# PROJECT 184:
# LANDSLIDE POTENTIAL ALONG THE EL DORADO CANAL

Prepared by: El Dorado Irrigation District
September 5, 2002

## INTRODUCTION

The El Dorado Canal has been conveying water from the El Dorado Diversion Dam, which diverts water from the American River approximately 1.5 miles downstream of Kyburz, to the El Dorado Forebay for over 65 years. The El Dorado Forebay regulates water that flows into a surge tank and through a penstock into the El Dorado Powerhouse where power is generated. The forebay also regulates water for consumptive water supply into El Dorado Irrigation District's main canal.

The purpose of this memorandum is to identify landslides that have impacted the El Dorado Canal, determine the probability that landslides will occur, and identify the potential for landslides to affect the canal in the future. The majority of the material in this memorandum was obtained from a 1997 study conducted by the California Department of Conservation, Division of Mines and Geology[1].

## GENERAL CONDITIONS

Landsliding is a natural erosion process in all upland areas, including the Sierra Nevada. In much of the range, the rocks are deeply weathered and mechanically weak. During wet years, weak rocks and unconsolidated surficial deposits become water saturated and may fail as landslides.

Slope stability is influenced by multiple factors, including slope inclination, bedrock geology, geologic structure, geomorphology, weathering, vegetation, and precipitation. A landslide is more likely to occur on a steep slope. The American River Canyon, which is where the canal is located, is relatively steep, with slope inclinations ranging from 40 to 70 percent.

Landslides often occur along the contact between the Mehrten formation, a volcanic material, and the underlying metamorphic and granitic rocks. The rocks are frequently sheared and deeply weathered along the contact. This mechanical disruption results in weakened material that is more susceptible to landsliding. Fractures also provide pathways for groundwater, and pore pressures become elevated. The structure of the bedrock also affects slope stability; landslides often occur along the trace of a fold axis.

[1] Wagner, D.L. and Spittler, T.E., 1997, "Landsliding along the Highway 50 Corridor: Geology and Slope Stability of the American River Canyon between Riverton and Strawberry, California", California Department of Conservation, Division of Mines and Geology Open File Report 97-22, 25 p.

The rapid input of water due to high intensity rain events, snowmelt, and rain-on-snow events can elevate pore pressures and accelerate or trigger new landslides.
When the soil becomes saturated and pore spaces fill with water, such as during a high intensity precipitation event, pressures within the pores will increase. Bare soil does not drain quickly enough to maintain low pore pressures, which is evident with the several active landslides that have occurred in recently burned areas. Vegetation often keeps these pore pressures from becoming elevated. Tree roots stabilize hillslopes by reinforcing forest soils and removing water through evapotranspiration. Trees and other vegetation not only remove water from the soil via transpiration, some water and snow is intercepted on branches and eventually evaporates. Vegetation plays an important role in removing water and reducing pore water pressures that could trigger slope failures.

## HISTORIC LANDSLIDES IMPACTING THE EL DORADO CANAL

Over half (52%) of the canal failures that occurred between 1937 and 1997 were due to landslides (see Canal Failure Analysis). Landslides often cause the canal to be shut down for extended periods of time. The longest duration of canal failure was 13 months, which was due to the 1983 Highway 50 Landslide that occurred on April 9, 1983 and destroyed 3,610 lineal feet (lf) of the canal. This landslide was a translational/rotational slide that was caused by rapid snowmelt. Translational/rotational slides are relatively slow moving slides characterized by a cohesive slide mass and a deep failure plane. Large masses are shifted downward in a translational slide, and rotational slides are similar except the mass is rotated to a certain degree. Slides commonly contain rotational heads and toes with translation in the middle section. Addition of water decreases stability, and often occurs when the soil becomes fully saturated and pore pressures are elevated. Usually during high intensity rain events, rain-on-snow events, and rapid snowmelt, the pores cannot be drained quickly enough to prevent elevated pore pressures.

Significant damage to the canal also occurred in January of 1997. Many landslides were triggered by the high intensity rain events in 1996-1997. The slope failures ranged from small roadcut slumps to large landslides, such as the Mill Creek Slide that shut down Highway 50 for 27 days. These landslides occurred in areas with poorly consolidated granitic colluvium, decomposed granite, soil, matrix supported debris flow material, and gravel, which are unstable on steep slopes and disaggregate during sliding. The Mill Creek Slide is classified as a rapid debris slide. This type of slide typically consists of unconsolidated rock, colluvium, and soil and moves downslope along a relatively shallow failure plane. Bedrock or an impervious slide plane restricts water movement to lateral flow parallel to the surface. High intensity precipitation saturates the soil, increases the rate of lateral subsurface flow, and causes the slope to fail.

