C-51 RESERVOIR – PRELIMINARY DESIGN AND COST ESTIMATE –

FINAL REPORT

Prepared By:
Lake Worth Drainage District
Palm Beach County
Broward County
South Florida Water Management District

February 2013

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Lake Worth Drainage District (LWDD) has spearheaded the effort to determine the feasibility of constructing a C-51 Reservoir for the past several years. Palm Beach and Broward Counties and the South Florida Water Management District (SFWMD) have supported ongoing efforts to study the potential design, costs and benefits of the project. This report is the result of efforts by many participants. Staff of the Hydrologic and Environmental Systems Modeling Section of SFWMD, complied information obtained from previous reports and recent studies by their staff, with additional documentation provided by LWDD, Broward County and Palm Beach County. Staff from Broward County and Lake Worth Drainage District Staff analyzed and summarized the water quality data. Staff and consultants from Palm Beach Aggregates, Inc.., Burns & McDonnell Engineering Company, Inc., Lake Worth Drainage District, Broward County and SFWMD provided cost analyses and descriptions, and design data for infrastructure components.

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Acronyms and Abbreviations

Ac-ft or ac-ft	acre-feet (unit of volume measurement)
ASR	Aquifer Storage and Retrieval
BEBR	Bureau of Economic and Business Research (University of Florida)
CERP	Comprehensive Everglades Restoration Program
B&M	Burns and McDonnell
BOD	biological oxygen demand
B.O.R. or BOR	Basis of Review
cfs	cubic feet per second
Chl-*a*	Chlorophyll-*a*
CS	Control structure
CUP	Consumptive Use Permit –issued by SFWMD
FDCA	Florida Department of Community Affairs
FDEP	Florida Department of Environmental Protection
DO	Dissolved oxygen
DOI or USDOI	United States Department of Interior
EAA	Everglades Agricultural Area
EPA or USEPA	United States Environmental Protection Agency
et or ET	evapotranspiration
FKAA	Florida Keys Aqueduct Authority
ft	feet
gpd/gpm	gallons per day/gallons per minute
ha	hectares
HEC-HMS	Hydrologic Engineering Center - Hydrologic Modeling System
HEC-RAS	Hydrologic Engineering Center - River Analysis System – model used for detailed analysis of surface water flows
l	liter
LEC	Lower East Coast – Area within SFWMD that includes coastal portions of Dade, Broward, Palm Beach and Monroe Counties located east of WCAs and Everglades National Park
LECSA	Lower East Coast Service Area The LEC is divided into three service areas (1, 2 or 3) based on which WCA provides surface water flow to canals in the area.
LNWR or ARM-LNWR	Arthur R Marshall Loxahatchee National Wildlife Refuge
LWDD	Lake Worth Drainage District
mgd or MGD	million gallons per day
mg	milligrams – 1 mg/l = 1 ppm
µg	micrograms - 1 µg/l = 1 ppb
MODFLOW	Modular Groundwater Flow model developed by United States Geological Survey
msl	mean sea level
N	nitrogen
NBCRS	Northern Broward County Recharge System
NGVD	National Geodetic Vertical Datum (national reference standard for elevation data)
NNR	North New River
NPBC Plan	Northern Palm Beach County Plan – a component of CERP
NSID	North Springs Improvement District
O&M	Operations and Maintenance
OPCC	Engineer's Opinion of Probable Construction Cost
P	phosphorus

PBA	Palm Beach Aggregates
PBC	Palm Beach County
PBCWUD	Palm Beach County Water Utilities Department
PDCER	Preliminary Design and Cost Estimate Report (this report)
ppb	parts per billion
ppm	parts per million
RSM	Regional Simulation Model
RWAR	Regional Water Availability Rule (SFWMD Basis of Review 3.2.1.E)
SFWMD	South Florida Water Management District
SFWMM	South Florida Water Management Model – general model used to analyze water movements within the regional canal system
sPBC51	South Palm Beach C-51 (Groundwater Model)
STA	Stormwater Treatment Area
TAZ	Traffic Analysis Zones
TMDL	Total Maximum Daily Loads
TN	Total nitrogen
TP	total phosphorus
USACE	United States Army Corps of Engineers
WCA	Water Conservation Area
yr	year

Units of Measure and Conversions

Area

acres	**square feet**	**square miles**	**square meters**	**hectares**
1	43,560	.00156	4046.9	.0404

Volume

million gallons	**cubic feet**	**acre feet**	**cubic meters**
1	133,681	3.0689	3,785

Flow

million gallons/ day	**gallons/ minute**	**cubic feet / second**	**acre-feet/ year**	**cubic meters/ second**	**cubic meters/ year**
1	694.4	1.55	1120.14	.04389	4,239,730

Executive Summary

In October 2010, the South Florida Water Management District (SFWMD) Governing Board discussed the potential for a multi-purpose C-51 reservoir to benefit public water supply. A key concern was to determine future water availability from the C-51 canal, and whether sufficient water could be captured and delivered to meet future demands. A second concern was whether construction of the reservoir could serve as an effective regional alternative water supply source for public water supply, thereby offsetting the need for utilities to develop other more costly local water supply alternatives. Other concerns were identified regarding the ability to obtain permits for the reservoir and how use of water from the reservoir would affect permits issued to local utilities.

This study primarily addresses preliminary technical issues associated with planning, design and operation of the reservoir, providing water to the reservoir, and distributing water from the reservoir to maintain local surface water management systems and provide recharge to the surficial aquifer system and utility wellfields. Initial cost estimates for facility construction, operation and maintenance are also provided. Issues not addressed in this report include detailed studies and modeling necessary to obtain individual permits for the reservoir, new structures and pump stations, and local utility wellfields. Other issues not addressed include financing and governance of the new infrastructure.

The study area included the Lake Worth Drainage District (LWDD) in Palm Beach County, from the C-51 canal south and east of Water Conservation Area 1, and Coastal Broward County, east of Water Conservation Areas 2 and 3.

A number of more detailed technical issues requiring additional study were subsequently identified and are addressed in this report. These include determination of how much water needs to be delivered from the C-51 reservoir to meet future utility water demands and whether sufficient water can be captured from the C-51 canal basin. Details of how to capture, store and redistribute the water; seepage into and out of the canals; aquifer recharge and potential effects of water withdrawals on groundwater levels; costs and facilities associated with various distribution options; and water quality issues were also addressed. In addition, this study also considered the potential availability of water from an additional proposed storage and treatment facility (the Lake Point reservoir) located in southwestern Martin County. Some issues associated with obtaining permits were considered, but more detailed analyses need to be conducted in a regulatory context by individual permit applicants.

System Components

The proposed C-51 reservoir would be located just north of West Palm Beach canal, immediately west of the existing L-8 reservoir, and have a storage capacity of 75,000 acre-feet. Structures, pumps and canals would be constructed to deliver water to and from the reservoir. The source of water is the C-51 canal basin. The amount of water available to the reservoir would be increased by placing a pump station near the intersection of Southern Boulevard and US 441 to pump water from the eastern C-51 canal basin back into the western basin. Water would be pumped into the reservoir during wet periods and released from the reservoir back into C-51 canal during dry periods.

During dry periods, water from C-51 canal would be pumped and/or flow by gravity south through canals of the LWDD to maintain local canal water levels and provide recharge to groundwater and wellfields in southern Palm Beach County. An additional amount of water would be routed south through major canals of LWDD to the Hillsboro canal in northern Broward County. The Broward County water management system would then be used to redistribute this water to local canals and drainage districts. Water would continue flowing south to regional canals C-14, C-11 and C-9. From the C-9 canal,

it may also be possible to provide water to wellfields in Miami-Dade County. This option has not yet been considered in detail.

Future Population and Water Use Projections

Existing water demands for areas in Palm Beach and Broward counties that would potentially be served by this project were determined based on current (2010) population. 2010 population in southeastern Palm Beach County was approximately 1.16 million and in eastern Broward County was 1.65 million.

Current water use was determined from pumpage records and existing permits. In Palm Beach County, utilities pumped 197 mgd in 2010. Existing permits (some of which extend to 2030) allow for pumpages of 259 mgd. In eastern Broward County, 216 mgd was pumped in 2010 and existing permits allow pumpages up to 276 mgd.

Future water demands for the year 2060 were determine by two primary methods. For the first method (Option 1), letters were sent to all utilities in both counties requesting them to estimate future water demands. Of these utilities, only 10 responded with estimates of increased future demands. The Option 1 demands were developed based on amounts of water available from existing permits (some of which extend to 2030) and the estimated amounts of additional water demand provided by the utilities. For Palm Beach County, the estimated 2060 pumpage was 286 mgd, whereas for Broward County the estimated future pumpage was 324 mgd. This was considered to be a lower boundary (conservative) estimate of future water requirements.

A second method was employed by projecting populations out to 2060 based on the University of Florida's Bureau of Economic Business Report, (Smith and Rayer, 2011) as a starting point. The “high” ranges of these population projections (which extended to 2040) were analyzed further to estimate populations for individual utility service areas. The estimated future (2060) population for Palm Beach County was 2.34 million, whereas the estimated population for Broward County was 2.72 million. These future populations were multiplied by current (2010) per capita water use data for each utility to calculate the future water demand. The values provided by this method (402 mgd for southeastern Palm Beach County and 365 mgd for eastern Broward County) are considered to be an upper limit of potential future water demands. Future water use is likely to fall between the values used for Option 1 and Option 2.

Modeling Approach

Regional/subregional modeling

SFWMD’s premier regional-scale hydrologic simulation model, the South Florida Water Management Model (SFWMM), was used to analyze overall hydrologic conditions in the primary canal system and interaction with other regional facilities. Surface and groundwater hydrologic issues associated with the study were analyzed with two models. The U.S. Army Corps of Engineers’ HEC-RAS Model was applied to address local surface water conveyance capabilities in the C-51 basin. The popular groundwater model developed by US Geological Survey, MODFLOW, was customized to analyze groundwater movement and seepage in southern Palm Beach County.

Regional modeling

A water availability analysis for this project was conducted using the regional SFWMM. This model simulates water movement in the primary regional canals and is used to evaluate the ability to deliver water to and from the reservoir and to the downstream regional canal system. Results of this modeling indicate the amount of water available for storage in the reservoir, effects of the reservoir on downstream discharges to Lake Worth Lagoon, how much water could potentially be distributed from the reservoir to downstream canals, and how this additional water would affect regional surface water

and groundwater levels. This model was also used to evaluate how much water could potentially be captured and distributed from the Lake Point reservoir in Martin County.

Results of regional modeling studies indicated that sufficient water can likely be captured in the reservoir and redistributed to meet water demands in Palm Beach and Broward counties. The higher demands used for the Option 2 scenario result in much more efficient operation of the reservoir, since more space is available to capture runoff. For Option 1, an average flow of 25 mgd is provided to the reservoir, with a range from 4 mgd (10^{th} percentile) to 52 mgd (90^{th} percentile) whereas for Option 2, the average flow is 67 mgd, with a range from 35 to 101 mgd. The amount of water discharged into the reservoir reduces the amount of water released into Lake Worth Lagoon by a corresponding amount, providing benefits to the estuary.

The reservoir could provide up to 170 mgd of flow, on average, during the dry season, During extreme drought conditions for Option 1, this was likely sufficient to meet most demands within the study area. For Option 2, less water (160 mgd) was available from the reservoir because the reservoir was not full at the beginning of the drought period.

Water delivered from the reservoir could significantly reduce the amount of water that would be needed from the regional system during droughts. However, during extreme droughts, the amount of water available in the reservoir alone may be insufficient to meet the amount of water supply necessary to maintain regional canals. This shortage during extreme years is not deemed to be a major concern since water shortage policies will require wellfield pumpage cutbacks lessening the demand and any additional water may be made available from the regional system.

The Lake Point reservoir could potentially provide a significant amount of additional water. Furthermore, water may be available from this reservoir during dry periods when water is not available from other sources. The exact amount of water available and the timing of potential deliveries is uncertain at this time, and depends on the outcome of the L-8 reservoir studies, water supply plans for northern Palm Beach County, and Loxahatchee River Restoration Plan. Modeling studies indicate that from 18,000 to 30,000 acre-feet of additional water may be available from this source.

Because of its scale and large (2 mile x 2 mile) grid size, the regional model does not provide a detailed picture of how much water is captured and distributed and how localized areas within the subregion are likely to be affected. To address these concerns, two additional smaller scale models were applied.

Seepage flows and groundwater levels in LWDD (MODFLOW groundwater modeling)

A MODFLOW groundwater model for the southern Palm Beach County area was developed and used to answer several detailed questions concerning local conditions and impact. A primary effort was made to determine how much seepage was likely to occur from LWDD canals as these canals were used to transfer water to Broward County. A second issue of concern was how much impact on surface and groundwater levels was likely to occur due to increased water withdrawals for the Option 1 and Option 2 scenarios, relative to current conditions.

Results indicated that the seepage rate from the canals is directly related to the water levels in the canals, i.e. whether canal water levels are kept at their “maintenance levels” or whether they are kept at their historical average seasonal water levels, which are somewhat lower than the “maintenance levels.” If canals are maintained at their historical levels, then the increase in the amount if water lost to seepage is about equal to the increased pumpages at the wellfields.

Seepage rates increased with increasing water withdrawals, especially during the dry season. Dry season seepage rates ranged from 143 mgd for the 2010 withdrawal conditions to 188 mgd for Option 2. When the increases in seepage rates were compared to increases in pumpages, the values were very

similar. For Option 1, an increase in pumpage of 29 mgd resulted in increased seepage of 25 mgd. For Option 2, increased pumpage of 92 mgd resulted in increased seepage of 92 mgd.

The MODFLOW model was also used to simulate effects of water withdrawals on local groundwater conditions. This analysis indicated that even with the additional water provided by the reservoir, significant local impacts could potentially occur during extended drought conditions. More detailed analysis of the localized effects of withdrawals from individual wellfields, conducted as part of the regulatory process, will be required to further define these issues.

Conveyance Analyses (HEC-RAS C-51 basin surface water modeling)

A more detailed surface water routing model was developed for the C-51 basin to analyze how much water was available from the eastern and western basins, how much of this water could effectively be stored in the reservoir, and the extent to which water transferred from the eastern C-51 basin to the reservoir would reduce the amount of water discharged into Lake Worth Lagoon. Results of this analysis indicated that the reservoir system was capable of capturing between 50 and 60% of available water during below average, average and above average rainfall conditions, resulting in a corresponding reduction of flow into Lake Worth Lagoon. However, during extremely wet conditions (such as occurred during Hurricane Irene in 1999) only about 18% of available water could be captured, due to limitations on the capacity of the pumps at S-155A and the amount of storage available in the reservoir.

Based on results of the above modeling studies, it was determined that the reservoir provides an effective means to capture, store and later release surface water from the C-51 basin. Studies indicate that water captured during wet periods is sufficient to meet the increased demands identified in the Option 1 and Option 2 scenarios.

Infrastructure Improvements needed to Convey Reservoir Water to Palm Beach and Broward Counties

Staff from the LWDD and Broward County examined various options for moving water from C-51 canal south through local drainage canals to provide connections to other regional canals and to provide recharge for local wellfields.

Conveyance through LWDD

LWDD identified several potential routes that could be used to distribute water from C-51 canal south to recharge local wellfields in southern Palm Beach County and deliver water to Broward County. Existing canals and facilities presently have capacity to route additional water during the dry season to the eastern portions of Palm Beach County. The major improvements would be needed in the western portion of the LWDD to provide a direct route from C-51 to the Hillsboro canal. LWDD analyzed infrastructure improvements needed and their costs to deliver water to Broward County through the E-1 canal. Several control structures and pumps need to be added and existing facilities improved to reliably provide 225 cfs (145 mgd) of additional flow from C-51 canal to the Hillsboro canal.

Conveyance through Broward County

In similar fashion, Broward County analyzed a number of potential routes that could be used to deliver water throughout the eastern areas of the county and routes to deliver water south to the C-9 canal in the event that Miami-Dade County should later desire to participate in this project. The county identified a number of existing facilities that would require improvement. In addition, facilities of several local drainage districts within the county would be involved. These facilities may also have to be modified. Formal legal agreements need to be developed to ensure that facilities are properly maintained and operated to ensure effective routing and storage of surface water and maintenance of appropriate groundwater levels during dry periods.

In addition to changes to local infrastructure, Broward County identified options that could involve routing water through SFWMD canals and structures. Several possibilities have been examined and District staff are developing preliminary costs associated with these options.

Water Quality Considerations

General water quality conditions were characterized in LWDD and more detailed analysis of water quality conditions was provided for Broward County. A primary difference between these two areas is the amount of data available and the degree to which these data have been analyzed. Broward County has conducted extensive and intensive field studies of water quality in its major canals for the past 30 years and published periodic reports assessing status and trends.

