LAKE & RESERVOIR ASSESSMENTS
TAR-PAMLICO RIVER BASIN


Tar River Reservoir

Intensive Survey Branch
Water Sciences Section
Division of Environmental 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 = 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	The range of surface 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 plant 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 plant 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 plant 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. DEQ 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 Tar-Pamlico River basin encompasses a 5,440 mi^2 watershed drained by 2,355 miles of streams, and with 634,400 acres classified as salt waters. It is the fourth largest river basin in the state and is contained entirely within the state. From its headwaters within the eastern piedmont ecoregion, the Tar River flows 180 miles southeast towards the coastal plain ecoregion and Pamlico Sound. The river is called the Tar River from its source in Person County to US 17 in the Town of Washington, a distance of about 140 miles. From Washington to Pamlico Sound it is called the Pamlico River. The Pamlico River is entirely estuarine, while the Tar River is primarily freshwater.

Most (about four-fifths) of the basin is located in the coastal plain and is characterized by flat terrain, black water streams, low-lying swamplands, and estuarine areas. Streams are often slow flowing with extensive swamps and bottomland hardwood forests or marshes in their floodplains. The entire basin was designated as Nutrient Sensitive Waters (NSW) in 1989 in response to the problems associated with nutrient loading and the resulting eutrophication.

Two lakes, Tar River Reservoir and Lake Mattamuskeet, were sampled in by DWR staff in 2017. The Tar River from Peppermint Branch, including Tar River Reservoir is on the 2014 303(d) List of Impaired Waters for low dissolved oxygen based on data collected in 2010 and 2012 (https://deq.nc.gov/about/divisions/water-resources/planning/modeling-assessment/water-quality-data-assessment/integrated-report-files).

On April 2, 2008, a state-wide fish consumption advisory was placed on fish caught in the state which may be high in mercury. These include largemouth bass, blackfish (bowfin), catfish, and jackfish (chain pickerel) See http://www.epi.state.nc.us/epi/fish/current.html for additional information on fish consumption advisories in the state.

Following the description of the assessment methodology used for the Lumber River Basin, there are individual summaries for each of the lakes.

Assessment Methodology

For this report, data from January 1, 2011 through December 31, 2016 were reviewed. Lake monitoring and sample collection activities performed by DWR 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) An interactive map of the state showing the locations of lake sites sampled by DWR may be found at http://www.arcgis.com/home/webmap/viewer.html?webmap=9dbc8edafb7743a9b7ef3f6fed5c4db0&extent=-87.8069,29.9342,-71.5801,38.7611.

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 and 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.

Quality Assurance of Field and Laboratory Lakes Data

Data collected in the field via multiparameter water quality meters are uploaded into the Labworks® Database within five days of the sampling date.

Chemistry data from the DWR Water Quality Laboratory are uploaded into Labworks®. If there are data entry mistakes, possible equipment, sampling, and/or analysis errors, these are investigated and corrected, if possible. Chemistry results received from the laboratory that are given a qualification code are entered along with the assigned laboratory code.

Information regarding the WSS Chemistry Laboratory Quality Assurance Program is available on the ISB website (https://deq.nc.gov/about/divisions/water-resources/water-resources-data/water-sciences-home-page/microbiology-inorganics-branch/methods-pqls-qa).

Weather Overview for Summer 2017

May 2017 moderate temperatures were primarily due to frequent cloudy skies which held down daytime temperatures and prevented the loss of heat at night. The average statewide temperature was 67.1°F. Average rainfall was 6.5", making May 2017 the 6th wettest May on record. Cool temperatures continued into June with a statewide average temperature of 73.2°F. Rainfall in the Tar River Basin in June ranged from 4" to 6".

Summer heat picked up in July with the statewide average temperature becoming 78.1°F. The central Piedmont region of the state received less than 50% of the normal July rainfall. The upper portion of the Tar River Basin was designated as Abnormally Dry by the State Drought Monitor in July.

The statewide average temperature in August dripped to 75.2°F. In the Tar River Basin, the Tar River Reservoir experienced approximately five days with temperatures above 90°F during the month. Very little rainfall from the remnants of Hurricane Irma fell within the Tar River Basin. The statewide average temperature in September was 69.7°F. The moderate temperatures in September reduced the potential severity of the dryness which continued in the central portion of the state.

