Engineering Report

Montgomery Dam
Hydrologic & Hydraulic Evaluation & Dam Embankment Stability Analysis

Pike Township
Clearfield County, Pennsylvania

May 2008

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EXECUTIVE SUMMARY

1. Montgomery Dam is classified as an intermediate size dam with a high hazard potential. The recommended flood flow criteria set forth by the PADEP is the Probable Maximum Flood (PMF) of 53,860 cubic feet per second. This runoff amount corresponds to a sustained rainfall of 35.7 inches over a 72-hour period. This flood criteria is similar to the adjacent Anderson Creek Reservoir owned by the City of DuBois Water Department.

2. Montgomery Dam's current spillway only passes about 23% of the PMF flow (13,420 cfs), making it severely inadequate under this criteria.

3. The PADEP has mandated that conduits running through earth embankments must have upstream control to "depressurize" the pipeline. This applies particularly to blowoff and dam pipes that are normally not operated. PADEP's concern is that pipes pressurized through the dam have the potential for leakage and eroding of material around the pipe. Unless PADEP changes this policy, a new full depth intake tower must be constructed.

4. The construction cost to construct a new intake tower is $1.6 million. The existing intake tower, constructed in 1960, is not deep enough to connect to existing dam drain lines. The intake tower is only used to draw water off (from mid-depth) for the water treatment plant. In an attempt to retain the current intake/drain arrangement, the Authority could prove the integrity of the 100-year old pipeline to PADEP. However, the Authority should budget for the erection of a new tower for planning purposes.

5. The recommended spillway consists of a roller-compacted concrete chute and uncontrolled ogee crest. Based on the layout of the existing spillway, it is not practical or feasible to reuse the existing spillway. Additionally, the layout of the embankment is not conducive to an increased spillway size. The embankment will need to be re-aligned to conform with the spillway. The total cost to do this work, is estimated at $5,430,000. The total project cost, including a new intake tower, is $7,340,000.

6. A review of seepage for the last eight years has shown consistently low flows. This seepage does not appear to be detrimental to the integrity of the embankment. Piezometric data over the same time period has shown water elevations through the embankment that were far less than those required to maintain embankment stability. It is recommended that the Authority continue monitoring seepage for any changes in flow or turbidity.

7. The most feasible time to clean and inspect the conduits in the embankment would be during construction of the dam rehabilitation since a draw-down of the dam would be necessary at that time. Any reservoir drawdown prior to this event would severely restrict water supply to the service area.

8. The purpose of Montgomery Reservoir is to provide a reliable water supply to the Clearfield service area. The proposed spillway facility is designed to maintain the existing storage of the reservoir. Any reduction is neither practical or desirable.

9. The proposed facilities will not result in any improvements to the quality and quantity of water entering the Clearfield water system. The required expenditure would be solely for providing adequate flood protection in the event of a project design flood occurrence.

10. Some elements of Montgomery Dam are approaching their useful life. The lower embankment and blowoff/drain lines are over 100-years old. The upper embankment, intake tower and spillway are approaching 50-years old. The useful life of an earth dam, with concrete construction, is 50 to 100 years old.

11. The PADEP has not mandated the upgrade of the Montgomery Dam spillway or other improvements. The Authority should advise the PADEP Division of Dam Safety of the need to program the dam improvement project over a 5-15 year period or until sufficient funding is made available. The cost for improvements should be made a part of the Authority's long range plan of water system improvements.

PURPOSE AND SCOPE

As requested by the PADEP Division of Dam Safety letter of July 18, 2007, the purpose of this report is to perform a hydrologic and hydraulic analysis of the Montgomery Run Dam along with a stability analysis of the existing embankment. If the spillway is found to be inadequate, a suitable spillway facility will be recommended. The recommended spillway will provide an adequate margin of safety to human life and property downstream and shall be selected on the basis of fulfilling its purpose at minimum cost. If the embankment stability analysis of the dam concludes that existing embankment slopes are excessive, suitable slopes will be recommended.

The scope of the report included the following:

1. A complete reconnaissance of the existing spillway and dam embankment.

2. Hydrological studies of Montgomery Reservoir watershed. This included the development of HEC-1 flood hydrology input using the watershed characteristics to develop a project Probable Maximum Flood (PMF) hydrograph and verify the PADEP hydrological investigation for Montgomery Dam.

3. Hydraulic evaluation of the existing spillway. If the existing structure is inadequate to pass the required flood flow, an adequate spillway shall be recommended. The recommended facility shall be chosen by an alternatives evaluation for maximum efficiency, cost effectiveness and minimal maintenance.

4. Develop feasibility of PADEP-mandated inspection of conduits through the embankment.

5. Perform a stability analysis of existing embankment. Include stability evaluation for normal water surface and rapid drawdown condition. Perform "dangerous circle" stability analysis of the slopes.