Many other smaller, unnamed landslides have occurred in the vicinity of the canal. These slides have caused damage ranging from minor (one section of a flume) to significant (multiple flumes), and were classified as translational/rotational, debris slides, earthflows, and debris flows. Earthflows occur when saturated soil and debris become semi-plastic and highly viscous, resulting in mass movement. The soil commonly consists of clayrich materials that swell when wet causing a reduction in intergranular friction. When the intergranular friction decreases, the soil no longer has any strength and acts like a fluid as it flows down the hill. Debris flows occur along stream channel banks that have been scoured and eroded by the stream. They commonly occur along bare streambanks, and originate in steep, intermittent and first and second order channels during high intensity precipitation events.

## PROBABILITY OF LANDSLIDES OCCURRING

The slopes between Pollock Pines, the approximate location of the El Dorado Forebay, and Riverton are relatively stable. No significant active landslides are located in this area[2]. It is unknown whether historic, dormant landslides exist.

Between Riverton and the Twenty-Nine Mile Station, the area has been identified as unstable[1]. It is underlain by a complex geology, which includes unstable surficial materials and highly deformed bedrock. Active landslides include the Ice House, Cleveland Corral, White Hall, Mill Creek, Fry Creek, Silver Fire, 1983 Highway 50 landslide, the 1996-1997 landslides, and numerous unnamed active slides both north and south of the American River. Although most of these landslides were north of the American River and thus would not affect the canal, both sides of the canyon consist of the same unstable geology.

The area between Twenty-Nine Mile Station and Kyburz is relatively stable[1]. The historic large bedrock landslides appear to be dormant. However, the slopes exhibit a well-defined landslide morphology, which includes head wall scarps, closed depressions, and poorly drained areas. These characteristics indicate that there is a potential for a landslide to occur.

The highest potential for landslide damage is in the Randall Tract-White Hall area[1]. Several debris flows and deep-seated landslides were identified on the north-facing slopes above Randall Tract. Intersecting joints (partings), foliations, and shears in the bedrock are parallel to the slope, resulting in unstable slopes. The canal is located in the middle of these landslides, so the potential for canal damage is high in this area.

## POTENTIAL FOR LANDSLIDES TO AFFECT THE CANAL

To further differentiate the relative stability of the slopes between Riverton and Kyburz that may affect the canal, the following categories were used[1]:

A. Landslide that moved during the winter of 1996-97.

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[1] Wagner, D.L. and Spittler, T.E., 1997, "Landsliding along the Highway 50 Corridor: Geology and Slope Stability of the American River Canyon between Riverton and Strawberry, California", California Department of Conservation, Division of Mines and Geology Open File Report 97-22, 25 p.

[2] Carlton Engineering, Inc. and Kessler and Associates, LLC, 2002, "Flume Assessment Report," 24 p.

B. Landslide that appears to be unstable under current conditions or that has distinct surface features, but did not move during 1996-97. This includes historic landslides such as the 1983 Highway 50 landslide.

C. Landslide that may be unstable under current conditions.

D. Slope with relatively distinct landslide geomorphology without evidence of active instability.

E. Slope with possible landslide geomorphology or area where geologic exposures indicate landslide displacement.

Figures 1 through 4 identify landslides along the canal with the corresponding classification.

Group A landslides may cause chronic problems unless remedial work is performed, such as installing erosion control measures. The acute failures that have already occurred may have removed the unstable materials, but it cannot be determined with the available data. Fifteen Group A landslides were identified that could potentially affect the canal (see Figures 1 through 4). It appears that the canal is located at the head of six of these landslides. Since the canal is at the head of the landslide, it may not have as significant of an impact as if it were in the middle or the toe of the landslide. However, an active landslide can quickly grow to include surrounding unstable soil. All of the identified Group A landslides near the canal are relatively small, and may only affect one or two sections of a flume.

