PERFORMANCE OF DAMS AND SPILLWAYS – 2009 GEORGIA FLOOD

Randall P. Bass, P.E.[1],
James R. Crowder, P.[2]
Joseph S. Monroe, P.E.[3]

ABSTRACT

During the latter part of September 2009, the Atlanta metro area received several days of steady rain that cumulated with a high intensity event in the early morning hours of 21st. Counties west of the metropolitan Atlanta area received in excess of 22 inches of rain in a 24 hour period. Other regions in the greater metropolitan area of Atlanta received between 7 and 15 inches over the same 24 hour period. As a result of the intense rainfall, record flooding ensued with some stream gages recording flow rates greater than five times the previously documented record flows.

As a result of the intense rainfall and associated flooding, the auxiliary spillway systems for numerous dams activated to discharge the storm water runoff from the reservoirs. In addition, several small unregulated low-hazard dams overtopped and breached. Thanks in large part to an active Safe Dams Program, no failures of high-hazard dams were reported; however, damage did occur to numerous spillway systems as result of the subject storm.

This paper will discuss the September 2009 storm and place the recorded rainfall into historical perspective as it is relate to past extreme events and hyrologic/hydraulic design requirements as required by both State and Federal agencies; review the design and performance of several Natural Resources Conservation Service dams experienced rainfall amounts in excess of the 100-year event; discuss the performance of several dams that overtopped; and present the performance of numerous earth and rock cut auxiliary spillway channels. In addition, the paper will discuss the actions that have been or will be implemented to repair or improve, if necessary, the damaged structures.

INTRODUCTION

In September 2009, portions of north and central Georgia experienced several days of steady, moderate to heavy rainfall that culminated in a 24-hour event that exceeded the 100-year amounts in many areas and approached, if not exceeded, fifty percent of the Probable Maximum Precipitation in other areas. The rainfall began as a relatively widespread event on or about September 15th. The rain event, which was the result of a low-pressure system drawing warm, moist air from the Gulf of Mexico, and the wetter than average month of August, created soil moisture conditions that were above average. Consequently, the creeks, streams, rivers, and reservoirs were at or above normal levels. Rainfall amounts during the

[1] Principal, Schnabel Engineering, 6445 Shiloh Road, Suite A, Alpharetta, Georgia 30005, rbass@schnabel-eng.com
[2] Senior Associate, Schnabel Engineering, 6445 Shiloh Road, Suite A, Alpharetta, Georgia 30005, jcrowder@schnabel-eng.com
[3] Senior Associate, Schnabel Engineering, 6445 Shiloh Road, Suite A, Alpharetta, Georgia 30005, jmonroe@schnabel-eng.com

period of the 15th through the 20th varied, but generally ranged from 2 to 5 inches in the Atlanta Metropolitan area. During the afternoon and evening of September 20th and the morning of September 21st, the slow moving storms reached a crescendo with more than 20 inches of rain falling in a 24-hour period in portions of Douglas and Paulding counties. Other counties located along the U.S. Interstate 20 corridor, west of Atlanta also received exceptionally high amounts of rain during the same 24-hour period. Atlanta and counties east of Atlanta experienced intense rainfall, but the amounts did not approach the amounts observed in Carroll, Douglas, Paulding, and Cobb counties. Radar-derived estimates of the rainfall amounts that fell during the period of September 19 through September 21, 2009 are provided in Figure 1 below.