6. Review seepage and piezometric data to determine possible long-term trends.

7. Prepare a report to include a summary of the hydrologic and hydraulic data, stability analysis, cost estimate of the recommended spillway alternatives, as well as, other necessary repairs or maintenance items.

DESCRIPTION

Montgomery Dam is a water supply dam, owned and operated by the Clearfield Municipal Authority. The dam is located on Montgomery Creek in Pike Township, Clearfield County about 3 miles upstream from the town of Hyde, PA. The existing dam was built in 1960 as an expansion of a smaller dam constructed in 1906.

The dam consists of a rolled, earthfill embankment having a crest length of 700 feet and a height of about 71 feet. The top of dam elevation is 1411 MSL and the toe is located at an elevation of 1340 MSL. The upstream embankment has a slope of 2H:1V down to an elevation of 1396 MSL and then the slope changes to 3H:1V down to an elevation of 1380 MSL where there is a 54 foot wide bench and the slope reverts to 2H:1V. The downstream embankment has a 2H:1V slope down to an elevation of 1380 MSL where it decreases to 2.5H:1V. Benches having widths of 10 feet and 13 feet are located at elevations of 1393 MSL and 1380 MSL, respectively. The crest width is 20 feet. See Attachment D for the current dam layout. The uncontrolled ogee spillway is located on the right abutment of the dam and has a length of 60 feet and a crest elevation of 1396.

Three conduits run through the embankment; a 24-inch blow-off pipe and two (2) 20-inch intake lines. The reservoir has two intake towers as a result of the expansion. The old intake tower is located underwater with a bottom elevation of 1340 MSL. The newer intake tower has a bottom elevation of 1370 MSL, 30 feet above the bottom of the dam. Pipes run from both intake towers through the embankment to the downstream toe of the embankment and into the chlorinator house. All three of the conduits are regulated and controlled on the downstream side of Montgomery Dam. The valves remain in the open position, and the intake amount it regulated at the water treatment facility. Having no upstream control of these pipes keeps them pressurized through the embankment.

PREVIOUS REPORTS ON MONTGOMERY DAM

Through the National Dam Inspection Program, a Phase I inspection report of Montgomery Dam (Inventory Number NDS 427) was conducted in July 1978 by Berger Associates, Inc., Harrisburg, PA. The investigation included a field inspection of the dam embankment and hydraulic calculations to estimate the spillway capacity. The Phase I report resulted in recommendations for repair which led to detailed evaluations and rehabilitation of Montgomery Dam.

Recommendations and comments in the Phase I report included the following:

1. Investigating the cause of a slide and seepage on the downstream embankment,
2. Investigate and correct the seepage issue at the left spillway wall,
3. Improve the toe drain performance,
4. The spillway is not adequate to safely pass the design flood.

The highest recorded flow at Montgomery Dam was 1,200 CFS 1972 during Tropical Storm Agnes. Just after this storm event, a slide occurred on the downstream slope of the embankment. No movement has been observed since. However, since the allowable freeboard on the dam is 15 feet, this slide raised concerns about the stability of the embankment during higher flow events.

As a result of the Phase I inspection report, Hill & Hill Engineering, Inc. installed 17 piezometers in Montgomery Dam to monitor seepage through the dam and to evaluate the stability of the embankment. Core borings were taken along the embankment. Lincoln DeVore Testing Laboratory, Inc. was hired to perform a stability analysis of the embankment. The stability analysis revealed that the existing embankment was not stable for high flow conditions.

Based on the evaluation of the embankment, two new berms were added to the downstream face to add weight to the dam and improve stability of the embankment (refer to Figure No. 1 & 2). A new toe drain was installed and gabion baskets were installed at the left end of the spillway wall to control seepage. Four (4) of the piezometers remain on Montgomery Dam for daily monitoring purposes.

Figure 1: Bench #2 Added for Embankment Stability

Figure 2: Piezometer Along Bench #1

The Phase I report estimated the spillway capacity at 14,300 cfs while the PMF peak flow was calculated at 26,300 cfs. The Phase I inspection report classified the spillway as "inadequate", but "not seriously inadequate" since it was capable of passing 54 percent of the PMF. A more recent review of the spillway capacity in September 2002 by the PADEP showed that Montgomery Dam spillway is only able to pass 26 percent of the updated PMF (53,859 cfs), which classifies the spillway as "seriously inadequate."

Up to this point, no attempt has been made to increase the capacity of the spillway at Montgomery Dam to prevent over-topping during the Probable Maximum Flood (PMF) event. The spillway at Montgomery Dam should be capable of passing the PMF flow based on the classification of Montgomery Dam (Intermediate High Hazard).

