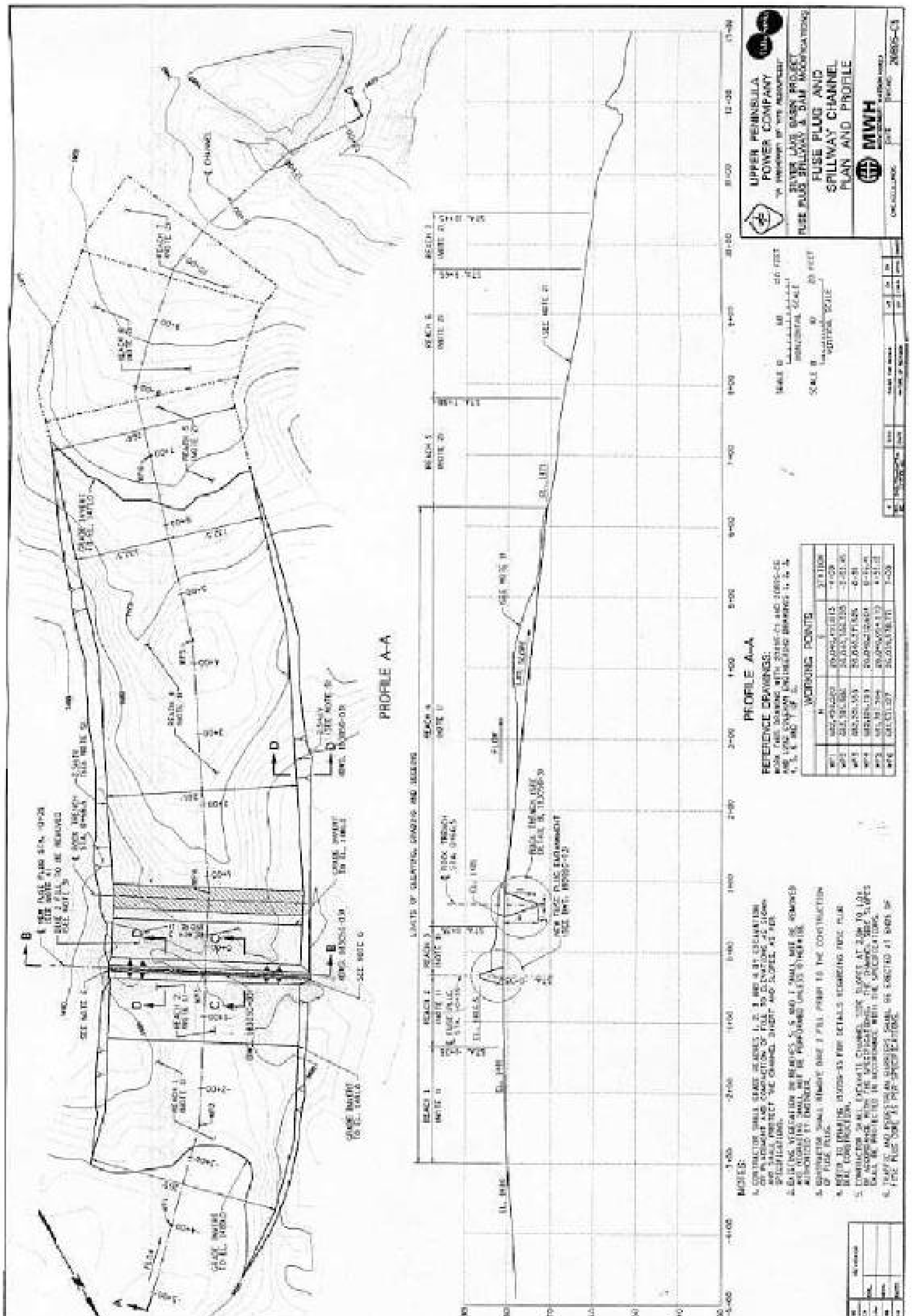
> "Zonation of the fuse plug dike was developed based on the guidelines outlined by USBR (USBR 1985). The central core of the fuse plug dike will be composed of silty sand material and will be one foot wide. The core will be angled at 45 degrees to facilitate maximum erosion and will separate the upstream and downstream shells. The core will be flanked by sand filters to help accelerate the breaching process and subsequent lateral erosion during a high flow event. The upstream and downstream shells will by constructed of a compacted sand and gravel granular fill material and will be protected using a riprap slope protection material. The pilot channels will be constructed using materials similar to that used in the upstream and downstream shells."

Table 6-1 which follows was the proposed gradations for the various zones of the fuse plug embankment.