LAKE & RESERVOIR ASSESSMENTS

HUC 03020101

Tar River Reservoir

Ambient Lakes Program Name	Tar River Reservoir			
Trophic Status (NC TSI)	Eutrophic			
Mean Depth (meters)	6.0			
Volume ($10^6 m^3$)	16.00			
Watershed Area (mi^2)	2007.0			
Classification	WS-IV B NSW CA			
Stations	TAR015E	TAR015G	TAR017C	TAR017F
Number of Times Sampled	5	5	5	5

Tar River Reservoir is the primary water supply source for the City of Rocky Mount. Completed in 1971, this reservoir is located on the confluence of the Tar River and Sapony Creek and is open to the public for boating and fishing.

DWR field staff monitored Tar River Reservoir monthly from May through September 2017. Secchi depths ranged from 0.4 to 1.0 meter, with the majority of the secchi readings in 2017 less than a meter (Appendix A). Surface dissolved oxygen ranged from 6.3 to 11.3 mg/L and surface pH values ranged from 7.0 to 8.8 s.u. The minimum and maximum readings for both surface dissolved oxygen and pH were measured in August. Surface conductivity ranged from 68 to 102 umhos/cm.

Total phosphorus concentrations in 2017 ranged from 0.05 to 0.19 mg/L and total organic nitrogen ranged from 0.48 to 1.09 mg/L. With the high availability of nutrients in the lake, nine out of twenty chlorophyll *a* observations in 2017 (45%) were greater than the state water quality standard of 40 *u*g/L (range = 9.9 to 85.0 ug/L). An Algal Growth Potential Test was conducted on water samples collected at three of the four lake sampling sites in July (Table 1). The results of the test indicated that algal growth in Tar Rive Reservoir was limited by nitrogen concentrations.

Table 1. Algal Growth Potential Test Results for Tar River Reservoir, July 19, 2017.

	Maximum Standing Crop, Dry Weight (mg/L)			
Station	Control	C+N	C+P	Limiting Nutrient
TAR015E	1.38	10.37	1.59	Nitrogen
TAR017F	1.07	6.29	1.09	Nitrogen
TAR017C	2.12	7.58	2.01	Nitrogen

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

In August, the turbidity value at TAR015E, located in the upper end of the Tar River Reservoir was 35 NTU. This was greater than the state water quality standard of 25 NTU for lakes and reservoirs (Appendix A).

Based on the calculated NCTSI scores for May through September, Tar River Reservoir was determined to exhibit elevated biological productivity (eutrophic conditions). This reservoir has been consistently eutrophic since DWR monitoring began in 1989.

Lake Mattamuskeet

Ambient Lakes Program Name	Lake Mattamuskeet
Trophic Status (NC TSI)	Hypereutrophic
Mean Depth (meters)	0.6
Volume ($10^6 m^3$)	10.20
Watershed Area (mi^2)	na
Classification	SC
Stations	PAS0123A
Number of Times Sampled	1

Lake Mattamuskeet is located in the Coastal Plains of North Carolina. Situated on a vast peninsula lying between Albemarle Sound on the north and the Pamlico River on the south, this natural lake is within the Mattamuskeet National Wildlife Refuge. Lake Mattamuskeet, which is the largest natural lake in North Carolina, is shallow with no natural outlets. There are no overland tributaries into the lake and recharge is the result of precipitation and water intrusion from a man-made canal system. These canals were originally built to provide outlets from the lake to Pamlico Sound. Water from the sound frequently enters the lake and this has resulted in a change from freshwater to brackish conditions. The surrounding land is primarily used for agriculture with some residences located near the lakeshore. Lake Mattamuskeet is a very popular site for recreational fishermen, hunters and wildlife enthusiasts who come to watch and photograph flocks of migratory waterfowl.

Lake Mattamuskeet is crossed by the NC Highway 94 causeway (constructed in 1942), which effectively divides the lake into two distinct basins. The western segment of Lake Mattamuskeet is turbid and dominated by phytoplankton while the eastern and larger segment of the lake is less turbid and dominated by submerged macrophytes. It is these plants that support a significant waterfowl population. Water exchange between the two segments of the lake occurs through five culverts located along the causeway.

This lake was monitored on May 18, 2017 by DWR field staff (Appendix A). The secchi depth was very low (0.2 meter), which is typical for this lake due to suspended sediments and tannin colored water. The pH value was 8.3 s.u. and the conductivity was 569 umhos/cm. Surface dissolved oxygen was 8.9 mg/L and the lake was well mixed due to its very shallow depth. Both total and suspended solids were high and the turbidity value of 80 NTU was greater than the state water quality standard of 25 NTU for aquatic life support in a lake (or in saltwater).

