Cape Fear River Basin Model Analyses for the Interbasin Transfer EIS

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The purpose of this memorandum is to summarize the evaluation of impacts of the proposed Cary/Apex/Morrisville/Wake County interbasin transfer (IBT), based on analyses performed using the Cape Fear River Basin Model (CFRBM).

The memorandum is organized into the following sections:

- **Background**
- **EIS Alternatives**
- **Model Input**
- **Modeling Scenarios**
- **Results**
- **Summary and Conclusions**
- **Attachments**

1.0 Background

Overview

During 1996, the Towns of Cary, Apex, and Morrisville, as well as the Wake County portion of Research Triangle Park (RTP South) requested authorization from NC Division of Water Resources (DWR) and the Environmental Management Commission (EMC) to increase water withdrawals from Jordan Lake. An existing water supply allocation of 16 million gallons per day (mgd) was granted to Cary and Apex in 1987. Through a joint agreement, Cary and Apex treat raw water from Jordan Lake at the Cary/Apex Water Treatment Plant (WTP). Finished water is supplied to Cary, Apex, Raleigh/Durham Airport Authority (RDU Airport), RTP South, and the Town of Morrisville. In 1997, DWR recommended additional water supply allocations for Cary/Apex, Morrisville, and RTP South from Jordan Lake totaling 9 mgd.

The boundary between the Cape Fear River basin and the Neuse River basin runs through the Towns of Cary and Apex. Cary and Apex withdraw water from Jordan Lake and discharge it to the Neuse River basin through three wastewater treatment facilities that serve Cary, Apex, RTP South, and Morrisville. Therefore, there is a transfer of water from the Haw River basin to the Neuse River basin. This interbasin transfer (IBT) requires a certificate from the EMC in accordance with North Carolina General Statute 143-215.22I. Thus, the additional water supply allocations that DWR recommended for Cary, Apex, Morrisville and RTP South are contingent upon the issuance of an IBT certificate.

Proposed IBT Increase

The Towns of Cary, Apex, and Morrisville, and Wake County, are requesting an IBT certificate from the EMC for an additional 11 mgd, for a total IBT of 27 mgd. The requested IBT certificate is for the maximum IBT that is estimated to occur during the planning period through 2030, plus an additional contingency factor. The total IBT, including the existing certificate and the requested amount, is 27 mgd. In 2030, the IBT is projected to be to about 25 mgd (Table 1).

TABLE 1
Proposed IBT

Year	IBT Maximum Day (mgd)
2000	19.7
2010	17.9
2020	18.4
2030	24.1

The proposed action assumes the future return of water to the source basin through a highly treated effluent from a regional treatment and water reclamation facility in the mainstem of the Cape Fear River. The Cary North Wastewater Treatment Plant (WWTP), the Cary South WWTP and the Apex WWTP will not be expanded as a result of the proposed IBT. No WWTP capacity will be requested in the Neuse River basin in conjunction with this IBT request, since current permitted discharge amounts are adequate. One or more WWTPs and/or water reclamation facilities, assumed to discharge to the mainstem of the Cape Fear River, are being considered or planned and will likely serve Cary, Apex, and the Wake County portion of RTP, as well as other portions of western Wake County. This will limit the amount of water discharged to the Neuse River basin, thereby minimizing the IBT amount.

Cape Fear River Basin Model

This memorandum summarizes the evaluation of the impacts of an increased IBT using the final version of the CFRBM provided by the DWR in May 2000. The CFRBM was developed using the Danish Hydraulic Institute's Mike Basin water resources model. The CFRBM utilizes ArcView as its graphical user interface. Daily naturalized flow sequences were developed by DWR's contractor by calibrating the CFRBM to observed flows throughout the basin for the 68-year period from January 1, 1930 through December 31, 1998.

2.0 EIS Alternatives

Alternatives to the proposed increase in the interbasin transfer are discussed below and summarized in Table 2.

2.1 Alternative 1A: No IBT Increase with No Additional Allocation of Water from Jordan Lake

Under this alternative, there is no increase in the existing 16-mgd Jordan Lake allocation, and the existing permitted IBT would remain 16 mgd. There would be no new regional treatment and water reclamation facility, or other additional discharges to the source basin, in western Wake County.

Cary, Apex, Morrisville and the Wake County portion of RTP would need to meet water demands by using other water supply sources such as the Cape Fear River via a Haw River intake, bulk water from other local water systems (see alternatives No. 2 and No. 4 below), and small community or individual wells. It is unlikely that any of these options would allow sufficient water supply to satisfy water demands based on current growth projections. Thus, local governments may implement very stringent water conservation measures, convert to a conservation rate structure, and cooperate with industries to lower water usage. Local governments may also consider creating permanent rules prohibiting the use of water from the municipal water system for landscaping, and instead, require residents and businesses to either install individual groundwater wells or utilize reclaimed water for landscaping purposes (Cary, 1999). These policies may result in a sharp decrease in growth and development.

2.2 Alternative 1B: No IBT Expansion With Additional Jordan Lake Water Allocation

Under this no action alternative, Cary, Apex, Morrisville and RTP South would limit increases in the IBT so that they are balanced by concurrent decreases in customer demand, through very significant conservation and reuse programs and by a regional discharge to the Cape Fear River basin. This alternative will limit water supply to the current capacity of 19 mgd (maximum day basis) until 2005 when a regional treatment and water reclamation facility is in operation. This option qualifies as a No Action alternative largely because it assumes, as currently planned, the eventual construction of a regional treatment and water reclamation facility in western Wake County, along with reuse and conservation measures, so that the existing IBT will not have to be increased above 16 mgd (maximum day basis).