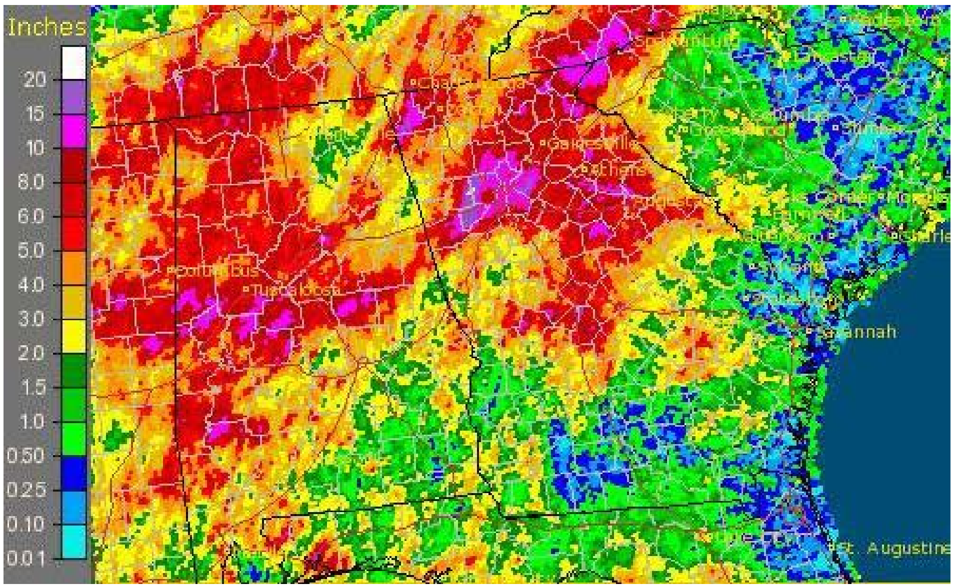

Figure 1. September 19th through September 21st Radar-Derived Estimates of Rainfall

The runoff from the intense rainfall resulted in damage to key infrastructure facilities such as dams. Auxiliary, or emergency, spillways for numerous dams in Carroll, Douglas, Paulding, Cobb, Fulton, Cherokee, and Gwinnett counties activated and experienced damage. Several structures overtopped. Contained herein is discussion of three facilities (Snake Creek Dam in Carroll County, Pumpkinvine Creek Watershed Structure No. 3 in Paulding County, and Yellow River Watershed Structure No. 16 in Gwinnett County) that were impacted by the storm. In addition to a description of the facilities, which will include an overview of the spillway hydraulics, drainage basin characteristics, and hydraulic design criteria, this paper presents a summary of the performance of the dams and spillways during the September 2009 flood event.

OVERVIEW OF GEORGIA RAINFALL

According to Technical Paper Number 40 (TP-40) titled "Rainfall Frequency Atlas of the Eastern United States for Duration from 30 Minutes to 24 hours and Return Periods from 1 to 100 Years" prepared by the U.S. Department of Commerce, Weather Bureau and dated 1961, the depth or amount of rain associated with 100-year return period, 24-hour duration event for northern Georgia is on the order of 8 inches. Figure 2 (obtained from TP-40) depicts the 100-year return period, 24-hour duration rainfall amounts for the United States.

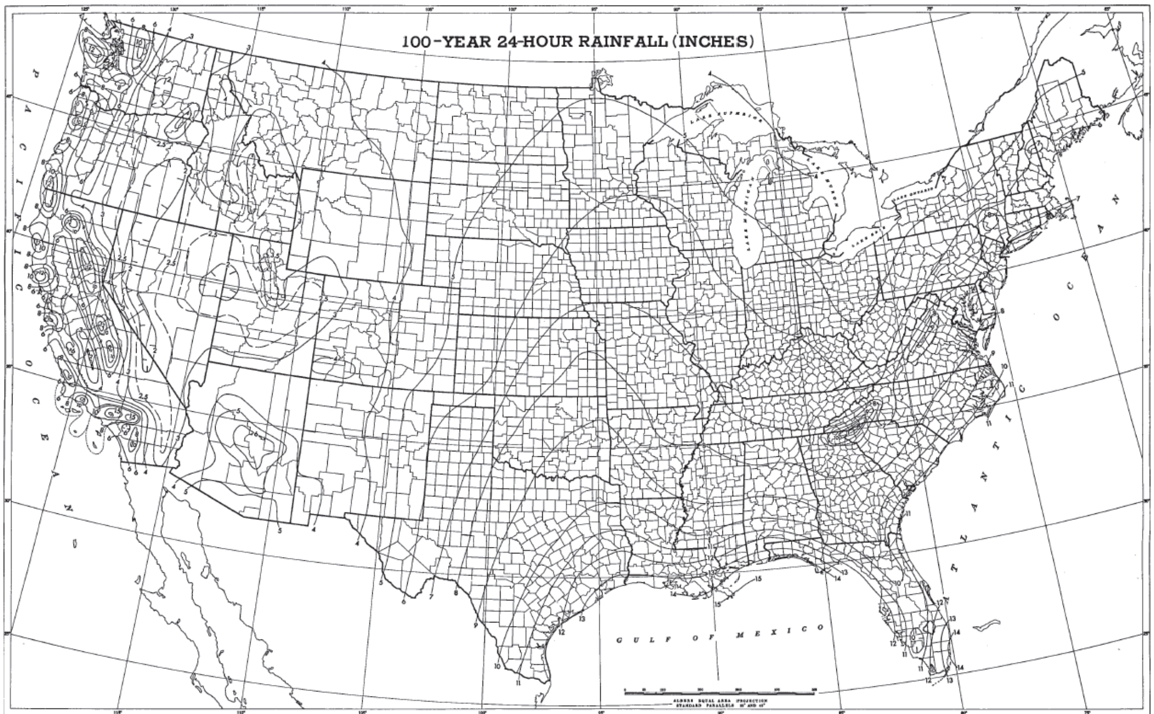

Figure 2. 100-Year Return Period, 24-hour Duration Rainfall (Obtained from TP-40)

In addition to providing rainfall depths/amounts for return periods ranging from 1 to 100 years, TP-40 also estimates the “probable maximum 6-hour precipitation for 10 square miles” to be on the order of 29 to 32 inches for the state of Georgia. More specifically, the 6-hour duration Probable Maximum Precipitation is estimated to be on the order of 30 to 31 inches for the Atlanta metropolitan area.

