Report of Findings on the Overtopping and Embankment Breach of the Upper Dam - Taum Sauk Pumped Storage Project, FERC No. 2277

FERC Taum Sauk Investigation Team

April 28 2006

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Preface

The purpose of this report is to present the findings of a team assembled by the Director, Division of Dam Safety and Inspections to investigate and document events surrounding the Breach of the Taum Sauk Pumped Storage upper reservoir on December 14, 2005. The team was charged with gathering all available information on the design and construction of the upper reservoir; the events leading to the overtopping; and the subsequent impacts affecting downstream lives, property, infrastructure, and the natural environment. Additional analyses were conducted, as necessary, to better understand the events and impacts of the incident.

The process included visits to the project site, the Osage Missouri control center, the licensee headquarters control center and energy trading center, interviews with the owner's management, engineering and operations staff. The report is intended to provide information and data to the independent Panel of Consultants engaged by FERC to investigate the breach.

Listed below are the members of the team responsible for preparation of this report:

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Executive Summary

The Upper Reservoir of the Taum Sauk Pumped Storage Project 2277-MO was overtopped during the final minutes of the pumping cycle on the morning of December 14, 2005. Reservoir data indicate that pumping stopped at 5:15 AM with the initial breach forming at approximately the same time. Once overtopping began, erosion started at the downstream toe of the 10-foot-high parapet wall. Erosion progressed below the parapet wall, likely causing instability and resulting in the initial loss of one or two parapet wall sections. Subsequent erosion and breach of the rockfill embankment formed a breach about 656 feet wide at the top of the rockfill dam and 496 feet at the base of the dam. The peak discharge from breach was about 273,000 cfs which occurred within 10 minutes of the initial breach. The complete evacuation of the reservoir occurred within 25 minutes.

The breach flows traveled down the west side of Proffit Mountain into the East Fork of the Black River. Flows destroyed the home of the Johnson's Shut-Ins State Park superintendent, flooded motorists on Highway N, significantly damaged the park, campground, and adjacent properties, and entered the Lower Taum Sauk Reservoir. The Lower Dam stored most of the releases and had a peak spillway discharge of approximately 1,600 cfs. This equates to about 1.1 feet over the spillway crest which is well within the capacity of the lower reservoir spillway. Upon leaving the Lower Dam area, flows proceeded downstream of the Black River to the town of Lesterville, MO, located about 3.5 miles downstream from the Lower Dam. The incremental rise in the river level at Lesterville was about two feet which remained within the banks of the river.

Post-breach inspections and evaluations revealed the following information:

1. The project had historically operated with a minimum of two feet of freeboard on the lowest section of the parapet wall. Following installation of a geomembrane liner in 2004, AmerenUE operated the project to fill the upper reservoir within one foot of the lowest section of the parapet wall. Post breach evidence shows the reservoir may have been routinely filled to within 0.25 foot of the lowest section of the parapet wall.

2. The December 14, 2005 breach was preceded by significant wave overtopping that occurred on September 25, 2005. Factors involved with

this event were waves due to winds from the remnants of Hurricane Rita combined with a reservoir level pumped to within 0.4 foot of the top of the parapet wall.

3. On September 27, 2005, AmerenUE adjusted the reservoir control programming to account for the difference between the actual reservoir levels and the readings from the reservoir level instrumentation.

4. On October 3-4, 2005, AmerenUE personnel discovered that the conduit which housed the instrumentation for monitoring reservoir levels was not properly secured to the dam. Deterioration of the instrumentation tie-down allowed the conduits to move adversely impacting the reservoir level readings. The instrumentation readings showed reservoir levels that were lower than actual levels. As a safety measure, AmerenUE adjusted the reservoir level control programming to shut down the pumps when the instruments showed the reservoir levels were two feet lower than normal settings.

5. Two Warrick Conductivity Sensors were used as a safety system for shutting down the units in case of high water levels. The sensors would send a signal to shut down the units when they became wet. The sensors were physically relocated to a height that was higher than the lowest point on the parapet wall. Therefore, if the Warrick Sensors were contacted by water, the Upper Dam would already be in an “overtopping” condition.

6. Modifications made to the reservoir control programming adversely affected how the signals from the Warrick Sensors were managed and reported. The modifications required that both sensors make contact with water to initiate shutdown. This removed a layer of redundancy to the safety system.

Section 1 Project Description

1.1 General

The Taum Sauk Project is located in Reynolds County, Missouri, on the East Fork of the Black River approximately 90 miles southwest of St. Louis, Missouri. The project is a reversible pumped storage project used to supplement the generation and transmission facilities of AmerenUE, and consists basically of a mountain ridge top upper reservoir, a shaft and tunnel conduit, a 450-MW, two-unit pump-turbine, motor-generator plant and a lower reservoir. It was the first of the large capacity pumped-storage stations to begin operation in the United States.

1.2 Dams

The Taum Sauk Project has two dams, known as the Upper Dam and the Lower Dam.

1.2.1 Upper Dam

The Upper Dam is a continuous hilltop dike 6,562-ft-long forming a kidney-shaped reservoir. The dike is a concrete-faced dumped rockfill dam from the foundation level to elevation 1570.0 ft and a rolled rockfill between Elevation 1570 and 1589. A 10-foot-high, l-foot-thick reinforced concrete parapet wall atop the fill extended the crest to elevation 1599 ft at the time of original construction. Since construction, settlement of the rockfill varied between 1 and 2 ft with the lowest area found after the breach at panel 72. At panel 72, the top of the embankment is at elevation 1586.99 ft and top of the parapet wall is at elevation 1596.99 ft.

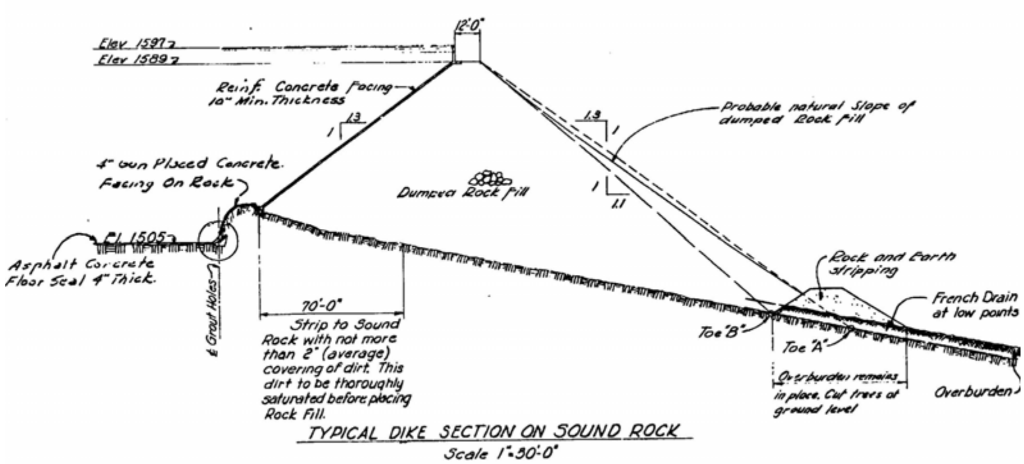

Figure 1.1- Cross section from original design drawings

Both the upstream and downstream slopes are 1.3H:1V which is likely the natural angle of repose of the material. The crest is 12 feet wide. The pneumatically placed upstream concrete face slab has a design thickness of 10 inches, and is reinforced with No. 7 bars at 12 inches both ways. In actual placement, the slab thickness averaged nearly 18 inches due to the unevenness of the rockfill. The upstream concrete face had joints (with copper waterstops) located at the junctures with the parapet wall, the toe block and adjacent face panels. The face slab was placed in panels, 60 feet wide at their widest dimension. Expansion joints between the slabs to accommodate movement, caused by settlement of the rockfill, used 3/4-in asphaltic expansion joint material and U-shaped copper water stops. The construction video shows the “expansion joint” with the copper waterstops was formed as a narrow section with the sprayed concrete placed later.

A reinforced concrete plinth (toe block) was provided at the toe of the concrete face. Where the natural rock surface was substantially higher than the reservoir floor, the rock was excavated on a near vertical slope and the plinth was at the top of the excavated rock. In these areas, the rock cut between the reservoir floor and the plinth was sealed with a 4-inch-thick layer of wire mesh-reinforced shotcrete. The entire reservoir bottom was sealed with two 2-inch-thick layers of hot-mix asphalt concrete placed over leveled and compacted quarry muck. Around the edge of the asphaltic concrete, a single line grout curtain was constructed to limit seepage under the dam. In 1964, a concrete cutoff up to eight feet deep was placed in front of the panel toe blocks in the fish pond area.

A tunnel through the northern side of the dam provides access to the reservoir floor. The access tunnel is a concrete lined, 19-foot-diameter, horseshoe shape. The upstream face is fitted with a hinged steel bulkhead gate that opens into the reservoir. The gate is 10.4 feet wide by 12.4 feet high and is hinged at the bottom. The gate is vertical when closed and horizontal when open.

Drainage ditches surrounding the toe of the dike direct a large portion of leakage into a collection pond. A small dike retains water in the collection pond, from where a maximum of about 10 cfs was pumped back into the upper reservoir. When the leakage rate exceeds the pump-back capacity, water spills from the collection pond small overflow spillway and eventually flows into the lower reservoir.

1.2.2 Lower Dam

The Lower Dam is located in a narrow steep-sided gorge just downstream of the junction of Taum Sauk Creek and the East Fork of the Black River, and forms a reservoir with a surface area of 395 acres with water level at spillway crest. The canyon at this location is in exposed hard blocky rhyolite rock of good quality. The reservoir design volume at the spillway crest is 6,350-acre-feet. This volume has been reduced by sedimentation, such that the useable volume is less than the useable volume of the upper reservoir. The Lower Dam is a concrete gravity dam founded on rock. The maximum height is 60 feet above bedrock to the spillway crest and 75 feet to the operating deck. Its height above streambed is 55 feet. The dam is 390 feet long, and except for two piers supporting the operating deck, is an uncontrolled overflow spillway. The spillway crest is at elevation 750 feet and the operating deck is at elevation 765 feet. The dam section has a base width at the maximum section equal to 1.25 of its height. The downstream slope is 0.83:1 (horizontal: vertical).

The Dam consists of 10 blocks alternatively 38 and 40 feet wide and labeled “A” to “J” from left to right. Copper waterstops are located at the joints between blocks. The joints between blocks contain no keys and were not grouted. The two piers supporting the operating deck are 4 feet and 13 wide. The 13-foot-wide pier contains a 42-inch-diameter vertical shaft and ladder that provides access to a 5-foot x 7-foot gallery with invert at elevation 720 feet. The upstream wall of the gallery is eight feet from the upstream face and extends through the middle eight blocks.

A single line grout curtain is located along the upstream side of the gallery. The grout holes are spaced 6 feet apart and extend 20 feet below the base of the dam. Foundation drainage consists of a longitudinal "box" drain formed with one-half of a 12-inch-diameter pipe. A longitudinal formed drain on the bedrock below the downstream side of the gallery connects to transverse formed "box" drains at each block joint that discharge to the downstream face of the dam. In addition, at each block joint, a formed drain extends from the foundation drain to the gallery floor. Observation wells were provided in the 8 central blocks. The piezometers consist of copper tubing extending vertically down from the middle of the gallery, then horizontally within the bottom lift of concrete to a point 10 feet downstream of the downstream gallery wall. The tubing is terminated in an excavated depression in the foundation rock filled with gravel.

1.3 Gravel Trap Dam

The gravel trap dam is a low head low hazard steel sheet-pile and rock crib structure located upstream of the powerhouse and designed to trap gravel in the river before it washes into the lower reservoir.

1.4 Spillways

1.4.1 Upper Dam Spillway

The Upper Dam was designed without a spillway, since it has a negligible drainage area and the only flow into it is by pumping and direct rainfall. Overfilling was to be prevented by a system of redundant water level controls that would automatically shut off the pumps.

1.4.2 Lower Dam Spillway

The entire 390-foot-long Lower Dam is an ungated overflow spillway. Two piers, 13- and 4-foot-wide, are located within the ogee section and support the operating deck. The spillway discharges to a reinforced concrete flip bucket with a 28-foot radius. The elevations of the flip buckets for the abutment blocks are higher than those for the center blocks.

1.5 Powerhouse

The powerhouse is located at the upstream end of the Lower Reservoir about 2-miles from the Lower dam. It is situated in a deep narrow canyon through which a tailrace channel was excavated to connect to the East Fork Black River. The Powerhouse is connected to the Upper Reservoir via a concrete and steel-lined shaft and tunnel. The initial reversible pump-turbine rating for each unit was 175 MW, but was upgraded to 204 MW in July 1972. The turbine runner upgrade conducted in 1998 resulted in a revised rating of 450 MW. The tailrace to the lower reservoir is about 65 feet wide and 2,000 feet long.

1.6 Intake and Outlet Works

1.6.1 Upper Dam Outlet Works

The Upper Dam outlet is the power conduit that consists of a 451-foot-long, 27.2-foot-diameter, vertical shaft, the top 110 feet of which is concrete lined; a 4,765-foot-long, 25-foot-diameter unlined horseshoe tunnel sloping at 5.7 percent; a horizontal 1,807-foot-long, 18.5-foot-diameter steel lined tunnel; and a short penstock that bifurcates to the pump-generating plant. The shaft bellmouth intake is located in the southwestern portion of the Upper Reservoir in an area of the floor that is 20 feet lower than the rest of the reservoir floor in order to suppress vortex development. Two 9-foot-diameter spherical valves in the powerhouse control flow through the outlet. Being a reversible pumped storage facility, the intake and outlet are the same.

1.6.2 Lower Dam Outlet Works

The outlet works of the Lower Dam consists of a small and large sluice. The small sluice is a 16-inch-diameter spiral welded pipe with an upstream invert at elevation 710 feet and downstream invert at elevation 707 feet. A 20-inch cast iron slide gate on the upstream face of the dam controls flow through the small sluice. The slide gate motor operator is located on the top of the 4-foot-wide pier on the crest of the dam. An intake structure extends 7 feet upstream of the Lower Dam and provides a single set of slots for either a trashrack or stoplogs. The large sluice is a horizontal 8-foot-wide by 10-foot-high steel-lined conduit with an invert elevation of 705 feet. An 8-foot by 10-foot cast iron slide gate located on the upstream face of the dam controls flow through the sluice. The slide gate motor operator is located atop the 13-foot-wide pier on the spillway crest.

1.7 Standard Operating Procedures

The Taum Sauk project is a peaking and emergency reserve facility. During a typical 24 hour period of operation at Taum Sauk, pump back to the upper reservoir begins around 9:30 PM to 10:00 PM as excess power from the grid becomes available for pumping. Pumping continues through the night until around 5:00 AM to 6:30 AM as either the upper reservoir limit level is reached or excess grid power is no longer available. From around 6:00 AM to noon the base load plants are generally able to supply the grid power demands so Taum Sauk is usually idle during this period. Generation of power at Taum Sauk usually begins by around noon and continues for four or five hours. Generation stops around 5:00 PM to 6:00 PM as the demand for power drops off. The project is usually then idle again for an hour or more before a shorter generation cycle occurs from around 7:00 PM to 9:30 PM. The daily operation sequences through the year are similar from day to day but with adjustments in times for pump back, idle time, and generation depending upon the demands on the power grid.

The project is controlled through a microwave system from the Osage Plant at the Lake of the Ozarks, under the direction of the load dispatcher in St. Louis. Both units can be put on full load in a few minutes. Generation, pump-start and duration are determined by system needs. In the fall, winter, and spring, the number of cycles is typically less, usually pumping at night and generating during the day. At times, during periods of low demand, the facility is not operated.

The normal minimum water level in the Lower Reservoir is elevation 736 feet. Although this is above the bottom of the Lower Reservoir, operation below this elevation pulls debris up the pump-generating station tailrace channel. The debris interferes with the pumping operations and sets the practical minimum water level elevation. The normal maximum water level is 749.5 feet or 6 inches below the spillway crest.

An automatic volume control system was installed to discharge through the sluice gates or over the lower dam an amount equal to the inflow from the East Fork of the Black River into the reservoir. Storm flows are passed over the Lower Dam spillway. Typically, the spillway discharges occur every spring.

As originally designed and constructed, the useable volume in the lower Reservoir was greater than the volume of the Upper Reservoir. The design volume of the Lower Reservoir was reduced by the need to raise the minimum operating water level from 734 feet to 736 feet due to the debris being pulled up the tailrace channel. Although trashracks prevented the debris from being pulled into the pumps, it interfered with pumping operations. Normal sedimentation over the years has reduced the useable volume above elevation 736 ft further, such that currently it is less than the volume of the Upper Reservoir. As a result, the full generating potential of the Upper Reservoir cannot be realized. According to the August 2003 Eighth Independent Consultant's Safety Inspection Report (Part 12D Report), the Upper Reservoir minimum level is limited to elevation 1,535 ft, or 30 feet above the bottom of the reservoir, to prevent discharging water over the Lower Dam spillway. Before the installation of the geomembrane liner in 2004, the normal automatic settings were as follows:

	UPPER RESERVOIR ELEVATIONS		LOWER RESERVOIR ELEVATIONS
	Summer [feet]	Winter [feet]	All seasons [feet]
1-st pump OFF	1595	1588	739
2-nd pump OFF	1596	1589	736.2
All pumps OFF	1597	1590	736

Prior to the installation of the geomembrane liner, upper reservoir levels were verified by a staff gage attached to the parapet wall near the gage house. Because the staff gage was affixed to the parapet wall, it settled about one foot along with the parapet wall. Due to the settling, AmerenUE believes the upper reservoir was actually operating at 1595 feet instead of 1596 ft. The staff gage was removed during the geomembrane liner replacement in the fall 2004. After the installation of the liner, operations typically pumped the upper reservoir to elevation 1596 ft.

Prior to installation of the geomembrane liner, reservoir levels were kept lower during the winter to limit leakage through the parapet walls. During winter months, the leakage would collect on the embankment crest and become ice, making it difficult for crest access. Since the liner extended near the top of the parapet wall, leakage through the parapet walls was longer a factor during the winter. According to the February 8, 2006 interview with Mr. Richard Cooper, AmerenUE had decided to no longer lower the reservoir during winter months after the liner was installed.

A detailed description of the project's instrumentation and reservoir control system at that time of the December 14, 2005 breach is presented in Section 5.

Section 2 Project History

2.1 History of Construction of the Upper Reservoir Dam

The top of Proffit Mountain was leveled and the excavated rock was used to construct the dike that forms the upper reservoir. The stone is predominantly a rhyolite porphyry. As described in available engineering reports, the overburden was stripped for the upstream-most 70 feet and placed downstream to form the bed of the perimeter road. All weathered material was stripped from this area to sound rock. Overburden varied from a few feet to as much as 65-feet thick. Clay seams were to be removed by excavating during construction. Excavated rock was end-dumped from trucks and sluiced with 30-psi water, to form the ring dike. A filter zone and several layers of compacted rock were placed over questionable areas where piping into the foundation might be possible. Outside the 70-foot stripped zone, the weathered rock was left in-place. Low areas in the natural topography were also filled with compacted rock. It was reported in the 1998 Seventh Part 12D Report that excavated fines were used to level the reservoir floor. A video of the original construction was provided by AmerenUE to show the construction of the embankments.

The dike is topped with a 12-foot layer of horizontally compacted rock placed in 4-foot lifts and compacted with a vibratory roller. The parapet wall was cast-in-place on top of this top layer. Based on post-breach inspections, it appears the crushed rock varies from 1000 lb stone to predominately less than 20 lb stone. The stone is predominately angular. The outer shell of the dike contains clean rock fill material with more sandy and pebble sized materials in the closure section, near panel 50.

2.2 Geology

2.2.1 Geology of Southeast Missiouri

The Saint Francois Mountains, a range located in southeast Missouri, is an outcrop of Precambrian igneous rock mountains rising over the Ozark Plateau. This range is one of the oldest exposures of igneous rock in North America. Formed through volcanic and intrusive activity over 1.4 billion years ago, nothing is left of these mountains but their roots. By comparison, the Appalachians started forming about 460 million years ago, and the Rockies a mere 70 million years ago. The St. Francois range was already twice as old as the Appalachians are today.

Unlike the rest of the mountainous areas in the Ozarks, the Saint Francois Mountains were formed by true volcanic activity. The localized vertical relief observed in most of the Ozarks, a dissected plateau, was caused by erosion. The volcanic activity that formed this mountain range is also thought to be the geological cause of the uplift of the Ozark Plateau. Geologists talk of the "Ozark dome" wherein elevations and stratigraphic inclines generally radiate down from the Saint Francois Mountains. These elevations may be the only area in the American Midwest never to have been submerged, existing as an island archipelago in the Paleozoic seas. Fossilized coral, the remains of ancient reefs, can be found among the rocks around the flanks of the mountains. These ancient reef complexes formed the localizing structures for the mineralizing fluids that resulted in the rich ore deposits of the area. The St. Francois Mountains are the center of the Missouri mining region yielding; iron, lead, barite, zinc, silver, manganese, cobalt, and nickel ores as well as granite and limestone quarries.

Mountains in this range include; Taum Sauk Mountain, Bell Mountain, Proffit Mountain, Pilot Knob Mountain, Hughes Mountain, Goggin Mountain, and Lead Hill Mountain. The Taum Sauk Hydroelectric Plant is actually not located on Taum Sauk Mountain, but on Proffit Mountain about five miles from Taum Sauk. Proffit Mountain is the termination of a ridge extending southwesterly from Taum Sauk Mountain. The elevations range from 500 feet to 1772 feet (Figures 2.1 and 2.2). Taum Sauk Mountain is the highest peak in the range, and the highest point in the state, with an elevation of 1772 feet. A part of the Ozark Trail winds through parts of the St. Francois Mountains, including a popular section that crosses Taum Sauk and Proffit Mountains. (From Wikipedia.)

The St. Francois Mountains are only a small remnant of the original volcanic activity in the area. It is thought that two continental plates collided during Precambrian times and led to the creation of the original mountains. Most of the rocks in the area are lighter weight rocks of a granitic composition. The darker dikes in the area, commonly found in road cuts, are formed from more basaltic minerals in the area and formed when rifting in the area started to split the plates apart about 900,000 years ago. These darker and heavier minerals originated deeper in the earth’s crust. This rift failed and is no longer active. Leftover faults from the collision and rift are now thought to form the New Madrid Fault Zone, which runs through far southeast Missouri. This fault zone is still active and has been responsible for some of the largest earthquakes in U.S. history.

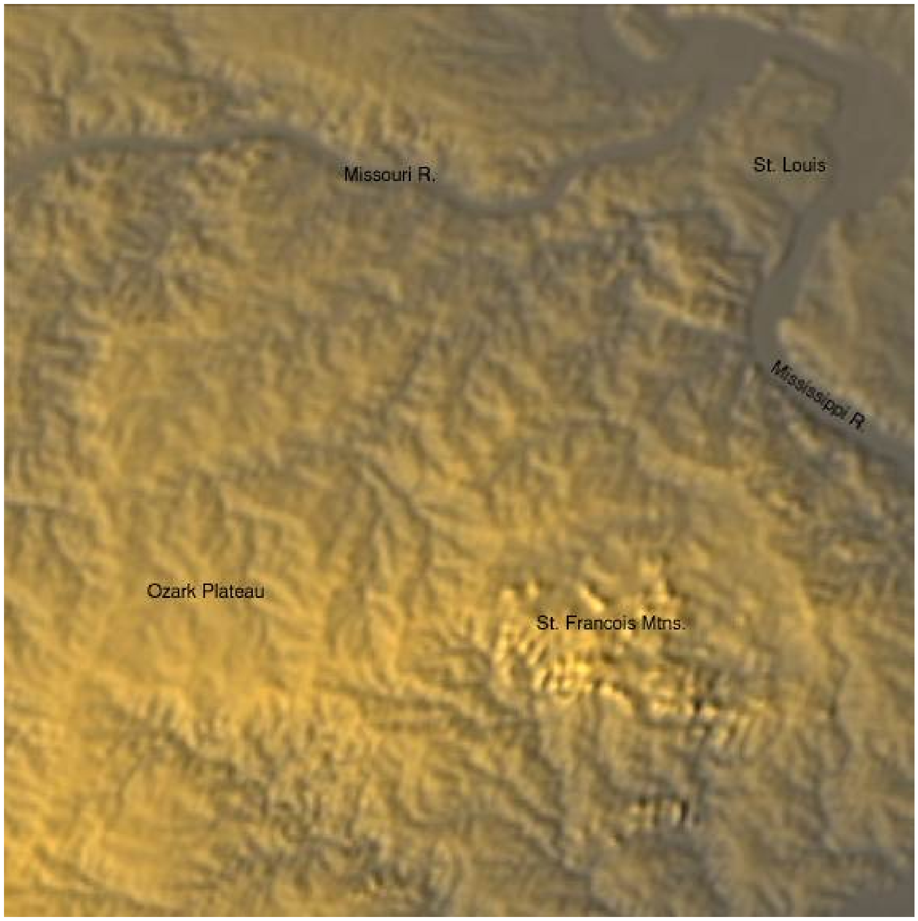

Figure 2.1 - Shaded relief map of area. (From Wikipedia.)

Figure 2.2 - Shaded topographic map of project. (From Wikipedia.)

2.2.2 Upper Reservoir Geology

The top of Proffit Mountain was leveled and the excavated rock was used to construct the dike that forms the Upper Reservoir (Figure 2.3). The foundation area was stripped to bedrock during the dam breach. The bedrock is hard rhyolite porphyry with areas of closely spaced vertical joints (Figures 2.4 and 2.5). This rock is volcanic and formed by relatively quiet lava flows on the earth's surface. These rocks are fine grained but contain mineral crystals that formed before the rock was erupted. Even though they are 1.4+ billion years old, these rocks still exhibit flow patterns from the original lava flow.

The vertical joints are in an orthogonal set that run roughly N-NE and W-NW. A second set of slickenside joints with lower dip angles were observed that had a line of intersection in a northerly direction. This joint set dipped roughly 45 degrees west and 45 degrees east. The rhyolite porphyry rests on granite porphyry, the contact is dipping easterly and is exposed just downstream of the breach area. During original exploration, it was conjectured the rhyolite had flowed out on the weathered surface of the granite, scorching and baking it. This means that the granite porphyry may be older than the rhyolite porphyry. However, there are different opinions regarding the age and sequence of intrusions and it is possible the granite porphyry is younger.

The series of Precambrian rhyolites at the adjacent Church Mountain form a stratigraphic sequence of flows that strike N45ºSW and dip 20ºN, and reportely have similar strikes as the rhyolites of Taum Sauk. As described in a 1973 report of the geology of the adjacent Church Mountain, the principle rock formations are:

"Precambrian Hogan Mountain Rhyolite. The rhyolite is 'typically reddish-brown, or reddish-purple in color and has a dense aphanitic groundmass. About 20 to 30 percent of the rock consists of salmon – red feldspar and glassy quartz phenocrysts. Flow layers, lighter in color than the massive rock, consist of microangular zones that generally dip at consistent low angles to the north and west... Many of the quartz phenocrysts and quartz grains in the ground mass are replaced by feldspar... The field relations and micro-textures suggest that this is a devitrified welded tuff'..."

Precambrian Munger Granite Porphyry. "This was encountered at the bottom of the upper Taum Sauk Dam... The predominant features are 'orthoclase phenocrysts up to 8 mm in length and quartz up to 4 mm in diameter. The rock is brownish-red with greenish mottling due to fine-grained mafic minerals. Quartz comprises about 30 percent: orthoclase, 33 percent: oligoclase (ab89), 33 percent: and extensively altered biotite and hornblende about 4 percent'...

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Figure 2.3 - View of upper Reservoir.

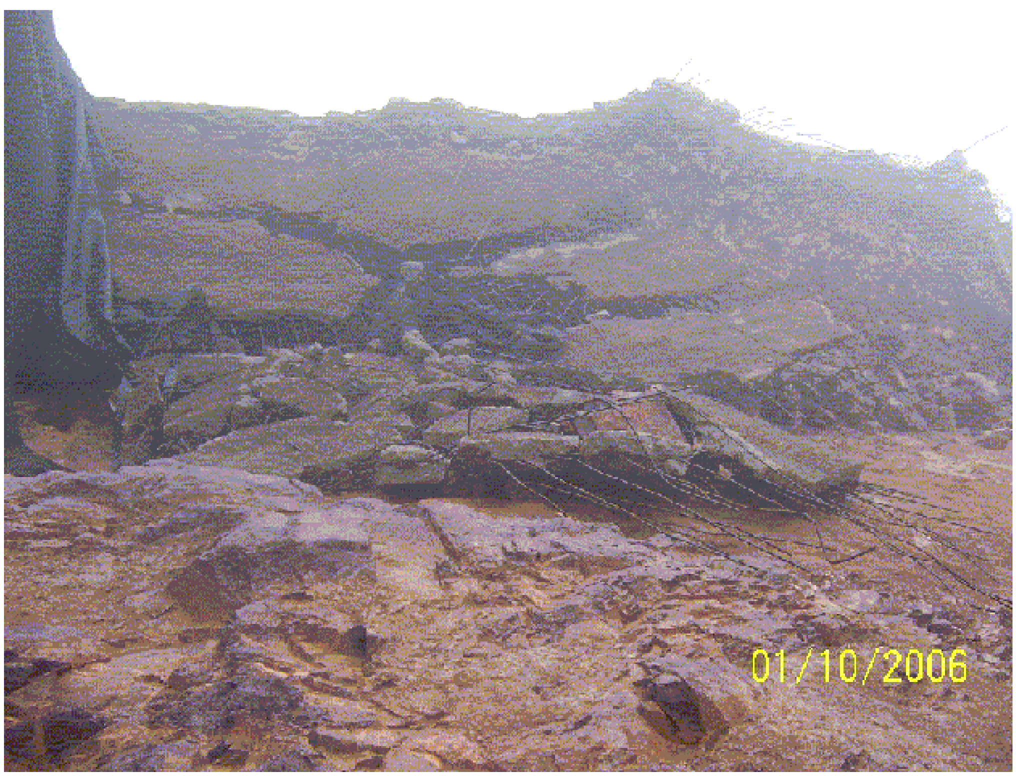

Figure 2.4 - View of bedrock immediately below failed embankment section. Note weathered clay in lower portions of the exposure.

Figure 2.5 - View of bedrock within, and immediately below failed embankment section. Note distribution of weathered rock (red-brown color) and topsoil (green-brown color). The "fish-pond" area contains water and is immediately upstream of the breach.

2.2.3 Breach Foundation Geology

An area of the foundation in the breach section contained clay with low-moderate plasticity and weathered rock in the area just beneath the breach. The clay and weathered rock zone could have provided a failure surface for embankment sliding. The clay appears to be a residual weathering product of the bedrock (Figure 2.6), and in areas, relict bedrock structure can be observed in partially and completely decomposed clay remnants. No records were made available that indicate the extent of clay that was left in the breach area. However it could be conjectured that the settlement of the parapet wall in this area may have been accentuated due to consolidation of this clay deposit if it was of substantial thickness. The clay appeared saturated and contained groove marks from debris (Figures 2.7-2.9). This area was over-excavated in the footprint of the reservoir due to the clay foundation conditions, forming the "fish-pond" area of the reservoir floor (Figure 2.10). There was also some remnant soils found in the breach area (Figure 2.11 and 2.12).

According to the 1964 Union Electric Company memo on "Leakage From Upper Pond" (pages 1-2) "…the exposed rhyolite at levels uncovered still contain fingers of weathered rock.…on the west side a deeper zone of weathering was excavated near drill hole #18 about where considerable spring flow is found at the outer toe. An inclined clay band at Sta. 6+00 on the west side apparently crossed the floor of the pond and occurs on the opposite side of the basin. The clay band was trenched and back-filled with concrete before material in the rockfill or seal cover was placed. These geologic zones are reflected in response of pond by seepage that collect upon reaching the underlying rock and by air bubbles near the west bank along the clay band, following initial filling of the pond. Most of the exploratory drill holes in rhyolite had substantial loss of water… …that led to asphalt lining of the pond floor… …indicat(ing) that joints are communicative. At the north end (Panels 90-95) a sudden increase in losses between January 8-10 (1964) was caused by open channels (under the asphalt lining and) in bedrock under the dam where eroded material had been removed by gradual piping. It was necessary to add concrete cutoff in this section, fill the visible channels and attempt to control water movement along bedrock joints by means of a shallow grout curtain across the floor at the northern end of the pond. The work was largely successful but should be watched for further aggravated losses beyond the section that was repaired."

According to the August 1968 Union Electric Company memo on "Review of Safety Report – Upper Reservoir" (page 4) "…the rhyolite porphyry…is generally fresh, dense, moderately to abundantly jointed… …Overburden ran from a few feet thickness to as much as 65 feet. Several significant clay seams, gently dipping, and up to 4 feet in thickness were encountered. Under the rockfill these seems were either excavated and plugged with concrete or covered with small compact rock. Weathered rock was left in place wherever its competence was judged equivalent to the rockfill. However, within the inside 70 feet of the base of the rockfill all weathered material was stripped to sound rock. A filter zone and several layers of compacted rock were placed over questionable areas where piping of the foundation might be possible. Low areas or depressions in the natural topography were filled with compacted rock."

According to the August 1967 Union Electric Company memo on "Taum Sauk Upper Reservoir Report on Safety" (page 2) "The… …rhyolite porphyry is an excellent high compressive strength rock that should have stabilized in its settlement. However, the formation contained frequent zones of soft weathered rock, all of which could not have been selectively wasted. The frequent cycling of the water load should not cause continued adjustment of competent rock but would affect poor rock. Actually, there is no other experience with such frequent cycling of load on a dumped rockfill, and whether a dumped rockfill of all sound rock would have stabilized by this time (1967) is not known. I believe a fill of 100% competent rock would have stabilized and that the percentage of weathered rock in the Taum Sauk is the cause."

Figure 2.6 - Foundation area composed of weathered rhyolite with some clay, located in breach area.

Figure 2.7 - Grooves cut into an area of clay-seam foundation by the floodwaters. This area is located immediately downstream and in the center of the breach.

Figure 2.8 - Overview of area shown in previous photograph. Note washed out access road (circled).

Figure 2.9 - Overview of area to the right of that shown in previous photograph. (See also Figure 2.4.) Note breach in background and toe of breach slope on left edge of photograph.

Figure 2.10 - Breached area. Note "fish pond" area immediately upstream of the breach. This area was over-excavated during original construction due to poor foundation conditions.

Figure 2.11 - Weathered rock and discontinuous clay seam foundation just downstream of fish-pond area.

Figure 2.12 - Root-laden remnant native soil in breach area, resting on fresh rhyolite.

During a geologic inspection conducted on April 12-13, 2006, it was noted that there is a shear zone that cuts through the breach area. There appeared to be a component of left lateral displacement across the shear zone. The exposed rhyolite beds in the breach area were composed of three to four descrete flows, separated by very thin to thin clay rich seams. The rhyolite complex rests on a saprolitic soil that was interpreted to be heavily weathered granite. The underlying granite appeared moderately weathered with alteration of the feldspars near the overlying contact with the saprolite, and was less weathered deeper in the profile. The rhyolite sequence varied from dark red-brown to purple brown flows with occasional lineation of the phenocrysts. The rhyolite resting on the saprolite was black and contained veins of clay near the base. The contact between the rhyolite and granite was water bearing. The saprolite varied from several inches to as much as 10-feet in thickness. Based on construction documentation, the saprolite appears to be present in the shaft and therefore may extent beneath the entire reservoir at unknown depths. Rock outcrops on the southwest side of the reservoir indicate the contact between the granite and rhyolite passes beneath the reservoir foot print, possibly in the area of Panel 60-75. However, more site work is needed to define the location of this contact. Boring information taken in preparation for reconstruction of the Upper Reservoir indicates that there is as much as 200 feet of relief on the granite surface, within the immediate reservoir area.

2.2.4 Geology of Johnson's Shut-Ins State Park

The Johnson's Shut-Ins State Park is located on the East Fork of the Black River which carved through fractures in hard volcanic rock to form a natural water park. The area is home to waterslides, waterfalls, a small underwater shelter, whirlpools, and much more. The rocks vary in color from pink to black depending on the nature of the volcanic eruption that led to their creation. The rocks at Johnson's Shut-ins consist of welded tuffs and ignimbrites, rocks formed from extremely violent volcanic eruptions. These rocks form when clouds of hot volcanic ash roar down a mountainside and settle to the ground. The residual heat melts the ash and 'welds' it together to form a rock. These rocks are very hard and form shut-ins where rivers have tried to erode. Shut-ins form when a stream down cutting softer rocks runs into harder rocks. These harder rocks channel the river into a smaller area and make for interesting scenery.

2.3 Design and Stability

2.3.1 Embankment Design and Stability Analysis

Stability of the embankment (slopes 1.3H:1V, 37.56º) was evaluated in the 1988, assuming fully drained conditions. The consultant performed an infinite slope stability analysis (using two phi angles) and compared this with a "SLOPE" stability analysis performed for a concrete faced rockfill dam with similar section geometry and fill properties. Zero cohesion and a phi angle of 45 degrees were assumed in the SLOPE computer analysis. Zero cohesion and a phi angle of 50 and 47 degrees were assumed in the infinite slope method. The infinite slope method yielded the lower factors of safety. The rockfill dike was also evaluated for seismic loading using a pseudostatic seismic coefficient of 0.14g for the SLOPE analysis and 0.10g for the infinite slope analysis. Estimated factors of safety for the dam for these various loading conditions are summarized below:

Method	Static Φ (50º/47º)	Seismic
Infinite Slope	1.55/1.39	1.26/1.14
SLOPE	1.7[1]	1.3

[1]A factor of safety of 1.5 was obtained for shallow sloughing failure surfaces. The factors of safety increase proportionally to the depth of the failure circle for the assumed homogeneous and drained materials.

Following breach of the dam, core material observed in the breach area contains a much larger percentage of finer materials than the outer shells. The processed materials, including the sand sizes, should be highly angular in nature and be similar to the values used in 1988.

2.3.2 Parapet Wall Design and Stability

A 10-foot-high, 1-foot-thick reinforced concrete parapet wall sits atop the crest of the Upper Reservoir Dam. The wall is comprised of 111 panels, each approximately 60 feet in length. The design crest elevation of the wall was 1599 feet. Originally, the project was to operate with a maximum operating level of 1597 feet, which would have stored 8 feet of water on the 10-foot-high panels. Since construction the crest elevation of the parapet wall has decreased and varied due to settlement of the dam (See Section 3.1 – Settlement).

The majority of the panels were placed using conventional forms and concrete. Figure 2.13 is a typical cross section of the walls, with a load diagram and overturning analysis from Drawing 8304-X-26157:

The initial portion of the concrete parapet wall, panels 3-20, were pneumatically placed concrete similar to the concrete face slab. However, this section was not accepted due to poor quality concrete. Based on a 1963 design drawing (8304-X-26122), parapet panels 3-20 were modified to have a sloping reinforced-concrete wall placed upstream of the parapet stem, with the area between the two walls filled with 3,000 psi concrete (see Figure 2.14).

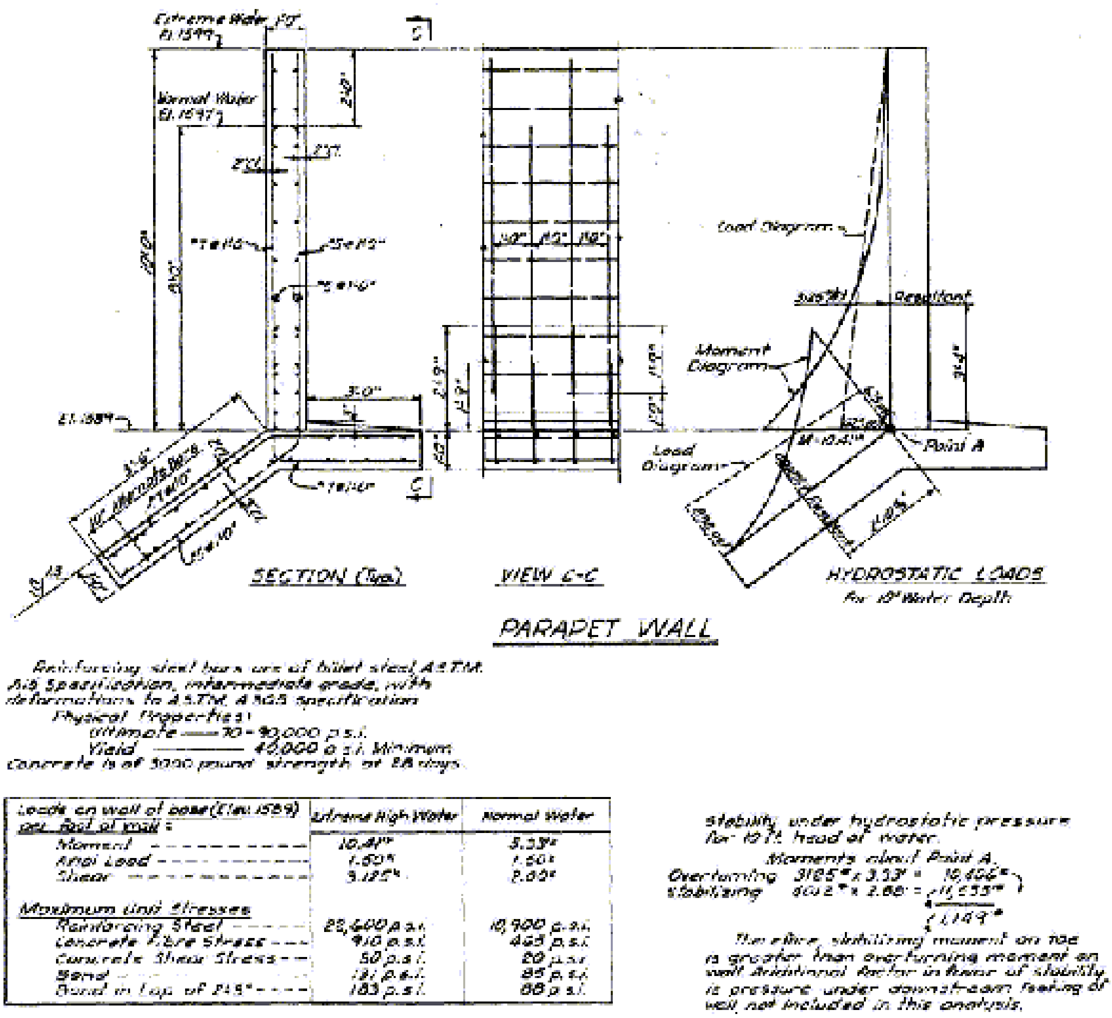

Figure 2.13

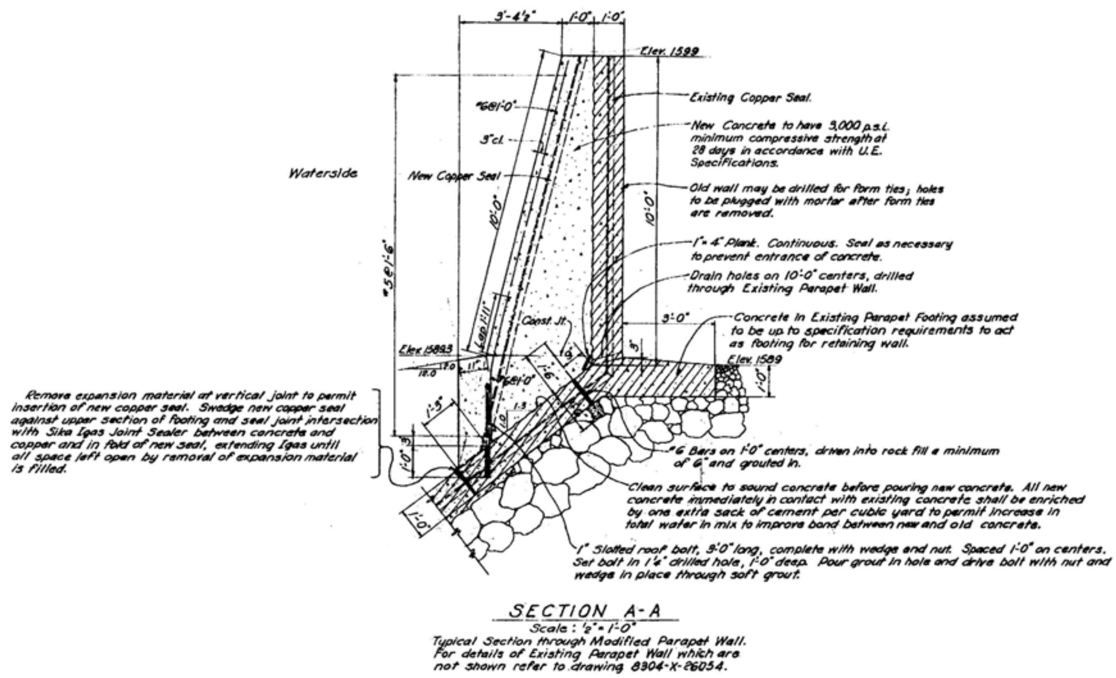

Figure 2.14

Parapet Wall Stability

Design Drawing 8304-X-26157 (Figure 2.13) shows the following results from an overturning stability analysis, taken about the point where upstream vertical surface intersects the sloping base of the parapet wall:

Overturning Moment: 10,406 Kip-feet
Stabilizing Moment: 11,155 Kip-feet

Taking moments about the downstream heel of the wall (Pt. A on Figure 2.15) yields an overturning factor of safety of 2.45. This calculations neglect uplift on the base of the wall, assuming a free draining foundation.

The Design Drawing includes a table with the maximum loads and unit stresses in the parapet wall under the normal (elevation 1597 ft) and extreme (elevation 1599 ft) water levels. The following table provides the maximum stresses as well as a comparison to allowable stress based on the ACI-Alternative Design Method, which would have been commonly used at the time of the dam design.

	Maximum Unit Stress (psi) (water level at 2 feet below top of wall)	Maximum Unit Stress (psi) (water level at top of wall)	Allowable Stress (psi) (ACI – Alternate Design Method)
Reinforcing Steel	10,900	22,600	20,000
Concrete, Fibre Stress (Flexure)	465	910	1,350
Concrete, Shear	20	30	60.2
Bond	85	131	

The table indicates the maximum unit tensile stresses in the reinforcement would meet the Alternate Design Method code for water levels two feet below the top of wall. For the extreme case of water levels at the top of the wall, the maximum unit tensile stress is higher than the allowable stress.

FERC Staff also compared the wall design to the 2005 Load Factor Design code:

Loading	Applied Moment (kip-ft)	Mu (kip-ft)
Water Level 2 Feet Below Top of the Parapet Wall	5.32	7.45
Water Level at the Top of the Parapet Wall	10.41	14.57

ΦMn: 15.20364 (assuming full development length)

Check development length
d: 10 in.
Cover: 2 in.
Dia: 0.875 in.
As: 0.60132 si
Fy: 40 ksi
Fc': 3 ksi
ld: 21 in.
Splice required: 27 in. (greater than the 21 in. provided)
Class B: 1.3 - Divide ΦMn by 1.3

ΦMn/1.3: 11.7 k-ft

The wall design meets Load Factor Design code when water levels are two feet below the top of the parapet wall. For the extreme condition with water levels at the top of the wall, Mu exceeds ΦMn/1.3.

Stability calculations were also included in the January 3, 2002 Design Report for the liner installation. Included with the anchorage calculations are stability checks of the existing parapet wall with imposed liner anchor loads. The design indicates there would be two anchors on the parapet wall:

Anchor	Location	Force (kips/linear foot)	Force Direction
Upper	One foot from the top of the wall	0.12	Down ↓
Lower	On the sloping base about one foot below the intersection with the vertical wall.	2.05	Along sloping wall into the reservoir.

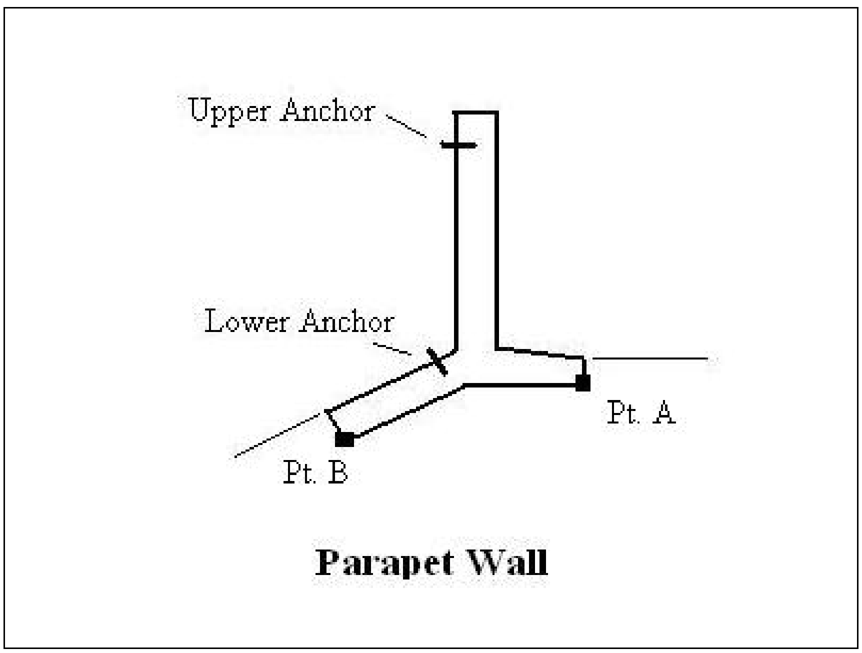

Figure 2.15

These forces result in a net increase in the stabilizing moment about the downstream heel of the wall (Pt. A on Figure 2.15). The Design Report includes calculations showing the effects of the anchor on overturning about the upstream toe of the sloping wall slab (Pt. B on Figure 2.15). This was done to determine if the anchors would pull the wall into the reservoir, especially when the water level was just below the parapet wall. The factor of safety for overturning about the upstream toe was determined to be 5.64.

2.4 Geomembrane Design

Repairs for the cracked and leaking concrete face of the dam consisted of an 80 mil liner manufactured by GSE Lining Technology, The original design (2001) included an underlayment consisting of a nonwoven polypropylene fabric and a HDPE geogrid drainage mat at the toe of the liner along the perimeter toe of the upper reservoir. The final design (2004) underlayment was a geogrid drainage mat with both sides bonded to a non-woven geotextile. The underlayment was placed from the toe block to the bottom of the vertical section of the parapet wall. A concrete anchor block with an embedded anchor section compatible with the geomembrane was installed at the base of the toe block of the concrete panels. The liner was anchored at an elevation approximately 1 ft below the top of the wall with Hilti type anchor bolts and near the top of the upstream footing. The original liner specifications call for concrete infilling of surface irregularities prior to placement of the geotextile/drainage underlayment and the geomenbrane. A geofoam filler was also used at the modified section of the parapet wall.

The December 2001 reservoir lining plans submitted to FERC on January 2, 2003 included notes that covered the demolition and removal of the original reservoir monitoring system, supporting concrete and staff gauges. Removal of the original instrumentation can be seen in the 2004 FERC Operation Inspection Report. A photograph of the new system was shown in the licensee's November 30, 2004 construction report.

Section 3 Historical Performance of Upper Reservoir

3.1 Settlement

Settlement of the Upper Reservoir Dam was monitored by a survey of 24 survey monuments located on the base of about every fifth parapet wall section and six monuments on the gaging station platform (Figure 3.1). The survey monuments were installed in 1962 and consist of 1/2 inch by 6 inch bolts embedded in the concrete footings of the parapet wall.

Settlement of the upper dam was measured by level survey with 0.01 foot accuracy. Annual measurements were recorded from installation in 1962 up to 1988, when annual settlement was insignificant. After 1988, surveys were performed once every four or five years. The settlement began to level off in 1975.

A correction was made early in the history of the monitoring to account for a number of pins that were damaged, reducing the elevations from the original survey. It appears that the correction that was applied may have been to add the difference rather than subtract the difference. Hence, some of the settlements shown may be slightly more than the actual settlement. Figure 3.2 shows that the primary settlement occurred prior to August 1976. Apparent movements following this time were very small from year to year and generally fall within the accuracy of the surveys. Figure 3.3 shows a more detailed view of settlement that has occurred during the past 24 years. For reference, Point 19 is within the breach area.

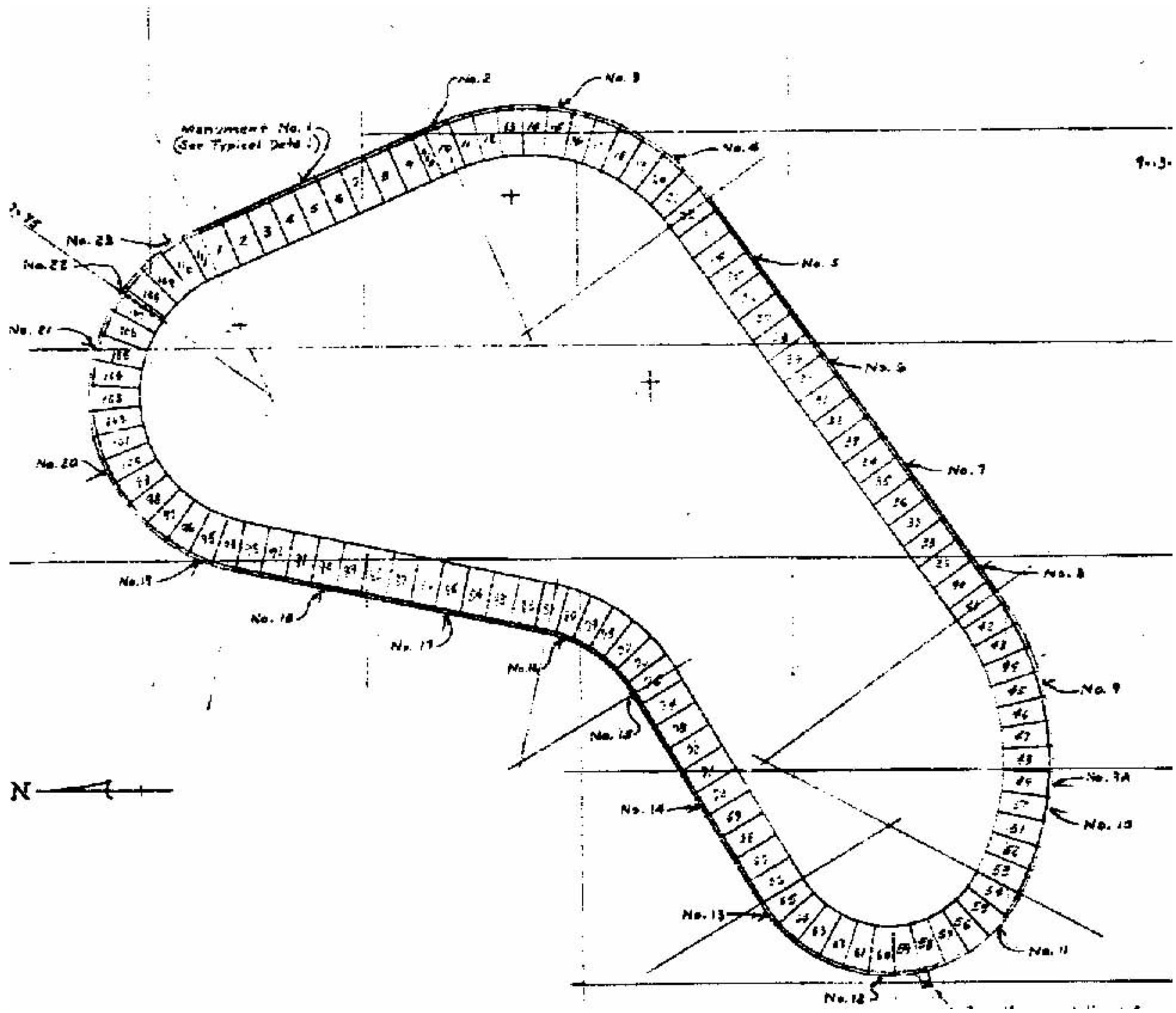

Figure 3.1 - Location of Settlement Survey Pins in Parapet Wall Footer

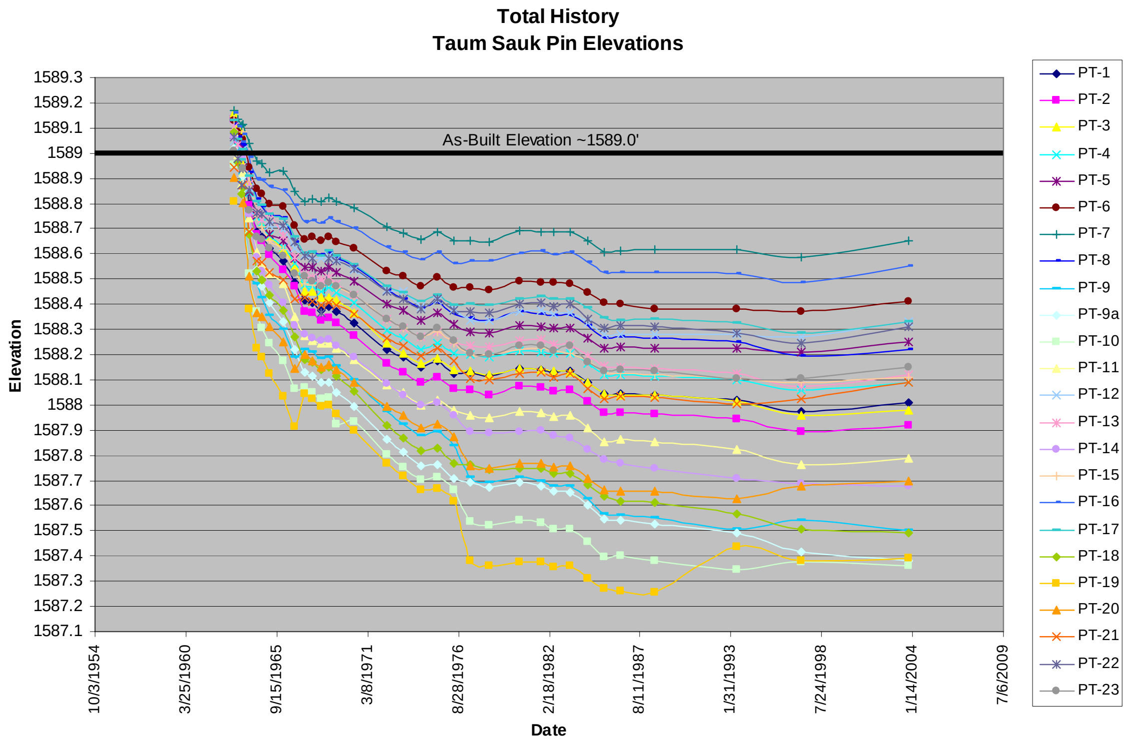

Figure 3.2 - Total History Settlement Data

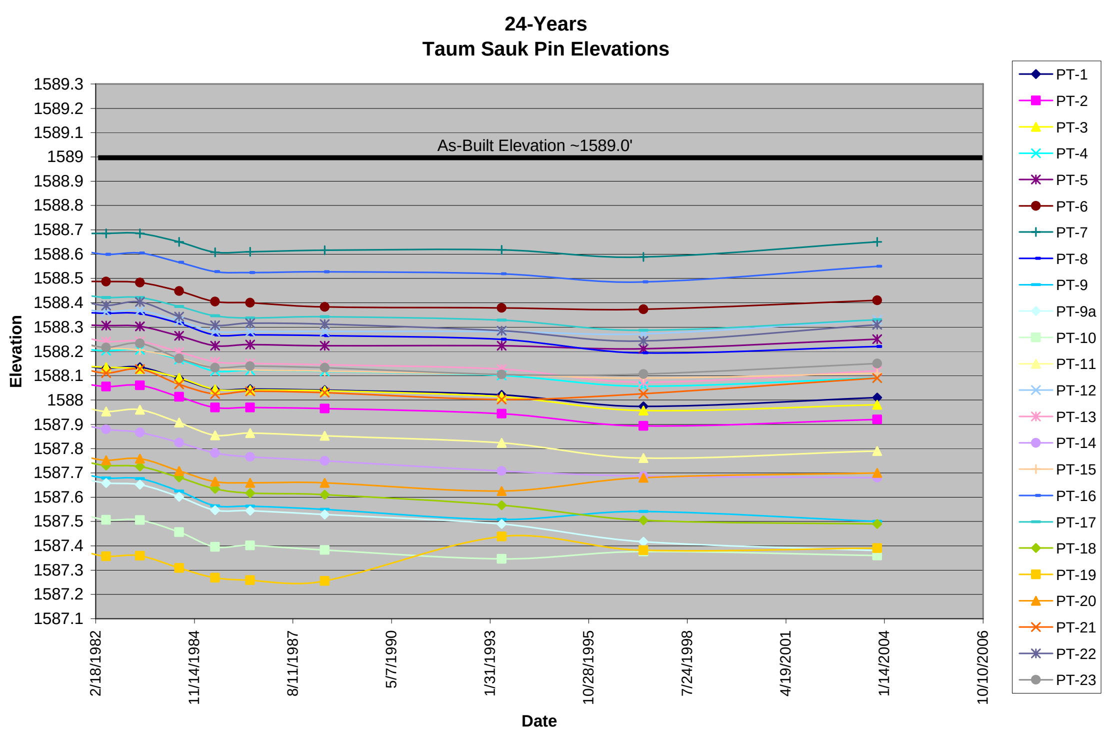

Figure 3.3 - Settlement Data 1983-2006

A crest survey was appended to the 2003 Eighth Part 12D Report after a survey was conducted in November 2003. In the 2003 survey data, it was found that some of the crest elevations were lower by as much as 0.5 foot from the previous survey. Another survey was conducted in October 2004, using the reference original datum, which is the top of copper bolt set in a granite boulder near the base of the Upper Reservoir. The benchmark used in the 2003 crest survey was taken from a different benchmark than used for all the previous survey data. The October 2004 survey data was more in-line with the previous survey data. The licensee has indicated that they used the top of copper bolt set in a granite boulder near the base of the Upper Reservoir to survey the elevations on the new staff gage and for installation of the water level instruments that were installed in 2004.

During construction of the membrane liner, the licensee obtained a parapet crest survey on November 6, 2004 in the area of panels 65-75. The purpose of this survey was to determine the minimum crest elevation of the parapet. These particular panels were chosen because the licensee believed this to be the lowest spot on the crest. The benchmark used for this survey is the top of copper bolt set in a granite boulder near the base of the Upper Reservoir. The November 2004 survey and the post breach survey shows that the minimum crest elevation in the area of panels 65-75 was at Panel 72, elevation 1596.99 ft**.**

Two survey pins were located in the breach area (Panels 88-99). The 2004 elevation of Footer Pin 18 (Panel 90) was 1587.49 ft. Adding 10 ft for the parapet wall, the top of wall at this location is estimated at 1597.49 ft. The 2004 survey data for Footer Pin 19 (Panel 95) was 1587.39 ft giving the top of the parapet wall adjacent to the monument at 1597.39 ft.

3.2 Crest Elongation

The crest length was originally 6,562 feet. However, in the August 19, 1967, Report on Safety, Mr. Barry Cooke notes crest elongation occurs at the dam due to the center of curvature of the dam axis in the reservoir. In that letter, Mr. Cooke stated the lengthening has been 15 inches between panels 40-67. He indicates this stretch or loosening of fill is associated with slightly higher settlement and could be visualized to cause continued settlement. It was noted that in the first Report on Safety, the five year elongation for the entire wall, based on joint opening measurements was 20 inches. In the 1973 five year report, the elongation increased another 3 inches.

