Attachment 6

An Engineering Report of the Slope Failure
at Capell Cove Launch Ramp

REGIONAL GEOLOGY SECTION
SACRAMENTO, CALIFORNIA

March 15, 1995

MEMORANDUM TO THE TECHNICAL FILES

FROM: Steven G. Sherer

SUBJECT: Capell Cove Boat Ramp Parking Lot Slide - Site Visits on January 27, February 2, 14, 15 and 24, 1995 - Subsurface Geologic Investigations - Capell Cove Boat Ramp, Lake Berryessa--Solano Project, California.

The Capell Cove Boat Ramp parking lot site was visited, mapped and photographed on Jan. 27 and Feb. 2, 1995 at the request of Reclamation's North Central California (NCC) Office. Employees of the county roads department, Bill Sanford and Richard Kristoff from the NCC Office, the local Reclamation Park Rangers, Jack Mellor, Reclamation's Lake Berryessa Park Manager, Bill Curry from the Department of Boating and Waterways and the author all met on site Thursday Feb. 2, 1995.

On January 27, 1995 cracks had developed in the south side of the parking lot about 12 feet north of the south side curb between base stations 5+75 and 8+25. These cracks were up to 4 inches wide (horizontal movement) with little to no settlement across the cracks (vertical movement). However, a small sag, with up to 6 inches of vertical settlement did occur between the cracks and slope below the south side curb.

Apparently on Sunday, January 29, 1995, the slide started to move vertically. At about 7 AM some vertical movement was noted. By 9 AM about a foot of vertical movement had occurred. By 1 PM vertical movement of about 3.5 feet had occurred. Also substantial additional cracks had developed downslope with additional horizontal movement throughout the slide mass. Additional slides had developed in the lower 20 feet of slope above the reservoir (El. 408) that resulted in slope failures with very steep scarps along about two thirds of the toe of the larger slide mass.

The area of cracking and settlement increased in size in both the upstream and downstream directions between Jan. 27 and Feb. 2, 1995. Since February 2, 1995 this area has not grown in size but has experienced significant movements. The over all area of cracking and settlement, shown on Figure 1, as of March 15, 1995, is about 243 feet wide, along the south curb, between stations 6+00 and 8+43 and over 425 feet wide at reservoir water surface El. 409. The slide plane is interpreted to daylight from the slope under the reservoir water surface which was at elevation 408 on February 2, 1995, see Figures 2 through 6.

On February 2, 1995, the local authorities wished to keep the facility open to the public. Therefore recommendations were made to increase the area barricaded to include the new areas of crack and slide development; to inspect the area visually every two hours when open to the public; and to measure survey points at least weekly. This monitoring schedule was to be increased in frequency if significant changes take place. If significant hazards to the public develop, this facility would be closed.

Slide Description

To aid in the description of crack and slide development in the parking lot and downslope areas, three areas of differential movement have been designated as Areas A, B, and C (Figure 1). These areas are described as follows, and shown on the attached map. Aerial photography from 1991 and topography prepared from these photographs was used to construct a plan view map and five sections through the slide mass. The map and the sections were used to calculate the slide mass. Current topography along the sections was obtained on February 24, 1995 using the reservoir elevation for a base elevation, a

stadia rod and a bubble site level for elevation changes, and a chain was used to measure distances between the measured elevations.

Area A is the area of the parking lot that first developed slide movement, has the greatest amount of surface failure, and continues to have the greatest amounts of total movement throughout the mass to date. The crown scarp (top) of this portion of the slide is located 14 feet north of the south curb at it's greatest encroachment into the parking lot. The crown scarp encroaches into the parking lot along the south curb between Stations 6+00 and 7+03. The toe of area A is located between Stations 5+50 and 9+00 below the reservoir water surface. On February 2, 1995 the maximum amount of movement at the crown scarp of the Area A slide was verbally reported by the surveyor to be 5.0 feet of vertical movement and 2.4 feet of horizontal movement. On February 10, 1995 the vertical settlement had increased to a maximum of 8.9 feet at the crown scarp. On February 24, 1995 the settlement in this area had increased to a total of 9.8 feet in the crown scarp area.

Superficially, Area A is about 100 feet wide at the top and about 350 feet wide at the base. The surface area is 4,200 yd^2. The slide has an estimated thickness of 10 yards, and a total volume of about 42,000 yd^3.

Area B is the area of the parking lot located mostly upslope of, and downstream (east) of Area A. This is an area that had some cracking and settlement on January 27, 1995 but, did not begin to settle and crack significantly until about February 10, 1995.