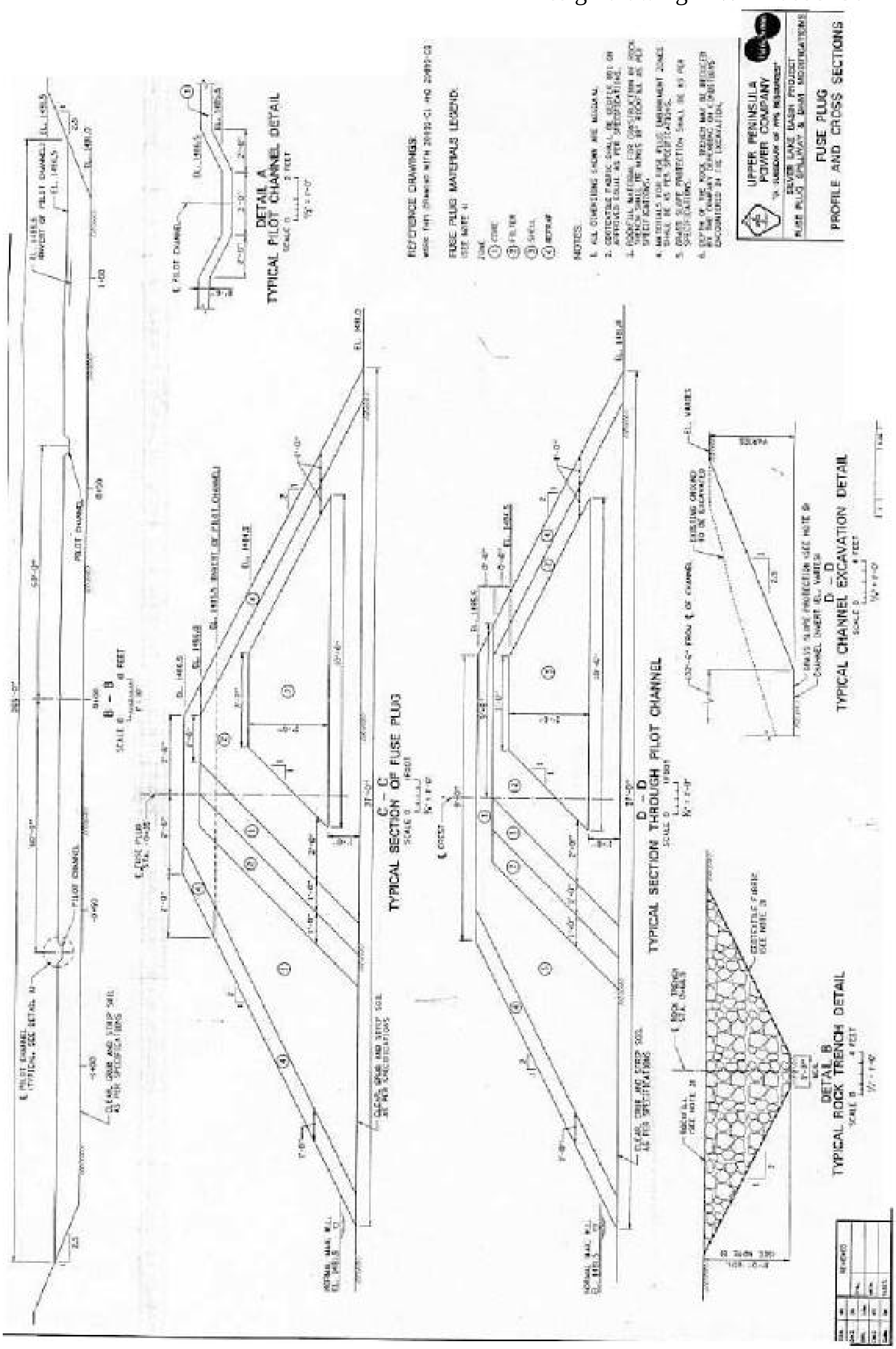
| Table 6-1<br>Recommended Gradations for Fuse Plug Dike Materials | | | | |
|---|---|---|---|---|
| **Material Zone** | **Description** | **Gradation** | | **Notes** |
| | | % passing | Size | |
| 1. | Core | 100 | #4 | USC ML |
| | | 30 | #200 | |
| 2. | Filter | 100 | ⅜" | MDOT 2NS |
| | | 95-100 | #4 | |
| | | 65-95 | #8 | |
| | | 35-75 | #16 | |
| | | 20-55 | #30 | |
| | | 10-30 | #50 | |
| | | 0-10 | #100 | |
| 3. | Shell | 100 | 1.5" | MDOT 3G |
| | | 85-100 | 1" | |
| | | 40-70 | ½ " | |
| | | 0-30 | #8 | |
| 4. | Fuse Plug Riprap | 100 | 6" | |
| | | 40-70 | 3" | |
| | | 20-40 | 1 ½" | |
| | | 0-10 | ¾" | |

The design plan of the fuse plug, its spillway channel, and profile are shown in MWH drawing 20895-C5. The design cross section of the fuse plug and rock trench section are in MWH drawing 20895-C6.

