LAKE & RESERVOIR ASSESSMENTS
FRENCH BROAD RIVER BASIN


Beetree Reservoir

Intensive Survey Unit
Environmental Sciences Section
Division of Water Quality
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GLOSSARY

Algae — Small aquatic plants that occur as single cells, colonies, or filaments. May also be referred to as phytoplankton, although phytoplankton are a subset of algae.

Algal biovolume — The volume of all living algae in a unit area at a given point in time. To determine biovolume, individual cells in a known amount of sample are counted. Cells are measured to obtain their cell volume, which is used in calculating biovolume

Algal density — The density of algae based on the number of units (single cells, filaments and/or colonies) present in a milliliter of water. The severity of an algae bloom may be determined by the algal density as follows:

Mild bloom = 10,000 to 20,000 units/ml
Mild bloom = 20,000 to 30,000 units/ml
Severe bloom = 30,000 to 100,000 units/ml
Extreme bloom = Greater than 100,000 units/ml

Algal Growth Potential Test (AGPT) — A test to determine the nutrient that is the most limiting to the growth of algae in a body of water. The sample water is split such that one sub-sample is given additional nitrogen, another is given phosphorus, a third may be given a combination of nitrogen and phosphorus, and one sub-sample is not treated and acts as the control. A specific species of algae is added to each sub-sample and is allowed to grow for a given period of time. The dry weights of algae in each sub-sample and the control are then measured to determine the rate of productivity in each treatment. The treatment (nitrogen or phosphorus) with the greatest algal productivity is said to be the limiting nutrient of the sample source. If the control sample has an algal dry weight greater than 5 mg/L, the source water is considered to be unlimited for either nitrogen or phosphorus.

Centric diatom — Diatoms are photosynthetic algae that have a siliceous skeleton (frustule) found in almost every aquatic environment including fresh and marine waters, as well as moist soils. Centric diatoms are circular in shape and are often found in the water column.

Chlorophyll *a* — Chlorophyll *a* is an algal pigment that is used as an approximate measure of algal biomass. The concentration of chlorophyll *a* is used in the calculation of the NCTSI, and the value listed is a lake-wide average from all sampling locations.

Clinograde — In productive lakes where oxygen levels drop to zero in the lower waters near the bottom, the graphed changes in oxygen from the surface to the lake bottom produces a curve known as clinograde curve.

Coccoid — Round or spherical shaped cell

Conductivity — This is a measure of the ability of water to conduct an electrical current. This measure increases as water becomes more mineralized. The concentrations listed are the range of values observed in surface readings from the sampling locations.

Dissolved oxygen — A measurement of oxygen concentrations found at the sampling locations.

Dissolved oxygen saturation — The capacity of water to absorb oxygen gas. Often expressed as a percentage, the amount of oxygen that can dissolve into water will change depending on a number of parameters, the most important being temperature. Dissolved oxygen saturation is inversely proportion to temperature, that is, as temperature increases, water's capacity for oxygen will decrease, and vice versa.

Eutrophic — Describes a lake with high biological productivity and low water transparency.

Eutrophication The process of physical, chemical, and biological changes associated with nutrient, organic matter, and silt enrichment and sedimentation of a lake.

Limiting nutrient The plant nutrient present in lowest concentration relative to need limits growth such that addition of the limiting nutrient will stimulate additional growth. In northern temperate lakes, phosphorus (P) is commonly the limiting nutrient for algal growth

Manganese A naturally occurring metal commonly found in soils and organic matter. As a trace nutrient, manganese is essential to all forms of biological life. Manganese in lakes is released from bottom sediments and enters the water column when the oxygen concentration in the water near the lake bottom is extremely low or absent. Manganese in lake water may cause taste and odor problems in drinking water and require additional treatment of the raw water at water treatment facilities to alleviate this problem.

Mesotrophic Describes a lake with moderate biological productivity and water transparency

NCTSI North Carolina Trophic State Index was specifically developed for North Carolina lakes as part of the state's original Clean Lakes Classification Survey (NRCD 1982). It takes the nutrients present along with chlorophyll *a* and Secchi depth to calculate a lake's biological productivity.

Oligotrophic Describes a lake with low biological productivity and high water transparency.

pH The range of surface pH readings found at the sampling locations. This value is used to express the relative acidity or alkalinity of water.

Photic zone The portion of the water column in which there is sufficient light for algal growth. DWQ considers 2 times the Secchi depth as depicting the photic zone.

Secchi depth This is a measure of water transparency expressed in meters. This parameter is used in the calculation of the NCTSI value for the lake. The depth listed is an average value from all sampling locations in the lake.

Temperature The range of surface temperatures found at the sampling locations.

Total Kjeldahl nitrogen The sum of organic nitrogen and ammonia in a water body. High measurements of TKN typically results from sewage and manure discharges in water bodies.

Total organic nitrogen (TON) Total Organic Nitrogen (TON) can represent a major reservoir of nitrogen in aquatic systems during summer months. Similar to phosphorus, this concentration can be related to lake productivity and is used in the calculation of the NCTSI. The concentration listed is a lake-wide average from all sampling stations and is calculated by subtracting Ammonia concentrations from TKN concentrations.

Total phosphorus (TP) Total phosphorus (TP) includes all forms of phosphorus that occur in water. This nutrient is essential for the growth of aquatic plants and is often the nutrient that limits the growth of phytoplankton. It is used to calculate the NCTSI. The concentration listed is a lake-wide average from all sampling stations.

Trophic state This is a relative description of the biological productivity of a lake based on the calculated NCTSI value. Trophic states may range from extremely productive (Hypereutrophic) to very low productivity (Oligotrophic).

Turbidity A measure of the ability of light to pass through a volume of water. Turbidity may be influenced by suspended sediment and/or algae in the water.

Watershed A drainage area in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Overview

The French Broad River basin covers 2,842 square miles with 4,113 miles of streams and is the ninth largest river basin in the state. It is located in the Blue Ridge Mountains and includes part or all of Transylvania, Buncombe, Henderson, Madison, Haywood, Yancey, Mitchell and Avery counties. All waters from the basin drain to the Gulf of Mexico *via* the Tennessee, Ohio, and Mississippi Rivers. The French Broad River Basin includes Mount Mitchell (elevation 6,684 feet), the highest mountain east of the Rocky Mountains. Much of the basin lies within the 1.2 million acre Pisgah National Forest or Pisgah Game Lands. The northwest corner of Haywood County is in the Great Smoky Mountains National Park. Over one-half of the basin is forested and the steep slopes limit the area suitable for development and crop production. The basin is composed of three major drainages, the French Broad, Pigeon, and Nolichucky Rivers, that individually flow north into Tennessee.

Six lakes were sampled in this river basin by DWQ staff in 2012. One of these, Lake Junaluska, was placed on the 303(d) List of Impaired Waters in 2006 due to water quality standard violations related to elevated pH values (http://portal.ncdenr.org/web/wq/ps/mtu/assessment).

For a more complete discussion of lake ecology and assessment, please go to http://portal.ncdenr.org/web/wq/ess/isu. The 1992 North Carolina Lake Assessment Report (downloadable from this website) contains a detailed chapter on ecological concepts that clarifies how the parameters discussed in this review relate to water quality and reservoir health.

Assessment Methodology

For this report, data from January 1, 2008 through December 31, 2012 were reviewed. Lake monitoring and sample collection activities performed by DWQ field staff are in accordance with the Intensive Survey Unit Standard Operating Procedures Manual (http://portal.ncdenr.org/c/document_library/get_file?uuid=522a90a4-b593-426f-8c11-21a35569dfd8&groupId=38364)

All lakes were sampled during the growing season from May through September. Data were assessed for excursions of the state's class C water quality standards for chlorophyll *a*, pH, dissolved oxygen, water temperature, turbidity, and surface metals. Other parameters discussed in this report include Secchi depth and percent dissolved oxygen saturation. Secchi depth provides a measure of water clarity and is used in calculating the trophic or nutrient enriched status of a lake. Percent dissolved oxygen saturation gives information on the amount of dissolved oxygen in the water column and may be increased by photosynthesis or depressed by oxygen-consuming decomposition.