Nutrient concentrations were exceptionally high with total phosphorus at 0.14 mg/L, total Kjeldahl nitrogen at 4.40 mg/L and total organic nitrogen at 4.39 mg/L. The chlorophyll *a* value was 190 *u*g/L, which was well above the state water quality limit of 40 ug/L. Chemistry data collected at two sampling sites (one either side of the NC 94 causeway) by USGS/USFW staff are similar to those collected by DWR (Table 2).

Table 2. USGS/USFW Chemistry Data.

			PHOTIC ZONE CHEMISTRY					
Lake	Date	Sampling Station	TP mg/L	TKN mg/L	NH3 mg/L	NOx mg/L	TON mg/L	CHL a µg/L
LAKE MATTAMUSKEET	September 28. 2017	208458892	0.12	3.90	<0.02	0.020	3.80	160
LAKE MATTAMUSKEET	September 28. 2017	208458893	0.16	4.10	<0.02	0.060	4.09	200
		LAKE AVERAGE	**0.14**	**4.00**	**<0.02**	**0.04**	**3.95**	**180**
LAKE MATTAMUSKEET	August 22, 2017	208458892	0.05	2.60	<0.02	<0.02	2.59	
LAKE MATTAMUSKEET	August 22, 2017	208458893	0.08	3.00	<0.02	<0.02	2.99	
		LAKE AVERAGE	**0.07**	**2.80**	**<0.02**	**<0.02**	**2.79**	
LAKE MATTAMUSKEET	July 25, 2017	208458892	0.06	3.40	<0.02	<0.02	3.39	140
LAKE MATTAMUSKEET	July 25, 2017	208458893	0.13	4.40	<0.02	<0.02	4.39	210
		LAKE AVERAGE	**0.10**	**3.90**	**<0.02**	**<0.02**	**3.89**	**175**
LAKE MATTAMUSKEET	May 18, 2017	208458892	0.16	4.80	<0.02	0.060	4.79	110
LAKE MATTAMUSKEET	May 18, 2017	208458893	0.14	4.70	<0.02	0.040	4.69	180
		LAKE AVERAGE	**0.14**	**4.70**	**<0.02**	**0.04**	**4.69**	**180**

208458892 = West of the NC 94 causeway
208458893 = East of the NC 94 causeway

Bluegreen algae were dominant by both density and biovolume in May and July (Table 3 and 4). Water samples for phytoplankton (algae) analysis were collected at the DWR sampling site (PAS0123A) located in the mid-lake or western side of Lake Mattamuskeet) and the two USGS/USFW sampling sites (208458892 and 208458893).

Table 3. Algal Density and Dominance at Lake Mattamuskeet.

Date	Station	Density (units/ml)	Bloom magnitude	Dominant Group	Group % Dominance	Dominant Taxa	Taxa % Dominance
5/18/17	PAS0123A	183,000	extreme	Bluegreens	84%	*Pseudanabaena*	45%
7/25/17	208458892	178,600	extreme	Bluegreens	98%	*Aphanizomenon/ Cylindrospermopsis*	54%/34%
7/26/17	208458893	190,200	extreme	Bluegreens	95%	*Aphanizomenon*	82%

Table 4. Algal Biovolume and Dominance at Lake Mattamuskeet.

Date	Station	Biovolume (mm^3/m^3)	Dominant Group	Group % Dominance	Dominant Taxa	Taxa % Dominance
5/18/17	PAS0123A	20,700	Bluegreens	55%	*Raphidiopsis*	44%
7/25/17	208458892	18,600	Bluegreens	97%	*Cylindrospermopsis*	81%
7/26/17	208458893	35,000	Bluegreens	95%	*Aphanizomenon*	87%

The calculated NCTSI score of 10.3 indicated that Lake Mattamuskeet was extremely productive (hypereutrophic). This lake was previously determined to be hypereutrophic in 2012, when it was monitored by DWR staff. Prior to 2012, the trophic state of Lake Mattamuskeet was eutrophic between 1981 and 1992. A decrease in the presence of aquatic macrophytes utilized by migrating waterfowl and an increase in algae has been noted by staff with the reserve in the western segment of the lake as compared to the eastern segment. The cause for this change is currently unknown. Water quality monitoring by USGS and the USFW staff is in progress to evaluate potential nutrient sources and other factors contributing to these changes observed in the lake.