Design drawing MWH 20895-C5

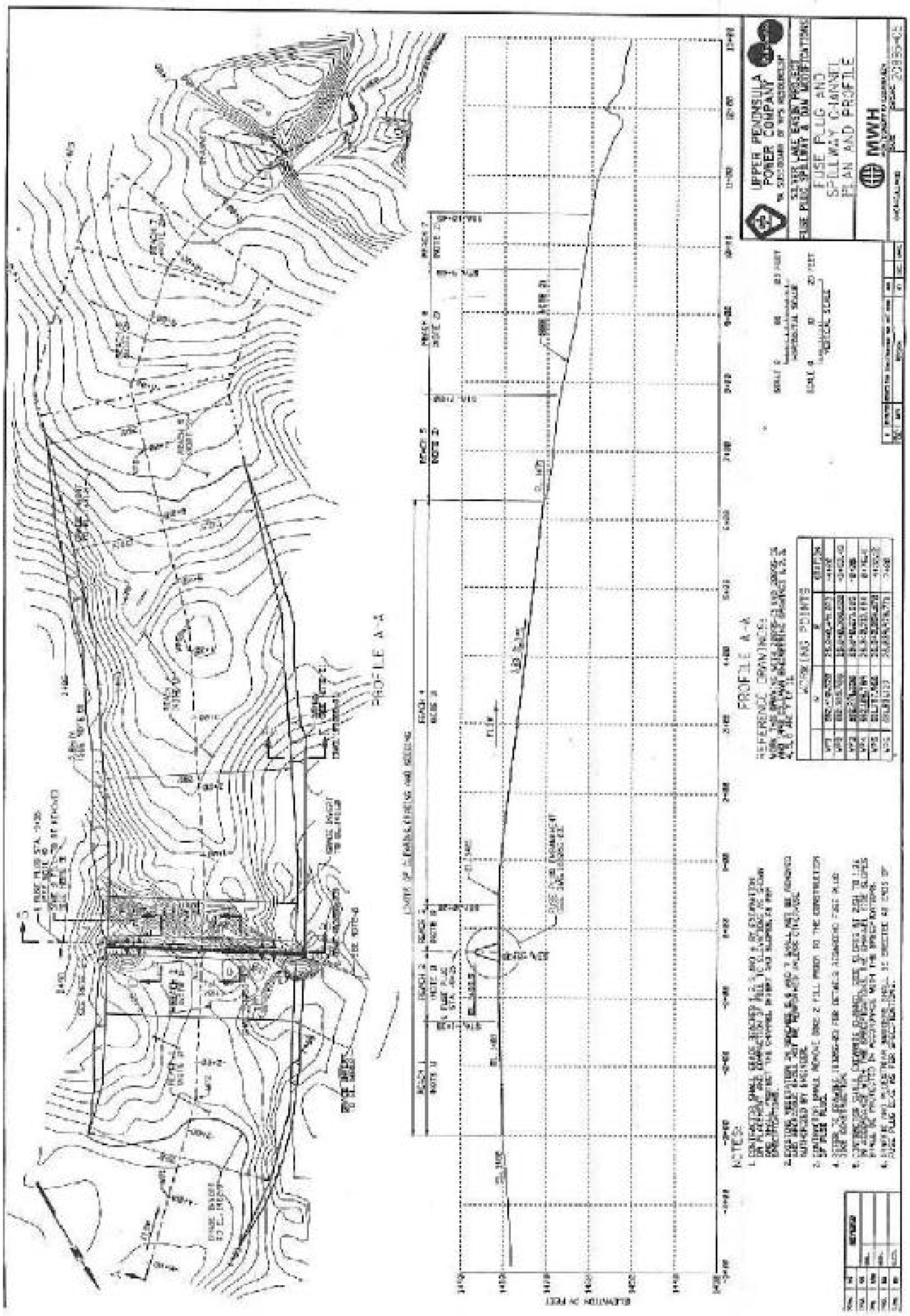


Design drawing MWH 20895-C6

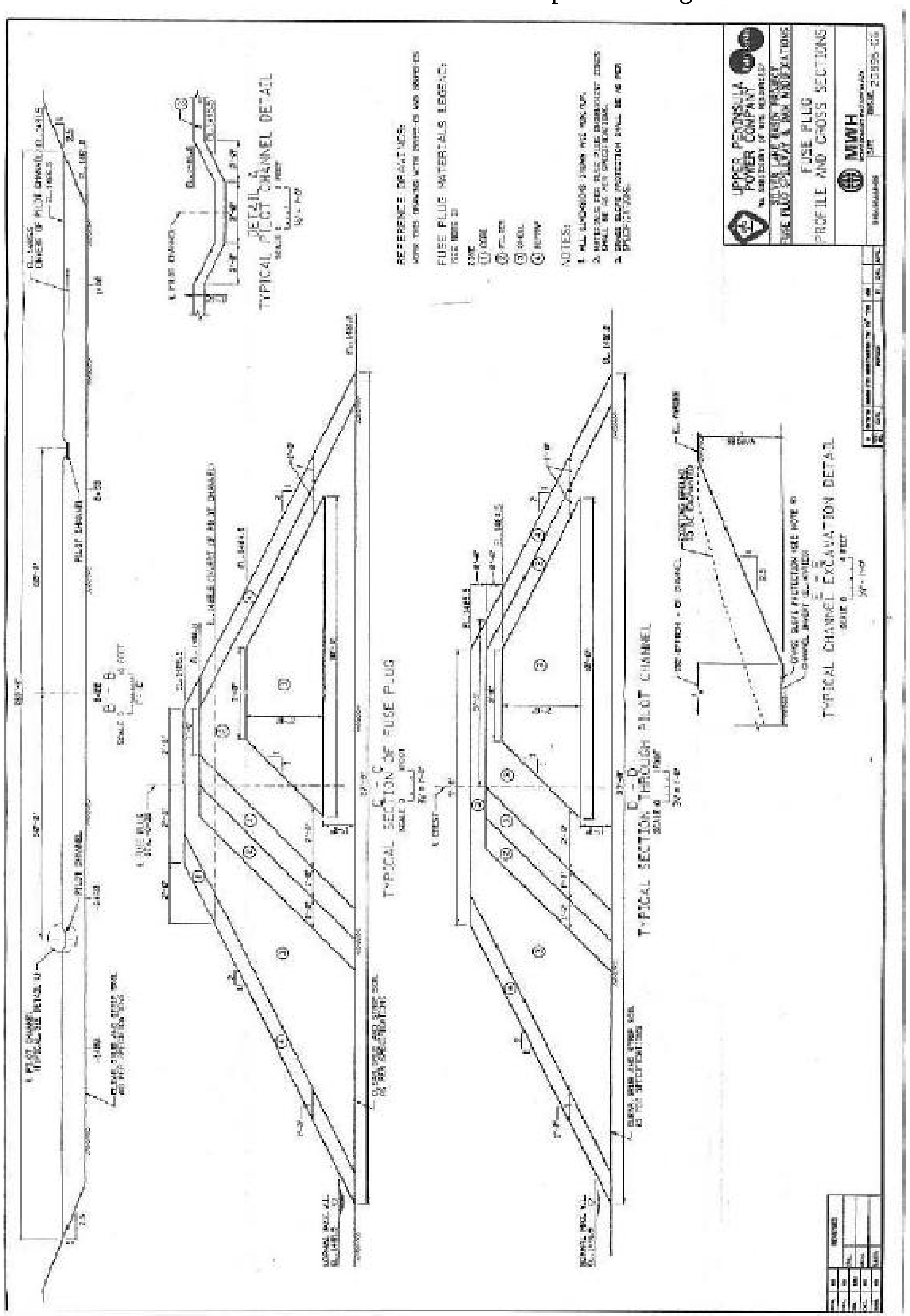


Revised MWH drawings 20895-C5 and 20895-C6 reflect the as-built construction of the fuse plug including removal of the rock trench, which was requested several times from MWH before being accepted.

Final Construction Report drawing MWH 20895-C5



Final Construction Report drawing MWH 20895-C6



As noted on the design and as-built fuse plug cross section and pilot channel cross section drawings, the top of the design fuse plug is elevation 1486.5 feet and the pilot channel elevation is 1485.5 feet respectively. As-constructed survey of the fuse plug dike indicates the two pilot channels to have invert elevations of 1,485.37 and 1,485.28 feet, approximately 1.5 to 2.6 inches below the design elevation of 1,485.5 feet. When these fuse plug elevations are compared to the elevation of the concrete ogee spillway crest elevation of 1486.25 feet, it becomes obvious that the concrete ogee spillway will no longer be the primary spillway. The fact the fuse plug will erode before the reservoir reaches the concrete ogee spillway crest elevation of 1486.25 feet was not discussed in the Design Report or pointed out in any other documentation that we have found. The design and as-built fuse plug cross sections and pilot channel cross sections indicate that the normal maximum water level will be 1481.5 feet. This elevation is also stated in Section 5.3 Reservoir Level, "The initial water level prior to the PMF event is at the normal maximum operating reservoir level of El. 1481.5 feet." The consultant apparently did not revised the plans and design documents to show that the normal maximum operating level was changed to El. 1482.5 feet per his letter dated September 24, 2001, which was enclosed with the licensee's September 27, 2001 letter to FERC.