By contrast, canals within LWDD have been sampled periodically and a few intensive studies have been undertaken, but the data, for the most part, have not been systematically compiled and analyzed. The most systematic data set for the area was compiled by Florida Department of Environmental Protection (FDEP) as part of statewide water quality assessments to identify impaired waters.

The general trend shown by the available data indicates that water in Broward County canals has generally low levels of phosphorus and nitrogen and levels of oxygen, suspended solids, coliform bacteria and other parameters that do not violate state standards for Class III waters (fish and wildlife propagation). A number of areas within LWDD have been listed by FDEP as impaired due to low oxygen concentrations, high coliform levels and/or elevated nutrient concentrations. This raises issues concerning the ability to transfer water from LWDD canals to Broward County canals without violating state or federal water quality standards and the potential need for alternative distribution routes, or additional treatment that may include retention within lakes and wetlands.

Cost Estimates

The total estimated capital cost for the system components analyzed so far (not including improvement to SFWMD/regional facilities in Broward County), as estimated by Burns and McDonnell, Inc., is $1,054 million for the reservoir and associated conveyance, in 2011 dollars. This initial estimate was further analyzed by Palm Beach Aggregates (PBA), LLC to better reflect construction work already completed and the value of rock mined from the excavation. PBA estimated a cost of $695 million for the reservoir.

Estimated costs for the S-155A pump station and other downstream water distribution system components obtained from other entities total $60.4 million, as follows:

S-155A Structure not including land	$25 million,	(from SFWMD)
LWDD improvements	$33.1 million	(from LWDD)
Broward County system(s)	$2.3 million	(Broward County)
Regional System improvements in Broward County	N/A	(SFWMD)

Based on these capital costs, assumed operations and maintenance costs of $2.4 million/year, and estimated usage of 185 mgd from the reservoir, the cost of water from the reservoir would be about $0.90/1000 gallons for the $755.4 million system cost and $1.24/1000 gallons for the $1,054 million cost. This compares to costs of $4.12 to $7.42/1000 gallons for groundwater recharge methods, and $2.83 to $4.01 for reverse osmosis technologies.

Although the examples are from systems of different sizes, producing different capacities of potable water and with different total capital costs, the capital cost in dollars per gallon of water capacity, the annual O&M cost in dollars per thousand gallons of water and the total cost per thousand gallons of water figures provide a rough comparison among the various options.

Conclusions and Recommendations

- The planning investigations documented in this report provide initial information necessary to assess the feasibility of the C-51 reservoir as a potential source of water for future regional public water supply needs of Palm Beach and Broward counties. The report and the modeling tools developed for this planning exercise may be used as the basis for future work on the C-51 reservoir to determine regulatory feasibility.
- SFWMD should facilitate meeting the permitting criteria necessary for developing water supply from the C-51 reservoir. Participating utilities should actively engage with SFWMD in discussions regarding the requirements of existing regulatory framework.
- Jointly with LWDD staff and the local water management agencies in Broward County, SFWMD should determine operational feasibility and a strategy for conveying water supply from the C-51 reservoir and its coordination with the current deliveries from the existing regional system. This effort should lead to the development of new facilities required to convey water which may be used for the detailed design phase of the project.
- If water from C-51 reservoir needs to be conveyed further south in Broward County and on to Miami-Dade, options to retrofit I-595 should be examined in a subsequent investigation.
- Analyses conducted for both Palm Beach and Broward counties have dealt primarily with conveying water from north to south. In order to provide effective recharge to coastal wellfields, improved capabilities must be provided to move water east, through existing canals or alternative conveyance means such as pipelines.
- SFWMD should reexamine wet season and dry season water levels maintained in coastal Broward County canals above the salinity structures, to determine if they are already at the maximum allowable levels or if there is opportunity to hold more freshwater in the upstream canals and coastal aquifer.
- More extensive water quality data are needed for LWDD. Part of this need may be addressed by systematically compiling and analyzing available historical data sets from other agencies and entities, including SFWMD, United States Geological Survey (USGS), FDEP, Palm Beach County and local municipalities. Due to potential water quality issues and concerns, implementation of a systematic monitoring program should be considered as a component of operation/ maintenance of the C-51 reservoir project to determine water quality at critical locations throughout the water capture, storage and distribution systems.
- Broward County and LWDD need to determine how best to resolve water quality issues that are an important consideration in the movement of water between the primary and secondary canal networks. Based on the total estimated capital cost for the system components analyzed so far, costs of obtaining water from the C-51 reservoir appear to be lower than costs of water from other commonly-used alternative water supply sources.

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Introduction

Background.

The C-51 canal is located in central Palm Beach County and drains a watershed of approximately 164 square miles. Major water management structures of this basin include the S-5A pump station at the western end, adjacent to WCA-1, and the S-155 structure on the eastern end that discharges excess surface water to Lake Worth Lagoon (Figure 1). An intermediate structure, S-155A, is located near the center of the basin, just west of State Road 441, and forms a divide between eastern and western sub-basins. A more detailed description of the basin can be found in Cooper and Lane (1988).

It has long been recognized that this basin contains a significant amount of "excess" stormwater that is discharged to Lake Worth Lagoon. Discharge rates above 500 cfs through S-155 result in low salinity conditions and transport of sediments and suspended solids that impact the lagoon (Palm Beach County, 2008). Several projects to capture this water for beneficial use have been proposed in the past. These initial concepts were never fully implemented, primarily because facilities to store the water were not considered feasible, and because of water quality concerns associated with discharging urban runoff water into natural systems of the Everglades (SFWMD, 1982).

The Everglades Construction Project, initiated in 1994, included components to construct stormwater treatment areas (STA1E and STA1W) that can receive runoff from the C-51 basin and provide treatment of this water prior to discharge to WCA-1. These facilities provide some degree of flood protection capacity to the C-51 basin and benefits to the Lake Worth Lagoon, but were primarily intended to treat agricultural runoff from the Everglades Agricultural Area (EAA) and enhance water supply to the Everglades.

The Central and Southern Florida Project Comprehensive Review Study (USACE and SFWMD, 1999), also known as the "Yellow Book," proposed a series of Aquifer Storage and Recovery (ASR) wells with a capacity of 170 million gallons per day (mgd) along the C-51 canal. The purpose of this concept was to capture and store excess flows from the C-51 canal for later beneficial use during dry times.

Storing water from the C-51 canal in a reservoir and/or ASR wells was also investigated as a component of the Comprehensive Everglades Restoration Plan (CERP). The North Palm Beach County CERP Project, Part 1 (NPBC Plan), and later the Loxahatchee River Restoration Plan also investigated this concept. These planning studies ultimately favored construction of the L-8 reservoir and delayed further consideration of a C-51 reservoir or ASR wells (USACE and SFWMD 2005).

Recent Efforts

In 2006, six south Florida water utilities (Fort Lauderdale, Plantation, Sunrise, Hollywood, Pompano, Broward County and Palm Beach County) elected to investigate the possibility of a collaborative, sub-regional, multi-jurisdictional approach to develop additional water supply. In December 2006, these utilities, through the City of Fort Lauderdale, retained consultants to conduct a conceptual feasibility

analysis of a C-51 reservoir. This reservoir would store wet season storm water from the C-51 canal and later release this water back to the canal system to recharge surficial aquifers in Palm Beach and Broward counties and possibly for other users. Results of the initial feasibility analysis were compiled into a Conceptual Feasibility Study report (Hazen and Sawyer and MacVicar, Federico and Lamb, 2009). The study concluded that capturing storm water previously lost to tide (via the Lake Worth Lagoon) had potential environmental and water supply benefits.

The Conceptual Feasibility Study suggested that the reservoir should be located to facilitate access to the regional canal system via the C-51 canal. A potential site was therefore chosen, located just north of C-51 canal and west of the L-8 reservoir, where a mining pit is presently under construction. The C-51 reservoir would add 48,000 acre-feet of storage to the regional water management system that could be used to store excess storm water from the C-51 canal and reduce the discharge of water to tide through the S-155 coastal structure. Water released from the reservoir during the dry season could be used to help meet water supply demands for consumptive use. Distribution of this water may allow water utilities (and others) in these counties to withdraw additional water from the surficial aquifer, in accordance with existing impact criteria. The study concluded that if the reservoir performs adequately, and studies undertaken as part of the permit process support its efficacy, the reservoir may provide sufficient water to function as a cost-effective alternative water supply source.

Additional Studies

Following the completion of the Hazen and Sawyer and MacVicar, Federico and Lamb (2009) study, some additional work (Phase 2A) was undertaken to address five key issues as follows.

- Update the raw water demand projections of water utilities;
- Describe a proposed process to address compliance with The Lower East Coast (LEC) Regional Water Availability Rule: B.O.R. 3.2.1. (E)
- Evaluate two direct conveyance alternatives: (1) through the Lake Worth Drainage District (LWDD) and (2) through the LWDD and the Everglades Agricultural Area (EAA);
- Describe the geologic and hydrologic conditions at the potential C-51 reservoir site; and
- Prepare an updated C-51 reservoir cost estimate, estimate the costs of the two conveyance alternatives, and provide a cost-effectiveness sensitivity analysis.

Results of this investigation were published in a second report by Hazen and Sawyer and MacVicar, Federico and Lamb (2010) and therein provided additional support to continue the reservoir project. An additional study (Powell Kugler, Inc., 2010) provided conceptual design features for an enlarged reservoir with a capacity of 73,000 ac-ft.

Current Investigation

In October 2010, the SFWMD Governing Board discussed the potential for a multi-purpose reservoir along C-51 canal to provide benefits to Everglades restoration in addition to public water supply. Restoration benefits will primarily derive from attenuating peak flows into the STAs, thereby improving their removal of phosphorus, and reducing the amount of freshwater released to tide in Lake Worth Lagoon, where excessive discharges of fresh water have adverse impacts on sea grasses, oysters and fisheries.

A number of key technical issues are covered in this study:

- Routing and timing of water deliveries to and releases from the reservoir;
- Water availability from the eastern C-51 basin;
- Effects of diverting water to the reservoir on the amount of water discharged to tide;
- The practicality and effects of delivering water into the LWDD as a means to recharge the aquifer and increase production in local utility wellfields;
- Canal conveyance and seepage issues that might affect water delivery through LWDD to the Broward County secondary canal system and other potential users;
- The potential to reduce the amount of water required from the regional system per existing criteria, and thus reduce the need for alternative water supply projects;
- Water quality issues associated with distribution of water from the reservoir;
- Improved estimates of costs associated with reservoir construction, infrastructure improvements, operation and maintenance; and
- Potential availability of water from an additional proposed storage and treatment facility (Lake Point reservoir) located in southwestern Martin County.

A stakeholder group was established to provide consultation and guidance for the duration of this study. Because of ongoing efforts to advance Everglades restoration and due to lack of sufficient information on additional natural system needs, the use of the C-51 reservoir to enhance restoration could not be considered explicitly. The team decided to focus on use of the reservoir to meet future urban demands of the Lower East Coast region. This planning study therefore addresses the feasibility and benefits of the C-51 reservoir to meet future urban water demands, potential conveyance constraints associated with the movement of water to and from the reservoir, and preliminary costs for the infrastructure that may be needed to meet the objectives of the reservoir. Further work will be needed to address the regulatory requirements of using C-51 reservoir as a source for permitting future demands and to develop detailed design plans for implementation of the plan features. The tools developed in this study should be useful in both the regulatory framework and detailed design phase.

Key Project Features

The proposed 75,000 ac-ft capacity C-51 reservoir is located just north of Water Conservation Area 1 (WCA-1) and west of the existing L-8 reservoir in central Palm Beach County. It is evaluated as an alternative water supply development project to meet future demands in the Lower East Coast region. The reservoir would be managed as a source of water supply to maintain the canals and aquifers in the Lower East Coast Service Areas (LECSA) 1 & 2 (**Figure 1**). The major source of water for the reservoir is excess water from the C-51- canal basin, which is currently discharging large quantities of flood waters to the Lake Worth Lagoon via the S-155 water control structure. This water is to be conveyed west to the C-51 reservoir when possible, but mostly during the wet season. During the dry season, water will be released from the reservoir and routed through the canals to maintain water levels in selected areas of Palm Beach and Broward counties and to other potential users. The canals recharge the groundwater in the surficial aquifer system, which is a source of water for wellfields that supply local water utilities. In

addition, the amount of water that could potentially be available from a proposed Lake Point reservoir, located in southwestern Martin County (**Figure 1**) is also identified.

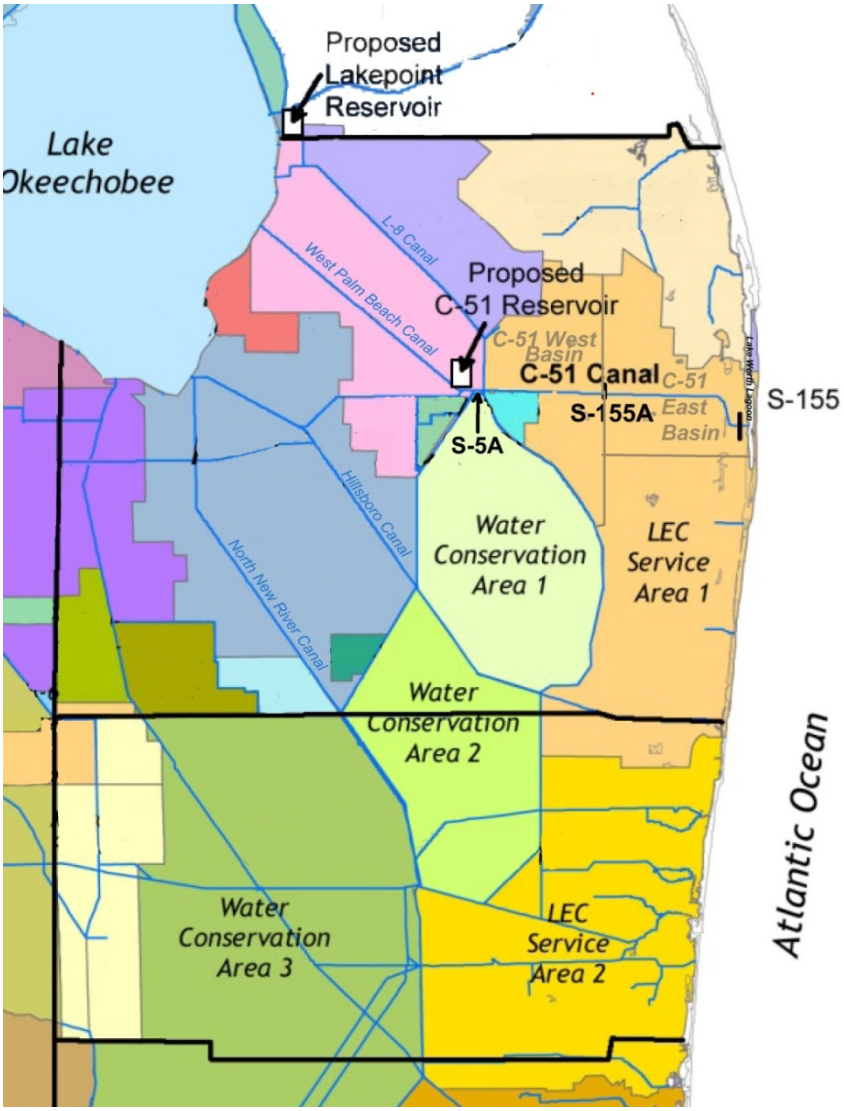

Figure 1. Major basins within the Lower East Coast subregion of the South Florida Water Management District (SFWMD) showing proposed reservoir locations and existing service areas that receive water from the Water Conservation Areas through the regional canal system.

The availability of the C-51 reservoir as a source of water for maintenance of canal water levels and aquifer recharge in the LEC and for other potential users may help avoid increased demands on the regional system storage (Water Conservation Areas and Lake Okeechobee) to meet future water utility demands. Avoiding future increases in regional deliveries to meet water utility demands may potentially benefit restoration of the Everglades, help utilities to satisfy the Regional Water Availability Rule (SFWMD Basis of Review 3.2.1.E), provide more cost-effective alternative water supplies, and reduce the frequency and/or magnitude of future water shortage events. This analysis was limited to the use of C-51 reservoir to meet utility demands -- no other demands were considered. Estimated costs of the C-51 reservoir and infrastructure needed to convey water are addressed at the end of this report.