Appendix A - Tar-Pamlico River Basin Lakes Data
January 1, 2013 Through December 31, 2017

	SURFACE PHYSICAL DATA								PHOTIC ZONE DATA											
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
TAR RIVER RESERVOIR	September 14, 2017	TAR015E	9.5	23.2	7.7	102	0.6	111.2	0.07	0.84	<0.02	0.05	0.89	0.83	0.06	62.0	94	12.0	13.0	
	September 14, 2017	TAR015G	10.4	24.1	8.3	94	0.8	123.6	0.06	0.76	<0.02	<0.02	0.77	0.75	0.02	72.0	88	6.8	5.5	
	September 14, 2017	TAR017C	8.1	24.2	7.7	78	0.9	96.6	0.06	0.84	<0.02	<0.02	0.85	0.83	0.02	30.0	78	<6.2	5.2	
	September 14, 2017	TAR017F	9.1	23.7	7.4	85	0.9	107.6	0.06	0.73	<0.02	<0.02	0.74	0.72	0.02	13.0	82	6.5	5.5	13.0
	August 17, 2017	TAR015E	6.3	29.7	7.0	68	0.6	83.3	0.11	0.68	0.03	0.19	0.87	0.65	0.22	11.0	98	16.0	35.0	
	August 17, 2017	TAR015G	11.3	30.1	8.8	80	0.4	149.4	0.10	0.92	<0.02	0.02	0.94	0.91	0.03	85.0	93	18.0	24.0	
	August 17, 2017	TAR017C	9.4	30.2	8.2	82	0.9	124.8	0.08	0.93	<0.02	0.02	0.95	0.92	0.03	49.0	80	7.5	7.1	
	August 17, 2017	TAR017F	10.1	30.3	8.6	85	0.7	134.5	0.07	0.83	<0.02	<0.02	0.84	0.82	0.02	64.0	85	9.2	11.0	27.0
	July 19, 2017	TAR015E	9.8	30.0	8.0	98	0.6	129.0	0.07	0.72	<0.02	<0.02	0.73	0.71	0.02	50.0	106	12.0	13.0	
	July 19, 2017	TAR015G	8.5	31.1	8.1	97	0.8	113.6	0.05	0.62	<0.02	<0.02	0.63	0.61	0.02	35.0	107	6.8	5.6	
	July 19, 2017	TAR017C	7.2	30.5	7.3	84	0.7	95.6	0.07	0.82	<0.02	<0.02	0.83	0.81	0.02	19.0	108	6.5	6.1	
	July 19, 2017	TAR017F	8.4	31.8	8.2	93	1.0	114.0	0.05	0.60	<0.02	<0.02	0.61	0.59	0.02	28.0	90	<12.0	5.0	25.0
	June 13, 2017	TAR015E	7.4	26.1	7.3	97	0.4	91.0	0.08	0.56	<0.02	0.24	0.80	0.55	0.25	17.0	130	<12.0	22.0	
	June 13, 2017	TAR015G	11.2	28.1	8.5	85	0.6	142.9	0.06	0.74	<0.02	0.02	0.76	0.73	0.03	49.0	154	13.0	16.0	
	June 13, 2017	TAR017C	9.9	29.1	7.6	70	0.6	128.3	0.08	1.10	<0.02	<0.02	1.11	1.09	0.02	59.0	143	7.5	8.8	
	June 13, 2017	TAR017F	10.5	28.0	8.4	84	0.7	134.1	0.07	0.75	<0.02	<0.02	0.76	0.74	0.02	52.0	109	7.0	9.0	25.0
	May 16, 2017	TAR015E	8.8	24.3	7.2	94	0.5	104.8	0.07	0.49	<0.02	0.32	0.81	0.48	0.33	9.9	124	9.0	17.0	
	May 16, 2017	TAR015G	10.2	22.7	7.2	86	0.7	118.3	0.19	0.64	0.02	0.27	0.91	0.62	0.29	12.0	92	7.8	14.0	
	May 16, 2017	TAR017C	9.1	23.5	7.3	76	0.6	107.2	0.08	1.00	<0.02	0.06	1.06	0.99	0.07	36.0	126	7.8	8.9	
	May 16, 2017	TAR017F	9.7	23.5	7.3	81	0.6	112.9	0.07	0.66	<0.02	0.24	0.90	0.65	0.25	12.0	116	7.8	13.0	25.0
LAKE NATTAMUSKEET	May 18, 2017	PAS0123A	8.9	24.4	8.3	569	0.2	106.5	0.14	4.40	<0.02	<0.02	4.41	4.39	0.02	190.0	744	206.0	80.0	