Estimates of Probable Maximum Precipitation for longer duration storm events are provided in Hydrometeorological Report Number 51 (HMR 51) titled “Probable Maximum Precipitation Estimates, United States East of the 105th Meridian” prepared by the U.S. Department of Commerce, National Oceanic and Atmospheric Administration and U.S. Department of the Army, Corps of Engineers and dated June 1978. For the Atlanta Metropolitan area, the all-season Probable Maximum Precipitation for drainage basin areas of 10 square miles is estimated to be on the order of 42 to 44 inches in 24 hours, while the all-season Probable Maximum Precipitation for drainage basin areas of 200 square miles is estimated to be on the order of 32 to 35 inches in 24 hours. Figure 3 (obtained from HMR 51) depicts the Probable Maximum Precipitation values for a storm duration of 24 hours and a drainage basin area of 200 square miles.

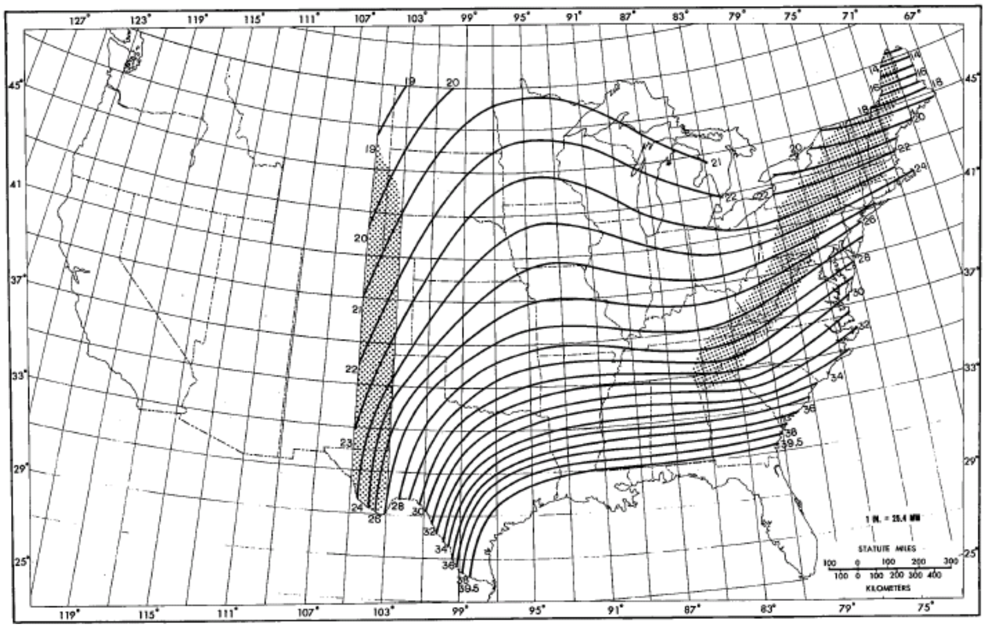

Figure 3. 24-Hour Duration, 200 square mile Drainage Basin All-Season Probable Maximum Precipitation Values (Obtained from HMR 51)

SUMMARY OF SEPTEMBER 2009 RAINFALL

As indicated in Figure 4 and Table 1 provided below, the rainfall amounts during the crescendo of the storm varied greatly. Several rainfall gauges in Douglas County recorded amounts in excess of 20-inches in twenty-four hours. Rainfall amounts of this magnitude approach 50 percent of 24-hour duration Probable Maximum Precipitation for drainage basins up to and including 10 square miles (21 inches) and exceed the 24-hour Probable Maximum Precipitation amounts for drainage basins of 200 square miles (16.5 inches).