Projected Water Demands

The purpose of this analysis was to assess the feasibility of using the C-51 reservoir to meet future demands of water supply utilities in Palm Beach and Broward counties. Emphasis was placed on public water supply utilities and their associated demands in areas that would potentially receive water from the C-51 reservoir. One set of future potential demands was provided by the participating utilities in the stakeholder group. A second set of future demands covering all the utilities within the two service areas was estimated based on projected population growth within the service areas of the utilities, and assumptions regarding per capita water consumption based on historical usage. The two demands sets are considered to provide a reasonable range of future demand that is suitable for investigating the feasibility of the C-51 reservoir.

Existing and Future Population

2010 Population Served by Individual Utilities

Projecting the Lower East Coast population began with an update of the public water supply entities within the planning region that meet the threshold of greater than 0.10 mgd. The 2010 public water supply service areas, by utility, were verified through complementary sources of information such as the 2005-2006 LEC Water Supply Plan update, recently renewed consumptive use permits, 10-year Water Supply Facility Work Plans as elements to comprehensive plan amendments, the Traffic Analysis Zones (TAZ) files, and final verification with the utilities.

The service area for each utility was first verified based on permit data, local plans, etc. Service areas were then linked to corresponding Traffic Analysis Zones and then to census data. Apportioning the 2010 Census populations into service area geographic datasets was completed by using the Census Block Data as the basic unit of analysis. The geographic areas represented by the Census Blocks and utility-served areas were both input as polygon layers into a Geographic Information System (GIS). The two layers were overlaid to determine if Census Blocks were either inside or outside the area served by each utility. Aerial and/or satellite imagery was used to review decisions when needed. The populations by Census Block, for each public water supply utility and for domestic self-supplied users, were calculated. The populations for each utility-served area and remaining self-supplied were then totaled to match to the county-wide total of the 2010 Census. Projections for Palm Beach County were provided directly by the county planning department using a similar method of analysis. The differences were assumed to be negligible.

Projecting Future Population

1. The projections of the 2040 populations were based on the county-wide forecast obtained from a recent report by Smith and Rayer (2011). These data were further analyzed to obtain population projections for utility service areas (see above). Results of these analyses by county are shown in **Table 1**.
2. For the 2050 and 2060 population projections, the following method was used to ensure some consistency in trends for the different counties:

Table 1. Current (2010) and projected future populations of Palm Beach and Broward counties within the Lower East Coast service sreas.

County	Census	Projected Populations			Projection Percentage Increases Estimated for 2020-2060				
	April 1, 2010	2020	2030	2040	2020	2030	2040	*2050**	*2060**
PALM BEACH	1,320,134								
Low		1,367,700	1,389,700	1,370,900	3.6%	1.6%	-1.4%	***0.0%***	***0.0%***
Medium		1,482,900	1,648,000	1,786,000	12.3%	11.1%	8.4%	***5.5%***	***5.0%***
High		1,605,600	1,919,200	2,236,700	21.6%	19.5%	16.5%	***13.6%***	***10.6%***
BROWARD	1,748,066								
Low		1,726,300	1,689,000	1,632,900	-1.2%	-2.2%	-3.3%	***-3.3%***	***-3.3%***
Medium		1,834,500	1,916,200	1,982,500	4.9%	4.5%	3.5%	***3.5%***	***3.5%***
High		1,946,700	2,149,600	2,349,700	11.4%	10.4%	9.3%	***9.0%***	***9.0%***

Note: Projections through 2040 were based on data obtained from Smith and Rayer, 2011.
*2050 and 2060 projections were estimated based on assuming the future growth trends (% change) would be similar to trends shown in prior decades

- For Broward County, census block populations compiled by utility service areas for the base year of 2010 (see above) were multiplied by percentage growth rates, derived from projected population increase rates used by Smith and Rayer (2011) for years 2020, 2030 and 2040. The trends of these rates were extrapolated to estimate populations for successive ten year periods. The percentage change values derived by this process are shown in **Table 1**.
- For Palm Beach County, the county planner's estimates for each utility were used for the base year of 2010 and then the projections of percentage growth rates (Smith and Rayer, 2011) were applied over each ten year period. The Palm Beach County Water Utilities Department was used as the control for the county totals.
- These steps were repeated for each level of population projections: low, medium, and high.
- An exception was allowed for the Town of Davie. The 2011 county projections could not have forecasted the approved amendments that would triple the town's population. Since these amendments were approved by Florida Department of Community Affairs (FDCA) and are approved in the recent Consumptive Use permit renewal, the populations were adjusted accordingly, adding about 3% to the 2010 census medium numbers overall.

Population projections for years beyond 2040 are considered as rough estimates. Future population projections may change considerably based on improved judgment decisions and realized growth.

Water Supply Demands

Current Demands

Existing water demands within the service areas were determined from existing (2010) SFWMD water use permit data. Some of these permits included water resource development during the duration of the permit (up to 20 years). Actual 2010 pumpages are shown as "current demands" in **Figure 2**. Further withdrawals allowed by existing permits are represented by the "2030 permitted" arrow in **Figure2**.

Future Water Demands

To estimate further increases in water demands through the year 2060, two options were used. First, through the participants in the stakeholder group, all water utilities were asked to provide estimates of increased water demands, beyond the amount presently available from 2010 permits, to meet expected water demands through 2060. This additional "unmet water demand" is represented by the dashed arrow labeled "stakeholder projections" (**Figure 2**). A second estimate was developed to reflect an expected upper bound for future water demand. This Option 2 "high demand" estimate was based on projected "high" rates of future population growth (Smith and Rayer, 2011) within utility service areas.

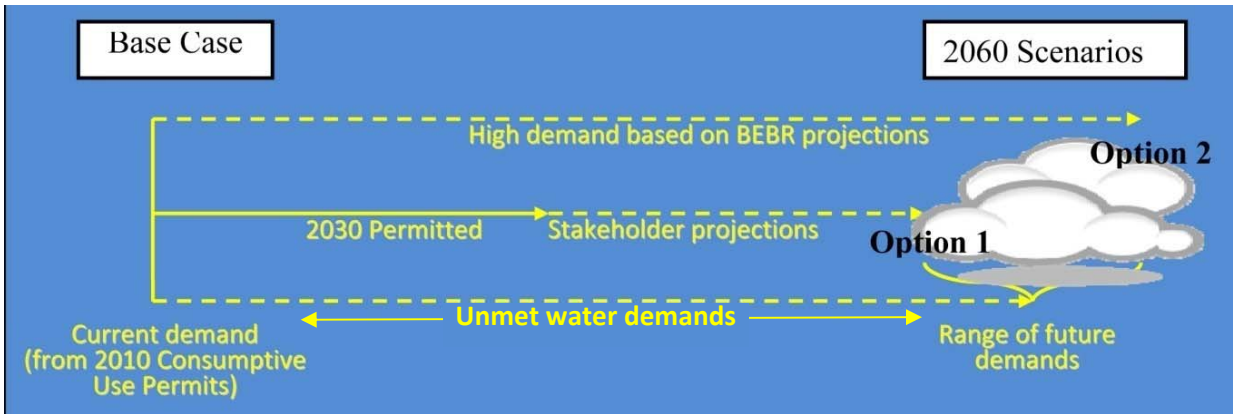

Figure 2. Conceptual representations of water demands used for C-51 reservoir study.

Table 2 summarizes existing and future pumpage quantities used in the analysis for each utility. The third and fourth columns represent actual 2010 (2010 Act) and future (2010 Permit) pumpages defined by existing permits. Ten utilities furnished estimates of projected future demands. These estimates were added to the 2010 permitted pumpages to develop the Option 1, 2060 water demands and unmet needs (green shaded boxes in the fifth and sixth columns).. For utilities that did not provide estimates, the unmet demand was assumed to be zero. Option 1 is considered to represent a lower bound for this analysis as it represents a low to moderate increase in future water supply demand.

The projected unmet needs and demands for Option 2 are shown in the last two columns of **Table 2**. For Option 2, a uniform method was used to project future water demands (see details in **Table 3**). The actual 2010 pumpages for each utility were divided by the 2010 estimated populations for the utility service area to determine a 2010 *per capita* use rate. The future population numbers were calculated

Table 2. Summary of future pumpage values (mgd) used in model runs for Option 1 and Option 2 scenarios , compared to existing (permitted) pumpages .

Permit Number	Description	2010 Act Pumpage (mgd)	2010 Permit (mgd)	Option 1 (mgd)		Option 2 (mgd)	
				Unmet Need	2060 Demand	Unmet Need	2060 Demand
Service Area 1 (Palm Beach County)							
06-00082-W	Deerfield Beach, City of	9.2	11.9	0	11.9	2.9	14.8
06-00242-W	Parkland Utilities	0.2	0.4	0	0.4	0	0.4
06-00274-W	North Springs Imp. District	4.3	5.2	0	5.2	1.7	6.9
50-00036-W	Palm Springs Village	3.5	4.5	0	4.5	3.0	7.5
50-00135-W	Palm Beach County Utilities	59.0	87.0	24.5	111.5	28.1	115.1
50-00137-W	Tropical Breeze Estates	0	0	0	0	0	0
50-00177-W	Delray Beach, City of	19.3	19.1	1.7	20.8	22	41.1
50-00234-W	Lake Worth Utilities	4.8	5.3	0	5.3	4.8	10.1
50-00367-W	Boca Raton, City of	42.2	51.5	0.9	52.4	38.2	89.7
50-00444-W	Royal Palm Beach Utilities	2.4	3.0	0	3.0	2.0	5.0
50-00464-W	Wellington, Village of	6.7	7.0	0	7.0	7.4	14.3
50-00499-W	Boynton Beach	12.3	20.9	0	20.9	5.3	26.1
50-00506-W	Manalapan, Town of	1.3	0.6	0	0.6	2.2	2.8
50-00572-W	Lake Worth Village	0	0	0	0	0	0
50-00575-W	Lantana, Town of	1.7	2.5	0	2.5	1.1	3.6
50-00605-W	Lion Country Safari	0	0	0	0	0	0
50-00612-W	Golf, Village of	0.5	0.6	0	0.6	0.5	1.1
50-00615-W	West Palm Beach, City of	29.2	39.3	0	39.3	22.8	62.1
50-01092-W	A G Holley State Hospital	0.1	0.1	0	0.1	0	0.1
50-01283-W	Maralago Cay	0.2	0.3	0	0.3	0.1	0.4
50-03711-W	Seminole Improvement District	0.2	0.2	0	0.2	0.6	0.8
Service Area 1 Total Water Use	**LECSA 1 (MGD):**	**197.1**	**259.4**	**27.1**	**286.5**	**142.7**	**401.9**
	LECSA 1 (MGY):	**96,178**	**94,681**	**9,892**	**104,572**	**52,012**	**146,694**
Service Area 2 (Broward County)							
06-00001-W	Seminole Tribe	0.3	2.4	0	2.4	0	2.4
06-00003-W	Royal Utilities (University)	0.4	0.5	0	0.5	0.1	0.5
06-00004-W	North Lauderdale, City of	2.4	3.2	0	3.2	0.7	3.9
06-00038-W	Hollywood, City of	18.1	24.8	0	24.8	4.1	28.9
06-00054-W	Miramar, City of	12.5	13.3	0	13.3	6.6	19.9
06-00070-W[1]	Pompano Beach, City of	14.3	17.7	2.4	20.1	6,6	24.3
06-00071-W	Tamarac, City of	6.2	7.2	1.1	8.3	2.7	9.9
06-00100-W	Coral Springs Imp. District	4.3	5.4	0	5.4	1.5	6.9
06-00101-W	Hillsboro Beach, Town of	0.8	0.9	0	0.9	0.3	1.2
06-00102-W	Coral Springs, City of	6.1	9.4	0	9.4	0.3	9.8
06-00103-W	Plantation, City of	14.1	17.2	6.1	23.3	5.3	22.6
06-00120-W	Sunrise, City of	28.4	29.1	19.0	48.1	16.2	45.3
06-00121-W	Margate, City of	7.8	8.5	0	8.5	4.0	12.5
06-00123-W	Fort Lauderdale, City of	38.7	52.6	10.4	63.0	9.2	61.8
06-00129-W	Lauderhill, City of	5.8	8.7	0	8.7	2.5	11.2
06-00134-W	Davie, City of	4.0	5.0	0	5.0	14.0	19.0
06-00135-W	Pembroke Pines, City of	12.1	15.6	0	15.6	3.8	19.4
06-00138-W	Hallandale, City of	2.6	9.2	0.6	9.8	0	9.2
06-00146-W**	Broward County W.S.; Dist. 1**	7.6	10.2	4.1	14.3	2.0	12.2
06-00170-W	Tindall Hammock Cnsv. Dist.	0.7	0.7	0	0.7	0.4	1.1
06-00187-W	Dania, Town of*	1.0	1.1	0	1.1	0.5	1.6
06-00365-W	Cooper City, City of	3.5	4.6	0	4.6	1.0	5.5
06-01474-W	Broward County W.S; South	10.9	10.0	0	10.0	6.0	16.0
06-01634-W**	Broward County W.S.; Reg.**	13.4	17.5	5.2	22.7	3.8	21.3
Service Area 2 Total Water Use	**LECSA 2 (MGD):**	**216.3**	**276.5**	**46.5**	**323.0**	**88.9**	**365.4**
	LECSA 2 (MGY):	**101,397**	**100922**	**17,191**	**118,114**	**31,974**	**133590**
Combined Total Water Use for Both Service Areas							
	TOTAL (MGD):	**413.4**	**535.9**	**73.6**	**609.5**	**231.6**	**767.3**
	TOTAL (MGY):	**150,745**	**195,640**	**26,864**	**222,468**	**84,089**	**280,174**

Note: green shaded boxes include increases in Option 1 demands; pink shaded boxes include increases in Option 2 demands (see text)

* Dania's withdrawals are limited to 1.1 at its wellfield because of saltwater intrusion. Increases in this amount could only occur if a safe yield analysis is performed and approved. Otherwise, additional water would have to come from the Piccolo Wellfield.

** Broward County estimated an increase of 9.6 mgd, which was divided between these two permits

[1] Updated information differs slightly from values used in the modeling

Table 3. Data and calculations used to determine 2060 high water demands and unmet needs for the Option 2 scenario.

Permit Number	Utility/ Wellfield	1 2010 Census Population	2 2010 Act Pumpage (MGD)	3 2010 PCUR* (Cols 2/1)	4 2060 High Pop.** Projections	5 2060 High Demands (MGD) (Cols 3x4)	6 2010 Permitted (MGD)	7 2060 High Unmet Demands (Cols 5-6)
Palm Beach County (LECSA 1)								
06-00082-W	Deerfield Beach	51,842	9.2	178.43	82,796	14.8	11.9	2.9
06-00242-W	Parkland Utilities	2,161	0.2	101.80	3,451	0.4	0.4	0
06-00274-W	North Springs Imp. District	34,895	4.3	123.51	55,730	6.9	5.2	1.7
50-00036-W	Palm Springs	45,709	3.5	77.01	97,222	7.5	4.5	3.0
50-00135-W	PBCWUD	491,877	59.0	120.01	959,193	115.1	87	28.1
50-00177-W	Delray Beach	63,939	19.3	302.48	135,996	41.1	19.1	22
50-00234-W	Lake Worth	45,623	4.8	104.11	97,039	10.1	5.3	4.8
50-00367-W	Boca Raton	107,224	42.2	393.48	228,062	89.7	51.5	38.2
50-00444-W	PBC WUD WTP NO. 10 (RPB)	32,734	2.4	72.40	69,624	5.0	3.0	2.0
50-00464-W	Wellington	55,406	6.7	121.47	117,847	14.3	7.0	7.4
50-00499-W	Boynton Beach	103,291	12.3	118.89	219,697	26.1	20.9	5.3
50-00506-W	Manalapan	2,421	1.3	553.49	5,149	2.8	0.6	2.2
50-00575-W	Lantana	10,403	1.7	163.41	22,127	3.6	2.5	1.1
50-00612-W	Vilage of Golf	2,755	0.5	185.12	5,860	1.1	0.6	0.5
50-00615-W	West Palm Beach	109,401	29.2	266.91	232,692	62.1	39.3	22.8
50-01092-W	A G Holley	498	0.1	160.64	865	0.1	0.1	0
50-01283-W	Maralago Cay	1,240	0.2	145.16	3,075	0.4	0.3	0.1
50-03711-W	Seminole Imp. Dist.	1,000	0.2	220.00	3,575	0.8	0.2	0.6
	TOTALS	**1,162,419**	**197.1**	**340**	**2,340,000**	**401.9**	**259.4**	**142.7**
Broward County (LECSA 2)								
06-00001-W	Seminole Tribe of Florida	1,368	0.3	NA	2,185	2.4	2.4	0
06-00003-W	Royal Utilities	3,234	0.4	114.41	5,165	0.6	0.5	0.1
06-00004-W	North Lauderdale	32,994	2.4	73.95	52,694	3.9	3.2	0.7
06-00038-W	Hollywood- Chaminade	138,816	18.1	130.17	221,701	28.9	24.8	4.1
06-00054-W	Miramar	116,715	12.5	106.76	186,404	19.90	13.3	6.6
06-00070-W[1]	Pompano Beach	83,107	14.3	199	122,087	24.3	17.7	6.6
06-00071-W	Tamarac	56,064	6.2	110.77	89,539	9.9	7.2	2.7
06-00100-W	Coral Springs Imp. District	36,969	4.3	117.40	59,043	6.9	5.4	1.5
06-00101-W	Hillsboro Beach	1,875	0.8	405.33	2,995	1.2	0.9	0.3
06-00102-W	Coral Springs	58,029	6.1	105.46	92,677	9.8	9.4	0.3
06-00103-W	Plantation-central	84,584	14.1	167.17	135,088	22.6	17.2	5.3
06-00120-W	Sunrise- Sawgrass	211,403	28.4	134.29	337,628	45.3	29.1	16.2
06-00121-W	Margate	58,314	7.8	134.27	93,132	12.5	8.5	4.0
06-00123-W	Fort Lauderdale-Dixie	213,213	38.7	181.46	340,519	61.8	52.6	9.2
06-00129-W	Lauderhill	58,114	5.8	121.00	92,813	11.2	8.7	2.5
06-00134-W	Davie	27,548	4.0	144.84	131,023	19.0	5.0	14.0
06-00135-W	Pembroke Pines	152,002	12.1	79.80	242,760	19.4	15.6	3.8
06-00138-W	Hallandale	37,113	2.6	68.71	59,273	9.2	9.2	0
06-00146-W	Broward County -District 1	78,623	7.6	97.05	125,567	12.2	10.2	2.0
06-00170-W	Ferncrest/Tindall Hammock	2,639	0.7	261.46	4,215	1.1	0.7	0.4
06-00187-W	Dania Beach	14,840	1.0	68.73	23,701	1.6	1.1	0.5
06-00365-W	Cooper City	28,543	3.5	121.22	45,586	5.5	4.6	1.0
06-01474-W	Broward County -South Reg.	47,982	10.9	209.00	76,631	16.0	10.0	6.0
06-01634-W	Broward County -2A/North Reg.	114,144	13.4	117.05	182,297	21.3	17.5	3.8
	TOTALS	**1,651,570**	**216.3**		**2,724,723**	**365.4**	**276.5**	**88.9**