For algae collection and assessment, water samples are collected from the photic zone, preserved in the field and taken concurrently with chemical and physical parameters. Samples were quantitatively analyzed to determine assemblage structure, density (units/ml) and biovolume (m^3/mm^3).

For the purpose of reporting, algal blooms were determined by the measurement of unit density (units/ml). Unit density is a quantitative measurement of the number of filaments, colonies or single celled taxa in a waterbody. Blooms are considered mild if they are between 10,000 and 20,000 units/ml. Moderate blooms are those between 20,000 and 30,000 units/ml. Severe blooms are between 30,000 and 100,000 units/ml. Extreme blooms are those 100,000 units/ml or greater.

An algal group is considered dominant when it comprises 40% or more of the total unit density or total biovolume. A genus is considered dominant when it comprises 30% or more of the total unit density or total biovolume.

Additional data considered as part of the use support assessment include historic DWQ water quality data, documented algal blooms and/or fish kills, problematic aquatic macrophytes, or listing on the EPA's 303(d) List of Impaired Waters.

For a more complete discussion of lake ecology and assessment, please go to http://portal.ncdenr.org/web/wq/ess/isu. The 1992 North Carolina Lake Assessment Report (downloadable from this website) contains a detailed chapter on ecological concepts that clarifies how the parameters discussed in this review relate to water quality and reservoir health.

Quality Assurance of Field and Laboratory Lakes Data

Data collected in the field via single or multiparameter water quality meters are entered into the Ambient Lakes Database within 24 hours of the sampling date. These data are then reviewed for accuracy and completeness within a week of entry. Data that have not been reviewed are given a óPôcode for óProvisionaló (data has been entered but not been verified for accuracy and/or completeness). Data that have been verified are given an óAôcode for óAcceptedô

Chemistry data from the DWQ Water Quality Laboratory are entered into the Lakes Database within 48 hours of receipt from the lab. As with the field data, laboratory results are coded óPôuntil the entered data is verified for entry accuracy and completeness, after which, the code is changed to óAô Generally, laboratory data entered into the Lakes Database are verified within a week following the initial entry.

Data, either laboratory or field, which appear to be out of range for the lake sampled are double checked against field sheets or the laboratory results form by the Lakes Data Administrator for possible data entry error. If there are data entry mistakes, possible equipment, sampling, and/or analysis errors, these are investigated and corrected if possible. If the possible source of an error cannot be determined, the data remains in the database. If an error is determined, the data value is removed from the appropriate database parameter field and placed in the óNotesôfield along with a comment regarding the error. Chemistry results received from the laboratory that have been given an qualification code are also entered into the óNotesôfield along with the assigned laboratory code. Laboratory qualification coded data or data which may be in error due to sampling, handling, and/or equipment problems are only entered into the óNotesôfield and never in the data field(s) in the Ambient Lakes Database.

Additional information regarding the Quality Assurance Program is covered in the Ambient Lake Monitoring Program Quality Assurance Plan. Version 1.1 (July 2012) of this document is available on the ISU website (http://portal.ncdenr.org/web/wq/ess/isu).

Weather Overview for Summer 2012

After a dry, warm winter, May brought beneficial rainfall to the state and ranked as the 10th wettest May on record since 1895 based on statewide average rainfall. The coastal plains and the northwestern region of the state received the most rainfall during this month (Figure 1).

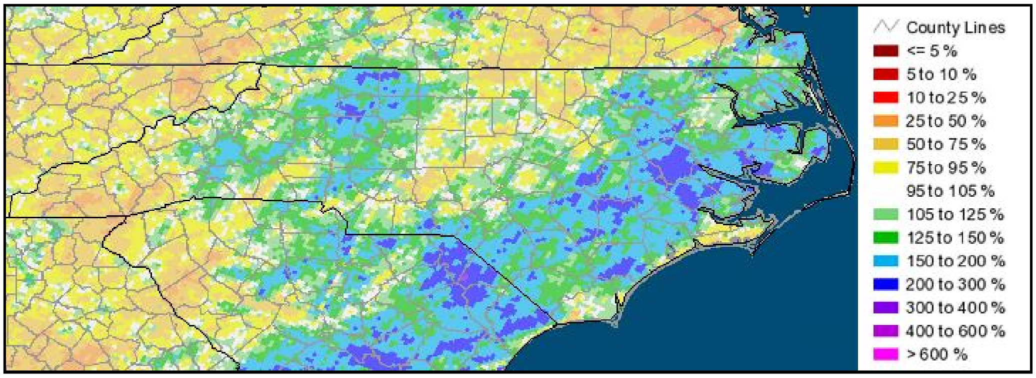


Figure 1. Precipitation for May 2012: Percent of Normal Based on Estimates From NWS Radar
(Data courtesy NWS/NCEP)

The wet conditions in May helped to alleviate most of the short-term concerns with hydrological drought in the state (Figure 2). Parts of the French Broad River Basin, however, ranged from 25% to 75% of the normal estimated rainfall amounts for the month. Temperatures in May were warm, averaging 3.5 °F above normal for the month.

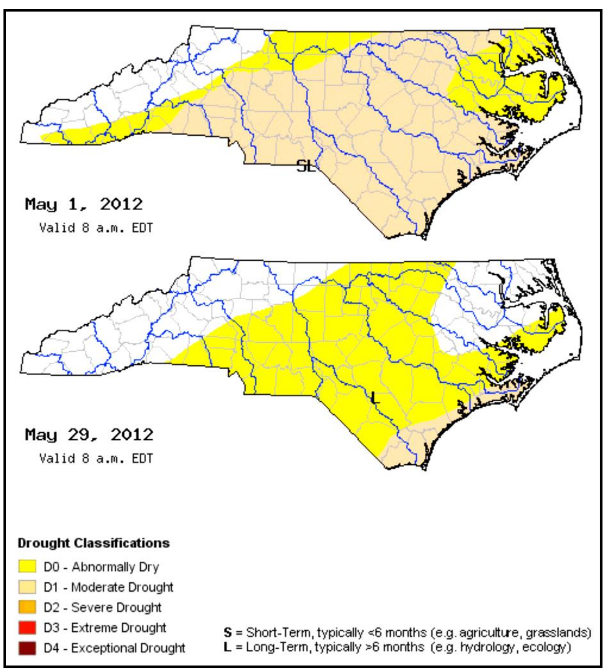


Figure 2. US Drought Monitor for North Carolina, May 2012
(Courtesy of NC DENR Division of Water Resources)

June temperatures in North Carolina were much cooler than normal, despite a heat wave that began on the last few days of the month. Overall, June 2012 ranked as the 29th coolest June since1895. The last half of June was also drier with most of the state receiving 75% less than the normal rainfall for the month (Figure 3). Estimated rainfall for the French Broad River Basin remained at 25% to 50% of normal for June.