Under this scenario, growth in the Cary, Apex, Morrisville and RTP South area would be expected to continue to occur, although at a somewhat slower rate than that currently projected. In the long-term, enough water and sewer service would be provided to future residents and businesses to accommodate growth.

2.3 Alternative 2: Obtain Water from the Neuse River Basin

Under this alternative, increases in the IBT would be avoided by implementation of water conservation and reuse programs, construction of a regional wastewater discharge to the Cape Fear River basin, and purchase of finished water from the water systems in the Neuse River basin. Slower growth is likely until 2005 when a regional water reclamation facility in

TABLE 2
Summary of Alternatives for Year 2030

	Proposed Action	**1A No Action**	**1B No Action**	**2 Water From Neuse**	**3 Move WWTP Discharges**	**4 Merger with Durham**	**5 No Regional WWTP**
Increase in IBT (mgd)	11	0	0	0	0	0	29
Additional Jordan Lake Allocations	Yes	No	Yes	Yes	Yes	Yes	Yes
2030 MDD Water Demands (mgd)	53.6	19	43.8	53.6	53.6	53.6	53.6
Maximum IBT (mgd)	25 [1]	16	16	16	16	19 (Neuse to Haw)	45
Total Capital Cost (million)	$226	$11.1	$207	$207	$279	$248	$84
Water Reuse (maximum day)	3.8 mgd	3.8 mgd	3.8 mgd	3.8 mgd	3.8 mgd	3.8 mgd	3.8 mgd
New Regional WWTP Capacity (maximum month)	18.0 mgd	No	18.0 mgd	18.0 mgd	18.0 mgd	18.0 mgd	No
Finished Water Purchases from the Neuse River Basin (maximum day)	No	No	No	9.2 mgd	No	No	No
Additional Cary/Apex WTP Capacity (maximum day)	20.0 mgd	No	9.0 mgd	9.0 mgd	20.0 mgd	20.0 mgd	20.0 mgd

1. Projected IBT in 2030 is approximately 25 mgd. The requested amount of 27 mgd includes some contingency.
2.

western Wake County is online. Beyond 2005, growth and development in Cary, Apex, Morrisville and RTP South would follow anticipated patterns.

To maintain an IBT of 16 mgd, the applicants would increase water withdrawals from the Neuse River basin through additional bulk purchases of finished water from the City of Durham and/or the City of Raleigh. This would require purchase of 2.4 mgd (annual average) in 2000, increasing to approximately 5.6 mgd in 2030 (annual average). Maximum day purchases are projected to be 4.0 mgd in 2000 and 9.2 mgd in 2030. Both the City of Durham and the City of Raleigh have expressed concern for maintaining sufficient capacity to satisfy their own demands, and may not have excess capacity to provide finished water to Cary, Apex, Morrisville, and RTP South on a long-term basis. Raleigh has recently denied Cary's request for additional water purchases through 2003.

2.4 Alternative 3: Increase Wastewater Discharges to Cape Fear River Basin

Under this alternative, wastewater flows to the Cape Fear River basin would increase due to the relocation of the wastewater discharges for the existing Apex and Cary WWTPs from the Neuse River basin. This scenario also includes implementation of water conservation to reduce the ADD by 18% by 2030 and a water reclamation program to produce up to 3.8 mgd of reclaimed water for non-potable uses.

2.5 Alternative 4: Merger of Water and Sewer Utilities

This alternative involves the merger of the water and sewer utility operations of the Town of Cary and the City of Durham. The City of Durham has an IBT from the Neuse River basin to the Haw River basin, while Cary has an IBT from the Haw River basin to the Neuse River basin. When these two systems are considered jointly, the existing net IBT would be from the Neuse River Basin to the Haw River Basin. If these two systems merged, then future IBT amounts would be reduced.

This alternative assumes that the City of Durham would continue to meet its water supply needs from the Neuse River basin and the Town of Cary would continue to meet its water supply needs from Jordan Lake (Haw River basin). Therefore, this alternative does not differ physically from the proposed action except for the expansion or addition of interconnections to provide additional reliability in the merged system.

2.6 Alternative 5: No Regional Treatment and Water Reclamation Facility

This alternative assumes that no regional water reclamation facility in the Cape Fear basin is constructed, and the Cary North, Cary South and Apex WWTPs are not expanded beyond current permitted capacities. It is assumed that these WWTPs may have sufficient permitted capacity to treat projected wastewater flows to 2030. Under this scenario, wastewater effluent discharges to the Cape Fear River basin remain at zero, and the quantity of the IBT increases as water withdrawals from Jordan Lake increase and are discharged through existing wastewater treatment facilities in the Neuse River basin. This alternative represents the maximum projected IBT compared to the proposed action and all other EIS alternatives.

3.0 Model Input

Key input to the CFRBM includes municipal, industrial, and agricultural water withdrawals; NPDES discharges; reservoir operating rules; and daily naturalized flows. The analyses were performed based on steady-state annual conditions. Thus, water supply withdrawals and discharges were assumed to be the same for every year during the study period.

Table 3 shows the 1998 monthly-to-annual ratios of water supply withdrawals and discharges for Cary/Apex. These ratios were used to develop monthly demands for Cary/Apex and the other Jordan Lake withdrawals and return flows in all of the modeling scenarios.