Group B landslides may be extremely unstable, or they may be the remnants of a failure that removed all of the unstable material. The landslides identified in Group B include rotational/translational landslides and earthflows that appear to be intermittently active. Relatively slow, incremental movement is separated by periods of dormancy. Group B landslides also include debris flows and debris slides that have recently failed and well defined, discrete colluvial source areas that appear to be highly unstable. Movement of these landslides is typically triggered by high precipitation, and can pose significant problems during intense rainfall events. Twelve Group B landslides were identified that could potentially affect the canal (see Figures 1 through 4). Most of these landslides are surrounding or adjacent to Group A landslides. The slopes identified in this group are most likely unstable soil surrounding the Group A landslides, and have the potential to create a larger landslide.

Landslides included in Group C are considered to be potentially unstable, although they are not as likely to fail as those in Group A or B. Group D and E landslides are dormant and have been modified by post-failure erosion. Their stability could be affected by any type of earth movement, such as grading and other land use activities. Eleven Group C landslides, seven Group D landslides, and eight Group E landslides were identified in the vicinity of the canal (see Figures 1 through 4). These landslides covered areas much larger than the Group A and Group B landslides.

El Dorado Irrigation District has replaced several sections of the canal with the El Dorado and Mill to Bull Tunnels in areas with a high potential for damage to minimize failures to the water system. With the El Dorado and Mill to Bull Tunnels, the number of Group A landslides decreases to three, Group B landslides to four, Group C landslides to seven, Group D landslides to four, and Group E landslides to three. This is a significant reduction in landslide risk to the canal.

## CONCLUSIONS

From this analysis, it is evident that there is a high potential for landslides to occur near the canal and cause canal failure between Riverton and Twenty-Nine Mile Station. Landslides are a common occurrence in upland areas, and are difficult to prevent. Rotational/translational landslides cannot be controlled or prevented. Debris slides, earthflows, and debris flows may be mitigated with erosion control measures. However, the extent of required erosion control measures is large and would be cost prohibitive. To completely prevent these types of landslides, erosion control measures may have to cover the entire north-facing slope of the American River Canyon. Since vegetation plays an important role in slope stability, maintaining a dense forest cover on the slopes above the canal may improve stability just as well as other erosion control measures.

Historically, an average of seven landslides have caused canal failures every 10 years. This is equivalent to one landslide causing a canal failure every 1.4 years. Canal failures occasionally cause environmental damage. When the canal fails, the water in the canal is spilled onto the soil, which erodes the hillslope. Erosion due to canal failure varied from washing away topsoil to the bedrock a couple of feet below to creating a large gully down to the American River. One incident required the removal of silt from the American River. To mitigate these problems, El Dorado Irrigation District has replaced the canal with tunnels in the areas that have the highest potential for landslides. A total of 32 landslides that have historically impacted the canal or have a high potential to impact the canal have been mitigated with the construction of the Mill to Bull and El Dorado Tunnels. Although the tunnels do not prevent landslides, the damage to the water system and environment is minimized.

## Legend

SOURCE: CALIFORNIA DIVISION OF MINES AND GEOLOGY, OFR 97-22, PLATES 3A AND 3B.

- ROTATIONAL OR TRANSLATIONAL LANDSLIDE - INITIAL MODE OF FAILURE AS COHERENT MASS. SLIDE MASS MAY DISAGGREGATE DURING FAILURE ON STEEP SLOPES. SCARPS WHERE MAPPABLE.
- SCARP (BREAK IN SLOPE). - HEADWALL.
- DEBRIS FLOW OR DEBRIS SLIDE - COHESIONLESS MATERIAL THAT IS IN POSITION WHERE DISAGGREGATED FAILURE HAS OR MAY OCCUR.
- DEBRIS TORRENT TRACK-RUNOUT AREA OF DEBRIS SLIDE OR DEBRIS FLOW.