3.3 Vertical Deflections of Parapet Wall

In Mr. Cooke's August 19, 1967 Report on Safety, he explained measures of vertical deflection indicate the parapet walls to be essentially plumb, the amounts out of plumb being usually 1/8 to ¼ inch with a few at ½ inch. About half tilted inward and half tilting outward. The 1973 five-year report described the amounts out of plumb were in the same range. In the 2003 Eighth Part 12D Report, vertical settlement between wall segments varied from no discernable movement to about one inch at a few joints. The consultant states vertical movement at the joints was modest apparently because the rockfill settlement varied with the height of the fill and so varied gradually along the crest.

3.4 Parapet Wall Horizontal Panel Misalignment at Joints

According to Mr. Cook's August 19, 1967 Report on Safety – "Joints (between parapet walls) were originally constructed to 1 inch open. Most have opened due to the curvature of the axis. The amount of opening has been ¼ to ½ inch except for about 10 of the 111 joints which have opened more than 1 inch. Joints approaching 2 inches require an inner seal to be installed." Many types of expansive joint materials have been placed between adjacent parapet wall panels and between the panels and the upstream concrete face slab since the project was constructed. The joints were provided with U-shaped copper water stops during original construction.

In the August 19, 1967 Report on Safety, Mr. Cooke explained offsets in March 1966 were on the order of ¼ inch **with several** joints near Panel 88 at 1-1.5 inches. Later in September 1966 the movements were generally 1/8 to ¼ inch with nearly half in the direction of the offset. He stated there was no indication of trouble developing in these small and in many cases restoring movements.

According to the 2003 Part 12D Report, the consultant states horizontal movement included rotation and translation of the wall joints. The report states:

> "The maximum horizontal movement observed was at joints 89/90 and 106/107, with about 4-5 inches of translation and rotational movement. Photograph 3 *(of the report – see below Figure 3.4)* shows panel 90 having moved downstream relative to panel 89. The copper waterstop was visible in the joint. This magnitude of movement is likely sufficient to tear the waterstop, but probably does not affect the wall stability."

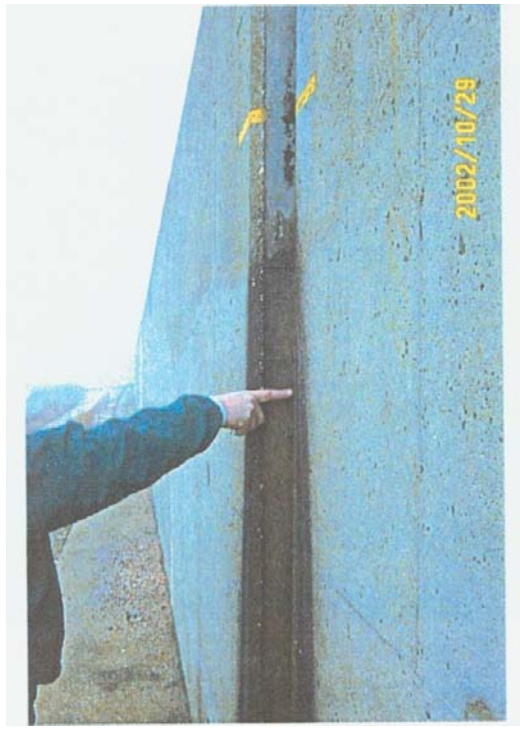

Figure 3.4- Movement at Upper Dam Parapet Wall at Joint 89/90 from 2003 Eighth Part 12D Report

3.5 Parapet Wall Cracking

There are slight vertical cracks in the central area and in the lower one-half of nearly all parapet walls. In Mr. Cooke's August 19, 1967 Report on Safety, he describes the cracking as about 10 feet spacing that start at the bottom and stop near the top and center, indicated high compressive stress. He stated the cracks are not structurally significant. He conjectured that shear at the base of the wall has caused slight movement and leakage in the Panel 10-25 area, in combination with a poor cold joint. He states it is probable that the redistribution of water load on the rock by the stiffness of the wall and its base will keep relative settlement compatible with the stresses in the parapet wall and base slab.

In the 1973 five year report, Mr. Cooke refers to the cracks as thin vertical shrinkage cracks that do not leak.

In the 2003 Part 12D report, the consultant states the parapet wall appeared to be generally in good condition, with some minor crack as would be expected. The exception was from panel 3 through panel 20, where the downstream side was cracked and spalled in a rectangular pattern, apparently at the rebar and due to insufficient cover. This entire section was reinforced with a thickened wall section during construction; therefore, the cracking and spalling do not appear to be a concern.

3.6 Leakage

Leakage through the reservoir floors, walls, and penstock valve seals was a problem from the first day of operation. The leakage has been reported to be clear of sediment in all the reports that we have reviewed that document the status of the leakage. Early investigations focused on potential leakage in the vortex area floors and shaft. A number of repairs were made through subsequent years focusing more on leakage through the horizontal and vertical joints in the concrete facing. Particular emphasis was on the joints between the concrete facing and bedrock, the joint at the toe of the parapet section, and the joint between the concrete facing and plinth.

Higher rates of leakage began in 1999 following an extended outage. A geomembrane liner was subsequently installed in 2004, which significantly reduced the leakage for the 12 months prior to the breach. Figure 3.5 shows the history of leakage and the periods of repairs (illustrated by periods of zero leakage).

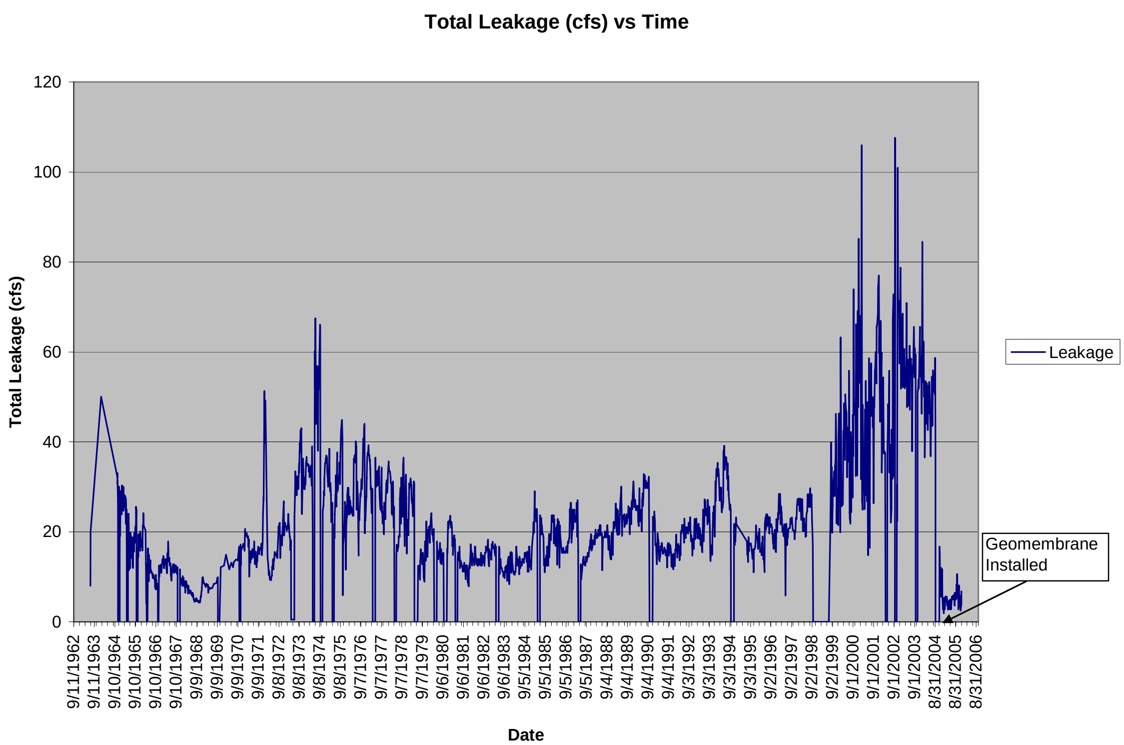

Figure 3.5- Historical leakage Rates

Leakage was historically concentrated in the area of the "fish pond", and near panel 72, and at a number of areas scattered along the east side of the reservoir. In 1963, a 2 to 8-foot-deep concrete cutoff was installed at the fish pond near panels 90-102. A grout curtain was also installed in the fish pond area to stem leakage through the bedrock foundation. Specific areas and characteristics of the leakage are discussed in the 2003 FERC Operation Inspection Report, at the time the leakage was greatest.

There were no significant trends between pool elevation and leakage rate for reservoir operating ranges above 1589 (Figure 3.6). However, total leakage appears to drop rapidly when the reservoir elevation was dropped below 1540 feet.

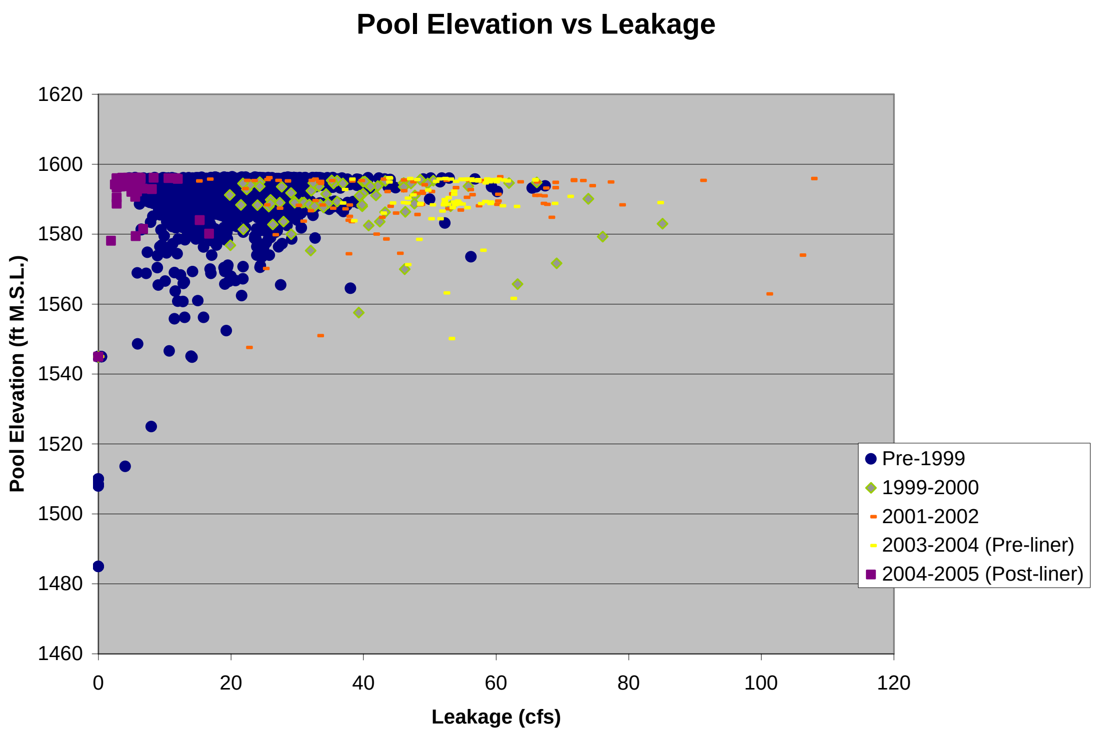

Figure 3.6- Leakage verses Upper Reservoir Pool Elevation

Figure 3.7 - Concentrated Seep Before liner installation
(2003 FERC Operation Inspection Report)

Figure 3.8 - Overflow of the seepage collection Pond before liner installation
(2003 FERC Operation Inspection Report)

Section 4 Post Breach Survey and Estimates of Overtopping

4.1 Post Breach Survey and Estimate of Overtopping

Following the breach, the licensee conducted a crest survey of the parapet wall (Figure 4.1). This survey was conducted using the same datum as previous surveys. Both horizontal and vertical elevation data is provided from this survey on Sheet S1, prepared by KdG and is dated December 20, 2005. The licensee subsequently reported that the horizontal data on this drawing is incorrect.

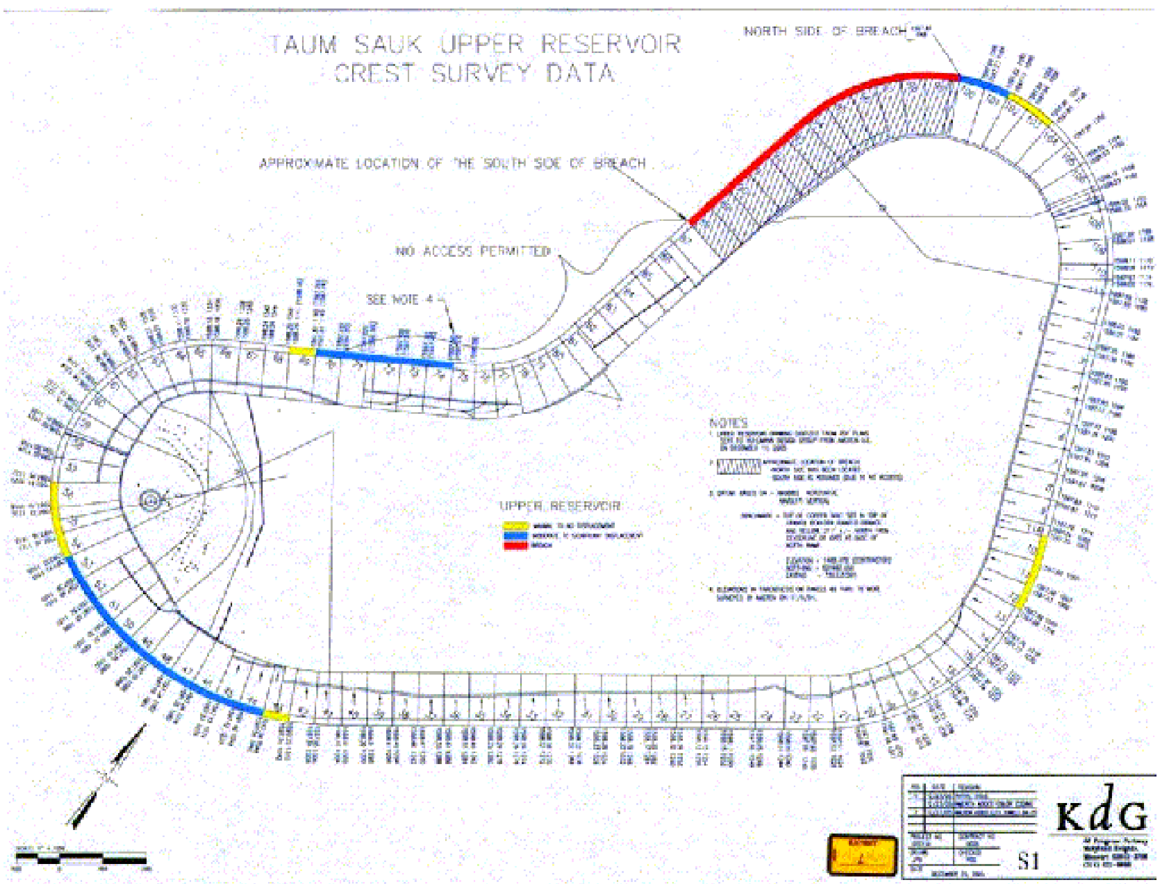

Figure 4.1 From KDG, Maryland Heights Missouri

4.1.1 Estimate of Peak Pool Elevation from Parapet Wall Elevations

Figure 4.1 shows the post breach survey and downstream damage assessment. The figure provides evident of where overtopping occurred:

Parapet wall panel	Wall Elevations	Damage Survey
• Panel 10 yellow	1597.60 -1597.70 ft	minimal to no damage
• Panel 12 yellow	1597.43 -1597.69 ft.	minimal to no damage
• Panel 103 yellow	1597.94 -1597.90 ft	minimal to no damage
• Panel 100 blue	1597.69 ft	moderate to significant
• Panel 43 yellow	1597.7 - 1597.58 ft	minimal to no damage
• Panel 49 blue	1597.2 -1597.33 ft	moderate to significant
• Panel 56 yellow	1597.79 -1597.91 ft	minimal to no damage
• Panel 69 yellow	1598.26 -1597.81 ft.	minimal to no damage
• Panel 72 blue	1596.99 -1597.15 ft	moderate to significant
• Panel 74 blue	1597.42 - 1597.80 ft	moderate to significant

From the above survey data the range of possible peak pool elevation appears to range between 1597.7 ft to 1597.9 ft.[1] (Note that the elevations referenced in this report from various surveys are assumed to be correct. No allowance for systematic error has been considered in the assessment of the overtopping event.)

Assuming a peak pool elevation of 1597.7 ft the maximum overtopping was about 0.7 ft at Panel 72, 0.5 ft at Panel 49, and 0.1 ft at Panel 10. This neglects the wind-induced waves, which may have been on the order of 0.5 foot along the north side of the reservoir on December 14.

The Overtopping in the breach area (blue zone on Figure 4.1) was estimated at two locations where the 2004 elevation data was available at the parapet wall footer survey pins. The elevations and estimate of overtopping in the breach area at the following locations:

Footer Pin 18 (Panel 90) Elev.	1587.49 ft *
Top of wall Elev.	1597.49
Amount of Overtopping	0.2 ft

[1] A peak elevation of about 1597.7 is also confirmed by two other methods. First, adding a four foot correction factor to the Druck pressure transducer reading yields a maximum level of about 1597.7 ft. Second, the HIGH-HIGH Warrick Conductivity sensor also did not get recorded on the event historian meaning the sensor did not see water at any time during December 14, 2005. Since the sensor was set at 1597.67 ft with a 60 second delay, the peak pool could have reached approximately this level.

Footer Pin 19(Panel 95) elev.	1587.39 ft*
Top of wall elev.	1597.39
Amount of Overtopping	0.3 ft

*2004 survey

4.1.2 Estimate of Volume Overpumped on December 14, 2005

AmerenUE's February 7, 2006 filing includes an analysis estimating the volume of water pumped into the Upper Reservoir from the Lower Reservoir on December 7-14, 2005. The analysis developed the volumes by two methods. The first method used pump flow and equipment data (i.e., power used by the pumps, pump curves, total head) to estimate the volume pumped into the upper reservoir. The second method used the drawdown of the lower reservoir and the lower reservoir storage curve to estimate the volume.

During the January 9-12 Site Investigation, AmerenUE staff indicated the volume estimates based on the lower reservoir storage curve were not reliable because the storage curve was not exact. For December 7-14, 2005, the estimated volume based on the lower reservoir storage was between 18 and 114 acre-ft higher than the volume based on pump flow data for each day that AmerenUE estimated.

FERC estimated the amount and duration of overtopping on December 14, 2005, using AmerenUE's volume estimate from pump flow and equipment data – with two exceptions:

(1) The starting elevation of the Upper Reservoir was based on the steady state penstock transducer reading, which should have been close to actual levels during winter months.

(2) The licensee's analysis based total head on the pump/generator units by subtracting the tailrace water level readings from the Upper Reservoir water level readings. The Upper Reservoir water level readings were about four feet lower than actual levels on December 14, 2005. Therefore, we modified the volumes to account for the higher head by the following equation:

$$\text{New Volume} = (\text{Head} + 4)^{0.5} / (\text{Head})^{0.5} * \text{Volume}$$

The following are the volume estimates for December 13-14, 2005:

Date	Time	Total Volume Pumped into the Upper Reservoir (acre-ft)	Upper Reservoir Volume (acre-ft)	Upper Reservoir Elevation Based on Volume (ft)
12/13/2005	22:36	-	1818.23	1547.8
12/14/2005	4:55	2548.11	4366.34	1596.99
12/14/2005	5:16	2617.73	Exceeds top of wall	Exceeds top of wall

Water levels (neglecting wave action) would have overtopped the low point of the parapet walls at around 4:55 am. This would result in about 21 minutes of overtopping until the dam started failing between 5:15 and 5:16 am. The total volume of water pumped into the upper reservoir above the low spot of the parapet wall would have been around 70 acre-ft. The amount of overtopping should be the total volume pumped into the reservoir minus the volume included in the storage. Assuming the maximum water level reached elevation 1597.7 ft, the overtopping volume is about:

70 acre-ft – (55 acre-ft per foot of storage * 0.71 foot of storage) = 31 acre-ft

This would result in an average total overtopping outflow of 1,070 cfs over the 21 minutes.

Referring to the wave height estimates for December 14, 2005 included in Section 8 of this report, 0.5-foot-high waves would have started overtopping the low points of the parapet wall about 8 minutes before the reservoir levels exceeded the low points of the wall.

4.2 Damage on Downstream Slope

Figures 4.2-4.12 document the different levels of damage that occurred on the embankment. The photos indicate the progression of how the embankment behaved as overtopping began and how erosion progressed with time and higher levels of flow. Damage assessments are those shown on KdG drawing S1 dated December 20, 2005 (Figure 4.1)

Figure 4.2 - Panel 10
Note grass is lain over near footing
Damage from overtopping was judged as Minimal
Estimate 0.1 ft. of overtopping

Figure 4.3 - Panel 100
Adjacent to the right side of the Breach
Note erosion at toe of parapet wall footing
Damage which was judged as moderate to significant

The elevations of Panels 100 and 101 were measured between elevations 1597.67 and 1597.82 ft (Figure 4.3). The damage at Panel 100 and 101, which was judged as moderate to severe, does not appear to agree with the estimates of the peak reservoir estimates occurring on December 14, 2005. However, wind-induced waves could have overtopped these walls by several inches on December 14, 2005. Damage may have been the result of the December 14, 2005 event and/or the September 25, 2005 wave overtopping event.

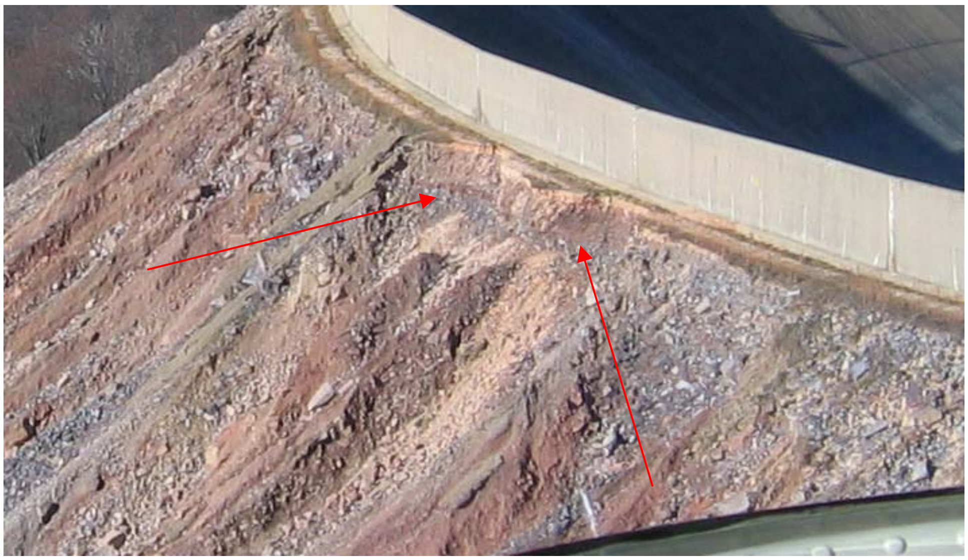

Figure 4.4 - Erosion Panel 48/49
Note scarps that may be the results of a localized slope failure
Damage judged as significant
Estimate 0.5 ft of overtopping

Figure 4.5 - Panels 48 and 49
Scarp near toe of parapet wall footing

Figure 4.6 - Panels 48 and 49
Scarp near toe of parapet wall footing
Note erosion rut adjacent to the footing

Figure 4.7 - Panel 72
Note erosion deep beneath the parapet wall
Damage judged as significant
Estimate 0.7 ft of overtopping

Figure 4.8 - Erosion at Panel 71 footing
Note the horizontal displacement between Panel 70 and 71(foreground) and bowing at the joint between Panels 71 and 72. Erosion at the footing is similar to that described during the September 25, 2005 wave overtopping.

AmerenUE's personnel identified the damage that occurred on September 25, 2005 as "ruts and trenches" adjacent to panels 90-96. The operators reported depths of 6 inches to 1 foot. The operators subsequently repaired and regraded the damage using crushed rock, with most of the rock used to repair and improve the access road. No formal procedure was used to repair the trenches and the ruts.

Figure 4.9 - Possible slope failure between Panel 100 and the full breach section

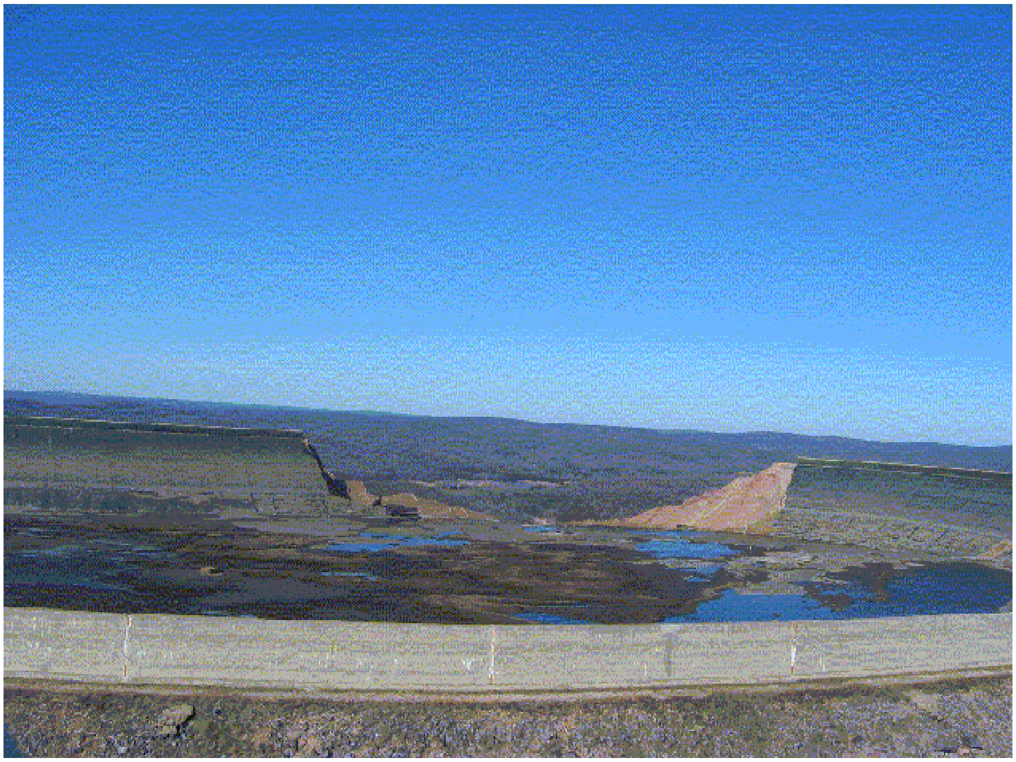

Figure 4.10 – Breach Panels 88 - 99 removed during the event Estimate 0.2 -0.3 ft. of overtopping. (Missouri DNR Photo)

Figure 4.11 - Left side of breach

Figure 4.12 - Right side of breach
Note layering of embankment

Section 5 Instrumentation and Controls

5.1 General

The project is controlled through a telephone and microwave system from the Osage Plant at the Lake of the Ozarks, under the direction of the load dispatcher in St. Louis. Both units can be put on full load in a few minutes.

A description of Standard Operating Procedures for the project is in Section 1.7.

5.2 Instrumentation History

A written description of the water level instrumentation was provided by AmerenUE during the January 9-12 FERC Taum Sauk Investigation Team site visit. The original reservoir monitoring system consisted of: (1) three Warrick conductivity sensors at elevations 1501.00, 1506.0 and 1508.0, (2) a skate type system (i.e., a float riding on a cable guided roller assembly in a pipe) to monitor upper reservoir levels for normal shutdown of the units, and (3) a set of mercury switches tied to a float in a stilling well for High and High-High backup pump shutoff. There was an encoder and chart recorder on the skate system to provide level indication and recording. Components of the system were anchored to the concrete face of the dam.

In 1994, a differential pressure transducer was added to provide secondary level indication at the plant. In 2000, the original skate system, encoder, and chart recorder were replaced with a differential pressure level transducer, Programmable Logic Controller (PLC), and a digital level indicator at the upper reservoir.

All of the upper reservoir level control and protection devices were replaced when the geomembrane liner was installed at the end of 2004. Three General Electric Druck Model PTX 1230 100 psi piezoresistive micro machined silicon strain gauge pressure transducers (referred to as Druck pressure transducers or transmitters) were installed for normal shutdown of the units. The Low and Low-Low Warrick conductivity sensors were replaced in kind. The High and High-High mercury switches were replaced with Warrick conductivity sensors. The upper reservoir PLC was replaced with an Allen-Bradley PLC. The unit shutdown relays at the plant were replaced with Allen-Bradley PLCs. The level indicators, alarming, and data acquisition systems were replaced with a WonderWare Operator Interface.

At the time of the December 14, 2005 breach, the upper reservoir control system consisted of two sets of sensors sending the signals through three independent

PLC computers. One set of sensors were two Druck pressure transducers used to monitor reservoir levels (the third Druck pressure transducer was not used due to inaccurate readings).

The second set of sensors consisted of four Warrick Conductivity sensors. Two of the Warrick sensors (HIGH and HIGH-HIGH) were to determine if water levels in the upper reservoir were too high. The other two Warrick sensors were to determine if water levels in the upper reservoir were too low. Activating these sensors would start a hard shutdown of the generator/pump units.

5.3 Description of Instrument Structural Support System

The upper reservoir controls and structural support system were replaced in 2004 following the installation of the geomembrane liner. Four 4-inch-diameter High Density Polyethylene (HDPE) pipes were installed extending down the interior slope of the embankment from the metal box at the top of the parapet wall panel 50 near the gage house. Reservoir levels were monitored initially with three Druck pressure transducers which were placed at elevation 1500 ft. in one of the HDPE pipes. Four Warrick conductivity sensors were place a separate HDPE pipe for emergency shutdown should extreme low or extreme high water levels were to occur.

The HDPE pipes were tied to 1 inch by 48 inch by 12 inch HDPE flat stock which was set on, but not connected to a HDPE rub pad which was glued to the geomembrane liner. These pipes were not firmly attached to the face of the dam. Instead, stability was intended to be provided by a configuration of stainless steel unistrut section, steel bolts, turnbuckles, jam nuts, eyebolts and U-shaped cable lock bolts tied to two stainless steel cables. The cables were anchored only at the toe block at the base of the slope and at the interior base of the parapet wall (Figure 5.1). Down slope movement of the HDPE pipe assembly was limited by clamps placed on the cabled just down slope of the eyebolt connection to the pipe assembly. A similar restriction to movement upslope was not included.

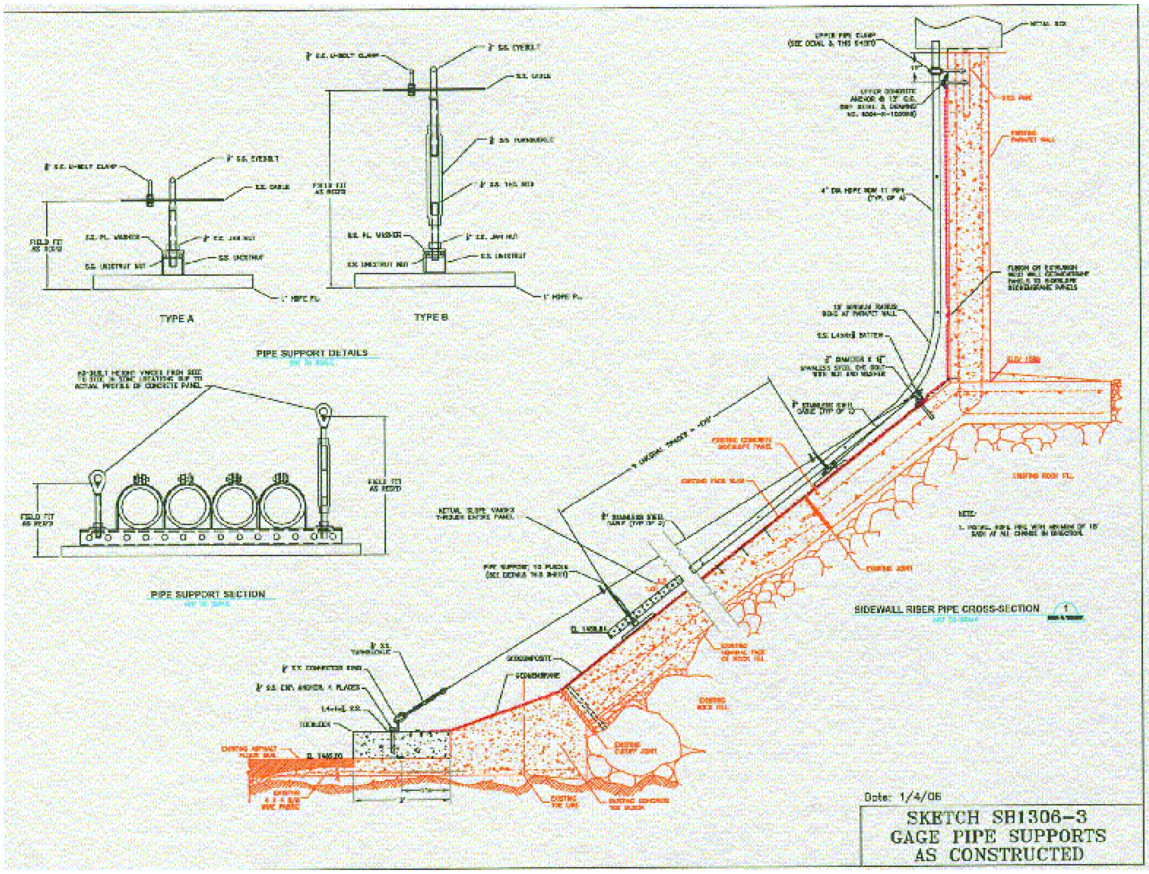

Figure 5.1 - Structural Design of the Upper Reservoir Control System December 2004

5.4 Upper Reservoir Overpumping Emergency Control

Following installation of new instruments in 2004, the elevations for normal shutdown via the Druck pressure transducers were 1592 for the first unit, 1596 for the second unit with a total shutdown to occur if the reservoir reached 1596.5 ft. This overlapped the original hard trip setting of 1596.0 for the HIGH and 1596.2 for the HIGH-HIGH Warrick conductivity sensor. The elevation of the conductivity sensors elevations were later changed to “avoid spurious trips” during the operation of the project after 2004.

The following shows the settings of the HIGH and HIGH-HIGH sensors from November 2004 through December 2005:

<u>November 2004</u>

HIGH Warrick Conductivity Sensor	1596.0 ft.
HIGH-HIGH Warrick Conductivity Sensor	1596.2 ft.

December 10, 2004 (from AmerenUE Drawing 8303-P-26648)

HIGH Warrick Conductivity Sensor	1596.7 ft.
HIGH-HIGH Warrick Conductivity Sensor	1596.9 ft.

September 30, 2005[2]-December 14, 2005

HIGH Warrick Conductivity Sensor	1597.4 ft.
HIGH-HIGH Warrick Conductivity Sensor	1597.66 ft.

Figures 5.2 show the configuration of the sensors within the instrument cabinet. The cabinet is located on the dam crest at the southwest end of the reservoir. Figure 5.3 shows distances from the Warrick Conductivity sensor tips to reference tapes placed on the wiring by AmerenUE staff. The tapes were used to place the sensors at the original design elevation (November 2004) and the as-found elevation on December 14, 2005.

Figure 5.2 - Cabinet containing the Druck pressure transducer and Warrick conductivity sensor wiring

[2] Elevation as found by Ameren employees on September 30, 2005 (reference Ameren October 7, 2005 Email(See Section 6, page 94 of this report). Note that this change could have made earlier.

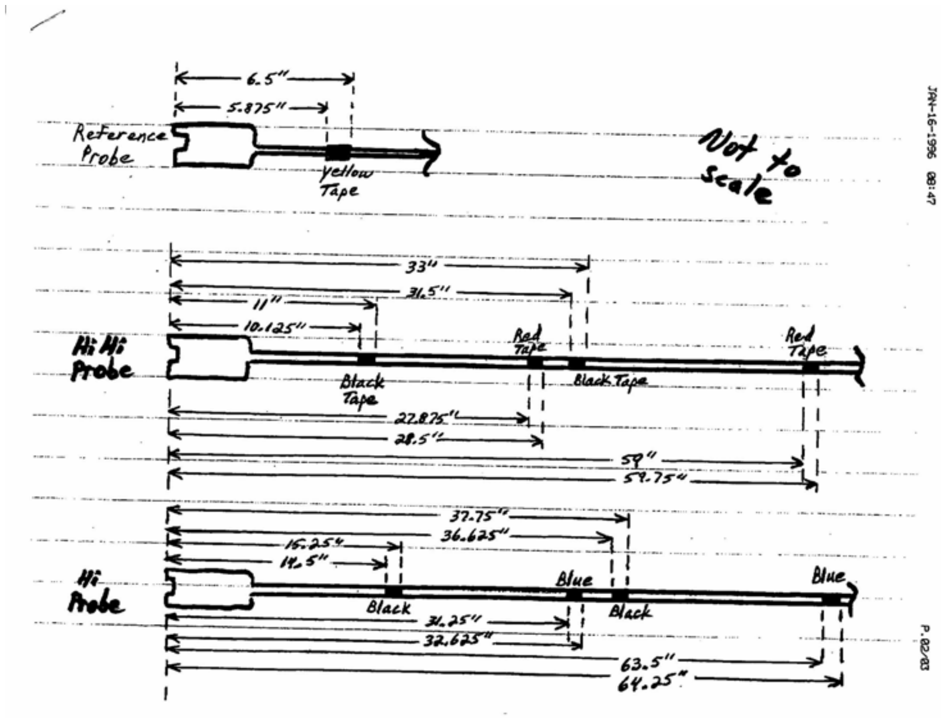

Figure 5.3 - Tape reference points on leads to the HIGH and HIGH-HIGH Warrick Conductivity Sensors (as Provided by AmerenUE)

5.5 Pre-Breach Events – Indication of Problems with Reservoir Monitoring System

At the time of the geomembrane liner installation in 2004, three Druck pressure transducers were installed to monitor reservoir levels and for shutting down the pump/generator units. The average of the three readings was used to monitor reservoir levels. The original elevations for normal pumping shutdown via the Druck pressure transducers were 1592 for the first unit, 1596 for the second unit with a total shutdown to occur if the reservoir reached 1596.5 ft.

5.5.1 September 2005 - Wave Overtopping

No problems were noted with the system until September 25, 2005 when an "overtopping" event associated with the winds generated from the remnants of Hurricane Rita. The overtopping was witnessed by project personnel at the northwest section of the reservoir (panels 90-96). Erosion occurred along the base of the parapet wall and access road. Approximately 0.5 to 1-foot-deep erosions gullies were formed at the base of the parapet wall. Five truck loads (79 Tons) of gravel were required to repair the damage.

It should be noted that although the reservoir level was close to the top of the low section of the parapet wall during this event, no signals were received from the Warrick conductivity sensors.

On September 27, 2005, AmerenUE employees inspected the upper reservoir and instrumentation. They estimated the Druck pressure transducers were 0.4 ft different than the actual reservoir elevation. The programming logic was modified to account for the 0.4 ft difference by adding 0.4 ft to the average of the instrument readings. Also, one of the three Druck pressure transducers was removed from the average. This value was then documented by the PLC.

AmerenUE did not verbally or formally report the wave overtopping, damage assessment, repair, and modification to the reservoir monitoring programming to the FERC until it was discovered by the FERC Taum Sauk Investigation Team following the December 14, 2005 breach.

5.5.2 October 2005 – Deterioration of Instrument Structural Support System

An October 3, 2005 inspection by AmerenUE of the reservoir monitoring system revealed the HDPE pipes were bowed out to one side an estimated 3 feet. (Figure 5.4 shows bowing after the breach) The bowing of the instrumentation pipes coincided with the failure of the fasteners holding the pipes to the stainless steel cables. The intake in the upper reservoir is about 125 ft from the location of the HDPE pipe and instrumentation.

The effect of the pipes bowing out to the side was to raise the elevation of the Druck pressure transducers. The pressure transducers were no longer at a known elevation to accurately report the water surface elevation of the reservoir. On October 7, 2005, the system was adjusted by resetting the stop pumping operations to elevations 1591.6 for the first unit and 1594.0 for the second unit. AmerenUE believed the adjustment was sufficient to prevent overtopping. Following this adjustment, the operating staff visually monitored the reservoir elevation with the staff gage, but only once a week. AmerenUE employees used check marks on their inspection sheets to verify the monitoring was performing properly.

Per AmerenUE staff, the design for a stiffer mounting system was completed October 25, 2005. Scheduling of the diver and a low water period for installation was not finalized with the last schedule for work being set for a spring 2006 drawdown.

AmerenUE did not verbally or formally report the results of the visual inspections of the HDPE pipes or the modifications to the pump/generator controls to the

FERC until it was discovered by the FERC Taum Sauk Investigation Team following the December 14, 2005 breach

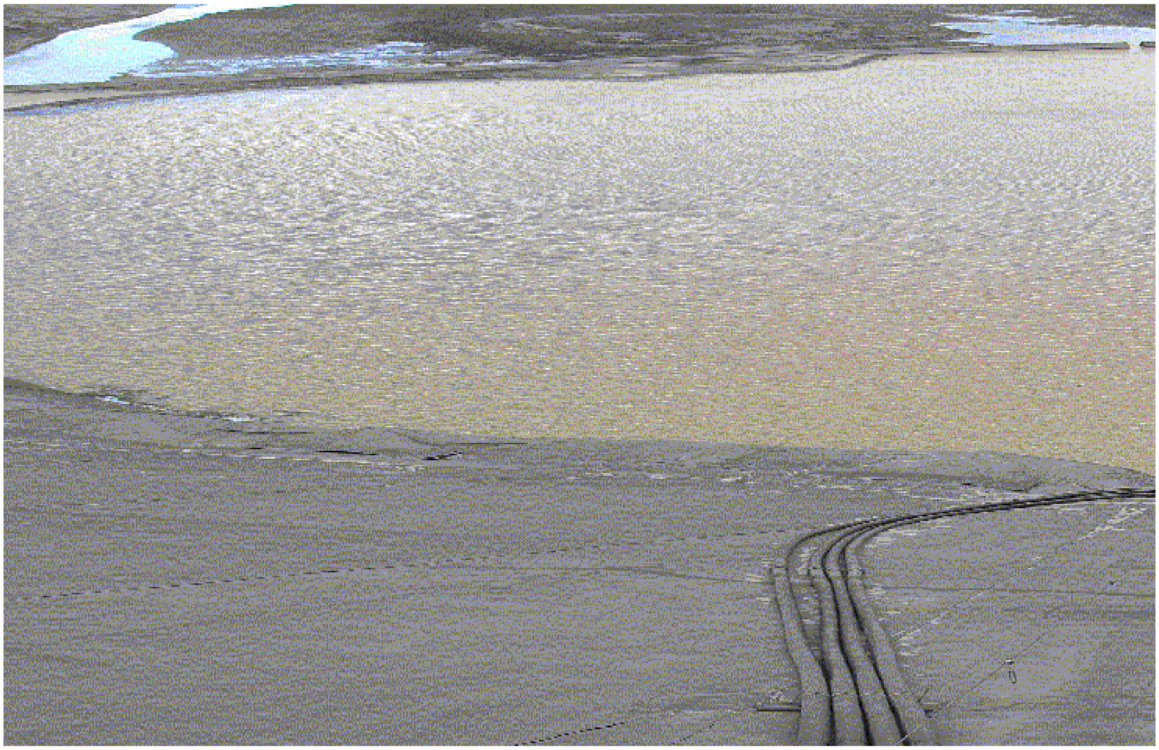

Figure 5.4 - Bowing of HDPE Tube position on December 15, 2005
(Courtesy of Missouri DNR)

5.6 Programming Logic Controls for the Upper Reservoir Controls and Emergency Controls

General

Two primary PLC devices – manufactured by Allen Bradley - comprise the reservoir control system. They are called the Common PLC and the Upper Reservoir PLC. Both of these devices are programmed using the RSX logic language. The Druck pressure transducers and the Warrick conductivity sensors are connected to these two devices. In the case of the Warrick sensors one sensor is connected to the Common PLC and the other sensor is connected to the Upper Reservoir PLC to provide redundancy for the safety backup system. During normal plant operations the operators access these two PLCs via the WonderWare Human Machine Interface (HMI). If changes are needed to the actual PLCs then selected personnel who have the appropriate access log into the PLC itself and make the required changes which are then downloaded into the PLC.

The basic operation of the project is controlled via the PLCs, with the primary sensors being the Druck pressure transducers. These pressure transducers determine the level of the Upper Reservoir and then determine if it is within the operational limits as selected by the operators from the HMI menus. If it is within the operational limits the system will continue to allow the plant operations to proceed (e.g., generating, pumping, or quiescent). The minimum operational level is used to “control” the generation cycle of the plant and the maximum operational level is used to “control” the pumping cycle of the plant.

In generation mode the plant will continue operations as long as the Upper Reservoir level does not reach the pre-set minimum operational level or until the operator commands generation to cease. In the pumping mode the plant will continue operations as long as the Upper Reservoir level does not reach the pre-set maximum operational level or until the operator commands the pumping to cease. If either of these levels is reached in its respective mode the PLC programming would shut down the operation smoothly. This basic operational structure is solely based on the Upper Reservoir Level as determined by the Druck pressure transducers.

The Warrick sensors are used as a safety mechanism. There are two Warrick sensors for a safety during generation and there are two Warrick sensors for a safety during pumping operations. These Safeties are designed to shut down operations when activated if for some reason the normal operational shutdown does not occur. In all cases, this shutdown is a “hard” emergency stop vice a “ramp” down method used for normal shut down operations. In normal operations these sensors should never be contacted unless something has gone wrong.

The two Warrick sensors used to shutdown the generation cycle are designated LOW and LOW-LOW. According to a comment in the Common PLC code the one sensor (LO-LO – as quoted from the code) is set to an elevation 1524 ft. Where as, in the Upper Reservoir Code the other sensor (LO) is set to an elevation of 1524.5 ft.

The two Warrick sensors used to shutdown the pumping cycle are designated HI and HI-HI. According to a comment in the Common PLC code the one sensor (HI) is set to an elevation of 1596.5 ft. Whereas in the Upper Reservoir PLC code, the other sensor (HI-HI) is set to an elevation of 1596.7 ft. (NOTE: At the time of the breach the “believed as found” physical locations of the Warrick sensors was 1597.4 ft (HI) and 1597.66 ft. (HI-HI), respectively.) There was redundancy built into the design as one sensor for each mode was available at each PLC. In addition, the design as implemented had each PLC having one of the critical sensors (e.g., LO-LO, HI-HI) on it so that no one PLC had both critical “hard” stop sensors. The initial code as developed would allow either of the Warrick sensors to trigger a "hard" stop as another form of redundancy (e.g., either HI or HI-HI could trigger a "hard" stop).

The initial code indicates the main control of the plant was via the Druck pressure transducers. If for some reason those transducers did not operate correctly when the first Warrick sensor was encountered (LO or HI) the process would be immediately terminated. If for some reason the process was not terminated (i.e., the first Warrick sensor had a failure that kept it from operating) when the second Warrick sensor was encountered (LO-LO or HI-HI) the system would again perform a "hard" emergency stop of the operations by tripping out a relay which results in a two phase operational approach to the shutdown of operations: first a normal automatic operations based on the Upper Reservoir Level as determined by the Druck pressure transducers, and then a "hard" emergency stop by either of the Warrick sensors in the event of a failed normal shutdown.

However, based on interviews with AmerenUE personnel and examination of the final code several changes had been made that affected this two tiered approach.

60 Second Delay

A 60 second time delay was added to the Warrick Sensor readings to minimize false trips of the relay. The Warrick sensor had to be activated for 60 seconds in order for the activation to be considered "real" and the relay for a "hard" stop tripped. This change was brought about due to several false trips of the relay ostensibly from "wave action". No documentation was obtained that discussed the technical ramifications of this solution or the technical rationale for why 60 seconds was chosen as the appropriate delay length.

A typical PLC has a scan time of 200 microseconds or below which means that the PLC is checking states 5000 times a second. One scan pass with a new state will start the time cycle over again. (Note: From interviews we were informed that the PLC scan time was around 40 microseconds). It is doubtful a wave would maintain contact with the Warrick Sensor for more than a few seconds. Using typical pumping rates for the project, a 60 second delay would result in the reservoir level rising more than 1.5 inches for two pumps running and about 0.75 inch per minute for one pump operating. If a 10 second delay was used, the rise in reservoir level would be slightly more than ¼ inch (or 1/8 inch for one pump approximately 374 thousand gallons or 187 thousand gallons of water respectively). A smaller delay would agree more with the intent of the Warrick sensors (HI and HI-HI) use as part of the safety system to prevent overtopping.

Series v. Parallel Code

Sometime after initial installation, the PLC was modified to tie the Warrick conductivity sensors in series rather than in parallel. For a "hard" emergency stop to occur, programming now required both Warrick sensors to be activated (e.g., LO and LO-LO would have to be contacted for 60 seconds before a "hard" stop of the generation process would occur assuming that both PLCs are functioning properly). However, if communications with one of the PLCs was not available then when the Warrick sensor on the "alive" PLC was activated (after the 60 second time delay) the system would perform a "hard" emergency stop regardless if it was the "first" or "second" Warrick sensor in the process.

Based on interviews, the LO-LO and HI-HI sensors were wired into the system to both alarm and perform a "hard" emergency stop. The LO and HI sensors were wired into the system but they would not generate an alarm, and if water contacted the sensor the PLC historian would NOT record in the logs that the sensor had been activated. This modification (basing the activation of the "hard" emergency stop on the Warrick sensors operating in series) was in response to false relay trips. No documentation was found that discussed the technical issues of this problem or the technical rationale for tying the sensors in series. In addition, it was discovered that the HI and HI-HI sensors were also tied in series rather than parallel. Again, no documentation was found that discussed the technical issues or the technical rationale for tying the HI and HI-HI sensors in series. One hypothesis that was postulated during interviews was that this modification was performed to keep the control processes "consistent".

Instead of having two separate systems for emergency shutdown for true redundancy, the programming changes resulted in only one system. This also led to a flaw in the operational logic of the plant processes. The code is contained in the two main modules that control the Unit 1 and Unit 2 pumps and generators (TSM01Unit1Main and TSM02Unit2Main respectively). The PLC code looks to see if a variable "Comm2UpperFault" is set (signifying that a PLC was not communicating) and if this variable is not set, the code requires both Warrick Sensors to be activated before it would trip the relay to stop the process. The flaw in the operational logic is as follows: Assuming that both PLCs are operating correctly, if one of the Warrick sensors fail in a manner that would not impact the Comm2UpperFault variable (e.g., the sensor is capable of sending the appropriate voltage level for non-activation but the circuitry for activation does not work so the "additional" voltage is not placed on the line.) then the relay would never be "tripped" to stop the process as one of the conditions would not be met (i.e., both sensors must be activated in order to trip the relay). So this change in the code could result in the safety system not activating upon the failure of one of the Warrick sensors.

Combination of Series Logic and Delay

Tests on the Warrick sensors after the December 14th incident showed that both Warrick sensors were capable of proper operation. Based on the "believed as found" physical locations, the Warrick Sensors were installed at 1597.4 ft. (HI) and 1597.67 ft. (HI-HI) which was higher than the height of the lowest panel. However, the HI sensor was below the estimated maximum reservoir level (1597.6 – 1597.8 ft). Because of the modification to have the Warrick sensors to operate in series, the PLC logic for the "hard" emergency stop was never executed. Due to the incorrect placement of the Warrick sensors the height of the HI sensor was 4.92 inches higher than the lowest panel of the parapet wall. However, if the Warrick sensor had been in parallel operation (with only a 10 second time delay), the HI sensor would still have shutdown the pumps and kept an additional 3.6+ inches of water from overtopping the wall (assuming a maximum pool of 1597.7 ft. during overtopping).

Other Code Discrepancy

Another flaw that was discovered by AmerenUE in the after incident investigation was that a coding modification located in Unit 2 Main PLC resulted in the disabling of the Unit 2 shutdown from the Warrick sensors. The Unit 2 Main PLC program was looking for the message tag "TSComWmgUrsLvlCtrl" instead of the correct message tag of "TSComWmgUrsLvlSwCtrl", (note missing "Sw"). This mistake meant that Unit 2 Main PLC program would never read the Warrick Sensor inputs so it would not know if the sensors had ever activated. During the incident the Unit 2 pump had already been shutdown several minutes before the HI Sensor contacted water

PLC Configuration Control Process and Testing Process

Based on interviews and other materials, there was no formal, robust Configuration Control Process for the PLC at the Taum Sauk facility. That meant that there was little control or oversight on changes that were made to the operational system. Due to this there is little to no documentation that discusses the problems that were encountered in the system, the technical rationale for proposed solutions, nor information concerning why a specific proposed solution was chosen.

It was also found that no formal testing program or procedures existed to test modifications made to the PLC code. The only testing that was performed was done by the individual who made the changes and only to the extent that they believed was necessary. The only documentation of any modifications was contingent on the individual who was responsible for implementing those changes. As a result there is little to no documentation on the problems that needed to be fixed, the technical ramifications of those problems, the technical rationale behind the proposed solution, and the testing that was performed to ensure that everything worked properly once the proposed solution was implemented.

Boundary Checking

From the pumping data there were several instances that the data reflected unusual activity like both pumps operating but the water level was not rising. In most instances, it takes only 7-8 minutes to raise the reservoir level one foot (with both pumps operating). The PLC system did maintain these values and they are displayed by the HMI, but there does not seem to be any “boundary checking” for values that did not make sense. In other words, the system did keep track of rate of level change but did not alarm if that rate of change was not within a “normal” range. For instance, on 13 December at 23:20 the reservoir was at 1549 feet, it took 20 minutes with both pumps working for the reservoir level to rise 1 foot to 1550 feet. Assuming a 1 foot rise per 8 minutes of pumping in 20 minutes the level should have increased by 2.5 feet. While this data was obviously recorded, the system did not highlight this abnormal situation. If the system would have included this type of “boundary checking” it is possible that an operator could have investigated the situation and taken corrective action. There was some boundary checking in the PLC logic. In fact, it was this boundary checking that allowed AmerenUE to determine that a Druck pressure transducer was out of alignment with the other two transducers and remove it from the Upper Reservoir level calculation.

5.7 Post Breach Inspection of Instrumentation and Analysis of Operations Data

5.7.1 Bowing in HDPE Tubes

The licensee reported that the offset and length of the arc of the HDPE pipes measured after the breach were 14 ft and 119 ft, respectively (see Figure 5.4). This was estimated to raise the reservoir control sensors approximately 2.5 feet. Due to the fact that the pipes have a tendency to straighten after the water is drawn down, it is not known what the maximum deflection was at the time of the breach. The estimate of peak pool level of about 1597.7 ft verses the Druck pressure transducer reading of 1593.72 indicates the transducers were about 4 feet higher in elevation than the original design. The following table presents the results of a geometric analysis of the bowing in the HDPE pipes showing several variations of offset and arc lengths and the resulting increase in elevation. Chord lengths were limited due to a cut in the rock outcrop where the pipes tended not to move laterally (see Figure 5.5).

Horizontal Offset (ft)	Chord Length (ft)	Arc Length (ft)	Delta Increase in Elevation (ft)
5.0	100	100.67	0.44
12	100	103.8	2.3
15	100	105.9	3.63
15	119	123.98	3.04
17.25	119	125.56	4.0
16.0	113.54	119.45	3.61
18.0	113.54	120.99	4.54

Figure 5.5 - Instrumentation location relative to the water conveyance shaft

5.7.2 High Water Marks on the HDPE Pipes

Evidence of the monitoring system not operating as designed was found at the gage house with water marks noted on the HDPE pipes. The elevation of the watermarks indicates the peak reservoir level may have been routinely above elevation 1596 ft. Figures 5.6 and 5.7 are a photograph and schematic of the high water marks, respectively.

Figure 5.6 - High Water marks on HDPE Tubes

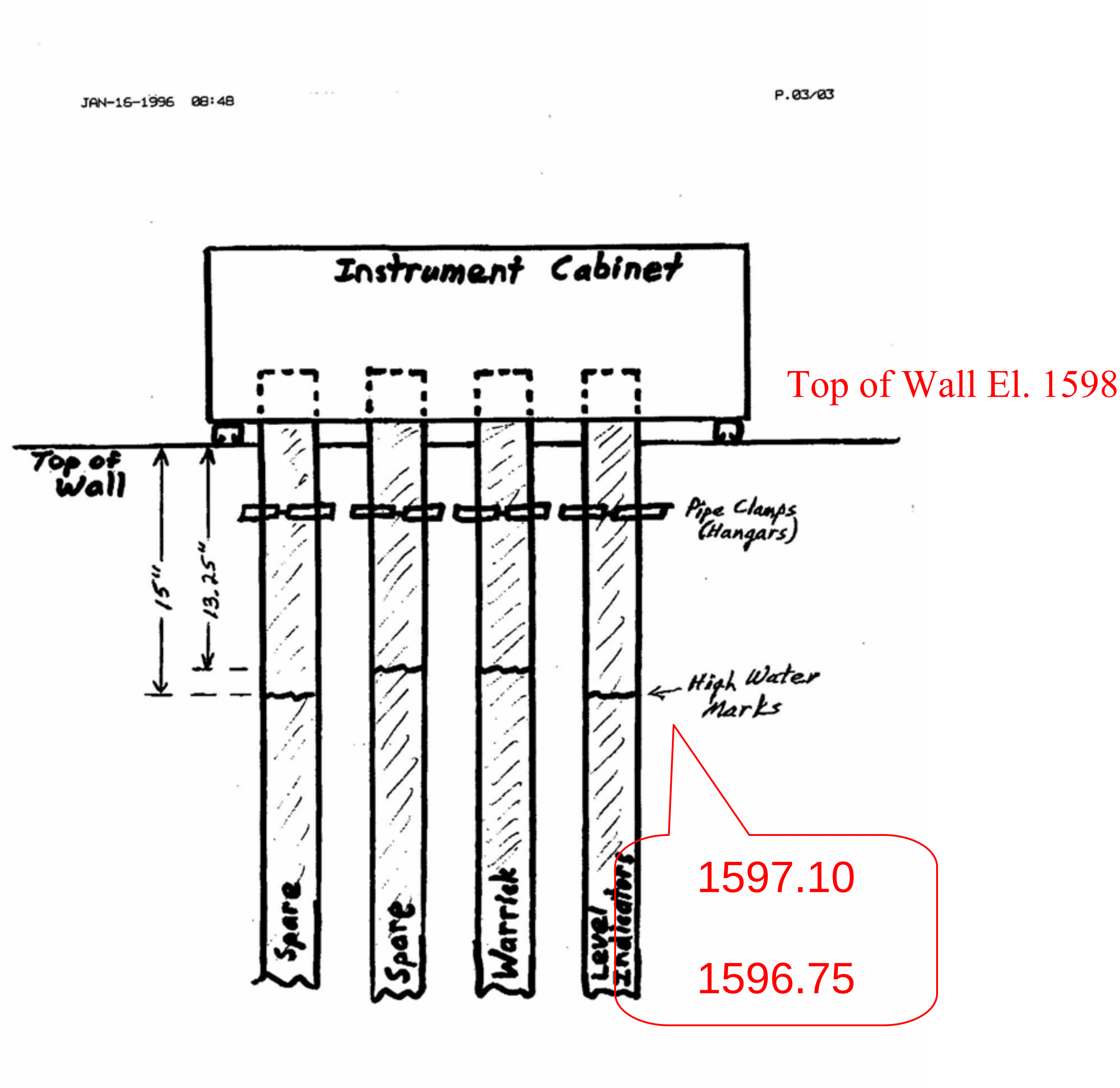

Figure 5.7 - Elevation of high water marks

5.7.3 Comparison of Penstock Transducer and Druck Pressure Transducer

Figure 5.8 plots the average difference between the penstock transducer and druck pressure transducer readings as provided by AmerenUE's letters dated December 27, 2005 and February 7, 2006. The chart plots the daily average differences on the first and fifteenth of each month from February 1 to December 1, 2005

The data points are the weighted average of readings for every minute during periods when the units were not operating (i.e., steady state). This was done because there are inconsistencies in the penstock readings when the units are operating. Readings were also neglected for 15 minutes before the units are put on-line and after they were taken off-line to ensure all readings had leveled off.

The bi-monthly plots show a sharp negative trend in the differences of the readings between April and August, reaching a low point in August. The differences then have a positive trend from August to December, approaching the readings experienced the previous winter. AmerenUE's February 7, 2006 submittal notes that the trend between the difference of readings correlates with the trend in water temperature. That is, the difference of readings became larger as water temperatures increased during the spring and summer and the difference became smaller as water temperatures decreased in the late summer and autumn.

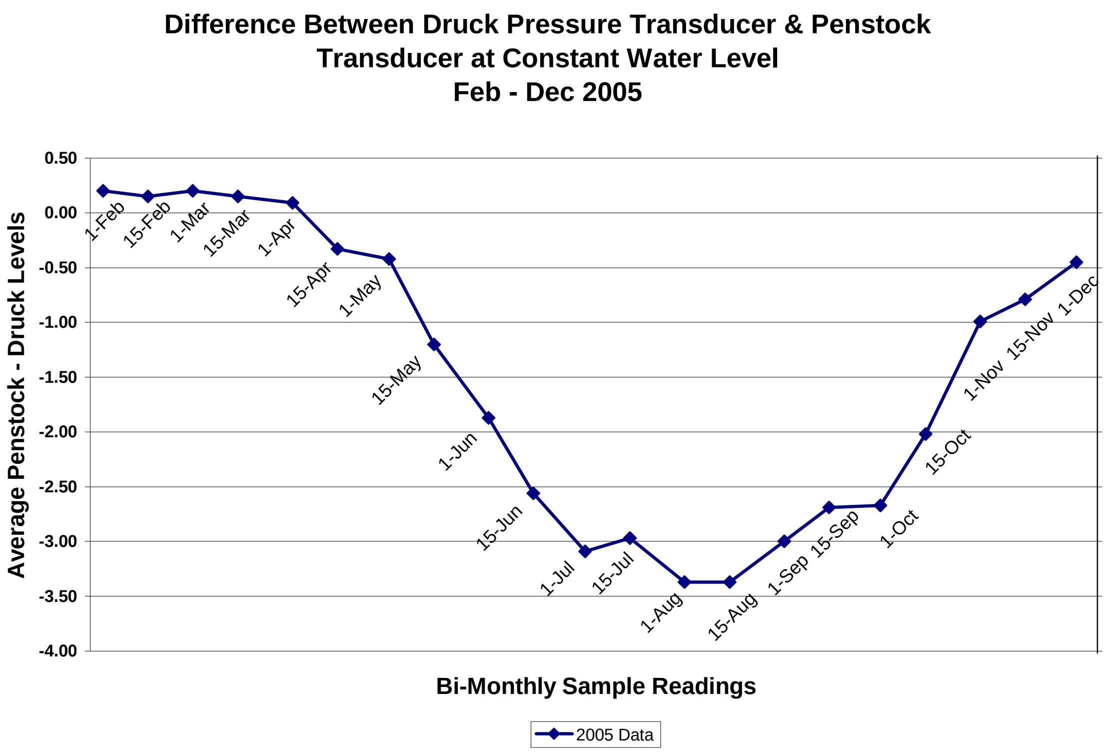

Figure 5.8

AmerenUE's February 7, 2006 filing also provides charts comparing the Druck pressure transducer (referred to as transmitter) readings and the penstock transducer readings, to determine if movement of the Upper Reservoir transducers could be detected. These charts give more specific information for each day in 2005 until December 14. Figures 5.9-5.12 show the graphs provided by AmerenUE for September through December 2005. September 27 shows a significant movement which coincides with the date one Druck pressure transducer was removed from averaging and a 0.4 foot correction was made in the PLC to the Druck pressure transducer readings. Significant and larger movements appear in December 2005, with increases in the differences on December 2 and December 13.