*Per capita use rate (gallons per person per day)
**Population Projections based on extrapolation form data provided by Smith and Rayer (2011) – see text for explanation
[1] Updated information differs slightly from values used in the modeling; PCUR adjusted, based on historical data

from the "high" projections predicted by University of Florida (Smith and Rayer, 2011) for LEC Service Areas 1 and 2, for the year 2040. For years beyond 2040, population growth was estimated based on projected growth rates for each area (**Table 1**). Population numbers were then used to calculate 2060 water demands based on the assumption that the 2010 calculated *per capita* rate of water consumption would stay constant. Future water conservation efforts were not considered. Resulting 2060 projected

total water use and unmet water demands used in Option 2 are shown in the pink shaded boxes in **Table 2**. In a few cases where growth was not expected to occur or utilities were severely limited in their ability to obtain additional water, the unmet need was set at zero. Locations of wells that had unmet needs for Option 1 and Option 2 scenarios are shown in **Figure 3**.

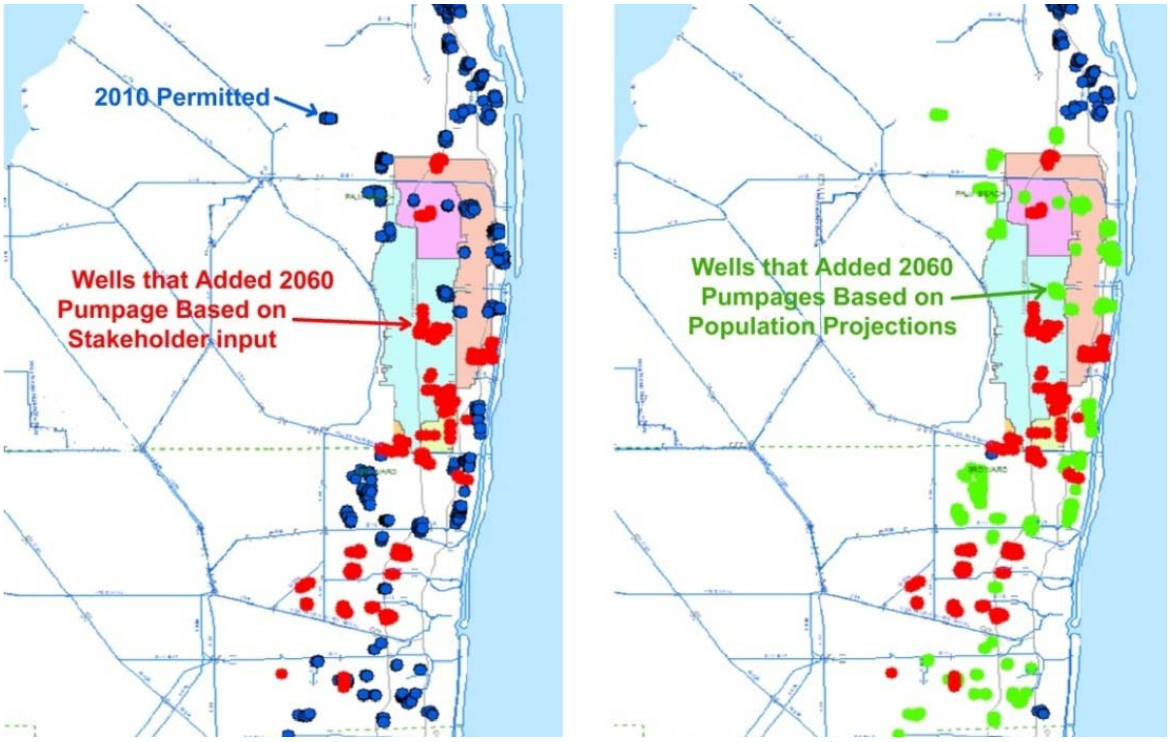

Figure 3. Wellfield locations in Palm Beach and Broward counties showing wells where increased withdrawals were simulated in the Option 1 and Option 2 model runs.

Results of this analysis for Option 1 (**Table 2**), indicate that water demands for utilities potentially served by this project in southern Palm Beach County increased from the current pumpage of 197 mgd in 2010 to the future demand of 286 mgd in 2060. The amount of water currently permitted is 259 mgd, so the unmet need is 27 mgd. For Broward County, water demands increased from 216 mgd in 2010 to 324 mgd in 2060. Presently 277 mgdis permitted, so the unmet need is 47 mgd.

The Option 2 scenario projects increases in population in the southeastern portion of Palm Beach County from 1,162,419 in 2010 to 2,340,000 in 2060 and water use increases from 197 mgd to 402 mgd (**Table 3**). Presently 259 mgd is permitted, so the unmet need is 143 mgd. Similarly, for areas of eastern Broward County served by utilities, population is projected to increase from 1,651,570 in 2010 to 2,724,723 in 2060 with a corresponding increase in water use from 216 mgd to 365 mgd (**Table 2**). Presently 276 mgd is permitted, so the unmet need is 89 mgd. The utility demands for Option 1 and Option 2 were used for all modeling discussed in the remainder of this report.

Water Availability Analysis

Conceptual Design

The conceptual design features for the C-51 reservoir and conveyance facilities, needed to move surface water within the C-51 basin (**Figure 4**), were adopted from a preliminary study conducted by Powell Kugler, Inc. (2010). The reservoir would be constructed from a 1505-acre mining pit, with a depth of 44 feet deep and a storage capacity of 75,000 ac-ft (24.4 billion gallons). Additional structures, canals and pumps would be built to move water in and out of the reservoir and within the C-51 basin.

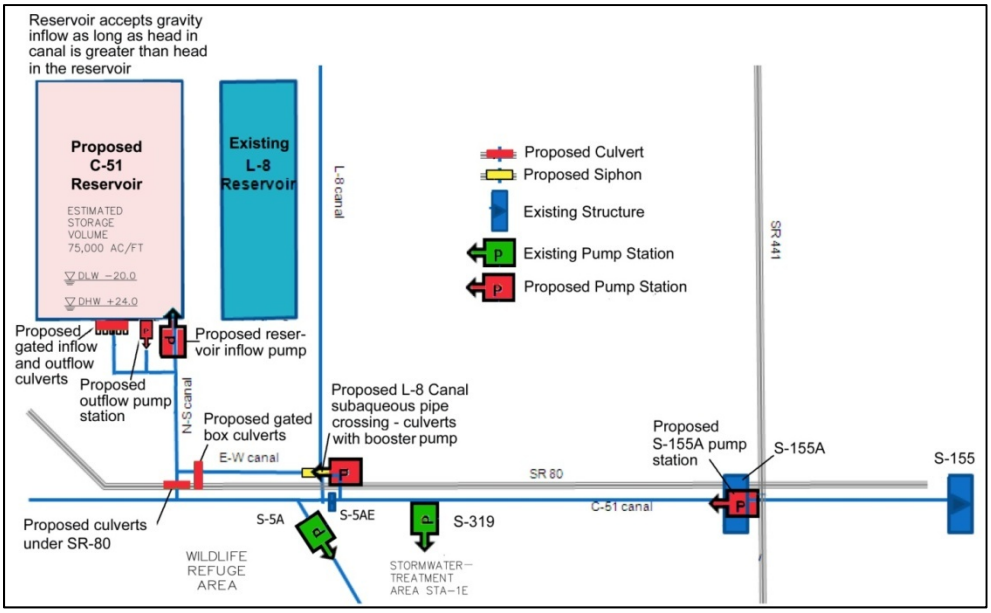

Figure 4. Major features of the C-51 reservoir and associated infrastructure in the C-51 canal to transfer water into and out of the reservoir (modified from Powell Kugler Inc., 2010)

Several technical issues need to be addressed in order to determine the feasibility of using additional storage in the C-51 reservoir to satisfy water utility needs in Palm Beach and Broward counties. For this investigation, the following questions were addressed:

1. Reservoir Utilization
    a. How much water would be captured from basin runoff into C-51 canal that would otherwise go to tide?
    b. What are the characteristics and requirements for filling and emptying the reservoir?
    c. How much water is needed to maintain canals in Palm Beach County (primarily Lake Worth Drainage District) and Broward County for the Base Scenario and Options 1 and 2?
    d. What are the hydraulic constraints for conveying water from east to west in C-51 canal; what fraction of basin runoff can realistically moved be moved west into the reservoir?
2. What are the anticipated seepage gains and losses? How much water is needed to maintain desired water levels in Lake Worth Drainage District canals in response to increased water demand?

3. What are the potential benefits of the proposed Lake Point reservoir as an additional source of water?

A primary focus of this feasibility study was to determine the quantity of water available to fill the C-51 reservoir and to help meet *future* water supply demands. To address this issue, SFWMD staff performed a water budget analysis using a suite of sophisticated computer models. Additional studies using more detailed models may need to be conducted within the existing regulatory framework and to develop a detailed design.

Additional studies are also required to determine detailed conveyance needs and seepage effects within LWDD and Broward County. Once more detailed information concerning appropriate routes and water levels for water transfer and distribution are available, the HEC-RAS and MODFLOW models, developed for this study (**Attachments 2 & 3** in **Appendix A**) may serve the above needs. The results reported here provide information that will help stakeholders determine whether they should pursue further efforts to develop the reservoir as a source of water to meet their future water demands.

Modeling Approach

The modeling strategy, developed to address the three questions described in the previous section, included the following tools and approaches:

- South Florida Water Management Model (SFWMM) (SFWMD 2005).

  This was the primary tool used to determine overall movement of water from the regional system to and through the C-51 basin. This is the premier regional-scale modeling tool available for South Florida and incorporates hydrology, water management system, water demands, and water shortage policies. An extensive review of historical data was conducted prior to the use of this model (Irizarry, 2010) to (a) determine if historical data alone would be adequate to perform reliable water budget analyses for the C-51 reservoir; and (b) evaluate the accuracy of SFWMM simulations for the C-51 canal system and its outlet structures.

  As a result of this analysis, it was determined that the historical data were inadequate to conduct the water budget analysis, primarily due to system changes such as installation of the S-155A and S-319 structures and changes to Lake Okeechobee operations during the period of record. Data generated by the SFWMM were used to fill gaps in areas and for periods where historical data were inadequate. Some coding changes, which were identified during the review, were made to the SFWMM to improve simulation of the C-51 canal system. These changes were completed prior to the use of the model for the C-51 project.

- Hydraulic routing model for C-51 basin using HEC-RAS/HEC-HMS models (Hydrologic Engineering Center, 2000; 2008)

  The primary purpose of using this model was to determine conveyance constraints, if any, associated with moving water west from the C-51 basin to the reservoir under different hydrologic conditions. This model includes primary canals (C-51), the major secondary canals, the LWDD equalizing canals, and control structures for each of the sub-basin outlets and secondary canals

discharging into the C-51 canal. The primary structures in the C-51 canal in the baseline model are the S-155 gated spillway on the eastern end, the S-155A gated structure located just west of S.R. 441 and the S-319 pump station that diverts water into stormwater treatment area STA-1E.

The current version of the model was first updated to include new features for operation of pumps and gated structures. The model was further modified to include several structural and operational changes in the existing system needed to capture water which is otherwise discharged to tide. These included additional pump stations, culverts and canals and operational modifications. The analysis only considered importing water from the eastern basin and conveying water to the reservoir and did not include conveyance of water supply releases out of the reservoir.

- A new groundwater model for the Lake Worth Drainage District (LWDD).

  A newly-developed South Palm Beach C-51 groundwater model (sPBC51) was applied chiefly to address gains and losses during conveyance through the LWDD and into Broward County. The conceptualization for sPBC51 involved an extensive evaluation of the water use, ET and recharge data sets. The source code for this project is MODFLOW-2000 (Harbaugh et al., 2000). This model was used to simulate groundwater flow (seepage) into and out of canals and between sub-basins within the LWDD, and to better estimate gains and losses (due to increased water demands) within the boundary of the LWDD and their effects on the total water conveyance via the LWDD system to Broward County. The model also indicates effects of increased water withdrawals on groundwater levels and water levels in canals.

Attachments 1, 2 and 3 in Appendix A to this report provide more information about the SFWMM, HEC-RAS and MODFLOW models, respectively, and how they were used in this study.

Reservoir Operation

To analyze performance of the 75,000 acre-ft capacity C-51 reservoir (**Figure 4),** it is assumed that the reservoir is lined to reduce seepage losses from the sides. Excess water from the C-51 canal would be pumped into the reservoir during wet periods and water would be released from the reservoir back into the C-51 canal during dry periods. Water could then be routed through LWDD and regional canals and facilities southward to recharge the canals, aquifer and local wellfields in Palm Beach and Broward counties. The actual timing and quantity of delivery from the reservoir to canals are linked to water needs of the regional canal system to maintain desired operational levels. Utility wellfields in the urban areas depend on the canal system to recharge the aquifer in their vicinity.

Distribution to Service Areas

The SFWMM (see **Attachment 1** in **Appendix A**) simulated deliveries of water to canals within Palm Beach and Broward counties, as shown in **Figure 5**. Actual conveyance of water through the canal system was not modeled in the SFWMM. Instead, for modeling purposes, water was moved directly from the reservoir to five receiving canals (e.g. C-51, LWDD E-2, Hillsboro, C-14, and North New River). This approach of direct transfer to the desired destinations was used in the water availability analysis to simplify the assessment of the C-51 reservoir. However, once a decision is made to pursue

implementation of the reservoir, more detailed conveyance investigations will be needed to determine how water can actually be moved at flow rates similar to those identified in this analysis.

Operational features of the SFWMM were adjusted to ensure that the water deliveries needed to maintain water levels in the canals during dry periods were first made from water available in the reservoir. If water was not available from the reservoir, and other criteria were met, then deliveries occurred from the regional system (primarily WCA-1 and WCA-2A) incorporating water shortage cutbacks and constraints imposed by regulation schedules as necessary (see Attachment 1 in Appendix A for details).

The results of modeling Options 1 and 2 water demands, with and without the reservoir, were compared to determine the performance of the reservoir in meeting its water supply objectives. An additional run was performed with Option 2 water demands, the C-51 reservoir, and the Lake Point reservoir (see **Figure 1** for the location). The water available from the Lake Point reservoir was assumed to be delivered to the L-8 canal, which in-turn could be an additional source of water for the C-51 reservoir and to meet demands elsewhere. For this study, no effort was made to model the conveyance of water from the Lake Point reservoir in detail.