TABLE 3
Withdrawal and Discharge Monthly-to-Annual Ratios

	Withdrawals	Discharges
January	0.94	1.00
February	0.95	1.61
March	1.00	1.10
April	1.01	1.03
May	0.98	1.03
June	1.13	0.86
July	1.11	0.91
August	1.08	0.65
September	1.08	0.82
October	1.09	1.03
November	0.77	1.00
December	0.85	0.96

The "capefear_base" scenario that was included in the final version of the CFRBM was used as the basis for all modeling scenarios. The "capefear_base" scenario includes 1998 withdrawal and discharge data for all users within the Cape Fear basin. Some modifications, outlined in Attachment 1, were made to the "capefear_base" scenario prior to modeling of IBT impacts. More detailed input information for all modeling scenarios is given in Section 4.0 and Attachment 2.

For the analysis of cumulative impacts, projected municipal water supply withdrawals and discharges in 2030 were extrapolated from data provided in the 1992 Local Water Supply Plans for each water system. Linear projections of 2030 water use were developed from actual water use data in 1992 and projected water use for the years 2000, 2010, and 2020. The projected 2030 values were then used with the base 1998 municipal withdrawals and

discharges to calculate demand multipliers for use in the CFRBM. Table 4 summarizes the demand multipliers that were used in all scenarios modeling the cumulative impacts of the IBT.

TABLE 4
Demand Multiplier used in Cumulative Impacts Analysis

Water System	Estimated 2030 Use/ Actual 1998 Use
Asheboro	2.1
Burlington	1.2
Durham	1.6
Fayetteville	1.9
Greensboro	1.6
Harnett County	2.0
High Point	1.7
OWASA	1.7
CP&L	1.0
All Other Municipal Systems	2.0
Industrial Users	2.0

4.0 Modeling Scenarios

Table 5 summarizes withdrawal and discharge amounts for the modeling scenarios that were evaluated, addressing the five alternatives presented in the Environmental Impact Statement. Additional information on input data for each EIS alternative is included in Attachment 2. The numbers at the beginning of the scenario names represent the corresponding alternative number as presented in the EIS. The potential impacts of Alternatives 2 and 4 are the same as those of other alternatives, as noted below, so they were not modeled separately.

The *Base 1998* scenario represents the existing conditions in 1998. Thus, water supply withdrawals and discharges throughout the basin are set to actual 1998 values. Withdrawals from Jordan Lake include Cary/Apex and Chatham County with annual average withdrawals of 10.7 and 0.8 mgd, respectively.

The *Base Future* scenario includes full use of the Jordan Lake water supply pool (total withdrawals = 100 mgd). Potential impacts of the requested IBT are evaluated in comparison to the *Base Future* scenario in order to isolate IBT impacts from the impacts of full Jordan Lake allocation use. For all scenarios except *Base 1998*, withdrawals from Jordan Lake total 100 mgd, with 50 percent of the "Other Jordan Lake withdrawals" returned to

Jordan Lake. Discharges from Cary/Apex are returned downstream of Jordan Lake and upstream of Lillington.

All scenarios except the *Base 1998* scenario are based on the assumption that current allocation holders (Chatham County, Orange County, and OWASA) are fully utilizing their water supply allocations, and the balance of the total Jordan Lake withdrawal is attributed to the "DWR" node in the CFRBM.

The *Proposed* scenario represents the requested IBT increase and includes planned Jordan Lake withdrawals in 2030 as well as planned 2030 discharges from a regional water reclamation facility to the mainstem of the Cape Fear River, downstream of Jordan Lake and upstream of Lillington. The modeling results for the *Proposed* action also represent the impacts of *Alternative 4 – Cary/Durham Merger*.

Alternative 1B and *Alternative 2* are represented by the same modeling scenario since the impacts on Jordan Lake and the Cape Fear River would be the same for those two alternatives.

Alternative 3 (Relocate WWTP Discharges) includes the proposed water reclamation facility discharging to the Cape Fear River. In addition, the existing WWTP discharges to the Neuse River basin are relocated to the mainstem of the Cape Fear River below Jordan Lake and upstream of Lillington, such that the IBT remains at the currently permitted amount of 16 mgd.

The only scenario that does not include the proposed regional water reclamation facility is *Alternative 5 (No Cape Fear WRF)*. This alternative represents the maximum IBT that could occur, with no wastewater discharges to the Cape Fear River basin to offset the IBT as in the proposed action.

TABLE 5
Modeling Scenarios for Interbasin Transfer Impact Evaluation

Scenario	Description	Base Year[1]	Average Day Flows (mgd)		
			Withdrawal at Cary/Apex Intake	Cape Fear Basin Discharges	Other Jordan Lake withdrawals[2]
Base 1998	Existing Conditions	1998	10.7	None	None
Base Future	Existing, plus Jordan Withdrawals = 100 mgd	1998	10.7	None	89.3
Alternatives for Incremental Impacts Evaluation					
Proposed Incremental	Requested IBT Increase	1998	32.8	12.7	67.2
Alt. 1A Incremental	No IBT Increase and No Additional Allocation	1998	11.6	None	88.4
Alt. 1B	Additional Allocation with No IBT Increase	1998	26.8	12.7	73.2
Alt. 2	Obtain Water from Neuse Basin				*Same as Alt. 1B*
Alt. 3	Relocate WWTP Discharges to Cape Fear	1998	32.8	17.6	67.2
Alt. 4	Merger with Durham			*Same as Proposed-Incremental*	
Alt. 5	No Regional WWTP	1998	32.8	0	67.2
Alternatives for Cumulative Impacts Evaluation					
Proposed Cumulative	Requested IBT Increase	2030	32.8	12.7	67.2
Alt. 1A Cumulative	No IBT Increase and No Additional Allocation	2030	11.6	None	88.4

[1] The Base Year is the data year used for all other nodes other than those listed, and as discussed in the preceeding section.
[2] "Other Jordan Lake Withdrawals" is calculated such that total Jordan Lake withdrawals = 100 mgd, considering Cary/Apex withdra
[3] "Other Return Flows" represents the return of 50 percent of "Other Jordan Lake Withdrawals" (excluding Chatham County's withdr
[4] From the Cape Fear Basin to the Neuse Basin on a maximum day basis, in mgd.
[5] From the Neuse Basin to the Cape Fear Basin, including Durham's grandfathered amount.