LEVEL OF ACTIVITY

- **A** - CURRENTLY ACTIVE LANSLIDE-EXHIBITS FRESH SCARPS, EXPERIENCED DISPLACEMENT DURING THE WINTER OF 1996-97. LOWEST STABILITY.
- **B** - RECENTLY ACTIVE LANDSLIDE-SCARPS FRESH TO SOMEWHAT SUBDUED. DISPLACEMENT DURING THE 1996-97 WINTER NOT CONFIRMED. LOW STABILITY.
- **C** - PROBABLE UNSTABLE SLOPE-GEOMOPHOLOGY, GEOLOGY, AND GEOMETRY OF SLOPE SUGGESTS THAT FAILURE COULD OCCUR UNDER CURRENT CONDITIONS.
- **D** - SLOPE WITH RELATIVELY DISTINCT LANDSLIDE GEOMOPHOLOGY WITHOUT EVIDENCE OF ACTIVE INSTABILITY.
- **E** - SLOPE WITH POSSIBLE LANDSLIDE GEOMOPHOLOGY OR AREA WHERE GEOLOGIC EXPOSURES INDICATE LANDSLIDE DISPLACEMENT.

SOURCE: GEOLOGIC DATA FROM CALIFORNIA DIVISION OF MINES AND GEOLOGY, GEOLOGIC MAP OF THE SACRAMENTO QUADRANGLE, 1997, AND SUPPLEMENTED BY US FOREST SERVICE "A", UNDATED; BEEBY, 1973d; McJUNKIN & TAYLOR, 1979b; AND JOHNSON, 1993b)

- Mzg - MESOZOIC GRANITE ROCKS
- Mzd - MESOZOIC DIORITIC ROCKS
- Tm - MEHRTEN FORMATION
- Tvs - VALLEY SPRINGS FORMATION
- Pzu - UNDIFFERENTIATED PALEOZOIC ROCKS
- DOsf - SHOO FLY COMPLEX
- — — — - UNIT BOUNDARIES

SOURCE: CALIFORNIA DIVISION OF MINES AND GEOLOGY, OFR 97-22.

- Qcl - COLLUVIUM AND GRUS
- Qr - RIVERBANK FORMATION, ALLUVIUM
- af - ARTIFICIAL FILL
- — — — - UNIT BOUNDARIES

SOURCE: HISTORIC FIRE BOUNDARIES, (PROVIDED BY USFS - UNDATED)

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400 0 200 400 800 1600

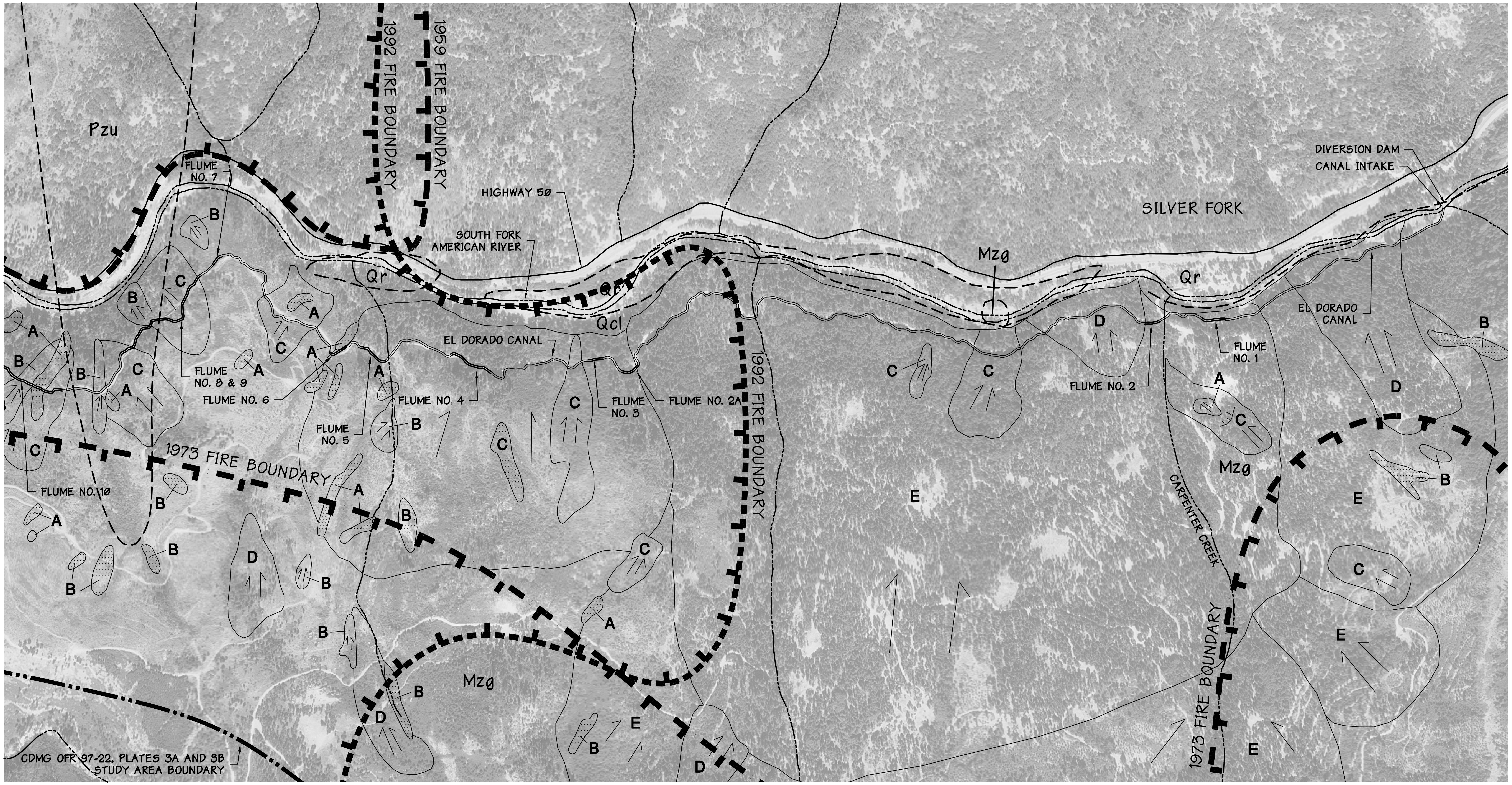
1 inch = 400 ft.