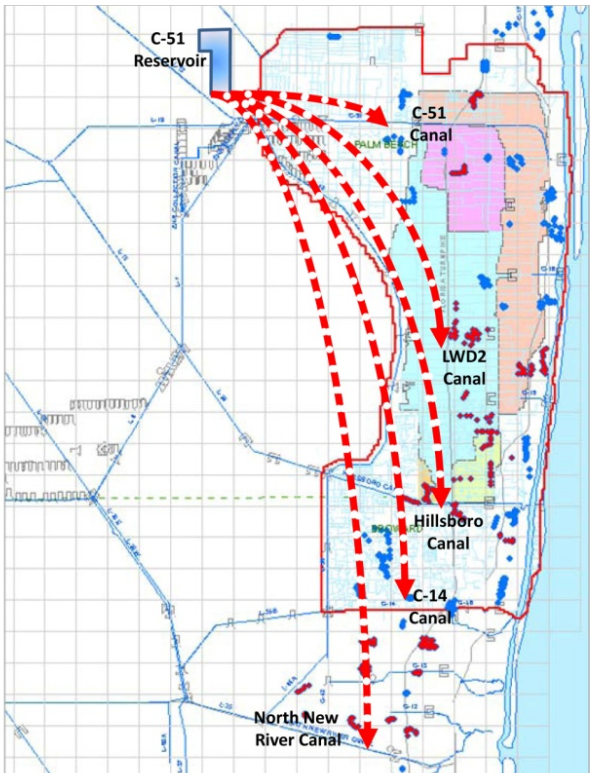

Figure 5. Conceptual representation of the direct delivery of water to utilities in Palm Beach and Broward counties as simulated by the South Florida Water Management Model.

C-51 Reservoir Performance

A particular feature of the C-51 reservoir is that its utilization (timing of filling and emptying) determines the amount of water that can be captured from the C-51 canal. In most wet seasons, the reservoir is

quickly filled and cannot receive additional water from the C-51 canal. During dry periods (typically every dry season) water demand increases, more water is discharged from the reservoir, and more space is created to store C-51 canal water. The C-51 reservoir will primarily be used for seasonal storage, i.e. to capture and retain seasonal runoff and redistribute the water during the following dry season. It may also have some multi-year, carryover capacity, except during prolonged droughts when the reservoir could potentially remain empty for long periods of time, depending on the amount of rainfall and the magnitude of water demand. There was no attempt to optimize reservoir size for each water demand option. Instead, reservoir storage capacity was fixed at 75,000 ac-ft.

The model simulated daily performance of the C-51 reservoir over the period of climatic data from January 1, 1965 to December 31, 2005 and provided a daily water budget for the entire period. **Figure 6** shows monthly and seasonal patterns of water levels in the reservoir and the percentage of time that the reservoir is full for each demand option. The stage decreases during the dry season and the increases during the wet season demonstrate the functionality of the reservoir for seasonal storage.

With Option 1 water demands the reservoir (whose bottom is assumed to be at -20 feet NGVD) generally maintained an average operational depth of over 40 feet (**Figure 6A**) and was full nearly 80% of the time (**Figure 6B**). For Option 2, more water was used from the reservoir during the dry season. Water depth was often less than 20 feet and the reservoir was full only 30% of the time (**Figure 6B**).

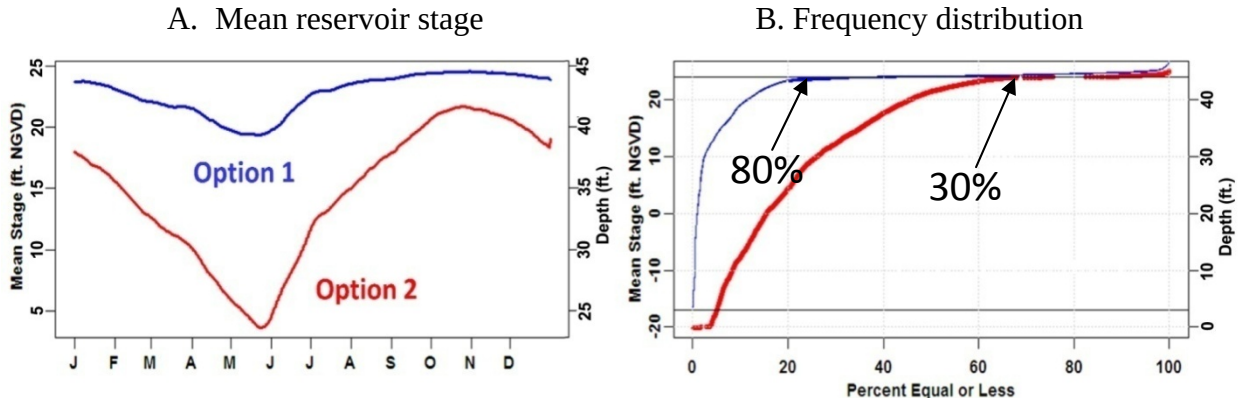

Figure 6. A) Average stage in the C-51 reservoir, and B) percent of the simulation period that the C-51 reservoir remains filled with water, for Option 1 and Option 2 water demand scenarios.

Figure 7 shows simulated daily operation of the reservoir from 1965 to 2005. During most years, the full storage capacity of the reservoir is not needed to meet the lower water demand in Option 1. Only during the most severe drought conditions (1971) was the reservoir fully utilized. Under Option 2, during major drought periods such as those which occurred in early 1970s and 1989-1990, the reservoir could be empty for extended periods of time. During such droughts, the reservoir may not have sufficient water to meet all the regional demands of the canal system in the urban area. However, it is expected that water shortage cutbacks, which will be in place during such events, will lower utility demands as well as deliveries from the regional system

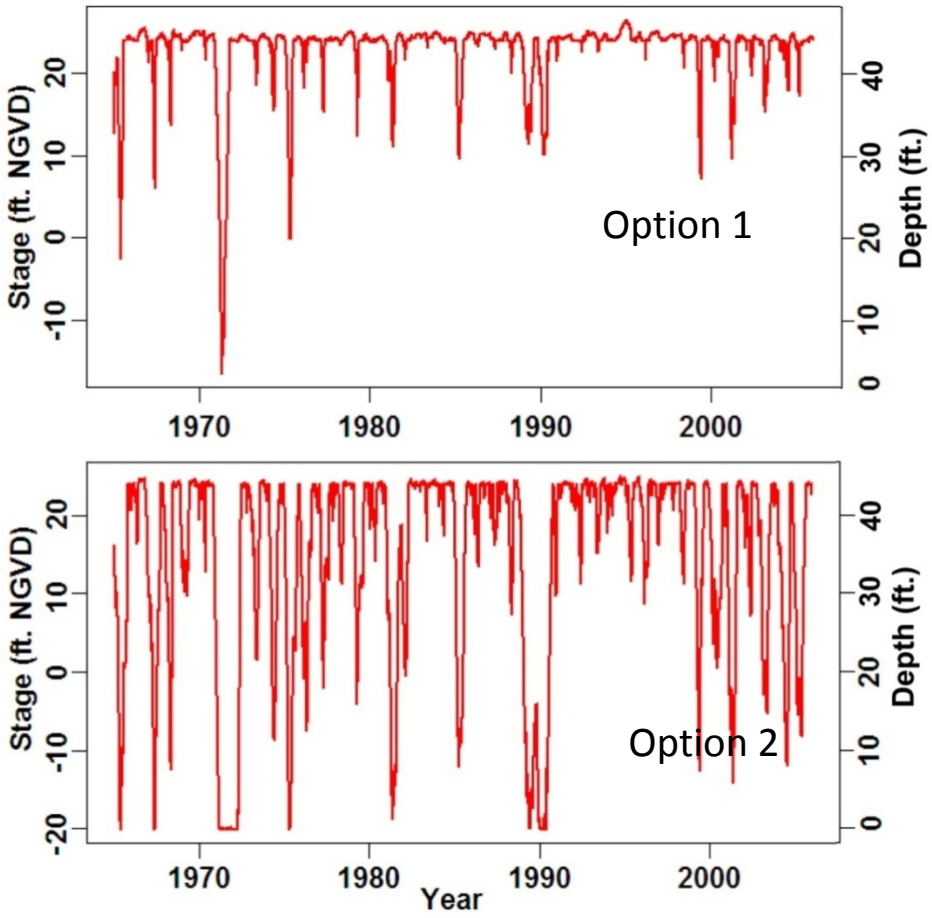

Figure 7. Water levels in the C-51 reservoir simulated by the regional model based on Option 1 and Option 2 water demands.

As noted above, a detailed design study to estimate the optimal size for a reservoir was not part of this investigation. Such a study could reduce the amount of time that the reservoir is completely full while also minimizing the frequency and duration of events when the reservoir is completely empty. Alternatively, additional demands placed on the reservoir may help achieve similar objectives. Future phases of this project may pursue such investigations.

Water Provided by the Reservoir

Reservoir delivery volumes, sorted according to magnitude, are shown in **Figure 8** for Option 1 and Option 2. These values represent the amount of water delivered by the reservoir during dry-season (Nov-May) in all years. During the extreme drought of 1971, for the Option 1 water demands, modeling studies indicate that the reservoir could have delivered 170 mgd on average during the dry season. Since the water level in the reservoir reached bottom for only a very short period of time (**Figure 7**), this amount may have been sufficient to meet water demands for that year. During the four driest years (red dashed line on the graphs in **Figure 8**, the reservoir would have delivered 85 mgd or more to the region, while not exceeding the storage capacity of the reservoir.

During at least two dry periods (1989-90 and 1971-72) for Option 2, the reservoir was dry for extended durations. Since the amount of water available from the reservoir would be limited, additional water

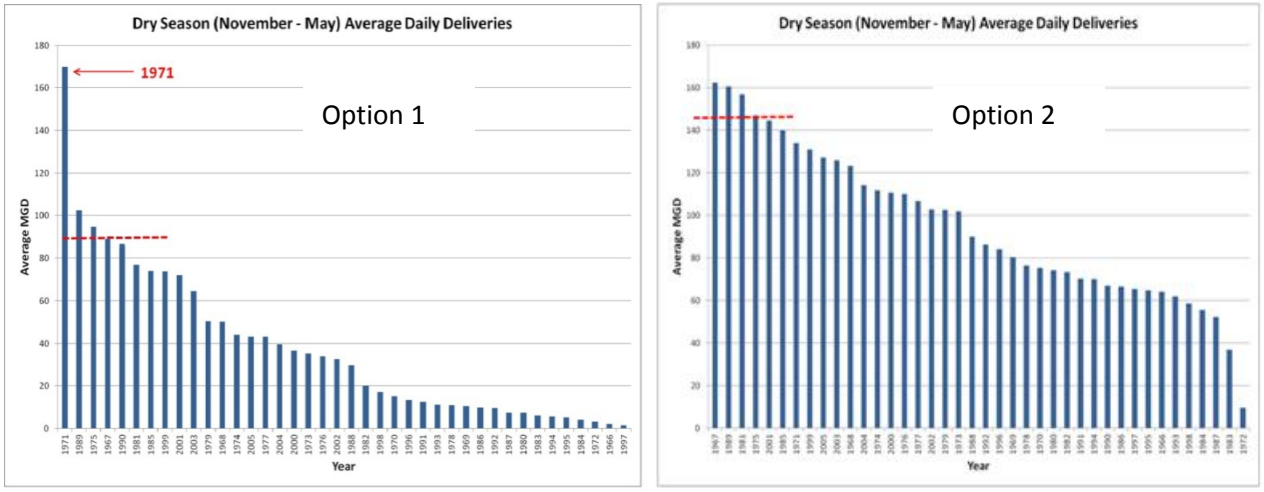

Figure 8. Dry season deliveries of water from the C-51 reservoir, sorted according to magnitude, for Option 1 and Option 2 water demand scenarios.

would be needed from the regional system to maintain water levels in the LEC basins. Dry season deliveries during each of the four years of highest delivery volume from the reservoir would have exceeded 145 mgd. During these extreme dry years, it is expected that water shortage cutbacks would be in place. Consequently, deliveries from the regional system would be reduced. The impact of these reductions may be offset, however, by reduced utility demands during declared water shortages.

Table 4 shows performance of the reservoir in terms of average yearly volumes of water delivered to the reservoir, water provided from the reservoir to LEC basins, and effects on the amount of water discharged to tide through the S-155 structure. The volume of water captured in the reservoir is essentially equal to the reduction in volume of water released to tide. In Option 1, the water released to tide via S-155 without the reservoir is 236 K ac-ft/yr. With the reservoir in place, the water volume to tide is 219 K ac-ft/yr and 29 K ac-ft/yr is stored in the reservoir. The total amount of water discharged to tide plus the water captured by the reservoir is 248 K ac-ft/yr. The difference of 12 K ac-ft/yr (250-236) occurs because there is more water in the LEC canal system due to C-51 reservoir deliveries. This pattern is similar for both Option 1 and Option 2.

Freshwater released to tide in Lake Worth Lagoon has adverse impacts on sea grasses, oysters and fisheries. The freshwater diverted into the reservoir therefore provides an incremental benefit to the coastal ecosystem. It should be noted that releases to tide are not reduced in the very wet years (90^{th} percentile) when the reservoir is under-utilized, such as in Option 1. The reservoir is full during the very wet years and does not have capacity to reduce releases of water from the C-51 canal to tide.

Regional-scale modeling results suggest that the C-51 reservoir can help reduce the future increased dependence on the regional system due to utility demand increases. In most years, the reduced demand on the regional system may be similar in magnitude to what is simulated under the 2010 permitted condition. This result demonstrates the utility of the reservoir as an alternative water supply

Table 4. Regional modeling results showing quantities of water sent to tide, to the reservoir, and from the reservoir to Lower East Coast Service Areas, with and without the reservoir, for Option 1 and Option 2 water demands.

Option 1												
	Without Reservoir						With Reservoir					
	Flow (1,000 ac-ft)			MGD			Flow (1,000 ac-ft)			MGD		
	10th Per-centile	*Mean*	*90th Per-centile*	*10th Per-centile*	*Mean*	*90th Per-centile*	*10th Per-centile*	*Mean*	*90th Per-centile*	*10th Per-centile*	*Mean*	*90th Per-centile*
S-155 to tide	124	**236**[1]	376	111	**210**	335	93,	**219**	375	83	**195**	335
S-155 to reservoir							3	**29**	60	3	**26**	54
Reservoir to LEC							4	**28**	59	4	**35**	52
Option 2												
	Without Reservoir						**With Reservoir**					
	Flow (1,000 ac-ft)			**MGD**			**Flow (1,000 ac-ft)**			**MGD**		
	10th Per-centile	*Mean*	*90th Per-centile*	*10th Per-centile*	*Mean*	*90th Per-centile*	*10th Per-centile*	*Mean*	*90th Per-centile*	*10th Per-centile*	*Mean*	*90th Per-centile*
S-155 to tide	111	**211**	343	99	**188**	306	28	**152**	306	25	**135**	273
S-155 to reservoir							51	**76**	100	45	**68**	89
Reservoir to LEC							39	**75**	114	35	**67**	101

Note 1: Flows from S-155 to tide are assumed to represent available water for the reservoir from both C-51 East and West.
Note 2: Flows from S-155 to tide represent flow remaining from the C-51 basins after removal of water pumped to the reservoir

source. No effort was made to verify whether conditions of the Regional Water Availability Rule – i.e. no net impacts to designated water bodies – or any other regulatory criteria, were met for individual utilities. In addition, no attempt was made to prove rule compliance for individual utilities. Future permitting of increased demands will address this issue in the regulatory framework.

Benefits of the Proposed Lake Point Reservoir

The proposed Lake Point reservoir is located just east of Lake Okeechobee at the north end of the L-8 basin (**Figure 9**). It has a surface area of 895 acres and an operational depth of 6 feet. A stormwater treatment area is associated with this reservoir that has an operational depth of 3 feet and covers an area of 608 acres. The storage capacity of this entire system is about 7,194 acre-feet.