When the designer representative was asked why the fuse plug was designed with a pilot channel elevation that is 0.75 feet lower than the concrete ogee spillway crest, he stated that it was not intended for the concrete ogee spillway to operate as the primary spillway after the fuse plug was installed. The designer representative stated that the primary capacity to pass lower floods would be handled by the outlet works, the slot in the fourth bay of the concrete ogee spillway (with stop logs at 1482.5 feet), and the storage volume from the lower reservoir operating level of 1481.5 feet. The outlet works and slot in the fourth bay of the concrete ogee spillway could be expected to pass approximately 634 cfs before the fuse plug would activate. The designer representative indicated that it should take greater than a 1 in 500 years event to activate the fuse plug with this design.

While the stated normal maximum operating level of 1481.5 feet is given in several places in the Design Report, the required lower operating level does not appear to have been discussed by the designer with the Licensee. In our discussions with Licensee personnel, the responses were that the designer did not discuss a requirement to operate the reservoir at a maximum normal level of 1481.5 feet. When the designer's representative was asked if the lower operating pool level requirement was discussed with the Licensee, the response was that the information is in the Design Report and the Licensee reads everything before it is sent forward.

The same uncertainty in transfer of information between designer and the Licensee exists when it was found that the stop logs in the fourth bay of the concrete ogee spillway had not been removed to elevation 1482.5 feet as called for in Section 9.0 of the Design Report. The requirement of this Section states, "Stop logs in the fourth bay of existing concrete spillway from the left will be removed to elevation, El. 1482.5. Again Licensee personnel, indicate that the designer never discussed this requirement with them. The designer's representative indicated that the information is in the Design Report and the Licensee reads everything before it is sent forward.

Section 6.5 Inlet and Exit Channel Slope and Erosion Protection provided the following information:

> "Slope and erosion protection will be required for the base and side slopes of the inlet channel from Station -3+00 and for the exit channel to Station 6+26. The existing vegetation established downstream of Station 6+26 will not be removed or disturbed and will serve as a grassed channel as is. As presented in Section 5.0, the maximum computed entrance velocity is 9.1 ft/sec. This velocity is greater than the maximum adjusted permissible velocity of a grassed channel of 7.5 ft/sec. Due to the high velocities expected for the flow from the PMF event, it is desirable to implement a system that will allow quick re-establishment of protective cover following a flood event. Erosion resistant grasses and fescue will be established to provide this protection. In the event of a breach, it is anticipated that the *high velocity of the flow will completely or nearly completely erode established vegetation within the grassed channel and damage the spillway channel.* Following a breach, damage to the exit channel will require repair to re-establish the necessary protection." Italics above have been added by the authors of this report.

Initially a rock trench was planned for as indicated in Section 6.6 Rock Trench to provide additional erosion resistance to head cutting at the upper end of the 1.8% slope downstream of the fuse plug location..

> "A rock trench is included downstream of Station 0+35 to provide a means to reduce the damage to the exit channel at the change in slope. The depth of the rock trench is 8 ft and the bottom width of the trench is 3.0 ft. The sides of the trench are sloped at 2.0 H:1.0V and are lined with a geotextile fabric (such as the Geotex 801 product as manufactured by SI Geosolutions). The trench will then be filled with rockfill meeting the following gradation:"

The gradation of the rock trench materials is provided below:

| **Table 6-2**<br>**Recommended Gradations for Rock Trench** | | | |
|---|---|---|---|
| Material Zone | Description | Gradation<br>% passing | size |
| Rock Trench | Rockfill | 100<br>0-5 | 18”<br>6” |

As shown in the as built drawings, the rock trench was not constructed as was initially planned. UPPCO, with the concurrence of MWH twice requested to FERC to remove the trench stating that it was not considered necessary due to the relatively flat slope into the reservoir, which was observed after reservoir draw down for construction of the fuse plug. The request was initially denied per FERC letter dated September 27, 2003, but was later granted per FERC letter dated November 5, 2002.

### B. Fuse Plug Construction.

#### a) Surficial Geology along the Silver Lake Fuse Plug (Dike No.2) Channel

A geologic reconnaissance along the channel of the Silver Lake Fuse Plug was made on June 24, 2003 by Frank Calcagno and William Allerton of the FERC Washington Office (Division of Dam Safety and Inspections). This section briefly summarizes the results of that reconnaissance.