## Legend (Continued)

- DRAINAGES - CREEKS, RIVERS, ETC.
- CANAL ALIGNMENT
- FLUME ALIGNMENT
- TUNNEL ALIGNMENT
- SIPHON ALIGNMENT

## Sheet Notes

AERIAL PHOTOGRAPHS AND TOPOGRAPHY PROVIDED BY PRICE GEOGRAPHIC CONSULTING, DECEMBER 2001. AERIAL PHOTOGRAPHS SHOWN MAY HAVE INCONSISTENCIES FROM SURVEY-BASED TOPOGRAPHY DUE TO DIFFERENT DATA COLLECTION METHODS.




**VERIFY SCALE**
BAR IS ONE INCH ON ORIGINAL DRAWING, ADJUST SCALE FOR REDUCED PLOTS
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TEAM DRIVEN SOLUTIONS FOR THE BUILT ENVIRONMENT
CARLTON Engineering Inc.
3932 Ponderosa Road, Shingle Springs, CA 95682
Voice 530.677.5515 Fax 530.677.6645


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**Revisions**

| SYM | DESCRIPTION | DATE | BY |
|---|---|---|---|

# EID LANDSLIDE MAPPING
# EL DORADO CANAL

# SITE DETAIL SHEET (FLUMES 1 - 8&9)

**Project Location:**
El Dorado County
California

**Ownership Information:**
El Dorado Irrigation District
2890 Mosquito Road
Placerville, CA 95667

| | |
|---|---|
| DESIGNED N/A | DATE 09/04/2002 |
| DRAWN MLI | Horz. SCALE 1"=400' |
| JOB No 2002-440 | Vert. SCALE N/A |
| SHEET | |