On February 10, 1995 there were sags in Area B of the parking lot that had from 2 inches of settlement on the north side to as much as a foot of settlement (in local areas) in the downstream portion of Area B, south of the parking lot planters. On February 24, 1995 settlement and cracking had progressed in Area B to increase the area of sliding. At the crown scarp, the Area B slide mass encroaches into the parking lot to about 25 to 28 feet north of the south curb, and crosses the south curb at curb stations 6+65 and 8+43. Settlement in this area was a maximum of about 1.4 feet near Station 8+00 on February 24, 1998. It was reported that by March 1, 1995 settlement in Area B is as much as 1.5 feet across the crown scarp and may be as much as 3 feet near Station 8+00. Another report received from Reclamation's Lake Berryessa Personnel indicated that by March 15, 1995 settlement of about 4 feet has occurred across the crown scarp in this area and settlement along the curb near Station 8+00 is 4 to 5 feet. Area B is currently deforming and failing slowly. The volume of area B, upslope of area A, is estimated to be 20,000 yd^3.

Area C is the area of the parking lot located upslope of Areas A and B and upstream of Area A. Cracks in this area are located as much as 50 feet north of the south curb of the parking lot between Stations 6+20 and 8+00 and cross the south curb at Stations 5+50 and 8+40. Area C has cracks with only slight amounts of settlement.

Since the January 27, 1995 inspection, new cracks have formed in the south side of the lot (Area C) that are as much as 50 feet north of the south curb. These cracks are up to 4.5 inches wide and have settled as much as 3 inches (down to the south). Many other cracks with lesser amounts of horizontal and vertical movement occur between these cracks and the south curb of the parking lot. This movement appears to indicate further additional progression of slide development. This area has a volume estimated to be 12,000 yd^3.

Monitoring Points

Monitoring points were established across the crown area of the slide by the Park Authorities prior to the major movement that started on January 29, 1995. On February 2, 1995 the author recommended many additional points above and across the top of the slide that the surveyor agreed to install and monitor for vertical and horizontal movements. These points are currently being read at least weekly. Also on February 15, the surveyor was asked to install two lines of points (cross-sections) perpendicular to the slope of the slide. These lines should start above the Boat Ramp Parking Lot, include some of the

established points across the parking lot, and continue downslope to the reservoir. Water elevation of the reservoir, can be used as a (known) base elevation, to calculate the vertical movements of the points in the cross sections. These points should be read weekly until the slide stabilizes. At that time monitoring should continue either monthly or quarterly until it is sure slide movement has stopped for at least a year. The Data from the monitoring of these points should be transmitted to the Mid-Pacific Regional Geology Office on a monthly basis.

GEOLOGIC INVESTIGATIONS

The topography of the slope above the boat ramp facility is bowl-like, resembling the upper portions of a failed slope (landslide). The natural bench of the boat ramp facility may be the failed material from this slope failure. The geologic investigation was carried out to determine the composition and competency of the material under the boat ramp facility.

Test Pit No. 1 at Station 6+00 to 6+38

On February 14, 1995 a large test pit was excavated across the crown scarp between Stations 6+00 and 6+38. This pit was 38 feet long, 18 feet deep on the north wall and about 20 feet wide. At total depth of the pit the crown scarp slide plane was still dipping at a 80^0 angle.

Test Pit No 2 at Station 6+65 to 6+90

On February 24, 1995 a second large test pit was excavated across the crown scarp between Stations 6+70 and 6+85. This pit was 25 feet wide, 30 feet deep on the north wall and about 30 feet long. At total depth of the pit the crown scarp slide plane was still dipping at a 70^0 angle.

Log of Test Pits

Soils encountered in both of the test pits are similar. The north wall of each test pit was logged (attached Figures 7 & 8). The following is a combined description of the materials encounter.

Both pits exposed about 3 inches of asphalt and 4 inches of sand and fine gravel road bedding. Beneath the road bedding there is either a 1.1- to 1.3-foot-thick layer of yellow-brown sandy lean clay to fat clay fill material and/or a one-foot-thick greenish-gray fat clay with about 10 percent fine gravel metashale fragments.

Underlying both the fill and/or the fat clay is a brecciated rock mass composed of metashale. This rock mass is mostly (90%) cobble and boulder size fragments to 26-inch maximum length that are elongated, slickensided and coated with a thin film of greenish-gray fat clay. About 10% of this rock is angular gravel size fragments. The rock mass occurs to a depth of 6.8 feet at the west end of Pit No. 1 (Sta. 6+00) and to a depth of 11.0 feet at the east end of Pit No. 2 (Sta. 6+90).

Underlying the rock mass is a sandy lean clay with gravel layer that is mottled gray-black to greenish-gray. The clay contains 10 to 15 percent by volume cobble and boulder size metashale fragments in Pit No. 2. Most of the cobbles and boulders dip downstream or downslope. This clay layer extends to a depth of 13.2 feet at the west end of Pit No. 1 (Sta 6+00) and to a depth of 16.2 feet at the east end of Pit No. 2 (Sta. 6+90).