The SFWMM was used to simulate performance of this reservoir and estimate how much water would be available for possible delivery to C-51 canal during dry periods. For this analysis, the source of water is assumed to be flood control releases from Lake Okeechobee through structure S-308. Water from the reservoir/STA may be delivered to L-8 canal, routed south, and potentially delivered to C-51 canal. Modeling of the Lake Point reservoir performance indicates that it could potentially have water supply benefits because, although water is not available every year, it is sometimes available for delivery during dry season months from December through June, even during dry years (see **Figure 9**). On average, the reservoir is able to deliver approximately 18,000 acre-feet (5,865 million gallons) annually, with several individual years delivering above 30,000 acre-feet 9,775 million gallons). Details of how the Lake Point reservoir could interact with the C-51 basin are not presently included in the SFWMM and hence were not evaluated. In this investigation the modeling was used to determine the amount of water that could be released south from the Lake Point reservoir, which otherwise may be discharged to tide through the St. Lucie canal. See **Attachment 1 in Appendix A** for more information on the SFWMM results.

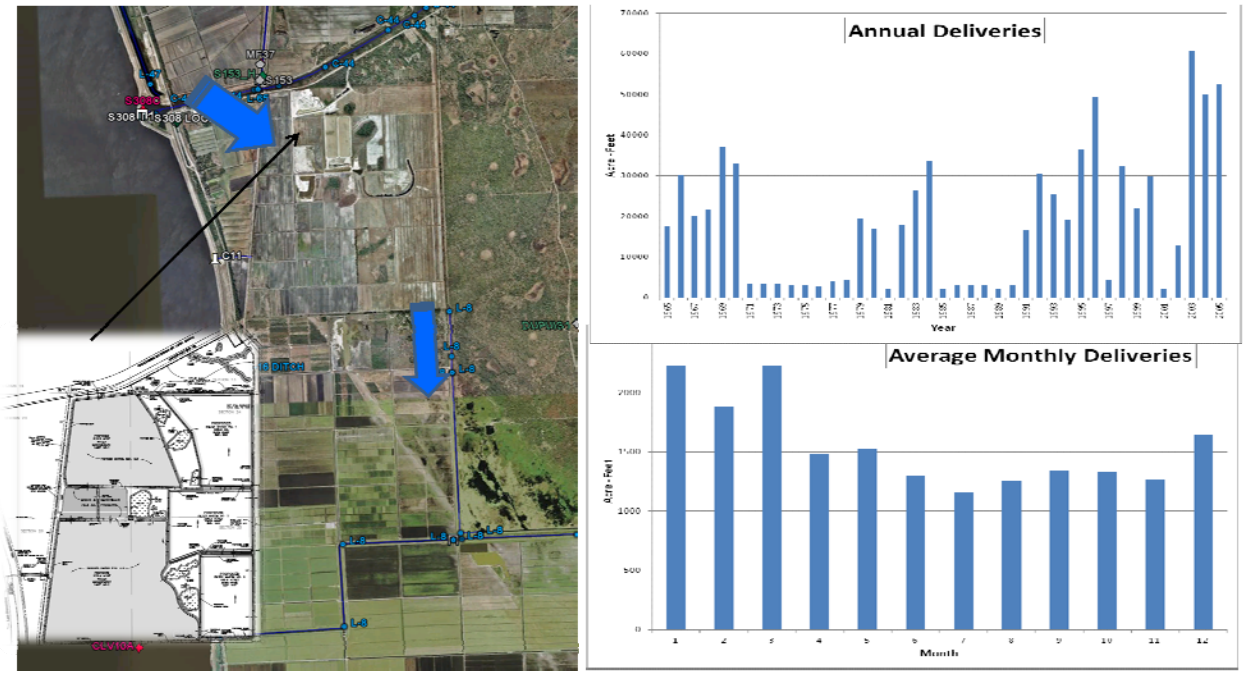

Figure 9. Configuration of the proposed Lake Point reservoir, simulated annual deliveries over a range of historic hydrological conditions, and seasonal availability of water from the reservoir.

Seepage Flows in the Lake Worth Drainage District (LWDD) System

The MODFLOW model was used to estimate seepage from canals within the LWDD. More information concerning features of the LWDD and application of the MODFLOW is provided in **Attachment 3** in **Appendix A**. The LWDD occupies most of eastern Palm Beach County, south of C-51 canal (**Figure 10**). The model provided quantitative estimates of average seepage over the period from 1986-2005, dry season seepage during that period, and dry season seepage during a severe drought condition (1989-1990) for the three different water demand options - a Base Scenario based on 2010 Consumptive Use Permits, Option 1 and Option 2.

On average, seepage flows simulated for the LWD16, LWD13.5, and LWD9.5 basins within the LWDD (LWDSUM) were positive, indicating net flows from the canals to the aquifer increased with increasing water demands.The average seepage estimated by the model ranged from 33.4 mgd for the Base Scenario to 78.1 mgd for Option 2 (**Table 5A**). Seepage rates increased during the dry season, ranging from 89.6 mgd (base scenario) to 134.5 mgd (Option 2). During the 1989-1990 drought, seepage rates were 40-50% above normal dry season seepage rates, and ranged from 143 mgd (Base) to 188 mgd (Option 2). I

n contrast to those three basins, the LWDD 8.5 basin typically had negative seepage values (flow from the aquifer into the canals). With increased withdrawals from the aquifer, flows from the aquifer to the canals decrease and the magnitude of seepage is less. For example, dry season seepage from the aquifer to the canal in LWDD basin 8.5 decreases from -102.8 mgd for the Base Scenario to -78.8 mgd for Option 2. Larger withdrawals by wellfields and the changes in the water budget in the eastern areas may result in increased potential for saltwater intrusion.

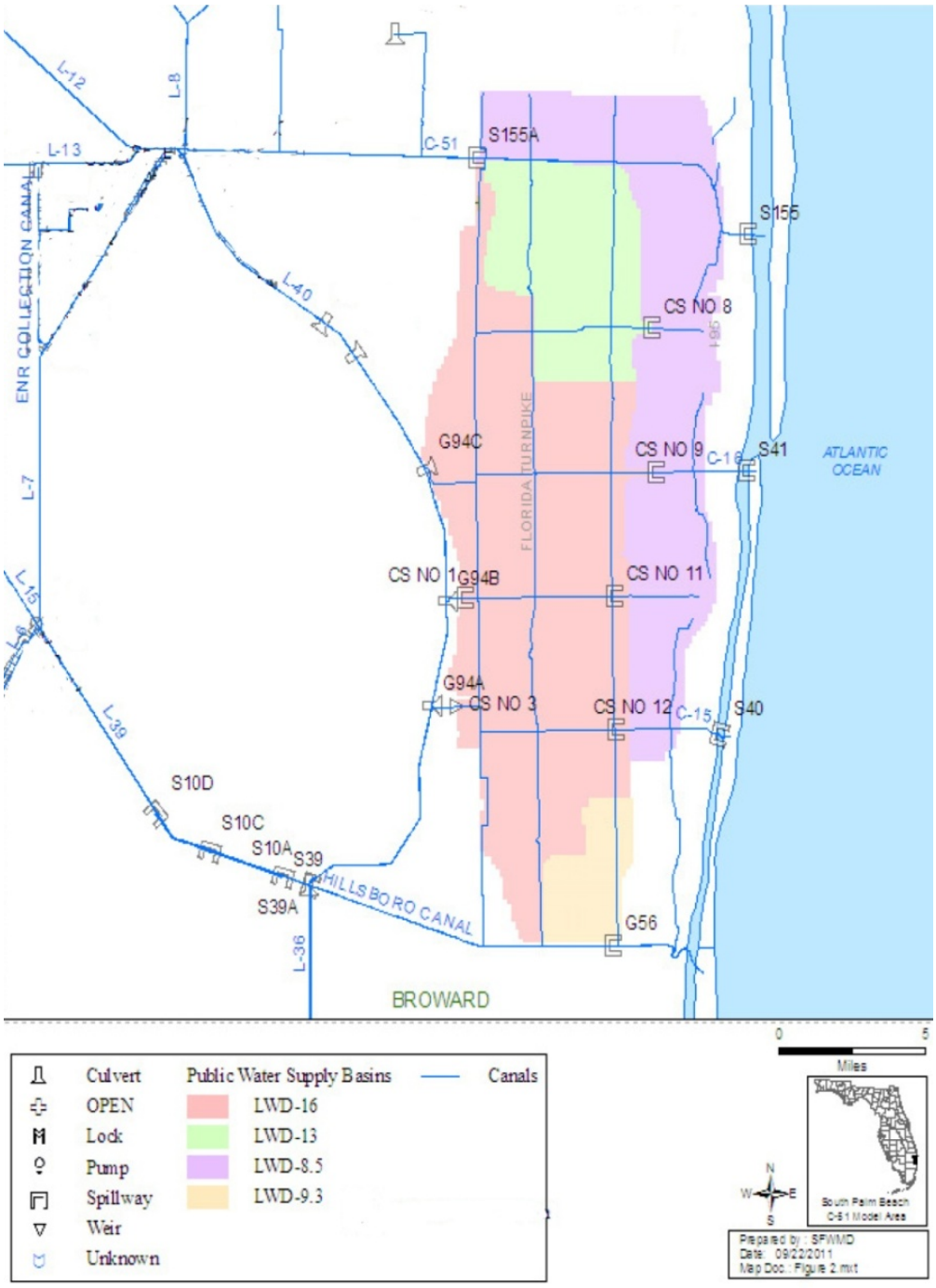

Figure 10. Major distribution canals, control structures and management basins within the Lake Worth Drainage District (without modification for C-51 reservoir deliveries).

Table 5B summarizes the increase in seepage within the LWDD caused by the different water demand scenarios relative to the Base (2010 CUP demand)Scenario. The average increase in seepage is approximately equal to the increase in the amount of water pumped out of each basin by the water supply utilities.

Table 5. Seepage rates within Lake Worth Drainage District computed using the C-51 basin MODFLOW model for the three water demand scenarios.

A. Average seepage in LWDD

Basin	Scenario	Seepage (MGD), 1986-2005	Seepage (MGD), Dry Seasons 1986-2005	Seepage (MGD), Dry Season 1989-1990
LWDSUM	BASE Scenario	33.4	89.6	143.4
	2060-Option 1	40.6	96.8	150.8
	2060-Option 2	78.1	134.5	188.4
LWDD-8.5	BASE Scenario	-135.7	-102.8	-71.7
	2060-Option 1	-128.2	-95.3	-64.2
	2060-Option 2	-111.7	-78.8	-47.5

B. Increases (Δ) in pumpage and seepage in LWDD to the BASE (2010 CUP) Scenario.

Basin	Scenario	Δ Pump, MGD	Δ Seepage (MGD), 1986-2005	Δ Seepage (MGD), Dry Seasons 1986-2005	Δ Seepage (MGD), Dry Season 1989-1990
LWDSUM	2060-Option 1	8.2	7.2	7.2	7.3
	2060-Option 2	47.2	44.7	44.9	45.0
LWDD-8.5	2060-Option 1	9.9	7.5	7.4	7.5
	2060-Option 2	21.3	24.0	23.9	24.2
HILLSBORO	2060-Option 1	11.1	9.8	9.7	9.7
	2060-Option 2	13.2	12.7	12.4	12.5
EAST REGION	2060-Option 1	0.0	0.4	0.3	0.4
	2060-Option 2	10.3	10.5	10.0	10.1
TOTALS	2060-Option 1	29.3	24.8	24.7	24.9
	2060-Option 2	92.1	91.9	91.2	91.7

Notes: LWDSUM: The source for this basin is C-51 and WCA through Hillsboro canal
LWDD-8.5: The source for this basin is C-51. When needed for public water supply, water is pumped from LWD-8.5 to LWD-16.

Effects of Increased Pumpages on Water Level Drawdowns

The MODFLOW model also provides a spatial map of the effects of increased pumpages on groundwater levels adjacent to wellfields. **Figure 11** is an example of one such map, showing relative effects of Option 1 and Option 2 water demands. This map represents one day in the driest month (May 1990) of the simulation period. Both increased demand scenarios (i.e. Option 1 and Option 2) assumed prescribed maintenance levels in the LWDD canals. However, it should be noted that the apparent stress may be less if the Base Scenario (2010 CUP demands) were run using historical rather than maintenance water levels for LWDD canals. This is because historical dry season water levels in the canals are lower than their published maintenance levels. If the Base Scenario were run using historical canal levels, the model would predict lower canal seepage rates and lower water table elevations than occur in the current analysis.

Even modest increases in demands may create problems for some wellfields of coastal communities that are threatened by saltwater intrusion, such as Lake Worth and Lantana in Palm Beach County, and Dania and Hallandale in Broward County. These results suggest that the withdrawals associated with Option 2 may create problems with saltwater intrusion or impacts on isolated wetlands or other existing users.

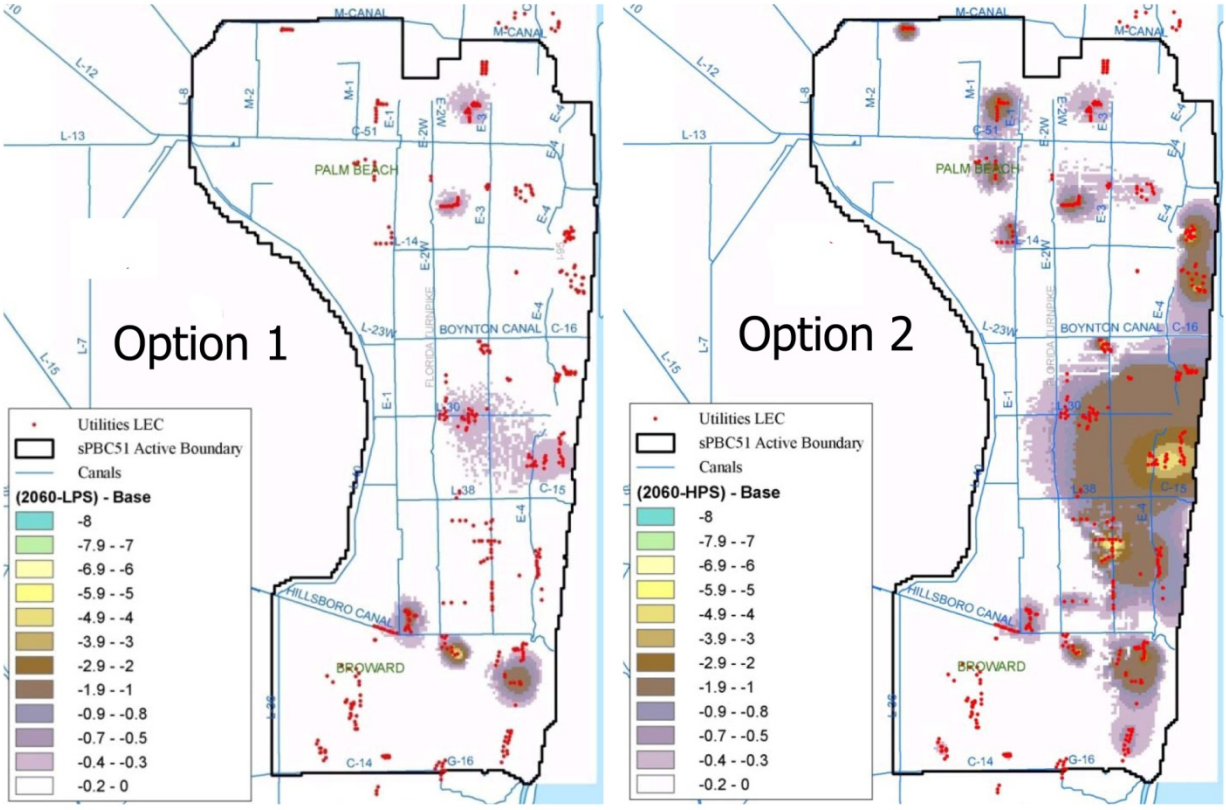

Figure 11. Effects of Option 1 and Option 2 water demand scenarios on water level drawdowns in the surficial aquifer in Palm Beach and Broward counties-- simulated conditions for a representative day during May 1990, the driest month of the modeled period (1986-2005).

Such modeling issues and impact concerns need to be addressed in detail in a regulatory framework associated with permitting of future demands. . The reader is referred to **Attachment 3** in **Appendix A** for more information on the MODFLOW model results.