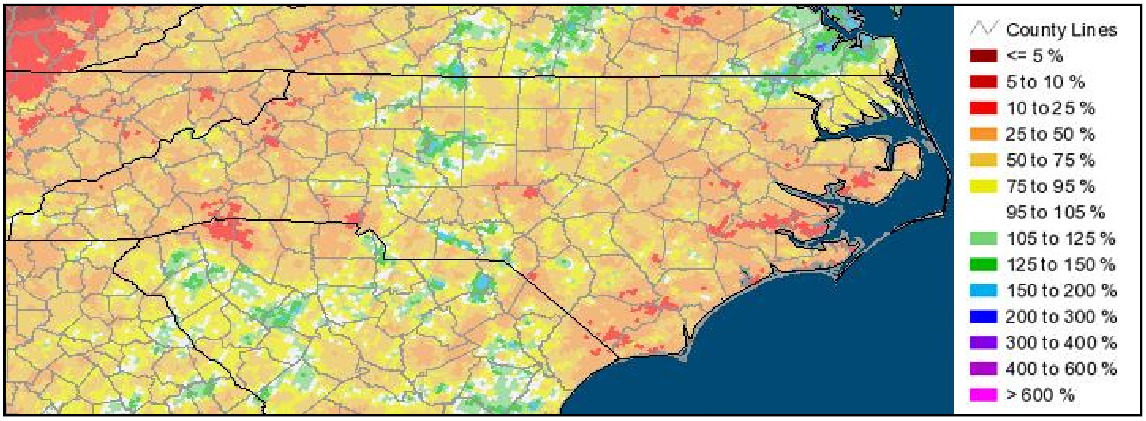


Figure 3. Precipitation for June 2012: Percent of Normal Based on estimates from NWS Radar
(Data courtesy NWS/NCEP)

Despite reduced rainfall, the French Broad River Basin remained outside of drought conditions.

July 2012 remained warm and, overall, the temperatures for the month ranked as the 3rd warmest for the state since 1895. Rainfall was closer to normal for a typical July in the state (Figures 4). In July, the southern region of the French Broad River Basin was experiencing abnormally dry drought conditions (Figure 5).

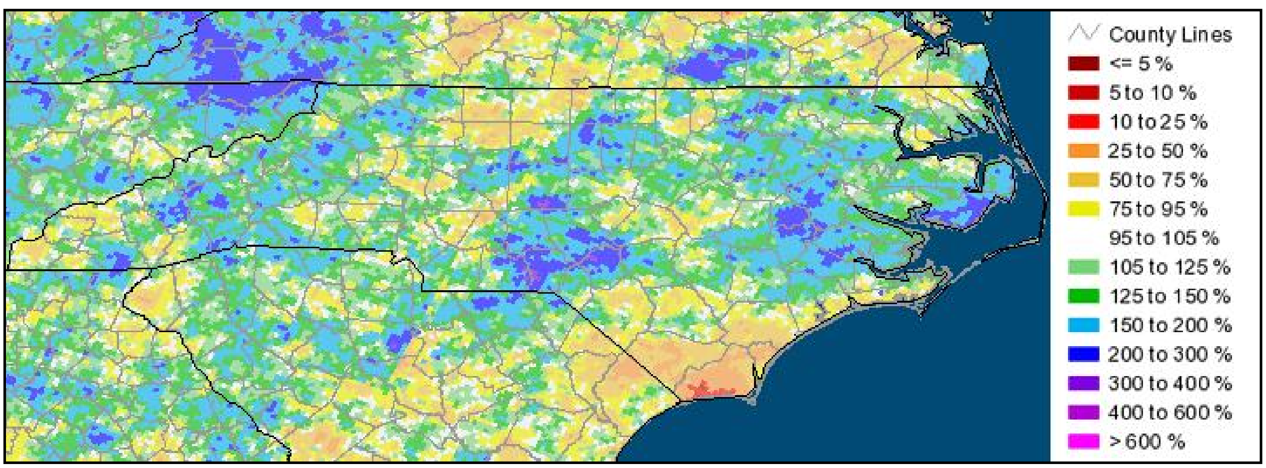


Figure 4. Precipitation for July 2012: Percent of Normal Based on Estimates From NWS Radar
(Data courtesy NWS/NCEP)

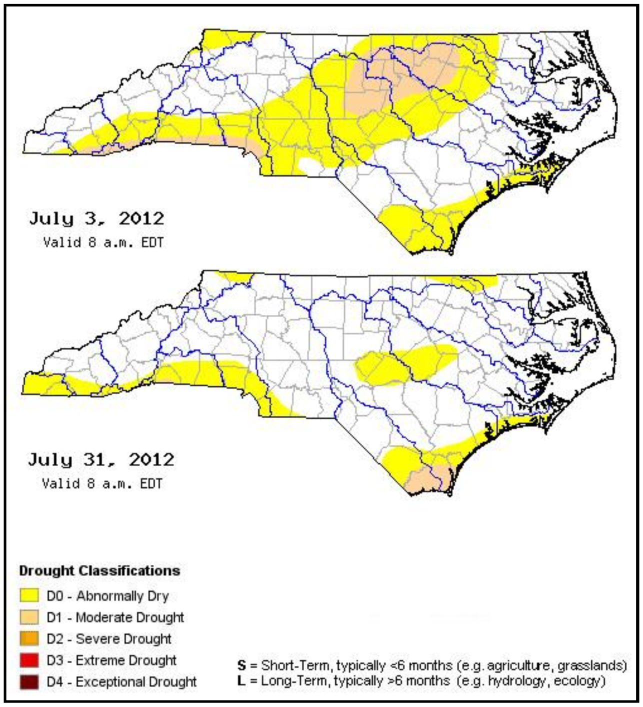
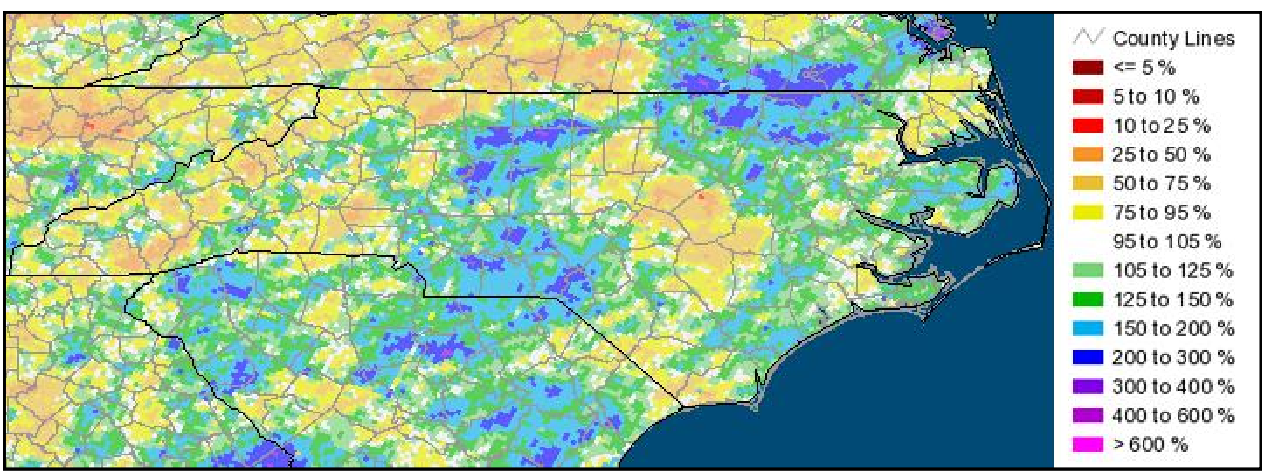


Figure 5. US Drought Monitor for North Carolina, July 2012
(Courtesy of NC DENR Division of Water Resources)

Temperatures in August 2012 averaged near normal in the state. Early August started out warmer while late August was cooler. Rainfall totals for the month were also closer to normal for the month, with wetter conditions occurring in the east and drier conditions present in the west. In August, some parts of the state experienced a few days of very heavy rainfall which resulted in localized flooding (Figure 6). Some areas of the French Broad River Basin experienced estimated rainfall amounts of 105 to 125% of normal for the month.



igure 6. Precipitation for August 2012: Percent of Normal Based on estimates from NWS Radar
(Data courtesy NWS/NCEP)

Drought conditions throughout the state were greatly diminished in August 2012 as compared to previous years. By the end of the month, only a few regions of abnormally dry conditions existed in the state (Figure 7).