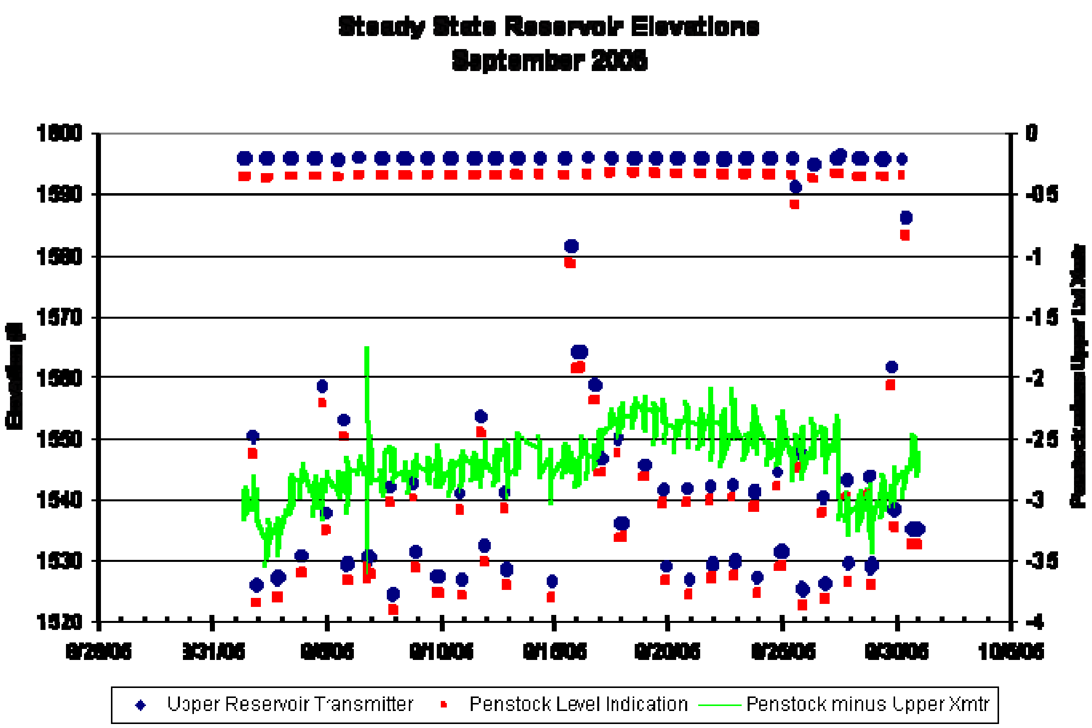

Figure 5.9

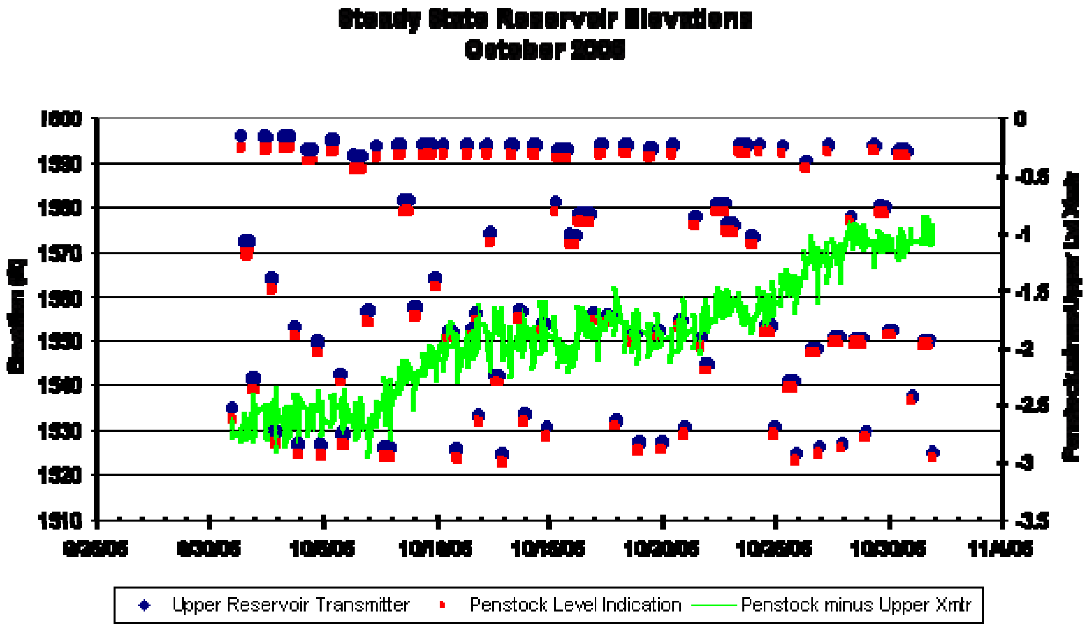

Figure 5.10

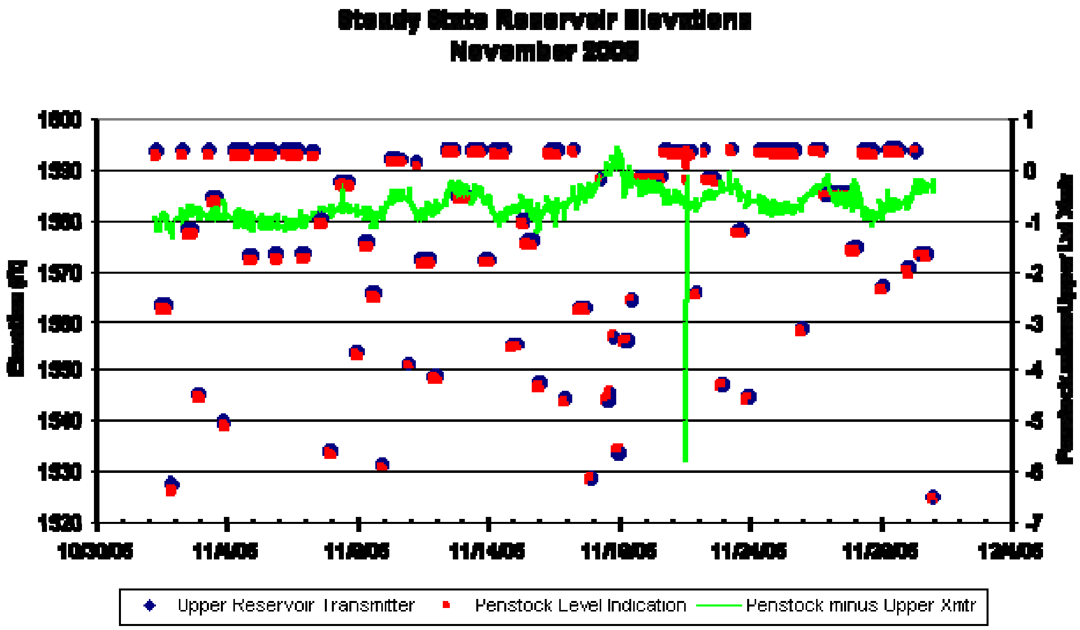

Figure 5.11

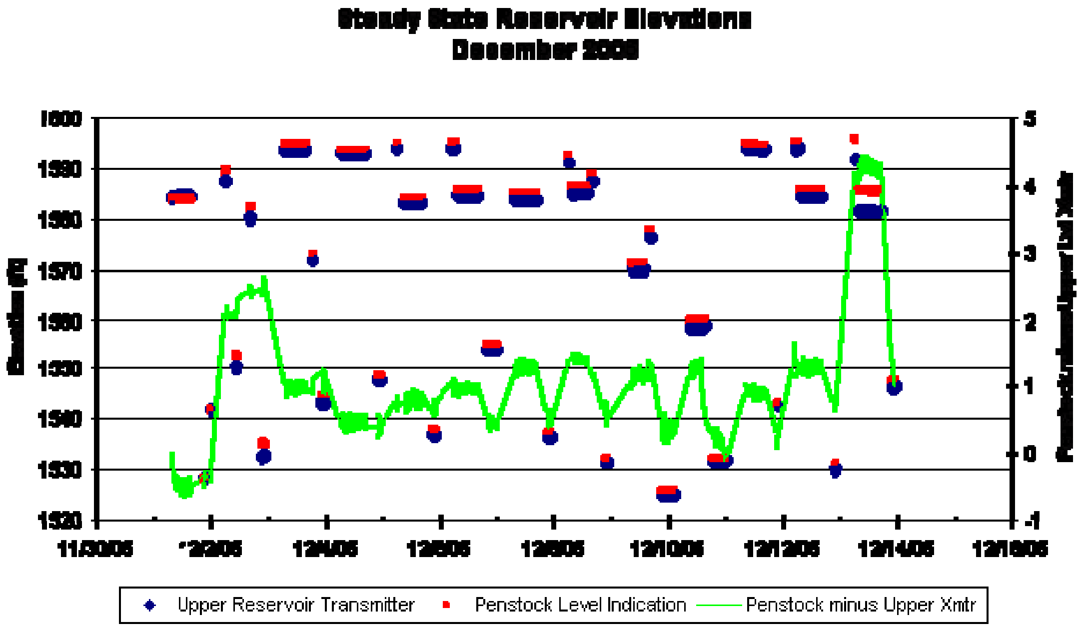

Figure 5.12

5.7.4 Assessment of the Reservoir Level Indicator Readings versus the Pump Back Times on December 13th and 14th, 2005 of Taum Sauk

5.7.4.1 <u>Daily Operations</u>

Typical daily operations at the Taum Sauk Upper Reservoir are illustrated for the period of September 1, 2005 to December 14, 2005 by the graphs found in Appendix B. A 1596 elevation line was added to the graphs for ease of monitoring the maximum reservoir pump back elevations. A written description of standard operating procedures is in Section 1.7.

5.7.4.2 <u>Average Pump Back Times per Foot of Reservoir Level Increase</u>

Appendix B – Figures B.9–B.14, examines pump back times on 6 random days in July 2005 for the purpose of determining the average pumping time in minutes it normally took to raise the reservoir 1 foot in elevation. The pump back times were examined for both one pump operating and for two pumps operating. The generating and idle times for the dates used were removed from the figures, since this data were not of interest for pumping times. A column with the calculated average pump back time was added at the right side of the AmerenUE data for the purpose of graphing this data and to identify normal and unusual readings. To reduce the scatter from one reading to the next due to waves and turbulence, the average pump back time was obtained by taking the difference between the reservoir elevation at a particular time and the reservoir elevation 20 minutes prior and dividing this difference into 20 minutes.

The pump back times for two pumps operating were observed to range from 5.5 minutes per foot to around 6.00 minutes per foot when the reservoir was below 1550 feet. From elevation 1550 feet to 1570 feet the time to raise the reservoir one foot with two pumps operating ranged from around 6:00 minutes to 7:00 minutes. The time to raise the reservoir one foot, from elevation 1570 feet to 1596 feet, generally ranges from 7:00 minutes to 8:00 minutes.

When one pump operated at the end of the pump back cycle in the early morning, the reservoir elevations were usually above the elevation 1589 ft with a constant reservoir surface area of 55 acres. The time to raise the reservoir one foot with one pump operating ranged from 14 minutes to around 18 minutes. The time for pump back with one pump operating was generally more variable than when both pumps were operating. These greater variations could be due to wave actions and turbulence influencing the actual reservoir elevations from minute to minute being used for calculations. Alternatively, greater turbulence could have caused the pipes with the reservoir sensors to move around.

The average pump back times were used as a base range to compare the pump back times on December 11 to 14, 2005 to observe for changes that may have been occurring.

5.7.4.3 <u>Reservoir Operation on September 27, 2005</u>

Appendix B – Figure B.15 shows data for the morning of September 27, 2005 during the idle mode after the reservoir had been pumped up to approximately 1596 elevation. As can be observed in the figure, the reservoir level indicator drifted downward by about 0.25 foot around 10:29 AM to 10:34 AM, which is reflected by an increased reservoir level reading of approximately 0.25 foot. Later around 11:15 AM there is another shift upward in the reservoir level reading of about 0.4 foot. This shift is probably the time at which the 0.4 foot adjustment was added into the PLC logic to shut the pumps off 0.4 foot short of elevation 1596 feet to account for observed differences in reservoir level indicator readings and staff gauge readings.

5.7.4.4 Pump Back Discrepancies

Event Discrepancies Chronology

An average pump back time per foot of reservoir increase was discussed above for 6 random days in July 2005. The pump back times ranged from around 6 minutes per foot of increase when the reservoir was at an elevation less than 1550 feet to a pump back time of 7.5 to 8 minutes per foot of rise as the reservoir elevation reached and exceeded 1570 feet. The normal fluctuations from one minute to the next could be attributed to variability in the sensor signals, wave actions and turbulence. Unusual pump back times that spike upward or downward out of the normal variation range can help identify reservoir sensor changes in and around that time.

Appendix B – Figure B.16-B.19 reviews pump back and reservoir data for approximately 72 hours prior to the breach of the upper reservoir. Graphs from this Exhibit are plotted for each day December 11th through December 14th.

In reviewing the reservoir pump back data for December 11th to 14th, several irregular pump back times were noted. On December 11th at 5:03 AM the reservoir level indicator read 1573.91 feet and 20 minutes later at 5:23 AM the reservoir level indicator read 1574.08 feet, which is a difference of only 0.17 foot. When this difference was divided into the 20 minute time period the pump back time rate is about 115 minutes/foot. During this period of time both pumps were operating and the rise in reservoir level over this 20 minute cycle should have been nearly 3 feet, not 0.17 foot. The HDPE pipes could have been moving during this time causing the reservoir sensors to show a nearly constant reservoir level over this 20 minute cycle, even though the reservoir was increasing by about 3.0 feet. At 5:24 AM, the reservoir level read 1575.45 feet which is a 1.4 foot increase from the 5:23 AM reading.

There were some extended pump times during the early morning hours of December 13th, when it took 12 to 14 minutes to raise the pond by 1 foot with 2 pumps operating. The accumulated increases during the morning of December 13th pump back, the night of December 13th, and the morning of December 14th could have raised the pond by more than 2 feet above what was actually being indicated.

An important point of interest also occurred on the night of December 13th between 23:20 hours and 23:21 hours. The reservoir level indicator dropped from 1548.97 feet to 1547.47 feet which is a 1.5 foot drop. This drop is shown on Appendix B - Figure B.8. This 1.5 foot drop could have been the result of multiple turn buckles coming loose and allowing the 4 HDPE pipes to move laterally to the extent that the lower ends of the HDPE pipes with the piezometer sensors were raised up 1.5 feet in elevation. This would have caused the reservoir level indicator to show that the reservoir was 1.5 feet lower than it actually was. There were fluctuations up, down, and laterally over the next 20 minutes while full pump back was going on with both pumps going. From the pumping and reservoir data one can see that the reservoir level was essentially at 1549 feet at 23:20 hours. It was not until 23:40 hours that the reservoir level reached 1550.15 feet. This indicates that it took 20 minutes of pumping with both pumps to raise the reservoir 1.15 feet. Again, the reservoir level increase during this period should have been approximately 3 feet due to the reservoir being around the 1550 level with a normal pump back time of 6 to 6.5 minutes per feet at this level.

5.7.5 Druck Pressure Transducers - Signal Variability

Specification for the Druck pressure transducers were +/-0.25% FSBSL (Full Scale Best Straight Line) for Combined Non-linearity, hysteresis and repeatability and +/-1.5% for temperature effects. Per the manufacturer's (General Electric Sensing) representative, the variability of the signals within the range of the instrument can be as high as +/- 0.25 % which is +/- 0.58 ft of head. Also, per the manufacturer's representative very little error would be introduced if the temperatures of the surrounding media are consistent. Variability of +/-0.58 ft of head is seen in the reservoir level data provided by AmerenUE at the start up of the new system and continues throughout 2005 (Figures 5.12-5.15). The accuracy of the Druck pressure transducers was 58% of the freeboard available at the lowest section of the parapet wall during the "normal" operations of the upper reservoir **if** the instrument structural support system was intact and properly functioning.

Figures 5.12-5.15 are charts developed from the license's minute-by-minute output data from the reservoir monitoring system. Analysis of the PLC indicates the system recorded a signal at a specific point in time, not an average. The dark blue plot is the difference of the elevation of the reservoir from one data point minus the elevation data from the previous minute (Y_{n}- Y_{n-1}). A positive variability ($Y_{n} > Y_{n-1}$) greater than the sum of the instrument error plus the rate of reservoir rise during the pump cycle represents a drop in elevation (higher head). A negative variability ($Y_n < Y_{n-1}$) represents an upward movement in elevation (lower head). The magenta lines in the figures are the reservoir elevation as determined from the Druck pressure transducers.

Important characteristics of this data examination are:

1. The variability in the system output when the reservoir was in pump mode appeared to be within the specification after initial installation.

2. Increases in variability of the Druck pressure transducer signals and output appear to increase from September 2005 through December 2005.

3. Variability appears to be greater than the sum of the electronic error and the rate of reservoir rise. Variability up to +/- 1.75 feet occurred December 13, 2005.

4. The greatest fluctuation in the output occurs during the pump cycle when the reservoir elevation is between 1545 ft and 1565 ft.

5. It is possible there is a relationship between the movement of the instrumentation pipes and the turbulence caused by the pumping cycle (Figure 5.16 – shows turbulence on first filling. Figure 5.5 shows proximity of pipes to the intake shaft.)

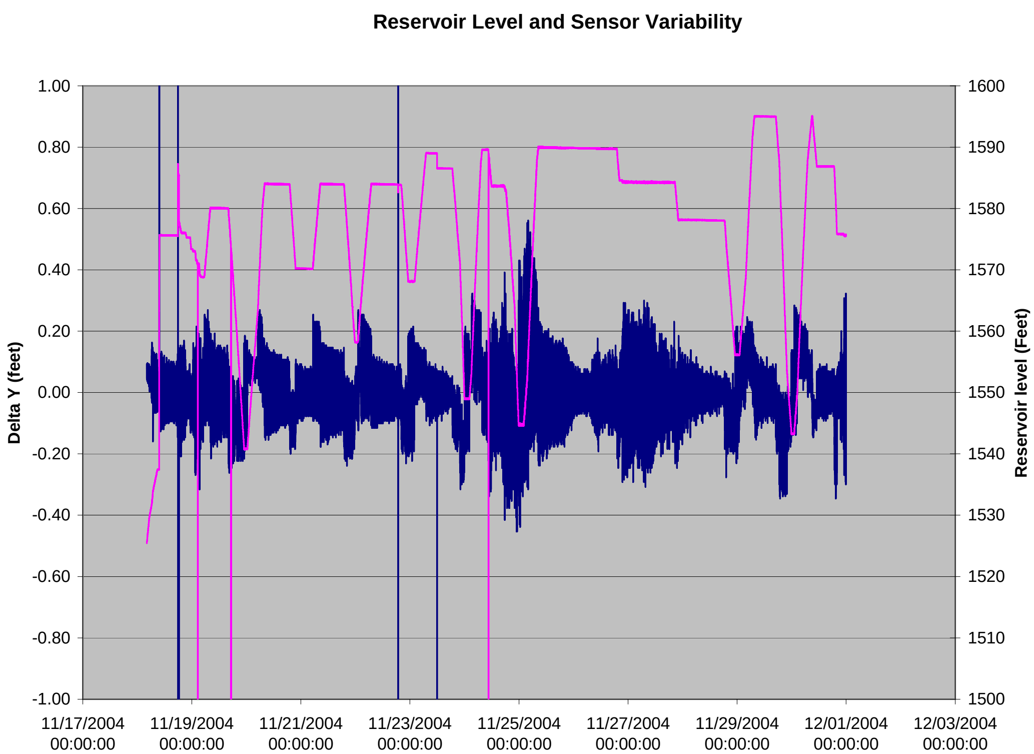

Figure 5.12 - System Variability November 2004 - After Installation

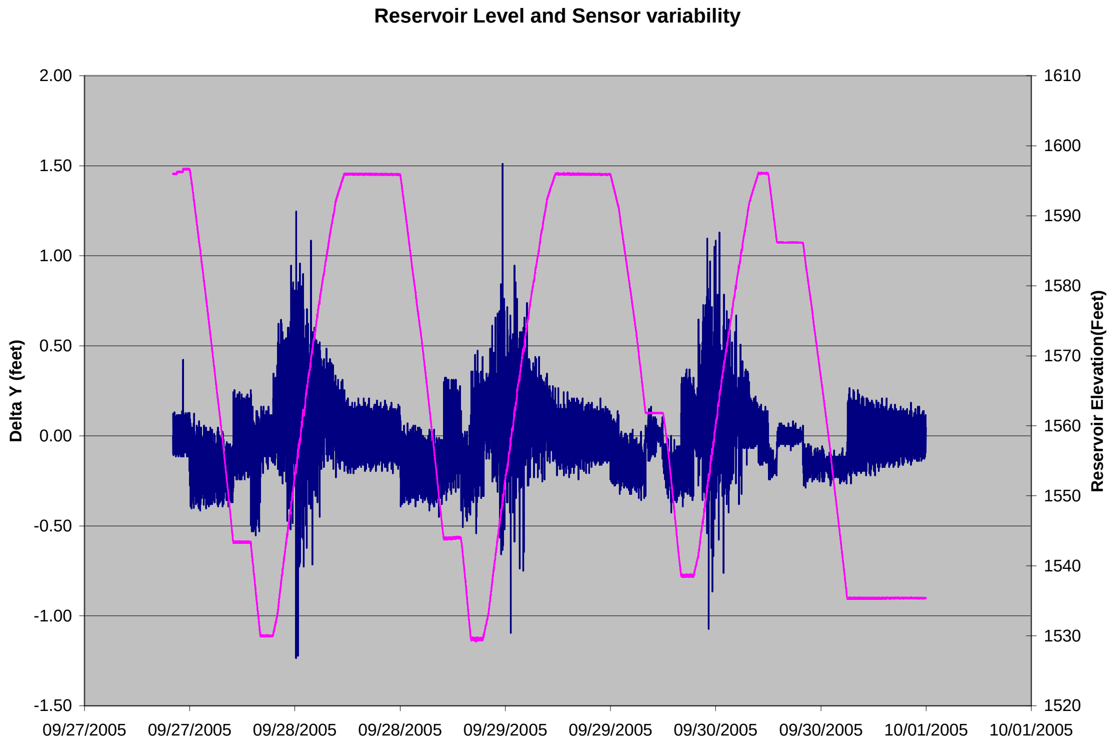

Figure 5.13 - System Variability September 27-October 1, 2005

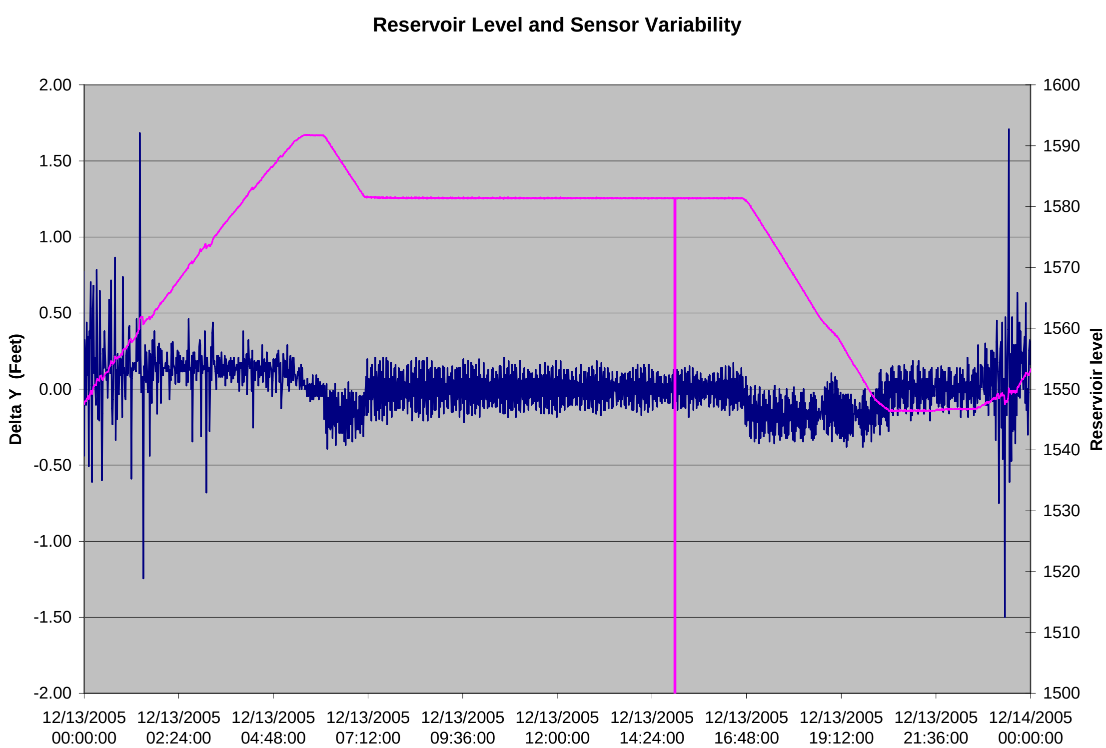

Figure 5.14 - System Variability December13, 2005

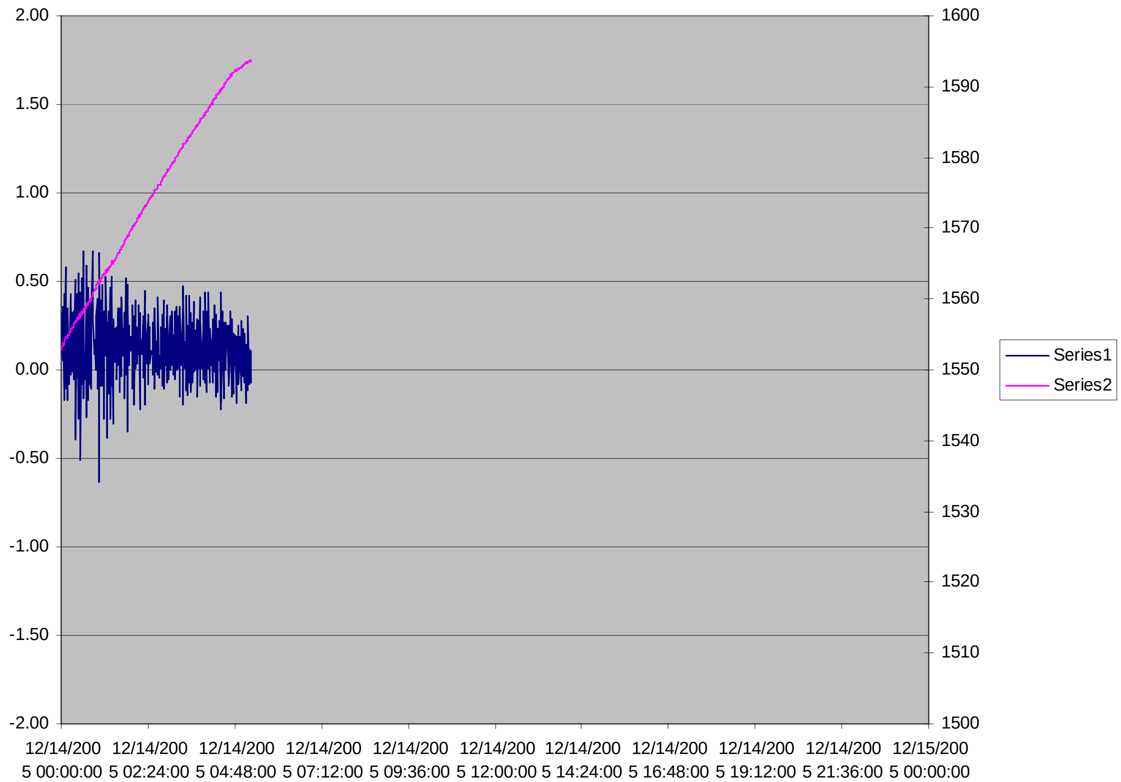

Figure 5.15 - System Variability December 14, 2005

Figure 5.16 - Turbulence on first filling (from AmerenUE)

5.7.6 Evaluation of Extended Seepage Pond Pump Back Times for September – December 2005

By email dated March 31, 2006, AmerenUE provided operation data of the seepage pond pumps from September through December 2005. The seepage pond pump information was examined to determine if days having extended operation times for the seepage pond pumps could indicate previous occasions when over pumping of the reservoir occurred. There were several days since mid-September when the seepage pond pump operated for extensive periods of time. Three of these days were September 25, November 15 and November 27.

There was no evidence; however, that water levels exceeded the top of the parapet wall on these three days. The extended pump back time on September 25th could be attributed to two factors: (1) 1.02 inches of rain that day and (2) wind-induced waves exceeded the top of the parapet wall after the reservoir was filled to within about 4 inches of the reservoir crest.

From the minute-by-minute generator-pump data from AmerenUE, the highest reservoir elevation on November 15th was about 1580 feet from 5:50 AM to 8:18 AM. The highest reservoir elevation on November 27th was about 1585.3 feet throughout the day until generating started at 5:01 PM. These elevations were taken from the Druck pressure transducer readings and are expected to be within about one foot of actual levels based on a comparison to the penstock transducer levels. Since the reservoir had over 10 feet of freeboard throughout the day on both of these days, over pumping did not occur. November 15th had 1.42 inches of rain and November 27th had 1.52 inches of rain, it is likely the long pump back time on these two days was due to rainfall.

The following chart shows daily rain totals at Farmington Airport, which is about 27 miles from the project, since mid-September 2005 and the number of hours that the seepage pond pump operated on the days when it rained. The days the pumps operated the most correlates with periods of high precipitation.

Date	Precipitation (inches)	Number of Minutes Seepage Pond Pump Operated
9/20/2005	0.89	175
9/24/2005	0.01	176
9/25/2004	1.02	452
9/28/2005	0.51	258
10/20/2005	0.02	334

Date	Precipitation (inches)	Number of Minutes Seepage Pond Pump Operated
10/22/2005	0.05	333
10/23/2005	0.31	442
10/31/2005	1.56	411
11/12/2005	0.06	388
11/13/2005	0.02	423
11/14/2005	0.60	448
11/15/2005	1.42	808
11/20/2005	0.03	540
11/27/2005	1.52	568
11/28/2005	0.36	816
12/8/2005	0.02	354
12/9/2005	0.03	400
12/14/2005 (to 5:16 am)	0.08	119

5.7.7 Seepage Collection - Pump Back Operation December 7 and 8, 2005.

Seepage pump back data was examined for several days in December prior to December 14th and for December 14th to evaluate whether a time for start of overtopping on December 14th could be observed. The following tables show seepage pump operation on December 7 and 8, 2005 (assumed to be normal days of seepage pump operation) and December 13 and 14, 2005. Comparisons were made to determine if any changes in the pump back cycle could be observed on the morning of December 14th. The first table shows pump on times between 63 minutes to 77 minutes. The off times ranged from 150 minutes to 237 minutes. The second table shows pump on times of 65 minutes to 82 minutes, until the breach occurred.

In comparing the On/Off times in these two tables, the seepage pump operation times for December 13th and 14th are similar to December 7th and 8th. The seepage pump had been off for 3 hours when it came on at 4:23 AM on December 14th, which is considered normal. The seepage pump had been operating for 53 minutes when the breach occurred at about 5:15 AM, which extended total pump operating times to 349 minutes.

Seepage Pump On-Off Data, December 7-8, 2005					
Date	**Time**	**On/OFF**	**Time On – Minutes**	**Time Off – Hours/mins**	**Time Off - Minutes**
12/07/05	01:36	On			
12/07/05	02:40	Off	64		
12/07/05	06:00	On		3:20	200
12/07/05	07:12	Off	72		
12/07/05	09:42	On		2:30	150
12/77/05	10:56	Off	74		
12/07/05	13:44	On		2:48	168
12/07/05	14:55	Off	71		
12/07/05	17:51	On		2:56	176
12/07/05	19:02	Off	71		
12/07/05	22:25	On		3:23	203
12/07/05	23:28	Off	63		
12/08/05	03:47	On		4:19	259
12/08/05	04:53	Off	76		
12/08/05	07:46	On		2:53	173
12/08/05	09:03	Off	77		
12/08/05	11:39	On		2:37	157
12/08/05	12:53	Off	74		
12/08/05	15:36	On		2:43	163
12/08/05	16:46	Off	70		
12/08/05	19:29	On		2:43	163
12/08/05	20:36	Off	67		
12/09/05	00:33	On		3:57	237

Seepage Pump On-Off Data, December 13-14, 2005					
Date	**Time**	**On/Off**	**Time On-Minutes**	**Time Off-Hours/Mins**	**Time Off-Minutes**
12/13/05	4:00	On			
12/13/05	5:12	Off	72		
12/13/05	7:45	On		2:33	153
12/13/05	9:07	Off	82		
12/13/05	11:40	On		2:33	153
12/13/05	12:56	Off	76		
12/13/05	15:38	On		2:42	162
12/13/05	16:52	Off	74		
12/13/05	19:37	On		2:45	165
12/13/05	20:47	Off	70		
12/14/05	00:18	On		3:31	211
12/14/05	1:23	Off	65		
12/14/05	4:23	On		3:00	180
12/14/05	10:12	Off	349		

Section 6 Taum Sauk Upper Reservoir Breach Time Line

Date	Event
January 3, 2002	• AmerenUE sends plans and specs and design calculations for installation of a geomembrane liner to FERC for review. The design documents cover installation of a geomembrane liner, no designs or computations were provided regarding installation of new instrumentation. Demolition notes on the construction drawing directs removal of the original monitoring system and concrete supports. • In the letter, AmerenUE proposes starting construction on March 25, 2002.
March 1, 2002	• FERC sends letter stating it has no comments on the plans and specs. The letter asks for an erosion control plan and states inspections will be performed in conjunction with the Operation Inspection and a final inspection near the end of construction.
March 14, 2002	• FERC performs Operation Inspection of the project. According to the June 13, 2002 Operation Report, the licensee was planning to start installation of the geomembrane. The contractor will install anchors on the parapet wall (bolts and batten strips), and install an anchorage system near the toe of the slope. The geomembrane was to be installed during the summer 2002. The licensee was planning to replace the float level indicator at the upper reservoir with an electronic system. The old float indicator will be maintained as a backup.
April 22, 2002	• AmerenUE informs FERC by phone that budget of the liner has been exceeded and work has not been completed within schedule. AmerenUE states the geomembrane installation will take place in Fall 2003. • Work completed to date includes installation of the toe sill and GSE Polylock anchor around the interior perimeter, patching of critical areas with gunite, and pouring concrete in an area that has the most severe leakage. • FERC construction inspection planned for May 6, 2002 is postponed to Fall 2003.
September 25, 2002	• Richard Cooper of AmerenUE sends an email to FERC stating that Unit 1 seal was damaged and the unit cannot be used for pump-back operation. A two-week outage was planned to start the following weekend.

October 29-30, 2002	• MWH performs Part 12D inspection of project.
November 5, 2002	• AmerenUE sends letter to FERC stating between September 26 and October 18 of that year, the upper reservoir and penstocks were drained to do maintenance work on the units. During this time an inspection of the liner revealed cracks in the floor of the tunnel liner about 1500 feet up from the plant. Repairs were made at that time. The repairs consisted primarily of welding and are documented in photographs attached to the letter report dated November 5, 2002
November 19, 2002	• AmerenUE sends letter to FERC that Richard Cooper replaced David Fitzgerald as plant superintendent.
December 3, 2002	• Richard Cooper of AmerenUE sends an email to FERC that a second outage is planned for March 2, 2003 through March 22, 2003 to repair the Unit 2 inlet valve seal. The seal was reportedly damaged the previous month. The licensee planned to dewater the tunnel completely during this planned outage.
March 6, 2003	• AmerenUE sends letter to FERC stating liner project is being postponed to start in September 2004 and be completed by the end of the year. • FERC construction inspection planned for Fall 2003 is postponed to 2004.
April 24, 2003	• FERC sends letter to AmerenUE regarding postponement of liner installation. The letter notes leakage is steadily increasing from an average of 30 cfs during 2000 to about 65 cfs during the first quarter of 2003. Some of the leakage has been attributed to leaky seals in the units. The revised schedule is accepted because AmerenUE is continually monitoring leakage and making underwater repairs to the concrete liner in the interim. The licensee was asked to notify FERC of any change in leakage.
July 3, 2003	• AmerenUE submits 6-month leakage report.
August 1, 2003	• FERC sends letter regarding the 6-month leakage report and notes leakage averaged 58 cfs in the first half of 2003. A portion of the leakage was attributed to leakage at the hydroplant and repairs were scheduled for the fall 2004.
August 26, 2003	• Part 12D Report filed with the FERC. The consultants observed that the original float level controls had been replaced and that the current controls are not well documented on drawings. Drawings of the new instruments were requested within one year. • Licensee's plan and schedule to address the Part 12D

	recommendations filed with the FERC. The licensee's plan and schedule was to provide the drawings of the modified Upper Reservoir level controls by the end of 2004.
October 23, 2003	• FERC performs Operation Inspection of the project (report for the inspection is dated February 12, 2004). During the inspection, the FERC was informed that the old float system was removed and replaced with two pressure transducers, to provide better redundancy. The same tubing that housed the float had been reportedly used to mount the pressure transducers. The FERC engineer discussed with the plant superintendent proper notification and coordination procedures for certain unauthorized modifications that were performed during the previous year at the project.
October 24, 2003	• FERC sends letter requesting a crest survey be performed of the upper dam to supplement the Part 12D report.
December 24, 2003	• AmerenUE submits upper dam survey readings taken in November 2003 to FERC.
January 15, 2004	• AmerenUE submits 6-month leakage report and notes the leakage rate has not gone down since repair of the Unit 2 valve seal. The letter indicates the liner work will resume in September 2004.
January 20, 2004	• FERC sends letter to AmerenUE asking for plan and schedule to address routine maintenance and surveillance issued discovered during October 2003 Operation Inspection. The letter notes that liner repairs should be completed by the end of 2004 and flow into the seepage pond should be maintained at acceptable levels.
February 13, 2004	• Richard Cooper of AmerenUE sends email to FERC with plan and schedule for items discussed in January 20, 2004 letter.
March 15, 2004	• FERC sends letter to AmerenUE requiring a Quality Control and Inspection Program be submitted at least 60 days before doing liner work schedule for September 2004.
July 23, 2004	• AmerenUE submits QCIP for liner installation to FERC. Notes contractor proposes to start work on September 13, 2004.
September 9, 2004	• FERC sends letter to AmerenUE regarding liner installation. • States the work was authorized in FERC letter dated April 24, 2003.

	• States the original plans and specifications were reviewed in 2002 and no items that would adversely affect dam safety were found. • FERC reviewed the plans and specifications submitted in 2002 and QCIP and has no comments. • Requires monthly construction reports and certifications from the design engineer, QCIP manager, and licensee that project is constructed in accordance with design intent and plans and specs. • Notes if plans and specs are revised, the licensee must assure that changes are coordinated between the engineer, QCIP manager, FERC, and the licensee. • Notes any changes in operation must be authorized by the FERC and properly coordinated between the licensee, FERC, and the operators. • Requires a Final Construction Report within 45 days of completing construction.
September 9, 2004 - November 15, 2004 **INSTALLATION OF GEOMEMBRANE LINER AND RESERVOIR CONTROLS**	• Liner installed on upstream slope of upper reservoir. • All of the upper reservoir level control and protection devices were replaced. Three GE Druck model no. 1230 pressure transducers were installed for normal shutdown of the pump/generators. The Low, Low/Low Warrick Conductivity sensors are replaced in kind. The High, High/High float switches were replaced with Warrick Conductivity sensors. The upper reservoir PLC was replaced with an Allen Bradley PLC. The pump/generator shutdown relays at the plant are replaced with Allen-Bradley PLCs. The level indicators, alarming, and data acquisition systems were replaced with a WonderWare Operator Interface. (source: Joe Raybuck's Draft Taum Sauk Upper Reservoir Level Control and Protection Systems - Information Sheet) • Instrumentation pipe supports are changed to cable support system (source: As-built Design Drawings). • AmerenUE replaced the existing staff gage, which had settled approximately one foot along with the parapet wall. The staff gage had been used to measure the normal operating level of the upper reservoir, which was 1596 ft. Due to the settling, AmerenUE believes that the upper reservoir was actually operating at 1595 ft. instead of 1596 ft. before the liner replacement project. (AmerenUE Chronology) • During the outage new visual level indications were painted on the liner reflecting true elevations. (AmerenUE Chronology)

September 30, 2004	• FERC performs Operation Inspection of the project (report for the inspection is dated December 23, 2004).
October 6, 2004	• Geo-Synthetic, Inc. ("GSI"), the installation contractor, installs the membrane in the area of the water level instruments at Panel 58. • GSI raised concerns that the March 7, 2003 gage piping design did not provide for adequate anchoring and could compromise the integrity of the liner and gage piping. In response, Emcon/OWT, Inc. ("Emcon"), an engineering firm retained to design the liner and gage piping, provided a new design drawing (8304-X-155099, Rev. 5, dated 10/5/04) proposing a new gage piping anchoring system. (AmerenUE Chronology - *See* Exhibit 8).
October 19, 2004	• Steve Bluemner of AmerenUE sends email to FERC documenting construction progress from start of construction (September 2, 2004) through September 30, 2004.
October 20-23, 2004	• Assembly of the gage piping on the reservoir floor starts on October 20 and is finished on October 23. (GSI daily construction progress reports.) • GSI installed the gage piping. (AmerenUE Chronology - *See* Exhibit 9). During installation, AmerenUE determined that Emcon's design (8304-X-155099, Rev. 5, dated 10/5/04) for the gage piping could not be installed as shown due to field conditions. In consultation with Emcon and with its approval, AmerenUE made field changes to the anchoring system in order to adapt the design to field conditions and to make it more robust. • Subsequently, on November 12, 2004, Emcon and AmerenUE performed a walk-through inspection of the liner and gage piping installation.
November 6, 2004	• AmerenUE field notes reported that the top of panel 72, the lowest known point on the upper reservoir parapet wall, was measured at elevation 1596.99 ft. (AmerenUE Chronology - *See* Exhibit 10).
November 8, 2004	• AmerenUE field notes reflected that the level protection sensors were intended to be installed at the following elevations: Lo-Lo sensor: 1524 ft.; Lo sensor: 1524.5 ft.; Hi sensor: 1596 ft.; Hi-Hi sensor: 1596.2 ft. (AmerenUE Chronology - *See* Exhibit 11.)
Mid-November 2004	• The Druck pressure transducers and Warrick conductivity sensors were lowered into the gage pipes. Wiring from the transducers and sensors to the upper

	reservoir gage house was marked with colored tape to distinguish one from another and to provide a visual elevation reference. AmerenUE believes the colored tape reflects the as-designed and installed elevations of the level protection sensors. These elevations approximate those indicated in AmerenUE field notes. (AmerenUE Chronology.)
November 15, 2004	• AmerenUE released the upper reservoir for operation. (AmerenUE Chronology - *See* Exhibit 12.) The normal operating level remained at 1596 ft., but now was being measured by the new level control transducers and visual level indications. As a result, the actual normal operating water level was 1596 ft. and not 1595 ft. as it had been prior to the liner replacement project, as further described in the September 10 2004 entry.
November 19, 2004	• FERC sends letter accepting Part 12D Report and requesting the following: o Perform a new crest survey before the end of 2004 to determine correct elevations. The data should be provided to the next Part 12D consultant and he should review and comment on the data. o Explain cause of penstock liner buckling in next Part 12D report. o Reevaluate post-seismic deformation and stability of the Upper Reservoir for the next Part 12D report. o Survey both the offset and deformation movement of the parapet panels and compare it to the measurements taken in 1987 or 1988, provide interpretation of the data. o Provide a plan and schedule to address these comments.
November 23, 2004	• Reference comment logged into the Upper Reservoir Programmable Logic Controller ("PLC") program indicated that the Hi sensor was at elevation 1596 ft. (AmerenUE Chronology - *See* Exhibit 13.) • AmerenUE believes, but has been unable to verify, that Tony Zamberlan of Laramore, Douglass, and Popham Consulting Engineers ("LDP"), entered the comments. LDP was retained by AmerenUE to provide engineering services related to the new level control and protection instrumentation.
November 30, 2004	• The Hi sensor actuated. An Osage operator recorded a trip of unit 2 with the upper reservoir level measuring elevation 1595.0 ft. (AmerenUE Chronology - *See*

	Exhibits 15 and 16.) • Later that day, the Lo Lo sensor relay lost DC power and shut down both generators. (AmerenUE Chronology - *See* Exhibits 15 and 16.) • An email from Taum Sauk's plant superintendent listed the shut down setpoints for the upper reservoir. (AmerenUE Chronology - *See* Exhibit 16.) When the average of the three level control transducer readings reflects that the upper reservoir level is at the following elevations, the corresponding pump shut downs will occur: Elevation 1592 ft. Normal shut down for first pump. Elevation 1596 ft. Normal shut down for second or last pump. Elevation 1596.5 ft. All pumps shut down. • The superintendent also stated that the setpoint for the level protection sensors is above elevation 1596.5 ft.
November 30, 2004	• Steve Bluemner of AmerenUE sends email to FERC documenting construction progress for October1 2004 through completion of the project. Photographs of the new instrumentation gage piping are included.
December 1, 2004	• To prevent intermittent trips, Tony Zamberlan added a one minute time delay to the PLC logic for all level protection sensor relays. (AmerenUE Chronology - *See* Exhibits 17 and 18.) • According to Mr. Zamberlan's Dec. 2nd email, he also was at the upper reservoir to "pull up the Hi level Warrick sensors to 1596.5." (AmerenUE Chronology - *See* Exhibit 17.) Mr. Zamberlan does not recall, and has been unable to explain why he set the sensors at elevation 1596.5 ft., or how he determined that elevation. (Note: According to the interview of Mr. Zamberlan of February 10, 2006, any modifications that were made by him were directed to the union workers at the Taum Sauk Plant and he did not make any physical changes. Mr. Zamberlan only modified the PLC programs himself.) • Reference comment logged into the Upper Reservoir PLC program indicated that the Hi sensor was at elevation 1596.7 ft. AmerenUE believes, but has been unable to verify, that Mr. Zamberlan entered the

	comment. (AmerenUE Chronology - *See* Exhibit 18.)
December 10, 2004	• LDP Consulting Engineers finalized and issued the schematic drawing for the upper reservoir level relaying and shut down controls (8303-P-26648, revision 15). (AmerenUE Chronology - *See* Exhibit 19.) The schematic indicated that the Hi sensor was at elevation 1596.7 ft. and the Hi-Hi sensor was at elevation 1596.9 ft. LDP personnel do not recall, and are unable to explain why the drawing reflects the stated elevations.
December 14, 2004	• Pump shutdown levels are indicated in the Taum Sauk PLC. When the average of the three level control transducer readings reflects that the upper reservoir level is at the following elevations, the corresponding pump shut downs will occur: <u>Elevation 1592 ft.</u> Normal shut down for first pump. <u>Elevation 1596 ft.</u> Normal shut down for second or last pump. <u>Elevation 1596.2 ft.</u> Normal all pumps shut down. <u>Elevation 1596.5 ft.</u> Non-configurable all pumps trip that, if activated, requires a reset. *(AmerenUE Chronology - See* Exhibit 20.) • Reference comment logged into the Taum Sauk Common PLC program indicated that the Hi-Hi sensor was set at elevation 1596.5 ft. AmerenUE believes, but has been unable to verify, that Mr. Zamberlan entered the comment. (AmerenUE Chronology - *See* Exhibit 20.)
December 20, 2004	• AmerenUE sends to letter to FERC in response to comments on the 8th Part 12D Report. As an attachment, AmerenUE includes the latest survey of the crest (taken November 2003 and corrected October 2004) and drawings and diagrams of the new Upper Reservoir Level Controls. The Schematic Diagram (revised on 12/10/2004) shows the Hi Warrick Sensor set at 1596.7 feet and the Hi-Hi Sensor set at 1596.9 feet. The design drawing of the instrument supports shows only three pipes attached to a Unistrut channel with spring nuts and no turnbuckles.
December 27, 2004	• A malfunctioning Lo-Lo sensor relay was replaced. (AmerenUE Chronology - *See* Exhibit 21.)

	• The PLC historian software recorded a Hi-Hi sensor alarm at 3:38 p.m. PST, or 5:38 CST, at an upper reservoir level reading of elevation 1586.4 ft.[3] (AmerenUE Chronology - *See* Exhibit 22.) At the time of the alarm, the units were neither pumping nor generating. (AmerenUE Chronology - *See* Exhibit 23.) • AmerenUE believes this alarm may have been associated with maintenance activities at Taum Sauk.
January 5, 2005	• AmerenUE sends letter to FERC showing leakage rate has significantly decreased since installation of liner (from around 50 cfs to around 15 cfs). • Indicates diver will seal all remaining leaks in the floor area during the Spring or Summer 2005.
February 12, 2005	• AmerenUE sends letter to FERC including the final construction report for the liner replacement. The report includes gage piping drawing (8304-X-155099, Rev. 5, dated 2/7/05) which does not identify the field changes made to the gage piping anchoring system. (AmerenUE Chronology - *See* Exhibit 24.)
February 14, 2005	• The PLC historian software recorded a six-second Hi-Hi sensor alarm at 3:57 p.m. CST, at an upper reservoir level reading of elevation 1593.5 ft. (AmerenUE Chronology - *See* Exhibit 22.) At the time of the alarm, the units were neither pumping nor generating. (AmerenUE Chronology - *See* Exhibit 25.) • AmerenUE believes this alarm may have been associated with maintenance activities at Taum Sauk.
February 15, 2005	• The PLC historian software recorded multiple Hi-Hi sensor alarms between 4:03 p.m. and 5:49 p.m. CST, at an upper reservoir level reading of elevation 1593.5 ft. (AmerenUE Chronology - *See* Exhibit 22.) At the time of the alarms, the units were neither pumping nor generating. (AmerenUE Chronology - *See* Exhibit 25.) • These alarms were associated with functional checks of the Hi-Hi sensor alarm that were performed by a contractor at the direction of AmerenUE personnel. The contractors lowered the Hi and Hi-Hi sensors into the water. • The generator trip logic for the Lo and Lo-Lo sensors

[3] On the date of the alarm, the PLC Historian software was programmed to Pacific time. In June 2005, the PLC Historian software was reprogrammed to Central time. Throughout this chronology, all noted alarms recorded by the PLC Historian software are expressed in Central time.

	was modified from parallel logic to series logic by Tony Zamberlan. (AmerenUE Chronology - *See* Exhibits 26 and 27.) In series logic, the generators would only shut off if both the Lo and Lo-Lo sensors actuate. A similar change was made by Mr. Zamberlan to the pump trip logic for the Hi and Hi-Hi sensors. AmerenUE believes the generator trip logic for the Lo and Lo-Lo sensors was modified to prevent spurious actuations. • In his February 10, 2006 interview (pg 30), Tony Zamberlan addressed this issue and stated that "…a hypothesis of as to why." He believed the change may have been due to maintaining consistency between how the sensors were handled, and since the Lo and Lo-Lo sensors were placed in series to avoid spurious shut offs the Hi and Hi-Hi sensors were similarly placed. "My hypothesis would be that being that this is half of the same system, the lower half of the, the backup protection scheme, that we did the same thing to the upper reservoir code, just to match it up so that it operated the same way, …".
March 14, 2005	• FERC sends letter accepting final construction report with no comments.
June 22, 2005	• FERC sends letter notifying licensee of upcoming Operation Inspection, copied to Missouri Dam and Reservoir Safety Program Chief Engineer so that he could arrange to participate in the inspection.
June 27, 2005	• Missouri Department of Natural Resources sends letter to FERC acknowledging operation inspection notice and providing updated contact information for the director of the Missouri Department of Natural Resources.
July 5, 2005	• AmerenUE provides 6-month leakage report that shows leakage from Upper Reservoir averaged less than 6 cfs during the first half of 2005 (as opposed to 65 cfs prior to installation of the geomembrane liner).
July 20, 2005	• The PLC historian software recorded a one-second Hi-Hi sensor alarm at 5:15 p.m. CDT, at an upper reservoir level reading of elevation 1573.8 ft. (AmerenUE Chronology - *See* Exhibit 22.) At the time of the alarm, the units were generating. (AmerenUE Chronology - *See* Exhibit 28.) • AmerenUE has been unable to determine why this alarm was recorded, but around the time of the alarm, a storm, likely accompanied by lightning, moved through the area of the project works. The storm may have caused momentary induced voltages on the wiring running between the Hi-Hi sensor relay and the plant PLC input

	card resulting in the PLC Historian recording a false Hi-Hi sensor alarm.
August 14, 2005	• The PLC historian software recorded a one-second Hi-Hi sensor alarm at 3:50 p.m. CDT, at an upper reservoir level reading of elevation 1591.6 ft. (AmerenUE Chronology - *See* Exhibit 22.) At the time of the alarm, the units were generating. (AmerenUE Chronology - *See* Exhibit 29.) • AmerenUE has been unable to determine why this alarm was recorded, but at the time of the alarm, a storm, accompanied by lightning, moved through the area of the project works. The storm may have caused momentary induced voltages on the wiring running between the Hi-Hi sensor relay and the plant PLC input card resulting in the PLC Historian recording a false Hi-Hi sensor alarm.
September 25, 2005	• Remnants of Hurricane Rita pass through area. • Workers witness overtopping, referred to as "Niagara Falls at the Northwest corner of the reservoir" • Units are immediately put on generate mode to lower reservoir. (source: 9/27/2005 email from Richard Cooper) • Refer to September 24-26 Operations Time Line
September 27, 2005	• The plant superintendent notes the visual level of the reservoir (as measured down from the crest of the parapet wall) does not match the average Druck pressure transducer level. The visual level was about 4 inches from the top of the parapet wall near "a couple of wet areas on the west side of the reservoir parapet walls", even though the transducers were showing elevation 1596 feet. *(Note: if the referred to west area was around panel 72, which is the lowest panel on the west side of the dam – 4 inches from the top of the crest would be elevation 1596.66 feet.)* • One Druck pressure transducer is found to be reading "a foot higher than the other two" and is eliminated from the average. When the one pressure transducer was taken out of the average, the reading was 1596.2 feet. Since this did not match the elevation in the field, a 0.4 ft programming adjustment was made to the two remaining pressure transducer readings, making the level read 1596.6 ft. • The plant superintendent states they would "check on what this does to the actual level the next several mornings." (source 9/27/2005 email from Richard Cooper)

	• At 10:11 a.m., an Osage operator noted in the operator log a "high upper resv. alarm [and] small gate setting changed to 7.7% by itself. HPTs (Hydro Plant Technicians) are working on something @ Sauk." (AmerenUE Chronology - *See* Exhibit 31.) At the time the notation was made, the units were neither pumping nor generating. AmerenUE believes this alarm is related to work being done on the PLC at approximately the same time. (AmerenUE Chronology - *See* Exhibit 22.) Between 10:03 and 10:05 a.m., the elevation level readings for the upper reservoir were not recorded, suggesting that the PLC was offline so that an adjustment to the logic could be made. The adjustment may have resulted in an alarm indication once the PLC came back online.
September 28, 2005	• The PLC historian software recorded a one-second Hi-Hi sensor alarm at 6:18 p.m. CDT, at an upper reservoir level reading of elevation 1544.1 ft. (AmerenUE Chronology - *See* Exhibit 22.) At the time of the alarm, the units were neither pumping nor generating. (AmerenUE Chronology - *See* Exhibit 31.) • AmerenUE has been unable to determine why this alarm was recorded, but at the time of the alarm, a storm, accompanied by lightning, moved through the area of the project works. The storm may have caused momentary induced voltages on the wiring running between the Hi-Hi sensor relay and the plant PLC input card resulting in the PLC Historian recording a false Hi-Hi sensor alarm.
September 30, 2005	• The Hi and Hi-Hi Warrick Sensors are verified to be 7 inches and 4 inches below the crest of the wall, respectively. *(Note: This results in elevations 1597.417 ft and 1597.667 ft, respectively, based on the recent survey of the parapet wall near the instrumentation.)* (Source: 10/7/2005 email from Thomas Pierie and AmerenUE Chronology.)
October 3-4, 2005	• A visual inspection of the upper reservoir revealed that portions of the gage piping support system had failed, allowing the gage piping to move. The piping was observed to be bent. AmerenUE operators recognized that a bend in the piping would produce an elevation reading that is lower than the actual elevation of the upper reservoir. (AmerenUE Chronology - *See* Exhibit 33.)
October 6, 2005	• The plant superintendent notes the HDPE pipes have come loose from the cables and are bowing at least 5

	feet out at about 50 feet down. • In the evening, Unit 1 tripped in the generate mode due to high vibrations. (Source: 10/7/2005 email from Richard Cooper)
October 7, 2005	• The maximum operating level is set at 1594 feet instead of the normal 1596 feet. • The set point for the "all pumps" shutdown was lowered from elevation 1596.2 ft. to elevation 1594.2 ft. (AmerenUE Chronology) • Arrangements are made to have a diver evaluate whether the piping could be straightened and reattached without draining the reservoir (AmerenUE Chronology – *See* Exhibit 34). • Plans were made to add redundancy to the upper reservoir level protection system. A wind speed measurement transmitter and alarm, were ordered for installation at the upper reservoir. AmerenUE also planned to install an additional sensor 2" below the normal last pump shut down setpoint *(i.e., at elevation 1595.83 ft.)* so that the water level pressure transducers could be checked. (AmerenUE Chronology - *See* Exhibit 32.) • In the morning, Unit 2 tripped on high vibration in the pump mode. • The plant superintendent believes some epoxy material is coming loose from the tunnel liner that was installed last fall. The epoxy was installed in the tunnel to cover cracks in the steel liner. The size of the epoxy patch was about 1 inch thick, 6 feet wide and 100 feet long. The tunnel drains were found to be flowing at full pipe like they were before the epoxy patch was installed. The vibration protection trips on the units were set to normal levels and the superintendent believed these would protect the units if more material is released. (Source: 10/7/2005 email from Richard Cooper)
October 11, 2005	• A diver visits the site and says the pipes can be straightened out but AmerenUE needs to develop/manufacture a new tie down system. (Source: 10/11/2005 email from Richard Cooper)
October 25, 2005	• The preliminary design was completed and materials were ordered for the gage piping support retrofit. (AmerenUE Chronology - *See* Exhibit 35.)
October 28, 2005	• FERC sends letter providing results of August 25, 2005 Operation Inspection. No follow-up actions required.
November 2, 2005	• The PLC historian software recorded a nine-second Hi-

	Hi sensor alarm at 12:49 p.m. CST, at an upper reservoir level reading of elevation 1578.4 ft. *See* Exhibit 22. At the time of the alarm, the units were neither pumping nor generating. (AmerenUE Chronology - *See* Exhibit 36.) AmerenUE has been unable to determine why this alarm was recorded.
November 23, 2005	• All materials are on hand to make repairs. • Emails indicate AmerenUE is having trouble scheduling repairs and notes the diver may not be available through the end of the year. (Source: 11/23/2005 email from Steven Bluemner)
November 29, 2005	• AmerenUE sends letter to FERC stating that the annual drill of the Taum Sauk EAP will be conducted on December 14, 2005.
December 13, 2005	• Operations data shows the Druck pressure transducer elevations drop about 1.9 feet at about 11:20 pm although both units are pumping. (Source: AmerenUE's Operation Data) • See December 13-14 Operations Time Line
December 14, 2005	• Dam Overtops and Breaches • See December 13-14 Operations Time Line

September 24-26 Operations Time Line
Taum Sauk Project, P-2277

Date	Time	Druck Pressure Transducer Elev. (ft)*	Unit Info.	Weather at Farmington, MO	Coincident Events
Sept. 24	13:00	1595.82	Generator 1 on-line	Wind 8 knots coming from 110 degrees of North, Clear	
	13:11	1595.03	Generator 2 on-line	Wind 6 knots coming from 110 degrees of North, Clear	
	18:01	1544.91	Generator 1 off-line	Wind 5 knots coming from 100 degrees of North, Clear	
	18:02	1544.91	Generator 2 off-line	Same	
	18:58	1544.75	Generator 2 on-line	Wind 6 knots coming from 100 degrees of North, Clear	
	19:01	1544.20	Generator 1 on-line	Same	
	20:01	1532.00	Generators 1 & 2 off-line	Wind 5 knots coming from 110 degrees of North	
Sept. 25	00:27	1531.65	Pump 2 on-line	Wind 3 knots coming from 110 degrees of North	
	01:57	1539.80	Pump 1 on-line	Wind 5 knots coming from 30 degrees of North	
	08:03	1592.11	Pump 2 off-line	Wind 10 knots (gust to 18 knots) coming from 100 degrees of North, precip.	
	9:03	1595.96	Pump 1 off-line	Wind 10 knots (gust to 18 knots) coming from 80 degrees of North, precip.	AmerenUE hydroplant technicians note overtopping during this period.
	11:03	1595.97	Generator 2 on-line	Wind 14 knots (gust to 22 knots) coming from 90 degrees of North, precip.	
	12:15	1590.92	Generator 2 off-line	Wind 10 knots (gust to 16 knots) coming from 100 degrees of North, precip.	
	13:56	1590.85	Generators 1 & 2 on-line	Wind 9 knots coming from 100 degrees of North, precip.	
	18:03	1547.91	Generators 1 & 2 off-line	No wind	
	18:59	1547.78	Generator 1 on-line	No wind	
	19:01	1547.68	Generator 2 on-line	Same	
	20:35	1528.18	Generator 2 off-line	Wind 5 knots coming from 320 degrees of	

Date	Time	Druck Pressure Transducer Elev. (ft)*	Unit Info.	Weather at Farmington, MO	Coincident Events
				North	
	20:59	1525.80	Generator 1 off-line	Same	
	21:58	1525.42	Pump 2 on-line	Wind 3 knots coming from 310 degrees of North	
	23:01	1531.49	Pump 1 on-line	Wind 8 knots coming from 350 degrees of North	
Sept. 26	05:53	1591.96	Pump 2 off-line	Wind 5 knots coming from 310 degrees of North, Clear	
	06:43	1594.9	Pump 1 off-line	Wind 3 knots coming from 310 degrees of North, Clear	

* Druck pressure transducer readings are not the true elevations of reservoir.
** Information for this chart is from AmerenUE's operation data & trice-hourly weather information at Farmington Airport.