Conveyance Analyses

Introduction

The ability to convey water within the canal system and into and out the C-51 reservoir is a key element of this project and one that still needs additional analysis. Major features of the proposed project are shown in **Figure 12**. The conveyance aspect of the project has been divided into three components:

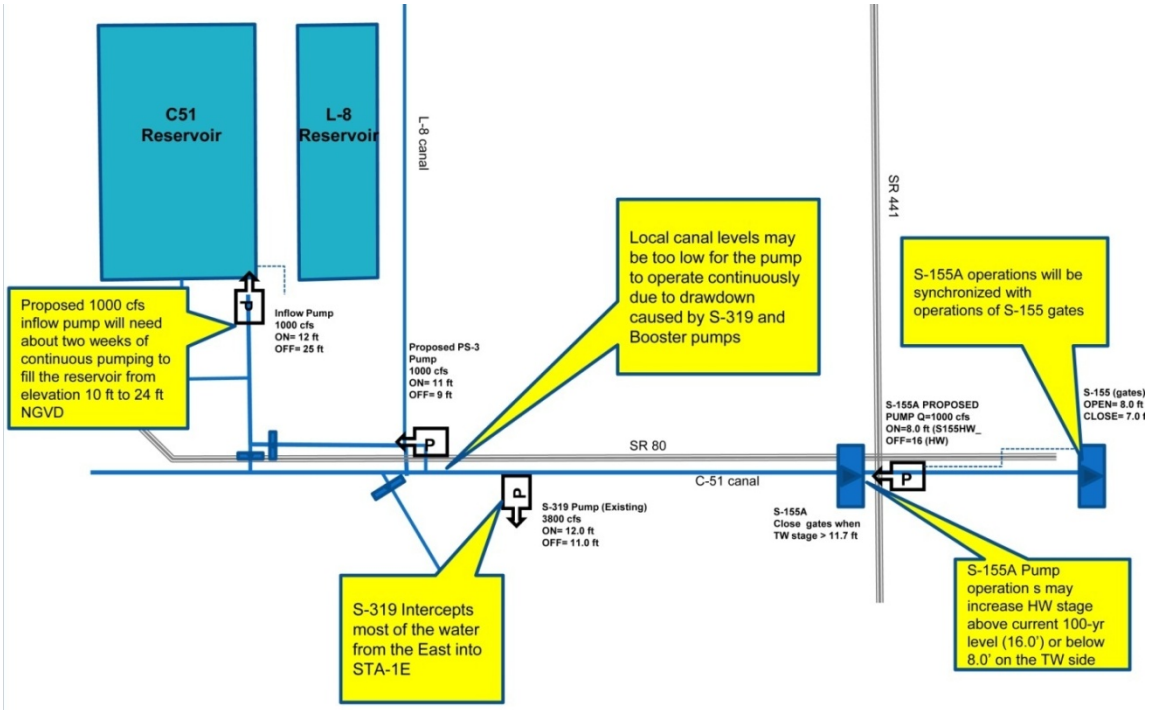

Figure 12. Operational constraints and challenges associated with hydraulics of moving water to the reservoir from within the C-51 basin.

Water delivered to the reservoir. Most of the water for the reservoir is obtained from within the C-51 canal. The critical feature is the ability to move excess surface water from the eastern portion of C -51 canal to the western portion of C-51 canal, and further westward into the reservoir.

Transfer of water through Lake Worth Drainage District. Various possible routes for distributing water from the C-51 reservoir southward through Palm Beach and Broward counties have been examined previously (see Hazen and Sawyer 2010). The most feasible approach seems to be to move water from the reservoir eastward through C-51 canal and then south into canals of the Lake Worth Drainage District. Water would then be moved through the canals to provide recharge for the surficial aquifer system and provide flow into the Hillsborough canal for use in Broward County (and perhaps areas further south in Miami-Dade County). Improvements to pumps, canals and structures in LWDD are needed to convey this additional water.

Transfer of water within Broward County. Various features of the existing primary and secondary water management systems will need to be modified to achieve the full benefits of this

project in northern and central Broward County. Several options for delivering water further south under the I-595 corridor are being investigated in order to provide water to southern Broward County and potentially to Miami-Dade County. The potential benefits achieved by altering the existing facilities to improve water supply capacity must be considered in the context of possible impacts on permitted users, local and regional environmental resource protection, water quality conditions, and flood control requirements.

Hydraulic Modeling of Water Availability for the Reservoir

Many constraints and potential operational challenges must be considered in order to convey water from the C-51 canal to the reservoir. Operational constraints and hydraulic limitations limit the ability to move large quantities of water to the reservoir under some climatic conditions, without impacting current flood control criteria. Detailed studies were undertaken using the HEC-RAS model (**Appendix A, Attachment 2**) to analyze water conveyance and the proportion of available water that could be captured from the C-51 basin and stored in the reservoir. Four time periods were analyzed representing below average, average, and above average conditions, and an extreme rainfall event (**Table 6**).

For low rainfall conditions, up to 66% of the water that would have flowed to tide or to STA-1, could be captured in the reservoir. Under average to above average rainfall conditions, this proportion is closer to 50%. Under extreme wet conditions when basin storage, the reservoir, and the STA are nearly full, the reservoir could accommodate only 18% of available water. Since it is not expected that all excess water in the C-51 basin would be moved west to the C-51 reservoir (see earlier water availability analysis), the fraction of water that can be moved appears adequate to transfer the necessary volumes to the reservoir. The reader is referred to **Attachment 2** in **Appendix A** for more details of the HEC-RAS modeling results.

Table 6. Summary of conveyance analysis results for below average, average, above average, and extreme wet four rainfall conditions.

Structure	Below-average Rainfall			Average Rainfall			Above-average Rainfall			Hurricane Irene		
	Feb 1 – Apr 31, 2007			Aug 18 – Oct 31, 2008			Jun 1 - Aug 31, 2007			Aug 18 -24, 1999		
	Base (ac-ft)	W/Res (ac-ft)	% Cap.	Base (ac-ft)	W/Res (ac-ft)	% Cap.	Base (ac-ft)	W/Res (ac-ft)	% Cap.	Base (ac-ft)	W/Res (ac-ft)	% Cap.
S-155	70,026	33,760		118,177	63,755		155,283	84,148		36,078	28,245	
S-155A pump	-	36,364		-	52,810		-	70,578		-	8,512	
S-319	41,084	23,564		89,733	78,310		155,710	131,541		30,649	30,999	
To C-51 res.		46,125	66		59,775	51	-	86,139	55	-	6,495	18

Conveyance through Lake Worth Drainage District

Previously, three options were considered as means to deliver water from C-51 reservoir south to Broward County. These were:

- Conveyance through L-40 canal within the Arthur R Marshall Loxahatchee National Wildlife Refuge (LNWR)
- Conveyance from C-51 canal south through LWDD canals, and

- Conveyance south through the Everglades Agricultural Area (EAA)

The LWDD route was deemed most suitable in terms of a) avoiding water quality impact issues within the LNWR, b) avoiding competition for use of the water by other consumptive uses or for environmental needs, and c) maintaining canal and groundwater levels that provide recharge to coastal wellfields in Palm Beach and Broward counties

The SFWMD and the LWDD investigated alternate ways to increase the use of the C-51 canal to deliver water to the LWDD to meet dry season demands, primarily by providing additional pumping capacity at Control Structure No. 2 (CS-2) pump station at the junction of the C-51 and E-1 canals (**Figure 13)**.

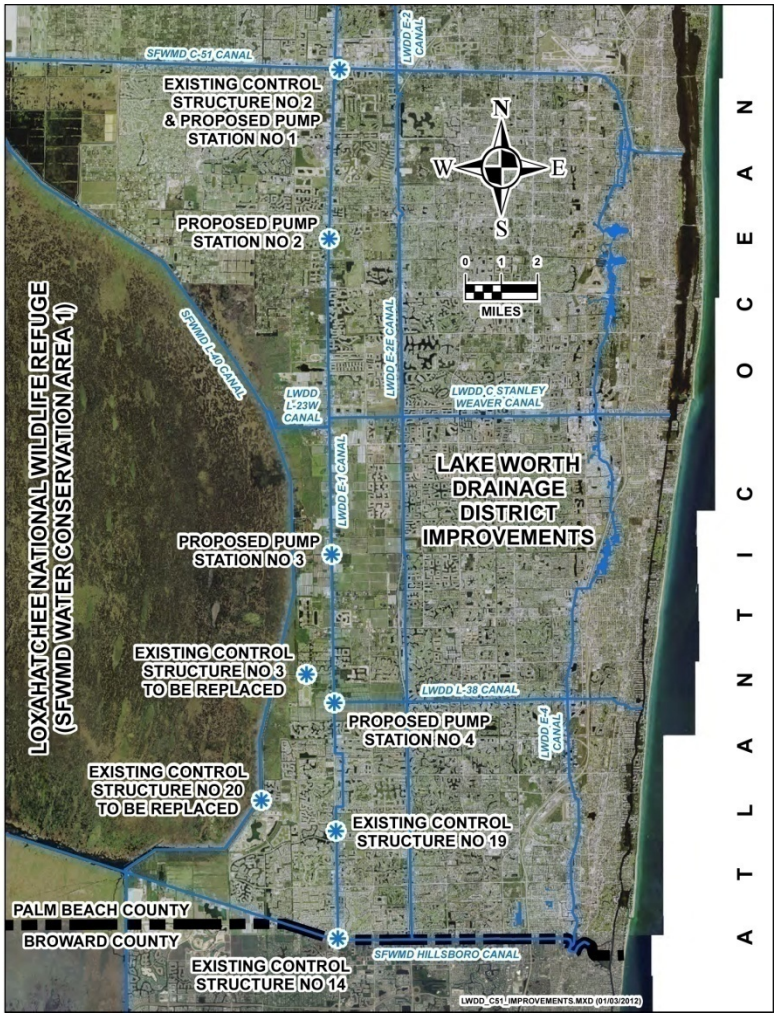

Figure 13. Major features of facilities needed to route water from C-51 reservoir south through Lake Worth Drainage District to Broward County.

The project involves delivery of water stored in the C-51 reservoir via SFWMD's C-51 canal to the LWDD E-1 canal. It is proposed that E-1 canal could convey 225 cfs (100,986 gpm) south to Broward County's conveyance system by adding or modifying the following facilities:

Pump Station No.1: A (150 cfs) pump station is to be constructed east of the existing LWDD control structure no. 2 (CS-2) gated spillway located at the confluence of the E-1 and C-51 canals. The station is to supplement the existing 75 cfs (33,662 gpm) pumping facility located west of the spillway. The pumping system shall include (2) 75 cfs axial flow submersible pumps, which will increase the total pumping capacity for the site to 225 cfs and will pump water from the C-51 canal south via the E-1 canal. The other proposed pump stations for the E-1 canal will be consistent with this pumping capacity. It is assumed the station will be capable of remote operation via a telemetry communications system.

Pump Stations No. 2, 3, and 4: Three additional pump stations (225 cfs) are required to convey the proposed water supply south via the E-1 canal through the LWDD. It was assumed that the three stations would be similar in design and cost. The pump stations would be constructed on the east bank of the E-1 canal at various sites south along SR7. Each station would require the addition of a gated spillway similar to CS-2 with (2) 12 ft. wide radial gates. The pumping system would include (3) 75 cfs axial flow submersible pumps with an automated trash collection system. Operation and control of pumping system and gated spillway would be housed in a control building adjacent to the pump intake.

In addition to the above new required infrastructure, two existing LWDD control structures, #3 and #20, need to be replaced (see **Figure 13**).

A number of possible alternative routes for distribution of water from the C-51 reservoir south through LWDD to provide recharge to wellfields in Palm Beach County and deliver water to the Hillsboro canal in Broward County are also being evaluated. The choice of delivery route may vary depending on local water level conditions, which areas can most benefit from the water, what location in the Hillsboro canal is best for Broward County, and water quality considerations. For the most part**,** existing LWDD infrastructure provides adequate capacity to move some of this water east or west of E-1 canal and south, as needed to maintain groundwater levels and protect against saltwater intrusion.

Preferred Routing of Water from the C-51 Reservoir through Broward County

Figure 15 shows approximate locations of some major wellfields within Broward County that are likely to benefit from the C-51 reservoir project. In order to achieve these benefits, a number of changes need to be made to Broward County's existing water management infrastructure. In addition, changes are suggested to features of the regional system of structures and canals that are operated and maintained by the SFWMD and USACE. The map shows one proposed option for routing this water.

Northern Broward County

It is anticipated that water deliveries from the C-51 reservoir will be made to the Hillsboro canal from the Lake Worth Drainage District via the E-1 canal (**Figure 13**). Water can then be easily pumped into the North Broward County Recharge System (NBCRS) secondary drainage canals, located between the Hillsboro and C-14 canals (**Figure 14**).

Figure 14. Locations of wellfields in Broward County that may benefit from additional water deliveries provided by the C-51 reservoir, and one proposed routing option (red and dotted lines) for providing these deliveries).

Three existing pump stations and a proposed fourth on the Hillsboro canal would provide a maximum combined rate of 117 mgd of flow from the Hillsboro canal into the NBCRS (see **Figure 14**). Water provided to that system could benefit Deerfield Beach, Pompano Beach, and Broward County's 2A and North Regional wellfields. In addition, releases from the NBCRS to the C-14 canal could offset impacts of Fort Lauderdale's Prospect Wellfield, with water to be routed south through one or more C-13 canal/C-14 canal interconnects.

Central Broward County

In order to move C-51 canal water to the central portion of Broward County, the S-39 and S-38 regional water management structures would be modified to deliver water south into L-36 canal. Currently these structures deliver water into the Hillsboro and C-14 canals, respectively. These traditional water deliveries support urban water supply withdrawals that could be instead offset by C-51 canal water. Water normally provided from the Water Conservation Areas could then be redirected into the L-36 canal to offset additional wellfield withdrawals by utilities in central and southern Broward County.

Routing water down the L-36 and further west along the L-35A would provide additional recharge for the City of Sunrise's wellfields. This water could also reduce seepage losses and offset impacts to the regional canal system and WCA-2B that might result from increased wellfield withdrawals. Water routed to L-36 could then flow south into C-42 and then into the C-13, C-12, and North New River canals to provide recharge to the City of Sunrise's and a Broward County regional wellfield located near C-13 canal, and the Fort Lauderdale wellfield located between C-14 and C-13. Similarly, water provided to the C-12 and North New River canals would benefit wellfields used by Sunrise, Plantation, and Fort Lauderdale.

Southern Broward County

Options for moving water from the north to the south sides of Interstate 595 are presently being investigated. Currently there are no county-owned structures that allow for the conveyance of water from the North New River canal (north of I-595) to canals to the south. Features within some local drainage districts could potentially be enlarged or improved. Local agreements would be needed with these entities to make necessary changes to facilities and ensure effective operation and maintenance. Retrofit of these systems to allow for a north-south conveyance of recharge water across the I-595 divide would expand C-51 reservoir benefits to several additional wellfields serving the communities of Sunrise, Davie, Hallandale Beach, and Hollywood, as well as the Broward County south regional wellfield. Dania Beach may benefit from additional water being available in this basin as well, even though the Dania Beach wellfield itself has saltwater intrusion problems that cannot be fully addressed by providing additional recharge.

A recommendation for future study, based on this analysis, is to determine if project benefits should be extended further south to include some portion of the Miami-Dade County service area. The canal identified as being the most advantageous for such deliveries is the C-11S canal. The issue of conveying water from North New River canal to southern canals would have to be addressed, as well as potential impacts of increased water deliveries on groundwater levels in low-lying areas of southwest Broward County. In these areas, canal stages are managed at lower control elevations to meet local drainage and flood control requirements.

Existing System Constraints and Potential Improvements

The primary limitation to the proposed routing plan is the ability to move water westward in northern Broward County. As mentioned, this may be accomplished by retrofitting the S-39 and S-38 structures to allow southward flow along L-36, in addition to eastward flow into the Hillsboro and C-14 canals (**Figure 14**). Another option may be to install pumps at these locations to move water from the Hillsboro and C-

14 canals into L-36. A third alternative may be to install gates on the Hillsboro and C-14 canals in order maintain higher water levels and induce gravity flow into L-36.

As described above, infrastructure improvements and local agreements are needed to convey water across I-595. Future options may involve retrofitting these existing features. Other needs may include upgrading and improving maintenance of the S-38B structure that sits between the S-39 and S-38 structures along the L-36 (**Figure 14**) to improve its operational state and ability to accommodate southward flows. Installation of a water control structure and/or pump may also be needed at the fork where L-36 splits into the L-35A and C-42 canals to control the amount of water flowing between the L-35A and C-42 segments. Details concerning changes needed to these regional facilities and associated costs are currently being investigated.

The SFWMD may also reexamine water levels maintained at the various salinity control structures along Broward County's coast to allow more mounding of freshwater at their heads. This change could provide increased local recharge and help abate saltwater intrusion, as long as flood management criteria were not negatively impacted.

More direct recharge around the wellfields could potentially be obtained by implementing some additional modifications to secondary canal systems within Broward County. Currently the county is working on a C-12/C-13 interconnect project to improve water transfer between these two canals and help capture a portion of the stormwater that would normally be discharged to tide from S-36 on the C-13 canal. A similar interconnect project may be considered for the C-13/C-14 and C-12 /NNR canal basins. If diversion of water from S-39 and S-38 is not possible, it may be possible to install a direct line, and any appurtenant infrastructure, to move water from the Hillsboro canal to L-36 through the North Springs Improvement District (NSID). A new line could potentially be installed coincident with development plans, including drainage and flood management infrastructure, for the land parcel recently annexed from Palm Beach County to Broward County.