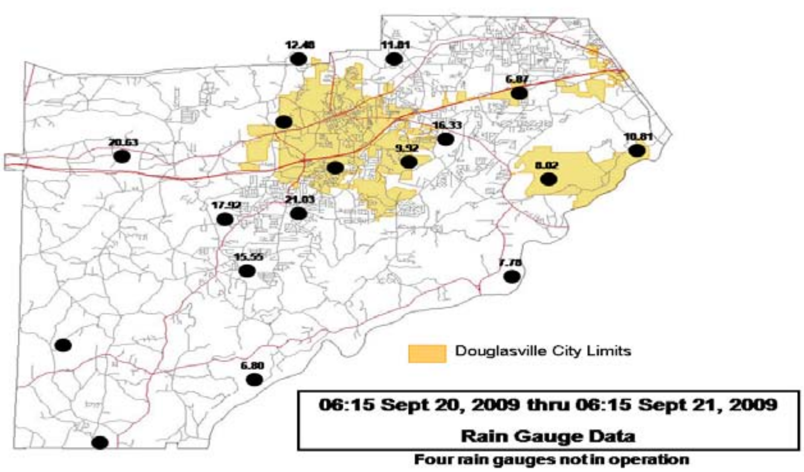

Figure 4. Douglas County Rain Gauge Data (Courtesy of Douglasville-Douglas County Water Authority)

Table 1. Douglas County Gauge readings (Courtesy of Douglasville-Douglas County Water Authority)

Location	**24 Hour Totals**	**1 Hour Totals**
Central Bap	21.03"	5.53"
Andy Mtn	20.63"	5.11"
Lions Gate	17.92"	3.09"
Bear Creek	15.55"	4.32"

Rainfall gauges in Carroll County, located to the west of Douglas County, recorded rainfall amounts on the order of 12 to 14 inches during the peak 24 hours of rainfall. These rainfall depths correspond to approximately one-quarter to one-third of the 24-hour duration Probable Maximum Precipitation for drainage basins less than or equal to 10 square miles (42 inches). The recorded rainfall amount for a single project in Paulding County as shown in Figure 5, located to the north of Douglas County, indicates that approximately 17 inches of rain fell in a 24-hour period. This amount of rainfall equates to approximately one-third to two-fifths of the 24-hour duration Probable Maximum Precipitation for drainage basins less than or equal to 10 square miles (42 inches).

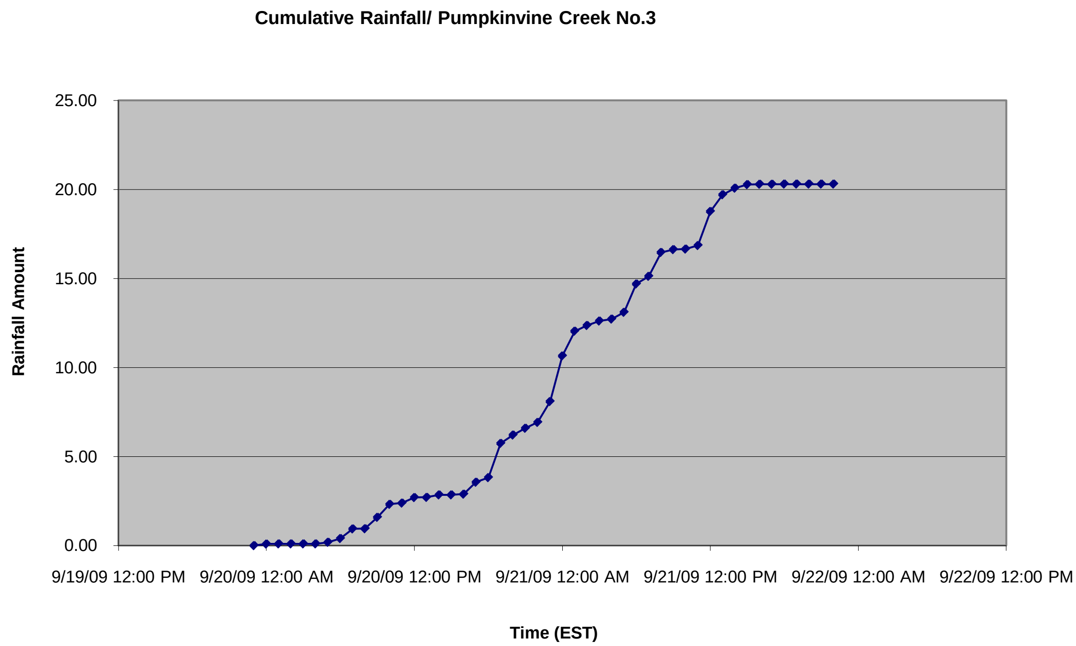

Figure 5. Pumpkinvine Creek Watershed Structure No. 3 Rainfall Data (Courtesy of the NRCS)

IMPACTED PROJECTS

Snake Creek Dam

The Snake Creek Dam is a 65-foot high earthfill structure located in Carroll County, Georgia approximately 40 miles west of downtown Atlanta. More specifically, the dam is located approximately 1000 feet south of the confluence of Guthrie Creek with Snake Creek.