December 13-14 Operations Time Line
Taum Sauk Project, P-2277

Date	Time	Druck Pressure Transducer Elev. (ft)*	Unit Info.	Weather at Farmington, MO	Coincident Events
Dec. 13	06:05	1591.52	Generator 1 on-line	27^o , No Wind	
	06:06	1591.54	Generator 2 on-line	Same	
	7:08	1581.57	Generators 1 & 2 off-line	25^o, No wind	
	16:43	1581.29	Generator 1 on-line	43^o , Wind at 11 knots coming from 160 degrees from North	
	16:50	1580.63	Generator 2 on-line	Same	
	20:06	1548.08	Generator 1 off-line	39^o, Wind at 10 knots coming from 150 degrees from North	
	20:27	1546.39	Generator 2 off-line	39^o, Wind at 11 knots coming from 170 degrees from North	
	22:33	1546.85	Pump 1 on-line	39^o, Wind at 10 knots coming from 150 degrees from North	
	23:13	1548.59	Pump 2 on-line	39^o, Wind at 16 knots coming from 160 degrees from North	At about 23:20 there is a 1.9 foot drop in the transmitter readings, although both pumps are operating.
Dec. 14	04:43	1591.85	Pump 2 off-line	36^o, Wind at 13 knots (Gusts to 16 knots) coming from 170 degrees from North	
	05:16	1593.39	Pump 1 off-line	36^o, Wind at 13 knots (Gusts to 16 knots) coming from 170 degrees from North	Upper Reservoir water levels start falling at 5:16. Between 5:15 and 5:30, USGS Gage 07061270 (East Fork Black River Near Lesterville) located near Highway N was damaged by the flood surge.
	05:20	1581.59		Same	
	05:25	1548.09		Same	
	05:30	1522.52		Same	
	05:35	1510.78		37^o, Wind at 13 knots coming from 170 degrees from North	At 5:38, the Osage Operator logs that the upper reservoir indication, tailwater level indication, and

Date	Time	Druck Pressure Transducer Elev. (ft)*	Unit Info.	Weather at Farmington, MO	Coincident Events
					generate permissives were not reading normal on the LDS and SCADA System
	05:40	1507.00		Same	At 5:40, Osage Operator notifies Taum Sauk Superintendent of unusual readings. At 5:41, the Reynolds County 911 dispatcher receives a call about water on Highway N.
	05:45	1505.72		Same	
	05:50	1505.12		Same	
	05:55	1504.77		Same	
	06:00	1504.55		37^o, Wind at 14 knots (gust to 19 knots) coming from 170 degrees from North	At 6:00, the plant superintendent confirms tailrace is muddy. The Lesterville Fire Department and Reynolds County Sheriff contact the Plant Superintendent to confirm the upper reservoir dam has breached. The plant superintendent begins contacting others on EAP.
	08:00	1503.52		37^o, Wind at 9 knots coming from 180 degrees from North	

* Druck pressure transducer readings are not the true elevations of reservoir.
** Information for this chart is from AmerenUE's operation data, thrice hourly surface climate data for Farmington, MO Airport Station, AmerenUE's 12.10 letter, an interview with Reynolds County Sheriff, and a 1/23/2006 email from USGS.

Section 7 Meteorology

7.1 General

The Taum Sauk area is located in Southeast Missouri near the geographical center of the United States. Its position in the middle latitudes allows it to be affected by warm, moist air masses from the Gulf of Mexico and cold, dry air masses that originate in Canada. The alternate invasion of these air masses produces a wide variety of weather conditions and allows for the region to enjoy a true four-season climate. The average annual temperature is 54 degrees. The average annual high temperature is 65 degrees, the average annual low temperature is 42 degrees.

By letter data January 19, 2006, AmerenUE provided weather information for most of 2005 as recorded at Farmington Regional Airport located about 1 mile south of Farmington, MO. The airport is at elevation 947 ft and at latitude 37.7610792 and longitude -90.4285972. The airport is about 27 miles northeast of the upper reservoir.

This section discusses the meteorology preceding and during three events:

1. September 25, 2005 - when overtopping occurred at the northwest corner of the reservoir.
2. September 27, 2005 - when a wet area was noted on the downstream side of parapet panel 72.
3. December 14, 2005 - when the upper reservoir breached.

Figure 7.1 contains a weather radar image of the United States at 10:00 a.m. on September 25. Appendix C shows thrice hourly weather data for the period September 24-27 and December 13-14, 2005.

7.2 September 25, 2005

The weather conditions in the Taum Sauk area (Farmington, MO Station), prior to and on September 25, 2005, as reported by the NWS, St. Charles, MO, were as follows:

"… Periods of rain and an occasional thunderstorm will continue over eastern Missouri and most of Illinois for the rest of this morning and into the afternoon hours. This precipitation is associated with the northern periphery of tropical depression Rita. Expect brief periods of heavy rain …up to half an inch at times.

In the meantime… a cold front will move into northern Missouri and bring in additional showers and thunderstorms tonight…"

Approximate Time Overtopping was witnessed

According to the February 8, 2006 interview with Mr. Ronald Robbs, he witnessed the September 25 overtopping at the Northwest corner of the reservoir during a "mid-morning" visit to the upper reservoir. He said the water was coming over the reservoir in waves. After witnessing the overtopping, he went to the plant, phoned the Osage Operator and told the operator to start the generators to draw down the reservoir.

According to the February 8, 2006 interview with Richard Cooper, he was contacted by the Osage Operator for confirmation that he should put the generators on-line. Mr. Cooper agreed that they should generate. Mr. Cooper estimated the elapsed time could have been about 30 minutes between when the overtopping was witnessed and putting the generators on-line, but he did not know for certain. According to the generation logs for September 25 provided by AmerenUE, the first generator was put on-line at 11:03 a.m. This indicates the overtopping was witnessed around 10:00-10:30 am.

Maximum Wind Speeds As Recorded on September 25 at Farmington Airport

According to weather information in Appendix C, the largest windspeed recorded at three times an hour at Farmington Airport on the morning of September 25 was 17 knots and the largest recorded gust was 23 knots. The weather was rainy. The wind was blowing from between 80 and 100 degrees from North, almost perpendicular to the northwest corner of the reservoir (panels 90-96).

According to the February 8, 2006 interview with Mr. Ronald Robbs who witnessed the overtopping, he estimated the wind speed at "40-50 miles an hour" based on an Evening New report which said maximum wind speeds at Farmington Airport were 38 miles per hour. He believed the wind was coming out of the Southeast.

Difference in Wind Speed between Elevations

Commission staff interviewed representatives from the National Weather Service (NWS) in St. Charles, Mo. on January 12, 2006. NWS personnel stated that there can be large variances in wind speed between the elevations of Farmington Airport and the Upper Reservoir, but they expect this would occur on clear days. They said it is not likely there would be drastically different wind speeds between the elevation of Farmington Airport and the Upper Reservoir on a rainy, cloudy day which was the case on September 25. They said one reason there could be a large difference in wind speeds between the two locations on September 25 is if there was an isolated thunderstorm on the mountain. According to the National Climatic Data Center website (www.ncdc.noaa.gov), there were no reported thunderstorms or high wind events from September 24 through October 1, 2005 in Reynolds County, MO. Mr. Robbs' interview also did not indicate a thunderstorm was occurring when he witnessed the overtopping.

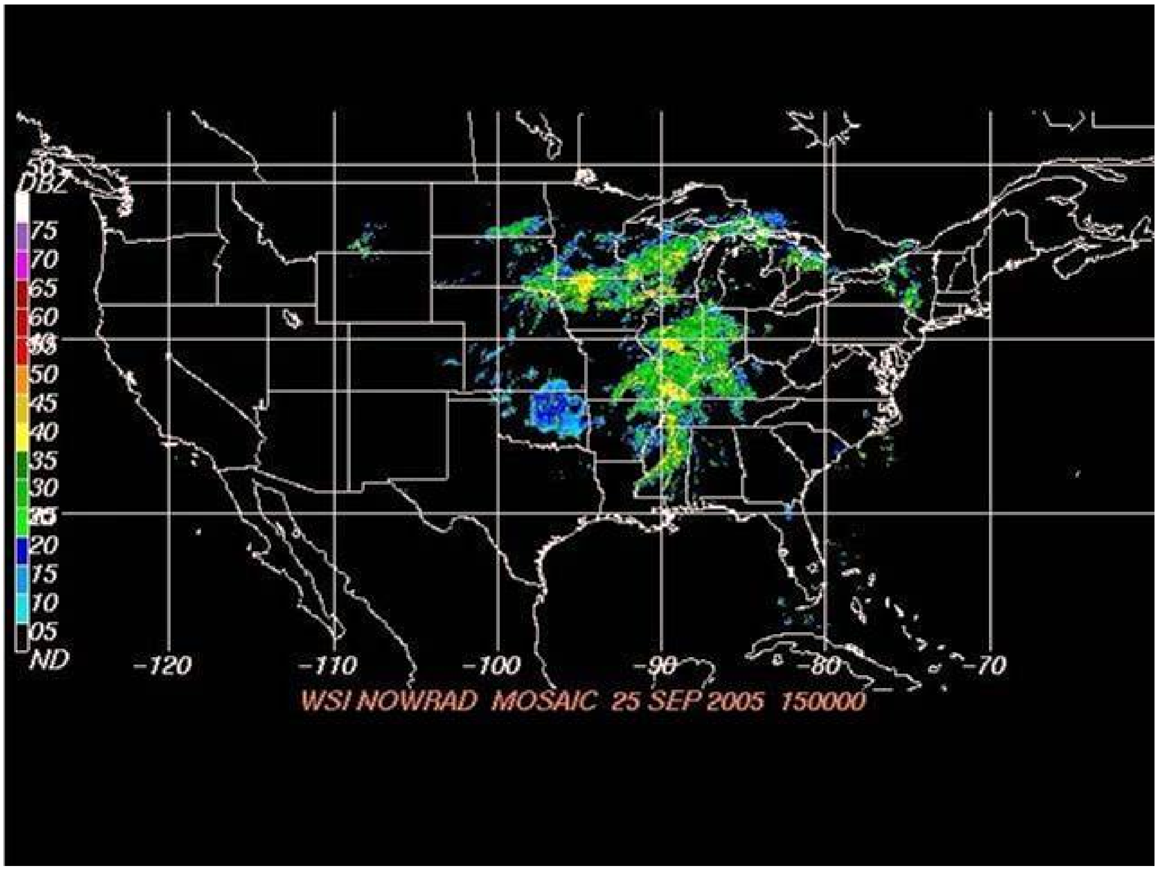

Figure 7.1 - Weather Radar Images September 25, 2005 – 10:00 a.m. CDT

7.3 September 27, 2005

According to the February 8, 2006 interview with Mr. Richard Cooper, he saw wet spots on the downstream side of the parapet wall, at the low point of the wall, during a morning visit to the upper reservoir. Panel 72 is the low point of the parapet wall. According to generation information the reservoir was filled to elevation 1596 this morning.

The weather information for the morning of September 27 indicated early morning fog leading to mostly to partly sunny conditions. During the morning there were steady winds of 3-5 knots at Farmington Airport. The wind direction changed during the morning. Winds came from 10-40 degrees from North at around 8:00-9:00 am then from 110-140 degrees from North after 10:00 am.

7.4 December 14, 2005

The Upper Reservoir breach started at around 5:15 a.m. The weather information for the early morning of December 14 indicated light snow, rain, and drizzle with temperatures in the mid-30s. At Farmington Regional Airport about 0.08 inches of precipitation occurred during the early morning. The recorded steady wind speeds ranged from 10-14 knots with gusts to 22 knots. Winds originated from 140-180 degrees from North.

Section 8 Hydrology and Hydraulics

8.1 Upper Dam

The Upper Dam has no spillway. It's outlet works consists of a 451-foot long, 27.2-foot diameter, vertical shaft, the top 110 feet of which is concrete lined; a 4,765-foot long, 25-foot diameter unlined horseshoe tunnel sloping at 5.7 percent; a horizontal 1,807-foot long, 18.5-foot diameter steel lined tunnel; and a short penstock that bifurcates to the pump-generating plant. The shaft bellmouth intake is located in the southwestern portion of the reservoir in a localized area of the floor that is 20 feet lower than the rest of the reservoir floor to suppress vortex development.

8.1.1 Drainage Area/Surface Area/Storage

The Upper Dam has a drainage area equal to the surface area of the reservoir, about 55 acres, and has a total storage of about 4,350 acre-feet at elevation 1596 ft.

8.1.2 Flood of Record

There is no information on the flood of record since the reservoir's drainage area is its surface area.

8.1.3 Inflow Design Flood

The IDF is the PMF. Since the drainage area for the Upper Dam is the reservoir's surface area, the maximum inflow would be the probable maximum precipitation (PMP). The PMP was developed for the basin and found to be 34.24-inches within a 72-hour period with a maximum six hour amount of 22.38-inches (this is discussed further in the Lower Dam section).

It should be noted that if a precipitation event caused a significant increase in reservoir levels, the turbines could be operated to lower the reservoir.

8.1.4 EAP Dam Break Analysis

The inundation map for the Upper Reservoir in the EAP is based on a sunny day dam break analysis. For the Sunny Day dam break, releases from the Upper

Reservoir would flow to the Lower Reservoir and be contained there. Since there is minimal drainage area for the Upper Reservoir, only a Sunny Day dam break was performed. One 60-foot wide parapet wall was assumed to fail and initiate the breach. The rockfill was assumed to erode full depth. The peak outflow was estimated as **30,000cfs.**

The breach parameters used in the analysis are:

BR = Average width of breach = 160.0 feet. The bottom breach width is 60.0 feet and the top breach width is 260.0 feet.

Z = Horizontal component of side slope of breach = 1 (1H: 1V)

TFH = Time to fully formed breach = 3 hours

Breach depth=100 feet

The assumed breach width would encompass about four 60-foot-long panels at the crest. Figures 8.1 and 8.2 describe the breach parameters and assumed outflows.

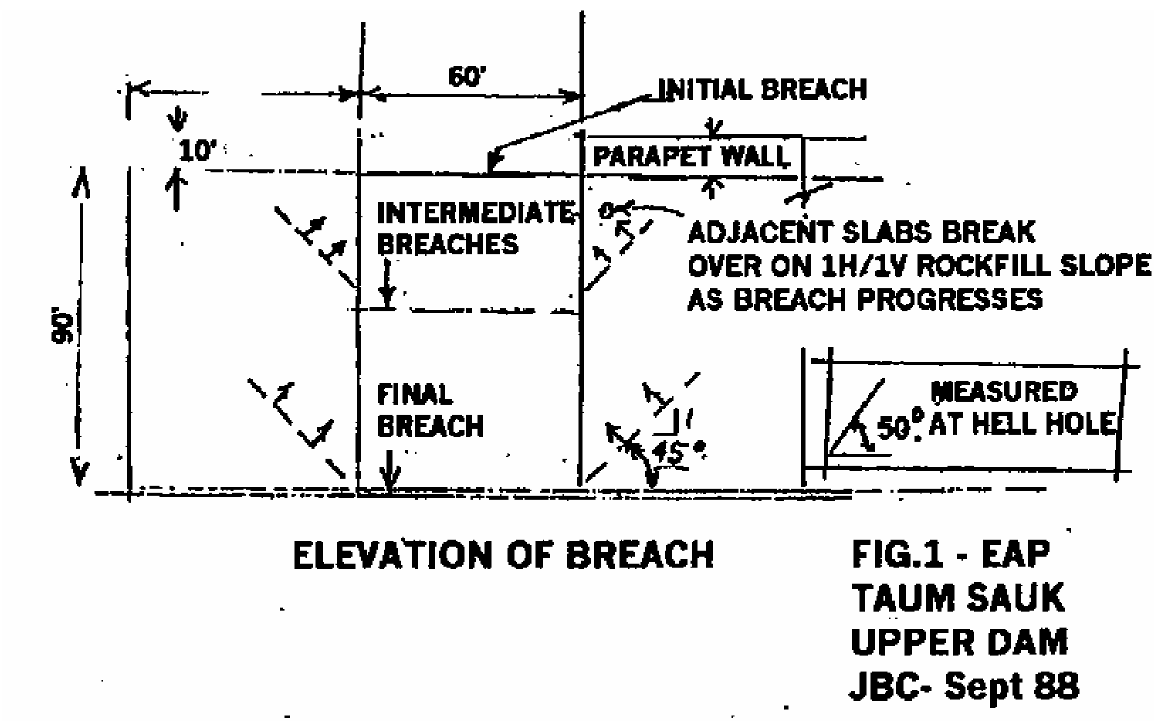

Figure 8.1- Breach parameters and breach formation for the upper dam.

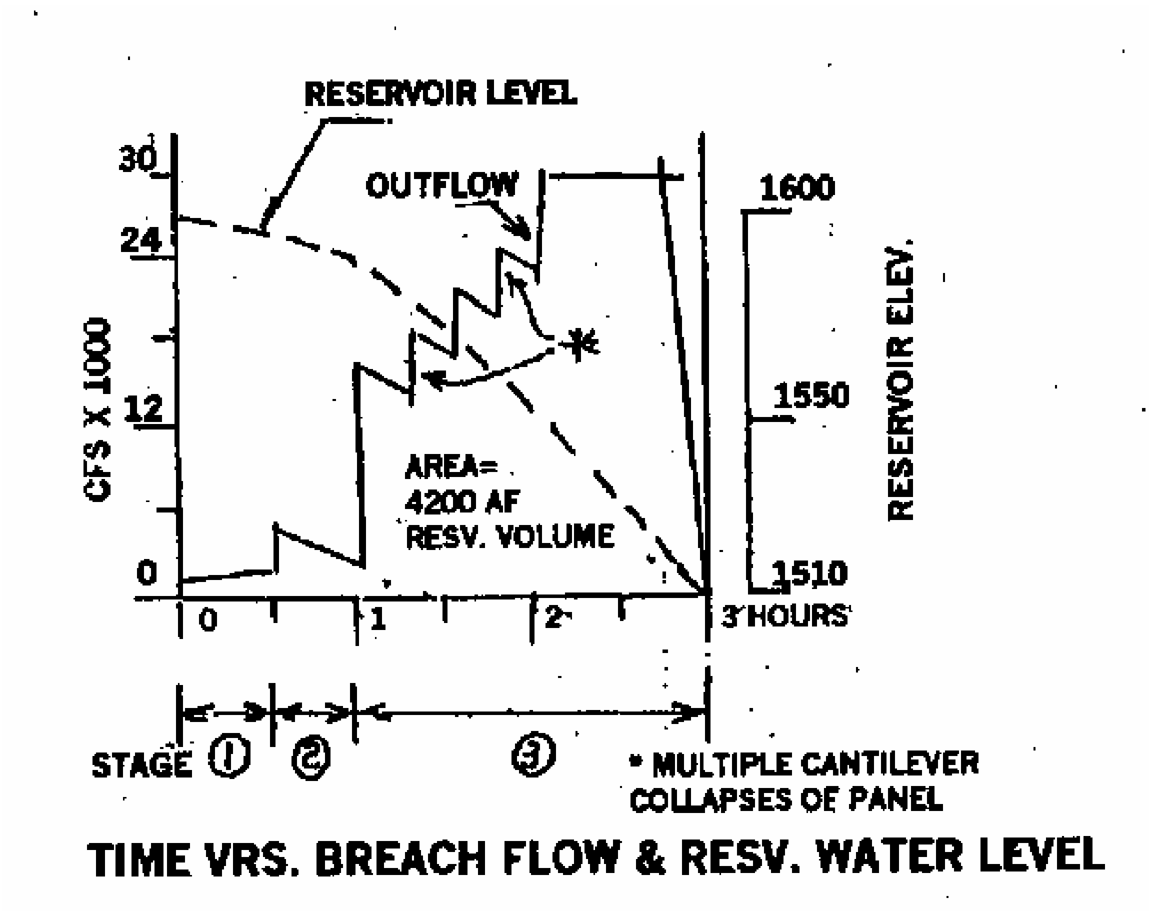

Figure 8.2 - Peak outflow and pool elevations as estimated in the dambreak analysis contained in the EAP.

8.1.5 Actual Dam Breach Parameters

The December 14, 2005 dam breach was significantly larger than the breach parameters assumed in the EAP. The actual breach parameters are as follows:

BR = Average width of breach =576 feet. According to the post breach aerial survey, the width of the breach at the crest is about 656 feet and the width of the breach at the elevation of the reservoir floor is about 496 feet. These are straight line distances between the ends of the breach and do not consider the curvature of the actual breached section. The actual breach included 12 parapet wall panels at the crest which is equivalent to about 720 feet.

Z = Horizontal component of side slope of breach = about 1:1. According to the post breach aerial survey, the weighted average of the left side slope (looking upstream into the reservoir) is 1V:1.06H and the right side slope is 1V:0.92H. The side slope is influenced by taking a straight line across the breach instead of going perpendicular to the contours. The side slope perpendicular to the contours is steeper.

TFH = Time to fully formed breach = 0.33 hour

Breach depth = 103 feet. This is based on the floor of the reservoir at elevation 1494 ft and the low point of the parapet wall at about elevation 1597 ft.

An elevation view of the breach based on the aerial survey is in Figure 8.3.

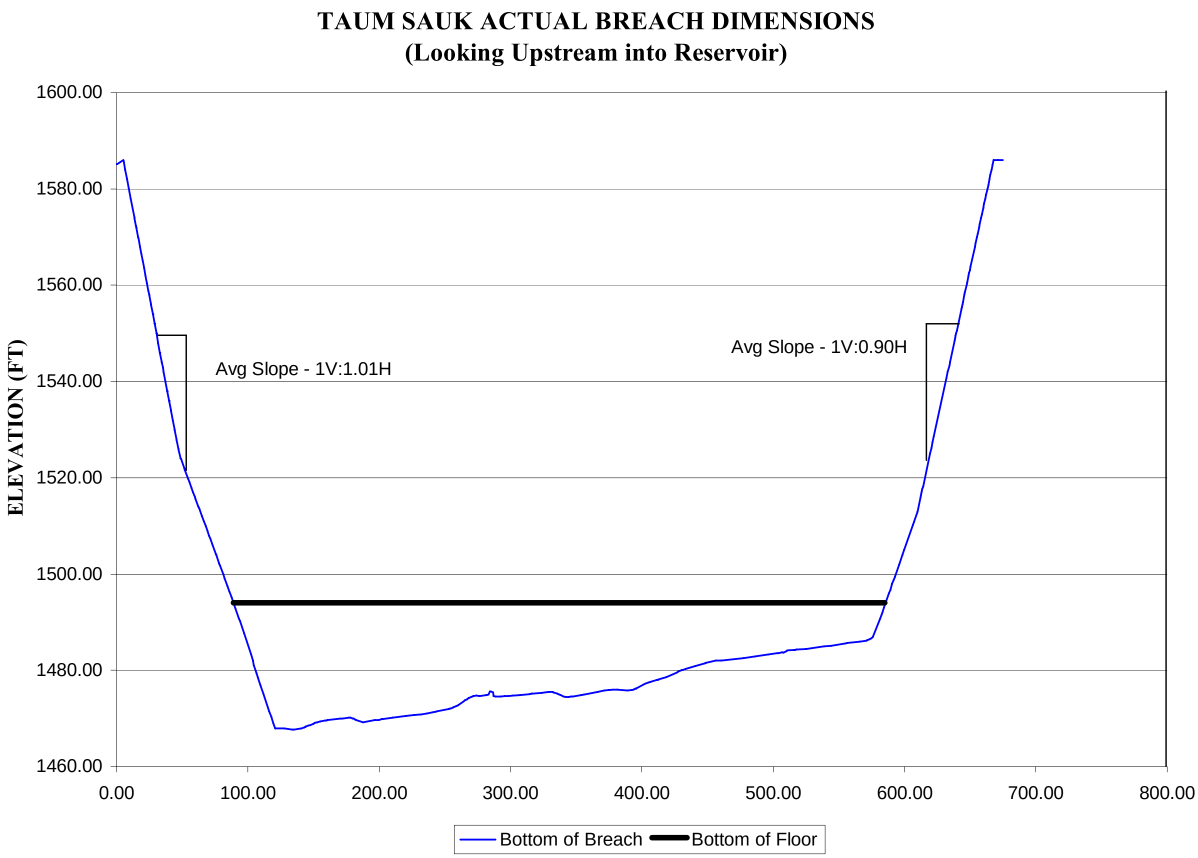

Figure 8.3– Breach Cross Section

8.1.6 Outflow hydrograph generation

The outflow hydrograph for the upper reservoir was calculated using the change in water surface height over time and the stage-storage curve for the reservoir. AmerenUE's December 27, 2005 filing included data showing reservoir levels vs.

time for the day of the event. The stage-storage curve was calculated in 1-foot increments using the post-breach aerial survey data (Figure 8.4) and a geographic information system (GIS). The stage-storage data was verified with the stage storage curve for the upper reservoir provided in AmerenUE's February 7, 2006 filing. As shown in Figure 8.5 the stage storage information from the two sources matches well.

Outflow was computed in one-minute intervals on December 14, 2005 from 5:15 am until the reservoir was mostly empty at 5:50 am. The change in stage for each one minute interval was interpolated on the stage-storage curve to a volume in acre-ft per minute, which was then converted to cfs. The outflow hydrograph is shown in Figure 8.6.

Because the reservoir level data was not reliable, with the reservoir approximately 4 feet above what the Druck pressure transducers were reading, a second curve was computed assuming a 4-foot under reading by the pressure transducers. The second curve should represent the upper limit of outflows due to the instrumentation movement.

Assuming that the pressure transducer readings were off by 4 feet, the calculated peak flow out of the breach was about 273,450 cfs. If the actual pressure transducer readings are used, the resulting peak outflow from the reservoir was about 269,000 cfs. Time to peak for the outflow hydrograph was approximately 8 minutes after the breach initiated.

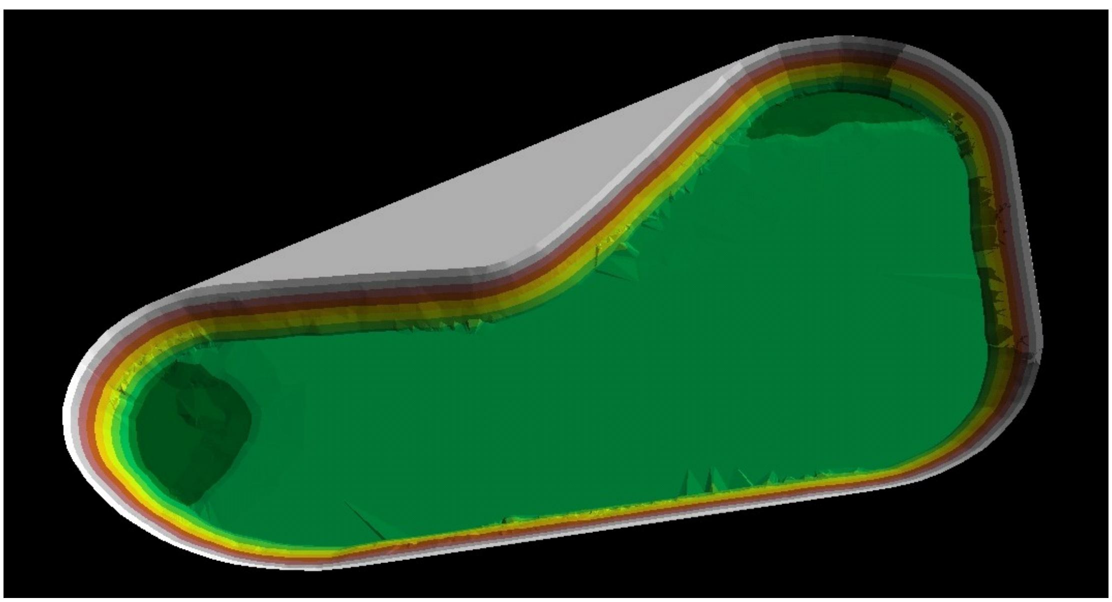

Figure 8.4 – Aerial Survey of empty upper reservoir

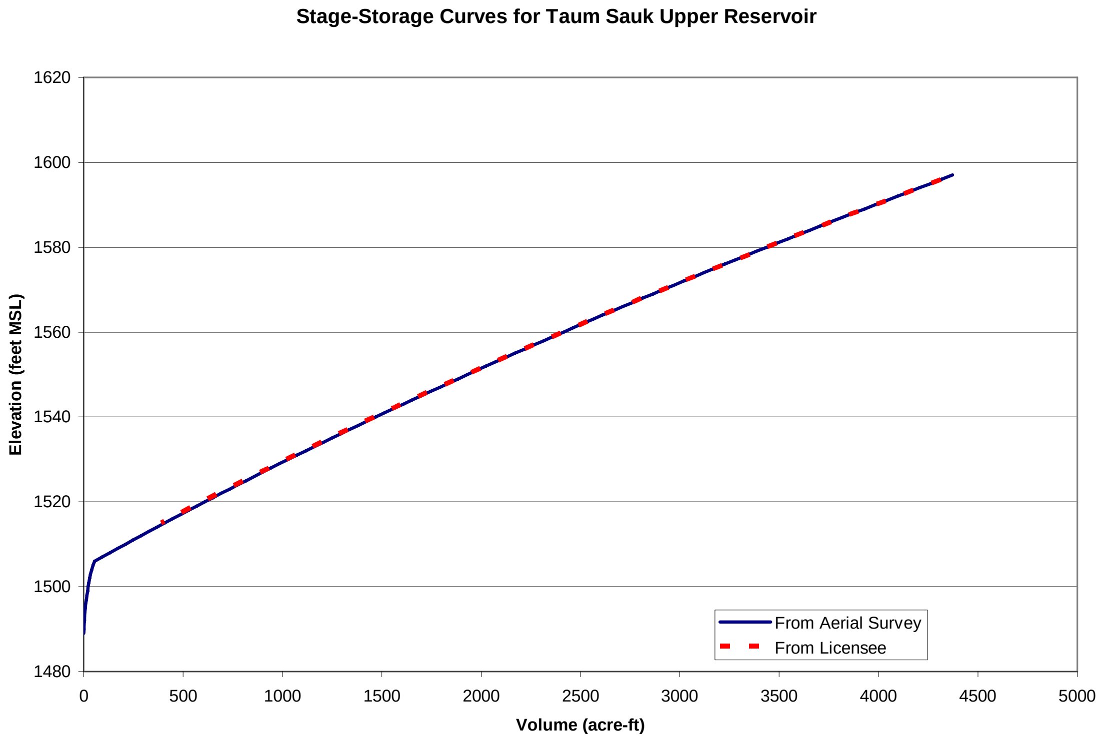

Figure 8.5 – Stage-Storage curves for Taum Saul Upper Reservoir

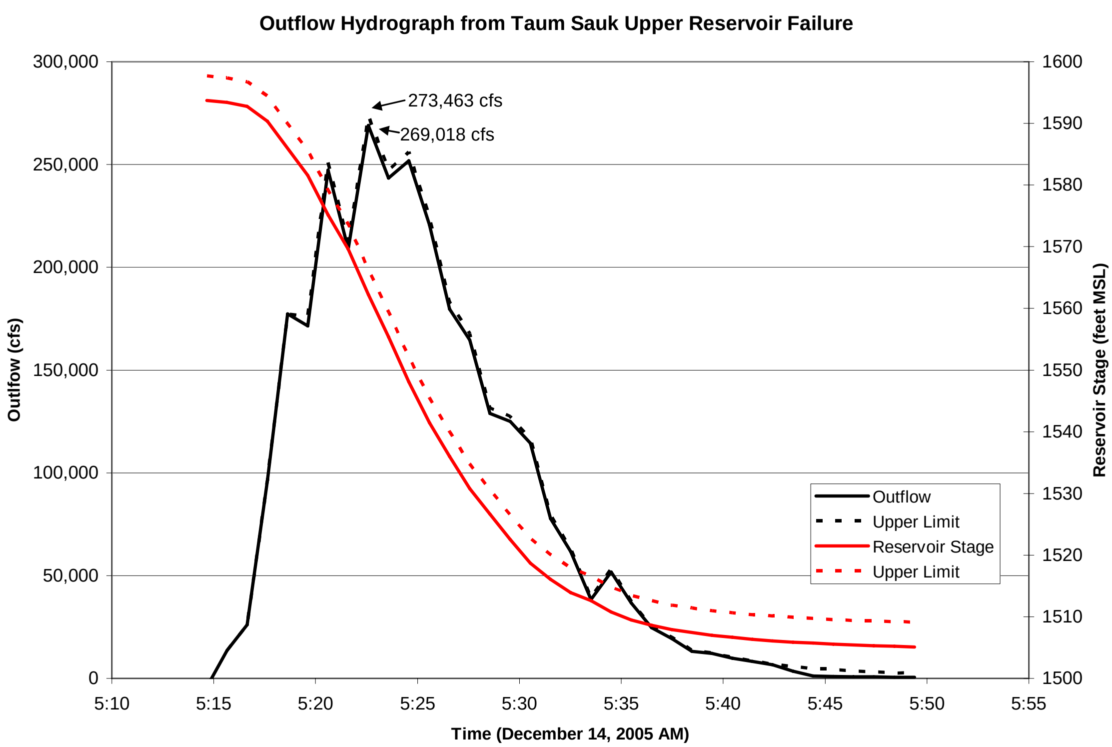

Figure 8.6 - Calculated Outflow Hydrograph for Taum Sauk Breach

The outflow hydrograph indicates initial flows may have been due to the loss of one and then two sections of the parapet wall. At 5:16 and 5:17 AM outflows were about 10,000 and 25,000 cfs, respectively. This corresponds with the outflow expected from the loss of one and then two sections of the parapet wall (see Section 8.1.9). After 5:17 AM flows increased rapidly peaking at 273,000 cfs at about 5:23 AM. This zig-zag shape of the outflow resembles somewhat the shape of the outflow estimated in the Emergency Action Plan (EAP), see Figure 8.2.

The calculated maximum outflow (273,000 cfs) is 9 times greater the maximum outflow assumed in the EAP dambreak (30,000 cfs). The major differences between the two events are the breach size and timing of event.

8.1.7 Wave Height Estimates

8.1.7.1 <u>Wave Height Estimates for September 25</u>

The overtopping on September 25 was described by eyewitnesses as occurring in waves near the Northwest corner of the Upper Reservoir (see February 8, 2006 interviews with Ronald Robbs, Chris Yordy, and Richard Cooper). AmerenUE's January 19, 2006 letter describes the affected panels were 90-96. On September 25, the remnants of Hurricane Rita were passing through the area. According to weather information from the NWS, wind data for the morning of September 25 at Farmington Airport is as follows:

Max Wind Speed (Steady): 17 knots
Max Wind Speed (Gust): 23 knots
Wind Direction coming from 80-100 degrees from North

In Mr. Robb's interview, he indicated he heard on the Evening News that winds at Farmington Airport peaked at 38 miles per hour (33 knots).

FERC staff interviewed representatives from the National Weather Service (NWS) in St. Charles, Mo. on January 12, 2006. NWS personnel stated that there can be large variances in wind speed between the elevations of Farmington Airport and the Upper Reservoir, but they expect this would occur on clear days. They said it is not likely there would be drastically different wind speeds between the elevation of Farmington Airport and the Upper Reservoir on a rainy, cloudy day which was the case on September 25. They said one reason there could be a large difference in wind speeds between the two locations on September 25 is if there was an isolated thunderstorm on the mountain. According to the National Climatic Data Center website (www.ncdc.noaa.gov), there were no reported thunderstorms or high wind events from September 24 through October 1, 2005 in Reynolds County, MO. Mr. Robbs' and Mr. Yordy's interviews also did not indicate a thunderstorm was occurring when they witnessed the overtopping.

The table below shows a range of possible wave heights for the September 25, 2005 event using the USGS wave height formulae from the *Shore Protection Manual*, Coastal Engineering Research Center, U.S. Army Corps of Engineering Waterways Experiment Station (1984). In addition to wind speed (meters/second), other parameters needed are the fetch (kilometers) and depth (meters) of reservoir. Winds coming out of the East/Southeast would be almost perpendicular to Panels 90-96 and result in a maximum fetch of about 0.35 km.

Wave Calculations – September 25, 2005

Wind Velocity (knots)	Wind Velocity (m/s)	Fetch (km)	Reservoir Depth (m)	Wave Ht (m)	Wave Ht (ft)
17	8.74	.35	31	.10	.33
23	11.83	.35	31	.14	.46
33	16.9	.35	31	.22	.72
40	20.57	.35	31	.28	.92

8.1.7.2 Wave Height Estimates for September 27, 2005

According to the February 8, 2006 interview with Mr. Richard Cooper, he saw wet spots on the downstream side of the parapet wall, at the low point of the wall, during a morning visit to the upper reservoir. Mr. Cooper did not witness waves exceeding the top of wall. The wet spots were possibly due to spray from waves over the wall as opposed to waves exceeding the top of the wall. Panel 72 is the low point of the parapet wall. According to generation information the reservoir was filled to elevation 1596 this morning.

The weather information for the morning of September 27 indicated early morning fog leading to mostly to partly sunny conditions. During the morning there were maximum steady winds of 3-5 knots. The wind direction changed during the morning. Winds came from 10-40 degrees from North at around 8:00-9:00 am then from 110-140 degrees from North after 10:00 am.

According to the interview with NWS staff on January 12, 2006, it is more likely to have higher winds at the Upper Reservoir compared to the Farmington Airport on clear days than rainy days. Since September 27 was mostly to partly sunny, it is possible the wind speeds were higher than 5 knots at the upper reservoir. According to a September 27, 2005 email from Richard Cooper to Thomas Pierie and Chris Hawkens of AmerenUE (included in the January 27, 2006 AmerenUE submittal), he did not see any waves at the Upper Reservoir on September 27.

The table below shows a range of possible wave heights for September 27, 2005 using the USGS wave height formulae from the *Shore Protection Manual*. Winds coming out of the Northeast would result in a maximum fetch of about 0.5 km at Panel 72. Before 10:00 am on this morning, the wind direction was almost parallel to the alignment of panel 72

Wave Calculations – September 27, 2005

Wind Velocity (knots)	Wind Velocity (m/s)	Fetch (km)	Reservoir Depth (m)	Wave Ht (m)	Wave Ht (ft)
5	2.57	.45	31	.024	.08
10	5.14	.45	31	.06	.20
15	7.72	.45	31	.10	.33

8.1.7.3 Wave Height Estimates for December 14, 2005

The weather information for the early morning of December 14 indicated light snow, rain, and drizzle with temperatures in the mid-30s. At Farmington Regional Airport about 0.08 inch of precipitation occurred during the early morning. The recorded steady wind speeds ranged from 10-14 knots with gusts to 22 knots. Winds originated from 140-180 degrees from North.

According to the interview with NWS staff on January 12, 2006, it is more likely to have higher winds at the Upper Reservoir compared to the Farmington Airport on clear days than rainy days. The morning of December 14 was rainy, so we would not expect wind speeds to be drastically different between Farmington and the Upper Reservoir.

Winds coming out of the South-Southeast would be almost perpendicular to the areas near panels 72 and 95-100 and result in a maximum fetch at the breach area of about 0.5 km.

Wave Calculations – December 14, 2005

Wind Velocity (knots)	Wind Velocity (m/s)	Fetch (km)	Reservoir Depth (m)	Wave Ht (m)	Wave Ht (ft)
14	7.20	.5	31	.092	.30
22	11.32	.5	31	.16	.52
30	15.43	.5	31	.23	.95

8.1.8 Velocity of Flows over Parapet Walls

Prior to the Upper Reservoir breach, flows overtopped the parapet wall and began eroding the downstream slope of the embankment. The velocity of the overtopping flows falling 10 feet from the top of the parapet wall to the embankment crest would be approximately:

$$V = (2 \cdot g \cdot h)^{0.5} = 25.4[ft / s]$$

where g is the gravitational constant and h is the height of falling water.

8.1.9 Estimated Outflow for Loss of One Section of Parapet Wall

The broad crested weir equation (below) was used to estimate the outflow that would result from the collapse of a single panel of the parapet wall.

$$Q = 0.385 \cdot C \cdot L\sqrt{2g}H^{3/2}$$

where Q is the discharge in cfs, C is the assumed weir coefficient, L is the length of a rectangular weir, g is the gravitational constant, and H is the height of water over the weir. For the loss of one parapet wall the weir length would be 60 feet, and the height of the weir would be about 10 feet, at the instant of loss. Varying the weir coefficient from 0.85 – 1.05, the discharge resulting from the loss of one parapet wall section would be between 4,980-6,160 cfs.

We note the heel of the parapet wall extends about 3.5 feet below crest of the embankment. Including this distance to the height of the wall would increase the range of flows to about 7,800-9,650 cfs.

8.2 Lower Dam

The 390-foot-long Lower Dam is an ungated overflow spillway except for two piers, 13- and 4-foot-wide that support the operating deck. The spillway crest is at elevation 750 feet. The spillway discharges to a concrete flip bucket with a 28-foot-radius.

The lower dam also has two sluices: the small sluice is a 16-inch-diameter spiral welded pipe with an upstream invert at elevation 710 feet and downstream invert at elevation 707 feet. A 20-inch cast iron slide gate on the upstream face of the dam controls flow through the small sluice. The slide gate motor operator is located on the top of the 4-foot-wide pier on the crest of the dam. An intake structure extends 7 feet upstream of the dam and provides a single set of slots for either a trashrack or stoplogs. The large sluice is a horizontal 8-foot-wide by 10-foot-high steel-lined conduit with an invert elevation of 705 feet. An 8-foot by 10-foot cast iron slide gate located on the upstream face of the dam controls flow through the sluice. The slide gate motor operator is located atop the 13-foot wide pier on the spillway crest.

8.2.1 Drainage Area/Surface Area/Storage

The lower dam has a drainage area of about 88 square miles. The surface area at the ogee crest is about 390 acres. According to the stage storage curve provided in AmerenUE's February 7, 2006 filing, the total volume of the reservoir is approximately 4,360 acre-feet at elevation 750ft and 424 acre-feet at elevation 736 ft.

8.2.2 Spillway Curve

The Rating curve of the ogee spillway is shown in Figure 8.7.

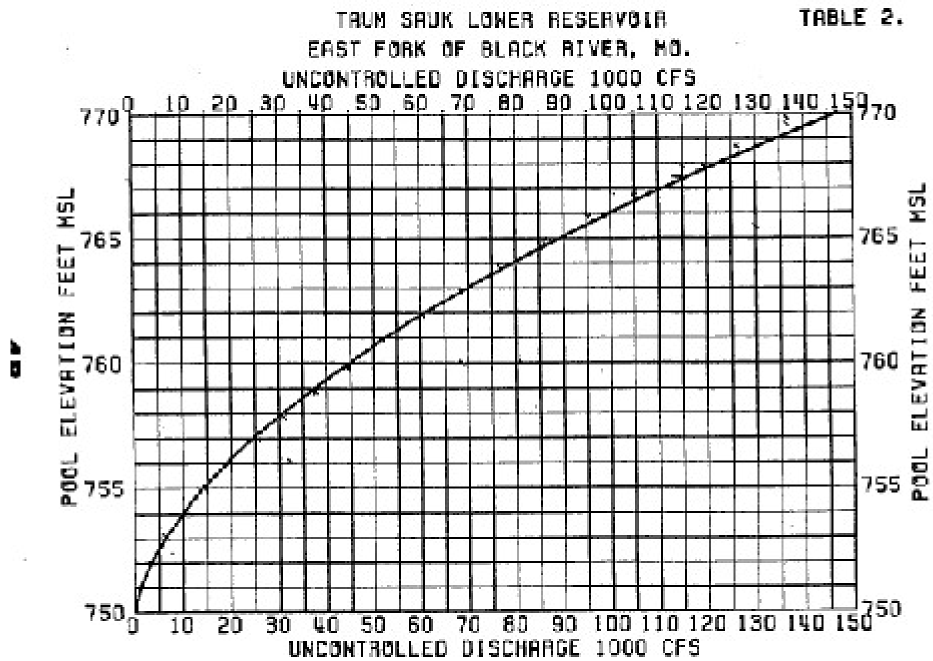

Figure 8.7- Lower Dam ogee rating curve.

8.2.3 Flood of Record

The maximum flow recorded by the USGS gaging station above the Lesterville Bridge was 35,800 cfs and occurred on November 19, 1985. Overflow depth at the Lower Dam was recorded at that time as 7 feet. From the Spillway Discharge Curve, the discharge at the dam was approximately 25,000 cfs. Adding about 2,500 cfs being released through the sluice gates gives a total flow of about 27,500-cfs.

On November 14, 1993, the depth of flow over the spillway reached about 7.5 ft or about 28,000 cfs. The sluices passed about another about 3,000 cfs, for a total flood of approximately 31,000 cfs. The Lesterville gage was no longer in service in 1993.

8.2.4 Inflow Design Flood

AmerenUE (1986) developed the Probable Maximum Flood (PMF) using the National Oceanic and Atmospheric Administration (NOAA) Hydrometeorlogical Reports (HMR) No. 52. The PMP for the basin was found to be 34.24-inches within a 72-hour period with a maximum six hour amount of 22.38-inches. The PMF was estimated to have a 2-hour crest of 120,464 cfs and produce peak stage of 767.09 feet or 17.09 feet above the spillway crest. The PMF hydrograph is shown on Figure 8.8. Considering that the significant depth of overtopping, an IDF less that the PMF may be justified. However, these studies have not been done and for the present, the IDF is assumed to be the PMF.

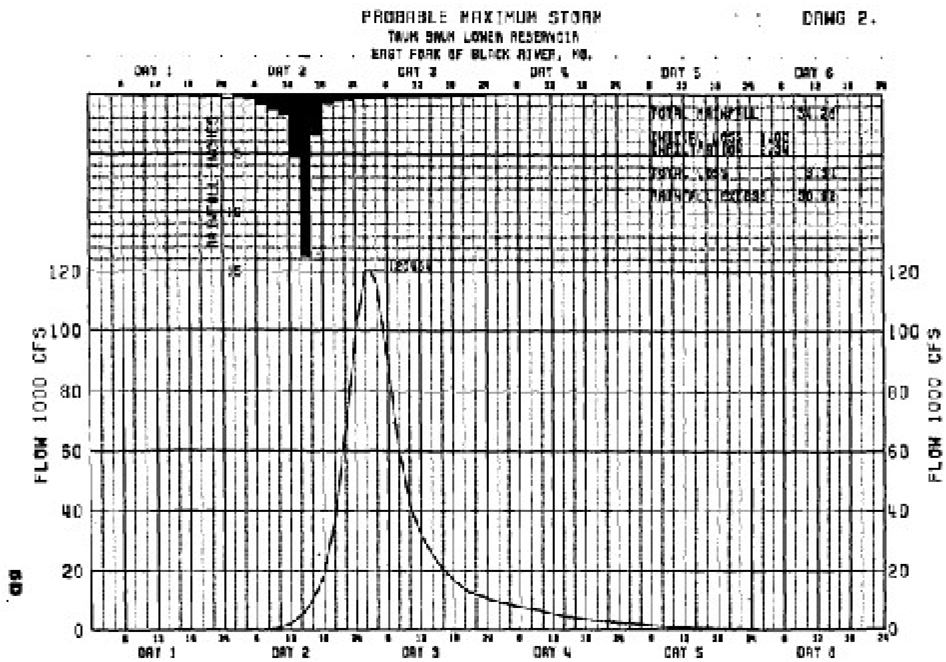

Figure 8.8 - The PMF hydrograph.

8.2.5 Freeboard Adequacy

Normal maximum water level for the Lower Dam is elevation 749.5 feet or 0.5 feet below the spillway crest. During floods, the entire dam overtops and freeboard is not a concern since the dam is also a spillway and the abutments are competent rock.

8.2.6 EAP Dam Break Analysis

A sunny day dam break analysis and associated inundation map for the Lower Reservoir are included in the EAP. The dam was assumed to fail quickly and the breach was assumed to be 3-blocks wide to the gallery elevation. The peak outflow from the Lower Reservoir was estimated to be about 51,000 cfs in 30 seconds.

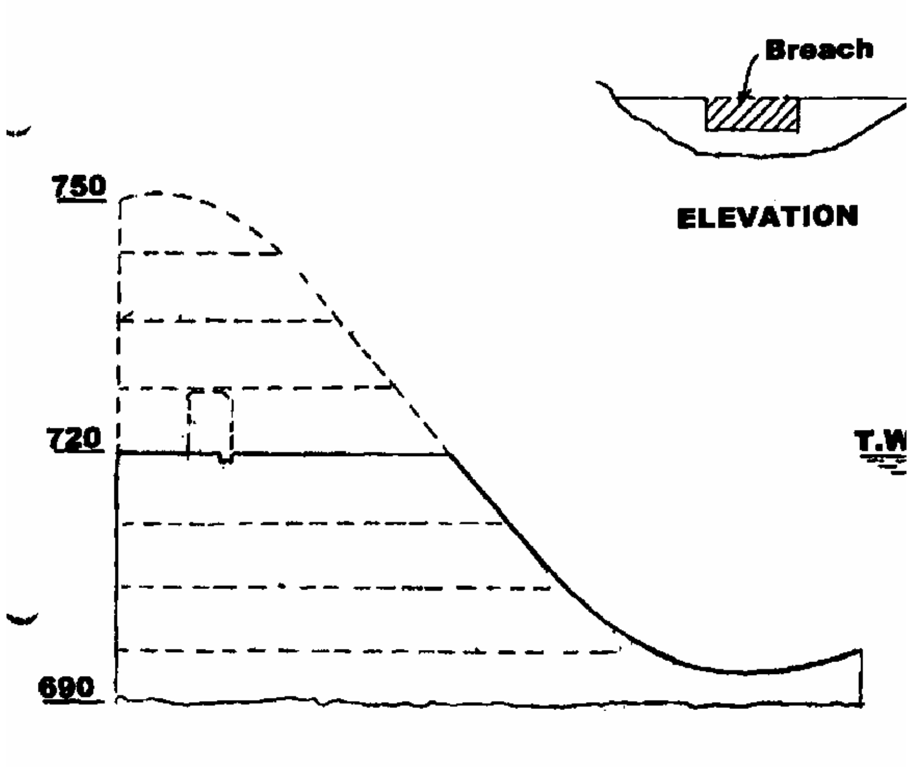

Figure 8.9 - Lower Dam Breach location.

The breach parameters used in the analysis shown in Figure 8.9 and described below:

BR (average width of breach) = 3*40 = 120 feet.

Z (side slope of breach) = 0 (vertical slopes)

TFH (time to breach) = less than 0.1 hour

Breach depth = 30 feet

8.2.7 Maximum Lower Reservoir Level Following Upper Reservoir Breach

Figure 8.10 shows water levels at the Lower Reservoir on December 13 and 14, 2005. The Lower Reservoir was able to store the majority of inflows from the Upper Reservoir breach. According to the reservoir level information provided by AmerenUE's letter dated December 27, 2006, the lower reservoir was drawn down to elevation 736.1 ft prior to the breach. This provided about 3,920 acre-feet of storage up to elevation 750 ft. The maximum recorded elevation in the lower reservoir following the breach was 751.1 ft, which occurred at about 8:00 am. This was approximately 1.1 feet of overtopping and resulted in a maximum outflow from the spillway of about 1,600 cfs (excluding flows through the sluice). The maximum reservoir level on December 14, 2005 was well below the flood of record.

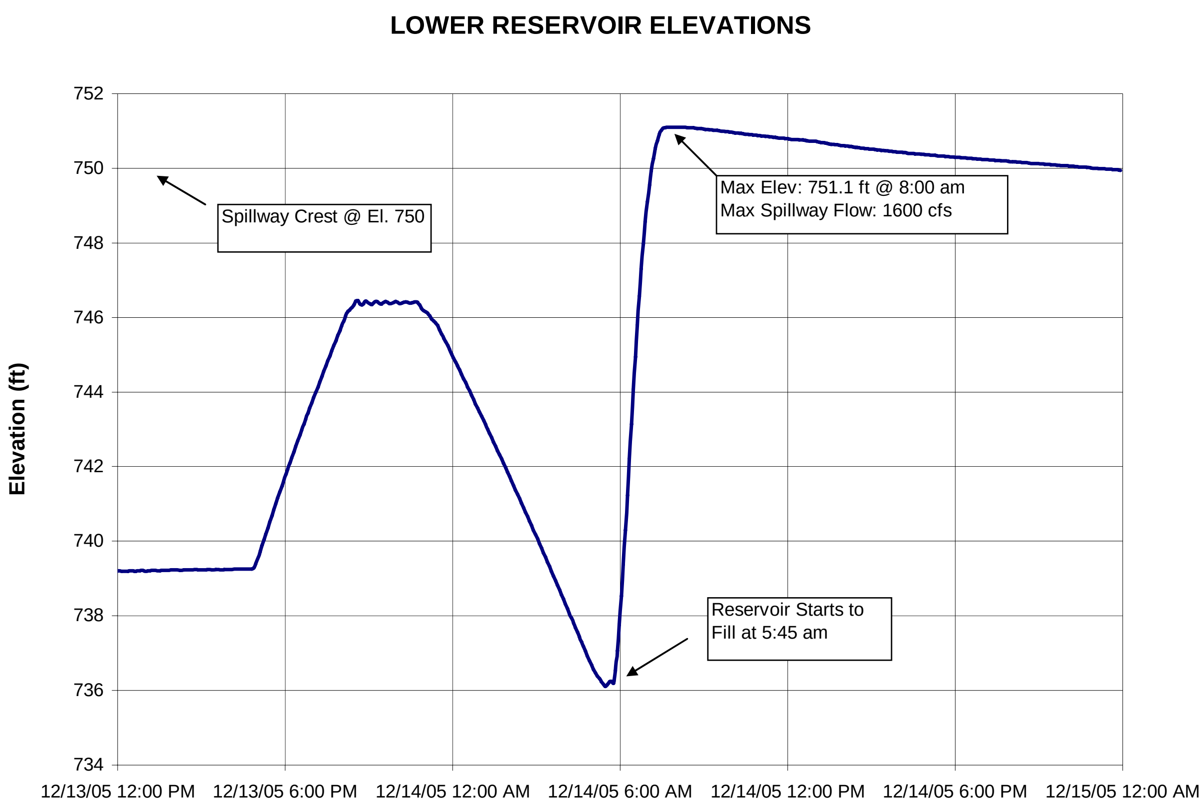

Figure 8.10 - Lower Reservoir Elevation December 13 and 14 2005

Section 9 Stability Analysis

9.1 Utexas4 Embankment Stability Analysis

FERC staff conducted forensic stability analyses in March 2006. Embankment and foundation parameters were determined from observations of the soils and bedrock in the breach area. A range of material shear strengths and piezometric levels were selected to evaluate embankment stability. A cross section was developed that passes through the center of the breach area based on the topography of the original embankment, original design drawings, and the aerial topography. The computer program Utexas4 was used in the analyses.

9.1.1 Reconstruction of the Embankment Section

The original project stationing was reconstructed using Sheets 8304-x-26052 and 8304-X-26117 of the as-built drawings (Disk 1 of the 9-CDs submitted February 7, 2006) with Sheet 1 of 1 of the SURDEX aerial topographic survey known as Exhibit 6. The center of the breach area occurred at approximately Station No. 21 + 69.81, which corresponds to the intersection of the access road and the dam crest on the northwest side of the dam. Using this information, the cross section of the dam was reconstructed and the access road was redrawn in its approximate position.

9.1.2 Original downstream slope angle

Questions were raised about the steepness of the downstream slope in the area of the breach. A second topographic section was made at the north end of the breach to assess the steepness of the slope in that area. Due to slope failures immediately adjacent to the breach, the section was taken 80 feet northeast of the breach edge (refer to Line 2 in Appendix D – Figure D.1). Figure 9.1 shows the cross section which represents the as-built configuration of the breach section.

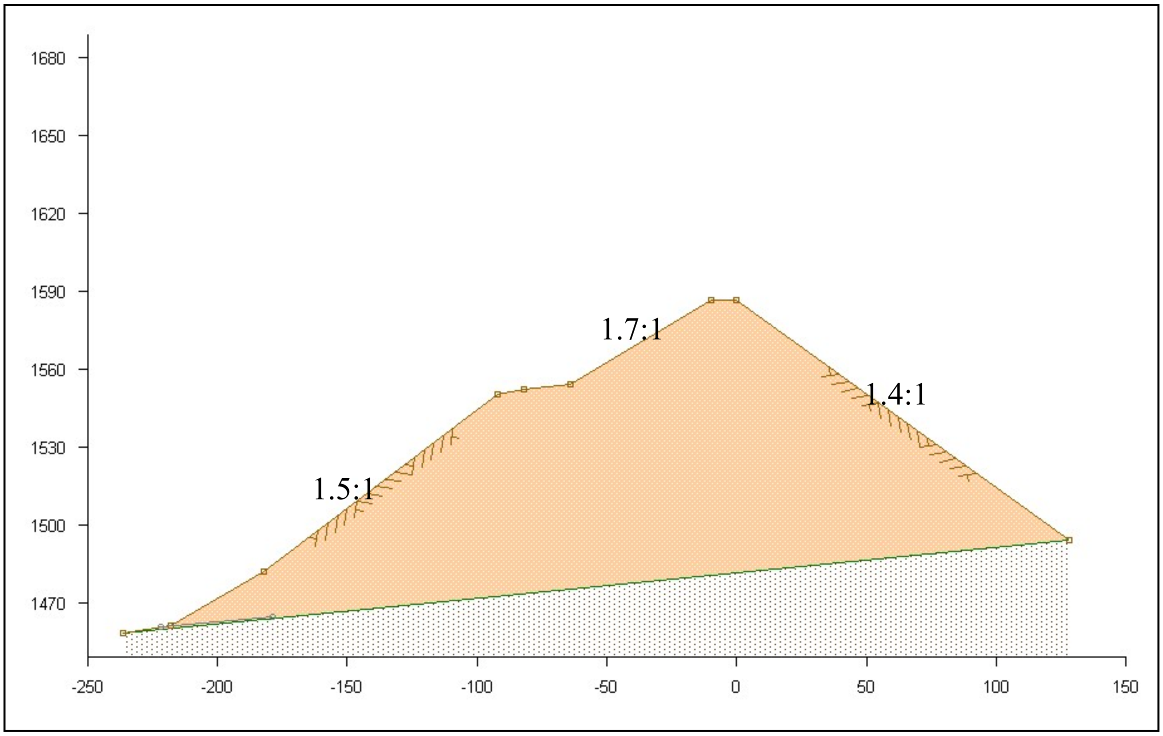

Figure 9.1– Embankment Cross Section

The upstream slope (right side of above drawing) is 1.4H:1.0V. The portion of the downstream slope that is above the access road is 1.7H:1.0V, and the portion of the downstream slope below the access road is 1.5H:1.0V. The downstream slope used in the stability analyses for the section taken at the center of the breach was 1.5H:1.0V. Rather than cutting into the original embankment to construct the access road, it appears the access road was placed with material dumped on top of the original embankment. The slope of the road fill material is slightly steeper than the original downstream embankment slope (1.5H:1.0V versus 1.7H:1.0V, respectively). The steeper slope of 1.5H:1.0V was used to represent of the downstream slope in the area of the breach.

9.1.3 Vertical Curve in Crest of Dam

Due to differential settlement, a vertical curve or sag, developed in the crest of the dam in the area of the breach (see Appendix D – Figure D.2). The lowest point in the curve is around the survey pin near Panel 95, with a crest elevation of 1587.39 (based on a 2004 survey). The crest elevation increased towards the north and south of Panel 95, up to elevation 1588.33 at Panel 85 and elevation 1587.70 at Panel 100. Based on our estimate of the maximum pool elevation during overtopping, overtopping flows occurred from Panel 88 through Panel 100, which roughly corresponds to the breach area. Initial overtopping flows in this area would tend to flow along the length of the crest towards the lowest point at Panel

94 and down the access road at Panel 95. Concentrated flows such as this may be expected to increase the erosive forces at the break point where the access road meets the crest of the dam, which corresponds to the center of the breach area. The stability analyses performed here do not take into account potential erosion, which may have been an important factor leading to undermining of the parapet in the area of Panels 94 and 95.

9.1.4 Foundation Geology and Rockfill Zonation

Paul C. Rizzo Consultants prepared a geologic map of the foundation area, which was used to evaluate the engineering behavior of the various materials present. The bedrock is a jointed rhyolite that is considered competent rock. No singular, continuous planes of weakness were observed within the bedrock that could be modeled as a failure plane. However, there is an area in the south side of the breach, that trends along the centerline of the low pond in the northwest corner of the reservoir floor, which contains weathered rhyolite (Figure 9.2). The material is slightly cohesive in some areas and granular in others and still contains some of the original rock fabric. Along the north side of the breach, near the road that ran along the toe of the dam, there is an area with about 6 to18-inches of a clay rich soil with roots and oganics, resting directly on fresh rhyolite (Figure 9.3). Most of the area of the breach is fresh competent rock with no traces of soil or weathered rock (Figure 9.4).

There is no evidence to support a conclusion that the weathered rock or clay layer extended beneath the entire footprint of the breach area. However, it was assumed in the stability analysis that there was a layer of weak material resting on top of bedrock throughout the area that was stripped by the discharge through the breach. Both the clay layer and weathered bedrock were treated as having the same shear strength. This assumed continuous layer of weak material results in more conservative (lower) factors of safety than would have existed if the rock fill had been placed directly on top of bedrock. This should give a lower-bound estimate for stability of the rock fill in the breach area. The foundation was divided into two components; 1) sound rock and, 2) weathered rock/topsoil.

Figure 9.2 - Area of weathered rhyolite, which is in-line with the "fish pond" depression in the reservoir (background).

Figure 9.3 - Residual topsoil on top of fresh rhyolite.

Figure 9.4 - Fresh rhyolite bedrock surface.

Based on descriptions of the construction of the dam, material that did not meet the specifications for clean rock fill was used to construct access roads. There are two access roads in the area of the breach; one at the toe of the dam and another that ran up the side of the dam. Although the upper portion of the rockfill was a compacted rockfill, no attempt was made to differentiate between the dumped and rolled sections of the rock fill. The dam was, therefore, divided into three sections; the rockfill section, the lower access road, and the upper access road (see Appendix D - Figure D.3). Both access road fill sections were assumed to have similar shear strengths, but lower than the rock fill.

A ten to sixteen-inch-thick reinforced concrete facing is present on the upstream side of the rock fill. This was also included in the analyses.

9.1.5 Shear Strengths

Stable slopes of 0.97H:1.0V on the south side and 0.98H:1.0V on the north side of remained after breach of the dam (averaged from top to bottom of breach). These slopes had remained stable for three months at the time this report was written. Slopes with this angle equate to a shear strength of $\varphi=45.9^{o}$. However, there is a definite break in slope in the breach sides, with much steeper slopes near the top half of the rock fill (Appendix D – Figure D.1). The steepest portion of the breach slopes are 0.65H:1.0V, or $\varphi=57.0^{o}$, which may represent better compaction near the crest of the dam. The lower portion of the breach slope is 1.2H:1.0V, which equates to φ=39.8º, which may represent the dumped rock fill. Hence, the phi angle of the rock fill is estimated to be between 40º to 57º.

9.1.6 Stability Analysis

The stability analyses were done using three ranges of shear strengths for the various materials present in the breach area. These trials are summarized below:

Material/Trial No.	1	2	3
Bedrock	φ'=45, c'=2000 psf	φ'=45, c'=2000 psf	φ'=45, c'=2000psf
Weathered Rock/Clay	φ'=15, c'=0	φ'=23, c'=0	φ'=30, c'=0
Road Fill	φ'=36, c'=0	φ'=40, c'=0	φ'=42, c'=0
Rock Fill	φ'=39, c'=0	φ'=43, c'=0	φ'=45, c'=0
Reinforced Concrete	φ'=0, c'=2000 psf	φ'=0, c'=2000 psf	φ'=0, c'=2000 psf

An infinite slope analysis was also conducted to compute a factor of safety for the saturated downstream slope. The lowest factor of safety computed using this method is 0.54. As a comparison, factors of safety computed using the UTEXAS4 - Spencer solution method were in the range of 0.30 to 0.33. The Spencer method computes the factor of safety based on simultaneous solution of mobilized shear strength along the base (for the given factor of safety) and the computed side force inclination required for force-moment balance and therefore will yield a slightly different value for the factor of safety than that computed by the infinite slope method. Comparing the computer analysis and the infinite slope analysis, while the exact results (0.54 and 0.30) do not appear complementary, both methods yield a factor of safety significantly below 1.0 indicating that the embankment was indeed susceptible to failure from overtopping saturation

Please note that extra conservatism is added by neglecting cohesion for the weathered rock/clay layer, although there is expected to be some cohesion present in these materials. In addition, cracks through the concrete facing were assumed in the analyses.