CURRENT CONDITION OF DAM & APPURTENANCES

The dam and its appurtenances were considered to be in good condition at the time of the 2007 inspection (refer to Figure No. 3). Seepage at the toe of the dam, noted in previous inspection reports, is being monitored by three (3) 90° V-notch weirs. These weirs were installed in 1991 by the Owner. The flow measurements at all three (3) weirs show a fairly constant flow throughout the year (refer to Figure No. 4). There were no signs of turbidity from this seepage at the time of inspection, nor has the Authority observed any signs of turbidity throughout the year. The Authority reports that accumulated sediment behind the weirs is cleaned out two days prior to weir readings.

Figure 3: Overall Downstream View of Dam

The concrete intake structure above the normal pool level was rehabilitated via shotcrete (pressure mortar surfacing) application in 1995. The structure is in good condition (Refer to Figure No. 5).

Figure 4: V-Notch - Seepage Monitoring Weir

Figure 5: Exterior of Intake Tower Structure above Reservoir Level

During previous inspections, the reinforced concrete spillway walls have shown signs of efflorescence and deterioration. The Authority repaired concrete deterioration via shotcrete application. However, during this inspection and due to the low water level, spalling was observed on the upstream approach channel corner and downstream right spillway wingwall. Efflorescence was also noted along the left spillway wall and downstream right corner. This condition should be monitored in subsequent years for any changes (refer to Figure No. 6 & 7).

In addition, the Authority replaced the cross drains downstream of Weir No. 1 with twin 24" reinforced concrete pipe barrels in 2003.

A follow-up underwater inspection (to that conducted in October 1998) was performed on the dam conduits (through the embankment), intake tower valves and intake tower structure in May 1999. The trashracks at the new intake tower were replaced and the 24" slide gate valve at the tower was reconditioned and restored to functional status. Video inspections of the 20" conduit (from the new tower) and the 20" conduit (from the old tower) revealed tuberculation and corrosion but no structural problems or joint leakage were evident in either conduit.

The stilling basin slopes have shown minor surface erosion since the 2004 inspection. Additionally, the stilling basin left slope has shown undermining at the gabion baskets. It was recommended that the Authority should take steps to prevent this surface erosion and undermining.

Figure 6: Spillway Chute, Looking Upstream

Figure 7: Spillway Discharge Basin

A wet area on the downstream slope of the dam has been observed since 2002 along the right side concrete gutter. The wet area was discovered in the area where the gutter was cleaned of debris. The wet area is 60 feet long measured from the end of the concrete gutter. Some standing water was observed near the bottom of this gutter, as well as cracking (refer to Photo No. 6).

In DEP's 2008 Acknowledgment Letter for the 2007 Annual Inspection Report, DEP had no additional maintenance and repair recommendations for the dam. However, the DEP requested that engineering studies be done in order to evaluate the spillway capacity. The Department also noted that the scheduling of the inspection of the embankment conduits be included with the spillway studies.

HYDROLOGIC EVALUATION

A. Introduction

Accurate estimates of runoff resulting from excessive storm events are necessary to adequately evaluate any hydraulic structure. The HEC-1 "Flood Hydrograph Package" was used to determine rainfall/runoff and produce inflow hydrographs. The procedures followed in this study to compute flood flows were in accordance with accepted practices of the Pennsylvania Department of Environmental Protection Division of Dam Safety and the U.S. Army Corps of Engineers, Baltimore District (Susquehanna River Basin).

B. Hazard Classification

Hazard Classification is an attempt to assess the impact a dam failure may have on human life and property. Montgomery Creek flows downstream from the dam for about three miles, through the community of Hyde and into the West Branch of the Susquehanna River. The area between the dam and Hyde is particularly flat and unpopulated. But, Hyde has several hundred homes which could be inundated in the event of a dam failure. As a result of the considerable loss of life and property damage potential in the event of a dam failure, the hazard category for Montgomery Dam is "1" as defined by the PADEP or "high" as described by the U.S. Army Corps of Engineers.

C. Size Classification

Size Classification is determined by either the impoundment storage or height, whichever provides the higher classification. Montgomery Dam has a height of 71 feet and a total capacity of 1,250 acre-feet (407 million gallons) (Refer to Figure No. 8). The top of dam elevation (Elev. 1411) was used to determine the total storage volume of the reservoir. Montgomery Dam would be classified as Class "B" by the PADEP or as "Intermediate" by the U.S. Army Corps of Engineers.

Figure 8: Reservoir Area

D. Project Design Flood Criteria

The project design flood is intended to represent the largest flood that need be considered in the evaluation of a given project. This means that the spillway of the dam under consideration should be capable of safely passing the appropriate design flood. The magnitude of the design flood is directly related to the hazard and size classification of the dam. Montgomery Dam is classified as “B-1” by the PADEP and as “Intermediate Size – High Hazard” by the U.S. Army Corps of Engineers. The design flood criterion for this classification is the Probable Maximum Flood (PMF).

