Management During Drought Conditions

OASIS Model-Drought Plan Setup

Droughts may be unpredictable but their occurrence is inevitable. A drought plan, to adjust normal operations when drought occurs, helps reduce the impacts to water resources and minimizes disruptions to water withdrawals. A water system's adopted water shortage response plan (WSRP) establishes drought stages that are implemented based on availability and link reductions in reservoir releases to constraints on demand, thus conserving and extending the water supply.

The OASIS model has the option to simulate outcomes when all WSRP within the basin are turned on or off. The demand-deficits analysis is performed with all WSRP turned off in the model.

Drought Condition Evaluation – Daily Flows

USGS gage flow is one of the indicators used to evaluate drought conditions. USGS historic flow percentiles are used to categorize the drought classifications from abnormally dry (D0) to exceptional drought (D4), as shown in Table 1. Gage flow is analyzed using the category classifications, and the number of days within each drought category and the percent difference of days within each are estimated with gage flow and simulated OASIS flow output (Simbase).

Table 1. Tar River near Tar River, NC Gage Summary of Drought Periods

Drought Category / Flow Percentile Range	**USGS (cfs)**	**USGS (#days)**	**Simbase (#days)**	**% Difference (Simbase-USGS)**
D0 Abnormally Dry 20% - 30%	16	2793	2864	2.54
D1 Moderate Drought 10% - 20%	8	2521	2735	8.49
D2 Severe Drought 5% - 10%	2.9	1180	1344	13.90
D3 Extreme Drought 2% - 5%	1.3	762	134	-82.41
D4 Exceptional Drought Less Than 2%	0.5	516	25	-95.16
D1-D4 Total time in drought conditions		**4979**	**4238**	**-14.88**

Color coded as US DM codes

From extreme drought (D3) to D4, the OASIS model underestimated the number of days, shown as negative percent difference. The combined total number of days in drought was underestimated approximately 15% of the days. The model produced a lower severe drought category because all WSRP were turned on and triggered the drought responses, precluding extreme drought conditions later in time. These evaluation techniques compared USGS data to Simbase data for all other gages listed in this section and appear in the appendix of this plan.

Drought Response

Water systems typically managed drought operations by conserving supply through reductions in releases from reservoirs and reductions in withdrawals associated with use restrictions. There are four water supply reservoirs in the Tar-Pamlico River Basin. As an example, the Tar River Reservoir, operated by City of Rocky Mount, has minimum release requirements and when water supplies become diminished during droughts, the flow requirement may be reduced to preserve storage. The reduction in the flow requirement is associated with voluntary or mandatory demand reductions. The flow reductions must be implemented with consideration for the impacts to water quality. The release schedule and reduction policy are incorporated into the OASIS model (Table 2).

Table 2. Minimum Release Policy for Rocky Mount's Tar River Reservoir.

Reservoirs Operating Condition	Drought Stage	Months	Minimum Release, cfs
Normal Condition		Jan - Dec	80
Drought Condition	1	Nov– May, June - Oct	80, 70
	2	Jan - Dec	70
	3	Jan - Dec	60
	3	Jan - Dec	50

As part of the WSRP, drought protocols are adopted by the subject water systems in the Tar-Pamlico River Basin. In the OASIS model, drought condition is assessed based on the stream flow or available river stage conditions at the intake or withdrawal location(s) or on the reservoir's predicted storage conditions. Some water system triggers are based on information that is not easily converted to a model data type and is therefore not modeled. The list of drought management demand reductions incorporated into the model is presented in Table 3.

Model Drought Evaluations

The simulated drought stages were calculated using the model with the three demand scenarios for the water supply systems. The model's drought stages triggered are based on reported triggers and responses for withdrawal reductions. The model's triggers were little modified from the actual triggers based on the best available data. As mentioned above, not all systems were included in the model's drought responses. A general basin-wide approach for responses is considered for modeling purposes.