The exposed geology along the Silver Lake Fuse Plug Channel (channel) is composed of unconsolidated glacial deposits of very complex origin. The area around the channel was subjected to periodic major glacial advances throughout the Pleistocene Epoch (approximately 2 million years). The last major advance and retreat of continental glaciers occurred in this area during the Wisconsinan Glaciation (approximately 14,500 to 9,500 years B.P. –Before Present) between the Superior and Michigan Ice Lobes. The channel area was covered by Wisconsinan glacial ice throughout the Port Huron readvance (13,000 B.P.) as well as during the 1,000-year interval when the Port Huron Ice stagnated and melted in place. Throughout this entire period, proto-Great Lakes Chicago, Saginaw, and Maumee/Whittlesey were forming to the south of the glacial ice lobes. The ice reached a temporary maximum retreat to the southern border area of the present Upper Peninsula at around 12,000 B.P. and then achieved another maximum advance during the Greatlakean readvanced (11,850 B.P.). The Greatlakean Ice in turn stagnated in place forming early Lake Algonquin, where at about 11,000 B.P. the channel area was located directly along the ice front immediately to the north. Swamps and deltas formed throughout this area that were periodically submerged by varying lake levels as the proto-great lakes shifted fronts. Just prior to the Marquette readvanced, the channel area was located at the shoreline of proto-Lake Superior (still at this time a part of Lake Algonquin). The ice achieved another minor advance during the Marquette readvance (10,000 B.P.) when the channel area was again covered by glacial ice. This ice lobe remained at the channel area for a considerable period of time as the ice retreated northward both to the east and west. This remnant Marquette ice lobe dammed Lake Duluth (soon to become Lake Nipissing, then Lake Superior) to the west. A river channel (the Au Train-Whitefish Channel) formed along the base of the ice lobe immediately to the northeast of the channel area that drained Lake Duluth (to the NW) into Lake Chippewa, soon to become Lake Michigan (to the SE). At this time (the Nipissing transgression) the North Bay outlet was rising due to isostatic rebound, thus also allowing the great lake levels to rise. By 4,500 B.P. the Upper Peninsula had nearly formed its present configuration. With the ice burden gone, the earth’s crust in the northern part of the region began to rise, and when the North Bay outlet rose to the same level as the Port Huron and Chicago outlets, the Nipissing Great Lakes were created. After about 2,000 years, and continual crustal rebound, the falls at Sault Ste. Marie formed, creating the current configuration of the modern Great Lakes.

As indicated by the brief glacial history cited above, the surficial deposits in the channel area have a complex and varied origin. Figure 1 is a glacial map of Michigan from the Michigan Department of Natural Resources. As shown in Figure 1, the glacial deposits in Marquette County (red arrow) are predominantly “thin to discontinuous glacial till over bedrock” (light brown unit). Aligned from the northwest to the southeast are glacial deposits indicated as “glacial outwash sand and gravel and postglacial alluvium” (pink) and “coarse-textured glacial till” (olive green). The Silver Lake Reservoir lies immediately to the NNW of a deposit of this “coarse-textured glacial till” (red arrow point of Figure 1). This deposit forms the channel outlet along the Fuse Plug spillway channel. These coarse deposits may likely be associated with the Au Train-Whitefish Channel that drained proto Lake Superior to proto Lake Michigan, as discussed above. As such, these deposits likely constitute a higher-energy depositional environment than that of a typical glacial till. Three glacial units were observed along the channel area during the authors’ reconnaissance and are described below from youngest to oldest.

a. Coarse-textured glacial till (Figures 2 through 8)

The Glacial Map of Michigan describes this unit as till. During the reconnaissance, some minor sorting and stratification within this deposit was observed. It is possible that, at least locally, this deposit is a stratified drift, which is defined by the AGI *Glossary of Geology* as a fluvioglacial drift consisting of sorted and layered material deposited by a meltwater stream or settled from suspension in a body of quiet water adjoining the glacier. The channel area was located immediately to the southwest of glacial ice for approximately 1,000 years prior to the Marquette readvance, was covered again by glacial ice for a period, then formed the drainage area between proto Lake Superior and proto Lake Michigan for an additional couple thousand years. This material may be transitional between till and fluvioglacial deposits. This unit is widespread along the entire channel area.

This material is visually classified as "poorly graded sand with silt (SP-SM), with occasional gravel, cobbles and boulders." It is generally 90% fine to coarse sand and 10% non-plastic fines. Upon exposure to air, it quickly dries out and may contain a minor amount of (carbonate?) weak cementation. It displays properties similar to loess in that it stands vertically but is cohesionless. It has a low dry strength (crushes easily with light finger pressure), rapid dilatancy, low toughness, and is nonplastic. This material contains approximately 10% angular, hard gravel on average about 2 inches in diameter and a trace amount of sub-rounded cobbles and boulders.