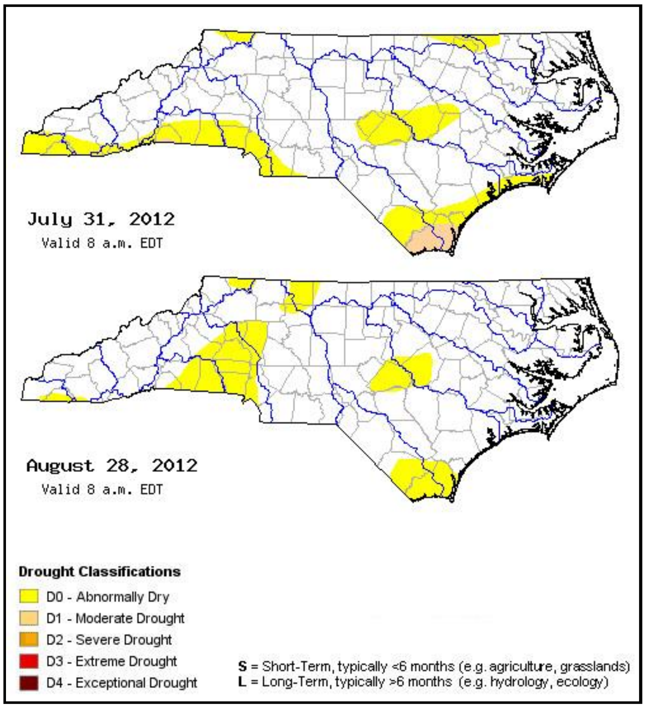


Figure 7. US Drought Monitor for North Carolina, August 2012
(Courtesy of NC DENR Division of Water Resources)

September storms brought substantial rainfall to central and western NC, while the coastal plain and southwestern corner of the state remained dry (Figure 8). The rainfall amounts helped to maintain streams and reservoirs to at or near normal levels throughout most of the state. Areas of the French Broad River Basin experienced rainfall estimates of 105% to 125% of normal for the month. Temperatures were cooler than normal for the central piedmont and coastal plain and within the normal ranges for the mountains.

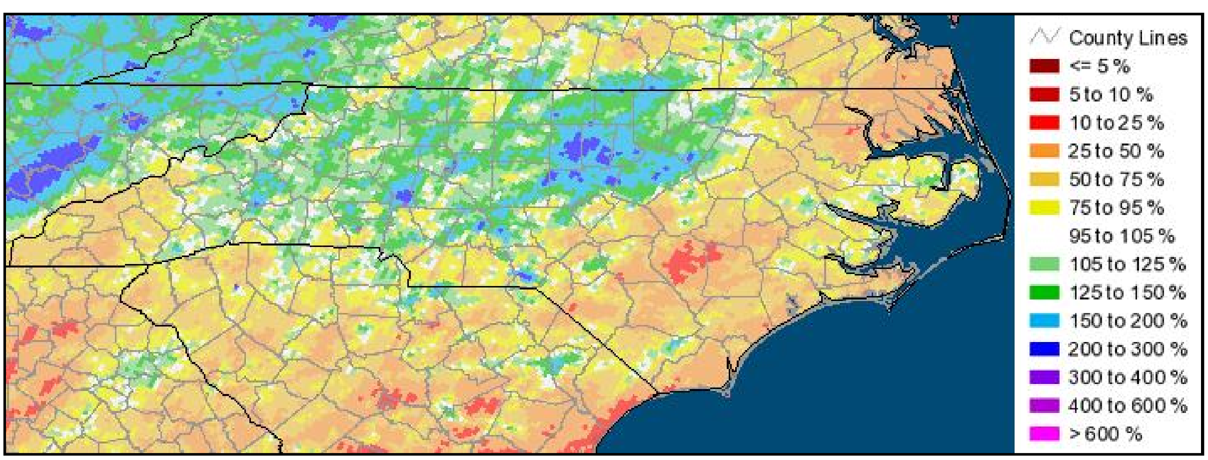


Figure 8. Precipitation for September 2012: Percent of Normal Based on estimates from NWS Radar
(Data courtesy NWS/NCEP)

Drought conditions in the state continued to decline in September with abnormally dry conditions persisting in three isolated regions of the state (Figure 9).

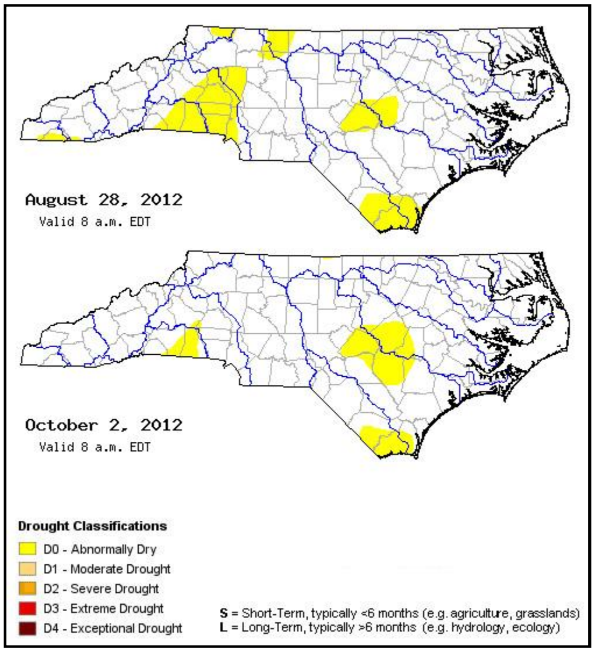


Figure 9. US Drought Monitor for North Carolina, September 2012
(Courtesy of NC DENR Division of Water Resources)

LAKE & RESERVOIR ASSESSMENTS

HUC 06010105

Beetree Reservoir

Ambient Lakes Program Name	Beetree Reservoir
Trophic Status (NC TSI)	Oligotrophic
Mean Depth (meters)	10.0
Volume ($10^6 m^3$)	1.90
Watershed Area (mi^2)	8.0
Classification	WS-I HQW
Stations	FRBBTR1
Number of Times Sampled	5

Beetree Creek was impounded in 1926 to form Beetree Reservoir, a water supply for the City of Asheville. The City of Asheville owns the 20 km^2 watershed which is undeveloped. Beetree Reservoir is designated as a High Quality Water (HQW), Water Supply-I and has a maximum depth of 25 meters. This lake is not used for recreation and public access is restricted.

Beetree Reservoir was monitored by DWQ staff in May through September, 2012. Secchi depths, a measurement of light penetration into the lake and general water clarity, ranged from 3.5 to 4.5 meters (Appendix A). Dissolved oxygen in this small reservoir was consistently greater than 4.0 mg/L down to a depth of approximately 15 to 20 meters from the surface with the exception of the September sampling date when the dissolved oxygen level dropped between 10 and 15 meters from the surface. Surface pH values in 2012 ranged from 7.5 to 8.1 s.u. and conductivity at the lake surface ranged from 19 to 20 µmhos/cm.

Nutrient concentrations in Beetree Reservoir were low, as would be expected in a mountain lake with an undeveloped shoreline. Total phosphorus, total Kjeldahl nitrogen and ammonia values were below the DWQ laboratory detection levels. Chlorophyll *a* ranged from <1.0 µg/L to 8.1 µg/L. Phytoplankton assemblages were diverse and densities were generally low (<8,000 units/ml). Turbidity values were consistently below the DWQ laboratory detection level of 1.0 mg/L. Based on the calculated NCTSI scores, Beetree Reservoir was determined to exhibit very low biological productivity (oligotrophic conditions) during the sampling season of 2012. This reservoir has consistently demonstrated oligotrophic conditions since it was first monitored by DWQ in 1990.