The hydrologic modeling of the 33.6 square mile drainage basin was based upon a USGS stream gage located immediately downstream of the dam site. A continuous record of 44 years at the stream gage was used to correlate the time of concentration and runoff curve number for the drainage basin contributing flows to the dam. The minimum design storm required by Georgia Dam Safety regulations for a structure of this size is one-Half (½) of the Probable Maximum Precipitation. The Probable Maximum Precipitation rainfall amount and distribution were calculated using the U.S. Army Corps of Engineers' computer program HMR-52. Rainfall amounts for other events analyzed were obtained from the National Weather Service, Technical Paper 40.

The spillways for the Snake Creek Dam consist of a conduit and riser serving as the principal spillway and a total width of 400-feet of earth cut auxiliary spillway. The conduit is comprised of twin 6' by 6' reinforced concrete box culverts. The reinforced concrete riser has inside dimensions of 27' by 13'. The principal spillway was designed to pass the 100-year storm event without activating the auxiliary spillways. In conjunction with the principal spillway, construction of 200 feet of earth cut spillway on each abutment provided sufficient emergency spillway capacity to pass runoff from the design storm with more than 2 feet of freeboard. The results of the hydrologic and hydraulic modeling with respect to reservoir routing are contained in the Table 2 below.

Table 2. Summary of Snake Creek Dam Hydrologic and Hydraulic Data

Storm Event (12 Hour Duration)	Peak Reservoir Inflow (cfs)	Peak Reservoir Outflow (cfs)	Peak Reservoir Water Surface Elevation (ft MSL)
50 Year	6514	1881	930.83
100 Year	7464	2112	931.47
½ PMP	29975	21776	937.88

Normal Pool Elevation – 926 ft MSL
Auxiliary Spillway Crest Elevation – 931.5 ft MSL
Crest of Dam – 940 ft MSL

Consideration was given in the design of the auxiliary spillways to the potential for erosion and subsequent headcut that could possibly breach the unlined spillways as a result of the depth of flow being in excess of 7 feet in each spillway. Each spillway was analyzed using technology developed by the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) known as SITES. Typical subsurface profiles of each spillway were developed using data obtained from the subsurface exploration and from laboratory analysis of recovered subsurface materials. The profiles developed for each spillway were analyzed independently to approximate the headcut based upon the ½ PMP spillway design hydrograph.

The subsurface materials encountered in the soil test borings and soil auger probes include sandy silt – silty sand soil, partially weathered rock, rock, and hard rock. The subsurface profile analyzed in SITES included all four materials. The maximum depth of cut required for the construction of the right abutment auxiliary spillway exceeded 40 feet. The left abutment auxiliary spillway subsurface profile was similar to that of the right abutment; however, rock was encountered above the design grades in the control section and outlet channel of the right emergency spillway and below the design grades in the left emergency spillway. Both spillways were modeled to be stable (i.e., not breach) during the design storm event.

The drainage basin contributing runoff to Snake Creek reservoir received approximately 13 inches of rain in a 12 to 15 hour period during the September 2009 flood event. The resulting runoff activated both of the auxiliary spillways. Figure 6 provides an aerial view of the Snake Creek Dam with both auxiliary spillways flowing. At the peak reservoir elevation, the depth of flow through the control section of the auxiliary spillways was estimated to be about 4 feet. Based upon available data, the rainfall amounts in the Snake Creek drainage basin approached, if not exceeded, one-third Probable Maximum Precipitation values. The runoff into the Snake Creek reservoir was increased by the failure of a relatively small dam and subsequent release of stored water.

Figure 6. Snake Creek Dam with Auxiliary Spillways Engaged

The entire spillway system for the Snake Creek Dam performed as designed with the right abutment auxiliary spillway experiencing little, if any, damage in the constructed inlet channel, control section, or outlet channel. The left abutment auxiliary spillway, while functioning as designed, did experience damage immediately downstream of the constructed outlet channel. As modeled utilizing the SITES computer program, the left abutment auxiliary spillway was determined to be more erodible than the right spillway. The damage that occurred during the September 2009 flood event was largely the result of the left abutment auxiliary spillway being discharged into a swale or draw that conveyed flow at a 70 to 80 degree angle to the alignment of the spillway. The abrupt change in flow direction, as well as the presence of trees that cause erosion generating eddies, resulted in the damage downstream of the constructed outlet channel shown in Figure 7.