## Legend

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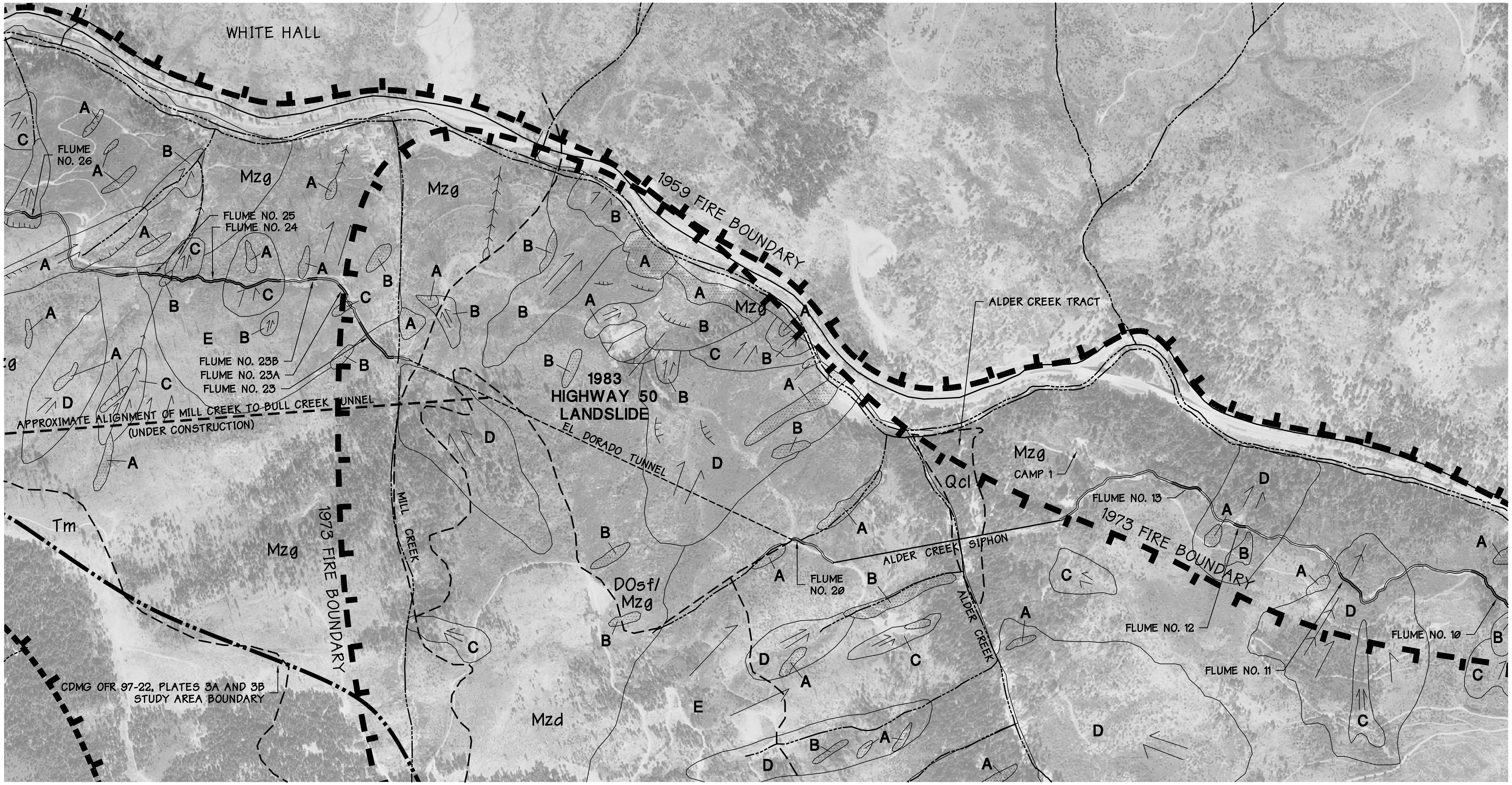


**VERIFY SCALE**
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0 1"

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| SYM | DESCRIPTION | DATE | BY |
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Revisions

EID LANDSLIDE MAPPING
EL DORADO CANAL

**SITE DETAIL SHEET (FLUMES 10 - 26)**

**Project Location:** El Dorado County California

**Ownership Information:** El Dorado Irrigation District 2890 Mosquito Road Placerville, CA 95667

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|---|---|
| DESIGNED N/A | DATE 09/04/2002 |
| DRAWN MLI | Horz. SCALE 1"=400' |
| JOB No. 2002-440 | Vert. SCALE N/A |
| SHEET 2 | |

## Legend

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1 inch = 400 ft.