Underlying the black to gray clay is an interval of mottled yellow-brown to greenish-gray sandy lean clay with gravel. In Pit No. 2 the clay contains about 5 percent by volume cobble and boulder size metashale fragments. Most of the cobbles and boulders dip downstream or are flat lying. Water seeped out of this layer near its lower contact with the underlying blue-green clay. This clay layer extends to a depth of 18.0-feet near Station 6+10 in Pit No. 1 (the pits total depth) and to a depth of 22.2 feet at the east end of Pit No. 2 (Sta. 6+90).

Underlying the brown to gray clay layer is another layer of sandy lean clay that is blue-green to black. At the lower limits of this layer there was rotten wood resembling former trees trunks. This layer may be the slide plane from an ancient slide that created the natural bench that the boat ramp facility was built on. This clay layer extends to a depth of 23.3 feet in Pit No. 2.

Underlying the blue-green clay layer is a layer of medium brown colored fat clay with scattered roots throughout and some rotten wood at the upper contact. This layer of fat clay extended to the total depth of the pit (29.8 feet).

The contacts between each of the layers of materials in the pit were linear surfaces with no apparent zones of mixing. There is a thickening of the rock mass and clay layers above the blue-green clay in the downstream direction between Stations 6+00 and 6+90.

Cause of Slide Development

The test pits revealed that clayey materials extend to a great depth under the parking lot. The surface features of the slide that include a high angle back scarp to at least 30.0 feet of depth, wide blocks of material between cracks near the top of the slide, uplift along the lower half of the slope and a slide plane that has to day-light at or near the toe of the slope all indicate a deep-seated slide.

During the geologic investigation local inhabitants and Reclamation personnel were interviewed and Reclamation's construction and geological files were researched for historical information on this area. The information revealed that the slopes above the facility had periodically experienced movement in localized areas since at least the early 1970's. In 1992, many of the slopes near the reservoir rim in Capell Cove had slope failure. Apparently when the reservoir is low, flows are significant enough to cause excessive erosion along the toes of the slope, along Capell Creek.

The aerial photographs taken of the facility in 1991, when the cove was dry, reveal that during the rainfall season, when flows from Capell Creek are high and the reservoir is low, the creek had been eroding the toe of the slope below the current slide. This erosion oversteepened the lower portion of the slope enough that small slope failures started to occur below elevation 420 in 1992 during heavy rains in the area. As the toe of the slope was eroded away the upper slope became more and more unstable.

During heavy rainfall events the sheet flow off of the county highway above the boat ramps parking lot has been "jumping the curb." This curb is in place to direct this flow to drop inlet drains. The errant sheet flow has eroded small gullies in the hillside below the county road to the point that the water has been sinking into holes in the hillside. Holes were eroded into the hillside by water as it carried the soil cover down into the underlying (boulder size) rock fill by way of rodent holes. The 1.5- to 3.0-foot-diameter holes have been allowing water to infiltrate quickly and deeply into the hillside above the boat ramp parking lot.

There is an elaborate system of drains in place along and above the county road in a portion of the slope above the parking lot that failed during construction, and along the northern, upslope edge of the parking lot. With the exception of the sheet flow passing over the gutters described above, these drains seem to be functioning. The efficiency of these drains is undeterminable at this time.

An older landslide, composed of clay and rock material, that has previously failed, exists beneath the boat ramp parking lot. Because of this years very heavy rainfall, water has reached and saturated these materials and reduced their shear strength. These factors combined with the destabilization and erosion of the toe area of the slope, and the saturation of the slope itself, all combined to cause the current slope failure.

Safety of Keeping the Facility Open to the Public

The Capell Cove Boat Ramp parking lot slide has failed at a rate that has not exceeded more than 3.5 feet in a single day. There are numerous slides in the local vicinity that have exhibited similar past rates of failure. The historical and geomorphic evidence from these numerous local slides in the vicinity of Capell Cove Boat Ramp facility indicate that these slides should not represent a threat to life by sudden, rapid failure. Events that could trigger a sudden failure are as follows; 1) a large magnitude nearby earthquake, or 2) sudden rapid drawdown of the reservoir and 3) by a prolonged period of very heavy rainfall.

The earthquake or rapid reservoir drawdown have only a small and remote probability of happening. The prolonged period of very heavy rainfall has a higher probability of occurrence. However, in this type of event there should be adequate warning evidenced by the from rapidly developing cracks prior to failure and the facility could be closed before lives are endangered.

Recommended Repair

On March 1, 1995 the author and Dave Sparks from Reclamation's MP-Regional Office met with Bill Sanford, of Reclamation's Northern Central California Office and with Jack Mellor and Jim Peterson of Reclamation's Berryessa Office to discuss the findings from the geologic exploration and to recommend a repair for the facility. The following is a synopsis of the recommended repair.