Figure 7. Damage to the left auxiliary spillway of the Snake Creek Dam

The owners of the Snake Creek Dam and Reservoir are currently repairing the damage to the spillway by extending and straightening the outlet channel of the left abutment auxiliary spillway, as well as backfilling the eroded areas with structural fill. Repairs to the spillway are scheduled to be completed in the winter of 2010-2011.

NRCS Pumpkinvine Creek Dam No. 3

The Pumpkinvine Creek Watershed Dam No. 3, which was designed by the United States Department of Agriculture Soil Conservation Service (SCS), is a 35-foot high earthfill structure located in Paulding County, Georgia. More specifically, the subject dam is located approximately 1 mile east of Dallas, Georgia on Griffin Creek. When designed, the subject dam was considered a low hazard or ‘Class A’ structure; however, due to downstream development, the dam is now considered a high hazard or ‘Class C’ structure.

When designed, the hydrologic modeling of the 1.8 square mile drainage basin was completed utilizing graphical methods. Subsequent hydrologic modeling efforts performed by Schnabel were completed in general accordance with both Natural Resources Conservation Service (NRCS, formerly known as the SCS) criteria and Georgia Safe Dams Program criteria. The minimum design storm for this structure is either the Freeboard Hydrograph, according to NRCS standards, or 50 percent of Probable Maximum Precipitation, according to Georgia Safe Dams Program criteria. The Freeboard Hydrograph varies depending on the hazard classification of the structure. For a 'Class A' structure, the Freeboard Hydrograph varies from slightly more than the 100-year storm to slightly less than 50 percent of the Probable Maximum Precipitation. For a 'Class C' structure, the Freeboard Hydrograph is the Probable Maximum Precipitation. Presented in Table 3 below is a summary of the design rainfall data for the subject dam. The PSH, SDH, and FBH information presented below are for Class A criteria. The remedial repair of the erosion will only return the dam to its pre-storm configuration, as funding for an upgrade is not currently available.

Table 3. Summary of Pumpkinvine Creek Watershed Structure No. 3A Hydrologic Data

Description	**Duration (hrs.)**	**Amount (in.)**	**Source**	**Distribution**
25-Yr (PSH)	24	6.5	TP-40	SCS Type II
25-Yr (PSH)	240	11.5	TP-49	SCS Type II
100-Yr (SDH)	6	5.7	TP-40	SCS Standard
100-Yr (SDH)	24	7.8	TP-40	SCS Five-point
50% of PMP	6	15.2	HMR-52	HMR-52
FBH	6	8.68	TR-60	SCS Standard
FBH	24	11.8	TR-60	SCS Five-point

The spillways for the Pumpkinvine Creek Watershed Dam No. 3 consist of a pipe-and-riser principal spillway and an earth cut channel auxiliary spillway. The reinforced concrete riser has a total of 12 feet of weir at the normal pool elevation (921.14 feet MSL). A 24-inch diameter reinforced concrete pipe with an approximate length of 216 feet serves as the low-level outlet conduit. The emergency spillway is a 100-foot wide broad-crested spillway located in the left abutment of the dam. The crest of the existing auxiliary spillway control section is at elevation 940 feet MSL. The crest of the dam is at approximate elevation 946 feet MSL. The pre-storm configuration of the dam will pass 36.9% of the PMP, while maintaining sufficient freeboard to meet Georgia Dam Safety criteria. The Georgia Dam Safety criteria for the design storm for a dam of this size is the ½ PMP. The results of the hydrology and hydraulic analysis are provided in Table 4 below.

Table 4. Summary of Pumpkinvine Creek Watershed Structure No. 3 Hydrologic and Hydraulic Analyses

Storm Event	Duration (hrs)	Peak Inflow (cfs)	Peak Outflow (cfs)	Peak Reservoir Elevation (ft MSL)
PSH	N/A	1,554	58	934.01
SDH	6	1,079	58	933.70
SDH	24	890	62	937.22
FBH	6	2,408	141	940.62
FBH	24	1,723	325	941.19
36.9% PMP (ARC III)	6	5,833	2,584	944.43

During the intense rainfall of September 2009, the auxiliary spillway activated. A flow depth through the auxiliary spillway of approximately three feet was estimated by NRCS personnel. The duration of flow through the existing auxiliary spillway was estimated by NRCS personnel to be about 20 hours. During this flood event, the auxiliary spillway eroded over 20 feet deep at the control section (Figure 8). Erosion in the auxiliary spillway exposed a sanitary sewer line that had been constructed through the abutment of the dam and followed the flow path of the auxiliary spillway.