9.1.7 Phreatic Levels

Four phreatic levels were assumed for each trial of shear strengths. A summary of the different levels of phreatic levels assumed for the analyses are shown below:

Phreatic Conditions Assumed

a	b	c	d
Lower 1/3 of dam saturated	Entire base of dam saturated to upstream toe	Entire base of dam saturated up to middle upstream face	Condition b plus upper portion of downstream slope saturated

9.1.8 Other Trials

Trial 4 was done to evaluate the stability of the shallow failure of the downstream slope without water saturation.

Trial 5 was done to evaluate the stability of the toe of the dam if it were saturated by the overtopping water. The phreatic level assumed in this analysis assumes the geomembrane liner is effective, but that a water saturation front extends from the center of the downstream slope.

Trial 6 was done to evaluate the post-shallow failure stability of the remaining portion of the dam. This involved evaluating wedge failure along the weakest foundation zone with a moderate phreatic level (phreatic level b).

9.1.9 Results

Non-circular (wedge) slope stability analysis was evaluated using the non-circular search method of Utexas4 and the Spencer method of solution. Graphical results for each trial run are included in the Appendix and the factors of safety are summarized below:

Phreatic Condition/ Trial No.	1	2	3	4 shallow wedge	5 toe wedge	6 post-slide stability
a (deep wedge)	1.15	1.83	2.51	-	-	-
b (deep wedge)	1.10	1.73	2.10	-	-	1.24
c (deep wedge)	0.84	1.31	1.75	-	-	-
D (shallow slope wedge)	0.30	0.35	0.38	-	-	-
no overtopping	-	-	-	1.24	-	-
overtopping	-	-	-	-	0.75	-

These results only consider static stability and do not take into consideration the exacerbating affects of potential rapid erosion from overtopping flows.

The results indicate the following:

1. The downstream toe is likely to fail as the phreatic surface rises at the toe. The outer layers of the downstream slope are likely fail as overtopping flows saturate these layers. Progressive failures would likely occur with continued overtopping.
2. At the lowest shear strength assumed in the analysis for the weathered bedrock/clay layer (phi = 15 degrees, no cohesion) combined with a phreatic surface located at the mid-height of the embankment indicates massive embankment failure could occur.
3. Analyses using higher strength parameters (> phi = 20 degrees) in the weathered rock/clay layer indicate the embankment is likely to be stable even with the phreatic surface located at the mid-height of the embankment.

9.2 FLAC Analysis of Parapet Wall Considering Erosion of Downstream Face

FERC staff performed an analysis of the parapet wall and embankment considering downstream erosion from overtopping using the FLAC model. Erosion of the downstream slope was simulated by allowing the FLAC model to come to equilibrium, removing a 1-foot-thick slice of the downstream face at an angle slightly less than the friction angle, and then re-iterating. The analysis assumed a friction angle of the embankment material of 42 degrees and no phreatic surface under the wall.

The analysis was stopped when the top of the parapet wall deflected more than 1 foot, which occurred when embankment erosion approached the toe of the wall. This deflection would cause significantly more overtopping to occur, further undermining the wall. Also, it is possible the geomembrane and concrete liner would have ruptured due to the significant wall movement allowing substantial leakage through the open joint, accelerating the loss of embankment material beneath the wall. (See Figures 9.5 and 9.6)

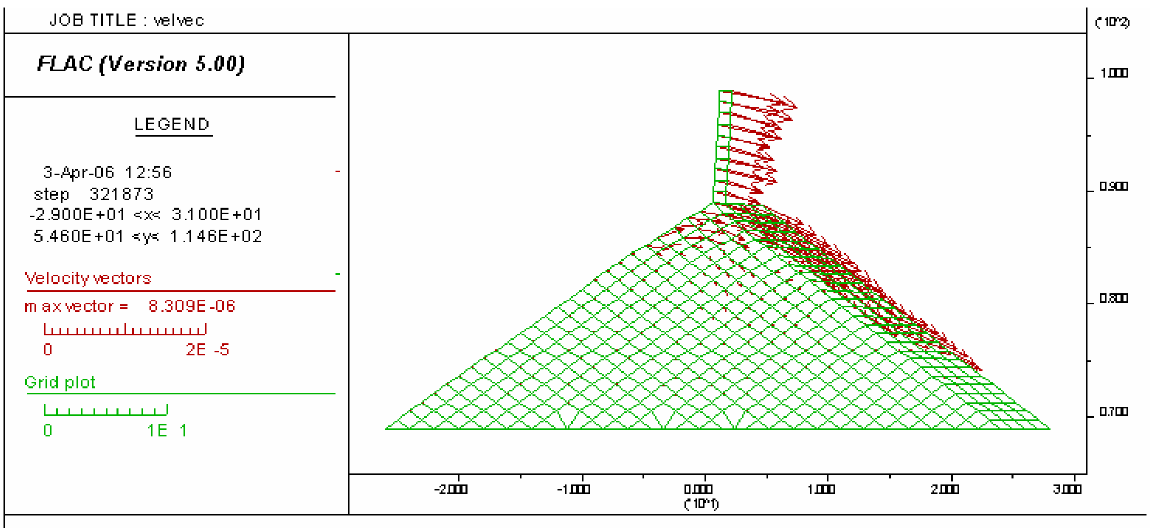

Figure 9.5 – FLAC Analysis

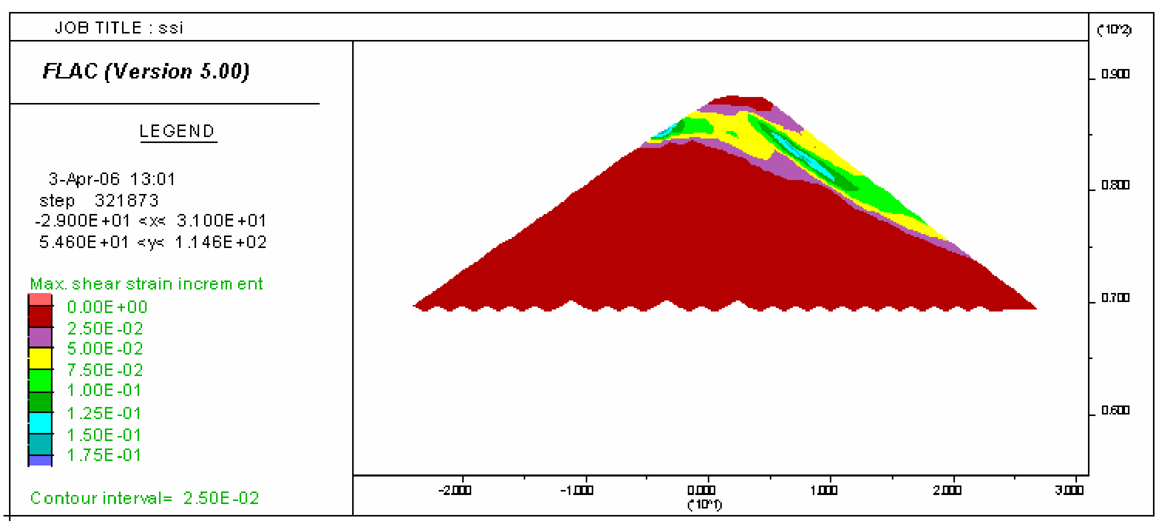

Figure 9.6 - Shear strain from the final FLAC iteration.

Note the band of high shear strain parallel to the slope

Section 10 Emergency Response

10.1 Emergency Action Plan

The Emergency Action Plan for the Taum Sauk Project was last reprinted in January 2003 and the most recent annual update was submitted by letter dated August 24, 2005.

10.1.1 Notification Flow Charts

The EAP contains two notification flow charts. Figure 10.1 is the flow chart is for an incident at the Upper Reservoir. There is also another flow chart for an incident at the Lower Reservoir. The Upper Reservoir version calls for immediate notifications of the Johnson's Shut–Ins Park Superintendent and sends plant personnel to warn boaters/campers on the Lower Reservoir. Following these actions, calls are made to the Lesterville Fire Department, Reynolds County Sheriff, AmerenUE employees, FERC staff, and the National Weather Service. The flow chart for the Lower Reservoir is similar except the Johnson's Shut-Ins Superintendent is not notified since they are upstream of the Lower Reservoir and would not be impacted.

The EAP contains the names, addresses, and phone numbers of all residents downstream of the Lower Reservoir that would need to be evacuated from a dam breach. The Lesterville Fire Department would be divided into three teams to notify these residents.

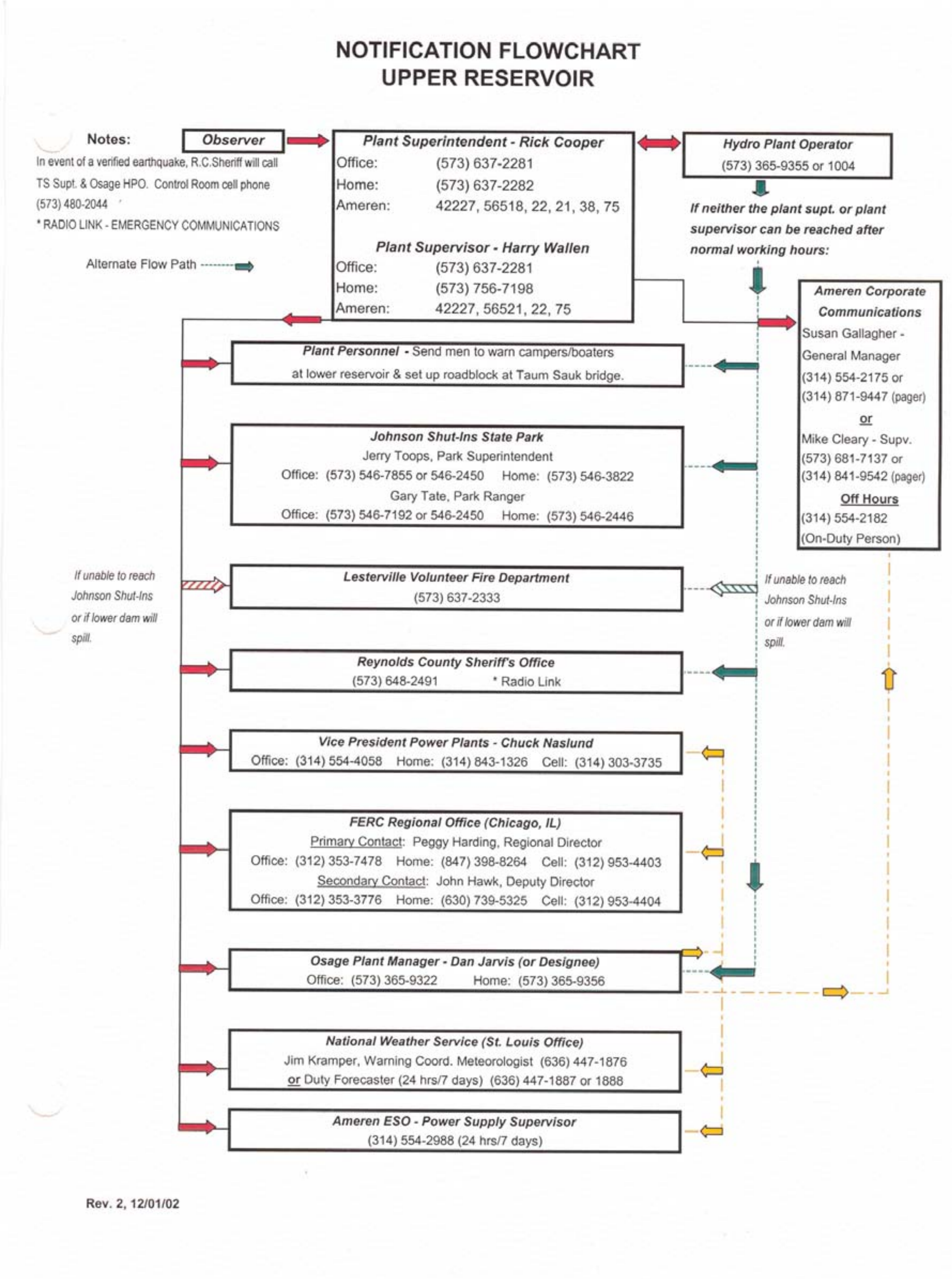

Figure 10.1 – EAP Notification Flow Chart

10.1.2 Detection of Emergencies

The EAP explains how an emergency at the project would be detected and evaluated. It was expected an emergency would be detected by (1) first hand observation by plant and security personnel; (2) monitoring of the local and remote instrumentation at the Taum Sauk plant, Osage plant, or load dispatch office; and (3) current weather and new and forecasts obtained from several media sources. The plant and security personnel are on duty from 7:00 am to 6:30 pm and the plant superintendent lives at the project site. It was also noted that abnormal leakage or signs of failure could be observed at Johnson's Shut-Ins State Park by the presence of high or muddy flows.

10.1.3 Inundation Maps

The inundation maps were prepared for a dam breach of the Upper Reservoir and Lower Reservoir Dams. The maps are based on dambreak analysis performed in 1988. It is not clear what kind of computer model was used to perform the analysis.

10.1.3.1 Upper Reservoir – Inundation Maps

The inundation zone assumed a breach of the west slope of the Upper Reservoir. The failure scenario was initiated by a parapet wall failure leading to breach of the dam. The assumed failure would be preceded by an increase of leakage which would trigger the EAP. About 0.5 hour after the leakage started, the parapet wall fails, releasing 4,500 cfs. It was expected to take about 15 minutes for these flows to reach the flood plain between Highway N and the Johnson's Shut-Ins. In another 0.5 hour, the first slab would breach releasing 14,000 cfs. In the next two hours additional slabs would fail and the reservoir would empty, peak flows would be 30,000 cfs. The final breach would have a bottom width of 60 feet, 1:1 side slopes, and a top with of 240 feet. The peak flow estimate of 30,000 cfs is comparable to the flood of record for the East Fork of the Black River which occurred in 1986. It was expected that the Lower Reservoir would be able to hold the majority of the breach flows.

The path of the flows from the breach is divided into four sections: (1) from the dam, flows would travel 9,000 feet down the wooded slope to the East Fork of the Brown River; (2) flows would travel through the level 5,000 foot flood plain along the East Fork between Highway N and the Johnson's Shut-Ins; (3) flows would travel through a campground and the narrow rock canyon of the Johnson Shut – Ins; (4) flows would pass through 700-foot-long stretch of the East Fork and then enter the Lower Reservoir.

The inundation map for the Upper Reservoir does not include arrival times or times to peak flows.

There are no developments in the projected floodway from a breach of the north or east sides of the Upper Reservoir. Therefore, the inundation maps do not show a breach in these areas. The flood wave from a breach of the north or east sides would eventually flow into the lower reservoir via the Black River and place the recreational users of the lower reservoir at risk.

10.1.3.2 <u>Lower Reservoir – Inundation Maps</u>

The inundation maps assume a sudden breach of the dam from the crest at elevation 750 ft to the bottom of the gallery at elevation 720 ft. This would release a peak flow of 50,000 cfs. The river channel downstream of the dam is wide and opens to about 1000 feet wide within 1500 feet of the dam. The channel widens further over the next three miles to the Town of Lesterville. Beyond Lesterville, the channel is restricted by a road fill and steel bridge. About one mile downstream of the bridge the East Fork merges with the Middle Fork of the Black River. Eventually flows would travel to the U.S. Army Corps of Engineers' Clearwater Dam, located about 10 miles downstream of the Lower Dam.

The first structure would be impacted by a breach of the Lower Dam in about 15 minutes. Flows would reach Lesterville in about an hour. It was estimated about 25 structures could be impacted upstream of the bridge in Lesterville. About 0.25 mile downstream of the bridge is a summer recreational camp.

10.1.4 Training and Exercises

The project operators received annual training on the EAP. The plant superintendent also performed an annual drill based on a made-up failure scenario and included both licensee personnel and emergency response personnel on the notification flow chart (i.e., Reynolds County Sheriff, Lesterville Fire Department, National Weather Service). The participants were warned of the drill prior to implementing the scenario. The drill was meant to ensure Osage and Taum Sauk Operators acknowledge the alarm and followed their internal procedures and the Taum Sauk superintendent or designee performs notifications according to the postulated emergency. After the drill, the superintendent made follow-up calls to all participants to evaluate the procedures.

The last functional exercise for the Taum Sauk Project was performed in May 1998. The licensee alternated functional exercises between its Osage and Taum

Sauk Projects. A functional exercise was performed at Osage in 2003 and the next functional exercise at Taum Sauk is scheduled for 2008.

10.2 Licensee's Account of the December 14, 2005 EAP Activation and Coordination

By letter dated December 27, 2005, AmerenUE provided their detailed account of the EAP detection, activation, and coordination. The following is a paraphrased version. For more details, see AmerenUE's December 27, 2005 letter.

Time	Event
5:40 a.m.	Plant Superintendent Richard Cooper receives call from Osage operator that they lost indication of the upper reservoir, tailrace, and penstock level transmitter (i.e., the Osage Operator received alarms that reservoir was too low).
6:00 a.m.	Mr. Cooper arrives at project and notices tailrace is muddy.
	As Mr. Cooper enters powerhouse he receives call from Lesterville Fire Department reporting flooding at Johnson Shut-Ins. Mr. Cooper informs Fire Department that there are signs the Upper Reservoir has breached. The Fire Department states it will contact the Reynolds County Sheriff, who was currently on another line.
	Mr. Cooper notified the parties on the notification list, with the exception of the Lesterville Fire Department and Reynolds County Sheriff who were already warned. The Johnson's Shut-Ins park superintendent, Mr. Jerry Toops, is on the notification list, but Mr. Cooper received no answer.
6:30 a.m.	Mr. Cooper completed the EAP contact list.
	In addition to the contact list, Mr. Cooper also has telephone contact with additional FERC staff, AmerenUE personnel, the U.S. Coast Guard, and Missouri Highway Patrol

According to their December 27, 2005 letter, AmerenUE states there were no significant problems with implementing the EAP.

10.3 Interview with Reynolds County Emergency Personnel

On January 10, 2006, FERC staff met with Reynolds County Sheriff Gary Barton regarding the emergency response during the dam breach. Also in attendance were the Reynolds County Board of Supervisors and other Reynolds County employees.

Sheriff Barton explained that at 5:41 a.m. the Reynolds County 911 dispatcher received a call from a motorist on Route N with a report of high water. The dispatcher immediately called the Lesterville Fire Department and Reynolds County Sheriff with this information. Ironically, the Taum Sauk annual drill was schedule to take place on this date and the 911 dispatcher asked the Sheriff if this could be part of the drill. The Reynolds County Sheriff assured the dispatcher the drill would not be happening at this time of the day. The Sheriff advised the dispatcher to get their copy of the EAP and keep it handy.

Reynolds County personnel began making emergency contacts. The Lesterville Fire Department contacted with Taum Sauk Superintendent Mr. Cooper. A call was placed to the Toops' house but there was no answer.

Emergency personnel arriving at the scene noted the Toops house was destroyed, a tractor trailer and car traveling on Route N had been carried into a field upstream of the Toops house, a dump truck traveling on Route N was inundated, and the surrounding area was devastated by the high flows. The Toops family had been pushed by the flood wave in the upstream direction across Rte. N and into a field. Flows receded in about 30 minutes and emergency personnel were able to rescue the drivers, as well as the Toops family. According to logs of the event, the ambulance carrying the Toops left the scene at 7:24 a.m.

By 7:00 a.m. the decision was made to close the Lesterville School so it could be used as a shelter. Both the American Red Cross and the Salvation Army provided aid at the shelter. AmerenUE also rented a local motel as an additional shelter. Following the National Weather Service announcement of the possibility for severe flooding downstream of the lower dam, emergency response personnel began going house-to-house to evacuate residents. The sheriff said the evacuations were not mandatory.

By noon, a helicopter had flown over the impacted site to look for any others that could have been impacted by the breach.

Route N was closed throughout the day due to flooding damage. Portions of Route K and Highway 49 were also closed during the day due to the threat of flooding. The Johnson Shut-Ins Campground, playground, and shower house were found to be severely damaged.

The sheriff praised AmerenUE personnel for their coordination prior to and during the emergency. He had face-to-face meetings with the Taum Sauk superintendent and participated in annual drills as preparation for what his role would be in just such a scenario. He was familiar with the inundation maps from previous drills and found them helpful. He said during previous drill when it was thought a radio line between the Taum Sauk plant and the Sheriff's office would enhance communication during an emergency, AmerenUE provided one quickly.

Sheriff Barton stated there were a couple problems during the emergency. He explained there were two 911 lines which were inundated with hundreds of calls and the operators could not handle all the calls. He estimates they received 600-800 calls that day. He said during the emergency his office received a large number of calls reporting missing people. He believed the calls were made by people that could not initially contact local residents. As the day progressed, the list of missing persons diminished until all people were accounted for.

The sheriff had concerns with the National Weather Service flood warning which assumed a breach of the lower reservoir. He said early during the event it was apparent that the lower dam was not in danger of breaching but the flood warning was not called off until later in the day. In response to this warning, emergency personnel were sent to evacuate people downstream of the Lower Reservoir.

The sheriff made suggestions for possible improvements to handling similar emergency. He suggested some type of early warning system, such as an automatic call out system or siren, be installed to ensure downstream residents could be notified in a timely manner. This is particularly a concern during warmer months when the Johnson's Shut-Ins campground is full. He also noted that during emergencies it would be helpful to have a single point of contact for the media, so reporters would not be getting information from non-experts.

10.4 Interview with National Weather Service

On January 12, 2006, FERC staff met with National Weather Service staff at their St. Charles, MO offices. During the meeting, NWS staff explained their emergency response during the December 14, 2005 event and provided copies of the flood warnings and flood statements which they issued following the breach. The following is a chronology of NWS' actions:

Date	Time	Event
12/14/2005	6:20 AM	NWS is notified of breach by AmerenUE.
	6:27 AM	NWS issues flash flood warning for Northeastern Reynolds County. The warning states large quantities of water will move downstream causing extreme flooding of the Black (River) below the Dam. It states flooding can be expected in Lesterville, Highway N and areas in and near Johnson Shut-In Park
	6:52 AM	NWS issues second flash flood warning for

		Northeastern Reynolds County, effective until 8:45 a.m. This warning predicts water will reach Highway K west of Annapolis, MO by 9:00 a.m. and reach a level of 20 feet (flood stage is 8 feet). The warning stated the record crest was 27 feet. *Although not stated in the warning, the flood crest is based on a worst case scenario where the Lower Dam would also breach. The flood crests at Annapolis are based on the Inundation Maps in the EAP*.
	6:57 AM	NWS issues a flood warning for the Black River, gives the estimated 20 foot crest at Annapolis and states the forecast is based on the Taum Sauk Lake Dam breach.
	8:54 AM	NWS issues a flood statement stating the flood warning for the Black River remains in effect. Statement calls for crest of 20 feet at Annapolis around noon. States the forecast is based on the breach of the Taum Sauk Lake Dam and crest is based on a worse case failure (Lower Reservoir failure.)
	12:01 PM	NWS issues a flood statement saying the flood warning for the Black River is still in effect. It downgrades the crest at Annapolis to 12 feet which would occur at 3:00 PM assuming the Lower Taum Sauk Lake holding and not failing.
	3:04 PM	NWS issues a flood statement saying the flood warning for Black River is still in effect. It downgrades the crest at Annapolis to 8.0 feet at 6:00 PM. States most of the flood water was captured by the Lower Reservoir and AmerenUE officials state the Lower Reservoir is structurally sound.
	9:01 PM	NWS downgrades flood crest to 4.0 feet at Annapolis.
12/15/2005	2:16 AM	NWS cancels the flood warning for the Black River.

During the January 12, 2006 meeting, NWS staff discussed the incident and their response.

They pointed out NWS was notified of the breach almost one hour after it occurred which detracted from how quickly it could issue warnings for downstream residents.

They noted they had closer coordination with the Taum Sauk Plant Superintendent after both parties attended the 2003 functional exercise at the Osage Project and participated in their 2004 annual drill. They also pointed out the 2005 annual drill was scheduled for the day the breach occurred.

They noted it was difficult to receive information from AmerenUE employees early during the event. This led the NWS to use the worst case scenario that the Lower Reservoir dam would also breach. As the day went on and more information became available, NWS lowered their downstream crest estimates after it was clear the Lower Reservoir Dam was not at risk of failing.

Section 11 Environmental Effects Associated with the Breach of the Upper Reservoir at the Taum Sauk Project

This review examines the environmental impacts resulting from the breach of the upper reservoir rim dike at the Taum Sauk Pumped-Storage Hydroelectric Project (FERC Project No. 2277), operated by AmerenUE (licensee). At approximately 5:20 a.m. on December 14, 2005, the northwest corner of the upper reservoir failed, releasing approximately 4,300 acre-feet of water in approximately one half hour. The water flowed down Proffit Mountain into the East Fork Black River, through a State Park and campground and into the lower reservoir. The flows overtopped the project's lower reservoir dam and traveled downstream in the Black River through the town of Lesterville, Missouri located approximately six miles downstream. The incremental rise in the river level at Lesterville was estimated at two feet which remained within the banks of the river.

The following assessment is general in nature and the result of site visits, field interviews, public data filed with the Commission, internet available information and published accounts of the events. When available, quantifiable data of the impacts associated with the breach are presented, otherwise, a qualitative analysis is provided to describe the effects of the event. It is recognized that the environmental impacts of flooding are varied and wide ranging. This report outlines the major environmental and socio-economic effects of the flooding immediately following the event. The breach of the upper reservoir dike is described in detail in the preceding sections of this report.

11.1 General Description of the Hydro Project and Project Area

The Taum Sauk Project is located in Reynolds County, Missouri approximately 100 miles south of St. Louis and six miles north of Lesterville, MO. It is a pumped storage facility with a 55-acre upper reservoir on Proffit Mountain and a 370-acre lower reservoir located on the East Fork Black River at its confluence with Taum Sauk Creek. The lower reservoir is operated as a run-of-river reservoir and provides storage for water to be pumped to the upper reservoir at night or during periods of low power demand. During the day, or periods of high energy demand, the two reversible pump/generators are used to generate electricity.

The project is located in the heavily forested St. François Mountains with two large portions of the Mark Twain National Forest lying to the east and west of the project area. The project in near Taum Sauk Mountain Tower and Trail, Bell Mountain Wilderness and Elephant Rocks State Park and abuts the Johnson Shut-

Ins State Park. Some outstanding natural features of these mountains include igneous rock glaciers, igneous glades, extensive gravel washes, fens, and forests of oak, hickory and pine.

The Taum Sauk Project is near the upper end of the Black River drainage basin with approximately 88 square miles of drainage upstream from the lower reservoir. The project is located on the East Fork Black River which originates in the Mark Twain National Forest near Graniteville, MO. The East Fork Black River generally flows south through Johnson Shut-Ins State Park and then into the project's lower reservoir. The three mile stretch of the East Fork Black River that flows through the State Park is on Missouri's Clean Water Commission list of Outstanding State Resource Waters.

Below the project's lower reservoir, the river continues to flow south for approximately six miles to the town of Lesterville, MO where it joins the West Fork Black River to form the Black River. The Black River continues to flow south through Clearwater Lake before leaving the state in a southwest direction. There it flows into the White River in northeast Arkansas.

11.2 Environmental Effects Resulting from the Dam Breach

The breach of the upper reservoir rim dike resulted in the release of approximately 4,300 acre-feet of water. The torrent water flowed in a northwest direction down Proffit Mountain to the valley floor were it met the East Fork Black River and began flowing south in the East Fork Black River. Because of the path the water followed, the most extensive damage was outside the project boundaries. In addition to the human impacts, the dam breach affected various land and water resources which are discussed in more detail below.

11.2.1 Immediate Health and Human Impacts

The upper reservoir, atop Proffit Mountain, breached at approximately at 5:15 a.m., releasing a wall of water that rushed down the mountain to the valley floor. There it crashed into the state park superintendent's home shattering it from its foundation while the superintendent and his family were still inside (Figure 11.1). Reports of the event indicate that first responders quickly found the superintendent clinging to a tree; however, it took another hour and half to locate his wife and three small children (ages 5, 3 and 7 months) who were swept up to quarter mile for their home. The family members suffered various contusions and abrasions and were covered in mud. The children were hospitalized in St. Louis, MO and listed in critical condition with hypothermia and breathing problems

(Compiled from news sources, Dec. 14 2005). Eventually, after varying weeks of hospitalization for the children, they were all released from the hospital in good health.

Figure 11.1 - State park superintendent's former home. (Source: Staff)

Search and rescue teams were dispatched within the State Park and vicinity. No other casualties were reported owing in large part to the time of year and time of day when attendance at the park is/was minimal. However, it was reported by the Associated Press that the flood waters slammed into a truck hauling a load of zinc on Route N near the reservoir. The driver climbed onto the roof of the truck and saw that another truck and a car were also submerged, with the drivers also on the roofs of their cars. It was also reported that a mobile home, several cars and a tractor-trailer were washed away.

Early during the event, not knowing whether the lower dam would be able to sustain the sudden impact of flood waters, emergency personnel called for a voluntary evacuation of parts of Lesterville. However, the lower reservoir was nearly empty as a result of previously pumping water to the upper reservoir and was therefore able to absorb the flood flows. River levels in Lesterville rose to an estimated level of 2 feet above the normal river level but still within its banks.

One home approximately 200 hundred yards from the Superintendent's residence (located off Route N) was surrounded by flood waters but, because it is located on a small hill, the flood waters encircled the residence but did not flood it. The surrounding farmland however, was flooded and debris and sediment was deposited in the fields. Additionally, some of the farmland fencing was destroyed (Figure 11.2).

Figure 11.2 - Farmland with debris on north side of Route N. Note home on small hill. (Source: U.S. Geological Survey)

11.3 Geology and Soils

As discussed in more detail in Section 2.2, Proffit Mountain was created 1.4 billion years ago from volcanic ash and lava and when cooled formed hard rhyolite porphyry. Later, seas extending up from the Gulf of Mexico covered the area and deposited sedimentary rock. As the land rose, the sea retreated exposing the area to weathering conditions. Soil in the project area is shallow and generally consists of stone and gravel. In the valleys and floodplains of the area, soils are alluvial in nature.

To keep river-borne sediment from reducing the Lower Reservoir storage capacity or blocking the canal between the power plant and the lake, a bin wall dam was constructed to trap gravel in the East Fork of the Black River just upstream of the reservoir. In the past 30 years, this gravel trap has been cleaned out five times. Each time approximately 30,000 cubic yards of material were removed (MDOC, 2005a).

11.3.1 Environmental Impacts to Geology and Soils

Approximately 317 acres, between the upper and lower reservoir, were directly impacted by the release of water immediately following the dam breach. A map and description of the land uses and soils of this impacted area can be found in Appendix E in the back of this report. The erosive force of the water from the breach removed all topsoil to bedrock in an approximate 200-yard swath, down the face of the Proffit Mountain (Figure 11.3) along the course of an intermittent unnamed tributary. Also, seen in Figure 11.3 is the shallowness of the topsoil along the tree line.

Figure 11.3– Downstream view from breach (Source: Staff, 12/22/05)

A break in the slope of the terrain is located where the unnamed tributary joins the East Fork Black River at the lower portion of the mountain. Most of the deposition of eroded sediments and rock fill from the dam embankment occurred at this point, forming a debris dam (Figure 11.4) and pond at the approximate location of U.S. Geological Survey gage station (No. 070661270) which was severely damaged during the event. The material deposited at this point ranged from boulders several feet in diameter to sand and fine silts. Concrete, rebar, and sections of the geomembrane lining from the Upper reservoir were also present in the debris field.

Figure 11.4 – Looking upstream from debris dam (Source: Staff, 12/22/05)

It is expected that there will be continued soil erosion and transport of material of varying sizes from the slope of Proffit Mountain and the associated debris field. The licensee has proposed a series of temporary sediment retention structures along the affected area to prevent further transport of the sediments, until they can be stabilized.

A large amount of sediment was also captured by the existing bin wall dam, upstream of the lower reservoir. The bin wall is approximately 400 feet long and constructed of two rows of sheet piles driven into the river bed with rock fill between the sheet piles. It serves as a trap for gravel in the stream and is located just upstream of the pump/ generating plant. The licensee maintains a dredging permit with the Army Corps of Engineers. Additional land has been acquired on the west side of the East Fork Black River to dispose of dredge spoils.

11.4 Water Quality

The East Fork Black River is located in the Upper Saint Francis watershed, and is not listed on the Missouri or U.S. EPA list of impaired streams. An impaired stream is a stream that has had a Total Maximum Daily Load study completed and is believed to be affected by point-source or non-point source pollution. The basin has some of the lowest erosion potential in the state of Missouri, which results in particularly low sediment yields, bed loads, and turbidities. The annual erosion rate for all land types in the upper basin totals only 2.9 tons/acre. Sheet erosion on tilled land is the most serious threat in the area at 13-18 tons/acre, which is considered moderate. Gully erosion and sheet erosion on permanent pasture and non-grazed forest is considered slight. Sediment yield to streams, typically low in the Ozark region, is extremely low at only 0.6 tons/acre/year (MDOC, 2005a).

Municipal waste discharges throughout the sparsely populated East Fork Black River subbasin, are mostly small, adequately designed, and pose few serious threats to the water quality of receiving streams. Eight National Pollution Discharge Elimination System permitted wastewater discharges are located in the upper subbasin. Upgraded facilities and improved operation and maintenance of the municipal sewage systems have reduced the frequency of untreated effluent releases, which most often resulted in only minor aesthetic impacts on six miles of permanent streams (MDNR, 2005a). Filamentous algal blooms often occur during the summer in the main stem below Farmington, MO, which indicates nutrient enrichment and the potential for periods of low dissolved oxygen. The planned upgrade in the Farmington Treatment Plant should alleviate this problem. (MDOC, 2005a)

11.4.1 Environmental Impacts to Water Quality

Data collected to date suggest that the impact to water quality is a large increase in turbidity. The initial breach removed all of the overburden on the slope of Proffit Mountain. The larger sediments, and the material from the embankment, were mostly deposited upstream of the “shut-ins” area in the state park. Smaller clay particles suspended during the event stayed in suspension, and did not show any signs of settling two weeks after the event. Small particles, such as clays, can have an electrostatic charge that repels other particles and allows clay to stay in suspension in the water column indefinitely.

In order to reduce turbidity in the lower reservoir, AmerenUE, with the approval of the Missouri DNR and Commission, used common alum based flocculants (used primarily for drinking water treatment) to remove the charge on the particles and allow them to settle. Flocculation is a process by which the electrostatic charge of suspended particles is neutralized by a flocculent, allowing the particles to stick to one another and form flocs. Once the flocs are large enough they fall from suspension. After receiving state approval of the plan on January 20, 2006, and Commission approval on January 25, 2006, the licensee applied the flocculent to the lower reservoir on January 25-27, 2006. Without use of a flocculent the particles would have stayed in suspension, and the water in the lower reservoir would have cleared much more slowly. In addition, turbidity caused by suspended clay particles would have remained in the river downstream over a longer period and likely extended further downstream.

Figure 11.5 – Turbidity at Johnson's Shut-ins (Source: Staff, 12/22/05)

Figure 11.6 – Turbidity at Lower Dam (Source: Staff, 12/22/05)

11.5 Biological Resources

11.5.1 Aquatic Resources

11.5.1.1 <u>Fisheries Resources</u>

The state classifies the fishery of the East Fork Black River as a warm water fishery. AmerenUE, in its initial consultation document for relicensing the Taum Sauk Project, indicated that from the Missouri Department of Natural Resources (DNR) literature, 42 fish species occur in the East Fork Black River (in Johnson's Shut-Ins State Park and below the lower project reservoir) (Table 1).

Table 11-1 - Fish species in the East Fork Black River. Those listed below the lower dam identified from one sample collection. (Source: Cieslewicz 2004 cited in Initial Consultation Document, AmerenUE, 2004)

Common Name	Species	Present Down-stream of Project	Present Upstream of Lower Dam
Longear sunfish	*Lepomis megalotis*	X	X
Bluegill	*L. macrochirus*	X	X

Redear sunfish	*L. microlophus*	X	
Green sunfish	*L. cyanellus*	X	X
Redspotted sunfish	*L. miniatus*	X	
Shadow bass	*Ambloplites ariommus*	X	
Rock bass	*A. rupestris*		X
Largemouth bass	*Micropterus salmoides*	X	X
Smallmouth bass	*M. dolomieu*	X	X
Spotted bass	*M. punctulatus*		X
Grass pickerel	*Esox americanus*		X
Greenside darter	*Etheostoma blennioides*		X
Rainbow darter	*E. caeruleum*		X
Fantail darter	*E. flabellare*		X
Orangethrout darter	*E. spectabile*		X
Banded darter	*E. zonale*		X
Logperch	*Percina caprodes*		X
Channel catfish	*Ictalurus punctatus*	X	
Yellow bullhead	*Ameiurus natalis*	X	X
Ozark madtom	*Noturus albater*		X
Northern hogsucker	*Hypentelium nigricans*	X	X
Creek chubsucker	*Erimyzon oblongus*		X
Golden redhorse	*Moxostoma erythrurum*	X	
Black redhorse	*M. duquesnei*	X	
Central stoneroller	*Campostoma anomalum*		X
Largescale stoneroller	*C. oligolepis*		X
Whitetail shiner	*Cyprinella galacturus*		X
Hornyhead chub	*Nocomis biguttatus*		X
Bigeye shiner	*Notropis amblops*		X
Wedgespot shiner	*N. greenei*		X
Rosyface shiner	*N. rubellus*		X
Telescope shiner	*N. telescopus*		X
Ozark minnow	*N. nubilus*		X
Bleeding shiner	*Luxilus zonatus*		X
Southern redbelly dace	*Phoxinus erythrogaster*		X
Bluntnose minnow	*Pimephales notatus*		X
Creek chub	*Semotilus astromaculatus*		X
Common carp	*Cyprinus carpio*	X	
Gizzard shad	*Dorosoma cepedianum*	X	
Blackspotted topminnow	*Fundulus olivaceus*		X
Northern studfish	*F. catenatus*		X
Mottled sculpin	*Cottus bairdi*		X

The East Fork Black River exhibits good aquatic biodiversity. The majority of the fish species above occur in rivers and streams where the preferred habitat is clear moving water with gravel-cobble-boulder bottoms (Pflieger, 1991). The East Fork Black River substrates are typically diverse and stable, and bank erosion is generally not a problem in this area since the riparian corridors are mostly forested.

Many of the game fish species in the list above inhabit lakes, reservoirs, or pools in rivers. This type of habitat has little or no current, generally clear water, and continuous cover such as submerged timber or aquatic vegetation.

11.5.1.2 Environmental Impacts to Fisheries

From where the flood water initially entered the East Fork Black River (near the entrance to the state park) to the lower reservoir is approximately 3 miles. Water from the upper reservoir flooded the banks of the East Fork Black River between the entry point and the lower reservoir. Given the volume of the flood waters and the rock debris it carried, it is highly likely that many fish were killed and most of the remaining fish were washed downstream and into the flood plain. Following the event and reconnaissance of the area, neither the licensee nor resource agencies reported to the Commission any dead or stranded fish in pools. This seems to indicate that most fish in the reach were washed downstream into the lower reservoir which was at a low elevation after water was pumped to the upper reservoir. During the event, it is likely many surviving fishes were washed into areas for which they were not adapted and were subjected to additional environmental stressors. For example, the ability of riverine species to survive in a highly turbid lentic environment for an uncertain length of time is unknown. Some generalist species, which can naturally utilize a variety of habitats, may have survived while others did not due to poor water quality, lack of food sources, and cover. As water quality conditions improve in the river, fish will gradually recolonize the impacted reach of river provided suitable habitat and food sources are available. The species rich diversity of the Shut-Ins State Park will be slow to recover, possibly taking several years.

The high flows immediately following the rim dike breach, carried a tremendous amount of sediment and boulders into the river from the upper dam's embankment, in addition to the scour created down the side of the mountain. Vegetative debris and earthen sediment was deposited on the valley floor and in the East Fork Black River (Figure 11.7). The volume of the debris and sediment altered the configuration of the river from the point of entry to the Shut-Ins area of the park and destroyed riparian habitat (Figure 11.8). It also reduced aquatic habitat and adversely affected the river channel by creating pools, barrier dams and disjoining habitats.

Figure 11.7 - Modified channel of the East Fork Black River (Source: Staff)

Figure 11.8 - East Fork Black River within State Park. (Source: Missouri Department of Conservation)

The channel modification was most extensive upstream from the Shut-Ins at the entrance to the State Park. The natural boulder and bedrock area of the Shut-Ins helped prevent excessive scour and the reconfiguration of the channel in that area; however, below the Shut-Ins area and upstream of the lower reservoir, significant loss of riparian habitat, flooding, scour, and turbidity were sustained (Figure 11.9).

For natural fish reproduction in streams, the channel generally consists of a series of pools, chutes and riffles. Inspection of the stream channel within the state park to the Shut-Ins area indicated substantial alteration of the natural stream channel thereby creating the loss of habitat as well as food sources.

Figure 11.9 - Scour and loss of riparian habitat below the Shut-Ins. (Source: Missouri Department of Conservation)

At the time of staff's inspection on December 22, the river and reservoir were still extremely turbid from the event. The river upstream from the lower reservoir was showing signs of clearing as continuous clear water from the headwaters above where the event occurred continued to flow into the East Fork Black River at the state park. The reservoir, however, remained very turbid as a result of the event. Further, discharge flows spilling from the lower reservoir were also turbid creating a muddy appearance in the Black River below the dam. Verbal accounts from the DNR indicated that the turbidity extended for over 20 miles to Clearwater Lake. Similarly, the turbidity in this stretch of the Black River would also adversely impact aquatic resources.

Excess turbidity reduces aquatic photosynthesis and oxygen levels in the water and can cause stress or death to fish as well as other organisms. Different species are more susceptible to turbid conditions. Prolonged exposure may adversely affect fishes' gills and respiration. Additionally, large quantities of suspended materials can kill or bury fish eggs; however, in a warm water fishery, little to no reproduction occurs in December. Nevertheless, excessive turbidity or prolonged turbidity may prevent fish from spawning later in the spring. Further, habitat degradation caused by sediment reduces or eliminates essential habitat. For instance, the hornyhead chub requires clear streams with clean gravel or rubble bottoms to construct its nest from stones (Pflieger, 1991). Many riverine species require sediment-free substrate for reproduction. In addition to the direct impact on reproductive life history, excessive turbidity also adversely impacts food sources such as macroinvertebrate populations which are discussed more below. Careful design will be required to mitigate terrestrial impacts and to restore essential fluvial geomorphic and aquatic habitats.

11.5.2 Aquatic Macroinvertebrate Resources

Aquatic macroinvertebrates are good overall indicators of stream quality because they are affected by water chemistry and the physical and biological conditions of a stream. They are also a critical part of the stream's food web; an adverse impact to smaller macroinvertebrates quickly affects the many species of fishes that feed upon them. Some macroinvertebrate species are intolerant of pollution and can not easily escape adverse conditions. Thus, when environmental changes occur, the species must endure the disturbance, adapt quickly, or die.

The MDC lists four mussel species and one clam species collected in the Black River water basin above Clearwater dam. They are the giant floater (*Anodonta grandis*), fatmucket (*Lampsilis siliquoidea*), northern broken-ray (*L. reeviana brittsi*), squawfoot (*Strophitus undulatus*), and the non-native invasive Asiatic clam (*Corbicula fluminea*) (MDC, 2002). Mussels are filter feeders. Good water quality and low siltation are general characteristics of suitable habitat for a diverse mussel community. Substrate characteristics such as gravel or sandy bottoms are also necessary for many mussel species. The licensee indicated in its relicensing document that only one species, broken-ray, was found below the project's lower reservoir dam. The licensee added that the invasive Asiatic clam is found throughout the lower reservoir.

The MDC states that three crayfish species have been collected in the upper Black River basin. They are the woodland crayfish (*Orconectes hylas*), the spothanded crayfish (*O. punctimanus*), and the Hubbs crayfish (*Cambarus hubbsi*) (MDC, 2002). These crayfish species generally inhabit streams with low turbidity, free flowing water with gravel and large rubble substrates.

Concerning aquatic insects, the Missouri DNR has recently conducted surveys in Johnson Shut-Ins and Taum Sauk State Parks in 2004. The results of those surveys have not been published to date. However, given the good water quality of the East Fork Black River prior to the event, it is expected that a diverse and species-rich community of aquatic insects existed before the December 14 event.

11.5.2.1 <u>Environmental Impacts to Macroinvertebrates</u>

Given the massive amount of debris and sediment that entered the river, it is highly probable that the flooding event likely killed the vast majority of marcroinvertebrate species in the State Park area by grinding or smothering. Some transport of invertebrates downstream also likely occurred. Further down the river, as the larger boulders and cobble settled out, the high flows flushed organisms downstream, and even further down river (in areas where fine sediment and turbidity remained) voluntary drift most likely occurred. Consequently, long reaches of the East Fork Black River below the impact site are likely to have been significantly depleted of macroinvertebrate populations.

The ecological relationship between macroinvertebrate populations and fish productivity is well known. Habitat reduction caused by the breach event decreased invertebrate populations and adversely impacted fish by reducing food availability. Natural recolonization of the affected areas will be a lengthy process dependent on clear water and the flushing of the sediments from the substrate.

11.5.3 Land Resources

11.5.3.1 <u>Flora Resources</u>

Proffit Mountain is a heavily forested area lying on the western edge of the Central hardwood Region (Figure 11.10). The MDC (2001) states that the forests of this region contain more than 70 deciduous tree species, several evergreens, and many shrubs and forest plants. Oak and hickory species make up the majority of trees found in this area; however in the southern and southeastern Ozarks, shortleaf pine may comprise 25 to 50 percent of the stand. The MDC adds that the remaining trees in this upland area are dominated primarily by oaks such as white, black, scarlet, and northern red oak and the less common species include southern red, chinkapin, burr, and pin oak. Hickory makes up a small percentage, but is a consistent part of the forest. Other important large tree species include blackgum, red and sugar maple, ash, elm, black walnut, and red cedar. Also, there are many small tree species associated with oak-hickory forests. These include dogwood, sassafras, redbud, serviceberry, eastern hop hornbeam, and American hornbeam (MDC, 2001).

Figure 11.10 - Forested area surrounding Proffit Mountain (opposite side of breach) with upper reservoir in the background. December 2005. (Source: Missouri Department of Conservation)

The forest resources continue to the valley floor and along the reaches of the East Fork Black River and through Johnson's Shut-Ins State Park. In addition to the park's geologic and hydraulic formations that draw many visitors, Johnson's Shut-Ins State Park is also known for two fen areas. A "fen" is a wetland environment where soils are saturated from the upwelling of mineral-rich groundwater that can create a spring. A fen, or bog-like area, is usually hydraulically connected to a creek or stream. The fen areas at Johnson's Shut-Ins State Park occupy approximately 8 acres. (MDC, 1999).

The wetland areas at the state park consist of a seep forest and calcareous fen located within the floodplain of the East Fork Black River (MDC, 1999). According the MDC, seep forests are rare in Missouri and are comprised of red maple, green ash, slippery elm and honey locust. Additionally, two rare plants are also found in the fens along with other notable wetland species including closed gentian, silky willow (Figure 11.11 and Figure 11.12) and an uncommon variety of southern blue flag (MDC, 1999).

Figure 11.11 - Silky Willow (*Salix sericea*) (Source: MDC, 1999)

Figure 11.12 - Closed Gentian (*Gentiania andewsii*) (Source: MDC, 1999)

11.5.3.2 Flora Environmental Impacts

Prior to the December 14 event, Proffit Mountain was heavily forested as seen in the satellite photograph (Figure 11.13). From the base of the upper reservoir in the northwest corner, where the breach occurred, to the valley floor and state park, over 250 acres of forest vegetation was denuded. Compounding the problem of deforestation is the fact that all soil in a 200 yard swath down Proffit Mountain was removed down to bedrock. Therefore, the ability to reforest this area is highly problematic. It is expected that due to the absence of topsoil, this area will remain deforested.

Figure 11.13 - Pre-event satellite photograph of the forested area surrounding Proffit Mountain. (Source: Google Earth, 2005)

In addition to the deforested mountain areas, the fen areas within the state park were submerged in layers of sediment. In some areas of the state park, several feet of sediment were observed. Cleanup and recovery of the fen area began in January 2006, however, the extent of the damage to the sensitive and rare plants in the fen areas will not be known until the spring and summer, after emergence. Since many of the plants within the fen areas are on the state's species of concern list, the loss of any listed plants would be highly significant.

Figure 11.14 - Deforested riparian vegetation below Shut-Ins area of state park. (Source: MDC)

The riparian vegetation along the East Fork Black River was another area that suffered substantial deforestation (Figures 11.1-11.5). The extent of the damage is severe and extends from the entrance to the state park through the Shut-Ins area and below the Shut-Ins area to the lower reservoir. In some areas over one hundred yards of riparian vegetation was washed out due to the breach. In other areas ground-covering riparian vegetation was buried in silt and sand limiting recruitment. Natural recovery of the riparian areas will be hampered by poor soil quality and lack of soil (bedrock exposure) due to the flood.

11.5.3.3 <u>Wildlife Resources</u>

The hardwood forest of Proffit Mountain provide habitat for a variety of wildlife species. The more common mammals found in the upland wood areas include: whitetail deer, coyote, bobcat, red and gray foxes, raccoons, mice, rabbits, skunks, and gray, flying and fox squirrels (MDC, 2005).

The MDC lists over 125 species of birds found in Reynolds County with approximately 29 species associated with upland habitat. The more common species include: the great-horned owl; wild turkey; Cooper's, red tailed and sharp-shinned hawks; grouse; blackbird; crow; grackle; and song birds such as bunting, blue jay, cardinal, finch, mockingbird, robin, sparrow and warbler species.

In the forested bottomland areas and the riverine and reservoir areas of the project (Figure 11.15) there are a number of additional bird species that occur in these habitats. Common species include the wood duck, mallard, Canada goose, heron, flycatcher, pileated woodpecker, various warblers, gnatcatcher, wren, wood thrush and barred owl (MDC, 2005).

According to the MDC, there are approximately 15 amphibian species and 18 reptilian species in the forested and aquatic areas of the project. The species include: seven frog and one toad species; six salamander species and the red-river mudpuppy; 12 snake species such as the copperhead, black rat, eastern garter, kingsnake, and timber rattlesnake; four turtle species; and two skink species (MDC, 2005).

Figure 11.15 - East Fork Black River leading into Taum Sauk lower reservoir. December 2005. (Source: MDC)

11.5.3.4 <u>Environmental Impacts to Wildlife</u>

At the time of staff's environmental inspection following the event, the DNR indicated that one turtle was found dead as a result of the flood. No other report or recovery of terrestrial animals was filed; however, any slow moving forest species unable to escape the flood waters were most likely swept away or killed by the torrent flows. A substantial amount of forested habitat (approximately 270 acres) has been lost to both terrestrial and avian species. In addition to the habitat loss, the forest provides a valuable food source for many species. The loss of the trees and undergrowth reduces food availability.

Further, the torrent flows created a vertical corridor down Proffit Mountain, up to 200 yards wide, extending from the valley floor to the base of the upper reservoir. The corridor prevents normal behavioral movement for many species located in the area. For instance, the movement of raccoons, squirrels or mice from one edge of the deforested area to the other edge (over the open bedrock area) exposes these small mammals to predation, therefore, the open bedrock area acts as a barrier to movement.

11.6 Threatened and Endangered Species

For plant and terrestrial animals potentially occurring in the project area, the U.S. Fish and Wildlife Service (FWS) lists two species as threatened or endangered: the gray bat (*Myotis grisescens*) as endangered and Mead's milkweed (*Asclepias meadii*) as threatened (FWS, 2002). Further, in a letter dated June 8, 2005, filed with the Commission regarding the licensee's initial consultation document, the FWS stated that in addition to the two species above, it believes that the bald eagle (*Haliaeetus leucocephalus*), Indiana bat (*Myotis sodalist*), and Hine's emerald dragonfly (*Somatochlora hineana*) could potentially occur within the project area.

For the various habitats in the project vicinity, the MDC lists 11 plant, seven bird, two amphibian, two insect, two mammal, and two fish species as species of concern (MDC, 2005). The state status of these species varies from widespread and apparently secure (but of long term concern), to critically imperiled.

11.6.1 Environmental Impacts to Threatened and Endangered Species

Gray bats require undisturbed caves as their preferred habitat and forage over streams, rivers and reservoirs. Although some caves do occur in Reynolds County, no caves are believed to exist in the project area or the area affected by the breach.

The MDC states that Mead's milkweed occurs primarily in western and southwestern portions of the state, but can also be found in scattered locations of southeastern and northern Missouri. The preferred habitat for Mead's milkweed is tall grass prairies and igneous glades. This species has not been identified to occur in the project area.

If bald eagles occur in the area, the loss of forested habitat reduces nesting opportunities for the species. Further, the reduction in riverine and reservoir fisheries could adversely impact an important food source of any bald eagles in the area.

In addition to the two listed federally threatened and endangered species, the state lists 26 species of concern for the project area. Within the forested area of Proffit Mountain, the black bear is state listed as rare. If black bears occur or migrate in the project area, the swath of deforestation down Proffit Mountain may have eliminated some feeding areas as well as disrupted corridors between feeding areas. Additionally, the exposed mountainside no longer provides protective cover for movement in that area.

Of the six state listed bird species, two have the preferred habitat of forested uplands. Cooper's hawk and the sharp-shinned hawk prefer dense shortleaf pine or oak-hickory stands for nesting habitat. The deforested area of Proffit Mountain reduced the available nesting habitat for these species if they occur in the area. Similarly, two amphibians, the wood frog and four-toed salamander, inhabit forested upland environs. Both occur in leaf litter in deciduous forests. The wood frog breeds in ephemeral pools and intermittent streams such as the one the flood waters followed down the side of Proffit Mountain. The deforested area of Proffit Mountain potentially reduced the available breeding habitat. Further, unlike the avian species, the slower moving amphibians in the pathway of the initial surge of water after the breach could have been killed, injured or swept away.

The remaining state listed species in Reynolds County are plants of which several species occur within Johnson's Shut-Ins State Park. Again, as mentioned in the Flora section, the extent of the destruction of these sensitive and rare plants will not be known until a survey is completed in the spring and summer.

11.7 Cultural Resources

It is generally known that prehistoric communities in this area resided near rivers and in lowland areas. Prehistoric and indigenous Indian tribes are known to have lived in the project area. Prior to the event, the licensee was planning to conduct a comprehensive survey of historic, archaeological and cultural properties in the project area as a part of the relicensing process.

The impacts associated with the December 14 event may have exposed previously undiscovered remnant artifacts or washed artifacts downstream. The impact of the event as it relates to cultural resources on Proffit Mountain are not known, however, they will be more fully understood after completion of the licensee's cultural resource study that would occur in consultation with Indian tribes and the State Historical Preservation Office.

11.8 Recreational Resources

The Taum Sauk Project is rurally located and surrounded by three state parks: Johnson's Shut-Ins, Elephant Rocks and Taum Sauk Mountain. Each of these parks provide a variety of recreational opportunities such as camping, hiking and swimming at Johnson's Shut-Ins, hiking and viewing geologic wonders at Elephant Rocks, and hiking and wilderness exploration in the rugged and scenic Taum Sauk Mountain State Park.

Recreational opportunities within the project boundary include fishing in the lower reservoir, picnicking, camping, viewing the upper reservoir and visiting an interpretive center and museum. On March 27, 2003, the licensee filed, with the Commission, its Form 80 Recreational Report (FERC, 2003). The report indicated that for year 2002, the annual, daytime recreation days were approximately 30,000 and about 800 days of nighttime recreational use (utilizing the project's 25 campsites). The licensee stated that the primary activity at the project is fishing for warm water game fish in the lower reservoir; however, a large percentage of the recreational day users are visitors to the project's museum and visitor center which often include school children on field trips. Hunting is prohibited on project land as well as swimming and water skiing in the lower reservoir.

Approximately six miles downstream from the lower reservoir is the town of Lesterville, MO. There are several commercial outfitters in the area that attract considerable numbers of tourist. The outfitters provide float trips, kayaking, and canoeing on the Black River and camping facilities for both recreational vehicles (RV) and tents. Below the Taum Sauk Project's lower reservoir, the Black River flows from river mile 8.4, or the junction with the Middle Fork near Lesterville, to river mile 25.0 (Highway K Bridge), or the last take-out above Clearwater Lake at full reservoir. Clearwater Lake is a 1630 acre reservoir operated primarily for flood control by the U.S. Army Corps of Engineers.

11.8.1 Recreational Impacts

As a result of the December 14 event, and at the time of this report, Johnson's Shut-Ins State Park is closed until further notice. The park is one of the state's most popular state parks which draw nearly 250,000 visitors yearly (DNR, 2006). In addition to the reconfiguration of the river and sediment and debris deposited in it, the majority of the physical damage to the park was in the area adjacent to the East Fork of the Black River. Extensive damage was reported to the superintendent's residence, the campground, the fen areas (which are the park's signature natural feature), and to the park store and office which were flooded but, are still standing. The boardwalk to the shut-ins area was also slightly damaged.

Restoration of the park is currently underway. If the cleanup of the park cannot be completed by the beginning of the summer of 2006, recreational opportunities associated with the park will be adversely affected limiting (and perhaps eliminating) the public's use of the park for the summer.

Similarly, the licensee has indefinitely closed public access to the upper reservoir, the visitors' center and the museum while it continues restoration work at the project. The lower reservoir also remains closed while the licensee continues to monitor water quality and control sediments. During the winter months, fishing and camping usage is minimal, however, in late spring and summer, recreational angling and camping normally increases. If the lower reservoir remains closed at that time, recreation at the project will also be adversely affected.

Since the event, the Missouri DNR has been holding monthly meetings at the Lesterville High School to keep the public informed of cleanup and recovery activities at the Johnson's Shut-Ins State Park. At those meetings, it was reported that several of the recreational outfitters speculated that if the river remains turbid through the spring and early summer, their businesses (and recreational opportunities) would be adversely affected because fewer people would want to float a muddy river when the public is use to the Black River being a clear river.

On January 25, 2006, the licensee, in consultation with the state resource agencies, undertook measures, to use flocculates to restore water clarity to the reservoir and river. Reports indicate that there has been a noticeable improvement in water clarity in the lower reservoir and river below the dam following the treatment. It is expected that water quality and clarity would improve through the spring; therefore, the extent of any decrease in recreational river-based businesses can not be calculated at this time.

The impacts of the event with respect to the other nearby state parks should be negligible. None of those facilities were directly affected by the event.

11.9 Transportation

As the flood waters reached the bottom of the mountain and the East Fork Black River, flows carrying mud, rocks and many trees were deposited on Route N. The Missouri Department of Transportation (MoDOT) stated that maintenance crews were dispatched immediately to the scene and worked to clear the roadways of the debris. MoDOT bridge crews were also dispatched to monitor bridges in the effected area. No damage was reported in the MoDOT's December 14, 2005 press release (modot.mo.gov).

III. REFERENCES CITED

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U.S. Fish and Wildlife Service, 2002. Endangered species in Region 3. http://www.fws.gov/midwest/endangered/lists/state-mo.html. Updated: June 2002.

Bibliography of AmerenUE Submittals to FERC from December 2006 to March 10, 2006
(Includes a few other select letters of interest. eLibrary Submittal number shown in brackets.)

December 15, 2006 Childers to Kelliher: Missouri Department of Natural Resources reports that on 12/14/06 a section of the Taum Sauk Hydropower Reservoir Failed.
[Submittal 20051228-0164]

December 27, 2005 Mark Birk to Constantine Tjoumas: incident report prepared pursuant to Section 12.10(a)(2) in response to additional questions set forth in CRO letter December 15, 2005; CD attached dated 12/27/05.
[Submittal 20051227-4006, 20060118-0222, 20060118-0223]

January 4, 2006 Cooper to Peggy Harding: AmerenUE reports that the rockfill dike was inspected once each month during the second half of 2005 and submits a tabulation and graphs indicating leakage, in compliance with Article 34 of the Taum Sauk Plant.
[Submittal 20060123-0226]

January 10. 2006 Birk to Constantine Tjoumas: AmerenUE submits supplemental incident report prepared pursuant to Section 12.10 (a)(2) of FERC's regulations.
[Submittal 20060124-0220, 20060124-0221]

January 10, 2006 AmerenUE's CD containing the supplemental incident report prepared pursuant to Section 12.10 (a)(2) of FERC's regulations for the Taum Sauk Hydro Project.
[Submittal 20060111-4006]

CD: January 12, 2006 Slide slow for FERC GOB visit. (Provided in person at meeting.)

January 19. 2006 Mark Birk to Constantine Tjoumas: supplemental incident report pursuant to section 12.10(a)(2) in response to additional questions set forth in CRO letter January 13, 2006.
[Submittal 20060130-0178]

CD: January 19, 2006 12.10(a) Report, Exhibit 2 Farmington Weather 2005.
[Submittal 20060120-4011]

January 23, 2006 Mark Birk to Constantine Tjoumas: submittal of drawing 8304-X-155099, Rev 5 showing actual as built of gauge piping supports; also attached is sketch SB1306-3, dated 1/4/06 depicting configuration of gauge piping supports in the filed.
[Submittal ?]

January 24, 2006 Joseph Kelliher to James Talent: response to inquiry.
[Submittal 20060208-0132]

January 24, 2006 Joseph Kelliher to Matt Blunt: response to inquiry.

January 25, 2006 Mark Birk to Wayne King: Ameren Corp submits its responses to FERC's 1/20/06 information request re the data from approx 11/15/04 through 12/14/05.
[Submittal 20060207-0076]

January 25, 2006: AmerenUE's CD containing their response to FERC's 1/25/06 data request (Reservoir level 11/2004 – present).
[Submittal 20060126-4022]

January 26, 2006 Rizzo to Constantine Tjoumas: AmerenUE submits its Data Book for the upcoming first meeting of the Independent Board of Consultants for the Taum Sauk Plant.
[Submittal 20060206-0087]

January 27, 2006 Mark Birk to Constantine Tjoumas: supplemental incident report prepared pursuant to Section 12.10(a)(2) in response to additional questions set forth in CRO letter December 15, 2005.
[Submittal 20060216-0185, 20060216-0186, 20060216-0187, 20060216-0188, 20060216-0189, 20060216-0190, 20060216-0278,]

January 1 (in eLibrary from Powers): The Board of Consultants provides to Ameren Services the First Report of meeting held January 30, 31 and February 1, 2006 re Taum Sauk Plant Forensic Investigations under P-2277
[Submittal 20060302-023]

February 7, 2006 Mark Birk to Constantine Tjoumas: responses to questions set forth in enclosures 1 and 2 of January 20, 2006 letter. On Feb 2, 3, 2006 Ameren sent IPOC responses to certain encl 1 requests per IPOC's prioritized list. Encl filing includes responses to other encl 1 and 2, sec III requests. Responses to encl 2, sec I and II provided to FERC on Jan 10, 12, 19, 23, 25, 27, 2006. Much of information in FERC encl 2, sec I and II being provided again in this filing in response to FERC encl 1 and 2, sec III. Under separate cover Ameren will provide to IPOC responses to all non-redundant encl 2, secs I and II requests.
[Submittal 20060208-4003, 20060208-4004, 20060208-4005, 20060208-4006, 20060208-4007, 20060208-4008, 20060208-4009, 20060208-4010, 20060208-4011, 20060208-4012, 20060208-4013, 20060208-4014, 20060208-4015, 20060208-4016, 20060208-4017, 20060208-4018, 20060208-4019, 20060208-4020, 20060208-4021, 20060208-4022, 20060208-4023, 20060208-4024, 20060208-4025, 20060208-4026, 20060208-4027, 20060208-4028, 20060208-4029, 20060208-4030, 20060208-4031, 20060208-4032, 20060208-4034, 20060215-0096] – 9 CDs.