The geologic exploration revealed that the facility was built on an old landslide. To **FIX** this facility and assure that no additional movement would occur, would require excavation of slide and replacement with suitable, compacted material and installation of drains. This type of fix would cost in excess of $750,000 dollars. Current budget constraints and practicality of this option rule out this type of fix at this time.

If left alone the failure will get larger and the facility which at present is in partial use, will be lost. The southern, outside portion of the parking lot and the area downslope of it will continue to move until the mass reaches a new equilibrium and excess pore pressures driving the failure, drain off. The portion of the parking lot that is failing could be repaired periodically to return the facility to full operation.

It is suggested that a multi-phased repair (not an **ENGINEERED FIX**) be undertaken to quickly place the facility into maximum use and to maintain that use for the future is as follows:

Phase 1.) It is recommended that in the failed portion of the parking lot, using Reclamation forces and equipment that:

A.) The asphalt pavement in the area that is cracking and deforming be removed and stockpile off location to later be recycled.
B.) The road bed material, underlying the asphalt pavement, composed of sandy gravel, be removed (if possible) and stockpiled nearby for later reuse.
C.) The failed area needs to be graded and compacted prior to
D.) beginning repair work. The grading and compaction should be extended down the slope to elevation 435.
D.) Place acceptable fill material in the graded area of the parking lot to it's former elevation in lifts of 6-inches. The fill should be placed out to the former curb location (Reference Figures 2 through 6). The last 4-inches of f ill should be road base sand and gravel. The outside slope of the fill should be constructed to a 1 1/2:1 or flatter slope.
E.) Additional fill material should be stockpiled nearby (possibly near the boat ramp) to fill in areas of additional settlement with compacted fill.
E.) The parking area should be filled with additional material to
F.) maintain grade periodically till settlement stops.

It is estimated that 1,600 yd^3 of suitable fill will be required to backfill the slide area to its original elevation. An additional 400 yd^3 of suitable fill should be stockpiled to be used for continuing repairs.

The fill should be constructed with any material free of organic matter, serpentinite, or fat clay. Crushed shale with lean clay or silty sand found locally are suitable. According to local suppliers the cost of fill material delivered to the site is $ 9.00/yd^3.

To cover the parking lot fill 4-inches thick will require 33 yd^3 of sand and gravel. Approximately 50 yd^3 of road base sand and gravel should be purchased and stock piled for this use. The cost of sand and gravel delivered to the site is approximately $ 25.00/yd^3.

The total estimated cost for Phase 1 backfill and roadbase sand and gravel materials is approximately $ 19,200.

Phase 2.) When the toe of the slide is exposed above reservoir water, the slope failure can be stabilized by compacting a portion of the failed material at the toe and by "loading" the toe area with additional suitable compacted fill material. Once the water in the reservoir recedes below elevation 395 the toe area of the slide should be:

A.) Photographed and geologically inspected.
B.) Graded and compact the lower slope as much as possible.
C.) For additional stability a twenty-foot-wide berm should be constructed in the slide toe area that catches the existing slope at elevation 420, see Figures 2 through 6. This berm should have an 1.5:1 outside slope angle to the bottom of the cove (approximate elevation 403 on the east and 394 on the west).
D.) To prevent the berm from being eroded by flows in Capell Creek the outside slope
E.) should be covered with coarse gravel bedding (0.3 foot thick) and rip-rapped (1.0-foot-thick). The velocity of the stream flows in Capell Creek is very high when the reservoir is low. Rip-rap should be sized to resist erosion from these flash flood type flows.

To accomplish Phase 2 it is estimated that 8,600 yd^3 of suitable fill will be required to build the berm. The fill material should be free of organic matter, serpentinite, or fat clay. Crushed shale with lean clay or silty sand found locally are suitable. Approximately 680 yd^3 of riprap and 135 yd^3 of coarse gravel will be required to armor the berm.

Estimated cost of fill material delivered to site is approximately $ 77,400. The estimated cost for rip-rap material delivered to site is $30.00/$yd^3$ for cost of $ 20,400. The estimated cost for coarse gravel delivered to site is
$ 23.80/yd^3 for a cost of $ 3,200.

The total estimated cost of Phase 2 slide stabilization is $ 101,000.

Phase 3.) After perhaps three years of no settlement in the parking lot area, the slide area could be repaved with asphalt.

Estimated cost of suitable (class 2) road-base delivered to the site is
$ 25.00/yd^3. The estimated repair is of 2975 ft^2 of asphalt parking lot. This will require approximately 33 yd^3 of road-base material to place a 0.3-foot-thick layer for a cost of $ 830. To have 2975 ft^2 of asphalt pavement supplied and placed is estimated to cost $ 0.80/ft^2 for a cost of $ 2,400.

The total estimated cost for Phase 3 materials is $ 3,230.