Burnett Reservoir

Ambient Lakes Program Name	Burnett Reservoir	
Trophic Status (NC TSI)	Oligotrophic	
Mean Depth (meters)	12.0	
Volume ($10^6 m^3$)	22.00	
Watershed Area (mi^2)	2.0	
Classification	WS-I HQW	
Stations	FRBBUR2	FRBBUR4
Number of Times Sampled	5	5

Burnett Reservoir (also known as North Fork Reservoir) was built in 1954 to provide drinking water for the City of Asheville. Maximum depth in this reservoir is approximately 121 feet (37 meters) and average depth is 39 feet (12 meters). Burnett Reservoir has a shoreline length of five miles. The undisturbed 15,000-acre watershed is drained by the North Fork Swannanoa River, Sugar Fork and several unnamed tributaries. Burnett Reservoir is classified as a Water Supply-I (WS-I) and as a High Quality Water (HQW).

DWQ field staff monitored Burnett Reservoir in May through September, 2012. Secchi depths ranged from 5.4 to 12.0 meters, indicating that the clarity of the water in this reservoir was very good. Surface dissolved oxygen ranged from 7.2 to 9.1 mg/L. The highest dissolved oxygen values (recorded in May) were the result of low water temperatures and not algal productivity (Appendix A). Surface pH values were near neutral (range = 7.1 to 7.9 s.u.).

Total phosphorus, total Kjeldahl nitrogen and ammonia concentrations in Burnett Reservoir were below DWQ laboratory detection levels during the 2012 sampling season. Nitrite plus nitrate concentrations ranged from 0.07 mg/L in May and June to <0.01 mg/L in September. Chlorophyll *a* concentrations in 2012 ranged from <1.0 μg/L to 12 μg/L. These values are similar to previously recorded chlorophyll *a* concentrations recorded for this reservoir by DWQ. Phytoplankton samples collected from the upper end of the reservoir (FBRBUR2) were analyzed and densities were consistently low (<5,000 units/ml) in 2012. The dominant algal groups by biovolume and density were golden-brown algae (chrysophytes) and small bluegreen algas.

Results of the Algal Growth Potential Test conducted by the EPA Region IV Laboratory using water samples collected in July indicated that Burnett Reservoir was limited for the nutrient, phosphorus (Table 1). The lower level of this nutrient in the lake limits the growth of algae and any increase in phosphorus may increase algal productivity.

Table 1. Algal Growth Potential Test Results for Burnett Reservoir, July 9, 2012.

Station	Maximum Standing Crop, Dry Weight (mg/L)			Limiting Nutrient
	Control	C+N	C+P	
FRBBUR2	0.04	0.04	1.43	Phosphorus
FRBBUR4	0.06	0.06	1.25	Phosphorus

Freshwater AGPT using *Selenastrum capricornutum* as test alga

C+N = Control + 1.0 mg/L Nitrate-N

C+P = Control + 0.05 mg/L Phosphate-P

C+N+P = Control + 1.0 mg/L Nitrate-N + 0.05 mg/L Phosphate-P

Turbidity was also very low (<1.0 to 1.5 NTUs). Based on the calculated NCTSI scores for 2012, Burnett reservoir was determined to exhibit very low biological productivity (oligotrophic conditions). This reservoir has been consistently oligotrophic since it was first monitored by DWQ in 1990.

Lake Julian

Ambient Lakes Program Name	Lake Julian		
Trophic Status (NC TSI)	Oligotrophic		
Mean Depth (meters)	20.0		
Volume ($10^6 m^3$)	2.60		
Watershed Area (mi^2)	5.0		
Classification	C		
Stations	FRBLJ2	FRBLJ4	FRBLJ6
Number of Times Sampled	5	5	5

Lake Julian is an impoundment of Powell's Creek, a tributary of the French Broad River. Constructed in 1963, this lake was created as a source of once-through condenser cooling water for the Asheville Steam Electric Plant, which is owned by Progress Energy. Lake Julian's watershed is primarily residential and urban. Lake Julian Park is a county recreational facility operated by Buncombe County Parks and Recreation Services near Skyland, NC. Recreational boating (electric motors, only) and fishing are allowed on the lake. Sport fish caught in Lake Julian include catfish, largemouth bass and tilapia.

DWQ staff monitored this reservoir in May through September, 2012. Secchi depths ranged from 1.5 to 3.0 meters and surface dissolved oxygen ranged from 5.4 to 7.0 mg/L (Appendix A). Dissolved oxygen at the deepest sampling site, which was located near the dam, was greater than 4.0 mg/L to a depth of 15 meters from the surface. Surface water temperatures ranged from 20.6 to 36.6 °C. These elevated water temperatures are typical for this reservoir which receives a thermal discharge from the Asheville Steam Plant.

In 2012, total phosphorus, ammonia and nitrite plus nitrate concentrations were at or below DWQ laboratory detection levels (Appendix A). Total Kjeldahl nitrogen ranged from 0.20 to 0.31 mg/L. Chlorophyll *a* concentrations ranged from 3.4 to 31 μg/L. The greatest concentrations of chlorophyll *a* were observed in September and were the highest levels observed for this reservoir since it was first sampled by DWQ in 1990. Analysis of phytoplankton collected at sampling site FBRLJ6 indicated the presence of a moderate bloom ($\geq$20,000 units/ml) in May, August and September. Severe blooms ($\geq$ 30,000 units/ml) were observed in June and July and were dominated by pennate diatoms (*Fragilaria sp.*).

Based on the calculated NCTSI scores for 2012, Lake Julian was determined to exhibit very low biological productivity (oligotrophic conditions) and has exhibited this trophic state since 1990.

Progress Energy routinely monitors the water quality of Lake Julian. This includes identification of any natural or power plant-induced water quality changes to the lake and any introductions or impacts from nonnative plant and animal species. Limnological monitoring of the lake was conducted in 2007 and included water chemistry and phytoplankton analysis (Progress Energy, September 2010).

<u>Reference</u>:

Progress Energy. September 2010. Asheville Stem Electric Plant, 2007 - 2008 Environmental Monitoring Report. Environmental Services Section, Progress Energy Service Company. Raleigh, NC.

LAKE & RESERVOIR ASSESSMENTS

HUC 06010106

Allen Creek Reservoir

Ambient Lakes Program Name	Allen Creek Reservoir	
Trophic Status (NC TSI)	Oligotrophic	
Mean Depth (meters)	14.0	
Volume ($10^6 m^3$)	3.30	
Watershed Area (mi^2)	13.0	
Classification	WS-I Tr HWQ	
Stations	FRBACR2	FRBACR4
Number of Times Sampled	5	5

Allen Creek Reservoir (also known as Waynesville Reservoir) is a small water supply lake located in the western mountains of North Carolina and owned by the City of Waynesville. Construction of the lake was completed in December. The maximum and average depths are 75 feet (23 meters) and 46 feet (14 meters), respectively. Several tributaries flow into Allen Creek Reservoir, including Steestachee Branch, Bald Creek, Long Branch Creek and Allen Creek.

DWQ staff monitored this reservoir in May through September, 2012. Secchi depths ranged from 2.1 to 4.8 meters and turbidity, indicating very good water clarity (Appendix A). This is supported by the turbidity values that ranged from <1.0 to 2.5 NTUs. Surface dissolved oxygen ranged from 8.3 to 9.6 mg/L and surface water temperatures in this reservoir ranged from 15.8 °C to 25.2 °C. The thermocline in this reservoir near the dam generally occurred at a depth of seven to eight meters from the surface, with the exception of September when the thermocline was observed at a depth between 10 and 15 meters. Surface conductivity values for Allen Creek Reservoir ranged from 16 to 18 µmhos/cm

In 2012, total phosphorus concentrations ranged from <0.02 mg/L to 0.07 mg/L (Appendix A). Total Kjeldahl nitrogen ranged from <0.02 mg/L to 0.58 mg/L. Both elevated values for total phosphorus and total Kjeldahl nitrogen were found in water samples collected near the dam (FRBACR4) in August and were the highest values for these two nutrients recorded for Allen Creek Reservoir by DWQ. Environmental and analytical factors were reviewed for these samples, and they represent accurate conditions at the time of collection. Nitrite plus nitrate concentrations in Allen Creek Reservoir ranged from <0.02 to 0.10 mg/L and were similar to previously recorded values for these nutrients. Chlorophyll *a* concentrations ranged from 2.2 to 6.8 µg/L. Phytoplankton samples were collected at the mid-lake sampling site for analysis in 2012. Densities were generally low (<5,000 units/ml) and were dominated in May through August by golden-brown algae (chrysophytes). No particular phytoplankton group dominated the sample collected in September 2012. Chrysophytes are typically present in cool, low-nutrient waters.