February 8, 2006 interview notes for the Taum Sauk Hydroelectric Project Investigation:
Vol 1: Richard Cooper
Vol 2: Warren Witt

Vol 3: Keith Mentel
Vol 4: Tom Butkovich
Vol 5: Phillip M. Thompson
Vol 6: Hugh Wilson
Vol 7: Ronald Robbs
Vol 8: Chris Yordy
Vol 9: Robert Scott
Vol 10: Jeffrey T. Scott

February 9, interview notes for the Taum Sauk Hydroelectric Project Investigation:
Vol 1: John Preusser
Vol 2: Darin Ferguson
Vol 3: James Earl Bolding
Vol 4: Steve Schoolcraft
Vol 5: Tom Pierie
Vol 6: Chris Hawkins
Vol 7: Robert Ferguson
Vol 8: Steve Bluemner
Vol 9: Thomas L. Hollenkamp

February 10, 2006 interview notes for the Taum Sauk Hydroelectric Project Investigation:
Vol 1: Mark Christopher Birk
Vol 2: Tony Zamberlan

February 10, 2006 Mark Birk to Hendron, Paul, 7 Ehasz: comprehensive data request of January 20, 2006 which includes all data previously requested on February 2, 2006; some on CD, specifically original construction video, enclosure 2, sec III, question 4, encl 1, sec I, question 28 drawings. Also included are mailings previously submitted to FERC: hard copies including CD's submitted to FERC on Dec 27, Jan 10, 19, 15, 27, 2006; CD's submitted to FERC during forensic visit of January 12, 2006.

February 14, 2006 Mark Birk to Constantine Tjoumas: AmerenUE submits its Report prepared by the Board of Consultants resulting from the 1st Meeting of the BOC on January 30 to February 1, 2006.
[Submittal 20060307-0114]

February 15, 2006 Rebecca Wickhem to Daniel Mahoney: original exhibits that were marked during the interviews conducted on February 8-10, 2006.
[Submittal ?]

CDs (February 22, 2006 in eLibrary): KDG Drawings S3 (Lower Reservoir Dam Scour Survey), S4 (Lower Reservoir Dam Scour Survey), S5 (Upper Reservoir Silt Area Data). [Submittal 20060223-4009, 20060310-0009]

February 24, 2006 Mark Birk to Constantine Tjoumas: response to FERC's request numbers 32 and 33 from January 20, 2006. Also included is cover sheet for Ameren supplemental response to request number 20, also from the January 20 submittal (re. MWH draft report dated December 2005; inadvertently omitted from previous submittal). [Submittal 20060308-0074]

February 27, 2006 Mark Birk to Constantine Tjoumas: AmerenUE's proposed Safety Stabilization Plan for the Upper Reservoir at the Taum Sauk plant.
[Submittal 20060310-0194]

March 2, 2006 Mark Birk to Constantine Tjoumas: response to request number 4 of Section I and request number 1 of Section II from request dated February 3, 2006. Mike Peters discussions of 2/10 and 2/14, 2006 agreed that information request numbers 1, 2, 3 & 5 in Section I, and request numbers 2 & 3 in Section II have been responded to verbally during IPOC interviews and documented via interview notes; thus those responses are not being resubmitted with AmerenUE's response to the February 3rd inquiry.
[Submittal 20060313-0052]

March 6, 2006 Mark Birk to Constantine Tjoumas: responses to FERC's request numbers 1 through 6 on Enclosure 1 of Feb 21, 2006 request.
[Submittal 20060307-4009, 20060307-4010, 20060313-0154, 20060313-0155]

March 7, 2006 Mark Birk to Constantine Tjoumas: information inadvertently omitted from submittal to you dated Feb 7, 2006:
IMG093063 – 093139 – Enclosure 1, Question 3 and 16
IMG099001 – Enclosure 1, Question 3
IMG145770 – 145771 – Enclosure 2, Section III, Question 7
IMG146015 – 146588 – Enclosure 1, Question 29
IMG146596 – Enclosure 1, Question 36
IMG146598 – 146602 – Enclosure 1, Question 19
CDs: "2/7/06 Omitted – Submitted 3/7/06"
[Submittal 20060308-4003, 20060314-0034]

March 10, 2006 Mark Birk to Constantine Tjoumas: CD copy of information transmitted February 28, 2006 via an email sent to Wayne King in response to February 3, 2006 data request sec I, question 4. (CD labeled PLC Ladder Logic FERC Resp 2/3/06, Submitted 2/28/06).
[Not submitted to eLibrary as of March 23, 2006]

<u>Bibliography of FERC information Request to AmerenUE from December 2006 to March 10, 2006</u>

December 15, 2005 FERC-CRO 12.10 letter regarding the Breach Event

January 13, 2006 FERC- CRO 12.10 Letter regarding the September 25 Wave Overtopping

January 20, 2006 FERC-WO Information Request

February 3, 2006 FERC-WO Supplemental Information Request 1

February 21 FERC-WO Information Request

Appendices

A. **List of Excel Files- Reservoir Levels, Generation and Pump Records**
B. **Section 4 - Reservoir Levels, Pumping Intervals Analysis Charts**
C **Section 7 - Weather Data**
D. **Section 8 - Embankment Stability**
E. **Section 10 - List of Soils in the Impact Zone of Upper Reservoir Failure**

Appendix A.

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Appendix B. Reservoir Levels, Pumping Intervals Analysis Charts

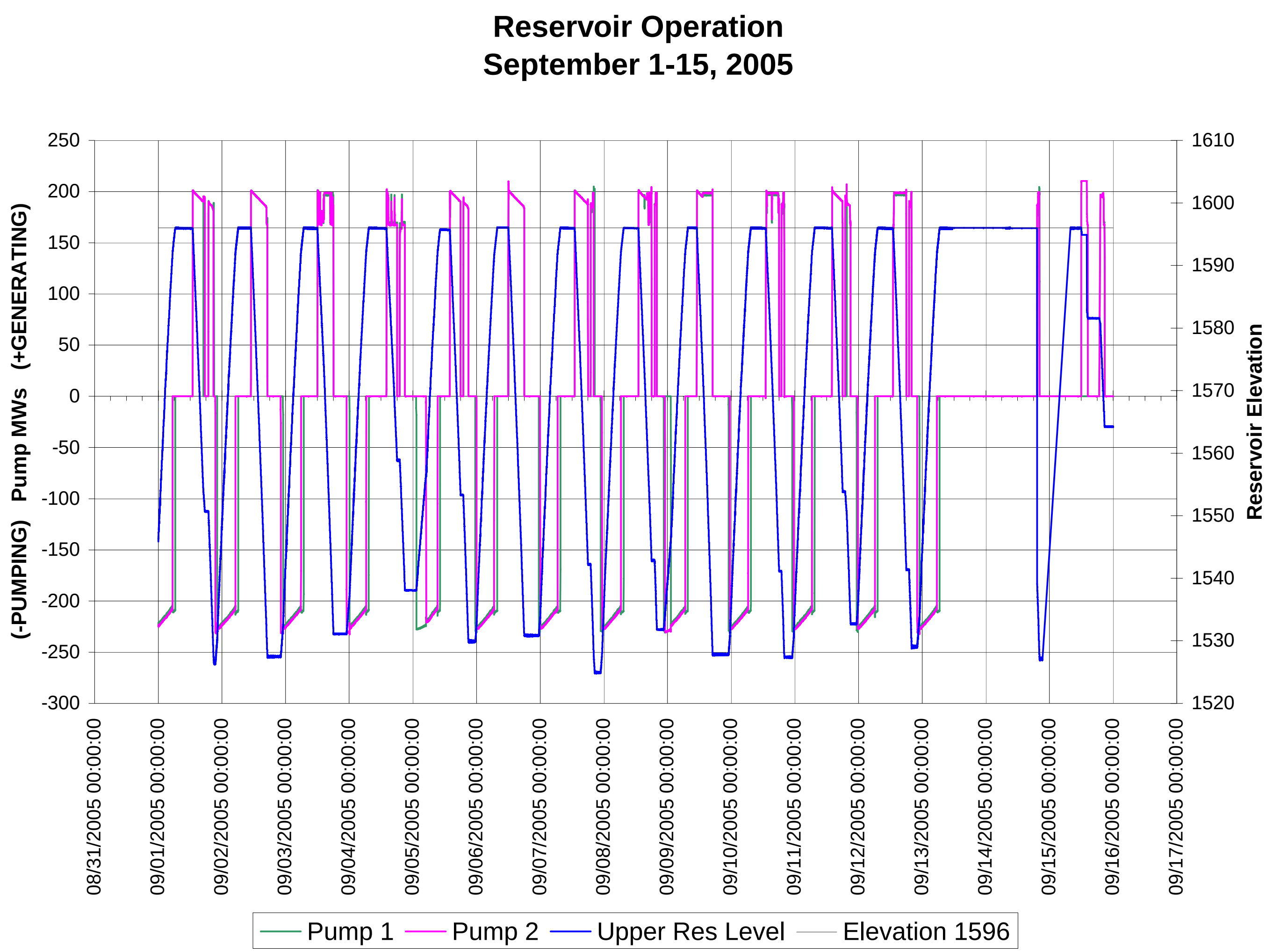

Reservoir Operation
September 1-15, 2005
(-PUMPING) Pump MWs (+GENERATING)
Reservoir Elevation
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1610
1600
1590
1580
1570
1560
1550
1540
1530
1520
08/31/2005 00:00:00
09/01/2005 00:00:00
09/02/2005 00:00:00
09/03/2005 00:00:00
09/04/2005 00:00:00
09/05/2005 00:00:00
09/06/2005 00:00:00
09/07/2005 00:00:00
09/08/2005 00:00:00
09/09/2005 00:00:00
09/10/2005 00:00:00
09/11/2005 00:00:00
09/12/2005 00:00:00
09/13/2005 00:00:00
09/14/2005 00:00:00
09/15/2005 00:00:00
09/16/2005 00:00:00
09/17/2005 00:00:00
Pump 1
Pump 2
Upper Res Level
Elevation 1596

Figure B.1

Reservoir Operation
September 15-30, 2005

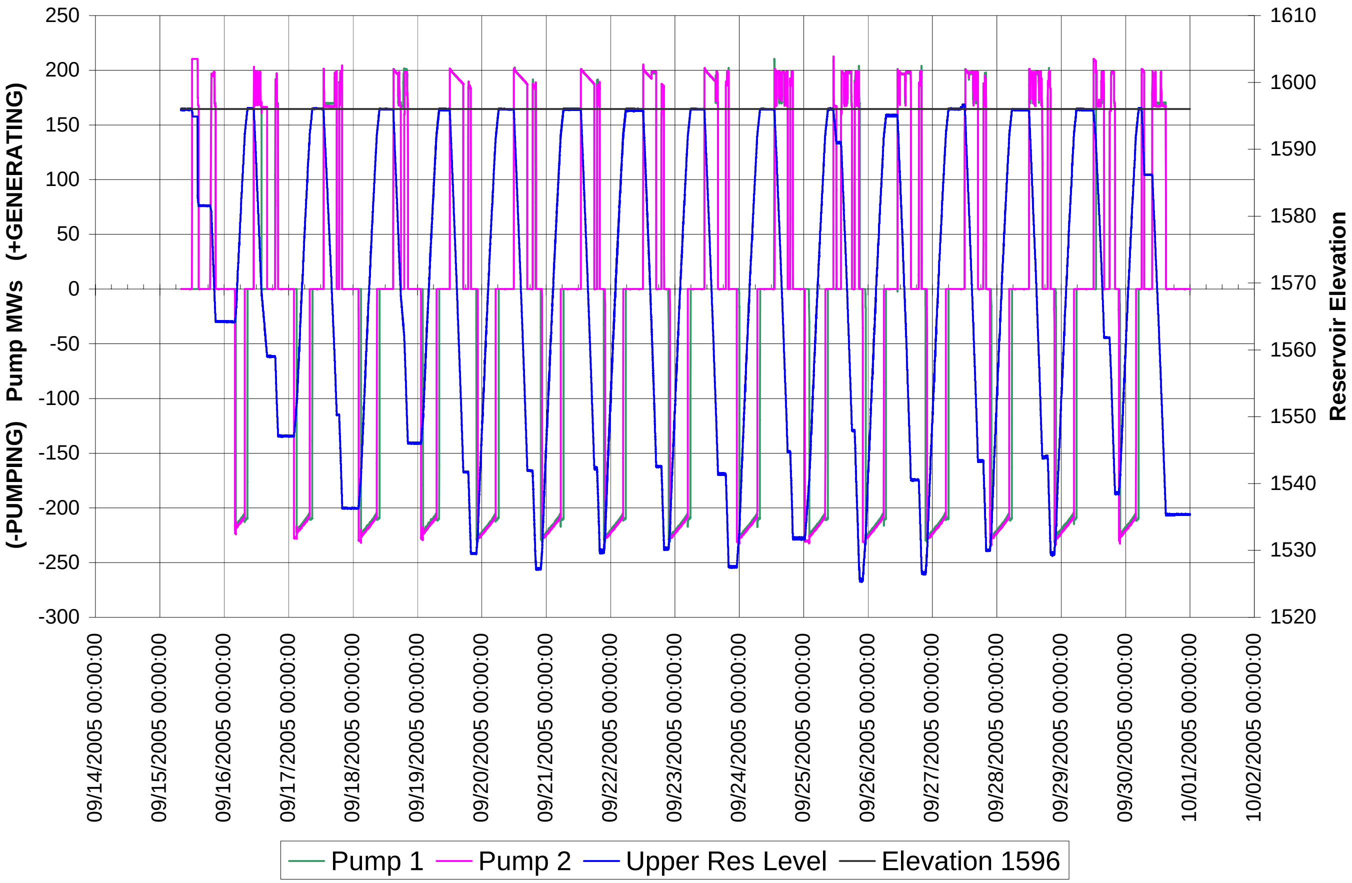


Figure B.2

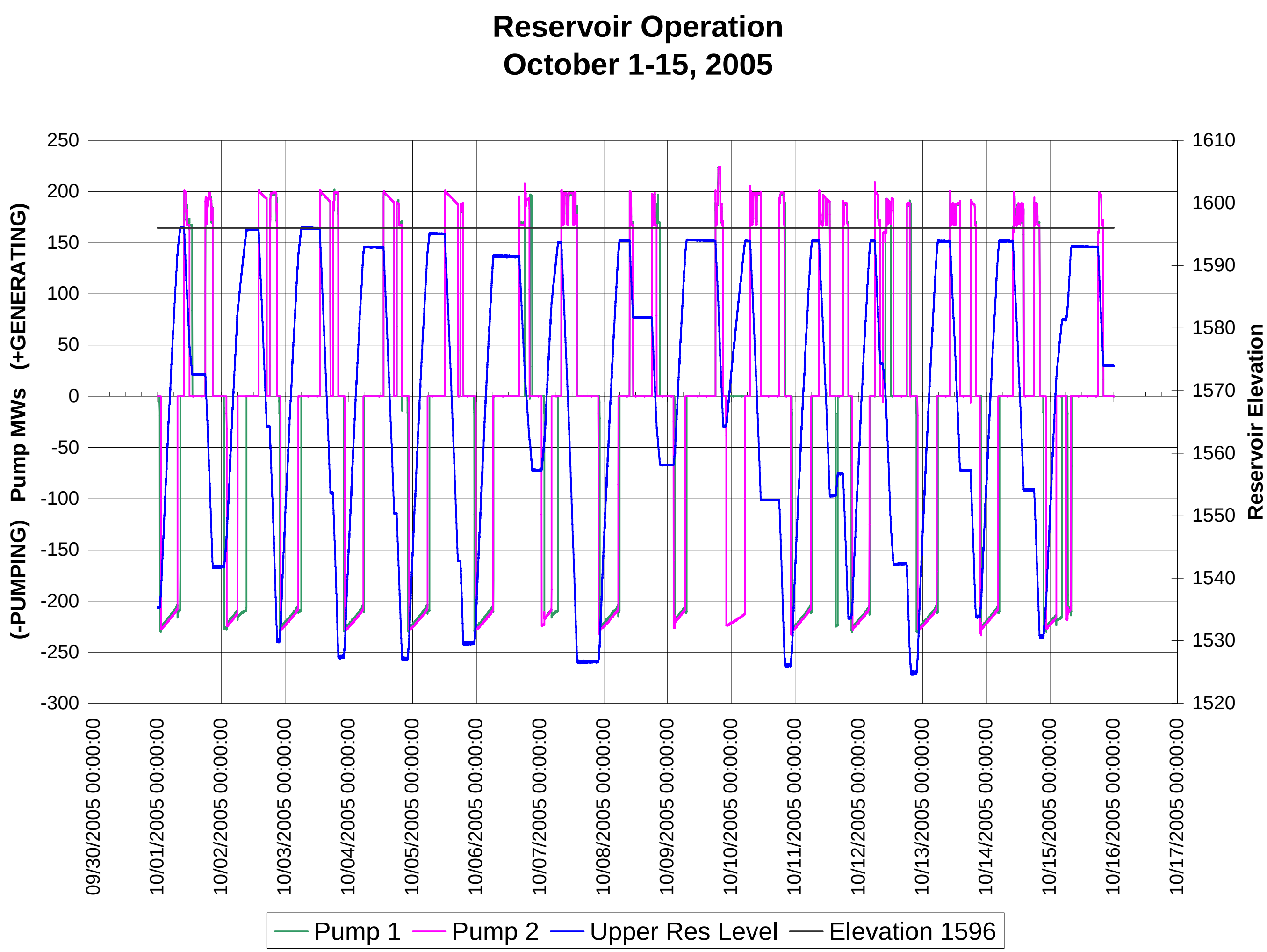
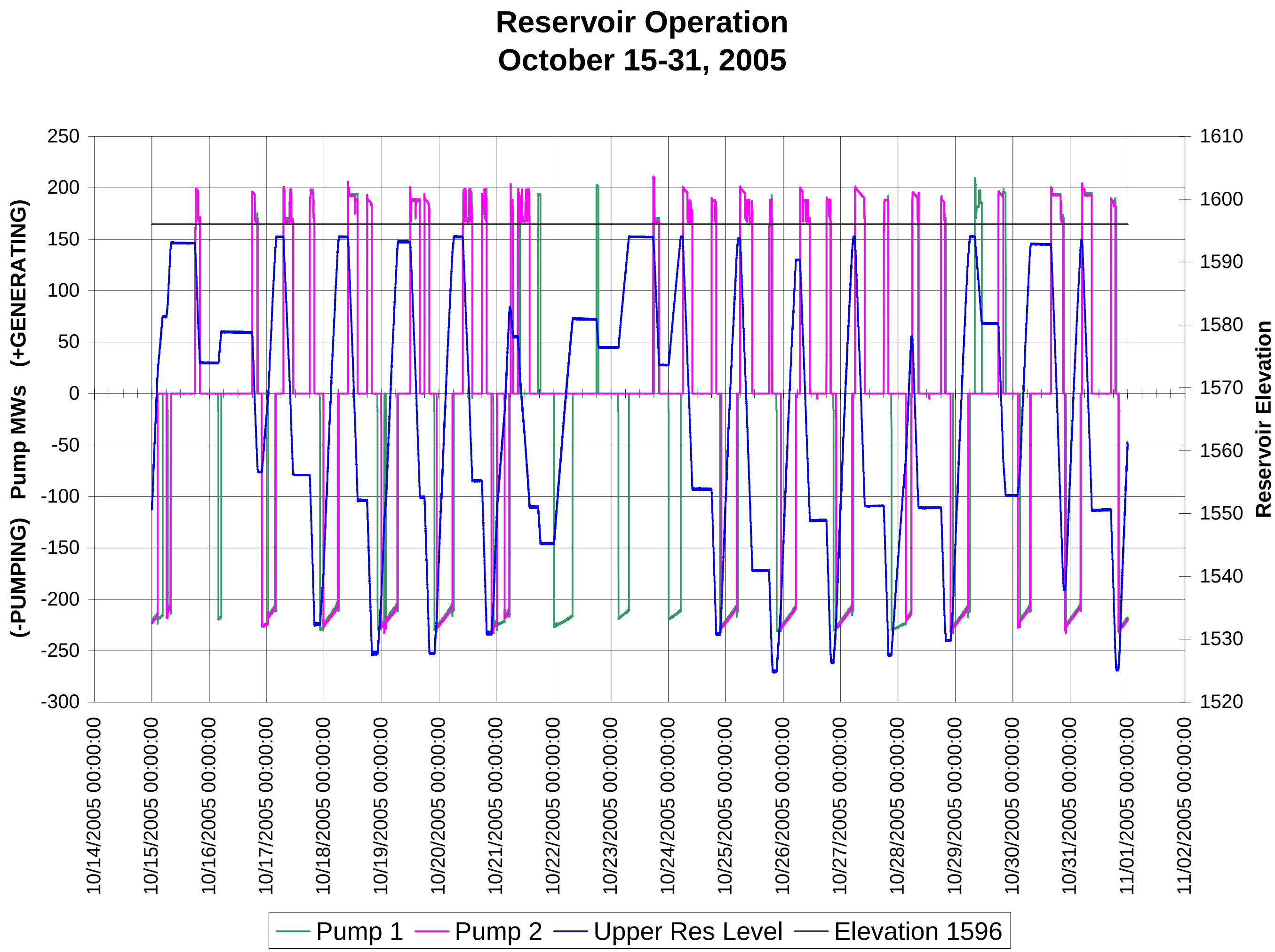

Reservoir Operation
October 1-15, 2005
(-PUMPING) Pump MWs (+GENERATING)
Reservoir Elevation
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1610
1600
1590
1580
1570
1560
1550
1540
1530
1520
09/30/2005 00:00:00
10/01/2005 00:00:00
10/02/2005 00:00:00
10/03/2005 00:00:00
10/04/2005 00:00:00
10/05/2005 00:00:00
10/06/2005 00:00:00
10/07/2005 00:00:00
10/08/2005 00:00:00
10/09/2005 00:00:00
10/10/2005 00:00:00
10/11/2005 00:00:00
10/12/2005 00:00:00
10/13/2005 00:00:00
10/14/2005 00:00:00
10/15/2005 00:00:00
10/16/2005 00:00:00
10/17/2005 00:00:00
Pump 1
Pump 2
Upper Res Level
Elevation 1596

Figure B.3



Reservoir Operation
October 15-31, 2005
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
(-PUMPING) Pump MWs (+GENERATING)
1610
1600
1590
1580
1570
1560
1550
1540
1530
1520
Reservoir Elevation
10/14/2005 00:00:00
10/15/2005 00:00:00
10/16/2005 00:00:00
10/17/2005 00:00:00
10/18/2005 00:00:00
10/19/2005 00:00:00
10/20/2005 00:00:00
10/21/2005 00:00:00
10/22/2005 00:00:00
10/23/2005 00:00:00
10/24/2005 00:00:00
10/25/2005 00:00:00
10/26/2005 00:00:00
10/27/2005 00:00:00
10/28/2005 00:00:00
10/29/2005 00:00:00
10/30/2005 00:00:00
10/31/2005 00:00:00
11/01/2005 00:00:00
11/02/2005 00:00:00
Pump 1
Pump 2
Upper Res Level
Elevation 1596

Figure B.4

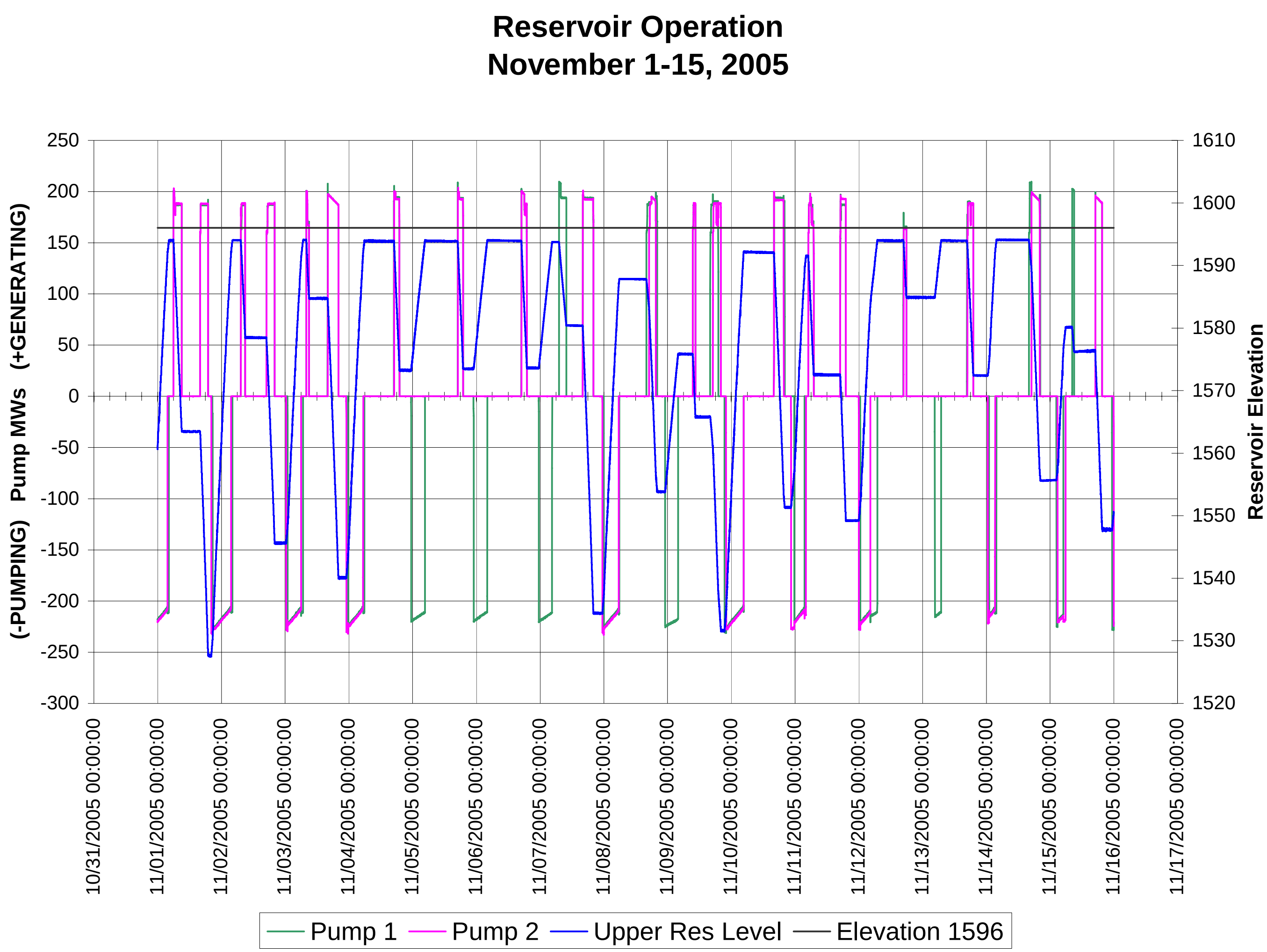
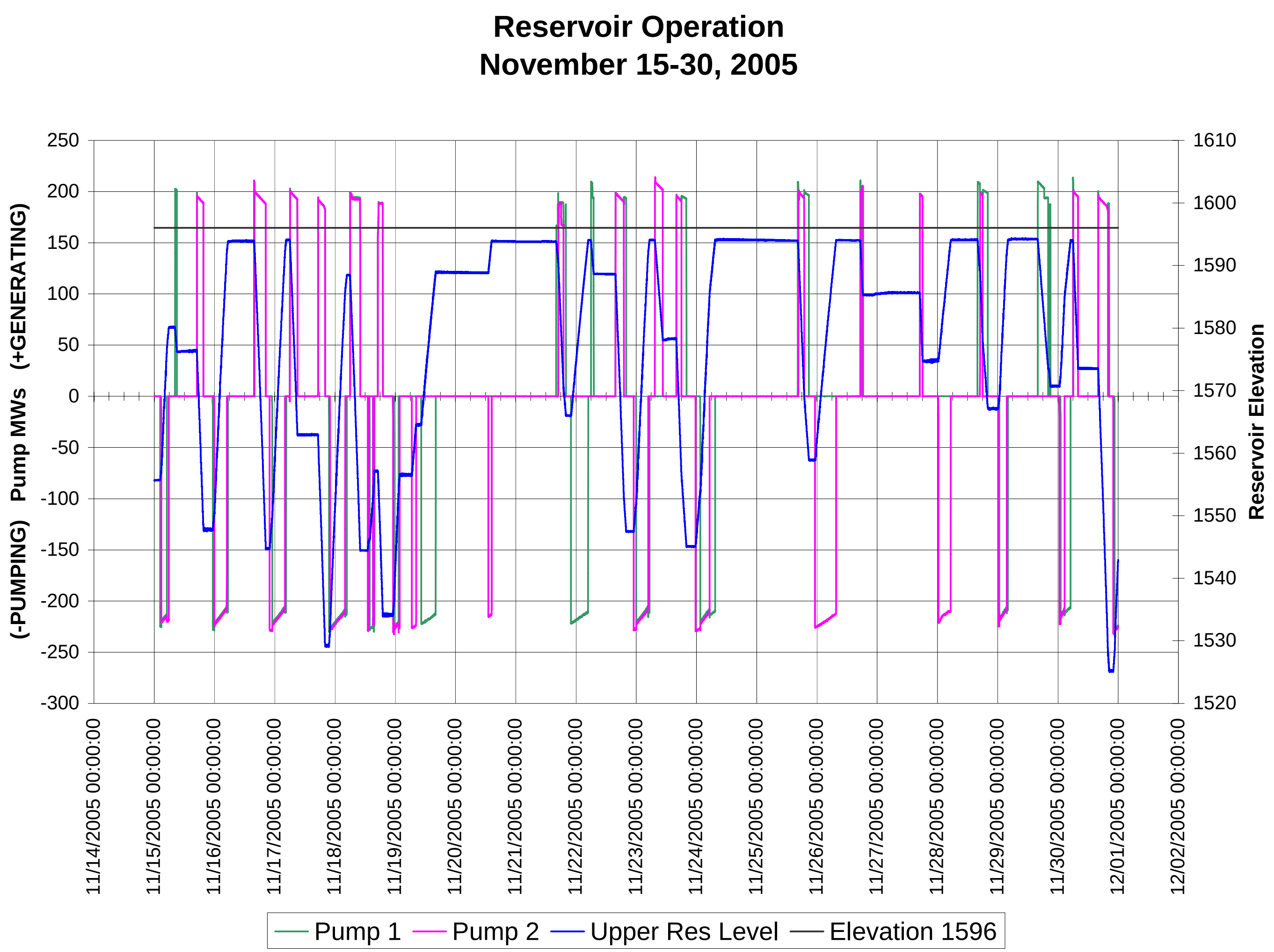

Reservoir Operation
November 1-15, 2005
(-PUMPING) Pump MWs (+GENERATING)
Reservoir Elevation
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1610
1600
1590
1580
1570
1560
1550
1540
1530
1520
10/31/2005 00:00:00
11/01/2005 00:00:00
11/02/2005 00:00:00
11/03/2005 00:00:00
11/04/2005 00:00:00
11/05/2005 00:00:00
11/06/2005 00:00:00
11/07/2005 00:00:00
11/08/2005 00:00:00
11/09/2005 00:00:00
11/10/2005 00:00:00
11/11/2005 00:00:00
11/12/2005 00:00:00
11/13/2005 00:00:00
11/14/2005 00:00:00
11/15/2005 00:00:00
11/16/2005 00:00:00
11/17/2005 00:00:00
Pump 1
Pump 2
Upper Res Level
Elevation 1596

Figure B.5



Reservoir Operation
November 15-30, 2005
(-PUMPING) Pump MWs (+GENERATING)
Reservoir Elevation
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1610
1600
1590
1580
1570
1560
1550
1540
1530
1520
11/14/2005 00:00:00
11/15/2005 00:00:00
11/16/2005 00:00:00
11/17/2005 00:00:00
11/18/2005 00:00:00
11/19/2005 00:00:00
11/20/2005 00:00:00
11/21/2005 00:00:00
11/22/2005 00:00:00
11/23/2005 00:00:00
11/24/2005 00:00:00
11/25/2005 00:00:00
11/26/2005 00:00:00
11/27/2005 00:00:00
11/28/2005 00:00:00
11/29/2005 00:00:00
11/30/2005 00:00:00
12/01/2005 00:00:00
12/02/2005 00:00:00
Pump 1
Pump 2
Upper Res Level
Elevation 1596

Figure B.6


Reservoir Operation
December 1-14, 2005
(-PUMPING) Pump MWs (+GENERATING)
Reservoir Elevation
250
200
150
100
50
0
-50
-100
-150
-200
-250
-300
1610
1600
1590
1580
1570
1560
1550
1540
1530
1520
11/30/2005 00:00:00
12/01/2005 00:00:00
12/02/2005 00:00:00
12/03/2005 00:00:00
12/04/2005 00:00:00
12/05/2005 00:00:00
12/06/2005 00:00:00
12/07/2005 00:00:00
12/08/2005 00:00:00
12/09/2005 00:00:00
12/10/2005 00:00:00
12/11/2005 00:00:00
12/12/2005 00:00:00
12/13/2005 00:00:00
12/14/2005 00:00:00
12/15/2005 00:00:00
Pump 1
Pump 2
Upper Res Level
Elevation 1596

Figure B.7

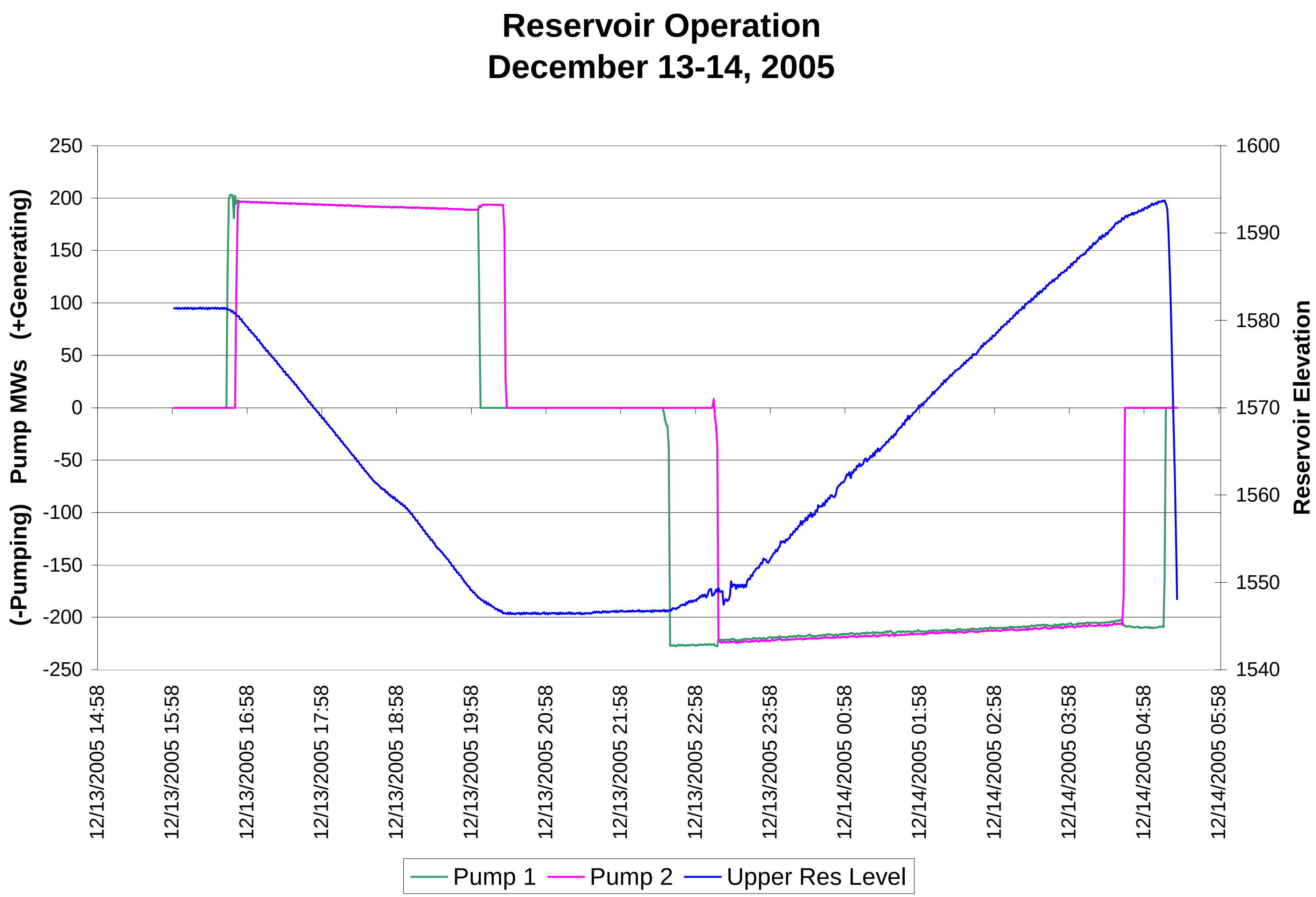
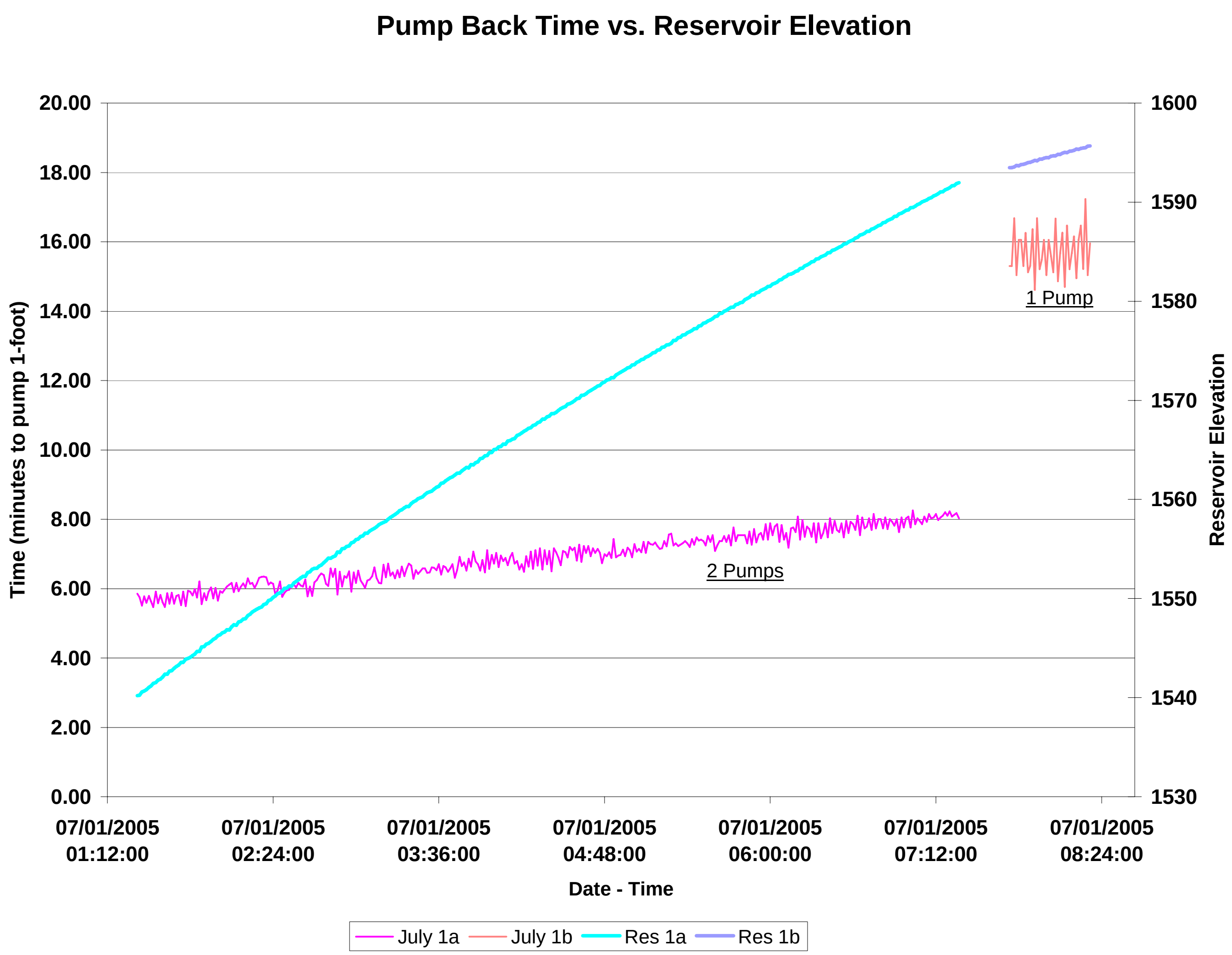

Reservoir Operation
December 13-14, 2005
(-Pumping) Pump MWs (+Generating)
250
200
150
100
50
0
-50
-100
-150
-200
-250
Reservoir Elevation
1600
1590
1580
1570
1560
1550
1540
12/13/2005 14:58
12/13/2005 15:58
12/13/2005 16:58
12/13/2005 17:58
12/13/2005 18:58
12/13/2005 19:58
12/13/2005 20:58
12/13/2005 21:58
12/13/2005 22:58
12/13/2005 23:58
12/14/2005 00:58
12/14/2005 01:58
12/14/2005 02:58
12/14/2005 03:58
12/14/2005 04:58
12/14/2005 05:58
Pump 1
Pump 2
Upper Res Level

Figure B.8



Pump Back Time vs. Reservoir Elevation
Time (minutes to pump 1-foot)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1600
1590
1580
1570
1560
1550
1540
1530
Reservoir Elevation
1 Pump
2 Pumps
07/01/2005 01:12:00
07/01/2005 02:24:00
07/01/2005 03:36:00
07/01/2005 04:48:00
07/01/2005 06:00:00
07/01/2005 07:12:00
07/01/2005 08:24:00
Date - Time
July 1a
July 1b
Res 1a
Res 1b

Figure B.9

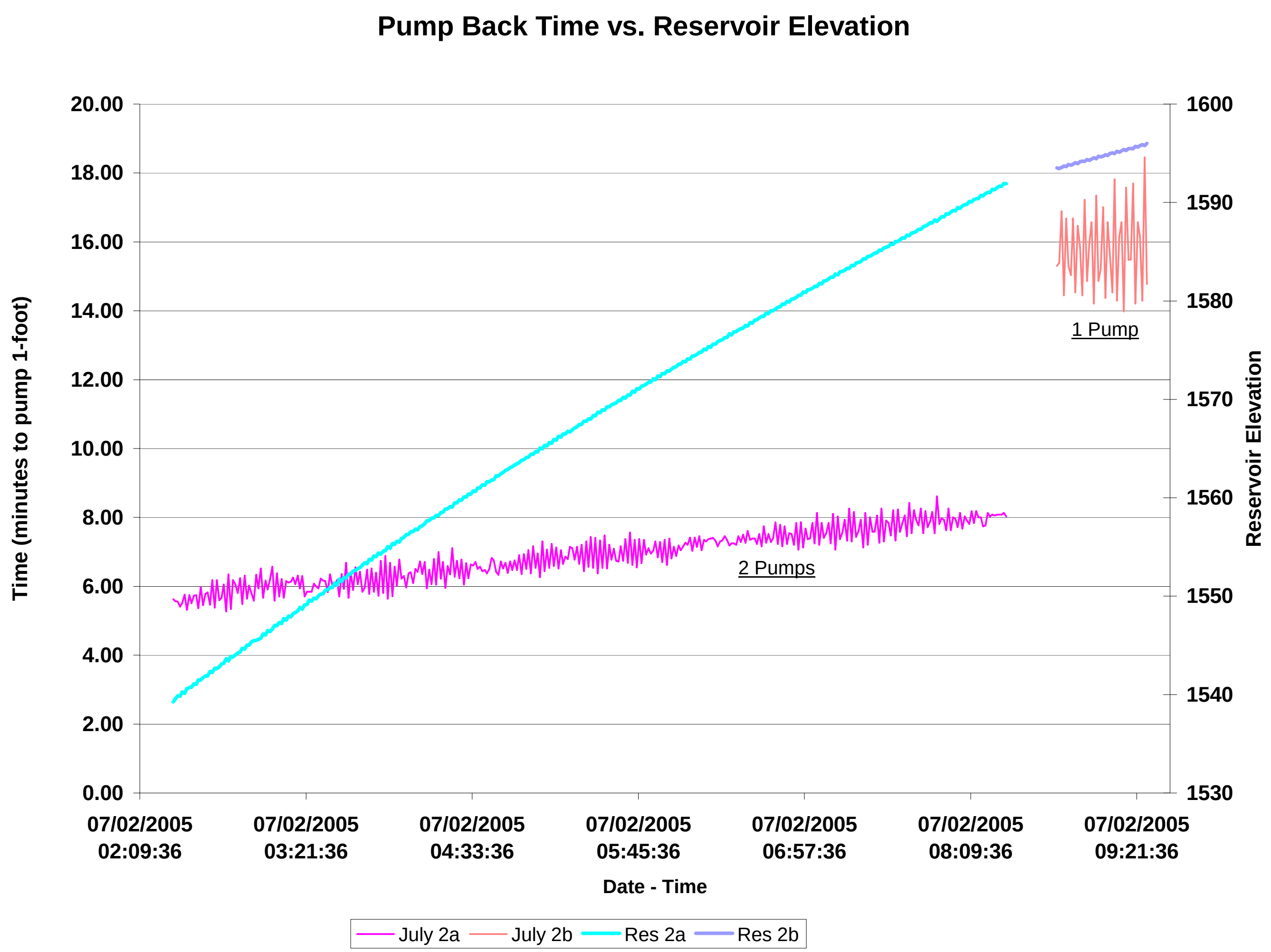

Pump Back Time vs. Reservoir Elevation
Time (minutes to pump 1-foot)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1600
1590
1580
1570
1560
1550
1540
1530
Reservoir Elevation
1 Pump
2 Pumps
07/02/2005 02:09:36
07/02/2005 03:21:36
07/02/2005 04:33:36
07/02/2005 05:45:36
07/02/2005 06:57:36
07/02/2005 08:09:36
07/02/2005 09:21:36
Date - Time
July 2a
July 2b
Res 2a
Res 2b

Figure B.10

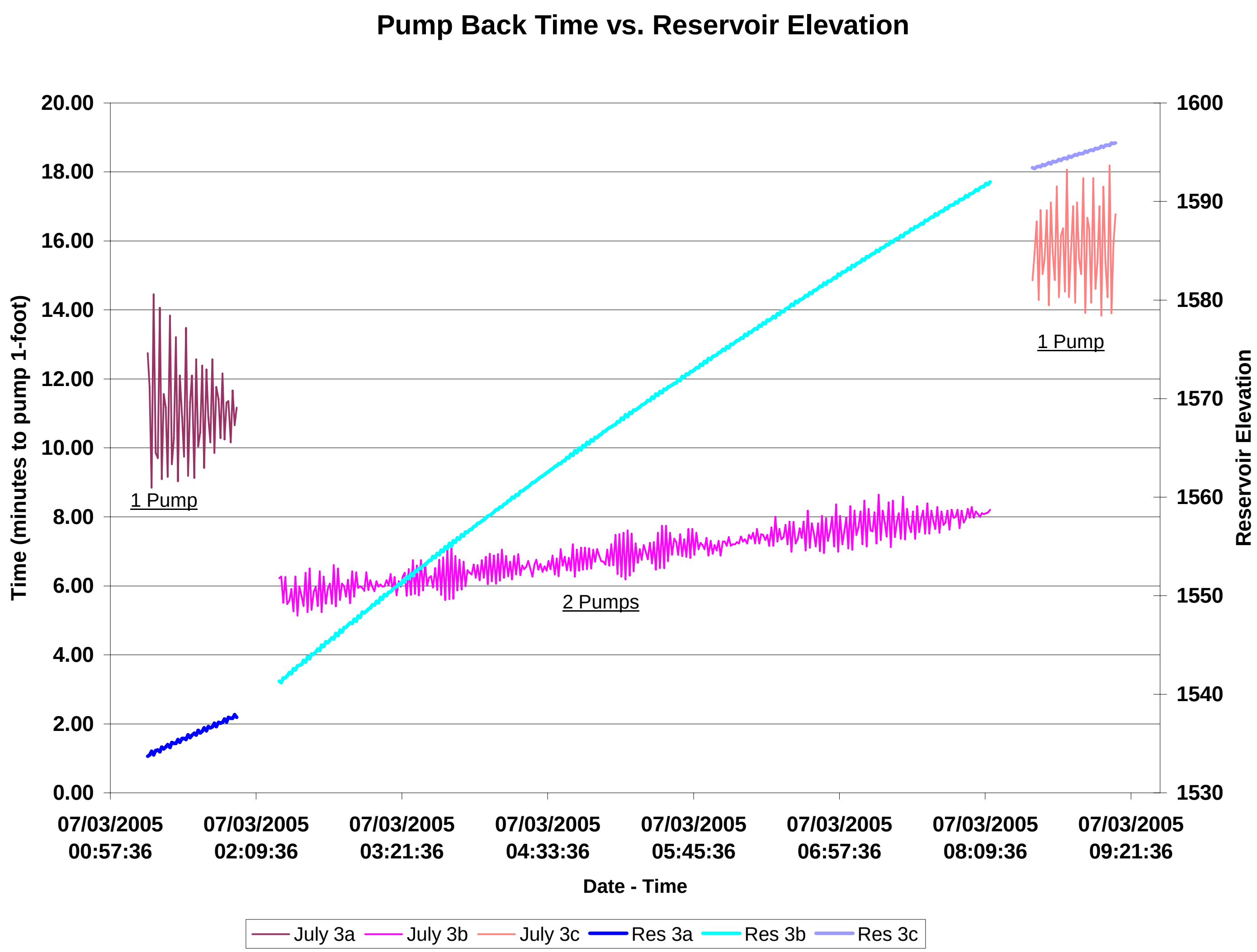
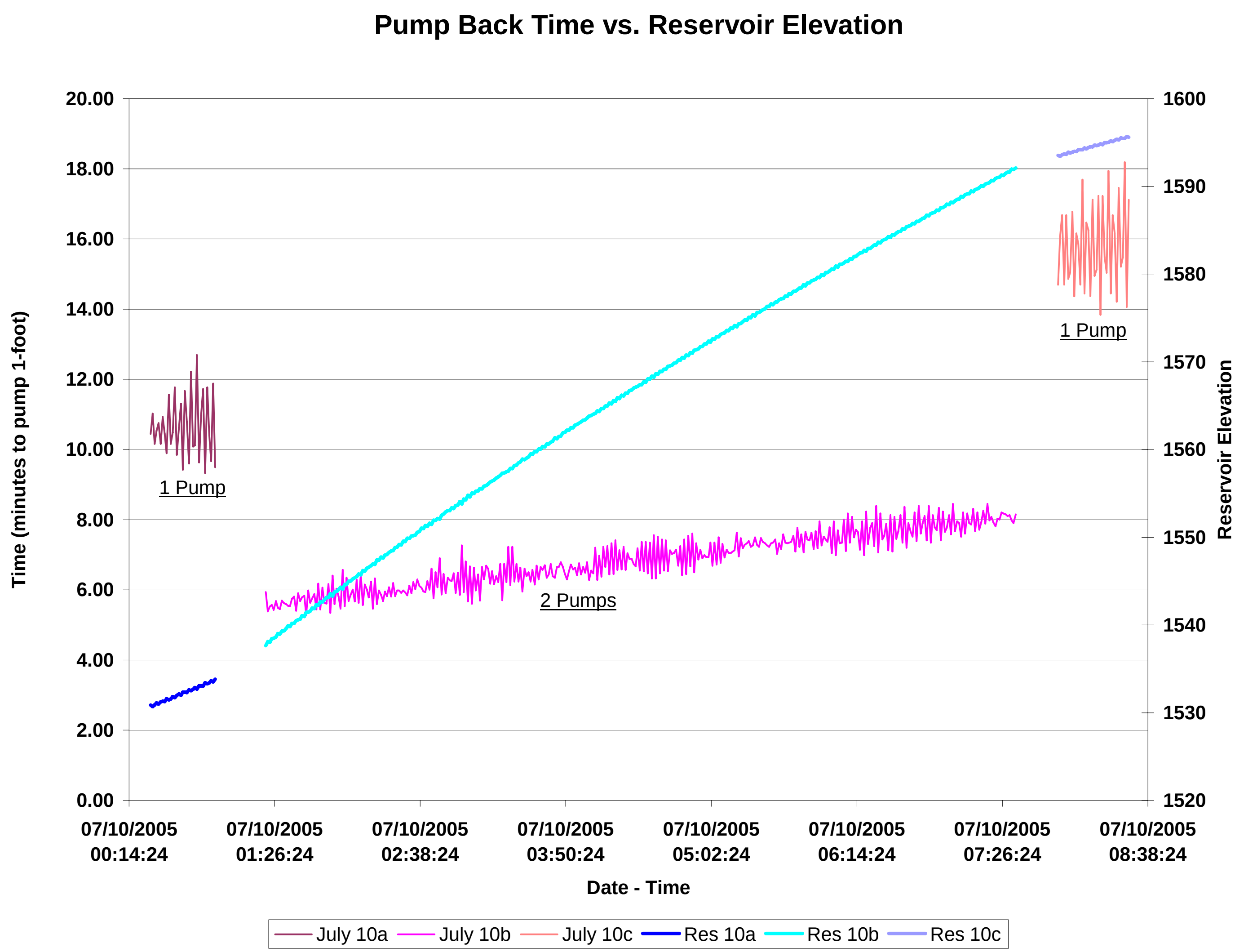
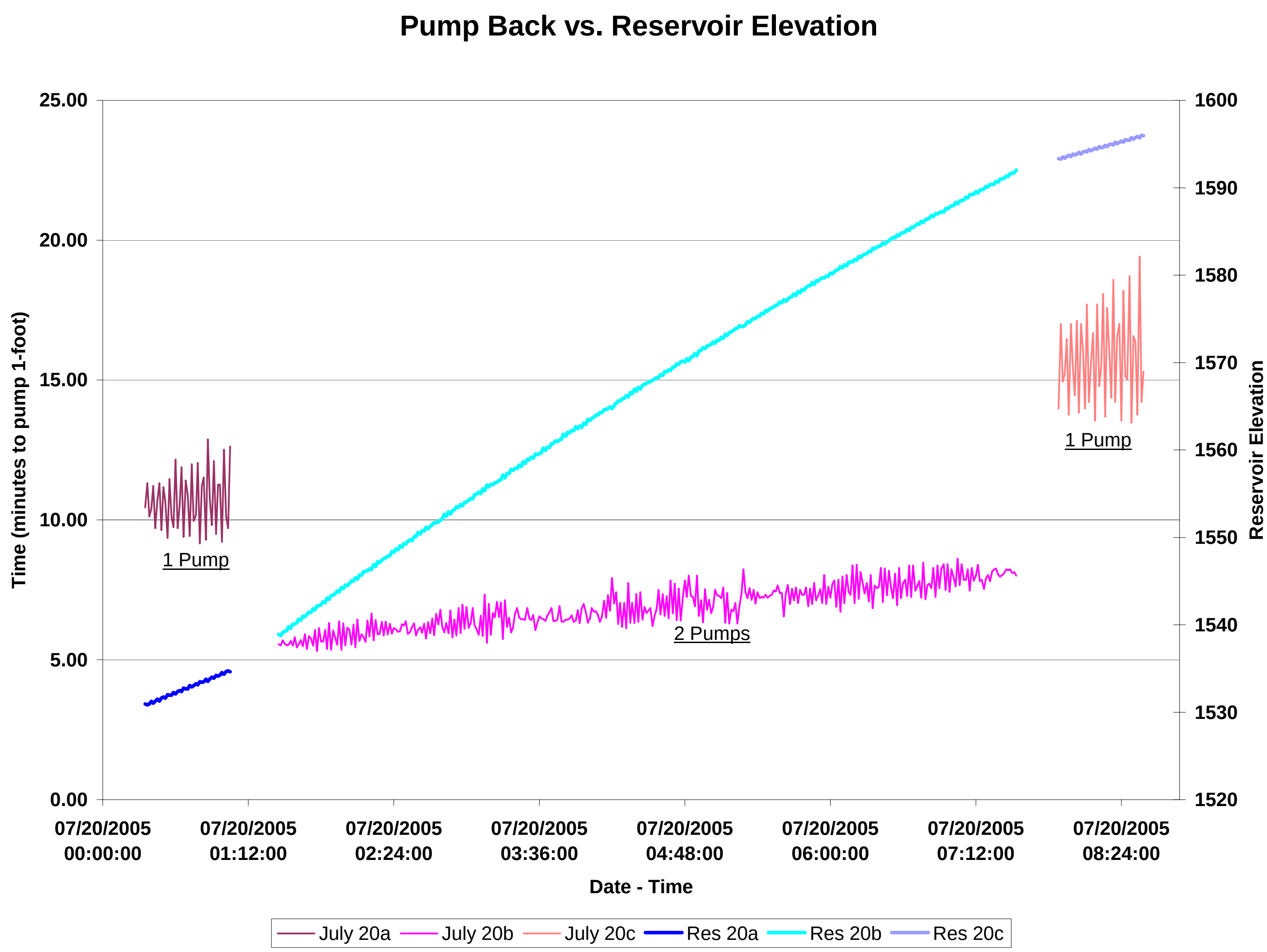

Pump Back Time vs. Reservoir Elevation
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Time (minutes to pump 1-foot)
1600
1590
1580
1570
1560
1550
1540
1530
Reservoir Elevation
1 Pump
2 Pumps
1 Pump
07/03/2005 00:57:36
07/03/2005 02:09:36
07/03/2005 03:21:36
07/03/2005 04:33:36
07/03/2005 05:45:36
07/03/2005 06:57:36
07/03/2005 08:09:36
07/03/2005 09:21:36
Date - Time
July 3a
July 3b
July 3c
Res 3a
Res 3b
Res 3c

Figure B.11



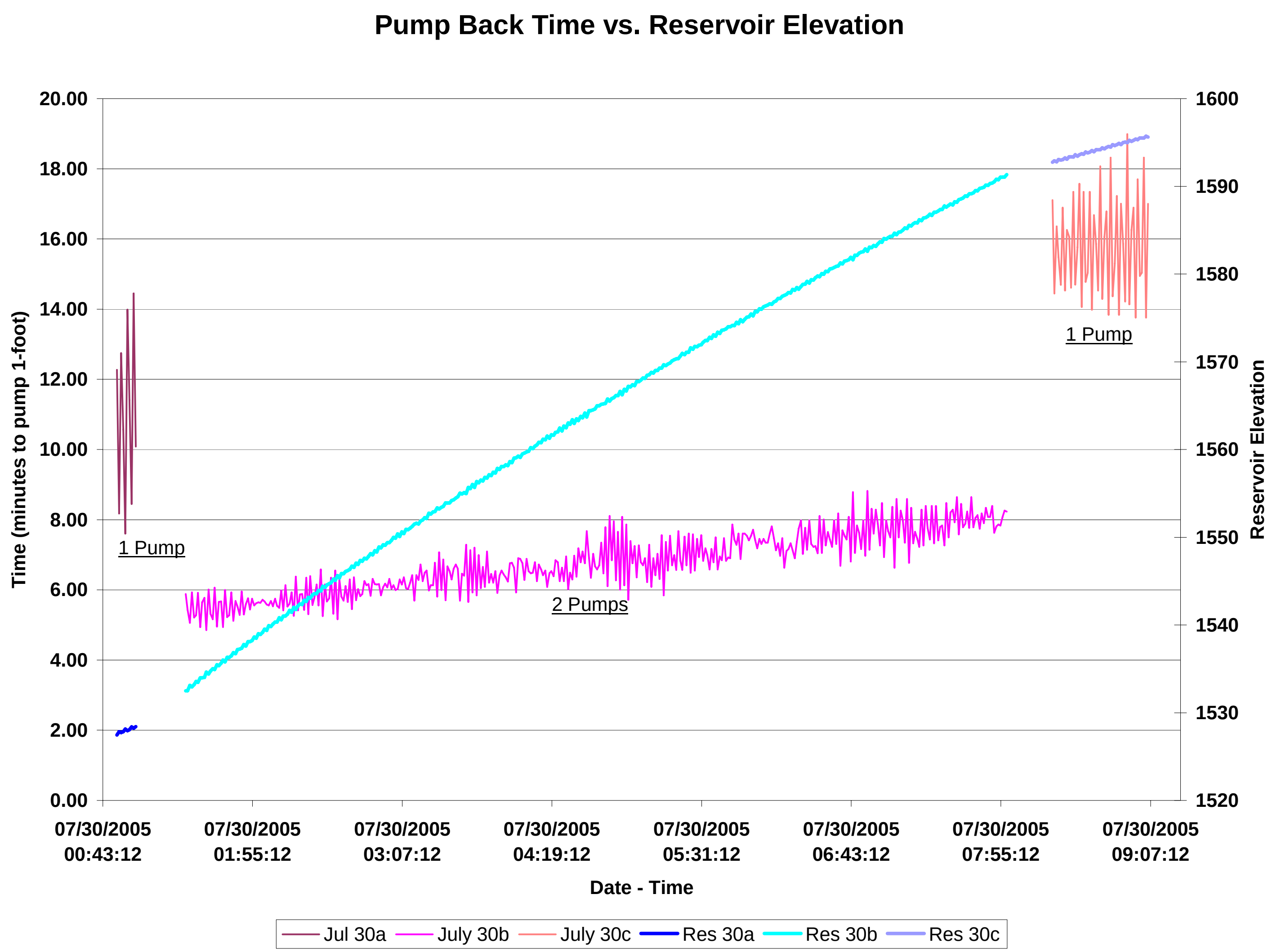
Pump Back Time vs. Reservoir Elevation
Time (minutes to pump 1-foot)
Reservoir Elevation
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
1600
1590
1580
1570
1560
1550
1540
1530
1520
1 Pump
2 Pumps
1 Pump
07/10/2005 00:14:24
07/10/2005 01:26:24
07/10/2005 02:38:24
07/10/2005 03:50:24
07/10/2005 05:02:24
07/10/2005 06:14:24
07/10/2005 07:26:24
07/10/2005 08:38:24
Date - Time
July 10a
July 10b
July 10c
Res 10a
Res 10b
Res 10c

Figure B.12



Pump Back vs. Reservoir Elevation
25.00
20.00
15.00
10.00
5.00
0.00
Time (minutes to pump 1-foot)
1600
1590
1580
1570
1560
1550
1540
1530
1520
Reservoir Elevation
1 Pump
2 Pumps
1 Pump
07/20/2005 00:00:00
07/20/2005 01:12:00
07/20/2005 02:24:00
07/20/2005 03:36:00
07/20/2005 04:48:00
07/20/2005 06:00:00
07/20/2005 07:12:00
07/20/2005 08:24:00
Date - Time
July 20a
July 20b
July 20c
Res 20a
Res 20b
Res 20c

Figure B.13



Pump Back Time vs. Reservoir Elevation
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Time (minutes to pump 1-foot)
1600
1590
1580
1570
1560
1550
1540
1530
1520
Reservoir Elevation
1 Pump
2 Pumps
1 Pump
07/30/2005 00:43:12
07/30/2005 01:55:12
07/30/2005 03:07:12
07/30/2005 04:19:12
07/30/2005 05:31:12
07/30/2005 06:43:12
07/30/2005 07:55:12
07/30/2005 09:07:12
Date - Time
Jul 30a
July 30b
July 30c
Res 30a
Res 30b
Res 30c