5.0 Results

For evaluating direct hydrologic impacts of the proposed IBT increase, the following indicators were used:

- Jordan Lake elevation
- Jordan Lake outflow
- Cape Fear River flow at Lillington
- Cape Fear River flow at Fayetteville
- Water Quality Pool level

For each indicator, the following graphs were developed from model runs using a daily time step:

- *Cumulative frequency distribution for 1930-1998*: This represents the overall impact for the study period. Also, the cumulative frequency of Jordan Lake levels during the summer months of June, July, and August is presented to illustrate potential impacts on recreation.

- *Daily time series for 1950-1955*: This represents the worst drought during the 1930-1998 period. The 1950 – 1955 period was selected based on a CFRBM simulation of the 1930 to 1998 period on a daily time step. Water quality pool levels in Jordan Lake were evaluated to determine the most severe droughts (lowest water pool level) and droughts with the longest duration in the *Base 1998* and *Base Future* scenarios. Droughts were defined as any period in which the water quality pool level dropped below the long-term average of 86.8%.

In addition to the graphs, the following low flow statistics, calculated by the CFRBM, are reported for the Cape Fear River at Lillington and at Fayetteville:

- 7Q10
- 30Q20
- 30Q50

5.1 Incremental Impacts

Cumulative Frequency Analysis

Results from the incremental impacts analysis are shown in the cumulative frequency diagrams in Figures 1-5 and in Table 6. For most parameters, there is little difference between the proposed action and the other alternatives. The largest difference is found between the *Base 1998* scenario and the other alternatives, especially in Jordan Lake outflows and lake levels (Figures 1 and 2). This illustrates that, compared to current conditions, the largest impacts on the Jordan Lake system will occur from the increased use of the water supply pool. However, this simply represents transition to full utilization of the lake as it was designed, and is not an impact of the proposed IBT.

Figures 3 and 4 show no difference in downstream Cape Fear River flows at Lillington or Fayetteville between the proposed action, the other alternatives, and the base scenarios.

Insert Fig1

Insert Fig 2

Insert Fig 3

Insert Fig 4

Insert Fig 5

Table 6.

This is even true for Alternative 5, which represents a much larger IBT amount than is being requested.

Figure 5 shows that there is little difference in water quality pool levels between the different scenarios.

Low Flow Statistics

Low-flow statistics for Cape Fear River flows at Lillington and Fayetteville are summarized for each scenario in Table 7. The 7Q10 flow at Lillington is 217 cubic feet per second (cfs) under the *Proposed* scenario compared to 183 cfs under the *Base Future* scenario. The 7Q10 flow at Lillington was lowest under the *Base 1998* scenario, although the total withdrawal from Jordan Lake is lowest in this scenario compared to the other scenarios.

Examination of daily flows at Lillington in the *Base 1998* and *Base Future* scenarios reveals that flows are higher under the *Base 1998* scenario most of the time. However, when the water quality pool drops to zero during drought conditions, Jordan Lake releases are dependent upon inflows. Under all scenarios except *Base 1998*, discharges from allocation holders to Jordan Lake supplement inflows and increases downstream releases during these drought periods.

TABLE 7.
Low Flow Statistics for Cape Fear River Flows at Lillington and Fayetteville

Scenario	Lillington			Fayetteville		
	7Q10	30Q20	30Q50	7Q10	30Q20	30Q50
Base 1998	133	225	134	406	428	301
Base Future	183	260	160	446	458	335
Proposed and Alt. 4	217	279	178	466	473	352
Alt. 1A	182	259	160	445	458	335
Alts. 1B and 2	220	282	180	470	475	354
Alt. 3	231	291	188	476	481	360
Alt. 5	162	248	152	426	449	327

Note: all values in cfs.

Incremental Impacts under Drought Conditions

To illustrate the incremental impacts of all alternatives under drought conditions, results for the period 1950 to 1955 are shown in Figures 6 through 10. Figure 7 illustrates that outflows dropped below the minimum release amount of 100 cfs on three occasions during the 1950 to 1955 period. During these periods, the water quality pool was depleted (Figure 10) and Cape Fear River flows at Lillington dropped below the target flow of 600 cfs. To further illustrate the impacts of the alternatives under drought conditions, the number of days in which Cape Fear River flows at Lillington dropped below the target flow are summarized in

Table 8. Flows at Lillington dropped below the target flow less frequently under the *Proposed* scenario compared to the *Base Future* and *Base 1998* scenarios.

TABLE 8.
Comparison of Cape Fear River Flows Under Drought Conditions (1950-1955)

Scenario	Days Below Target Flow (600 cfs) at Lillington	Minimum Flow at Lillington (cfs)	Minimum Flow at Fayetteville (cfs)
Base 1998	118	0	109
Base Future	111	0	104
Proposed and Alt. 4	107	15	130
Alt. 1A	111	0	104
Alts. 1B and 2	103	15	129
Alt. 3	100	23	137
Alt. 5	117	0	76

To assess the impacts of the *Proposed* action on recreation, Jordan Lake levels during the summer months (June, July, and August) were evaluated. Table 9 illustrates that summertime Jordan Lake levels were between 204 and 216 ft MSL under all scenarios during the 1950 to 1955 period. Summertime lake levels under the Proposed action were lower than the Base 1998 scenario, but were similar to all other scenarios, indicating that any impacts are due to the full utilization of the water supply pool and not an increase in the IBT.