Based on calculated NCTSI scores, Allen Creek Reservoir was determined to exhibit very low biological productivity (oligotrophic conditions) in 2012. This reservoir has consistently exhibited oligotrophic conditions since it was first monitored by DWQ in 1990.

Lake Junaluska

Ambient Lakes Program Name	Lake Junaluska		
Trophic Status (NC TSI)	Mesotrophic		
Mean Depth (meters)	5.5		
Volume ($10^6 m^3$)	4.50		
Watershed Area (mi^2)	63.0		
Classification	B		
Stations	FRB047A	FRB047B	FRB047C
Number of Times Sampled	5	5	5

Lake Junaluska is a 200 acre reservoir located in the mountains of southwestern North Carolina. The lake is privately owned by the United Methodist Church and was built by the Lake Junaluska Assembly as a meeting ground for Southern Methodists in 1913. The lake was formed by impounding a segment of Richland Creek. Lake Junaluska was placed on the 303(d) List of Impaired Waters in 2006 due to pH values in excess of the state water quality standard of 9.0 (2012 North Carolina 303(d) List, approved by EPA August 10, 2012).

DWQ monitored this reservoir from May through September, 2012. Secchi depths ranged from 0.6 to 2.3 meters and surface dissolved oxygen ranged from 8.6 to 11.6 mg/L (Appendix A). Surface dissolved oxygen values were greatest in July (11.1 to 11.6 mg/L) and surface percent dissolved oxygen values ranged from 137.1% to 144.3% at that time. Surface pH values were also elevated (9.2 to 9.4 s.u.). These physical readings were suggestive of increased algal productivity. Analytical values for chlorophyll *a* values were not available for this sampling event.

Total phosphorus concentrations in Lake Junaluska ranged from <0.02 mg/L to 0.04 mg/L. Total Kjeldahl nitrogen ranged from 0.10 to 0.38 mg/L and nitrite plus nitrate ranged from <0.02 to 0.34 mg/L. Turbidity values ranged from 1.4 to 12.0 NTUs.

Chlorophyll *a* values for Lake Junaluska in 2012 ranged from 5.8 to 28.0 µg/L. Phytoplankton samples were analyzed from two lake sampling sites ï FRB047C (near the dam) and FRB047A (in the upper end of the lake) in 2012. Based on cell densities, Lake Junaluska was determined to exhibit mild to moderate bloom conditions in May and June, a severe bloom in July and August, and a drop in algal cell densities in September. Algal blooms were predominantly dominated by diatoms and assemblages shifted between these, chrysophytes (golden-brown algae), and green algae reflecting good diversity.
Based on the calculated NCTSI scores, Lake Junaluska was determined to exhibit moderate biological productivity (mesotrophic conditions) in 2012. The trophic state of this lake has ranged from oligotrophic to eutrophic since it was first monitored by DWQ in 1981.

According to a lake sediment management study by McKay and Young (May 3, 2012), Lake Junaluska has been subject to sediment loads entering the lake from Richland Creek. Development and land clearing activities in the Richland Creek watershed have had a significant impact on the turbidity, nutrient loading and sediment input on this lake. In 2007, 20,000 cubic yards of material was dredged from the lake bottom and removed to the Waynesville landfill. In 2012, approximately 13,000 cubic yards of sediment was removed and deposited at a newly constructed disposal site on the Assembly property. Future maintenance of Lake Junaluska will require a program of regular excavations of the lake bottom to remove accumulated sediments as well as a plan for the disposal of this sediment and preventative erosion practices in the Richland Creek watershed to reduce sediment transport to the lake (McKay and Young, May 30. 2012).

Reference:
McKay, Mackie and Buddy Young. May 30, 2012. Lake Junaluska Assembly Public Works, Lake Sediment Management Study. Lake Junaluska Assembly Public Works. Lake Junaluska, NC.

Waterville Lake

Ambient Lakes Program Name	Waterville Lake		
Trophic Status (NC TSI)	Mesotrophic		
Mean Depth (meters)	23.0		
Volume ($10^6 m^3$)	31.60		
Watershed Area (mi^2)	455.0		
Classification	C		
Stations	FRBWL2	FRBWL4	FRBWL8
Number of Times Sampled	4	4	4

Built in the late 1920's, Waterville Lake (also known as Walters Lake) is an impoundment of the Pigeon River which drains most of Haywood County. This reservoir has a maximum depth of 35 meters. Carolina Power and Light Company (now known as Progress Energy) constructed this reservoir to produce hydroelectric power for Asheville and the surrounding area. Access to this lake is restricted to the public.

DWQ field staff monitored this reservoir in May through September, 2012. Secchi depths ranged from 0.3 to 3.1 meters with the lower Secchi readings observed at the upper end of the reservoir (FRBWL2; Appendix A). Surface dissolved oxygen ranged from 3.1 mg/L near the dam (FRBWL8) in September to 14.8 mg/L at the upper end of the lake in August. The low dissolved oxygen value observed near the dam in September was below the state water quality standard of 4.0 mg/L for an instantaneous reading. The dissolved oxygen measurements within the entire water column, however, indicated that dissolved oxygen near the bottom was higher (6.1 mg/L at a depth of 30 meters) than near the surface (2.6 mg/L at two meters) and is suggestive of the replacement of the lake bottom water by the surface water, or a lake turnover, in response to cooling air temperatures and cooling of the surface of the lake in relation to the water at the bottom of the lake. Surface conductivity measurements in Waterville Lake were higher than those of other lakes monitored in the French Broad River Basin in 2012, ranging from 154 to 351 μmhos/cm.

Total phosphorus in Waterville Lake ranged from <0.02 to 0.23 mg/L, total Kjeldahl nitrogen ranged from 0.20 to 2.40 mg/L, and ammonia ranged from <0.02 to 0.08 mg/L. Total solids in this lake ranged from 110 to 247 mg/L in 2012 and turbidity values ranged from 1.5 to 39 NTUs. Turbidity values at the most upstream lake sampling site exceeded the state water quality standard of 25 NTUs in May and August 2012.

Chlorophyll *a* concentrations ranged from 2.4 to 189 μg/L. The chlorophyll *a* value at the most upstream lake sampling site (FRBWL2) in August was greater than the state water quality standard of 40 μg/L. Observations by field staff indicated that the lake water appeared very green in color with green specks and small pea-sized clumps of floating algae (Figure 10.). Phytoplankton samples were regularly collected near the dam (FRBWL8) during the summer of 2012. Cell densities increased from <5,000 units/ml in May to severe bloom levels (>30,000 units/ml) in June. A moderate bloom continued in August before cell densities dropped to <5,000 units/ml in September. The initial algae bloom in the early part of the summer was dominated by the small, single celled bluegreen, *Chroococcus* before shifting to the larger colonial bluegreen *Microcystis*. *Microcystis* forms visible green clumps or flecks in the water which collect to form a thin surface bloom. The presence of severe surface blooms of bluegreen algae suggests that Waterville Lake may have conditions (i.e., elevated nutrient concentrations) that favor the reoccurrence of nuisance algal blooms.

Figure 10. Surface Bloom of Bluegreen Algae, Waterville Lake, June 2012

Waterville Lake was determined to exhibit elevated biological productivity, or eutrophic conditions, in 2012 based on the calculated NCTSI scores.