Figure B.14

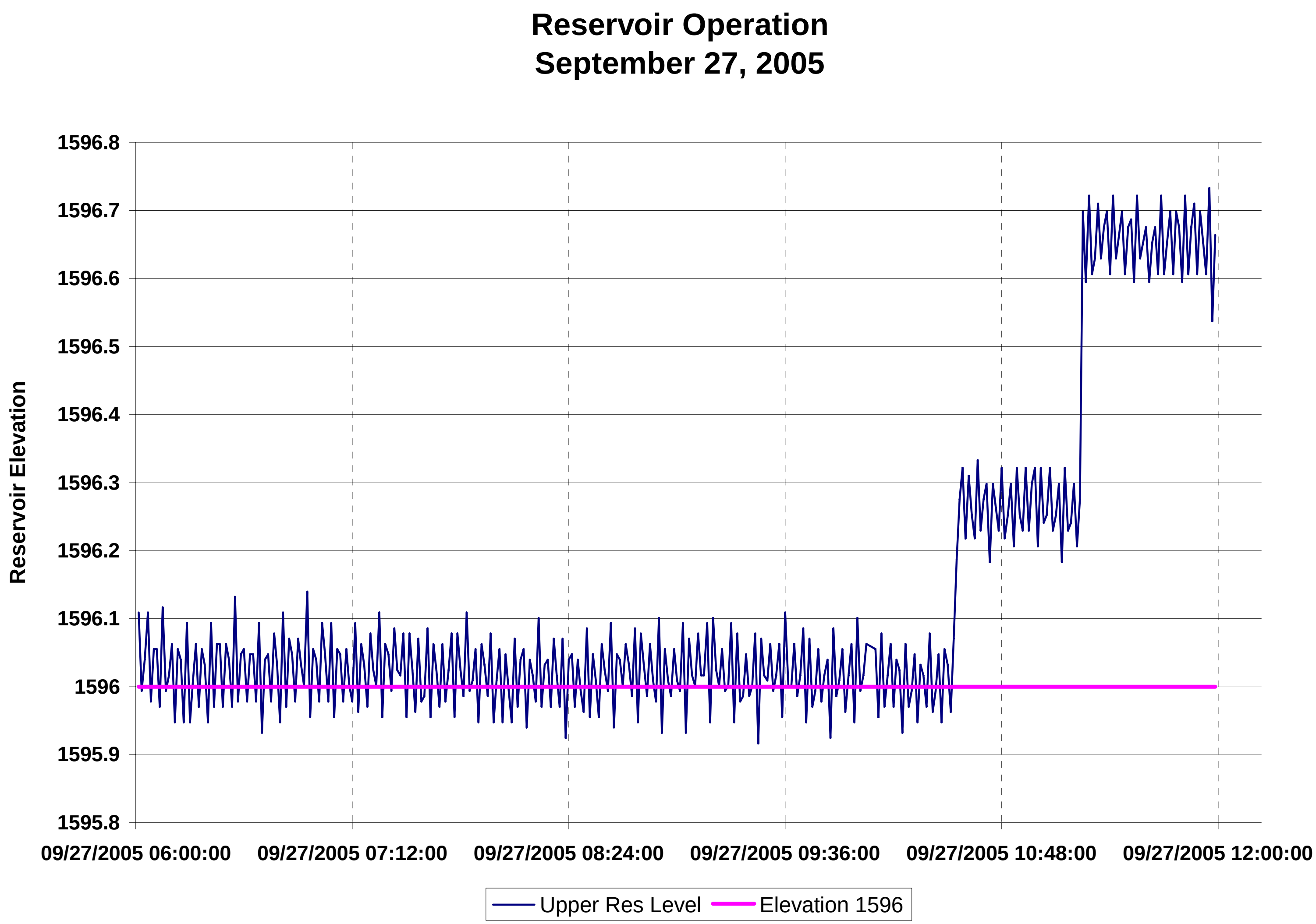

Reservoir Operation
September 27, 2005
Reservoir Elevation
1596.8
1596.7
1596.6
1596.5
1596.4
1596.3
1596.2
1596.1
1596
1595.9
1595.8
09/27/2005 06:00:00
09/27/2005 07:12:00
09/27/2005 08:24:00
09/27/2005 09:36:00
09/27/2005 10:48:00
09/27/2005 12:00:00
Upper Res Level
Elevation 1596

Figure B.15

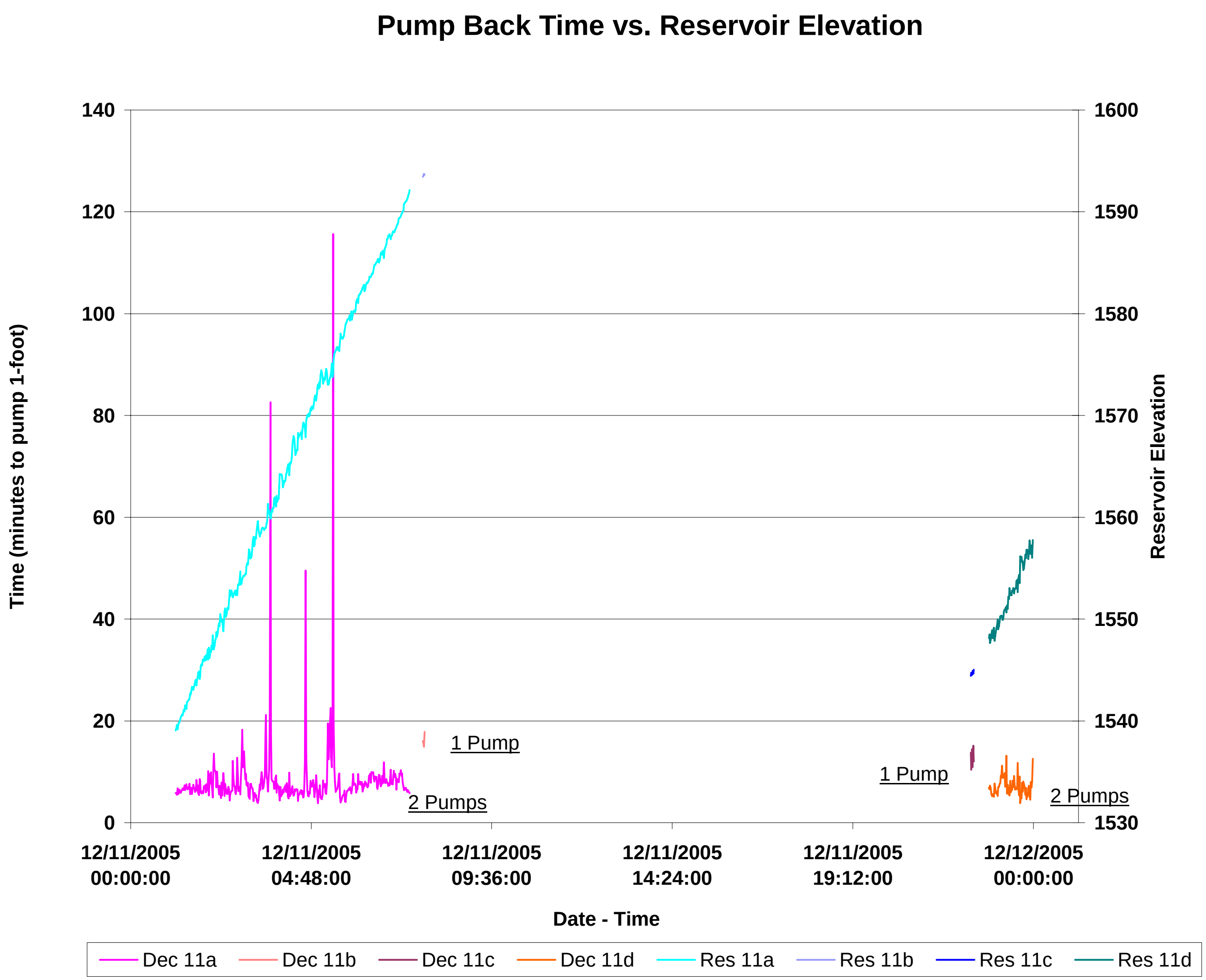

Pump Back Time vs. Reservoir Elevation
Time (minutes to pump 1-foot)
Reservoir Elevation
0
20
40
60
80
100
120
140
1530
1540
1550
1560
1570
1580
1590
1600
1 Pump
2 Pumps
1 Pump
2 Pumps
12/11/2005 00:00:00
12/11/2005 04:48:00
12/11/2005 09:36:00
12/11/2005 14:24:00
12/11/2005 19:12:00
12/12/2005 00:00:00
Date - Time
Dec 11a
Dec 11b
Dec 11c
Dec 11d
Res 11a
Res 11b
Res 11c
Res 11d

Figure B.16

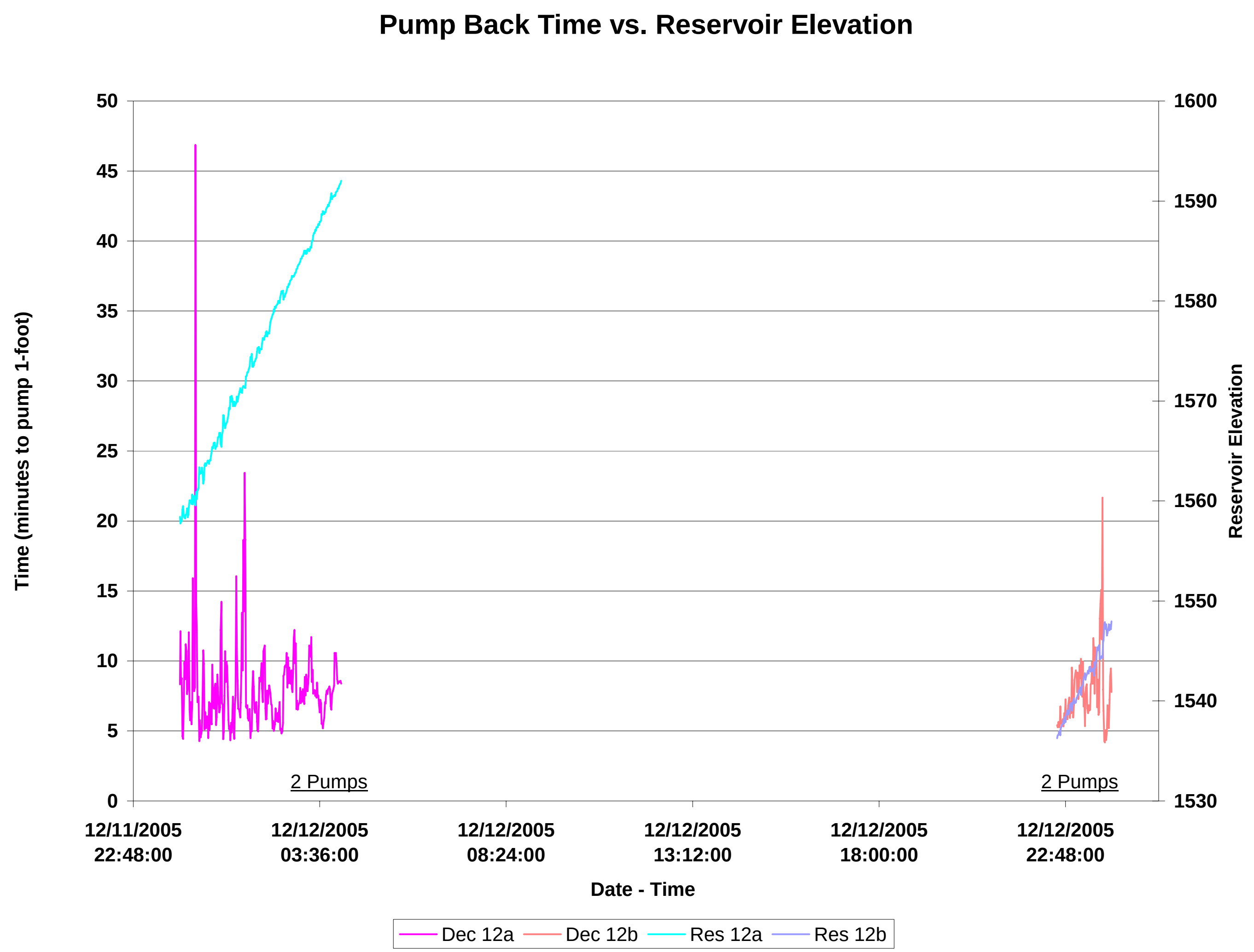
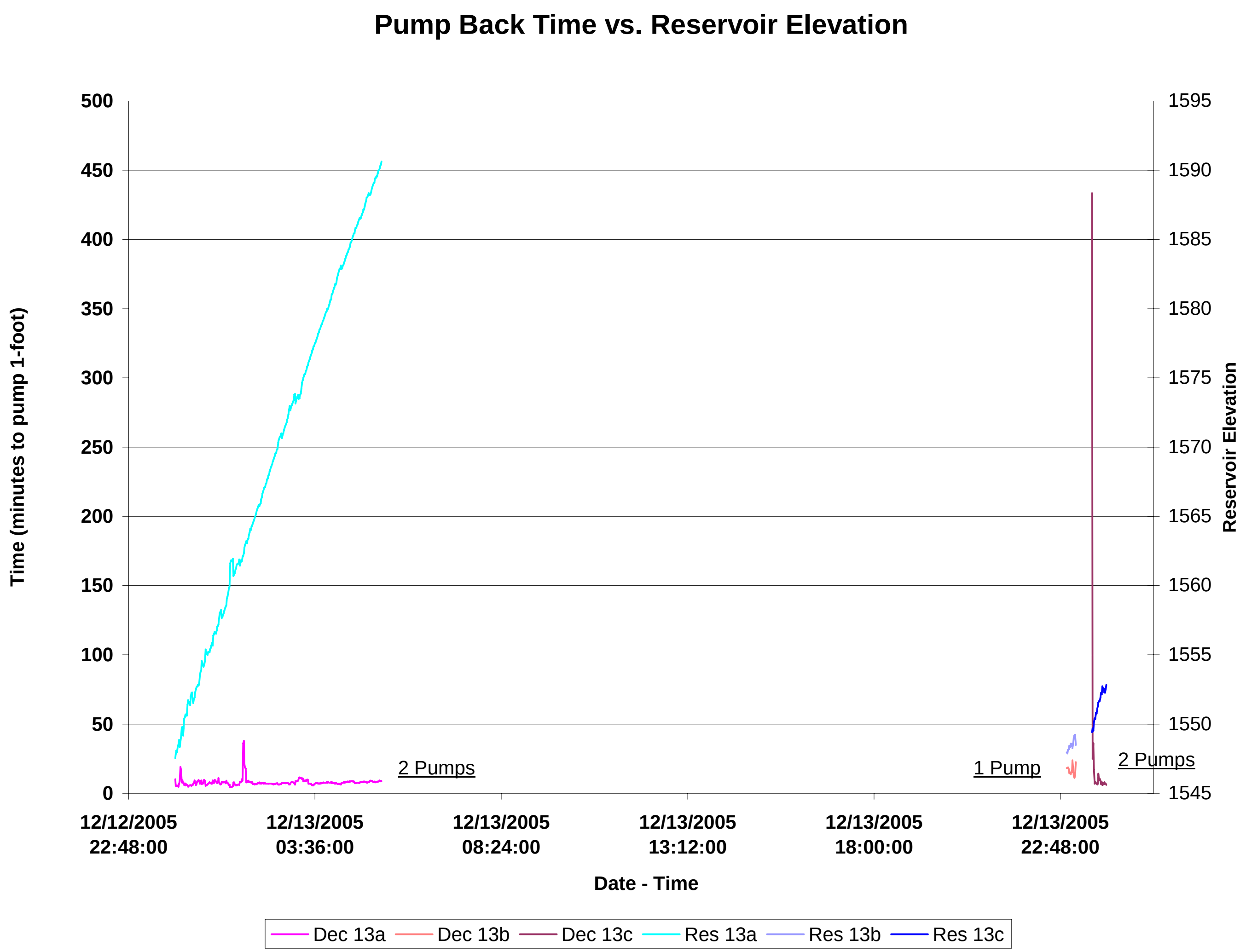

Pump Back Time vs. Reservoir Elevation
Time (minutes to pump 1-foot)
Reservoir Elevation
50
45
40
35
30
25
20
15
10
5
0
1600
1590
1580
1570
1560
1550
1540
1530
2 Pumps
2 Pumps
12/11/2005 22:48:00
12/12/2005 03:36:00
12/12/2005 08:24:00
12/12/2005 13:12:00
12/12/2005 18:00:00
12/12/2005 22:48:00
Date - Time
Dec 12a
Dec 12b
Res 12a
Res 12b

Figure B.17



Pump Back Time vs. Reservoir Elevation
Time (minutes to pump 1-foot)
500
450
400
350
300
250
200
150
100
50
0
Reservoir Elevation
1595
1590
1585
1580
1575
1570
1565
1560
1555
1550
1545
2 Pumps
1 Pump
2 Pumps
12/12/2005 22:48:00
12/13/2005 03:36:00
12/13/2005 08:24:00
12/13/2005 13:12:00
12/13/2005 18:00:00
12/13/2005 22:48:00
Date - Time
Dec 13a
Dec 13b
Dec 13c
Res 13a
Res 13b
Res 13c

Figure B.18

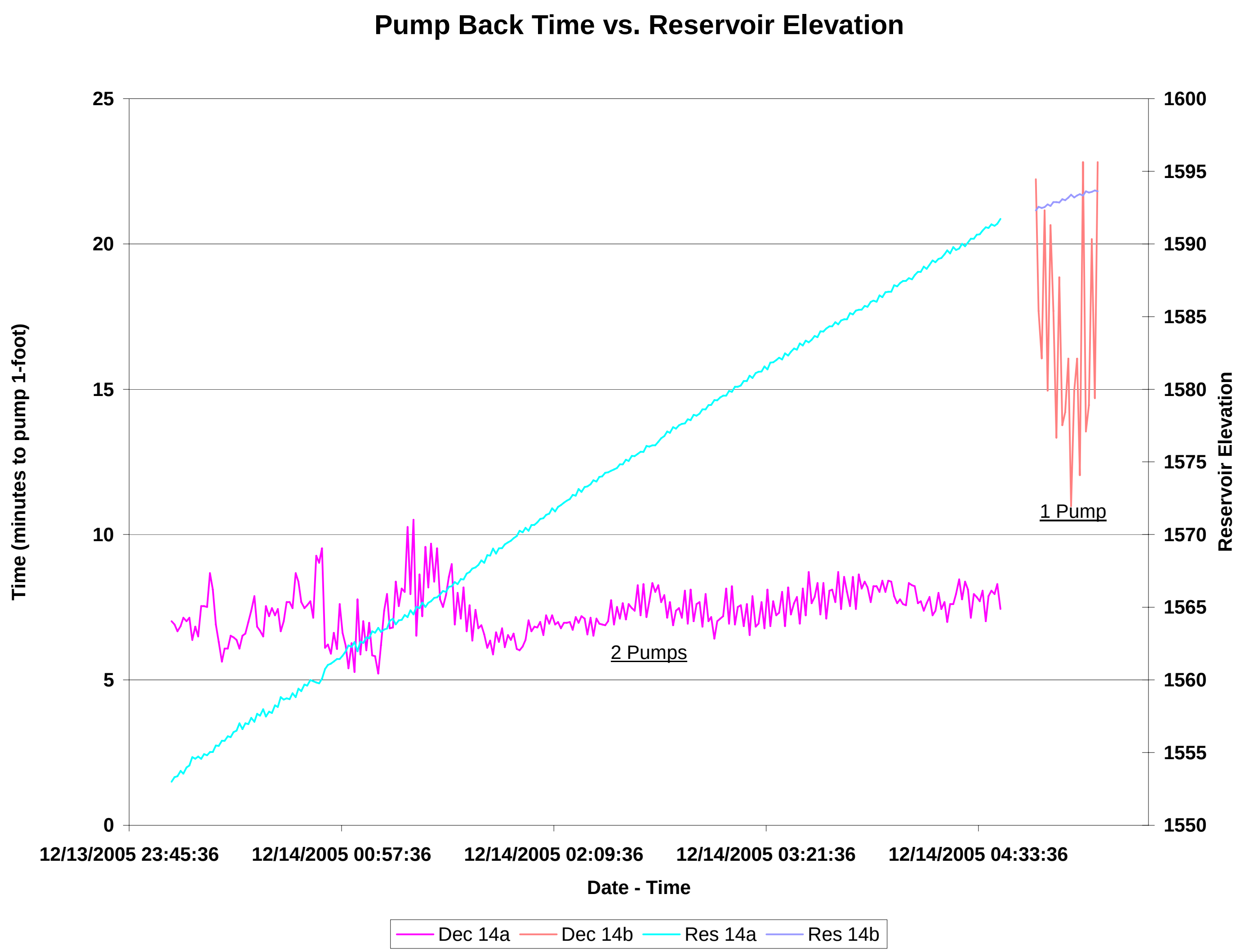

Pump Back Time vs. Reservoir Elevation
25
20
15
10
5
0
1600
1595
1590
1585
1580
1575
1570
1565
1560
1555
1550
Time (minutes to pump 1-foot)
Reservoir Elevation
1 Pump
2 Pumps
12/13/2005 23:45:36
12/14/2005 00:57:36
12/14/2005 02:09:36
12/14/2005 03:21:36
12/14/2005 04:33:36
Date - Time
Dec 14a
Dec 14b
Res 14a
Res 14b

Figure B.19

Appendix C. Weather Data

September 24-27 Weather Information

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/24/05 12:00 AM		0		2	7.0		72	70	30.05				
9/24/05 12:15 AM		0		2	5.0		72	70	30.05				
9/24/05 12:35 AM		0		2	3.0		70	70	30.05				
9/24/05 1:00 AM		0		2	4.0		70	70	30.05				
9/24/05 1:15 AM		0		2	3.0		70	70	30.04				
9/24/05 1:35 AM		0		2	4.0		70	70	30.04				
9/24/05 2:00 AM		0		2	5.0		70	70	30.04				
9/24/05 2:15 AM		0		2	3.0		70	70	30.04				
9/24/05 2:35 AM		0		2	3.0		70	70	30.04				
9/24/05 3:00 AM		0		2	2.0		68	68	30.03				
9/24/05 3:15 AM		0		2	3.0		70	70	30.03				
9/24/05 3:35 AM		0		5	0.5		68	68	30.04				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/24/05 4:00 AM		0		2	1.8		68	68	30.04				
9/24/05 4:15 AM		0		2	3.0		70	70	30.04				
9/24/05 4:35 AM		0		2	2.5		68	68	30.03				
9/24/05 5:00 AM		0		2	2.5		68	68	30.03				
9/24/05 5:15 AM		0		2	2.0		68	68	30.04				
9/24/05 5:35 AM	060	3		1	2.0		68	68	30.04				
9/24/05 6:00 AM	080	3		1	0.5		68	68	30.04				
9/24/05 6:15 AM	080	5		1	0.3		68	68	30.04				
9/24/05 6:35 AM	100	5		1	0.3		68	68	30.04				
9/24/05 7:00 AM		0		1	0.3		68	68	30.05				
9/24/05 7:15 AM		0		1	0.3		68	68	30.06				
9/24/05 7:35 AM		0		1	0.3		68	68	30.05				
9/24/05 8:00 AM		0		1	0.3		68	68	30.05				
9/24/05 8:15 AM		0		1	0.3		68	66	30.04				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/24/05 8:35 AM		0		1	0.5		70	70	30.04				
9/24/05 9:00 AM		0		2	4.0		70	70	30.05				
9/24/05 9:15 AM		0		2	10.0		72	70	30.05				
9/24/05 9:35 AM	160	3		2	10.0		73	70	30.05				
9/24/05 10:00 AM	150	7		2	10.0		75	70	30.04				
9/24/05 10:15 AM	150	7		2	10.0		79	70	30.04				
9/24/05 10:35 AM	130	6		2	10.0		79	70	30.04				
9/24/05 11:00 AM	160	7		2	10.0		81	70	30.04				
9/24/05 11:15 AM	160	9		2	10.0		81	70	30.04				
9/24/05 11:35 AM	140	8		2	10.0		81	70	30.04				
9/24/05 12:00 PM	130	7		2	10.0		81	70	30.04				
9/24/05 12:15 PM	140	9		2	10.0		81	70	30.03				
9/24/05 12:35 PM	130	8		2	10.0		82	70	30.03				
9/24/05 1:00 PM	110	8		2	10.0		82	72	30.02				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/24/05 1:15 PM	110	6		2	10.0		82	72	30.01				
9/24/05 1:35 PM	140	5		2	10.0		82	72	30.01				
9/24/05 2:00 PM	110	9		2	10.0		82	72	30.00				
9/24/05 2:15 PM	120	9		2	10.0		82	72	29.99				
9/24/05 2:35 PM	130	9		2	10.0		82	72	29.99				
9/24/05 3:00 PM	120	10		2	10.0		82	72	29.98				
9/24/05 3:15 PM	130	7		2	10.0		82	72	29.98				
9/24/05 3:35 PM	120	7		2	10.0		82	72	29.98				
9/24/05 4:00 PM	120	6		2	10.0		82	72	29.97				
9/24/05 4:15 PM	140	7		2	10.0		81	72	29.97				
9/24/05 4:35 PM	130	7		2	10.0		81	72	29.97				
9/24/05 5:00 PM	120	7		2	10.0		81	72	29.97				
9/24/05 5:15 PM	100	3		2	10.0		81	72	29.97				
9/24/05 5:35 PM	090	7		2	10.0		81	72	29.96				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/24/05 6:00 PM	100	5		2	10.0		79	72	29.96				
9/24/05 6:15 PM	100	6		2	10.0		79	72	29.96				
9/24/05 6:35 PM	100	6		2	10.0		79	72	29.97				
9/24/05 7:00 PM	100	6		2	10.0		77	72	29.97				
9/24/05 7:15 PM	100	5		2	10.0		77	72	29.96				
9/24/05 7:35 PM	090	5		2	10.0		77	72	29.95				
9/24/05 8:00 PM	110	5		2	10.0		77	72	29.96				
9/24/05 8:15 PM	110	8		2	10.0		77	72	29.96				
9/24/05 8:35 PM	110	7		2	10.0		75	72	29.97				
9/24/05 9:00 PM	110	7		2	10.0		75	72	29.98				
9/24/05 9:15 PM	120	10		2	10.0		73	72	29.98	0.01			
9/24/05 9:35 PM	110	8		2	10.0		73	72	29.98	0.01			
9/24/05 10:00 PM	110	8		3	10.0		72	72	29.99	0.01			0.01
9/24/05 10:15 PM	110	7		9	10.0		73	72	29.98				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/24/05 10:35 PM	100	5		9	10.0		73	72	29.98				
9/24/05 11:00 PM	100	6		9	10.0	17	73	72	29.97				
9/24/05 11:15 PM	140	5		9	10.0		73	70	29.98				
9/24/05 11:35 PM	080	7		5	8.0		73	72	29.98	0.01			
9/25/05 12:00 AM	090	5		4	10.0		72	72	29.97	0.01			
9/25/05 12:15 AM		0		6	8.0		72	72	29.96	0.02			
9/25/05 12:35 AM	110	3		4	3.0		72	72	29.95	0.13			
9/25/05 1:00 AM	120	3		4	5.0	17	72	70	29.95	0.18	0.20		
9/25/05 1:15 AM	100	3		5	10.0		72	72	29.94				
9/25/05 1:35 AM	060	5		7	10.0		72	72	29.94				
9/25/05 2:00 AM	030	5		7	10.0		72	72	29.92				
9/25/05 2:15 AM	050	6		9	10.0	17	72	72	29.92				
9/25/05 5:00 AM	090	6		9	10.0		70	70	29.88	0.08			
9/25/05 5:15 AM	080	7		9	10.0		70	70	29.87	0.03			

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/25/05 5:35 AM	080	6		7	10.0		70	70	29.87	0.03			
9/25/05 6:00 AM	080	9		7	10.0		70	68	29.86	0.03			
9/25/05 6:15 AM	080	8		9	10.0		70	68	29.86				
9/25/05 6:35 AM	090	8		2	10.0		70	68	29.86				
9/25/05 7:00 AM	080	11		2	10.0		70	70	29.85		0.14	0.34	
9/25/05 7:15 AM	090	9		2	10.0		70	70	29.85	0.01			
9/25/05 7:35 AM	100	10		9	5.0		70	70	29.85	0.02			
9/25/05 8:00 AM	100	10	18	4	7.0		70	70	29.85	0.03			
9/25/05 8:15 AM	090	10		4	5.0		70	70	29.84	0.02			
9/25/05 8:35 AM	080	13		1	4.0		70	70	29.83	0.04			
9/25/05 9:00 AM	080	10	18	9	5.0		70	70	29.82	0.11			
9/25/05 9:15 AM	090	13	18	0	7.0		70	68	29.82	0.01			
9/25/05 9:35 AM	090	13	17	6	5.0		70	70	29.80	0.01			
9/25/05 10:00 AM	080	16	23	4	2.0		70	68	29.79	0.06			0.20

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/25/05 10:15 AM	080	14		2	7.0		70	70	29.78	0.02			
9/25/05 10:35 AM	100	14	22	9	3.0		70	70	29.77	0.06			
9/25/05 11:00 AM	090	14	22	1	2.5		70	68	29.77	0.14			
9/25/05 11:15 AM	070	17	22	6	2.0		70	68	29.74	0.11			
9/25/05 11:35 AM	100	11	19	8	1.5		70	70	29.74	0.13			
9/25/05 12:00 PM	100	9		8	2.5		70	70	29.73	0.17			
9/25/05 12:15 PM	100	10	16	1	4.0		70	70	29.73	0.05			
9/25/05 12:35 PM	080	9		2	1.8		70	68	29.72	0.06			
9/25/05 1:00 PM	080	10		9	1.5		70	70	29.71	0.08	0.59		
9/25/05 1:15 PM	070	10		6	3.0		70	70	29.70	0.01			
9/25/05 1:35 PM	090	9		8	2.5		70	70	29.68	0.04			
9/25/05 2:00 PM	100	9		6	3.0		70	70	29.67	0.06			
9/25/05 2:15 PM	120	11		8	6.0		72	72	29.66	0.01			
9/25/05 2:35 PM	120	10		8	7.0		72	72	29.66	0.01			

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/25/05 3:00 PM	140	8		8	10.0		72	72	29.66	0.02			
9/25/05 3:15 PM	160	3		8	7.0		72	72	29.67				
9/25/05 3:35 PM		0		9	2.5		72	72	29.67				
9/25/05 4:00 PM	110	5		1	2.0		72	70	29.67	0.02			0.10
9/25/05 4:15 PM	090	3		3	8.0		72	72	29.66				
9/25/05 4:35 PM		0		6	10.0		72	72	29.67				
9/25/05 5:00 PM		0		0	9.1		72	70	29.67				
9/25/05 5:15 PM		0		9	4.0		72	72	29.68				
9/25/05 5:35 PM	100	3		0	10.0		72	72	29.67				
9/25/05 6:00 PM		0		2	10.0		72	72	29.68				
9/25/05 6:15 PM		0		6	10.0		72	72	29.69				
9/25/05 6:35 PM		0		6	10.0		72	72	29.70				
9/25/05 7:00 PM		0		4	2.5		72	70	29.70	0.01	0.11		
9/25/05 7:15 PM		0		6	5.0		72	72	29.71				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/25/05 7:35 PM		0		7	10.0		72	72	29.71				
9/25/05 8:00 PM		0		1	10.0		72	70	29.72				
9/25/05 8:15 PM	340	3		2	10.0		72	70	29.72				
9/25/05 8:35 PM	320	5		6	10.0		72	70	29.73				
9/25/05 9:00 PM	320	5		6	10.0		72	70	29.73				
9/25/05 9:15 PM	310	7		6	10.0		72	70	29.75				
9/25/05 9:35 PM	320	7		6	9.1		72	70	29.75				
9/25/05 10:00 PM	310	3		6	4.0		72	70	29.76				
9/25/05 10:15 PM	320	6		6	4.0		70	70	29.76				
9/25/05 10:35 PM	350	6		3	4.0		70	70	29.76				
9/25/05 11:00 PM	350	8		2	3.0		70	68	29.77				
9/25/05 11:15 PM	320	7	16	2	5.0		70	68	29.78				
9/25/05 11:35 PM	320	8		5	5.0		70	68	29.78				
9/26/05 1:00 AM	320	6		0	10.0		68	66	29.80				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/26/05 1:15 AM	320	8		0	10.0		68	66	29.80				
9/26/05 1:35 AM	310	6		0	10.0		68	66	29.81				
9/26/05 2:00 AM	320	8		0	10.0		68	66	29.82				
9/26/05 2:15 AM	330	8		8	10.0		68	66	29.82				
9/26/05 2:35 AM	320	7		8	10.0		68	66	29.83				
9/26/05 3:00 AM	310	8		8	10.0		68	66	29.83				
9/26/05 3:15 AM	310	5		8	10.0		68	66	29.84				
9/26/05 3:35 AM	300	8		6	10.0		68	66	29.85				
9/26/05 4:00 AM	310	7		5	10.0		68	66	29.85				
9/26/05 4:15 AM	310	5		5	10.0		68	66	29.86				
9/26/05 4:35 AM	320	5		5	10.0		68	66	29.86				
9/26/05 5:00 AM	320	3		4	10.0		68	66	29.87				
9/26/05 5:15 AM	320	3		5	10.0		70	66	29.88				
9/26/05 5:35 AM	320	5		5	10.0		70	66	29.89				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/26/05 6:00 AM	310	5		5	10.0		68	66	29.89				
9/26/05 6:15 AM	310	5		2	10.0		68	66	29.90				
9/26/05 6:35 AM	310	3		2	10.0		68	66	29.90				
9/26/05 7:00 AM	300	3		2	10.0		68	66	29.90			0.70	
9/26/05 7:15 AM	290	3		2	10.0		68	66	29.90				
9/26/05 7:35 AM	270	3		2	10.0		68	66	29.92				
9/26/05 8:00 AM	260	6		2	10.0		68	66	29.93				
9/26/05 8:15 AM	300	5		2	10.0		70	68	29.93				
9/26/05 8:35 AM	310	5		2	10.0		72	68	29.94				
9/26/05 9:00 AM	300	6		2	10.0		73	68	29.95				
9/26/05 9:15 AM	330	6		2	10.0		73	70	29.95				
9/26/05 9:35 AM	340	10		2	10.0		73	70	29.96				
9/26/05 10:00 AM	330	8		2	10.0		73	68	29.97				
9/26/05 10:15 AM	340	9		8	10.0		75	68	29.98				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/26/05 10:35 AM		0		2	10.0		75	70	29.97				
9/26/05 11:00 AM	350	7		2	10.0		75	68	29.99				
9/26/05 11:15 AM	350	9		8	10.0		73	66	30.01				
9/26/05 11:35 AM	340	9		8	10.0		73	66	30.02				
9/26/05 12:15 PM	360	8		2	10.0		73	66	30.01				
9/26/05 12:35 PM	330	5		2	10.0		73	66	30.03				
9/26/05 1:00 PM	340	7		2	10.0		73	66	30.02				
9/26/05 1:15 PM	010	8		8	10.0		73	66	30.02				
9/26/05 1:35 PM	340	8		2	10.0		75	66	30.01				
9/26/05 2:00 PM	010	8		2	10.0		75	66	30.01				
9/26/05 2:15 PM	340	9		1	10.0		75	64	30.02				
9/26/05 2:35 PM	320	7		2	10.0		75	66	30.02				
9/26/05 3:00 PM	320	7		2	10.0		75	64	30.02				
9/26/05 3:15 PM	350	8		6	10.0		77	66	30.02				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/26/05 3:35 PM	350	9	19	6	10.0		77	64	30.03				
9/26/05 4:00 PM	350	9		8	10.0		75	63	30.03				
9/26/05 4:15 PM	350	8		8	10.0		75	64	30.04				
9/26/05 4:35 PM	350	8		8	10.0		73	63	30.04				
9/26/05 5:00 PM	340	8		2	10.0		75	63	30.04				
9/26/05 5:15 PM	340	6		2	10.0		73	64	30.05				
9/26/05 5:35 PM	340	7		2	10.0		73	63	30.06				
9/26/05 6:00 PM	360	9		2	10.0		73	63	30.06				
9/26/05 6:15 PM	350	7		2	10.0		73	63	30.07				
9/26/05 6:35 PM	340	8		2	10.0		72	63	30.07				
9/26/05 7:00 PM	340	9		2	10.0		72	63	30.08				
9/26/05 7:15 PM	010	8		6	10.0		70	63	30.09				
9/26/05 7:35 PM	360	5		6	10.0		70	63	30.09				
9/26/05 8:00 PM	360	3		2	10.0		70	61	30.09				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/26/05 8:15 PM	010	5		2	10.0		68	63	30.09				
9/26/05 8:35 PM	360	6		2	10.0		66	63	30.09				
9/26/05 9:00 PM	010	3		2	10.0		66	63	30.10				
9/26/05 9:15 PM		0		2	10.0		64	61	30.10				
9/26/05 9:35 PM		0		2	10.0		64	61	30.11				
9/26/05 10:00 PM	330	3		2	10.0		63	59	30.11				
9/26/05 10:15 PM	330	3		2	10.0		64	61	30.12				
9/26/05 10:35 PM	350	5		2	10.0		64	61	30.12				
9/26/05 11:00 PM	340	3		2	10.0		63	61	30.13				
9/26/05 11:15 PM	340	6		2	10.0		63	59	30.13				
9/26/05 11:35 PM	350	5		2	10.0		63	61	30.13				
9/27/05 12:00 AM	340	6		2	10.0		61	59	30.13				
9/27/05 12:15 AM	340	5		2	10.0		61	57	30.13				
9/27/05 12:35 AM	350	5		8	10.0		61	59	30.13				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/27/05 1:00 AM	020	5		4	10.0		61	59	30.13				
9/27/05 1:15 AM	020	5		5	10.0		61	61	30.13				
9/27/05 1:35 AM		0		2	10.0		61	59	30.13				
9/27/05 2:00 AM		0		2	10.0		57	55	30.14				
9/27/05 2:15 AM	350	3		2	10.0		57	55	30.14				
9/27/05 2:35 AM		0		2	10.0		57	55	30.14				
9/27/05 3:00 AM		0		2	5.0		57	55	30.13				
9/27/05 3:15 AM		0		2	8.0		57	55	30.13				
9/27/05 3:35 AM		0		5	0.5		55	55	30.13				
9/27/05 4:00 AM	340	3		2	4.0		55	54	30.13				
9/27/05 4:15 AM		0		2	10.0		57	55	30.13				
9/27/05 4:35 AM		0		2	10.0		57	55	30.13				
9/27/05 5:00 AM		0		2	8.0		55	54	30.14				
9/27/05 5:15 AM		0		2	8.0		55	54	30.14				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/27/05 5:35 AM		0		2	7.0		55	54	30.15				
9/27/05 6:00 AM		0		2	5.0		55	54	30.15				
9/27/05 6:15 AM		0		1	1.3		54	54	30.16				
9/27/05 6:35 AM		0		1	0.3		54	54	30.16				
9/27/05 7:00 AM		0		1	0.3		54	54	30.16				
9/27/05 7:15 AM		0		1	0.3		54	54	30.16				
9/27/05 7:35 AM		0		1	0.3		54	54	30.16				
9/27/05 8:00 AM		0		1	0.3		55	54	30.17				
9/27/05 8:15 AM		0		2	9.1		55	55	30.16				
9/27/05 8:35 AM	040	3		2	10.0		59	57	30.17				
9/27/05 9:00 AM	010	5		2	10.0		61	59	30.17				
9/27/05 9:15 AM		0		0	10.0		61	59	30.18				
9/27/05 10:00 AM	120	5		6	10.0		61	59	30.18				
9/27/05 10:15 AM	120	3		6	10.0		61	59	30.17				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/27/05 10:35 AM	120	3		6	10.0		63	61	30.18				
9/27/05 11:00 AM	110	3		6	10.0		63	61	30.17				
9/27/05 11:15 AM		0		8	10.0		64	61	30.17				
9/27/05 11:35 AM	140	3		0	10.0		66	63	30.16				
9/27/05 12:00 PM		0		2	10.0		68	63	30.15				
9/27/05 12:15 PM		0		2	10.0		68	63	30.15				
9/27/05 12:35 PM	110	5		8	10.0		70	61	30.15				
9/27/05 1:00 PM	130	3		2	10.0		72	61	30.13				
9/27/05 1:15 PM		0		2	10.0		72	61	30.11				
9/27/05 1:35 PM	140	3		2	10.0		73	63	30.11				
9/27/05 2:00 PM	170	3		2	10.0		73	61	30.10				
9/27/05 2:15 PM		0		2	10.0		73	61	30.09				
9/27/05 2:35 PM	210	3		2	10.0		75	61	30.08				
9/27/05 3:00 PM	220	3		2	10.0		73	59	30.08				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/27/05 3:15 PM	140	3		2	10.0		75	61	30.07				
9/27/05 3:35 PM		0		2	10.0		75	61	30.06				
9/27/05 4:00 PM	210	5		2	10.0		75	61	30.05				
9/27/05 4:15 PM	160	3		2	10.0		75	61	30.05				
9/27/05 4:35 PM	150	3		2	10.0		75	61	30.04				
9/27/05 5:00 PM	150	3		2	10.0		75	61	30.04				
9/27/05 5:15 PM		0		2	10.0		75	59	30.04				
9/27/05 5:35 PM	130	5		2	10.0		75	61	30.04				
9/27/05 6:00 PM		0		2	10.0		75	63	30.04				
9/27/05 6:15 PM		0		2	10.0		75	61	30.03				
9/27/05 6:35 PM	100	3		2	10.0		73	63	30.03				
9/27/05 7:00 PM		0		2	10.0		72	61	30.03				
9/27/05 7:15 PM	120	3		2	10.0		70	63	30.02				
9/27/05 7:35 PM		0		2	10.0		68	63	30.02				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis.	Weather	Temp	Dewpt	Baro	1HR Precip	6HR Precip	24 HR Precip	3HR Precip
9/27/05 8:00 PM		0		2	10.0		64	63	30.03				
9/27/05 8:15 PM		0		2	10.0		64	63	30.03				
9/27/05 8:35 PM		0		2	10.0		64	61	30.03				
9/27/05 9:00 PM		0		2	10.0		63	61	30.03				
9/27/05 9:15 PM		0		2	10.0		63	61	30.03				
9/27/05 9:35 PM		0		2	8.0		61	59	30.03				
9/27/05 10:00 PM		0		2	10.0		63	61	30.02				
9/27/05 10:15 PM		0		2	9.1		61	61	30.02				
9/27/05 10:35 PM		0		2	5.0		61	61	30.02				
9/27/05 11:00 PM		0		2	4.0		61	61	30.02				
9/27/05 11:15 PM		0		2	3.0		61	59	30.02				
9/27/05 11:35 PM		0		2	4.0		59	59	30.02				

* Degrees from North.

** Knots

December 13-14 Weather Information

Date	Dir*	Wind Spd**	Gust**	Cover	Vis	Weather	Temp	Dewpoint	Baro	1HR Precip	6HR Precip	24HR Precip	3HR Precip
12/13/05 12:00A	060	5		8	10.0		36	34	30.16				
12/13/05 12:15 A		0		6	10.0		36	32	30.16				
12/13/05 12:35 A		0		6	10.0		34	32	30.16				
12/13/05 1:00 AM		0		6	10.0		34	32	30.16				
12/13/05 1:15 AM		0		8	10.0		34	32	30.16				
12/13/05 1:35 AM		0		8	10.0		34	32	30.16				
12/13/05 2:00 AM		0		8	10.0		34	32	30.16				
12/13/05 2:15 AM		0		8	10.0		34	32	30.16				
12/13/05 2:35 AM		0		6	10.0		34	30	30.17				
12/13/05 3:00 AM		0		4	10.0		34	30	30.17				
12/13/05 3:15 AM		0		2	10.0		34	30	30.17				
12/13/05 3:35 AM		0		2	8.0		32	30	30.17				
12/13/05 4:00 AM		0		2	10.0		30	28	30.17				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis	Weather	Temp	Dewpoint	Baro	1HR Precip	6HR Precip	24HR Precip	3HR Precip
12/13/05 4:15 AM		0		2	9.1		30	28	30.18				
12/13/05 4:35 AM	070	5		2	9.1		30	30	30.18				
12/13/05 5:00 AM		0		2	10.0		28	27	30.18				
12/13/05 5:15 AM		0		2	9.1		30	28	30.19				
12/13/05 5:35 AM		0		2	6.0		30	30	30.19				
12/13/05 6:00 AM		0		2	6.0		27	27	30.20				
12/13/05 6:15 AM		0		2	2.0		27	27	30.20				
12/13/05 7:00 AM		0		1	4.0		25	25	30.20				
12/13/05 7:15 AM		0		2	5.0		25	25	30.21				
12/13/05 7:35 AM		0		2	5.0		25	23	30.21				
12/13/05 8:00 AM		0		2	10.0		27	27	30.20				
12/13/05 8:15 AM		0		2	10.0		27	25	30.20				
12/13/05 8:35 AM		0		2	8.0		28	28	30.20				
12/13/05 9:00 AM		0		2	8.0		30	30	30.20				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis	Weather	Temp	Dewpoint	Baro	1HR Precip	6HR Precip	24HR Precip	3HR Precip
12/13/05 9:15 AM		0		2	10.0		32	30	30.22				
12/13/05 9:35 AM		0		2	10.0		34	30	30.22				
12/13/05 10:00 A		0		2	10.0		37	32	30.23				
12/13/05 10:15 A													
12/13/05 10:35 A													
12/13/05 11:00 A	160	3		2	10.0		43	30	30.20				
12/13/05 11:15 A	230	5		2	10.0		43	28	30.19				
12/13/05 11:35 A	170	6		2	10.0		45	28	30.18				
12/13/05 12:00 P	150	3		2	10.0		45	27	30.16				
12/13/05 12:15 P	140	8		2	10.0		45	27	30.14				
12/13/05 12:35 P	160	7		2	10.0		45	27	30.13				
12/13/05 1:00 PM	140	9		2	10.0				30.12				
12/13/05 1:15 PM	170	7		2	10.0				30.11				
12/13/05 1:35 PM	150	9		2	10.0		45	28	30.12				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis	Weather	Temp	Dewpoint	Baro	1HR Precip	6HR Precip	24HR Precip	3HR Precip
12/13/05 2:00 PM	160	9		2	10.0		45	28	30.11				
12/13/05 2:15 PM	140	11		2	10.0		45	27	30.10				
12/13/05 2:35 PM	180	11		2	10.0		45	27	30.10				
12/13/05 3:00 PM	180	7		2	10.0		45	27	30.11				
12/13/05 3:15 PM	200	6		2	10.0		45	27	30.11				
12/13/05 3:35 PM	190	9		2	10.0		45	27	30.10				
12/13/05 4:00 PM	190	8		2	10.0		43	28	30.09				
12/13/05 4:15 PM	170	9		2	10.0		43	28	30.09				
12/13/05 4:35 PM	160	11		2	10.0		43	28	30.08				
12/13/05 5:00 PM	160	10		2	10.0		41	30	30.08				
12/13/05 5:15 PM	140	8		2	10.0		41	30	30.06				
12/13/05 5:35 PM	150	10		2	10.0		41	30	30.05				
12/13/05 6:00 PM	150	9		2	10.0		39	30	30.05				
12/13/05 6:15 PM	150	11	18	2	10.0		39	32	30.05				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis	Weather	Temp	Dewpoint	Baro	1HR Precip	6HR Precip	24HR Precip	3HR Precip
12/13/05 6:35 PM	160	11	17	2	10.0		39	32	30.05				
12/13/05 7:00 PM	160	10		2	10.0		39	30	30.06				
12/13/05 7:15 PM	160	10	16	2	10.0		39	30	30.05				
12/13/05 7:35 PM	170	13		2	10.0		39	30	30.06				
12/13/05 8:00 PM	150	10		2	10.0		39	30	30.04				
12/13/05 8:15 PM	140	11	17	2	10.0		39	30	30.04				
12/13/05 8:35 PM	170	11		2	10.0		39	30	30.06				
12/13/05 9:00 PM	160	11		2	10.0		39	30	30.05				
12/13/05 9:15 PM	160	10		2	10.0		39	30	30.05				
12/13/05 9:35 PM	160	10		2	10.0		39	30	30.05				
12/13/05 10:00 P	150	9		2	10.0		39	30	30.05				
12/13/05 10:15 P	150	8		2	10.0		39	30	30.04				
12/13/05 10:35 P	150	10		2	10.0		39	30	30.03				
12/13/05 11:00 P	150	11		2	10.0		39	28	30.02				

Date	Dir*	Wind Spd**	Gust**	Cover	Vis	Weather	Temp	Dewpoint	Baro	1HR Precip	6HR Precip	24HR Precip	3HR Precip
12/13/05 11:15 P	160	16		2	10.0		39	28	30.03				
12/13/05 11:35 P	170	13	19	2	10.0		39	28	30.02				
12/14/05 12:00 A	160	11	16	2	10.0		37	30	29.99				
12/14/05 12:15 A	150	15	19	2	10.0		37	30	29.94				
12/14/05 12:35 A	140	14	18	2	10.0		37	30	29.92				
12/14/05 1:00 AM	170	15	23	3	10.0		37	30	29.95				
12/14/05 1:15 AM	160	13		3	10.0		37	30	29.94				
12/14/05 1:35 AM	160	11		7	10.0		36	30	29.93	0.01			
12/14/05 2:00 AM	150	8		5	10.0		36	32	29.93	0.01			
12/14/05 2:15 AM	170	7		3	10.0		36	30	29.94				
12/14/05 2:35 AM	150	7		9	7.0		36	32	29.94	0.02			
12/14/05 3:00 AM	150	7		9	5.0		36	32	29.93	0.05			0.06
12/14/05 3:15 AM	140	10		1	9.1		36	34	29.91	0.01			
12/14/05 3:35 AM	150	11	21	9	10.0		36	34	29.89	0.01			

Date	Dir*	Wind Spd**	Gust**	Cover	Vis	Weather	Temp	Dewpoint	Baro	1HR Precip	6HR Precip	24HR Precip	3HR Precip
12/14/05 4:00 AM	160	10		4	8.0		36	34	29.89	0.02			
12/14/05 4:15 AM	170	10	22	9	10.0		36	34	29.88				
12/14/05 4:35 AM	170	13	16	3	10.0		36	34	29.87				
12/14/05 5:00 AM	170	10		8	10.0		36	34	29.86				
12/14/05 5:15 AM	170	13	16	2	10.0		36	34	29.86				
12/14/05 5:35 AM	170	13		0	10.0		37	36	29.85				
12/14/05 6:00 AM	170	14	19	8	6.0		37	36	29.85		0.08	0.08	
12/14/05 6:15 AM	170	13		6	6.0		37	36	29.86				
12/14/05 6:35 AM	180	10	16	5	7.0		37	37	29.86				
12/14/05 7:00 AM	180	13		5	5.0		37	37	29.86				
12/14/05 7:15 AM	180	9	18	4	4.0		37	37	29.87				
12/14/05 7:35 AM	180	11		3	3.0		37	37	29.87				
12/14/05 8:00 AM	180	9	16	3	2.5		37	37	29.86				

* Degrees from North.
** Knots

Appendix D. Stability Analyses

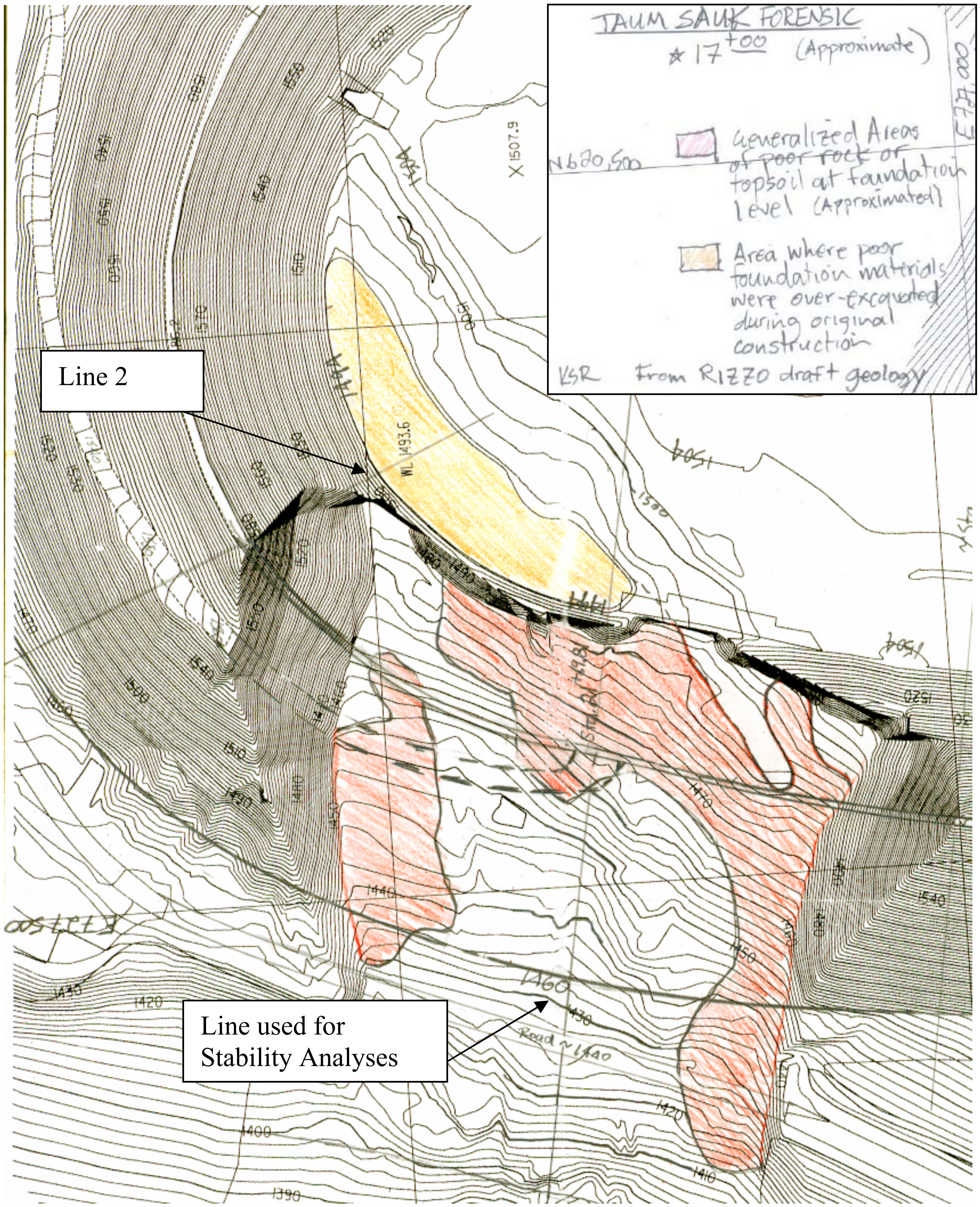


Figure D.1- Taum Sauk Forensic Reconstruction

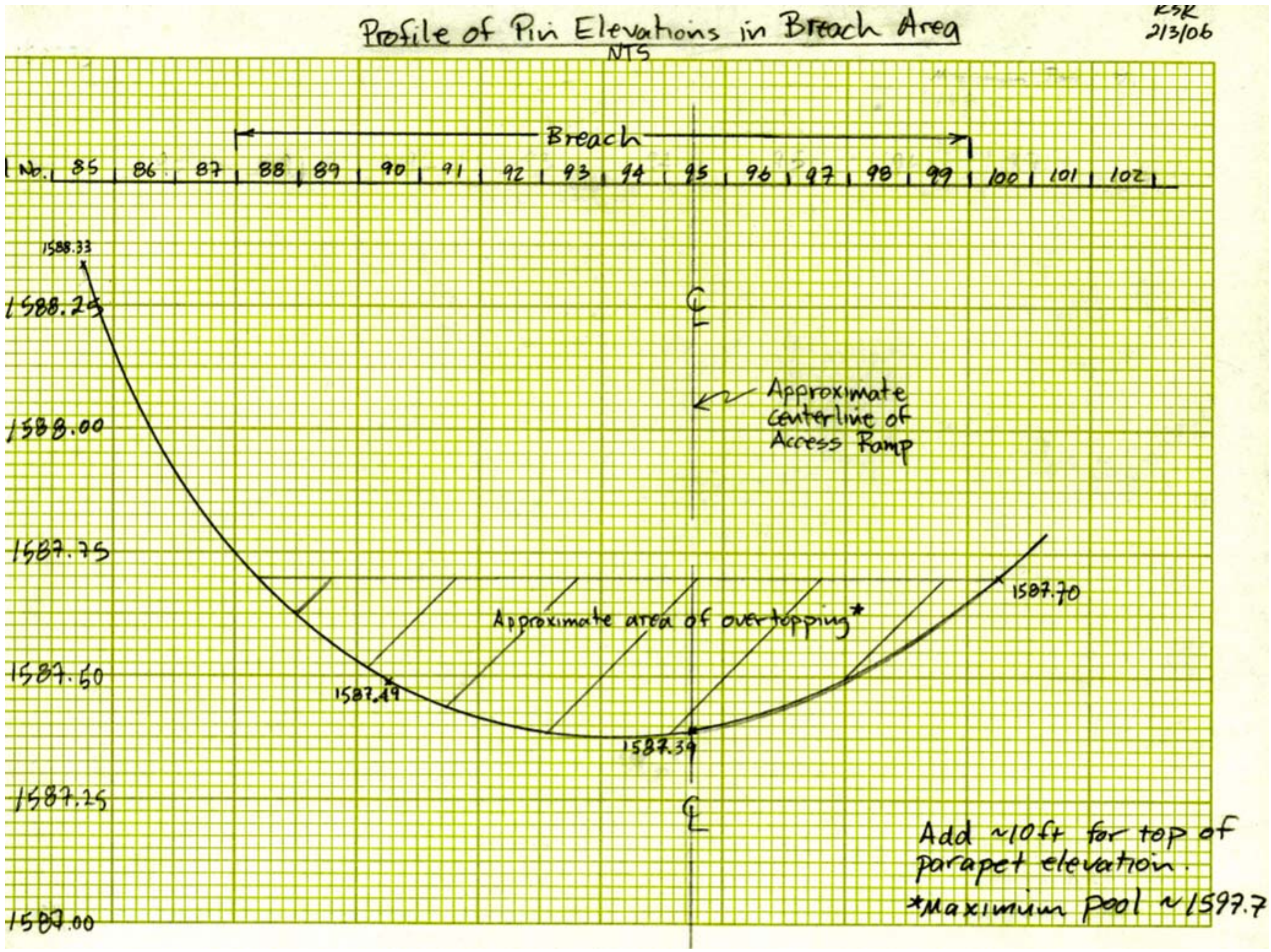


Figure D.2 - Vertical curve in the area of the breach. Approximate extent of overtopping is hatched.

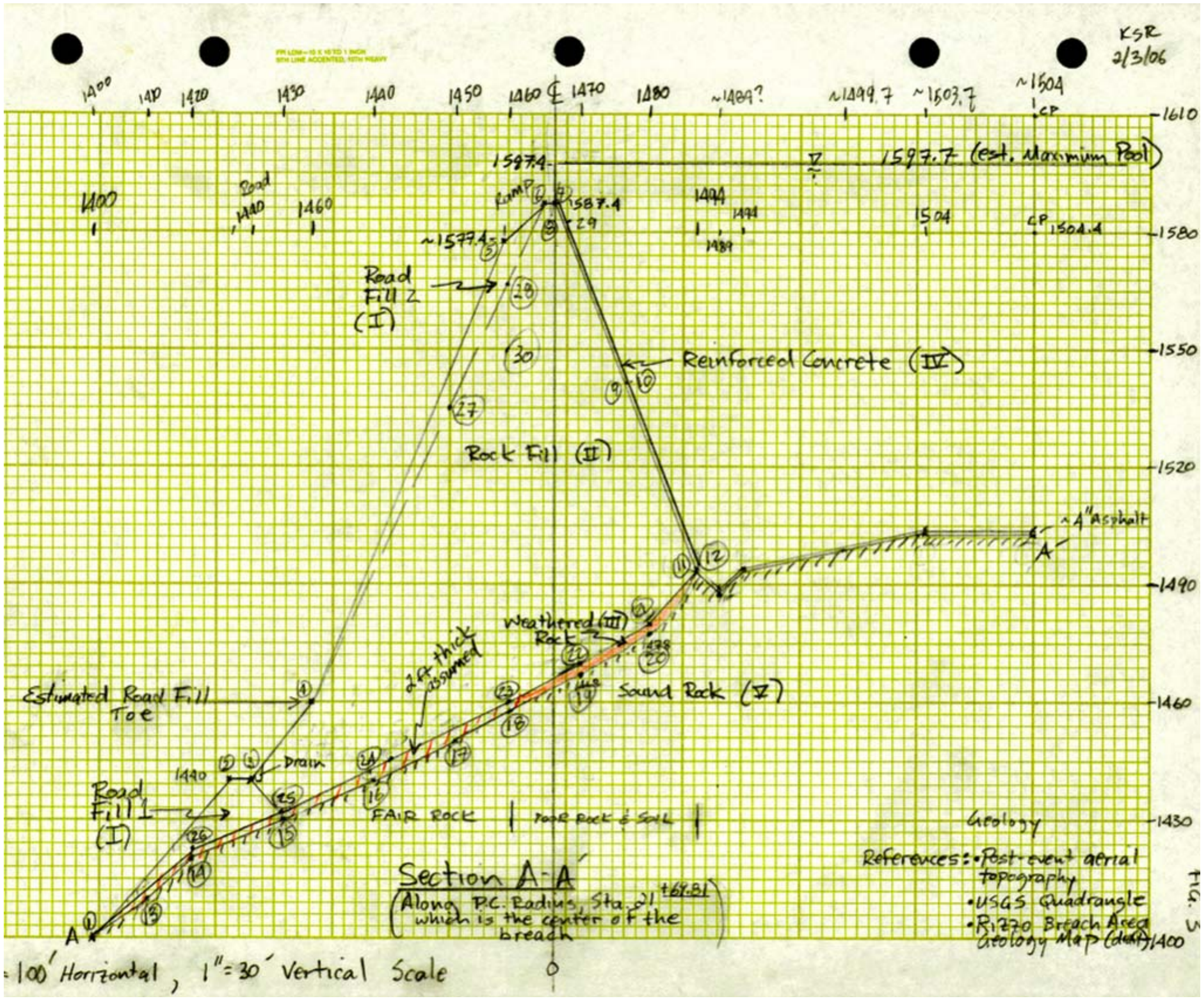


Figure D.3 - Zones selected for model parameters.