Table 3. Demand Reduction Factors based on Triggered Drought Stages

System Name	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Franklinton	5%	10%	20%	25%	35%
Franklin County Public Utilities	Follows Kerr Lake RWS triggers, not modeled				
Louisburg	Based on gage height, cannot convert flow to stage at intake location, not modeled				
Rocky Mount	Voluntary I/II *No mandatory demand reduction*	10%	18%		
Enfield	5%	10%	20%	25%	
Tarboro	5%	10%	20%	25%	
Greenville Utilities Commission (GUC)	Cannot convert flow to stage due to tidal influence, not modeled				

Table 4 shows the percent of days in different drought stages; the longest duration counted as days; the event start and end dates; the total number of years; and percent of years with at least one stage triggered in 80 years of simulated flows.

The summary results reveal that Enfield's WSRP triggered a drought response in all drought stages at least once in each of the 80 years. Stages were triggered 44%, 17%, and 6% of the days, respectively. The longest duration period was 1933 -1934. Enfield's withdrawal location is in the upper watershed of Fishing Creek, a low-yield stream, with a reported drainage area of 524 square miles; therefore, drought responses were annually.

Rocky Mount withdraws from the Tar River Reservoir and supplements river flow with a downstream quarry. A malfunctioning USGS gage downstream of the reservoir registered very low flows in the fall of 2007 and Rocky Mount faced false severe drought conditions for many consecutive months. Because the inflow for the model was generated based on historic USGS records the model results also showed similar trends of severity and duration of drought conditions during the same period.

Franklinton and Tarboro triggered few days of drought conditions. Tarboro to stayed fewer days in drought with future scenarios because more wastewater return is received in the upper basin, associated with future high withdrawal demands, reduced the demand on flow and thus fewer number of drought days and stages.

Table 4. Drought Stage Comparison for Three Demand Scenarios

PWSS	Plan Scenario		Period of Records								No. of Yrs with 1 or more stages	Percent of years in any drought stages
			Percent of Days				Longest Duration, Days					
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 1 - 4	Stage 2 - 4	Stage 3 - 4	Stage 4		
Enfield	Plan 2010		44%	17%	6%		178	164	149		80	100%
		Event Dates					9/3/1933-2/27/1934	9/17/1933-2/27/1934	10/1/1933-2/26/1934			
	Plan 2030		44%	17%	6%		178	164	149		80	100%
		Event Dates					9/3/1933-2/27/1934	9/17/1933-2/27/1934	10/1/1933-2/26/1934			
	Plan 2060		44%	17%	6%		178	164	149		80	100%
		Event Dates					9/3/1933-2/27/1934	9/17/1933-2/27/1934	10/1/1933-2/26/1934			
Franklinton	Plan 2010		0.3%	0.1%	0.0%	0.0%	35	21	0	0	3	4%
		Event Dates					9/27/1968-10/26/1968	10/6/1968-10/26/1968				
	Plan 2030		0.5%	0.4%	0.2%	0.0%	78	64	50	0	4	5%
		Event Dates					9/15/1968-12/1/1968	9/29/1968-12/1/1968	10/13/1968-12/1/1968			
	Plan 2060		0.9%	0.6%	0.4%	0.1%	85	71	57	42	6	8%
		Event Dates					9/8/1968-12/1/1968, 9/9/2007-12/1/2007	9/22/1968-12/1/1968, 9/23/2007-12/1/2007	10/6/1968-12/1/1968, 10/7/2007-12/1/2007	10/21/2007-12/1/2007		

Stage color coded as US Drought Monitor codes

Table 4. Drought Stage Comparison for Three Demand Scenarios (continued).