Progress Energy monitors the water quality of Waterville Lake as part of the monitoring requirements outlined in Article 414(e), Appendix A, <u>Criteria for Instream Flow Releases into the Bypassed Reach of the Pigeon River at the Walters Hydroelectric Project</u> of the operating license for the power facility. During the 2010 monitoring period, no violations of water quality standards were observed (Progress Energy, January 2012).

Reference:

Progress Energy. January 2012. Walters Hydroelectric Plant. Federal Energy Regulatory Commission Project No. 432. 2010 Water Quality and Biotic Indices Study, Appendix A Requirements. Progress Energy Carolinas, Inc., Raleigh, NC.

Appendix A - French Broad River Basin Lakes Data

January 1, 2008 Through December 31, 2012

Lake	Date	Sampling Station	DO mg/L	Temp Water C	pH s.u.	Cond. µmhos/cm	Secchi Depth meters	Percent SAT	TP mg/L	TKN mg/L	NH3 mg/L	NOx mg/L	TN mg/L	TON mg/L	TIN mg/L	Chla µg/L	Solids Total mg/L	Total Solids Suspended mg/L	Turbidity NTU	Total Hardness mg/L
	SURFACE PHYSICAL DATA								PHOTIC ZONE DATA											
BEETREE RESERVOIR	September 5, 2012	FRBBTR1	7.7	24.1	7.5	21	4.5	91.7%	<0.02	<0.2	<0.02	<0.02	0.21	0.19	0.02	5.2	31	<6.2	<1.0	5.9
	August 8, 2012	FRBBTR1	7.7	26.2	7.9	21	3.5	95.3%	<0.02	<0.2	<0.02	<0.02	0.11	0.09	0.02	3.9	27	<6.2	<1.0	5.0
	July 9, 2012	FRBBTR1	7.4	26.3	8.0	20	4.5	91.7%	<0.02	<0.2	<0.02	0.04	0.14	0.09	0.05	<1.0	29	<6.2	<1.0	4.9
	June 13, 2012	FRBBTR1	8.6	21.4	8.1	19	4.0	97.3%	<0.02	<0.2	<0.02	0.04	0.14	0.09	0.05	2.6	29	<6.2	<1.0	5.0
	May 15, 2012	FRBBTR1	9.0	16.3	7.5	19	3.9	91.8%	<0.02	<0.2	<0.02	0.04	0.14	0.09	0.05	8.1	16	<6.2	<1.0	5.0
BURNETT RESERVOIR	September 5, 2012	FRBBUR2	7.6	24.5	7.6	15	5.4	91.2%	<0.02	0.20	<0.02	<0.02	0.21	0.19	0.02	12.0	22	<6.2	1.5	
	September 5, 2012	FRBBUR4	7.3	24.5	7.7	15	8.4	87.6%	<0.02	<0.20	<0.02	<0.02	0.11	0.09	0.02	3.9	20	<6.2	<1.0	3.9
	August 8, 2012	FRBBUR2	7.5	26.3	7.8	14	6.0	93.0%	<0.02	<0.20	<0.02	<0.20	0.02	0.00	0.02	3.3	19	<6.2	<1.0	
	August 8, 2012	FRBBUR4	7.4	26.4	7.4	15	8.8	91.9%	<0.02	<0.20	<0.02	0.03	0.13	0.09	0.04	3.2	20	<6.2	<1.0	4.0
	July 9, 2012	FRBBUR2	7.4	26.5	7.1	14	9.0	92.1%	<0.02	<0.20	<0.02	0.05	0.15	0.09	0.06	<1.0	21	<6.2	<1.0	
	July 9, 2012	FRBBUR4	7.2	26.8	7.2	14	9.2	90.1%	<0.02	<0.20	<0.02	0.04	0.14	0.09	0.05	<1.0	18	<6.2	<1.0	3.9
	June 13, 2012	FRBBUR2	8.1	33.3	7.7	14	7.5	113.4%	<0.02	<0.20	<0.02	0.07	0.17	0.09	0.08	1.1	23	<6.2	1.1	
	June 13, 2012	FRBBUR4	8.0	22.7	7.9	14	9.5	92.8%	<0.02	<0.20	<0.02	0.06	0.16	0.09	0.07	1.5	25	<6.2	1.0	4.0
	May 15, 2012	FRBBUR2	9.1	18.6	7.3	14	8.9	97.3%	<0.02	0.20	<0.02	0.07	0.09	0.19	0.08	2.0	<12	<6.2	<1.0	
	May 15, 2012	FRBBUR4	9.0	18.6	7.2	14	12.0	96.3%	<0.02	<0.20	<0.02	0.06	0.09	0.09	0.07	2.1	<12	<6.2	<1.0	3.0
LAKE JULIAN	September 5, 2012	FRBLJ2	7.0	32.7	8.3	106	1.8	97.0%	<0.02	0.20	<0.02	<0.02	0.21	0.19	0.02	29.0	77	<6.2	2.1	
	September 5, 2012	FRBLJ4	6.1	32.9	8.2	106	1.6	84.8%	<0.02	0.23	<0.02	<0.02	0.24	0.22	0.02	28.0	75	<6.2	2.3	
	September 5, 2012	FRBLJ6	7.0	32.7	7.6	107	2.1	97.0%	<0.02	0.21	<0.02	<0.02	0.22	0.20	0.02	31.0	77	<6.2	2.0	31.0
	August 8, 2012	FRBLJ2	5.5	35.6	7.5	107	2.0	80.0%	<0.02	0.22	<0.02	<0.02	0.23	0.21	0.02	8.2	112	<6.2	1.4	
	August 8, 2012	FRBLJ4	5.5	35.8	7.2	107	2.0	80.2%	<0.02	0.23	0.02	<0.02	0.24	0.21	0.03	11.0	67	<6.2	1.5	
	August 8, 2012	FRBLJ6	5.5	36.1	7.2	106	2.1	80.6%	<0.02	0.31	0.02	<0.02	0.32	0.29	0.03	8.9	71	<6.2	1.3	31.0
	July 9, 2012	FRBLJ2	5.8	35.4	7.7	108	1.6	84.0%	<0.02	0.20	<0.02	<0.02	0.21	0.19	0.02	3.4	82	<6.2	1.7	
	July 9, 2012	FRBLJ4	5.4	36.6	7.4	106	1.9	79.8%	<0.02	0.20	<0.02	<0.02	0.21	0.19	0.02	3.9	74	<6.2	1.5	
	July 9, 2012	FRBLJ6	5.9	35.6	7.6	106	1.8	85.8%	<0.02	0.21	<0.02	<0.02	0.22	0.20	0.02	3.7	79	<6.2	1.1	29.0
	June 13, 2012	FRBLJ2	6.6	32.4	8.0	108	1.7	91.0%	<0.02	0.28	<0.02	<0.02	0.29	0.27	0.02	12.0	83	<6.2	2.6	
	June 13, 2012	FRBLJ4	6.3	32.5	7.8	110	1.5	87.0%	<0.02	0.25	<0.02	<0.02	0.26	0.24	0.02	13.0	82	<6.2	2.6	
	June 13, 2012	FRBLJ6	6.6	32.4	7.7	109	1.6	91.0%	<0.02	0.24	<0.02	<0.02	0.25	0.23	0.02	11.0	80	<6.2	2.1	33.0
	May 16, 2012	FRBLJ2	6.9	30.0	7.2	108	2.2	91.3%	<0.02	0.20	<0.02	0.03	0.23	0.19	0.04	7.0	58	<6.2	1.5	