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- CANAL ALIGNMENT
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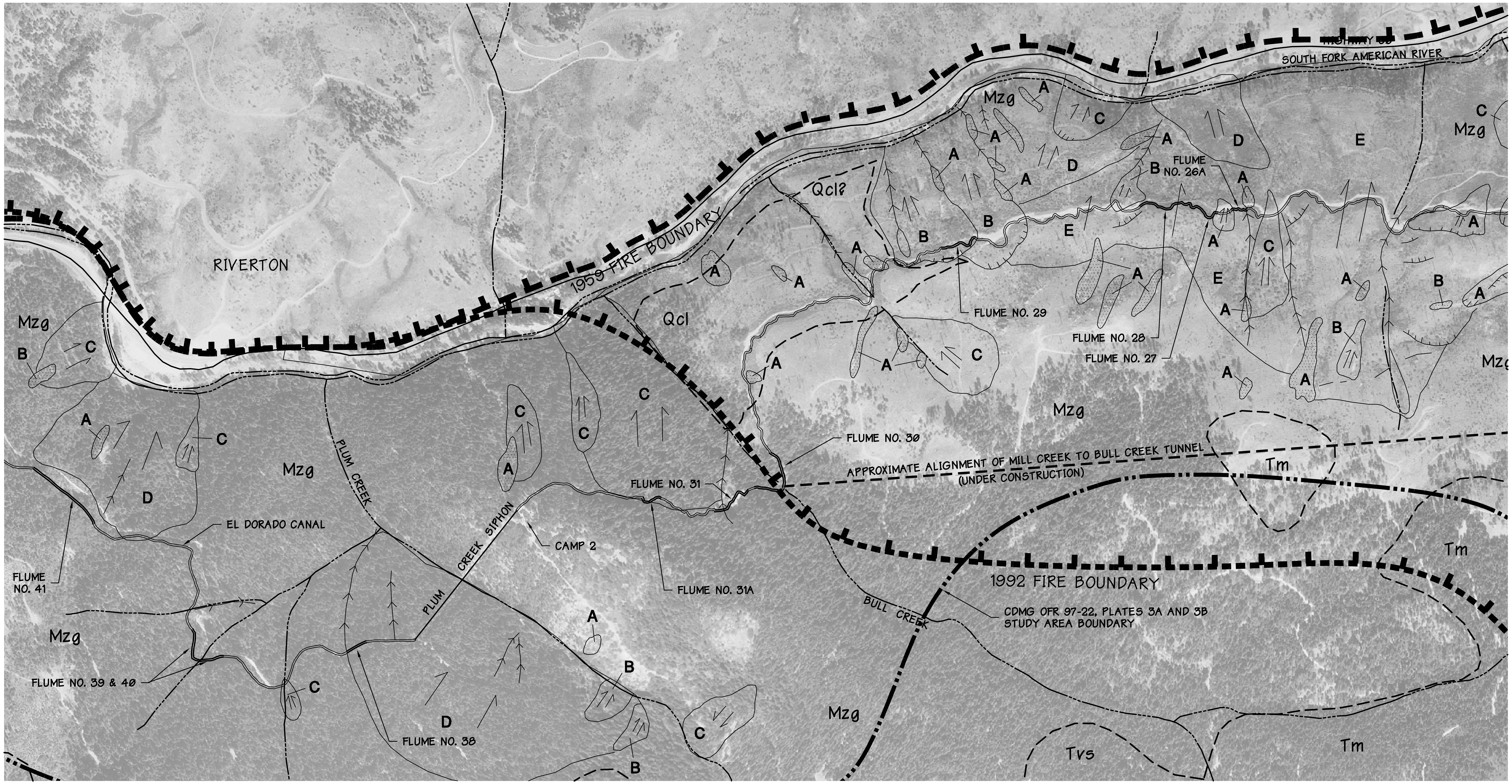


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# EID LANDSLIDE MAPPING EL DORADO CANAL