PWSS	Plan Scenario		Period of Records								No. of Yrs with 1 or more stages	Percent of years in any drought stages
			Percent of Days				Longest Duration, Days					
			Stage 1	Stage 2	Stage 3	Stage 4	Stage 1 - 4	Stage 2 - 4	Stage 3 - 4	Stage 4		
Rocky Mount	Plan 2010		1%	1%	0%		135	114	86		10	13%
		Event Dates					8/5/2007-12/17/2007	8/26/2007-12/15/2007	9/23/2007-12/15/2007			
	Plan 2030		2%	1%	0%		134	113	99		12	15%
		Event Dates					8/5/2007-12/15/2007	8/26/2007-12/15/2007	9/9/2007-12/15/2007			
	Plan 2060		2%	1%	0%		133	119	98		12	15%
		Event Dates					8/5/2007-12/15/2007	8/19/2007-12/15/2007	9/9/2007-12/15/2007			
Tarboro	Plan 2010		0.3%	0.1%	0.0%	0.0%	35	21	0	0	3	4%
		Event Dates					9/22/1968-10/26/1968	10/6/1968-10/26/1968				
	Plan 2030		0.1%	0.0%	0.0%	0.0%	19	0	0	0	3	4%
		Event Dates					10/7/2007-10/25/2007					
	Plan 2060		0.1%	0.0%	0.0%	0.0%	19	0	0	0	2	3%
		Event Dates					10/7/2007-10/25/2007					

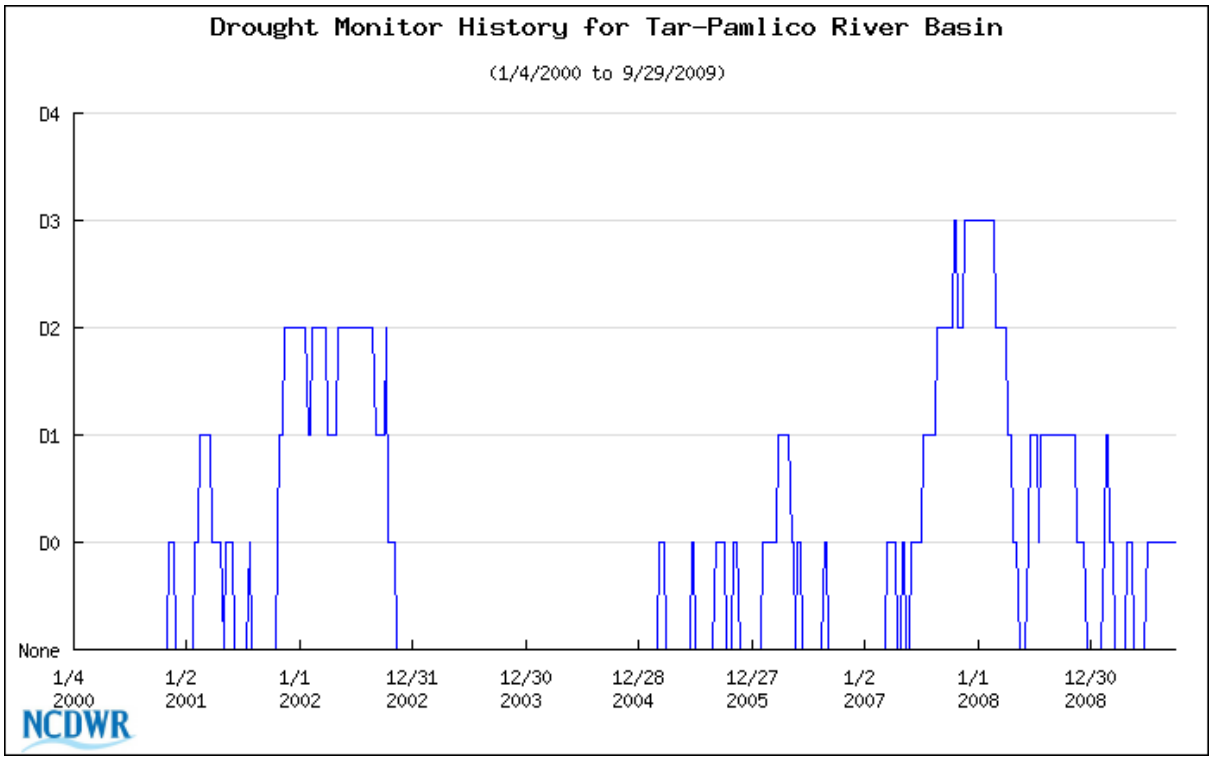
Stage color coded as US Drought Monitor codes

Historical Context of Drought in Tar-Pamlico River Basin

The North Carolina Drought Management Advisory Council (NCDMAC) started monitoring North Carolina drought conditions weekly in 2000.[1] The NCDMAC assesses drought conditions based on indices, including stream flow, groundwater, rainfall, reservoir levels, and soil moisture content while the OASIS model predicts the drought category based only on stream flow. Therefore, the NCDMAC drought levels depicted in real time may not replicate the basin model's predicted levels but should follow a similar trend and intensity.