E. Estimates of Probable Maximum Precipitation

The Probable Maximum Flood is the flood that may occur given the most severe combination of critical meteorological and hydrologic conditions that are possible in a specific region. Estimates of probable maximum precipitation (PMP) were provided in Hydrometeorological Report No. 51, “Probable Maximum Precipitation Estimates, United States East of 105th Meridian,” NOAA, National Weather Service.

The procedure for developing the PMP is outlined in Appendix A of this report. It consists of obtaining rainfall depths for storm durations up to 72 hours arranging the rainfall amounts in 6-hour increments to produce the maximum rainfall. The PMP values estimated in this manner were compared with results obtained by the PA DEP. The probable maximum precipitation for Montgomery Dam watershed (10.8 sq. mi.) is listed as follows:

Table 1. PMP Depths and Sequence (72 hour event) – Montgomery Dam Watershed (GD&F)

Time (hours)	6	12	18	24	30	36	42	48	54	60	66	72
PMP (inches)	2.57	2.57	0.88	2.20	2.58	3.79	5.81	6.05	0.83	4.54	2.77	2.42
Total Precipitation:			37.00 inches									
Maximum 6-hr rainfall:			6.05 inches									

Table 2. PMP Depths and Sequence (72 hour event) – Montgomery Dam Watershed (DEP)

Time (hours)	6	12	18	24	30	36	42	48	54	60	66	72
PMP (inches)	2.48	2.48	0.85	2.12	2.49	3.7	5.6	5.8	0.8	4.38	2.67	2.33
Total Precipitation:			35.68 inches									
Maximum 6-hr rainfall:			5.83 inches									

F. Runoff Determination from PMP

The six hour PMP increments were reduced to 15 minute increments in order to produce more accurate hydrographs. The maximum 15 minute rainfall during a 72 hour PMF event is 4.24 inches and 4.40 inches according to the DEP and GD&F data, respectively.

Losses due to infiltration are based on the calculated curve number (CN). The curve numbers are a function of land use and soil type in the area. The Montgomery Dam Reservoir watershed is a mostly forested area, and the most prominent hydrologic soil group is group B. These soil types are typically well drained and have a moderate infiltration rate. The CN for this watershed is about 60, which closely corresponds to the DEP calculated CN of 59.

HEC-1 subtracts the infiltration losses from the total PMP throughout the duration of the storm event. The rainfall excess is then used to generate the total runoff, which is routed through the unit hydrograph to develop a runoff hydrograph.

G. Flood Hydrographs

The synthetic unit hydrograph utilized in this study conforms to the Soil Conservation Service (SCS) Dimensionless Unit Hydrograph method. The time between the center of mass of rainfall excess and the time to the peak time of the hydrograph, or lag time, is used to develop the SCS unit hydrograph. The lag time is used to calculate the time to peak of the hydrograph and the time to peak is used to calculate the peak flow of the unit hydrograph. The lag time calculated by PA DEP and GD&F was 1.16 hrs and 1.08 hrs respectively. A peak discharge of 53,859 cfs at a time of 40.25 hours was calculated by the PA DEP and 59,143 cfs at a time of 40 hours by GD&F. The peak outflow used to size the spillway was 53,859 cfs as calculated by the PA DEP.

H. Reservoir Storage Evaluation

The storage capacity of Montgomery Reservoir was calculated based on data in the Phase I Inspection Report. Table 3 provides a tabulation of the normal pool and top of dam storage volumes for Montgomery Reservoir.

Table 3. Montgomery Reservoir – Storage Data

Normal Pool	Top of Dam	Storage Normal Pool		Storage Top of Dam	
(Elevation)	(Elevation)	(Gallons x 10^6)	(Acre-feet)	(Gallons x 10^6)	(Acre-feet)
1396	1411	227	696.6	407	1,250.0

HYDRAULIC EVALUATION

A. Introduction

The peak flow criteria for the Montgomery Dam spillway is the PMF as previously discussed. A proposed spillway was considered since the existing spillway at Montgomery Dam cannot safely pass the PMF. The existing spillway structure is not properly aligned with the damcrest, has a varying slope and the sidewalls are low in some areas and cannot contain the weir design flow (Refer to Photo No. 7). Therefore, it is not feasible to incorporate the existing spillway into the new facility.

B. Existing Spillway Evaluation

The existing spillway at Montgomery Dam consists of an uncontrolled overflow ogee weir and a spillway chute. The length of the weir is 60 feet and the total available head on the weir is 15 feet. The spillway chute varies from 60 feet to 30 feet in width with sidewalls that range between 7.9 feet and 25 feet in height.

The maximum capacity of the overflow weir is 13,420 cfs, and the maximum capacity of the spillway chute is 12,600 cfs. The maximum capacity of the existing spillway is only about 23% of the required Probable Maximum Flood.