The upper 12- to 18-inches of this deposit is oxidized to a medium to dark brown color, with some organic root material from surface vegetation. The lower 6 feet is unweathered, light tan in color, and is massive to faintly stratified. This material displays an unusual circular erosional characteristic (Figures 2 through 6) at the base of this unit that appears to concentrate immediately above the change in lithology. This erosion may be the result of washing away of silt and/or carbonate cementation.

Channel erosion during the Fuse Plug activation cut easily through the un-vegetated coarse-textured glacial till (Figure 9). Much of the sand from this unit appears to have settled out along the inner curve of the Fuse Plug channel, approximately 1,100 feet downstream of the old dike alignment (Figure 10).

b. <u>Fluvioglacial sand (Figures 3 through 8)</u>

Immediately below the coarse-textured glacial till is coarse-grained fluvioglacial sand deposit. This unit contains prominent thin beds and is locally cross-bedded. This unit may represent glacial outwash or deltaic deposits along the terminus of the glacial ice front. This unit is visually classified as “poorly graded sand” (SP) and is composed of dark brown fine to medium clean sand and trace amounts of silt. It is moist to wet, firm, and has low to no toughness, rapid dilatancy, low dry strength, and is nonplastic. A total exposure of this unit was not observed, but it may be approximately 5 feet thick. Channel erosion during the Fuse Plug activation appears to have terminated within this deposit, which may be coincident with the elevation of the base of the reservoir. This unit appears to be widespread along the entire channel area, however it is covered in many areas.

c. <u>Swamp (?) Deposit (Figures 7 and 8)</u>

Immediately below the fluvioglacial sands is a dark gray to black deposit that appears to be an organic silt (OL). This unit may represent a swampland or low-lying glacial slough that accumulated large amounts of vegetation during glacial times. Although predominantly fine-grained, it appears to be fibrous, dries rapidly upon exposure to air, and has high to very high dry strength (could not be crushed between fingers and a hard surface). A total exposure of this unit was not observed, but it appears to exceed two feet in thickness. The aerial extent of this deposit is unknown, but it is observed upstream of and along the old alignment of the original Dike No. 2.

A geologic map of the Fuse Plug channel area will be completed upon receipt of the one-foot contour map, geologic borings, and material sampling of the channel area.