The historical flow record shows that the Tar-Pamlico River Basin was hard hit by drought in the summer of 2002 and again in the fall of 2007, as shown in Figure 1. December 2007 was the worst month of recent years with the recorded drought category reaching D3, but the longest drought duration in the basin was a D2 category in 2002. Based on the weighted average area, the highest estimated level of drought for the basin was D3. Figures 2 and 3 show the December 2007 drought maps for the entire state and Tar-Pamlico River Basin, respectively. The majority of the Upper Tar Basin was in D4, whereas the Lower Tar Basin, Pamlico River and Pamlico Sound were in D3 and D2 category, respectively.

Figure 1: Tar Pamlico River Basin Drought Monitor Levels – 10-year Composite Status.



[1] http://www.ncdrought.org/index.php

Figure 2. North Carolina Drought Monitor Map in December 2007.

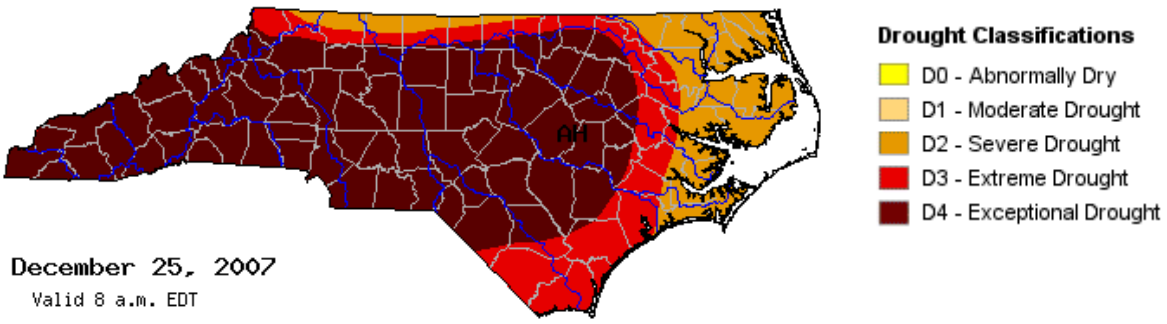
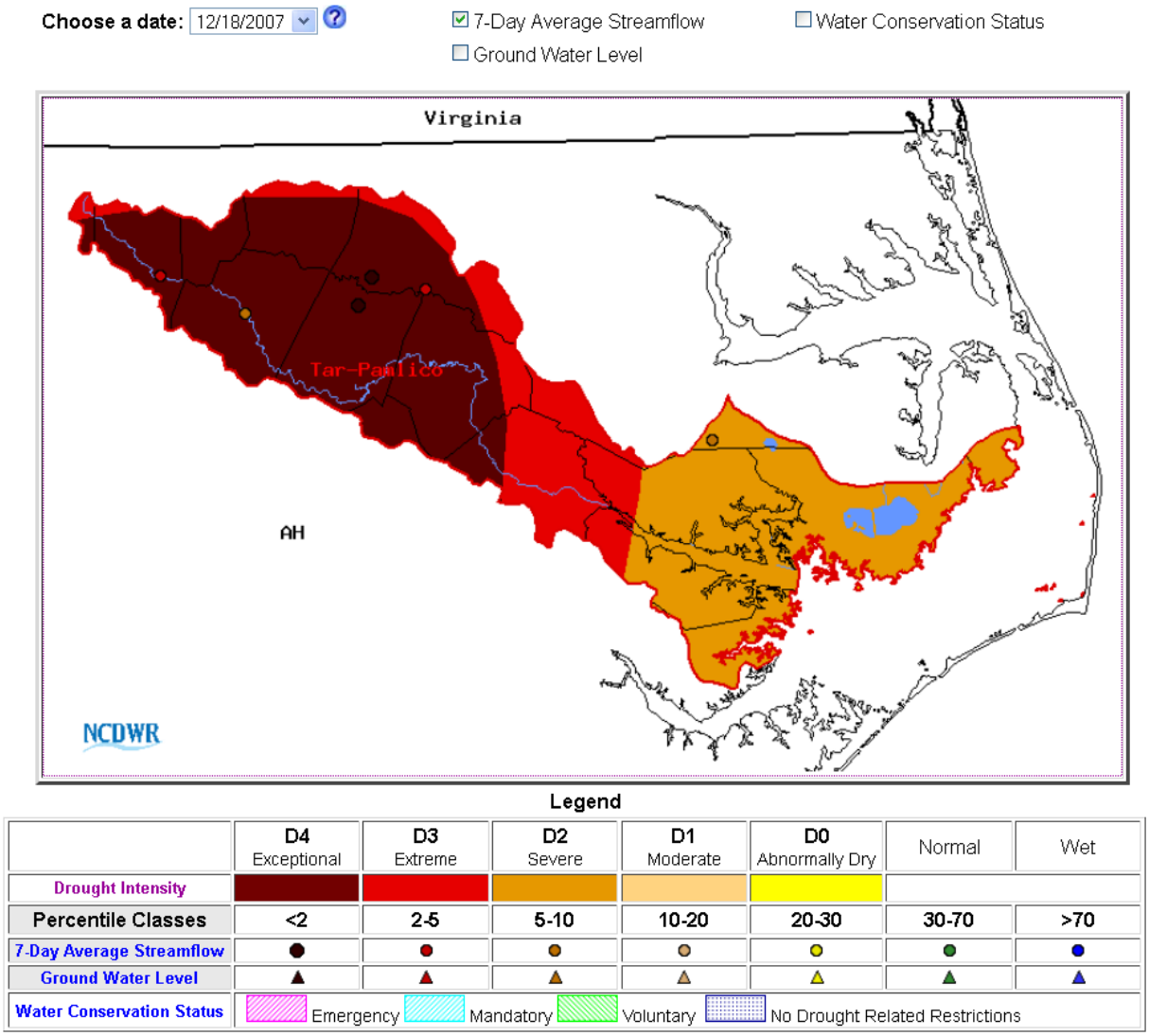