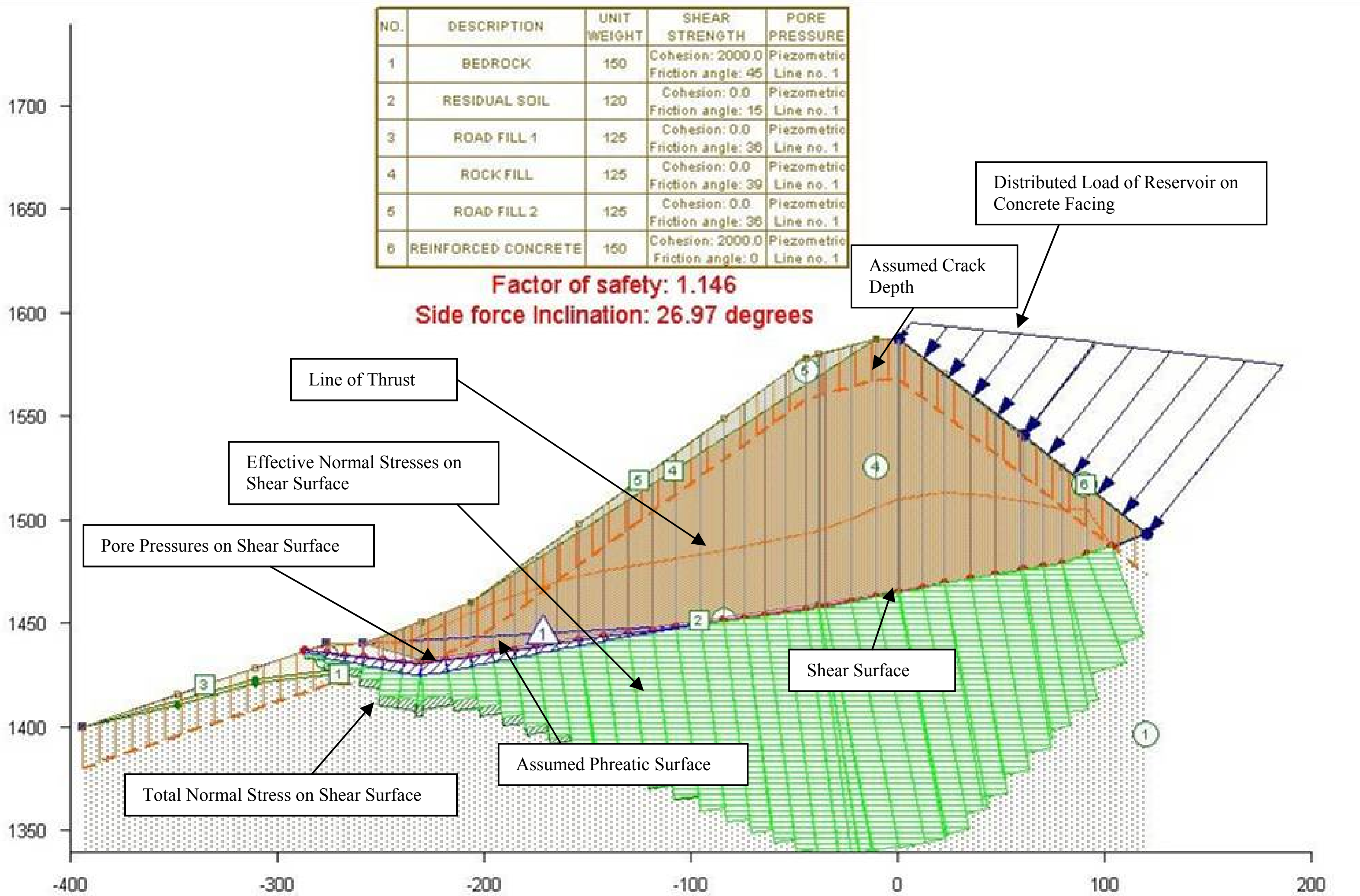
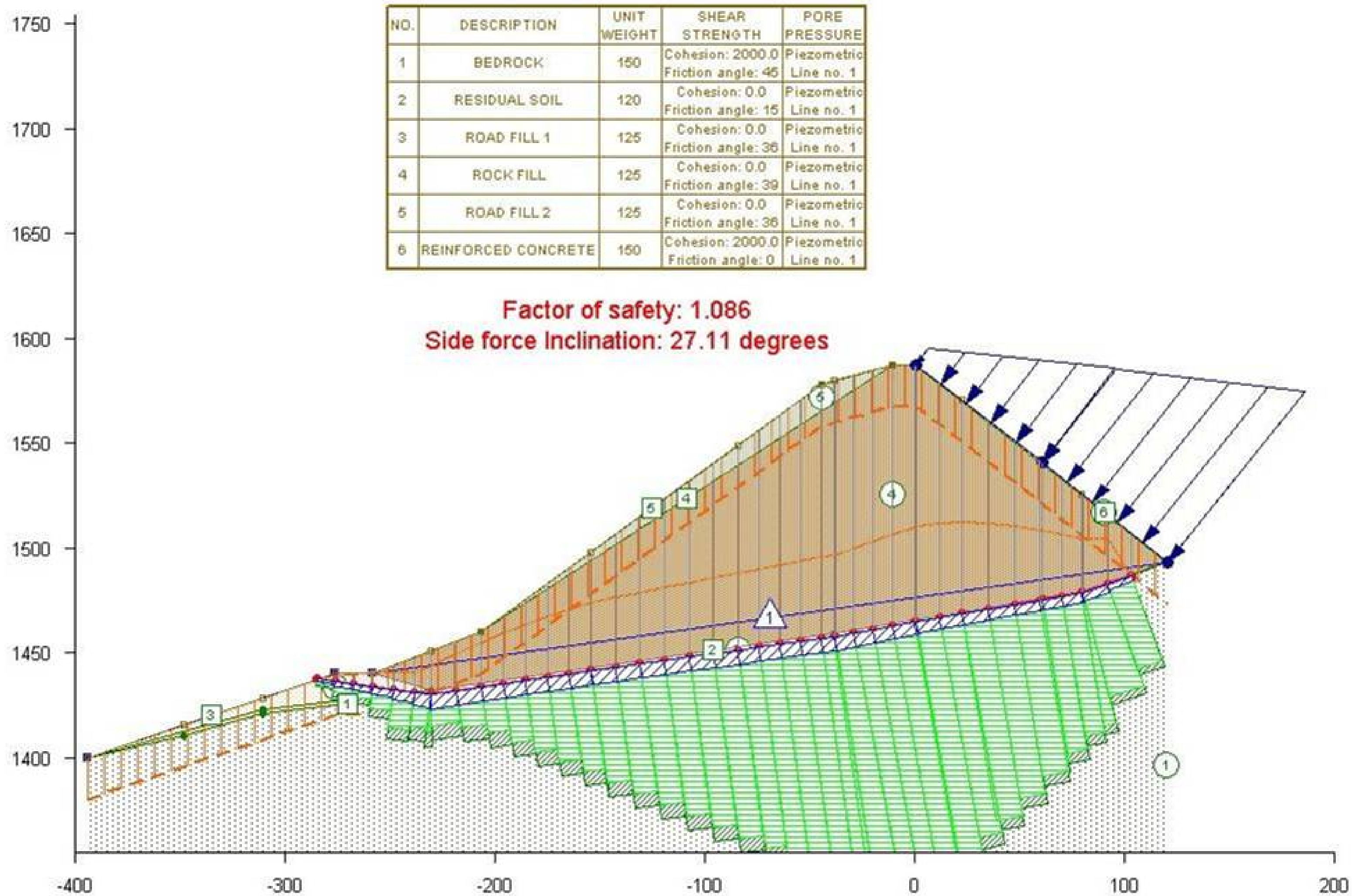


Figure D.4 - Trial 1a, and Key for other figures.



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	BEDROCK	150	Cohesion: 2000.0 Friction angle: 45	Piezometric Line no. 1
2	RESIDUAL SOIL	120	Cohesion: 0.0 Friction angle: 15	Piezometric Line no. 1
3	ROAD FILL 1	125	Cohesion: 0.0 Friction angle: 36	Piezometric Line no. 1
4	ROCK FILL	125	Cohesion: 0.0 Friction angle: 39	Piezometric Line no. 1
5	ROAD FILL 2	125	Cohesion: 0.0 Friction angle: 36	Piezometric Line no. 1
6	REINFORCED CONCRETE	150	Cohesion: 2000.0 Friction angle: 0	Piezometric Line no. 1

Figure D.5 - Trial 1b

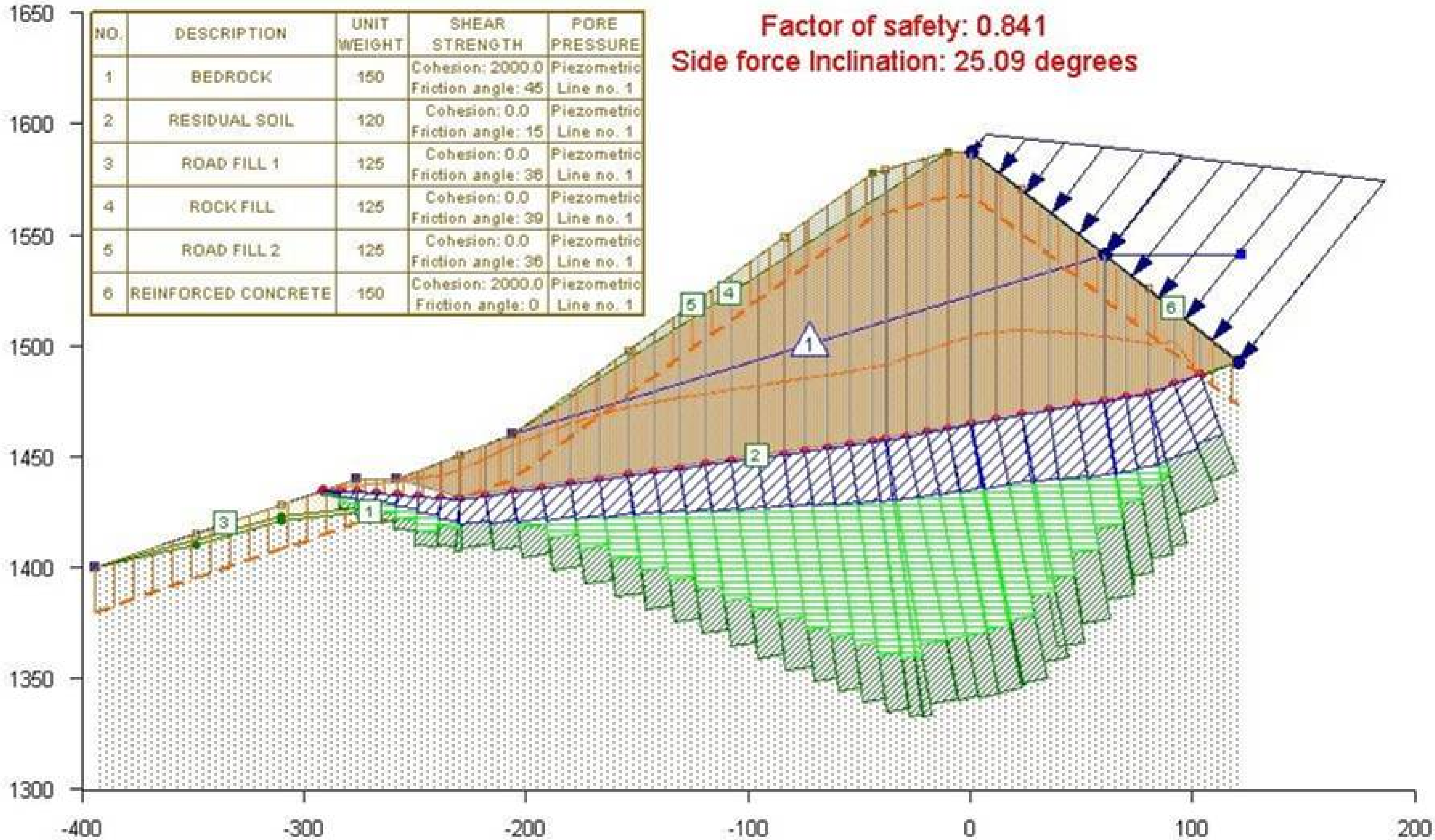


Figure D.6 - Trial 1c

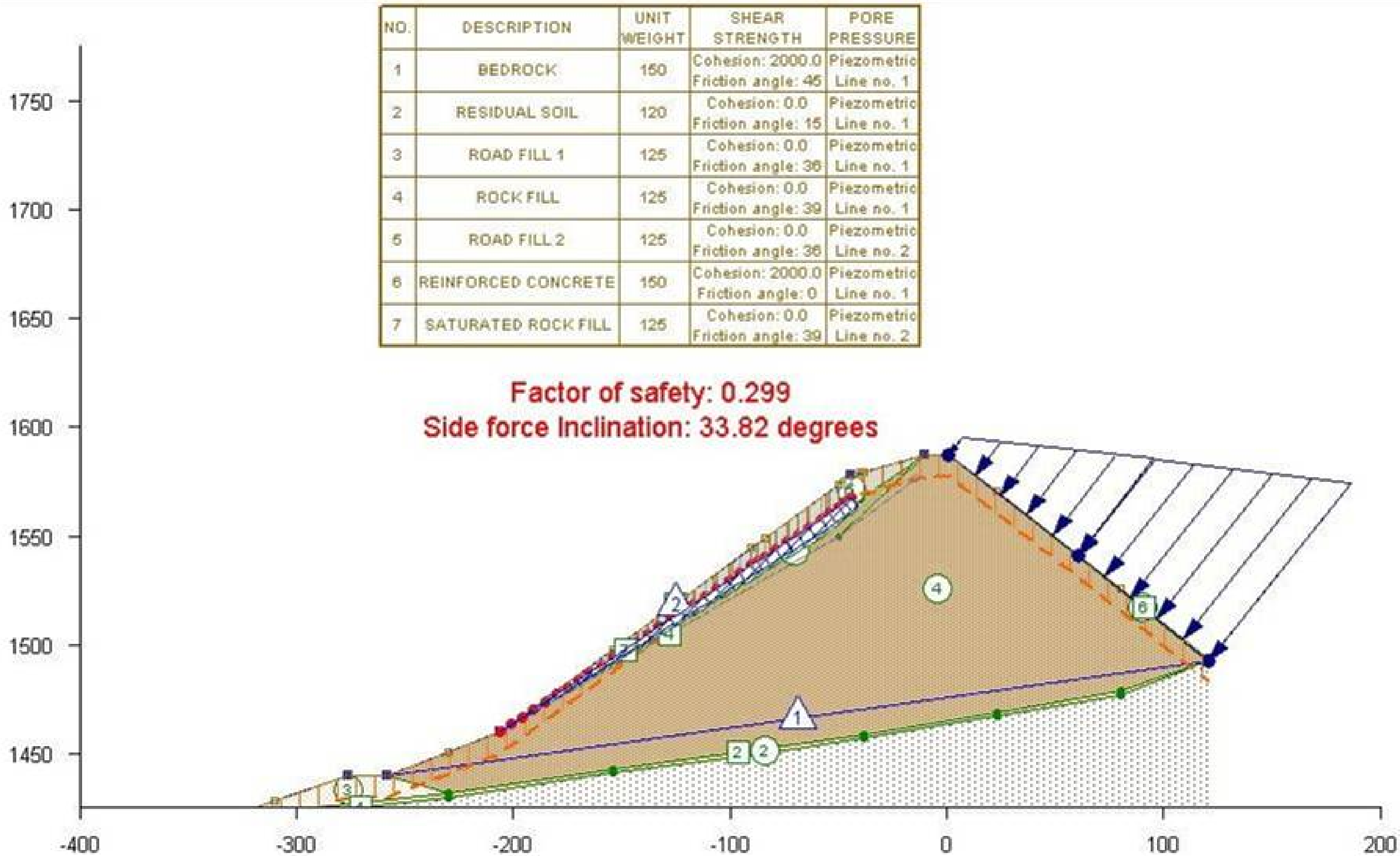


Figure D.7 - Trial 1d

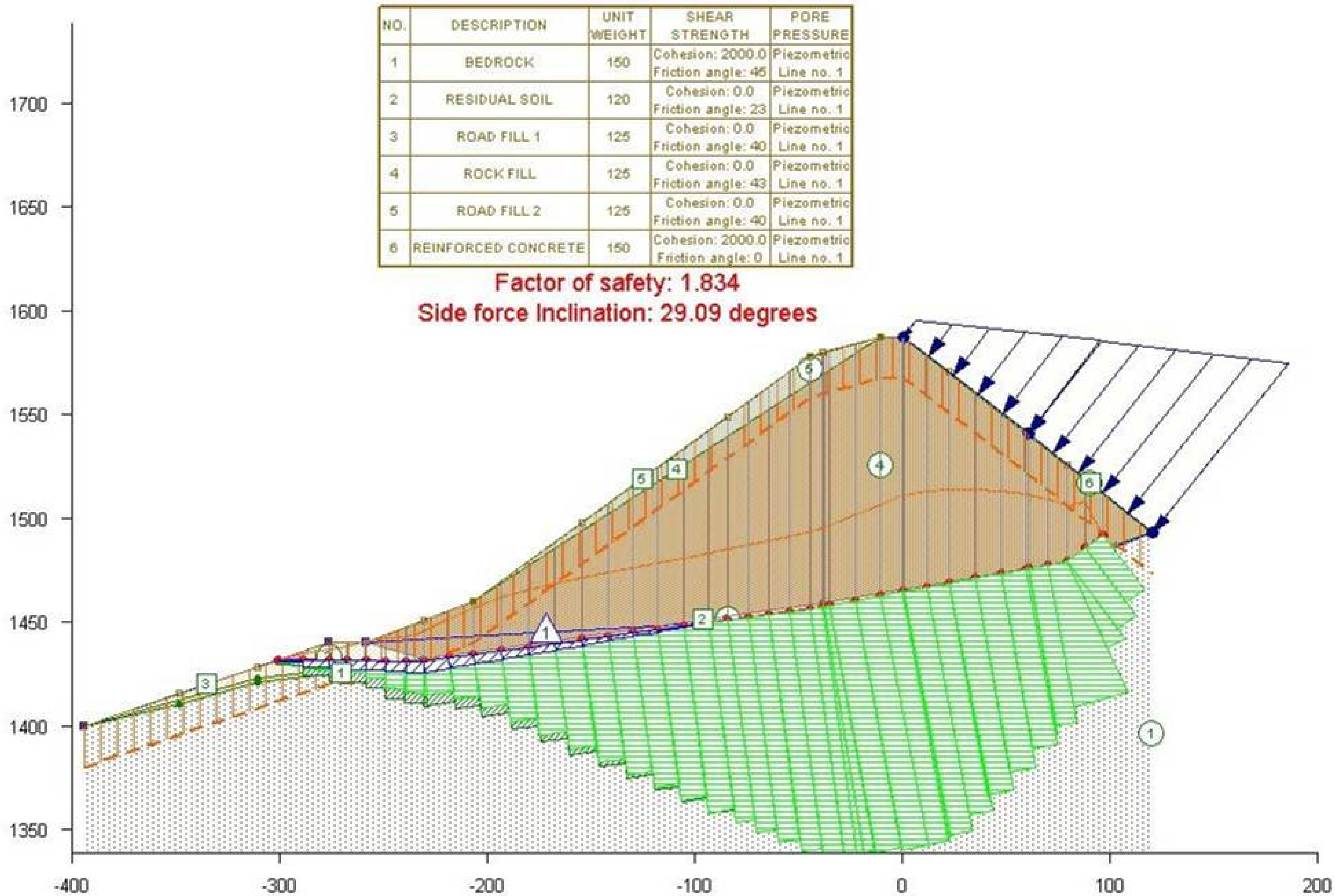


Figure D.8 - Trial 2a

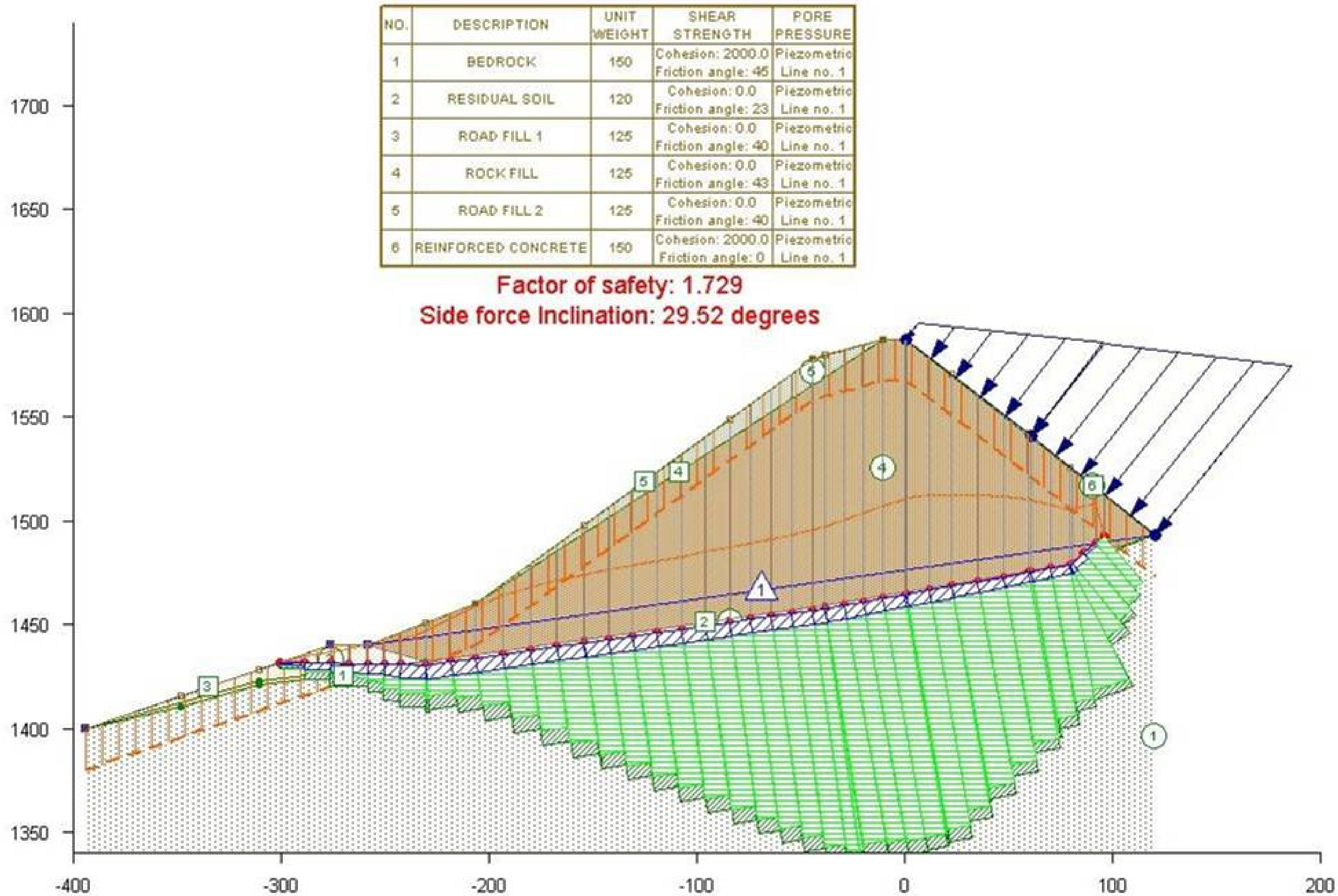


Figure D.9 - Trial 2b

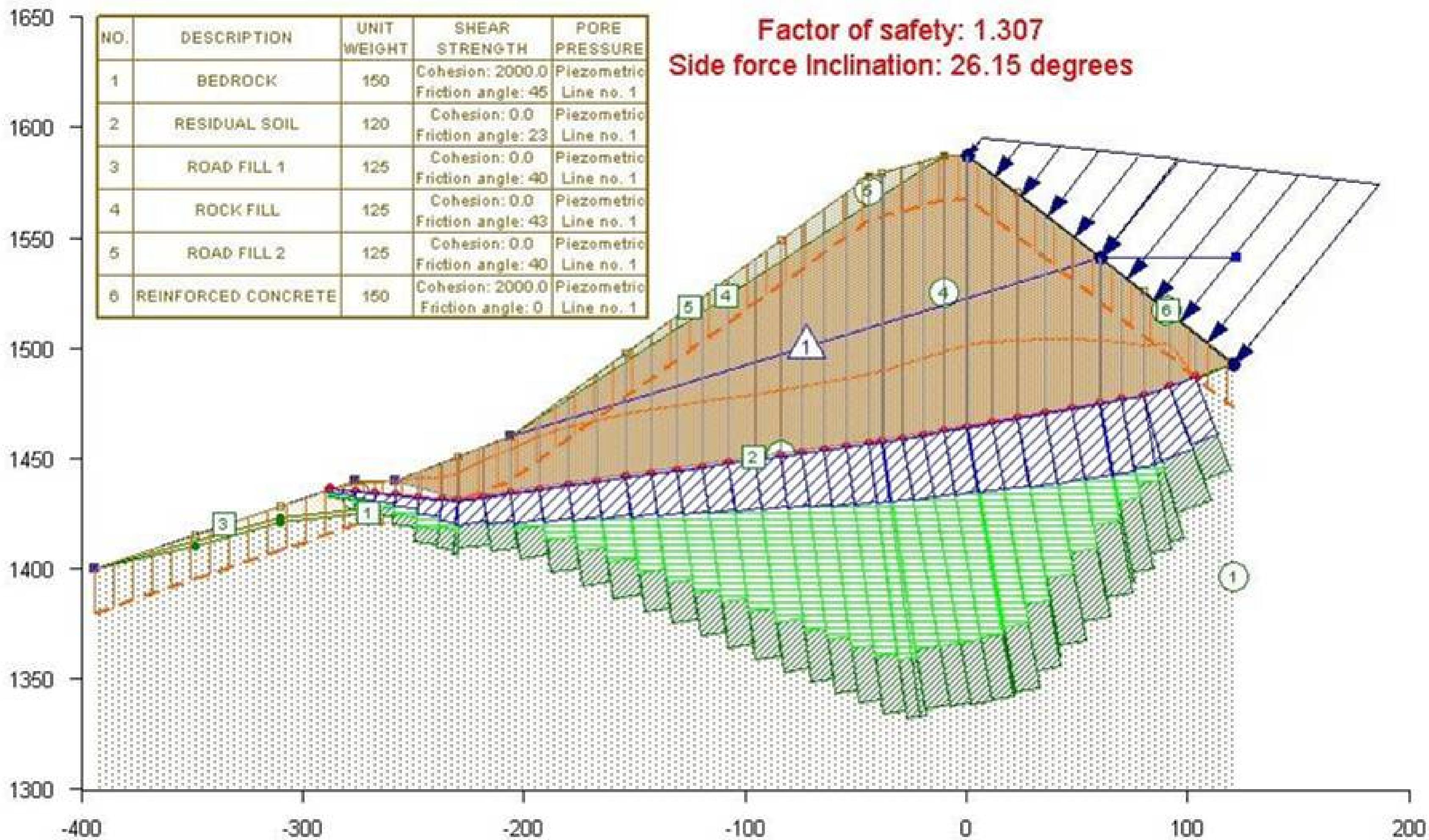
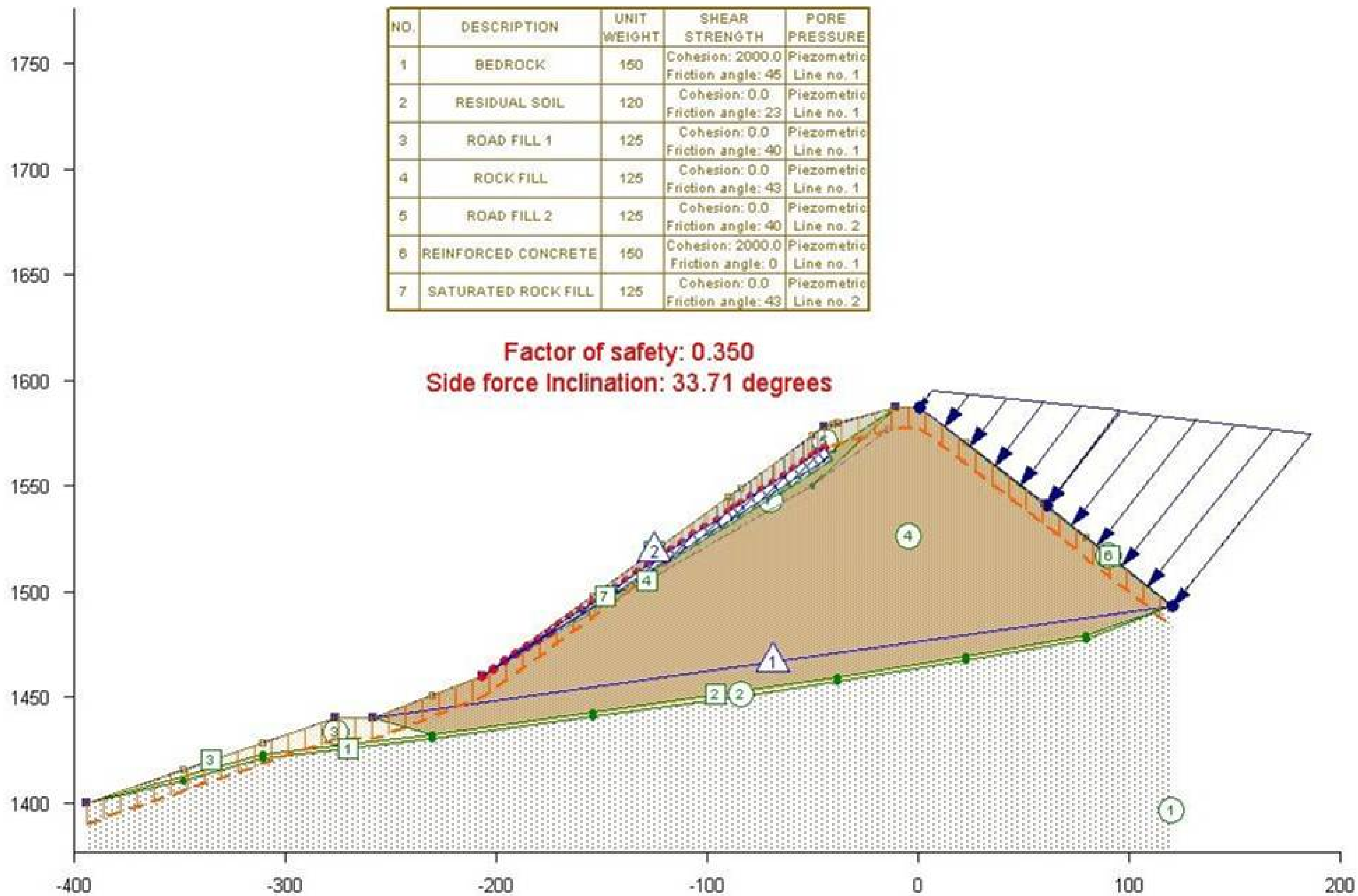


Figure D.10 - Trial 2c



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	BEDROCK	150	Cohesion: 2000.0 Friction angle: 45	Piezometric Line no. 1
2	RESIDUAL SOIL	120	Cohesion: 0.0 Friction angle: 23	Piezometric Line no. 1
3	ROAD FILL 1	125	Cohesion: 0.0 Friction angle: 40	Piezometric Line no. 1
4	ROCK FILL	125	Cohesion: 0.0 Friction angle: 43	Piezometric Line no. 1
5	ROAD FILL 2	125	Cohesion: 0.0 Friction angle: 40	Piezometric Line no. 2
6	REINFORCED CONCRETE	150	Cohesion: 2000.0 Friction angle: 0	Piezometric Line no. 1
7	SATURATED ROCK FILL	125	Cohesion: 0.0 Friction angle: 43	Piezometric Line no. 2

Figure D.11 - Trial 2d

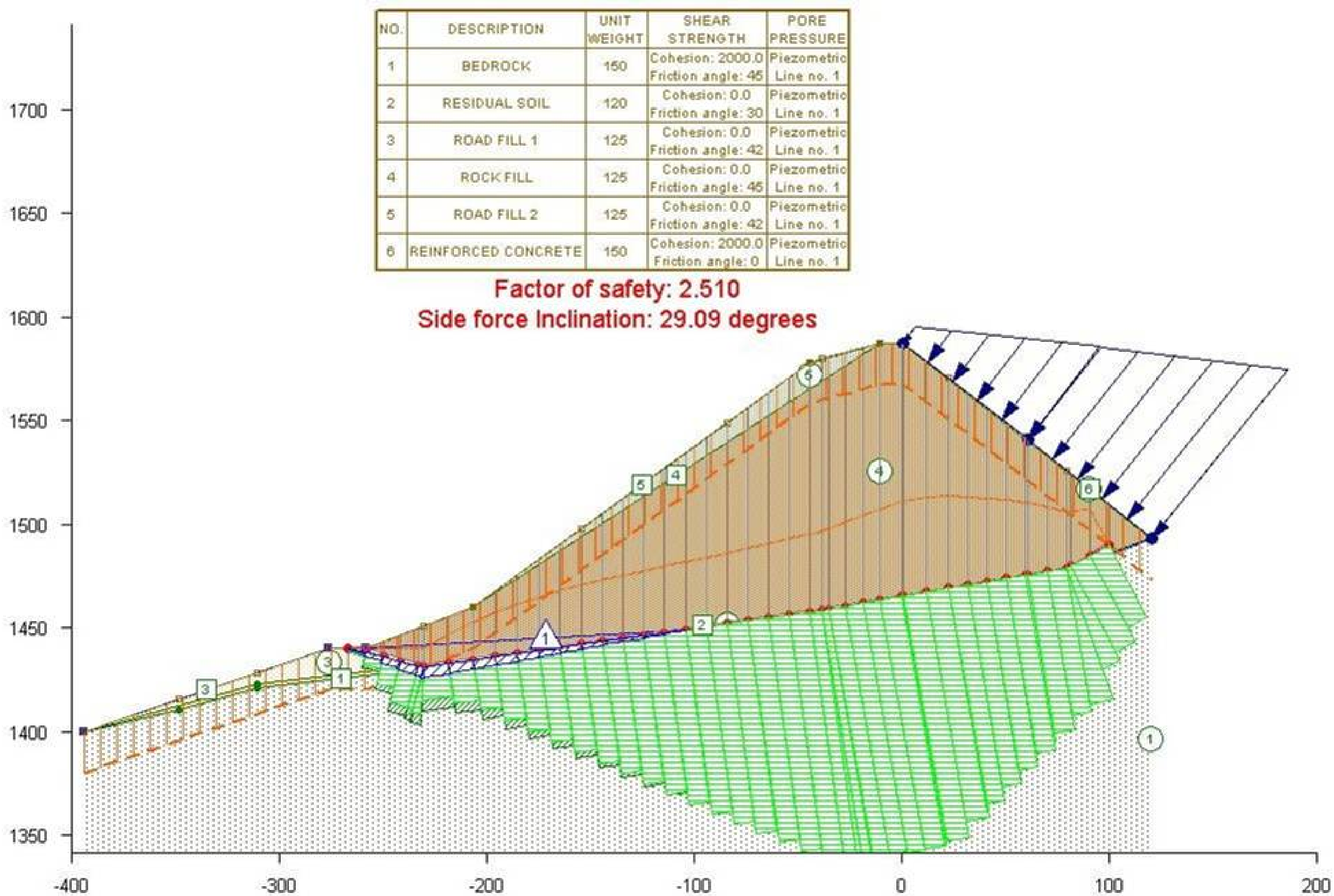


Figure D.12 - Trial 3a

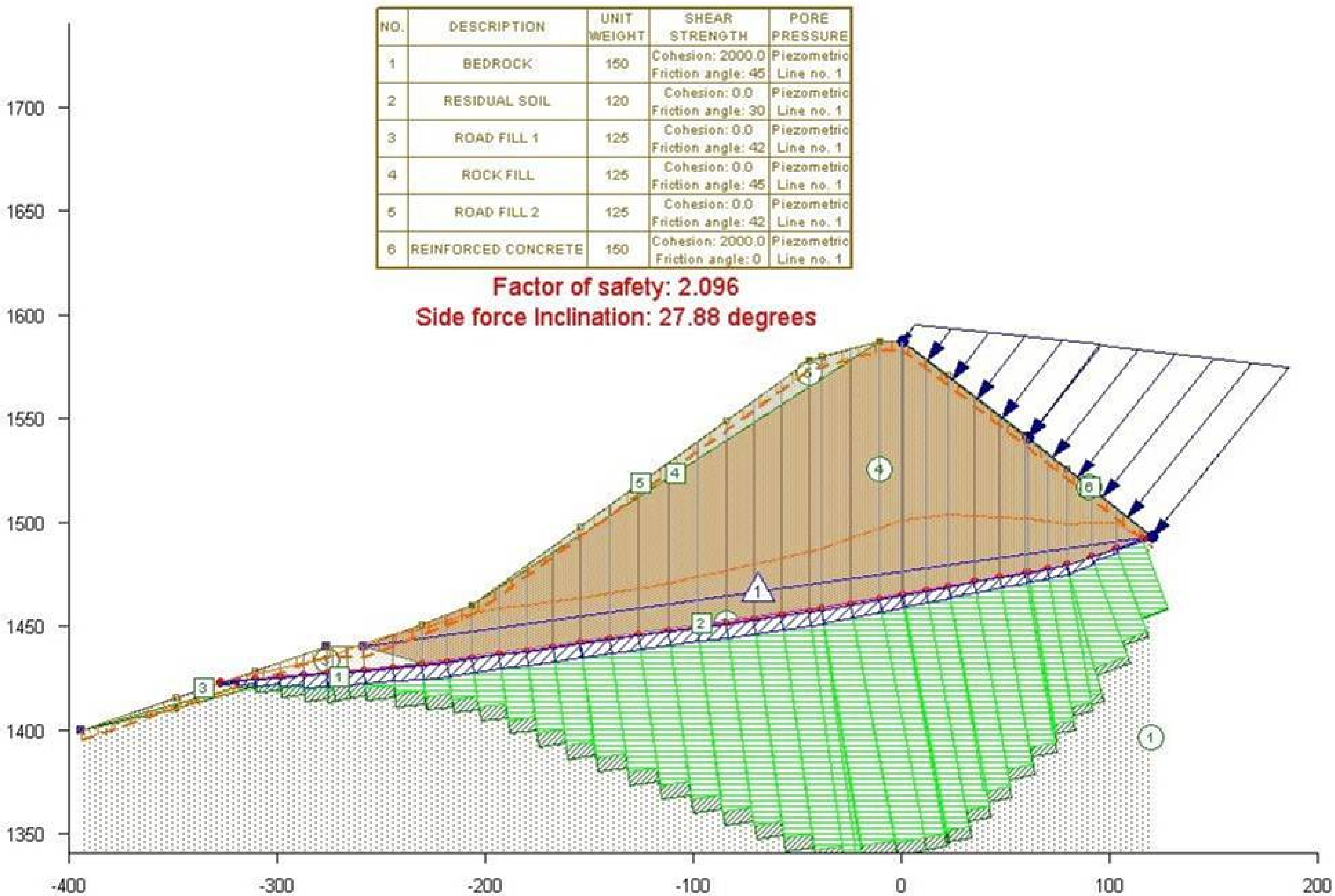


Figure D.13 - Trial 3b

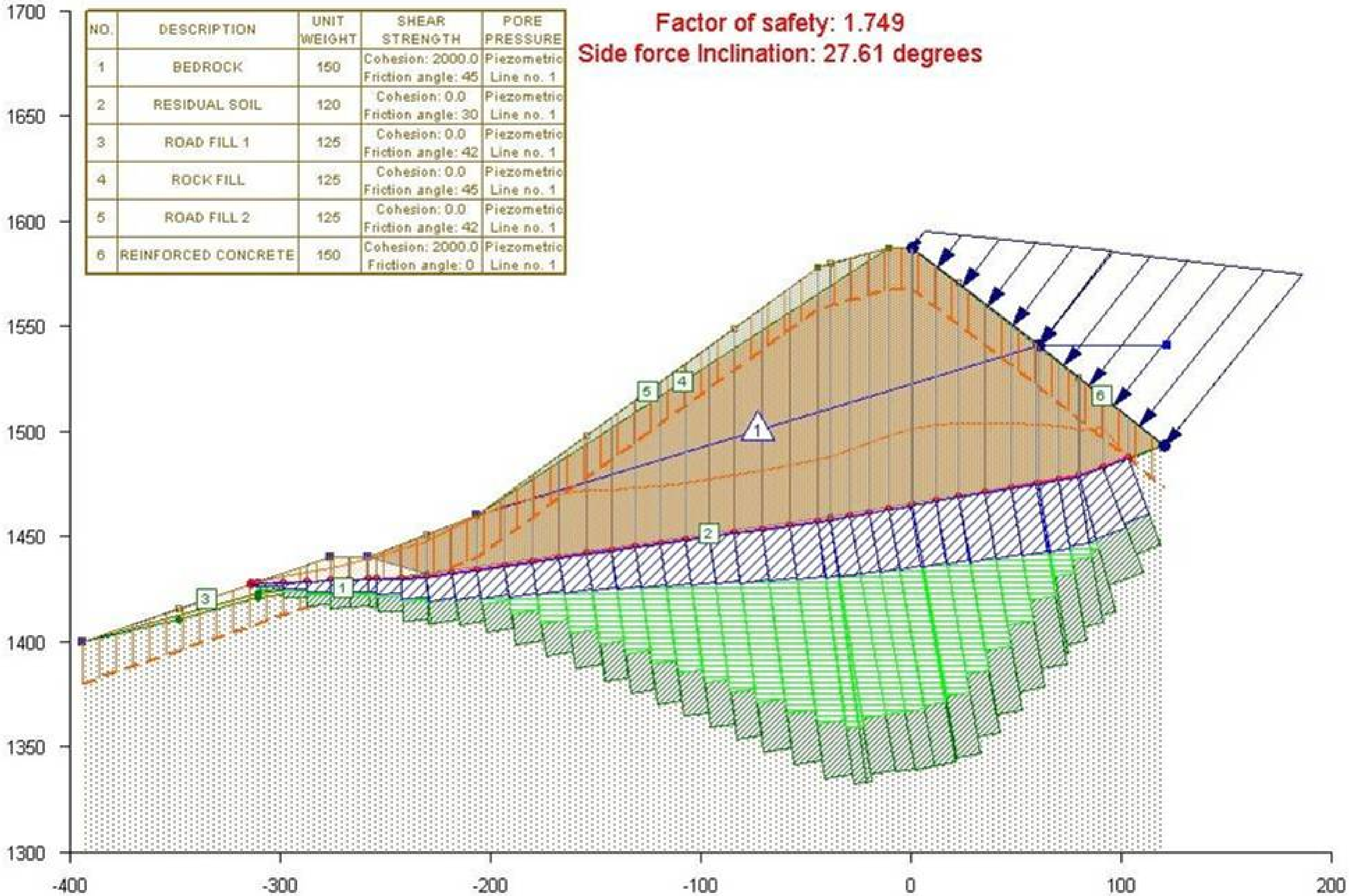
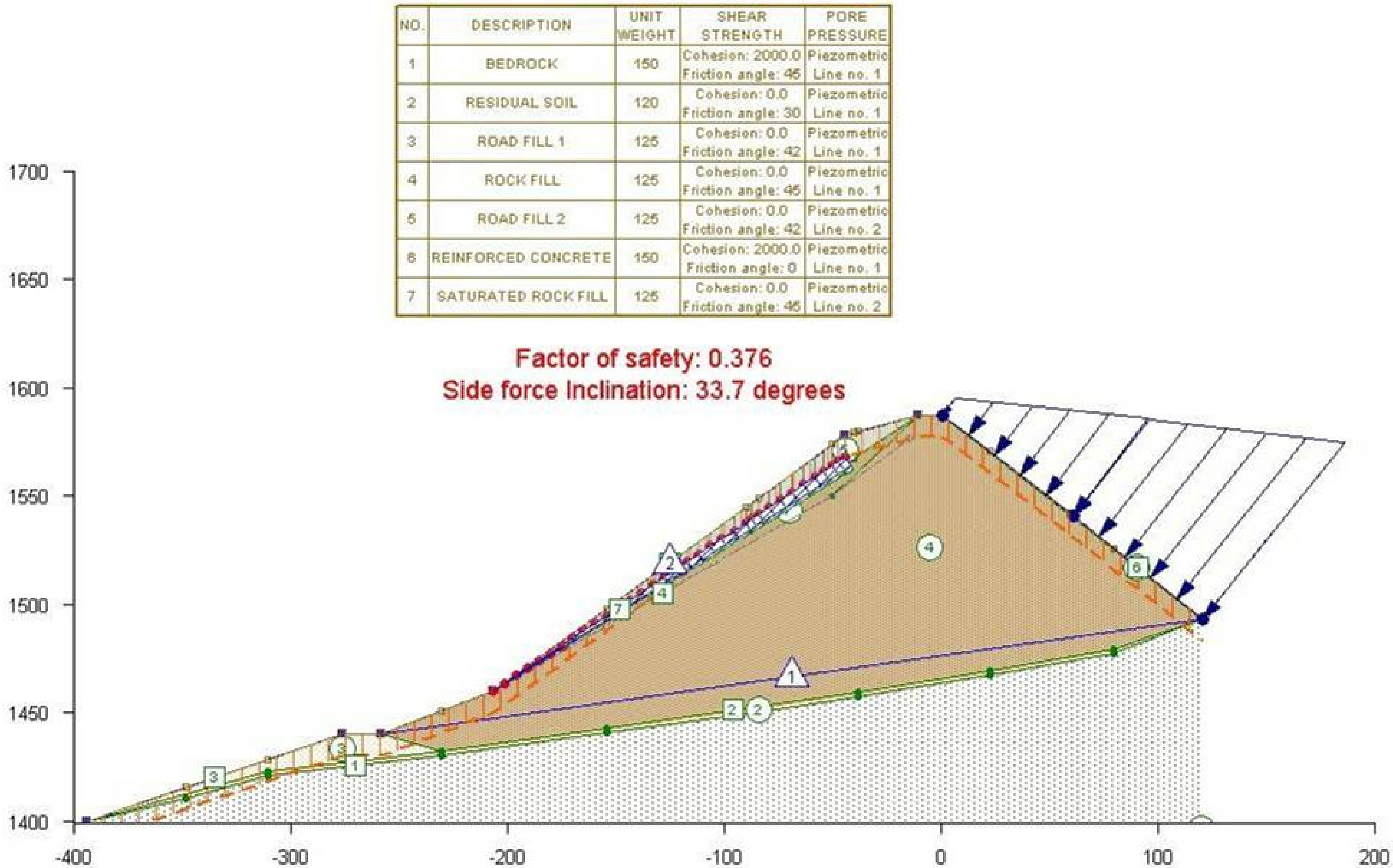
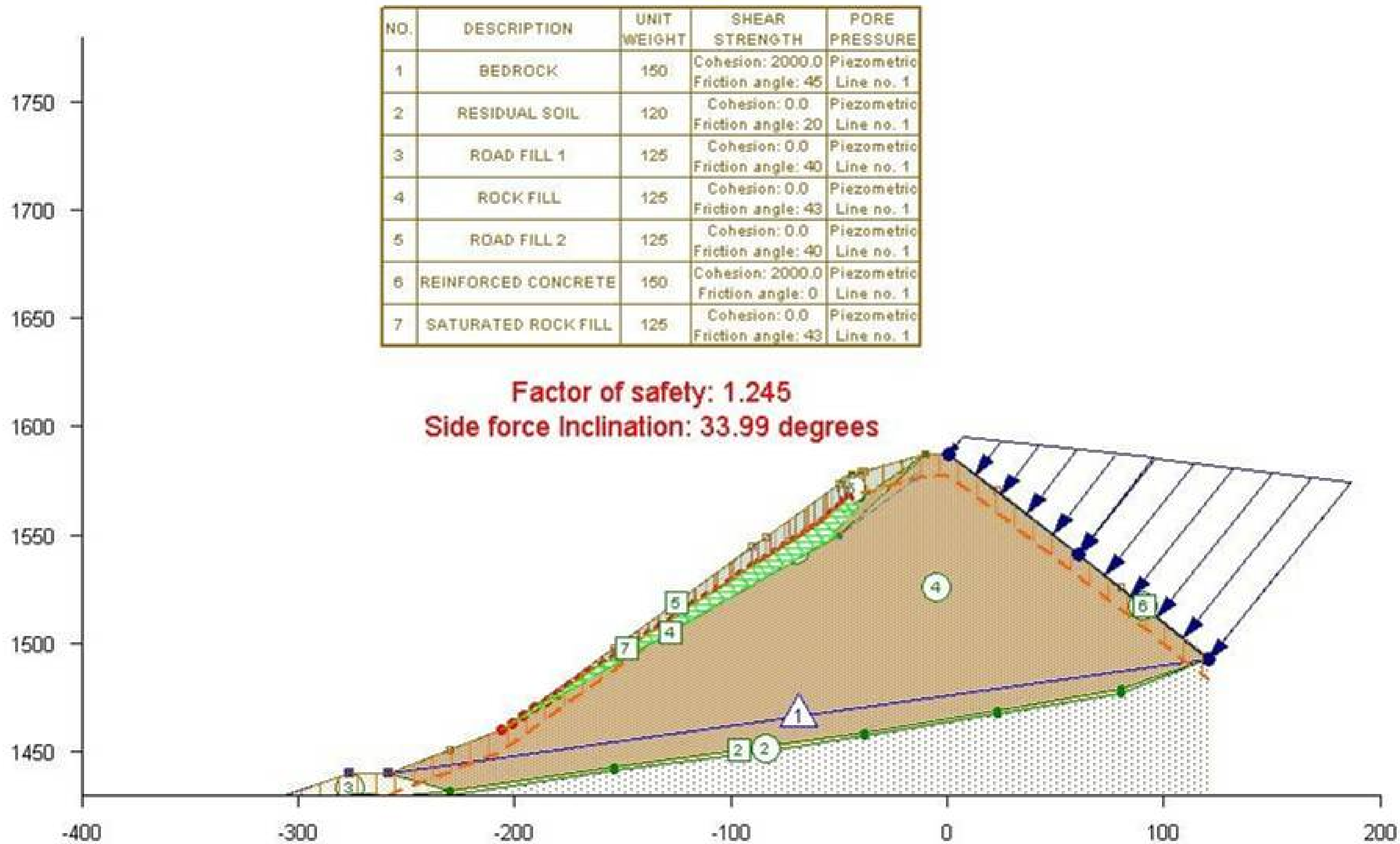


Figure D.14 - Trial 3c



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	BEDROCK	150	Cohesion: 2000.0 Friction angle: 45	Piezometric Line no. 1
2	RESIDUAL SOIL	120	Cohesion: 0.0 Friction angle: 30	Piezometric Line no. 1
3	ROAD FILL 1	125	Cohesion: 0.0 Friction angle: 42	Piezometric Line no. 1
4	ROCK FILL	125	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 1
5	ROAD FILL 2	125	Cohesion: 0.0 Friction angle: 42	Piezometric Line no. 2
6	REINFORCED CONCRETE	150	Cohesion: 2000.0 Friction angle: 0	Piezometric Line no. 1
7	SATURATED ROCK FILL	125	Cohesion: 0.0 Friction angle: 45	Piezometric Line no. 2

Figure D.15 - Trial 3d



NO.	DESCRIPTION	UNIT WEIGHT	SHEAR STRENGTH	PORE PRESSURE
1	BEDROCK	150	Cohesion: 2000.0 Friction angle: 45	Piezometric Line no. 1
2	RESIDUAL SOIL	120	Cohesion: 0.0 Friction angle: 20	Piezometric Line no. 1
3	ROAD FILL 1	125	Cohesion: 0.0 Friction angle: 40	Piezometric Line no. 1
4	ROCK FILL	125	Cohesion: 0.0 Friction angle: 43	Piezometric Line no. 1
5	ROAD FILL 2	125	Cohesion: 0.0 Friction angle: 40	Piezometric Line no. 1
6	REINFORCED CONCRETE	150	Cohesion: 2000.0 Friction angle: 0	Piezometric Line no. 1
7	SATURATED ROCK FILL	125	Cohesion: 0.0 Friction angle: 43	Piezometric Line no. 1

Figure D.16 - Trial 4

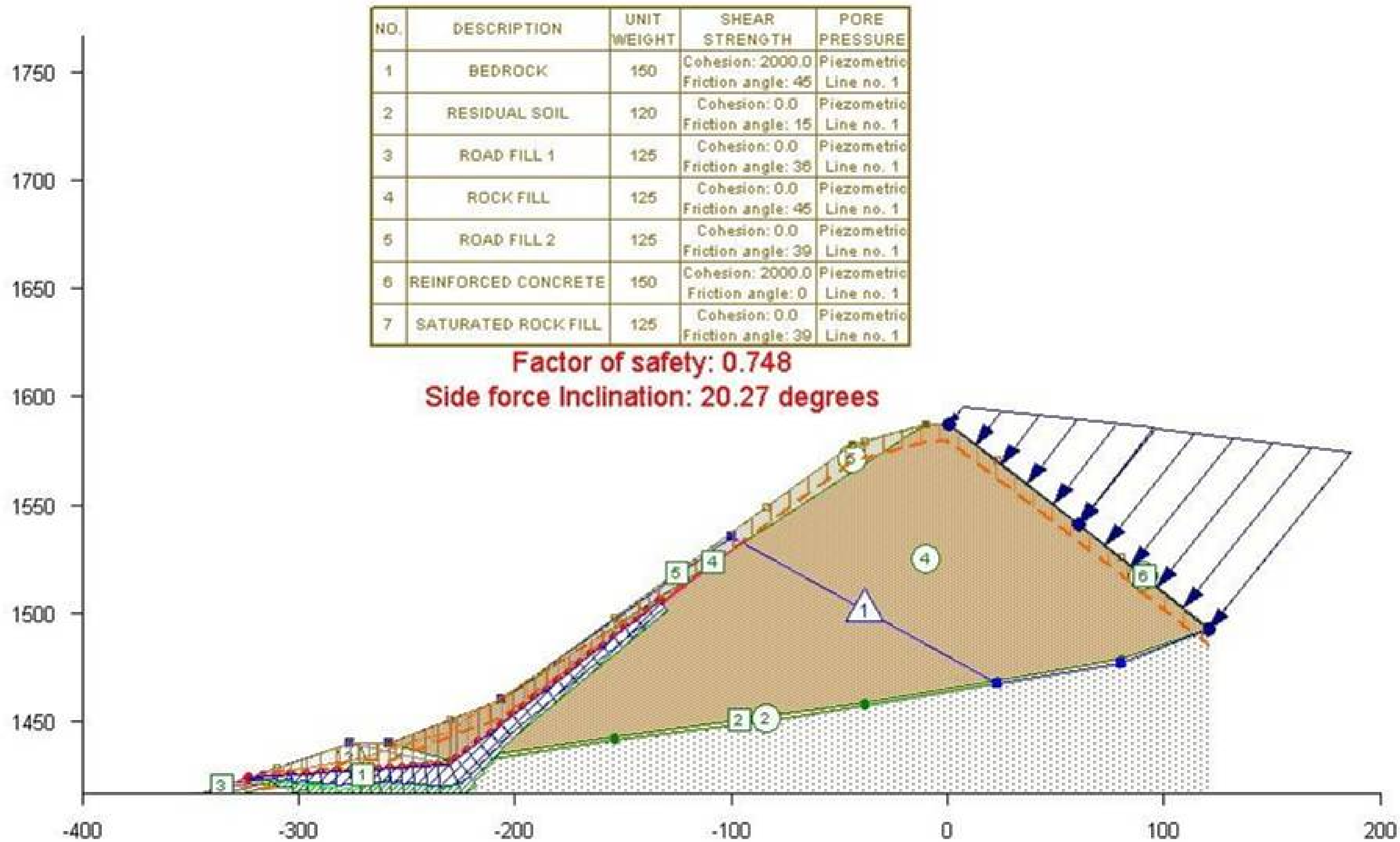


Figure D.17 - Trial 5

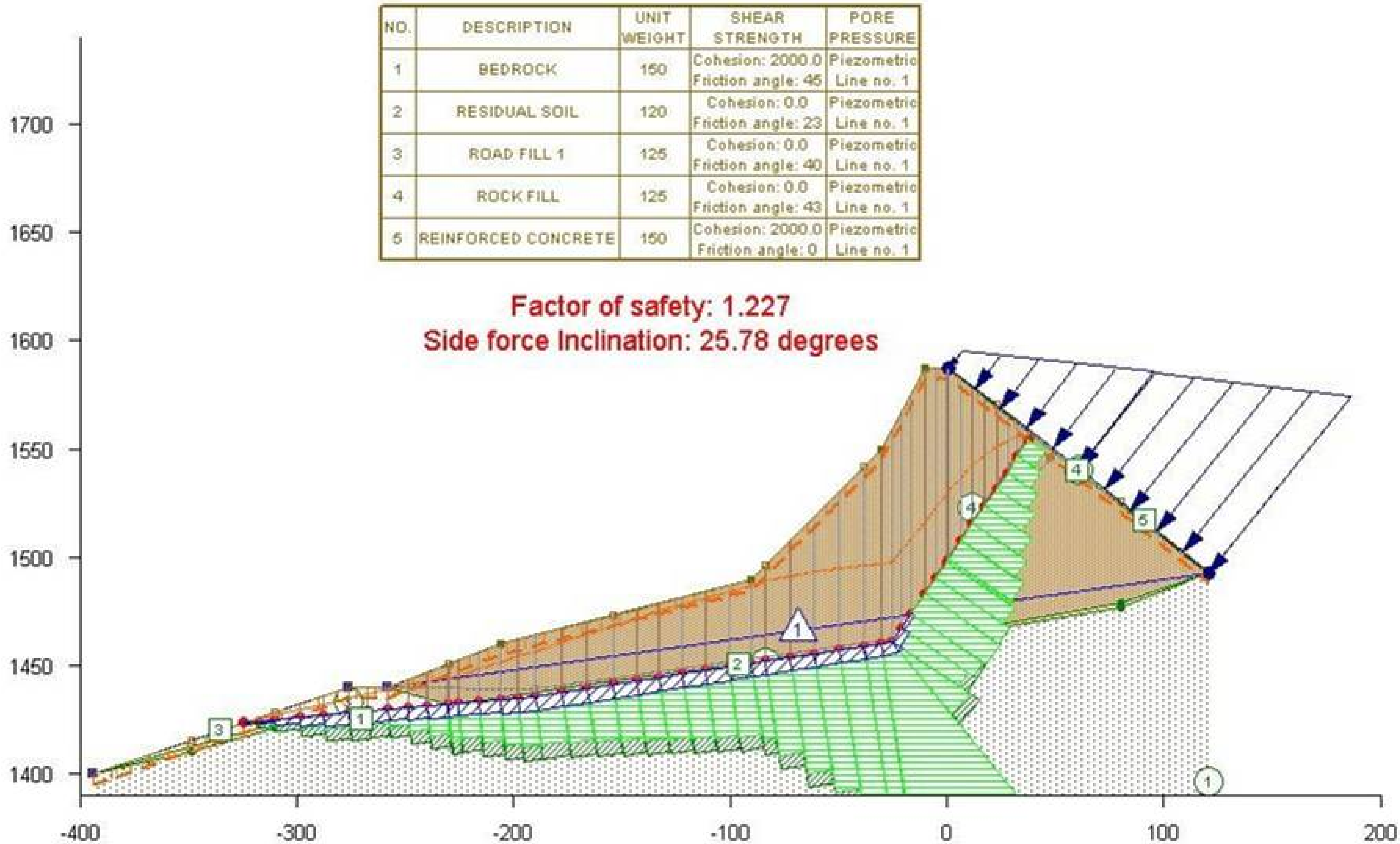


Figure D.18 - Trial 6

Appendix E
List of Soils in the Impact Zone of Upper Reservoir Failure

Area (acres)	Soil Group	Farmland Classification	Erosion Classification
96.00	Relfe-Sandbur complex, 0 to 3 percent slopes, frequently flooded	Farmland of statewide importance	Not highly erodible land
33.29	Killarney-Frenchmill complex, 15 to 45 percent slopes, rubbly	Not prime farmland	Highly erodible land
26.89	Relfe sandy loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide importance	Potentially highly erodible land
18.50	Taterhill silt loam, 1 to 3 percent slopes	All areas are prime farmland	Not highly erodible land
15.92	Relfe sandy loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide importance	Potentially highly erodible land
15.66	Gabriel silt loam, 0 to 3 percent slopes, rarely flooded	Prime farmland if drained	Not highly erodible land
13.93	Gabriel silt loam, 0 to 3 percent slopes, rarely flooded	Prime farmland if drained	Not highly erodible land
13.26	Irondale gravelly silt loam, 15 to 35 percent slopes, rocky, extremely bouldery	Not prime farmland	Highly erodible land
11.27	Taumsauk-Irondale-Rock outcrop complex, 15 to 45 percent slopes, extremely stony	Not prime farmland	Highly erodible land
10.79	Tilk very gravelly sandy loam, 0 to 3 percent slopes, rarely flooded	Farmland of statewide importance	Potentially highly erodible land
10.19	Rueter-Gepp complex, 8 to 15 percent slopes, stony	Not prime farmland	Highly erodible land
9.91	Midco very gravelly loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide importance	Not highly erodible land
8.91	Relfe sandy loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide importance	Potentially highly erodible land
7.73	Tilk very gravelly sandy loam, 0 to 3 percent slopes, rarely flooded	Farmland of statewide importance	Potentially highly erodible land
7.10	Waben gravelly silt loam, 3 to 8 percent slopes	Farmland of statewide importance	Potentially highly erodible land
6.98	Niangua-Bardley complex, 15 to 50	Not prime farmland	Highly erodible land

Area (acres)	Soil Group	Farmland Classification	Erosion Classification
	percent slopes, extremely stony		
6.85	Relfe sandy loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide importance	Potentially highly erodible land
6.67	Batcave-Farewell complex, 0 to 3 percent slopes, frequently flooded	Farmland of statewide importance	Not highly erodible land
6.33	Relfe sandy loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide importance	Potentially highly erodible land
6.25	Relfe sandy loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide importance	Potentially highly erodible land
5.95	Alred-Rueter complex, 15 to 35 percent slopes, very stony	Not prime farmland	Highly erodible land
5.58	Arkana-Gepp complex, 8 to 15 percent slopes, rocky, stony	Not prime farmland	Highly erodible land
4.85	Taumsauk-Irondale-Rock outcrop complex, 15 to 45 percent slopes, extremely stony	Not prime farmland	Highly erodible land
4.52	Taterhill silt loam, 3 to 8 percent slopes	Farmland of statewide importance	Potentially highly erodible land
4.24	Secesh silt loam, 0 to 3 percent slopes, rarely flooded	All areas are prime farmland	Potentially highly erodible land
4.11	Alred-Rueter complex, 15 to 35 percent slopes, very stony	Not prime farmland	Highly erodible land
2.44	Taterhill silt loam, 3 to 8 percent slopes	Farmland of statewide importance	Potentially highly erodible land
2.28	Taumsauk-Irondale-Rock outcrop complex, 15 to 45 percent slopes, extremely stony	Not prime farmland	Highly erodible land
2.18	Lecoma silt loam, 3 to 8 percent slopes	Farmland of statewide importance	Potentially highly erodible land
1.93	Relfe sandy loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide importance	Potentially highly erodible land
1.67	Irondale gravelly silt loam, 15 to 35 percent slopes, rocky, extremely bouldery	Not prime farmland	Highly erodible land
1.11	Relfe sandy loam, 0 to 3 percent slopes, occasionally flooded	Farmland of statewide	Potentially highly erodible land

Area (acres)	Soil Group	Farmland Classification	Erosion Classification
		importance	
1.01	Taterhill silt loam, 3 to 8 percent slopes	Farmland of statewide importance	Potentially highly erodible land
0.95	Water	Not prime farmland	
0.94	Waben gravelly silt loam, 3 to 8 percent slopes	Farmland of statewide importance	Potentially highly erodible land
0.68	Niangua-Bardley complex, 15 to 50 percent slopes, extremely stony	Not prime farmland	Highly erodible land
0.29	Delassus gravelly silt loam, 8 to 15 percent slopes, very bouldery	Farmland of statewide importance	Highly erodible land
0.02	Rueter-Gepp complex, 8 to 15 percent slopes, stony	Not prime farmland	Highly erodible land
377.14	**Total**		