Figure 8. Photograph of Eroded Auxiliary Spillway Channel at Pumpkinvine Creek Watershed Dam No. 3

Subsequent to the September 2009 floods, the auxiliary spillway was analyzed using the NRCS SITES program. Two profiles were analyzed to approximate the potential for headcut erosion based upon the freeboard hydrograph. A profile of the spillway was developed based on the field surveyed limits of the erosion. Another profile was developed through the portion of the spillway to the left (looking downstream) of the erosion gully that was not damaged by the erosion. The soil parameters for each stratum (fill associated with backfilling the erosion gully and native residual soil) were established utilizing laboratory data.

Vegetative cover in the vicinity of the emergency spillway was assumed to be a moderately maintained grass mixture. A “maintenance code” of 3 was utilized in the analysis of the eroded area to account for the driveway that exists parallel to the axis of flow. A maintenance code of 3 represents the most erosive option available in SITES. A maintenance code of 2 was utilized for the profile of the spillway outside of the eroded area, as the driveway is located entirely in the eroded area that is to be filled.

The results of the analysis indicated that the spillway would not breach during the ‘Class A’ FBH. The distances from the most upstream headcut erosion to the upstream edge of the emergency spillway control section given in the analysis of the fill profile are 27 and 428 feet for the 24-hour and 6-hour storms, respectively.

The results of the SITES analyses indicated that the auxiliary spillway for the Pumpkinvine Creek Watershed Dam No. 3 functioned as modeled (i.e. the extent of the headcut damage was reasonably well predicted by the SITES computer model). Given the presence of the sanitary sewer backfill and other geotechnical and hydraulic discontinuities, less correlation between the SITES model and the actual performance was anticipated. We note, however, that the spillway would have likely functioned better (i.e. experienced less erosion) had the sanitary sewer been constructed in another location and the spillway been founded in competent native residual soils as intended during the original design.

Repairs to Pumpkinvine Creek Watershed Dam No. 3 have been designed and approved by both the NRCS and the Georgia Safe Dams Program. Repairs to the spillway are scheduled to be completed in the winter of 2010-2011.

NRCS Yellow River Dam No. 16

The Yellow River Dam No. 16, also originally designed by the SCS, is located in Gwinnett County north of Lawrenceville, Georgia. The subject dam, which was originally designed as a Class ‘A’ structure, was reclassified as a ‘Class C’, or high hazard, structure as a result of downstream development. Consequently, the dam was deemed hydraulically inadequate. In 2007, the dam was upgraded by closing/abandoning the existing earth-cut auxiliary spillway and constructing a Roller Compacted Concrete (RCC) spillway over the dam.

When designed, the hydrologic modeling of the 2.86 square mile drainage basin was completed utilizing graphical methods. During the design of rehabilitation measures, revised hydrologic and hydraulic calculations were performed in general accordance with Georgia Safe Dams Program criteria. The minimum design storm for this structure is 50 percent of the Probable Maximum Precipitation according to Georgia Safe Dams Program criteria.

The principal spillway system for the rehabilitated dam consists of a pipe and riser. The riser structure, which was not modified during the rehabilitation process, has 15 feet of weir at the normal pool elevation of 977 feet. The principal spillway conduit has an inside diameter of 30 inches. The auxiliary spillway for the rehabilitated dam consists of a two-stage sharp-crested weir that discharges down a stepped 3H to 1V RCC protected slope. Unlike the previous projects discussed in this paper, the auxiliary spillway for the Y-16 project consists of non-erodible RCC. For aesthetic purposes, the RCC was covered with topsoil and grassed. An aerial photograph of the project after completion of the 2007 rehabilitation is shown below (Figure 9).

Figure 9. Y-16 Dam after 2009 renovations

In an effort to document the rainfall that occurred in September of 2009 and the impacts that occurred as a result, Gwinnett County retained Schnabel to revise the hydrology and hydraulics for the subject dam utilizing the rainfall data provided by North American Weather Consultants (NAWC). A report dated June, 2010 was prepared by NAWC per Schnabel's request to analyze the rainfall event that occurred between 19 and 21 September, 2009. This study included National Weather Service Next Generation Radar (NEXRAD) data scans, which were converted into rainfall estimates by way of generalized reflectivity-rainfall (Z-R) relationships, or custom best-fit trend lines based on local observations. NAWC's report summarizes the conditions of the watershed prior to the intense rainfall to aid in approximating the antecedent runoff condition of the basin. The average rainfall observed between five rain gage locations between 14 and 18 September 2009 was approximately 5.2 inches.