Figure 3. Tar Pamlico River Basin Drought Monitor Map in December 2007.



Tables 5 and 6 show the dryness rankings for two unregulated USGS gages in the upper Tar River and the Fishing Creek watersheds. Stream flow conditions at the gages rank 2007 as one of the driest years. Stream flow records from the Tar River near Tar River, NC gage ranks the 2010-2011 climatic year as the driest even though August through November 2007 were ranked as the driest months. On the other hand the Fishing Creek near Enfield, NC gage ranked the 2007-2008 climatic year as the driest.

Table 5. Stream Flow Ranking for Tar River near Tar River, NC Gage.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Climatic Year
1939/4 ~ 1940/3							41	34	19	15	50	22	
2007/4 ~ 2008/3	48	5	9	2	1	1	1	1	6	4	5	31	
2010/4 ~ 2011/3	10	44	23	6	17	16	31	11	5	2	1	16	1
2011/4 ~ 2012/3	20	28	5	16	12	47	28		21	5	3	13	2
1941/4 ~ 1942/3	33	2	21	57	25	28	3	2	1	1	15	21	3
1980/4 ~ 1981/3	51	51	32	21	13	12	21	27	8	3	17	2	4

Table 6. Stream Flow Ranking for Fishing Creek near Enfield, NC Gage.

Year	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Climatic Year ↓
1926/4 ~ 1927/3							13	22	49	18	39	35	
2007/4 ~ 2008/3	42	10	12	5	2	1	2	2	2	7	6	17	1
2011/4 ~ 2012/3	26	1	1	4	42	32	22	41	17	6	4	4	2
1980/4 ~ 1981/3	46	44	18	22	4	2	20	22	12	2	9	2	3
2010/4 ~ 2011/3	21	32	11	1	1		71	12	10	5	3	7	4