TABLE 9
Percent of Days Lake Levels Are Exceeded in June, July and August, 1950-1955

Jordan Lake Elevation (ft MSL)	Base 1998	Base Future	Proposed and Alt. 4	Alt 1A	Alts. 1B and 2	Alt 3	Alt 5
200	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
202	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
204	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
206	100.0%	99.1%	99.1%	99.1%	99.3%	99.3%	98.7%
208	99.1%	96.3%	96.3%	96.3%	96.3%	96.3%	95.9%
210	95.4%	91.3%	91.3%	91.3%	91.5%	91.7%	90.9%
212	83.7%	81.7%	81.7%	81.7%	81.7%	82.0%	81.1%
214	72.0%	56.7%	57.0%	56.7%	57.2%	57.2%	55.4%
216	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
218	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
220	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Insert Fig 6

Insert Fig 7

Insert Fig 8

Insert Fig 9

Insert Fig 10

5.2 Cumulative Impacts

Cumulative Frequency Analysis

Figures 11-15 and Table 10 show the cumulative impacts of the *Proposed* action and *Alternative 1A - No Action*, compared to the *Base Future* scenario, using estimated 2030 withdrawals and discharges throughout the Cape Fear basin. *Alternative 1A* represents the potential cumulative impacts in the basin without the proposed IBT increase. The results show that the *Proposed* action does not show a significant impact compared to *Alternative 1A*. Also, the potential cumulative impacts of increasing all water withdrawals and discharges throughout the Cape Fear basin do not seem significant compared to the *Base Future* scenario.

Low Flow Statistics

The cumulative impacts on Cape Fear River flows at Lillington and Fayetteville are summarized in Table 11. The 7Q10 flow at Lillington and Fayetteville is higher under the *Proposed* action compared to the *Base Future* scenario and *Alternative 1A*. As discussed in Section 5.2, this is due to increased discharges to Jordan Lake during drought periods. Inflows to Jordan Lake from tributary rivers and streams as well as wastewater discharges are distributed between the water quality pool and the individual water supply pools. Thus, increased discharge to Jordan Lake effectively augments the water supply pool, which allows for higher lake releases during severe drought periods and therefore higher Cape Fear River flows.

TABLE 11.
Low Flow Statistics for Cape Fear River Flows at Lillington and Fayetteville

Scenario	Lillington			Fayetteville		
	7Q10	30Q20	30Q50	7Q10	30Q20	30Q50
Base Future	183	260	160	446	458	335
Proposed Cumulative	357	368	271	511	521	420
Alt. 1A Cumulative	331	346	243	496	499	391

Note: all values in cfs.

Cumulative Impacts under Drought Conditions

Cumulative impacts under drought conditions (1950 to 1955) are shown in Figures 16-20. The results show that there is little cumulative impact of the proposed action when compared to the *Alt 1A – No Action* and *Base Future* scenarios.

Insert Fig 11

Insert Fig 12

Insert Fig 13

Insert Fig 14

Insert Fig 15

Insert Fig 16

Insert Fig 17

Insert Fig 18

Insert Fig 19

Insert Fig 20

Table 10

6.0 Summary and Conclusions

To summarize the results of the modeling, Table 12 shows the frequency with which the following conditions occur under each scenario:

- Jordan Lake Outflows < 100 cfs (minimum release)
- Jordan Lake Levels < 210 ft. MSL (lower limit for boat ramp use)
- Water Quality Pool < 20%
- Cape Fear River Flow at Lillington < 600 cfs (target flow)
- Cape Fear River Flow at Fayetteville < 600 cfs

Table 12 shows that Jordan Lake outflows are expected to be slightly lower with the requested IBT than they would be under either base conditions *(Base Future)* or the "No Action" scenario. Jordan Lake levels are expected to be similar under the *Proposed* scenario compared to the *Base Future* scenario and *Alternative 1A*. The impacts of the *Proposed* action on water quality pool levels and Cape Fear River flows at Lillington and Fayetteville are negligible compared to the *Base Future* scenario and the other EIS alternatives.

Compared to the *Base 1998* scenario, all scenarios impact Jordan Lake and Cape Fear River flows. However, comparison of the results of the *Base 1998*, *Base Future* and *Proposed* scenarios reveal that the impacts are related to the increased utilization of Jordan Lake to its maximum withdrawal rate of 100 mgd (annual average), rather than to the requested increase in IBT.

The results also indicate that impacts are more severe under *Alternative 5 (No regional WWTP)* compared all other EIS alternatives.

During drought periods, impacts on Jordan Lake and Cape Fear River flows may be expected, but these impacts are similar for the *Proposed* scenario and all other scenarios. The modeled scenarios do not include drought management for any water users, including users of Jordan Lake. All Jordan Lake water supply allocation holders are required to develop drought management plans, and DWR will be developing a drought management plan for the water quality pool. Since one purpose for developing the CFRBM will be to begin evaluating and developing these plans, drought management measures for Jordan Lake are not available for incorporation into this analysis. If drought management policies were considered, the impacts of the proposed action under drought conditions would be expected to be less than those reported in this TM.