C. Spillway Alternatives

Several spillway alternatives were considered in the evaluation of the Montgomery Dam including the following: 1) overtopping protection, 2) side channel spillway, 3) ogee spillway with floodwall, 4) ogee spillway without floodwall, and 5) ogee weir with roller compacted concrete chute. Each of the spillway options that were studied would require realigning the top of the dam for a larger overflow weir.

The overtopping protection investigated was Armortec's® open cell tapered blocks. It was discovered that the overtopping protection would not be adequate to pass the PMF alone or in conjunction with the existing spillway. The spillway width would have to be increased from 60 feet to 175 feet, which was deemed to be too costly and inefficient for this application. The side channel spillway was also ruled out due to the excessively deep trough which would be required to pass the PMF. Detailed analyses were completed of the remaining spillway options.

D. Ogee Spillway with Floodwall

A floodwall with a height of 5 feet and a weir length of 170.5 feet with a design flow equal to the PMF was considered. This uncontrolled overflow ogee weir spillway utilizing a floodwall was considered because the increased head from the floodwall would reduce the spillway width and decrease embankment excavation. However, the overall cost of concrete for this option is about $400,000 more than for the ogee spillway alternative without a floodwall. Even with a decreased spillway width, the floodwall option is not the most economical choice.

E. Ogee Spillway without Floodwall

The proposed spillway has an overflow weir that is 266.5 feet long with total available head of 15 feet. The design flow is the PMF or 53,859 cfs. This spillway was designed to have two stages or channels. The lower stage has a weir crest elevation of 1396, a width of 60 feet and a depth of 6 inches. This size of stage was chosen based on records of flows over the existing spillway. Two channels will increase the service life of the spillway and reduce maintenance associated with repairing eroded concrete across the entire width of the spillway channel.

This spillway option consists of an uncontrolled overflow ogee weir, spillway chute and deflector bucket. The spillway chute varies in width from 266.5 feet to about 256.3 feet. The deflector bucket is 256.3 feet wide and 42.6 feet long with an exit angle of 12 degrees. The overall length of the proposed reinforced concrete spillway from the top of the weir to the end of the deflector bucket is approximately 210 feet. The proposed channel downstream from the deflector bucket should be adequately armored for a distance of about 45 feet. Additional channel work must be done downstream of the armoring in order to align the spillway channel with the existing location of Montgomery Creek.

The embankment will be realigned to accommodate this spillway option, but the existing embankment slope will be maintained. This will include earthwork on both the upstream and downstream embankment. The changes to the embankment will not affect the embankment stability because the slope will not change; only the alignment of the top of the dam. Due to the location of the proposed spillway (near the middle of the embankment), the existing spillway will not need to be removed, but may be buried with fill to eliminate unnecessary excavation and demolition expenses.

F. Roller Compacted Concrete Spillway

Roller compacted concrete (RCC) is an attractive alternative due to the durability of the material and economical benefits resulting from the installation procedure. RCC is typically applied in lifts and can be spread using earthwork machinery, which eliminates the formwork and finishing labor involved with conventional concrete construction. These lifts are layered in a step-like fashion and create a stepped chute (Refer to Figure 9 & 10). When an existing embankment is not in place, an RCC spillway is most effectively sloped at 0.8H: 1V. When the slope of an RCC spillway is fixed and flatter than the most effective slope, it is best to have a reinforced concrete service spillway and an RCC auxiliary spillway so that the RCC portion is protected from erosion due to constant flow.

The application of RCC for dam rehabilitation projects has become more prevalent in recent years as the understanding of the material aspects of RCC has developed. It is now considered to be as durable and strong as conventional reinforced concrete in most cases.

A roller compacted concrete spillway used in conjunction with a reinforced concrete service spillway is the least expensive option. This option has an uncontrolled overflow ogee weir having a length of 266.5 feet and, similar to Option #2 has two-channels, separated by a concrete wall (refer to Figure 10). The slope of the chute is 2H:1V and the chute has a length of 115 feet, which aligns closely to the slope of the embankment and allows for shorter sidewalls than a steeper slope would. The reinforced concrete section will be designed for normal flow and the RCC section will accommodate larger flow events. A deflector bucket is proposed at the toe of the spillway and additional armoring downstream will also be required. This option will also require realignment of the top of the dam and the same earthwork activities as Option #2.