	May 16, 2012	FRBLJ4	6.2	20.6	7.1	109	2.5	69.0%	<0.02	0.20	<0.02	0.04	0.24	0.19	0.05	7.6	63	<6.2	1.7	
	May 16, 2012	FRBLJ6	6.6	30.4	6.9	109	3.0	87.9%	<0.02	0.23	<0.02	0.04	0.27	0.22	0.05	4.2	61	<6.2	1.7	22.0
ALLEN CREEK RESERVOIR	September 19, 2012	FRBACR2	8.4	18.4	7.8	17	2.1	89.5%	<0.02	0.20	<0.02	0.08	0.28	0.19	0.09	5.7	32	<12	2.3	
	September 19, 2012	FRBACR4	8.3	18.5	7.5	17	2.1	88.6%	<0.02	0.20	<0.02	0.08	0.28	0.19	0.09	6.8	26	<6.2	2.5	4.9
	August 22, 2012	FRBACR2	8.8	20.8	7.7	18	3.2	98.4%	<0.02	0.20	<0.02	0.08	0.28	0.19	0.09	5.2	19	<6.2	1.0	
	August 22, 2012	FRBACR4	8.4	21.1	7.9	17	3.7	94.4%	0.07	0.58	<0.02	0.03	0.61	0.57	0.04	3.6	17	<6.2	<1.0	4.9
	July 25, 2012	FRBACR2	8.5	25.2	7.8	17	3.5	103.3%	<0.02	0.20	<0.02	0.09	0.29	0.19	0.10	5.1	22	<6.2	1.6	
	July 25, 2012	FRBACR4	7.8	25.2	7.5	17	3.5	94.8%	<0.02	0.20	<0.02	0.08	0.28	0.19	0.09	6.4	23	<12	1.2	5.9
	June 26, 2012	FRBACR2		21.9	7.1	18	4.8		<0.02	<0.2	<0.02	0.09	0.19	0.09	0.10	3.5	26	<6.2	1.6	
	June 26, 2012	FRBACR4		21.6	6.9	17	4.5		<0.02	<0.2	<0.02	0.09	0.19	0.09	0.10	5.4	27	<6.2	1.5	5.0
	May 16, 2012	FRBACR2	9.6	16.1	6.8	16	3.3	97.5%	<0.02	<0.2	<0.02	0.10	0.20	0.09	0.11	2.2	15	<6.2	1.2	
	May 16, 2012	FRBACR4	9.6	15.8	7.0	16	2.4	96.9%	<0.02	<0.2	<0.02	0.10	0.20	0.09	0.11	2.8	17	<6.2	1.3	4.0
LAKE JUNALUSKA	September 6, 2012	FRB047A	8.9	24.4	7.8	66	1.8	106.5%	0.02	0.22	<0.02	0.11	0.33	0.21	0.12	5.8	31	<6.2	2.0	
	September 6, 2012	FRB047B	9.7	24.6	8.4	65	1.8	116.6%	0.02	0.24	<0.02	0.07	0.31	0.23	0.08	9.2	53	<6.2	1.7	
	September 6, 2012	FRB047C	9.3	25.1	8.5	64	1.8	112.8%	<0.02	0.20	<0.02	0.05	0.25	0.19	0.06	12.0	54	<6.2	1.4	
	August 9, 2012	FRB047A	9.7	24.0	7.7	60	0.8	115.3%	0.03	0.38	<0.02	0.15	0.53	0.37	0.16	23.0	50	7.2	6.2	
	August 9, 2012	FRB047B	9.4	23.8	7.3	59	0.8	111.3%	0.03	0.36	<0.02	0.16	0.52	0.35	0.17	28.0	50	7.2	6.2	
	August 9, 2012	FRB047C	9.6	24.2	6.8	59	0.8	114.5%	0.03	0.36	<0.02	0.16	0.52	0.35	0.17	28.0	48	6.8	5.5	
	July 10, 2012	FRB047A	11.1	26.1	9.4	66	0.8	137.1%	0.03	0.32	<0.02	<0.02	0.33	0.31	0.02		57	<11	4.8	
	July 10, 2012	FRB047B	11.3	26.3	9.2	66	1.3	140.1%	0.02	0.27	<0.02	<0.02	0.28	0.26	0.02		53	<9.3	2.1	
	July 10, 2012	FRB047C	11.6	26.5	9.2	67	1.6	144.3%	0.02	<0.2	<0.02	<0.02	0.11	0.09	0.02		55	<9.3	1.6	
	June 14, 2012	FRB047A	8.8	22.4	7.6	55	0.9	101.5%	0.03	0.28	<0.02	0.26	0.54	0.27	0.27	8.7	52	<6.2	8.0	
	June 14, 2012	FRB047B	9.3	22.4	7.9	55	1.1	107.2%	0.02	0.27	<0.02	0.21	0.48	0.26	0.22	9.2	51	<6.2	4.8	
	June 14, 2012	FRB047C	9.6	22.7	7.8	55	2.3	111.3%	<0.02	0.26	<0.02	0.19	0.45	0.25	0.20	7.5	46	<6.2	2.0	
	May 16, 2012	FRB047A	8.6	19.5	6.8	50	0.6	93.7%	0.04	0.28	<0.02	0.34	0.62	0.27	0.35	7.5	44	12.0	12.0	
	May 16, 2012	FRB047B	9.3	19.3	7.0	50	1.1	100.9%	0.02	0.20	<0.02	0.30	0.50	0.19	0.31	9.0	40	<6.2	3.6	
	May 16, 2012	FRB047C	9.5	19.9	7.0	50	1.4	104.3%	0.02	0.20	<0.02	0.30	0.50	0.19	0.31	7.5	36	<6.2	2.5	
WATERVILLE LAKE	September 20, 2012	FRBWL2	8.8	17.1	7.7	154	1.0	91.3%	0.06	0.27	0.03	0.28	0.55	0.24	0.31	3.3	112	7.0	6.3	
	September 20, 2012	FRBWL4	4.1	21.6	7.4	351	1.5	46.5%	0.09	0.37	0.04	0.34	0.71	0.33	0.38	12.0	230	<6.2	3.6	
	September 20, 2012	FRBWL8	3.1	22.9	7.2	338	1.9	36.1%	0.10	0.41	0.02	0.40	0.81	0.39	0.42	8.8	247	<6.2	1.9	
	August 23, 2012	FRBWL2	14.8	23.7	9.5	312	0.3	174.9%	0.23	2.40	<0.02	<0.02	2.41	2.39	0.02	189.0	214	26.0	39.0	
	August 23, 2012	FRBWL4	8.1	23.5	8.1	263	1.7	95.4%	0.08	0.62	0.02	0.02	0.64	0.60	0.04	28.0	177	12.0	9.6	
	August 23, 2012	FRBWL8	7.9	23.4	8.0	256	1.5	92.8%	<0.02	0.20	<0.02	0.08	0.28	0.19	0.09	32.0	170	11.0	11.0	
	June 27, 2012	FRBWL2		24.9	8.4	279	0.9		0.13	0.58	<0.02	0.09	0.67	0.57	0.10	22.0	196	11.0	9.5	
	June 27, 2012	FRBWL4		25.2	9.1	266	1.4		0.06	0.46	<0.02	0.03	0.49	0.45	0.04	25.0	173	<6.2	3.5	
	June 27, 2012	FRBWL8		24.9	9.1	249	1.6		0.05	0.52	<0.02	<0.02	0.53	0.51	0.02	28.0	162	6.3	11.0	
	May 16, 2012	FRBWL2	9.1	15.9	7.1	229	0.4	92.0%	0.05	0.31	0.08	0.35	0.66	0.23	0.43	3.6	195	41.0	29.0	
	May 16, 2012	FRBWL4	7.1	20.0	7.1	176	3.0	78.1%	0.17	0.53	0.02	0.36	0.89	0.51	0.38	2.4	112	<6.2	1.8	
	May 16, 2012	FRBWL8	7.4	19.8	7.0	177	3.1	81.1%	0.05	0.26	0.08	0.34	0.60	0.18	0.42	3.1	110	<6.2	1.5	