Overall, the conclusion of this evaluation is that the hydrologic impacts of the proposed increase in IBT will be insignificant. Some impact is expected compared to current conditions due to the eventual use of the full Jordan Lake water supply pool as designed, but this is unrelated to the proposed IBT. The cumulative impacts analysis shows that the impacts of the proposed action in 2030 will be similar to the impacts of *Alternative 1A* (no increase in IBT) and that any cumulative impacts are also due to increased use of basinwide water resources.

TABLE 12
Comparison of Hydrologic Impacts of EIS Alternatives[1]

Scenario	Description	Jordan Lake Outflow < 100 cfs	Jordan Lake Level < 210 ft. MSL	Water Quality Pool < 20%	Flows at Lillington < 600 cfs	Flows at Fayetteville < 600 cfs
Base 1998	Existing Conditions	12.6%	4.9%	4.2%	34.3%	2.0%
Base Future	Existing, plus Jordan Withdrawals = 100 mgd	15.2%	8.7%	3.8%	35.5%	1.9%
Alternatives for Incremental Impacts Evaluation						
Proposed Incremental	Requested IBT Increase	16.0%	8.6%	3.5%	34.9%	1.8%
Alt. 1A Incremental	No IBT Increase and No Additional Allocation	15.2%	8.7%	3.8%	35.5%	1.9%
Alt. 1B	Additional Allocation with No IBT Increase	15.9%	8.4%	3.4%	34.8%	1.8%
Alt. 2	Obtain Water from Neuse Basin	15.9%	8.4%	3.4%	34.8%	1.8%
Alt. 3	Relocate Existing WWTP Discharges to Cape Fear	16.2%	8.3%	3.4%	34.5%	1.8%
Alt. 4	Merger with Durham	16.0%	8.6%	3.5%	34.9%	1.8%
Alt. 5	No Regional WWTP	15.8%	9.2%	4.1%	35.7%	2.0%
Alternatives for Cumulative Impacts Evaluation						
Proposed Cumulative	Requested IBT Increase	13.7%	6.2%	2.6%	33.9%	1.8%
Alt. 1A Cumulative	No IBT Increase and No Additional Allocation	13.0%	6.3%	2.7%	34.5%	1.9%

1. Data represent percent of days in which value was below the treshold.

Attachments

Attachment 1: Modifications to CFRBM "Capefear_base" Scenario

The following modifications were made to the "capefear_base" scenario of the CFRBM. The modified scenario was then used as the basis for modeling of all scenarios.

1) Modified "Reservoir.shp" file to eliminate influence of Randleman.
   a) Created "zero_evapo.dfs0" with evaporation time series of zero for each time step.
   b) Created "zero_rain.dfs0" with precipitation time series of zero for each time step.
   c) Set "Precipitation" to "zero_rain.dfs0" for Randleman.
   d) Set "Evaporation" to "zero_evapo.dfs0" for Randleman.
   e) Set "Minimum downstream releases" and "Maximum downstream releases" to 1.0×10^9 cfs.
   f) Set "Initial water level" and "Top of dead storage" to 630 ft MSL.
2) Deleted file "caryapex.dfs0".
3) Created new water supply node for Cary/Apex discharges downstream of Jordan Lake at node 119..
4) Created new water supply node for "DWR Return" that discharges to Jordan Lake.

Attachment 2: Input Data for CFRBM Scenarios

The following tables outline the data inputs to the CFRBM for each modeling alternative.

TABLE 1
Jordan Lake Allocation Ratios for CFRBM

Water User Priority	Water User Name	Base1998	Base Future	Proposed and Alt. 4	Alt. 1A	Alts. 1B and 2	Alt. 3	Alt. 5
0	Water Quality Pool	0.6738	0.6738	0.6738	0.6738	0.6738	0.6738	0.6738
1	Cary/Apex	0.0522	0.0359	0.1076	0.0391	0.0881	0.1076	0.1076
2	Chatham County	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196	0.0196
3	OWASA	0.0326	0.0326	0.0326	0.0326	0.0326	0.0326	0.0326
4	Orange County	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033	0.0033
5	DWR	0.2186	0.2349	0.1631	0.2316	0.1827	0.1631	0.1631
6	DWR2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

TABLE 2.
CFRBM Input Data for Modeling Scenarios

Note: all values in mgd.

Month	Cary/Apex Withdrawal	Cary/Apex Discharge	Cary/Apex WTP discharge	Chatham County Withdrawal	OWASA Withdrawal	Orange Co. Withdrawal	DWR Withdrawal	DWR Return	Total Jordan Lake Withdrawal
filename	03-92-020-045caryapex.dfs0	carypapex_disch.dfs0	nc0081591caryapex.dfs0	chathamco.dfs0	owasa_with.dfs0	orangeco_with.dfs0	dwr_jl_with.dfs0	dwr_jl_disch.dfs0	
Base 1998									
Jan	10.15	0.00	0.51	0.58	0.00	0.00	0.00	0.00	10.73
Feb	10.20	0.00	0.51	0.60	0.00	0.00	0.00	0.00	10.80
Mar	10.80	0.00	0.53	0.60	0.00	0.00	0.00	0.00	11.40
Apr	10.83	0.00	0.54	0.71	0.00	0.00	0.00	0.00	11.54
May	10.48	0.00	0.52	0.83	0.00	0.00	0.00	0.00	11.31
Jun	12.16	0.00	0.77	1.09	0.00	0.00	0.00	0.00	13.25
Jul	11.95	0.00	1.10	0.99	0.00	0.00	0.00	0.00	12.94
Aug	11.58	0.00	0.66	0.89	0.00	0.00	0.00	0.00	12.47
Sep	11.66	0.00	0.59	1.00	0.00	0.00	0.00	0.00	12.66
Oct	11.71	0.00	0.58	0.93	0.00	0.00	0.00	0.00	12.64
Nov	8.28	0.00	0.55	0.75	0.00	0.00	0.00	0.00	9.03
Dec	9.17	0.00	0.50	0.73	0.00	0.00	0.00	0.00	9.90
Annual Average	**10.75**	**0.00**	**0.61**	**0.81**	**0.00**	**0.00**	**0.00**	**0.00**	**11.56**

TABLE 2.
CFRBM Input Data for Modeling Scenarios

Note: all values in mgd.