Figure 9: Typical RCC Construction (Courtesy of www.agpeltz.com)

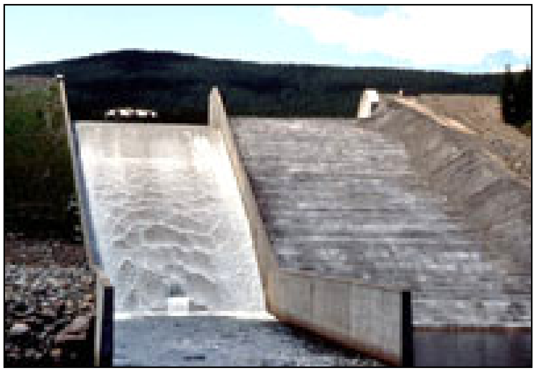


Figure 10: Typical Reinforced Concrete Service Chute and Auxiliary RCC Emergency Overflow Chute (Courtesy of www.cement.org/basics/concreteproducts-rcc.asp)

DAM EMBANKMENT STABILITY ANALYSIS

A. Introduction

A stability analysis was conducted on the dam embankment using soil properties from the field study conducted by Lincoln DeVore soil engineers in 1979. According to the report split spoon, soil samples were taken instead of conventional shelby tube samples because of the presence of coarse material. Triaxial testing was performed using remolded samples. The soil properties of the dam were estimated as follows:

Moist Unit Weight	108 pcf
Saturated Unit Weight	115 pcf
Submerged Unit Weight	52.6 pcf
Angle of Internal Friction	26.5°
Slide Friction Coefficient (c')	0

These estimates should provide a conservative factor of safety for the stability analyses. The slide friction coefficient shows that the soil in the embankment is cohesionless; however, based on several core borings taken at the time of the dam expansion, the soil in the dam has plastic characteristics, showing that the soil is not cohesionless. The cohesionless soil factor is likely a result of poor sampling.

A typical cross-section of the embankment was used, as shown on Drawing No. 2 of the stability calculations in Attachment C. The seepage line through the dam was determined based on piezometric data of the embankment. The highest piezometer levels were used in the stability analysis.

The following stability analyses were performed:

1. Stability against headwater pressure (existing slope and floodwall option).
2. Horizontal shear in the downstream portion of dam.
3. Horizontal shear in the upstream portion of dam.
4. Dangerous circle analysis of the downstream slope.
5. Dangerous circle analysis of the upstream slope.

Stability of the earth dam against headwater pressure was performed for the existing embankment slopes, which will remain unaltered, and for the floodwall spillway option to ensure that a floodwall would be feasible using the existing embankment slopes, and to verify previous stability analysis.

B. Seepage Flow and Piezometer Monitoring

Seepage at the toe of the dam, near the previous middle of the embankment, has been monitored since 1991 using three (3) V-notch weirs. Based on the previous Annual Dam Inspection Reports, there have been no signs of turbidity from this seepage, and the flow rate has been consistently low. This seepage does not appear to be problematic. Four (4) piezometers are located on the downstream side of the embankment to monitor water levels through the embankment as recommended in the Lincoln DeVore stability analysis report.

The Authority was concerned about a recent rise in piezometer water levels through the embankment. If the water levels were to exceed threshold elevations, the embankment stability would be in question. Although reflecting changes in reservoir level, the piezometer readings have remained at least 20 feet below these threshold values since monitoring began and the water levels have remained relatively static.

C. Existing Downstream Slope Analysis

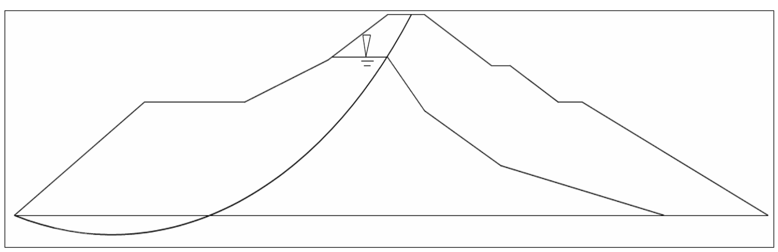
The existing downstream slope was analyzed for stability against headwater pressure for two cases; with and without a floodwall. The factor of safety for the headwater pressure without the floodwall was 5.66 and with a 5-foot floodwall was 3.07. The factor of safety for horizontal shear in the downstream portion of the dam is 2.2. The safety factors are well above the typical factor of safety of 1.5 for both of the stability conditions analyzed. A "dangerous circle" analysis of the downstream embankment yielded a minimum factor of safety of 1.31, which is less than the typical factor of safety for new embankments. However, based on the past performance of the existing embankment, modifications to the downstream slope are not recommended. The existing downstream slopes of 2H:1V and 2.5H:1V are acceptable.

D. Existing Upstream Slope Analysis

The existing upstream slope of the reservoir was analyzed for horizontal shear, which checks for safety against sudden or rapid drawdown. A factor of safety of 1.29 was calculated, which is an acceptable factor of safety according to U.S. Army Corps of Engineers guidelines which use a factor of safety of 1.1 for this condition. A "dangerous circle" analysis of the upstream embankment yielded a factor of safety of 0.90. The soil properties used were conservative, which may help to explain the low factor of safety. It is unlikely that the soil is cohesionless, based on previous soils data. The factor of safety is greater than 1.0 even if a small cohesion factor of 0.10 is used in the stability calculations.