Using the data provided by NAWC's rainfall study, Schnabel developed a rainfall hydrograph to simulate the flood event of September 2009. The USACE computer program HEC-1 was used to route the storm event. Because HEC-1 distributes the rainfall over the entire basin, it was necessary to approximate the geometric center of the basin in relation to the grid of data provided by NAWC. Bilinear interpolation was used to estimate the influence of the adjacent grid data and respective precipitation mass curves. The National Oceanic and Atmospheric Administration's Technical Paper No. 40 estimates rainfall in Gwinnett County during the 24-hour 100-year return frequency storm to be approximately 7.8 inches; the rainfall occurring during the peak 24-hour period of the September 2009 flood was on the order of 6.8 inches.

Precipitation data was analyzed in approximate 30-minute intervals. A cumulative hydrograph was selected because of the sporadic peaks and spikes of precipitation observed in the data. The most intense 24-hour period of rainfall was routed. This occurred between 0800 EDT 20 September 2009 and 0800 EDT 21 September 2009.

Figure 10. Looking from Left Side of Y-16 Dam on the morning of 21 September 2009

Based on a survey of the dam provided by another consultant documenting post flood conditions, the approximate high water mark and flood crest at the dam was between 988.6 ft MSL and 989.1 ft MSL. Using the rainfall data provided by the NAWC study and our modeled basin hydrology and hydraulics, the model yielded a water surface elevation that was within the range of observed flood crest elevations, as indicated by the surveyed high water marks. To account for the potential for the normal pool to be elevated by previous rainfall, additional analyses were performed assuming the pool level was one foot higher than normal at the beginning of the September 20-21 event. Table 5 provides a summary of the aforementioned routing results.

Table 5. Summary of Yellow River Watershed Structure No. 16 Hydrologic and Hydraulic Analyses

MODELED CONDITION		Peak Water Surface Elevation, ft MSL	Peak Discharge, cfs
ARC* 2	Normal Pool, 977 ft MSL	987.0	107
	1 ft Raised Pool, 978 ft MSL	987.3	179
	100 Year Return, Normal Pool 977 ft MSL	988.4	581
ARC* 3	Normal Pool, 977 ft MSL	988.8	841
	1 ft Raised Pool, 978 ft MSL	988.9	915
	100 Year Return, Normal Pool 977 ft MSL	989.4	1296

* ARC – Antecedent Runoff Conditions

Damage to the spillway was limited to the removal of grass and topsoil. As shown in Figure 11, the spillway activated and a portion of the topsoil and grass were removed. Based upon photographs taken during the peak of the flood event and observations made subsequent to the flooding event, only the low-stage sharp crested weir was engaged Figure 10). Given that the crest of the low-stage weir was established at the 25-year water surface elevation and the crest of the high-stage weir at the 100-year elevation, the observed conditions (i.e. activation of the low-stage but not the high-stage) match the rainfall that was observed in the region.

Figure 11. Photograph of Yellow River Watershed Dam No. 16 Auxiliary Spillway

Based upon the results of the hydrologic modeling and the observations made by representatives of Schnabel, the Y-16 dam performed as designed, with the only required repairs being the placement of topsoil and reestablishment of acceptable vegetation. Figure 11 shows the exposed RCC and the area that will be re-vegetated.

SUMMARY

Engineers often design structures for a condition that is seldom experienced by the structure. During the flood events of September 2009, the auxiliary spillways for each of the structures described herein activated. As a result, damage occurred. However, for two of the structures (Snake Creek and Y-16) the damage was relatively minimal, as the structures performed as intended. For the third structure (Pumpkinvine Watershed Dam No. 3), the structure generally performed as modeled given the 'unauthorized' construction activities that took place in the auxiliary spillway; however, had the sanitary sewer line been located away from the spillway, the extent of the damage would have likely been far less extensive.

The seriousness of flooding cannot be fully understood until the impact is felt by people in the community. With the heavy volume of development in the urbanized areas in the country, it is critical to upgrade and maintain dams and their spillways in preparation for major storm events. Although the rainfall of the September 2009 floods established new record highs, this does not provide immunity from a storm of this magnitude for another century; the probability of a storm occurring each year is an independent event.

It is critical that planners, engineers, local officials, and dam owners are diligent in the design, maintenance and integrity of key infrastructure facilities and especially dams. Unanticipated damages can and do occur when improper or unplanned construction activities occur. In addition, when a flood of record occurs, our dams and levees must be equipped properly and ready to operate. We cannot be certain when a natural disaster will occur, but with proper preparation and vigilance we can manage nature's challenges to better protect our families and neighbors.