Month	Cary/Apex Withdrawal	Cary/Apex Discharge	Cary/Apex WTP discharge	Chatham County Withdrawal	OWASA Withdrawal	Orange Co. Withdrawal	DWR Withdrawal	DWR Return	Total Jordan Lake Withdrawal
Base Future									
Jan	10.15	0.00	0.51	5.67	9.44	0.94	68.28	44.45	94.49
Feb	10.20	0.00	0.51	5.69	9.49	0.95	68.62	71.05	94.95
Mar	10.80	0.00	0.53	6.03	10.05	1.00	72.65	48.74	100.54
Apr	10.83	0.00	0.54	6.05	10.08	1.01	72.85	45.52	100.82
May	10.48	0.00	0.52	5.85	9.75	0.98	70.50	45.52	97.56
Jun	12.16	0.00	0.77	6.79	11.31	1.13	81.80	38.20	113.20
Jul	11.95	0.00	1.10	6.67	11.12	1.11	80.39	40.35	111.24
Aug	11.58	0.00	0.66	6.46	10.77	1.08	77.90	28.56	107.80
Sep	11.66	0.00	0.59	6.51	10.85	1.08	78.44	36.06	108.54
Oct	11.71	0.00	0.58	6.54	10.90	1.09	78.77	45.52	109.01
Nov	8.28	0.00	0.55	4.62	7.70	0.77	55.70	44.45	77.08
Dec	9.17	0.00	0.50	5.12	8.53	0.85	61.69	42.49	85.36
Annual Average	**10.75**	**0.00**	**0.61**	**6.00**	**10.00**	**1.00**	**72.30**	**44.25**	**100.05**

TABLE 2.
CFRBM Input Data for Modeling Scenarios

Note: all values in mgd.

Month	Cary/Apex Withdrawal	Cary/Apex Discharge	Cary/Apex WTP discharge	Chatham County Withdrawal	OWASA Withdrawal	Orange Co. Withdrawal	DWR Withdrawal	DWR Return	Total Jordan Lake Withdrawal
Proposed and Alternative 4									
Jan	30.98	12.76	1.56	5.67	9.44	0.94	47.41	33.36	94.44
Feb	31.13	20.40	1.56	5.69	9.49	0.95	47.64	53.32	94.91
Mar	32.96	13.99	1.62	6.03	10.05	1.00	50.45	36.57	100.49
Apr	33.05	13.07	1.65	6.05	10.08	1.01	50.59	34.16	100.77
May	31.98	13.07	1.59	5.85	9.75	0.98	48.95	34.16	97.51
Jun	37.11	10.97	2.35	6.79	11.31	1.13	56.80	28.67	113.14
Jul	36.47	11.58	3.36	6.67	11.12	1.11	55.82	30.28	111.19
Aug	35.34	8.20	2.01	6.46	10.77	1.08	54.09	21.43	107.75
Sep	35.58	10.35	1.80	6.51	10.85	1.08	54.46	27.06	108.49
Oct	35.74	13.07	1.77	6.54	10.90	1.09	54.70	34.16	108.96
Nov	25.27	12.76	1.68	4.62	7.70	0.77	38.67	33.36	77.04
Dec	27.99	12.20	1.53	5.12	8.53	0.85	42.83	31.88	85.32
Annual Average	**32.80**	**12.70**	**1.87**	**6.00**	**10.00**	**1.00**	**50.20**	**33.20**	**100.00**

TABLE 2.
CFRBM Input Data for Modeling Scenarios

Note: all values in mgd.

Month	Cary/Apex Withdrawal	Cary/Apex Discharge	Cary/Apex WTP discharge	Chatham County Withdrawal	OWASA Withdrawal	Orange Co. Withdrawal	DWR Withdrawal	DWR Return	Total Jordan Lake Withdrawal
Alternative 1A									
Jan	10.96	0.00	0.55	5.67	9.44	0.94	67.43	44.01	94.44
Feb	11.01	0.00	0.55	5.69	9.49	0.95	67.76	70.34	94.91
Mar	11.66	0.00	0.57	6.03	10.05	1.00	71.75	48.25	100.49
Apr	11.69	0.00	0.58	6.05	10.08	1.01	71.95	45.07	100.77
May	11.31	0.00	0.56	5.85	9.75	0.98	69.62	45.07	97.51
Jun	13.12	0.00	0.83	6.79	11.31	1.13	80.78	37.82	113.14
Jul	12.90	0.00	1.19	6.67	11.12	1.11	79.39	39.94	111.19
Aug	12.50	0.00	0.71	6.46	10.77	1.08	76.93	28.28	107.75
Sep	12.58	0.00	0.64	6.51	10.85	1.08	77.46	35.70	108.49
Oct	12.64	0.00	0.63	6.54	10.90	1.09	77.79	45.07	108.96
Nov	8.94	0.00	0.59	4.62	7.70	0.77	55.01	44.01	77.04
Dec	9.90	0.00	0.54	5.12	8.53	0.85	60.92	42.06	85.32
Annual Average	**11.60**	**0.00**	**0.66**	**6.00**	**10.00**	**1.00**	**71.40**	**43.80**	**100.00**

TABLE 2.
CFRBM Input Data for Modeling Scenarios

Note: all values in mgd.