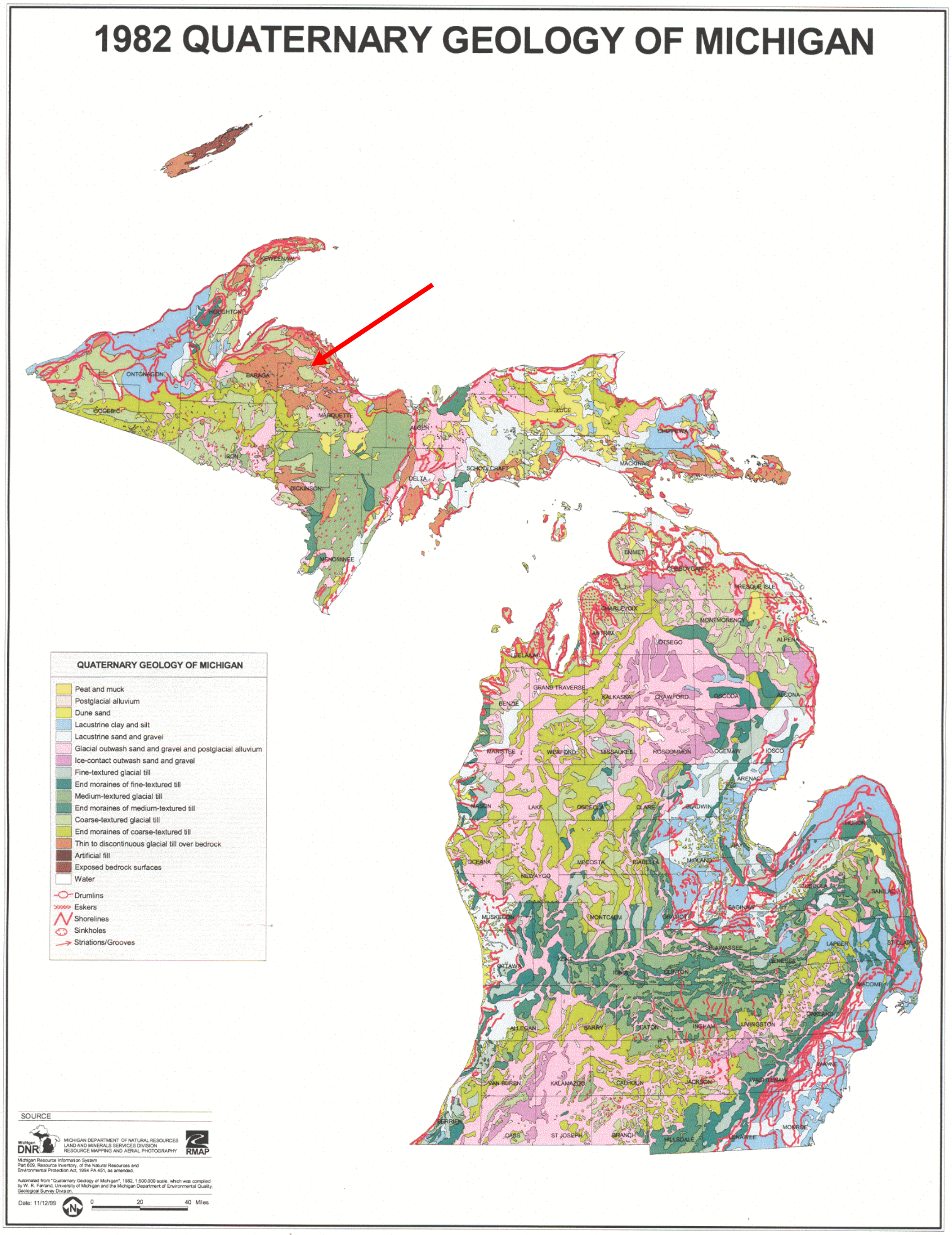



**Figure 1 Glacial Map of Michigan. Red arrow points to "Coarse-textured glacial till" (olive-green oval deposit). Silver Lake lies immediately to the N-NW of this unit (at point of arrow).**

**Figure 2 Detail of "Coarse-textured glacial till." This material is generally 90% fine to coarse sand and 10% non-plastic fines (SP-SM), with occasional gravel, cobbles and boulders. Note that some faint stratification is present. The stratification and coarse-grained material point to a higher-energy glacial environment, possibly originating closer toward the ice terminus. View is of left channel downstream of former fuse plug.**

**Figure 3  Overall view of "Coarse-textured glacial till."  Note vertical erosional gullies (at right) and circular erosional features near base.  Upper horizon is oxidized and contains some roots from surface vegetation.   This deposit stands vertically similar to loess.  On surface exposures, this material is dry.  This unit likely contains weak carbonate cementation, but is a cohesionless soil.  View is of left channel downstream of former fuse plug.**

**Figure 4  The upper SP-SM unit appears to contain a weak soil structure (weak carbonate cementation?)  that when disturbed loses strength and crumbles (pile at arrow).  This unit has a low dry strength and is easily broken by light finger pressure.  View is of left channel downstream of former fuse plug.**

**Figure 5  Note the dark brown unit immediately below the circular erosional features.  This unit is a fine to medium clean sand (SP), is moist to wet, and contains prominent thin bedding (locally cross-bedded).  The circular erosion appears to concentrate immediately above this change in lithology, and may be related to solution of the silt and/or carbonate content of the "coarse-textured glacial till".  View is of left channel downstream of former fuse plug.**

**Figure 6  View of similar erosional features as described in Figure 5.  Note the association of a vertical fracture with two of these erosional pockets.  View is of an "island" remnant downstream of former fuse plug.**

**Figure 7  Note the dark gray to black unit stratigraphically below the "Coarse-textured glacial till." This deposit appears to be an organic silt (OL) with a very high dry strength and contains a significant fibrous organic content.  View is of left channel upstream of former fuse plug.**

**Figure 8  Overall stratigraphy of the area.  Note the light-brown, dry SP-SM unit on the far channel wall and erosinal remnant within the channel (above upper red line), the dark-brown, moist to wet finely bedded SP unit below the SP-SM unit (between the red lines), and the black organic silt (OL) unit at the base (below lower red line).  View is from the right channel wall looking to the left directly along the alignment of the former fuse plug.**

**Figure 9 Foreground shows the original ground surface of the fuse plug channel. Flood erosion occurred to the right of the line marked by the arrow. Note the coarse-grained cobble and boulder deposition along the channel centerline. View is on left channel downstream of former fuse plug.**

**Figure 10 View of channel erosion and flood deposition downstream of former fuse plug. Note the light-colored deposits in the upper right of the photograph (arrow). This shows large amounts of well graded sand that were deposited along an inner bend of the channel alignment, approximately 1,100 feet downstream of the former fuse plug.**