It may be necessary to perform a geotechnical investigation during the design phase of this project to verify the embankment stability under rapid drawdown and "dangerous circle" conditions.

Figure 12: Typical Stability/Embankment Profile



EMBANKMENT CONDUITS AND INTAKE TOWER

The PADEP has raised concerns about the conduits that run through Montgomery Dam and requested that "the schedule for pigging, flushing and inspection of the conduit be included with the spillway studies" in a letter dated February 11, 2008. The condition of the conduits which run through the embankment are critical in maintaining the integrity of the dam. Undetected leaks or structural damage to the pipes put the water supply and downstream inundation area at risk by potentially draining the reservoir and leading to a piping failure of the dam.

Three conduits run through Montgomery Dam; two 20-inch intake lines and one 24-inch blow off pipe. An underwater inspection of these pipes was performed in May of 1999 which revealed tuberculation and corrosion of the intake pipes. No structural problems or joint leakage were evident in either conduit. In the Acknowledgement Letters for the 2006 and 2007 Annual Inspection Reports, the PADEP requested that the Clearfield Municipal Authority schedule pigging, flushing, and inspection of these pipes. Another concern with the conduits is the location of the control valves. The control valves for all three of the conduits are located downstream of the embankment pressurizing the pipe through the embankment, which presents safety and maintenance issues. It is currently not possible to perform maintenance on these pipes or to prevent water from entering them in the event of a leak or pipe failure due to the location of the control valves. In order to increase the safety of Montgomery Dam, the control valves for the embankment conduits must be installed upstream of the embankment.

Installing valves upstream of the embankment requires access to the valves with a full reservoir. The intake lines draw water from elevations of approximately 1345 and 1373 using the old submerged tower, and the newer above pool tower, respectively. The blow off pipe is located at an elevation near 1345. Access to the control valves may be achieved by running each of the supply lines to an intake tower. The submerged intake tower is not accessible by dam operating personnel, and the above pool tower only extends down to an elevation of 1370. As a result, an intake tower reaching from the bottom of the reservoir to the top of the dam will need to be constructed. The newest intake tower will be removed and the pipes will be run to the new intake tower at their respective elevations. Access to the proposed intake tower will be granted through an access bridge on the left abutment near the location of the current bridge and spanning 85 feet.

The intake tower installation, cleaning and inspection of the pipes, as well as any other required maintenance items discovered during the inspection must be conducted during construction of the new spillway when the dam is drawn down.

According to the Authority, Montgomery Dam cannot be removed from service to allow pigging and flushing of the intake pipe, regardless of the duration, without severe water restrictions and/or rationing in the service area. Depending on the duration of reservoir drawdown, pipe inspection and reservoir refilling, it is conceivable that Montgomery reservoir will be out of service from 90-150 days. Montgomery Reservoir is the sole source of supply for the entire service area with the exception of the lower capacity Moose Creek and Montgomery well fields. The Authority also has limited in-system storage in the distribution system (less than 2 days).

The Authority is also concerned that aggressive scraping and cleaning of the cast iron intake pipe inherent in pigging operations could cause damage to the pipe with resulting leakage and embankment piping. In summary, the Authority cannot tolerate the removal of Montgomery Reservoir from service or the potential of pipeline damage due to aggressive scrapping and cleaning operations.

If Moose Creek Reservoir is restored to service, draining of Montgomery Dam could be done in an emergency. The completion of the Moose Creek water treatment plant in late 2009 could facilitate this, however, current demand (1.75 MGD) could easily tax the Moose Creek water supply (including surface reservoir and well field) and the Montgomery well field.

Given the physical limitations of the Clearfield water supply system, inspection of the Montgomery Dam conduits must be deferred until major construction is undertaken at the dam site.

ESTIMATED COST OF RECOMMENDED IMPROVEMENTS

The following cost estimates are approximate and intended only to reveal the magnitude of the work required. Considerable modifications to the design and scope of work may be required during the design phase. In addition, the estimated cost represents current 2008 prices which would have to be corrected for inflation if projected beyond 2008.

The major work items consist of a new spillway facility, new intake tower and appurtenances, channel work downstream of the spillway chute, realigning the embankment, and pigging, flushing and inspection of the conduits that run through the embankment. An alternative evaluation of several rehabilitation options was performed. A screening of these options was done on the basis of engineering judgment. A summary of project costs for options utilizing a reinforced concrete spillway and roller compacted concrete spillway with and without installation of an intake tower is as follows:

Table 4: Project Cost Estimate for Option 1: Reinforced Concrete Spillway w/Intake Tower