Month	Cary/Apex Withdrawal	Cary/Apex Discharge	Cary/Apex WTP discharge	Chatham County Withdrawal	OWASA Withdrawal	Orange Co. Withdrawal	DWR Withdrawal	DWR Return	Total Jordan Lake Withdrawal
Alternatives 1B and 2									
Jan	25.31	12.76	1.27	5.67	9.44	0.94	53.08	36.37	94.44
Feb	25.43	20.40	1.27	5.69	9.49	0.95	53.34	58.13	94.91
Mar	26.93	13.99	1.32	6.03	10.05	1.00	56.47	39.88	100.49
Apr	27.01	13.07	1.35	6.05	10.08	1.01	56.63	37.25	100.77
May	26.13	13.07	1.30	5.85	9.75	0.98	54.80	37.25	97.51
Jun	30.32	10.97	1.92	6.79	11.31	1.13	63.59	31.26	113.14
Jul	29.80	11.58	2.74	6.67	11.12	1.11	62.49	33.01	111.19
Aug	28.88	8.20	1.65	6.46	10.77	1.08	60.55	23.37	107.75
Sep	29.08	10.35	1.47	6.51	10.85	1.08	60.97	29.51	108.49
Oct	29.20	13.07	1.45	6.54	10.90	1.09	61.23	37.25	108.96
Nov	20.65	12.76	1.37	4.62	7.70	0.77	43.30	36.37	77.04
Dec	22.87	12.20	1.25	5.12	8.53	0.85	47.95	34.76	85.32
Annual Average	**26.80**	**12.70**	**1.53**	**6.00**	**10.00**	**1.00**	**56.20**	**36.20**	**100.00**

TABLE 2.
CFRBM Input Data for Modeling Scenarios

Note: all values in mgd.

Month	Cary/Apex Withdrawal	Cary/Apex Discharge	Cary/Apex WTP discharge	Chatham County Withdrawal	OWASA Withdrawal	Orange Co. Withdrawal	DWR Withdrawal	DWR Return	Total Jordan Lake Withdrawal
Alternative 3									
Jan	30.98	17.68	1.27	5.67	9.44	0.94	47.41	33.36	94.44
Feb	31.13	28.26	1.27	5.69	9.49	0.95	47.64	53.32	94.91
Mar	32.96	19.39	1.32	6.03	10.05	1.00	50.45	36.57	100.49
Apr	33.05	18.11	1.35	6.05	10.08	1.01	50.59	34.16	100.77
May	31.98	18.11	1.30	5.85	9.75	0.98	48.95	34.16	97.51
Jun	37.11	15.20	1.92	6.79	11.31	1.13	56.80	28.67	113.14
Jul	36.47	16.05	2.74	6.67	11.12	1.11	55.82	30.28	111.19
Aug	35.34	11.36	1.65	6.46	10.77	1.08	54.09	21.43	107.75
Sep	35.58	14.35	1.47	6.51	10.85	1.08	54.46	27.06	108.49
Oct	35.74	18.11	1.45	6.54	10.90	1.09	54.70	34.16	108.96
Nov	25.27	17.68	1.37	4.62	7.70	0.77	38.67	33.36	77.04
Dec	27.99	16.90	1.25	5.12	8.53	0.85	42.83	31.88	85.32
Annual Average	**32.80**	**17.60**	**1.87**	**6.00**	**10.00**	**1.00**	**50.20**	**33.20**	**100.00**

TABLE 2.
CFRBM Input Data for Modeling Scenarios

Note: all values in mgd.

Month	Cary/Apex Withdrawal	Cary/Apex Discharge	Cary/Apex WTP discharge	Chatham County Withdrawal	OWASA Withdrawal	Orange Co. Withdrawal	DWR Withdrawal	DWR Return	Total Jordan Lake Withdrawal
Alternative 5									
Jan	30.98	0.00	1.27	5.67	9.44	0.94	47.41	33.36	94.44
Feb	31.13	0.00	1.27	5.69	9.49	0.95	47.64	53.32	94.91
Mar	32.96	0.00	1.32	6.03	10.05	1.00	50.45	36.57	100.49
Apr	33.05	0.00	1.35	6.05	10.08	1.01	50.59	34.16	100.77
May	31.98	0.00	1.30	5.85	9.75	0.98	48.95	34.16	97.51
Jun	37.11	0.00	1.92	6.79	11.31	1.13	56.80	28.67	113.14
Jul	36.47	0.00	2.74	6.67	11.12	1.11	55.82	30.28	111.19
Aug	35.34	0.00	1.65	6.46	10.77	1.08	54.09	21.43	107.75
Sep	35.58	0.00	1.47	6.51	10.85	1.08	54.46	27.06	108.49
Oct	35.74	0.00	1.45	6.54	10.90	1.09	54.70	34.16	108.96
Nov	25.27	0.00	1.37	4.62	7.70	0.77	38.67	33.36	77.04
Dec	27.99	0.00	1.25	5.12	8.53	0.85	42.83	31.88	85.32
Annual Average	**32.80**	**0.00**	**1.87**	**6.00**	**10.00**	**1.00**	**50.20**	**33.20**	**100.00**