# SITE DETAIL SHEET (FLUMES 27 - 41)

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California

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SHEET 3

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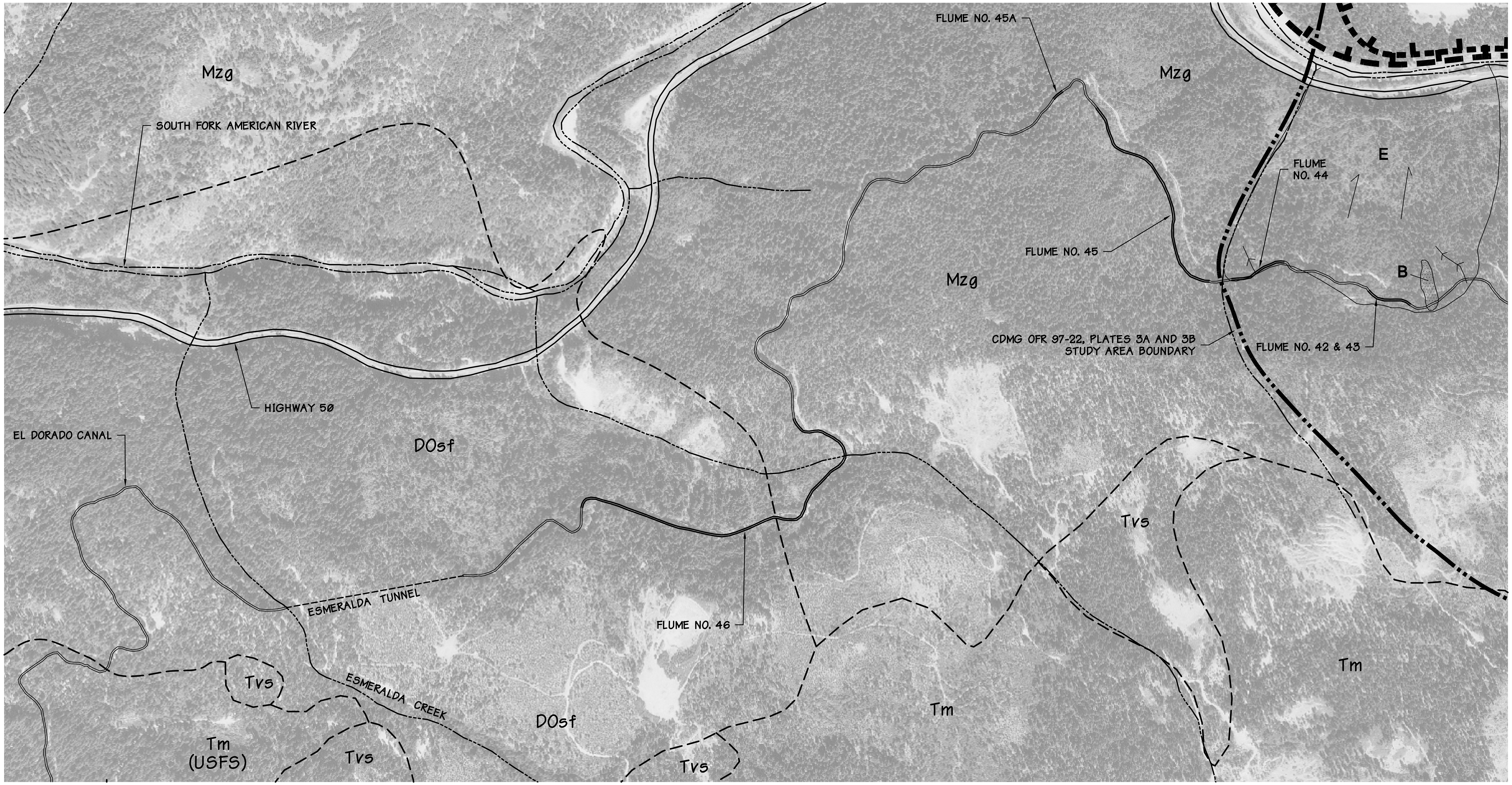
## Sheet Notes

AERIAL PHOTOGRAPHS AND TOPOGRAPHY PROVIDED BY PRICE GEOGRAPHIC CONSULTING, DECEMBER 2001. AERIAL PHOTOGRAPHS SHOWN MAY HAVE INCONSISTENCIES FROM SURVEY-BASED TOPOGRAPHY DUE TO DIFFERENT DATA COLLECTION METHODS.




TEAM DRIVEN SOLUTIONS FOR THE BUILT ENVIRONMENT

CARLTON Engineering Inc.

3932 Ponderosa Road, Shingle Springs, CA 95682 Voice 530.677.5515 Fax 530.677.6645

SCHEMATIC

| Revisions | | | |
|---|---|---|---|
| SYM | DESCRIPTION | DATE | BY |

**EID LANDSLIDE MAPPING**
**EL DORADO CANAL**

**SITE DETAIL SHEET (FLUMES 42&43 - 46)**

**Project Location:** El Dorado County California

**Ownership Information:** El Dorado Irrigation District 2890 Mosquito Road Placerville, CA 95667

| | |
|---|---|
| DESIGNED N/A | DATE 09/04/2002 |
| DRAWN ML | Horz. SCALE 1"=400' |
| JOB No 2002-440 | Vert. SCALE N/A |
| SHEET 4 | |

**VERIFY SCALE**
BAR IS ONE INCH ON ORIGINAL DRAWING. ADJUST SCALE FOR REDUCED PLOTS
0 1"