	Qty	Unit Cost	Total Cost	
Construction Cost				
1. Excavation (CY)	53,750	$20	$1,075,000	
2. Backfill (CY)	53,450	$35	1,870,750	
3. Reinforced Concrete Walls (CY)	500	$650	325,000	
4. Reinforced Concrete Chute (CY)	3,200	$650	2,080,000	
5. Intake Tower and Access Bridge	JOB	LS	1,600,000	
Total Construction Cost				*$6,950,750*
Other Costs				
1. Engineering/Design/Const. Admin.			$850,000	
2. Legal/Administrative			50,000	
3. Contingency (10% of Construction)			695,000	
4. Financing Cost			$100,000	
Total Other Costs				*$1,695,000*
Total Project Cost Estimate, Option 1				***$8,650,000***

Table 5: Project Cost Estimate for Option 2: Reinforced Concrete Spillway Only

	Qty	Unit Cost	Total Cost		
Construction Cost					
1. Excavation (CY)	53,750	$20	$1,075,000		
2. Backfill (CY)	53,450	$35	1,870,750		
3. Reinforced Concrete Walls (CY)	500	$650	325,000		
4. Reinforced Concrete Chute (CY)	3,200	$650	2,080,000		
Total Construction Cost				*$5,350,750*	
Other Costs					
1. Engineering/Design/Const. Admin.			$650,000		
2. Legal/Administrative			50,000		
3. Contingency (10% of Construction)			535,000		
4. Financing Cost			75,000		
Total Other Costs				*$1,310,000*	
Total Project Cost Estimate, Option 2					***$6,660,000***

Table 6: Project Cost Estimate for Option 3: Roller Compacted Concrete Spillway w/Intake Tower

	Qty	Unit Cost	Total Cost		
Construction Cost					
1. Excavation (CY)	53,750	$20	$1,075,000		
2. Backfill (CY)	53,450	$35	1,870,750		
3. Reinforced Concrete Walls (CY)	600	$650	390,000		
4. Reinforced Concrete Chute (CY)	500	$650	325,000		
5. RCC Chute (CY)	4,400	$150	660,000		
6. Intake Tower and Access Bridge	JOB	LS	1,600,000		
Total Construction Cost				*$5,920,750*	
Other Costs					
1. Engineering/Design/Const. Admin.			$750,000		
2. Legal/Administrative			50,000		
3. Contingency (10% of Construction)			535,000		
4. Financing Cost			80,000		
Total Other Costs				*$1,415,000*	
Total Project Cost Estimate, Option 3					***$7,340,000***

Table 7: Project Cost Estimate for Option 4: Roller Compacted Concrete Spillway Only

	Qty	Unit Cost	Total Cost		
Construction Cost					
1. Excavation (CY)	53,750	$20	$1,075,000		
2. Backfill (CY)	53,450	$35	1,870,750		
3. Reinforced Concrete Walls (CY)	600	$650	390,000		
4. Reinforced Concrete Chute (CY)	500	$650	325,000		
5. RCC Chute (CY)	4,400	$150	660,000		
Total Construction Cost				*$4,320,750*	
Other Costs					
1. Engineering/Design/Const. Admin.			$550,000		
2. Legal/Administrative			50,000		
3. Contingency (10% of Construction)			430,000		
4. Land/Rights-of-Way			75,000		
Total Other Costs				*$1,110,000*	
Total Project Cost Estimate, Option 4					***$5,430,750***

REFERENCES

Berger Associates, Inc. (1978) "Susquehanna River Basin Montgomery Dam Commonwealth of Pennsylvania Clearfield County Inventory Number NDS 427: Phase I Inspection Report National Dam Inspection Program," Harrisburg, PA.

Chow, V.T. (1959) *Open Channel Hydraulics*. McGraw-Hill Book Co., New York, NY.

Creager, W.P., Justin, J.D., and Hinds, Julian (1964) *Engineering for Dams*, Volume III, John Wiley and Sons, Inc., New York, NY.

Lincoln-Devore Testing Laboratory, Inc. (1979) "Field Study and Stability Analysis Montgomery Dam Clearfield, PA," Colorado Springs, CO.

Mays, Larry W. (2001) *Water Resources Engineering*, John Wiley and Sons, Inc. New York, NY.

Portland Cement Association (PCA) (2008). "Roller Compacted Concrete". <http://www.cement.org/water/dams_rcc.asp> (4/28/2008).

United States Army Corps of Engineers (USACE) Hydrologic Engineering Center (1998). HEC-1, Flood Hydrograph Package, User's Manual.

United States Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS), Conservation Engineering Division. (1986). Technical Release 55, Urban Hydrology for Small Watersheds.

USACE, Engineering and Design (2003). "Slope Stability GM-No. 1110-2-1902."

USDA, NRCS (2007). Web Soil Survey 2.0. <http://websoilsurvey.nrcs.usda.gov/app> (2/8/2008).

United States Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), USACE, (1978). Hydrometeorological Report No. 51, "Probably Maximum Precipitation Estimates, United States East of the 105th Meridian."

United States Geological Survey (USGS). (2007). StreamStats, <http://streamstats.usgs.gov/pastreamstats> (2/7/2008).