An important consideration for the C-51 reservoir project and routing options in Broward County is whether water needs to be routed south of the Interstate 595 corridor to provide additional recharge to the C-11 and C-9 canals and water supply benefits for southern Broward County interior and coastal wellfields. This route would also provide a means to deliver water to Miami-Dade County. One option is to route water further south utilizing secondary canal infrastructure within the South Broward Drainage District. Additional coordination efforts would then be needed to ensure that any required adjustments to control elevations would not compromise drainage and flood control needs within the western communities.

Water Quality in Lake Worth Drainage District and Broward County Canals

Introduction

The purpose of this section is to address urban water quality considerations, including regulatory requirements, water management concerns, and environmental constraints. Broward County has conducted a systematic and extensive water quality sampling program in the past and has thoroughly analyzed existing data to characterize water conditions and trends within its canals. By contrast, a number of water quality sampling programs have been conducted within LWDD by various entities, but sampling has not necessarily been systematic or extensive. Much of these data have not been analyzed. The most systematic analysis of LWDD data has been undertaken by the Florida Department of Environmental Protection (FDEP) as part of their statewide program to develop Total Maximum Daily Load (TMDL) criteria for surface water bodies. Currently, efforts are underway to analyze the water quality data in the LWDD canal system (LWDD, personal communication).

Runoff water quality

Nutrient concentrations and algal biomass are frequently used as indices of water quality. Nitrogen and phosphorus are the nutrients of greatest interest, however, as freshwater systems are typically considered phosphorus-limited and marine systems nitrogen-limited. Even minor increases in nutrient load to, and/or concentration in, these systems can contribute to undesirable shifts in biota and conditions of water quality impairment. Elevated nutrient concentrations and water quality impairments are often accompanied by increases in algal growth, measured as chlorophyll-*a* (Chl-*a*) concentrations. Thus, Chl-*a* can be an important indicator of water quality. Within the context of the C-51 reservoir, water quality considerations have been principally focused on total phosphorus (TP) due to water quality standards specific to the Everglades that restrict some of the otherwise preferred conveyance options.

Conveyance-Related Concerns

The quality of water within the proposed C-51 reservoir and water released to the C-51 canal needs to be considered. However, the potential also exists for water quality degradation to occur during conveyance and redistribution due to water quality issues specific to a basin or water management system. The LWDD includes a substantial secondary canal system with several existing north-south canals that could be used to route regional water from the C-51 reservoir south to the Hillsboro canal, allowing for subsequent recharge of the canal network within Broward County. This routing mechanism is attractive given the capacity of existing infrastructure to provide a relatively low-cost delivery, but water quality impairments within LWDD pose significant concerns. Several basins within the LWDD are identified by the FDEP as impaired for nutrients, including at least six basins through which C-51 reservoir water would likely be routed (see **Figure 15**).

Water Quality Conditions

In July, 2011, to better characterize the background water quality within the preferred conveyance canals and the C-51 canal, LWDD initiated a monthly surface water quality monitoring program that

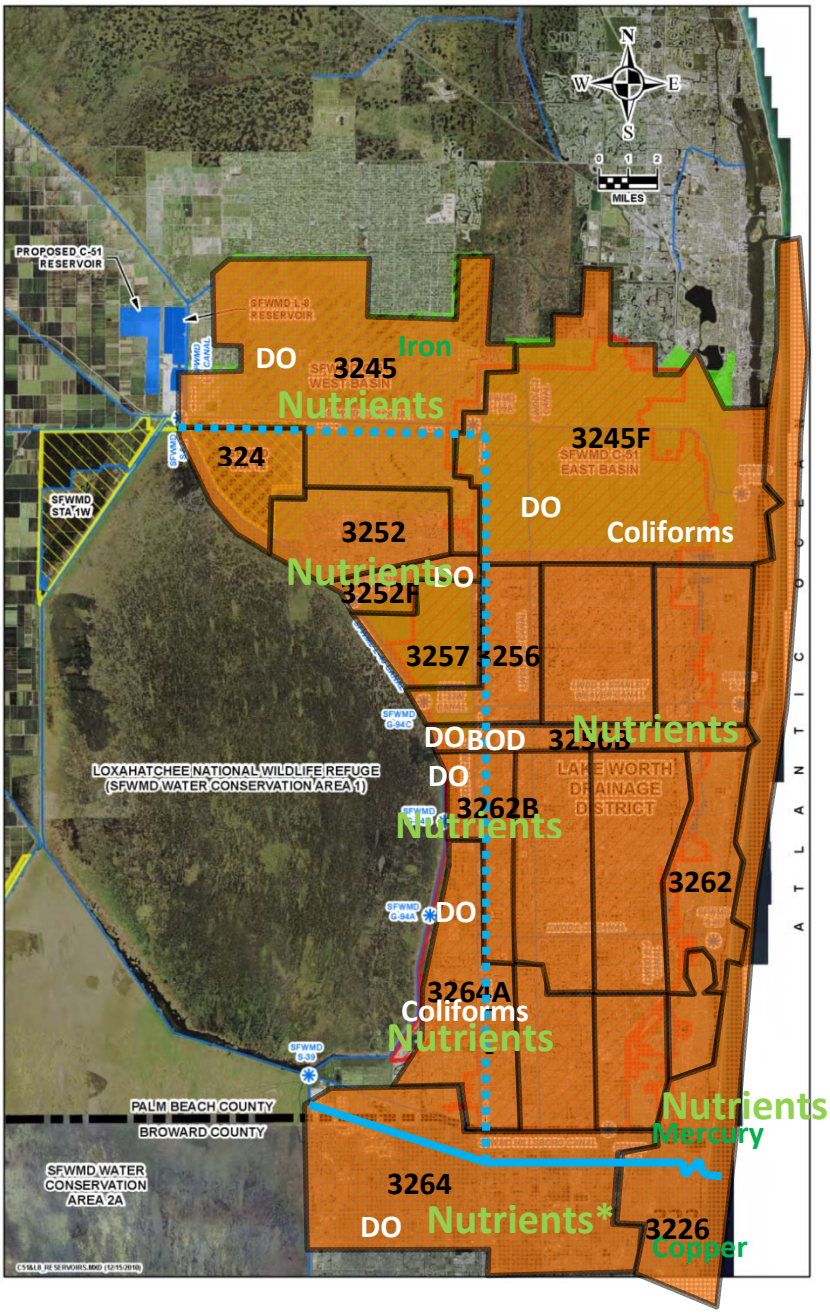

Figure 15. Basins within the LWDD that have been identified by the Florida Department of Environmental Protection as impaired for nutrients.

included assessment of total nitrogen (TN), total phosphorus (TP), and chlorophyll-*a* (Chl-*a*). These data have been reviewed and considered relative to background water quality measured in quarterly sampling of the primary canals in Broward County (**Figure 16**). This comparison is problematic because of the limited one-year period of the LWDD samples when compared to the extensive, multi-year (1998-2010) sampling data available for Broward County. These preliminary data reveal TP concentrations may be a concern. Although TP concentrations ranged from 20-50 parts per billion (ppb) at the representative C-51 sample location, TP concentrations at LWDD discharge points to the Hillsboro canal

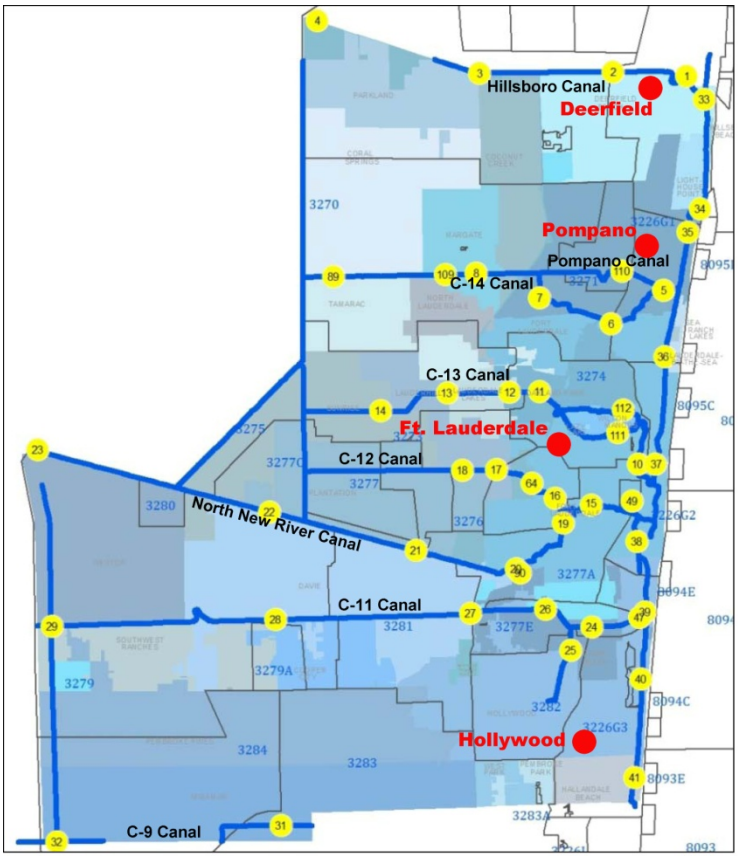

Figure 16. Stations included in quarterly sampling of surface water quality in Broward County.

ranged from 150-350 ppb at the westernmost station to 30 – 120 ppb at the easternmost station. In contrast, a 12-year data set shows that TP concentrations within the Broward County canal network achieved a mean of just 30 ppb; although substantial variability occurs both temporally and spatially (**Figure 17**). Concentrations of TP were notably higher at eastern stations along the Hillsboro canal.

Total nitrogen concentrations were relatively consistent between the representative C-51 station (0.5 to 1.4 mg/l), the LWDD canals (0.4 to 1.4 mg/l), and stations in Broward County where annual average concentrations ranged from 0.4 to 2.6 mg/l with a mean of 1.4 mg/l across all stations (**Figure 18).**

Chl-*a* followed a trend similar to that observed for TP. Values of 8 to 11 µg/l were measured in the C-51 canal and at LWDD's easternmost discharge points to the Hillsboro canal. However, Chl-*a* ranged from 27-39 µg/l in the westernmost part of the LWDD canal system, where TP concentrations were also greatest. In Broward County, the mean Chl-*a* value was 3.87 µg/l with few samples exceeding 20 µg/l and all stations having a long-term average of 10 µg/l or less (**Figure 19**).

Water Quality in LWDD Compared to Broward County Canals

The preliminary water quality monitoring performed by the LWDD suggests that the quality of C-51 Rreservoir source water might approximate that measured in Broward County's freshwater canals. The data also suggest that concentrations of total nitrogen and Chl-*a* within the LWDD are similar to those

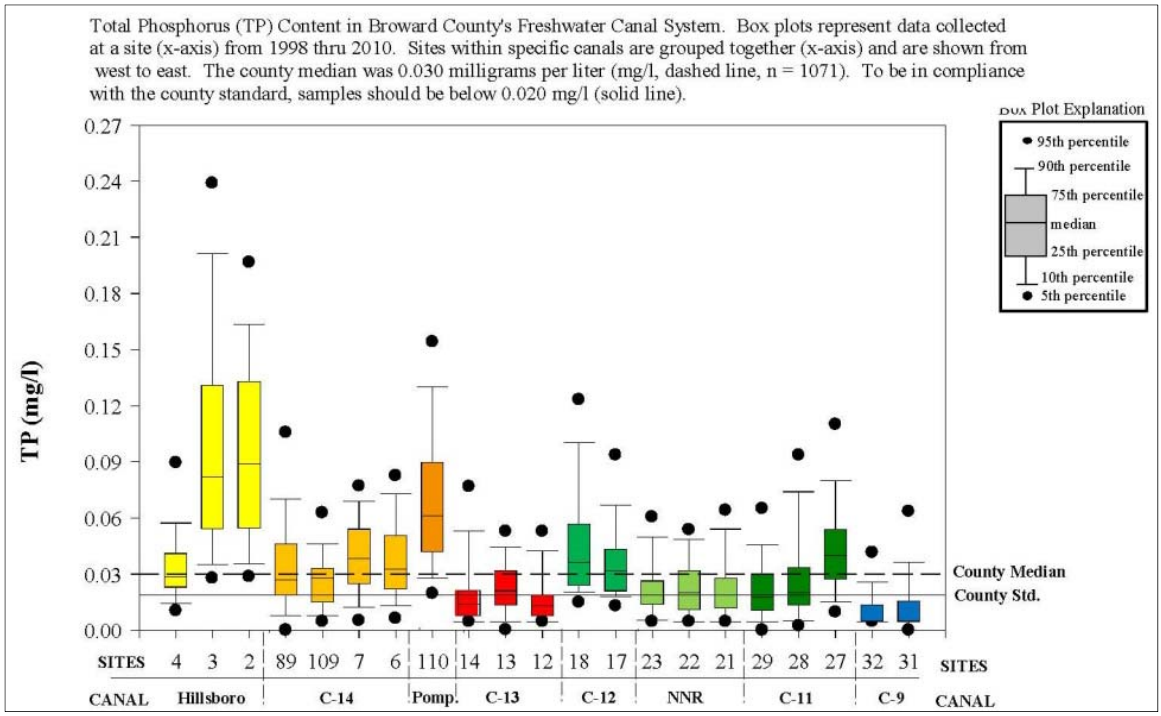

Figure 17. Total phosphorus concentrations measured in freshwater canals in Broward County

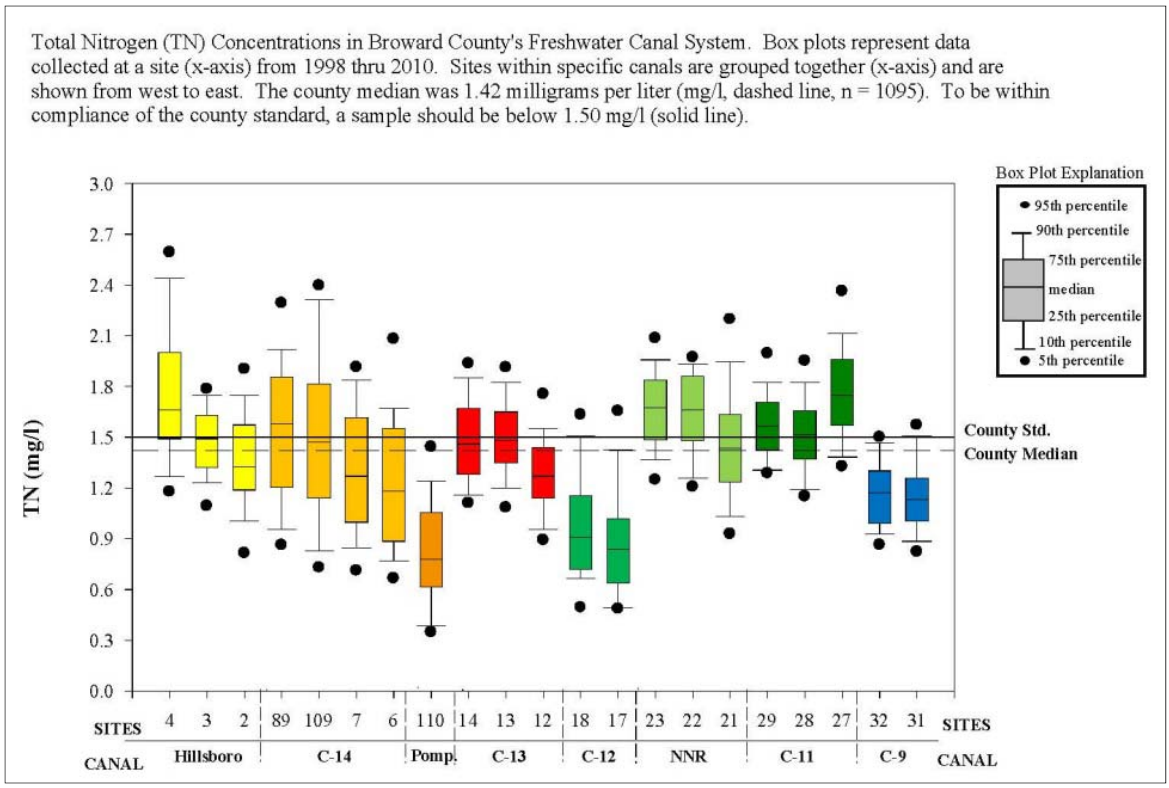

Figure 18. Total nitrogen concentrations measured in freshwater canals in Broward County

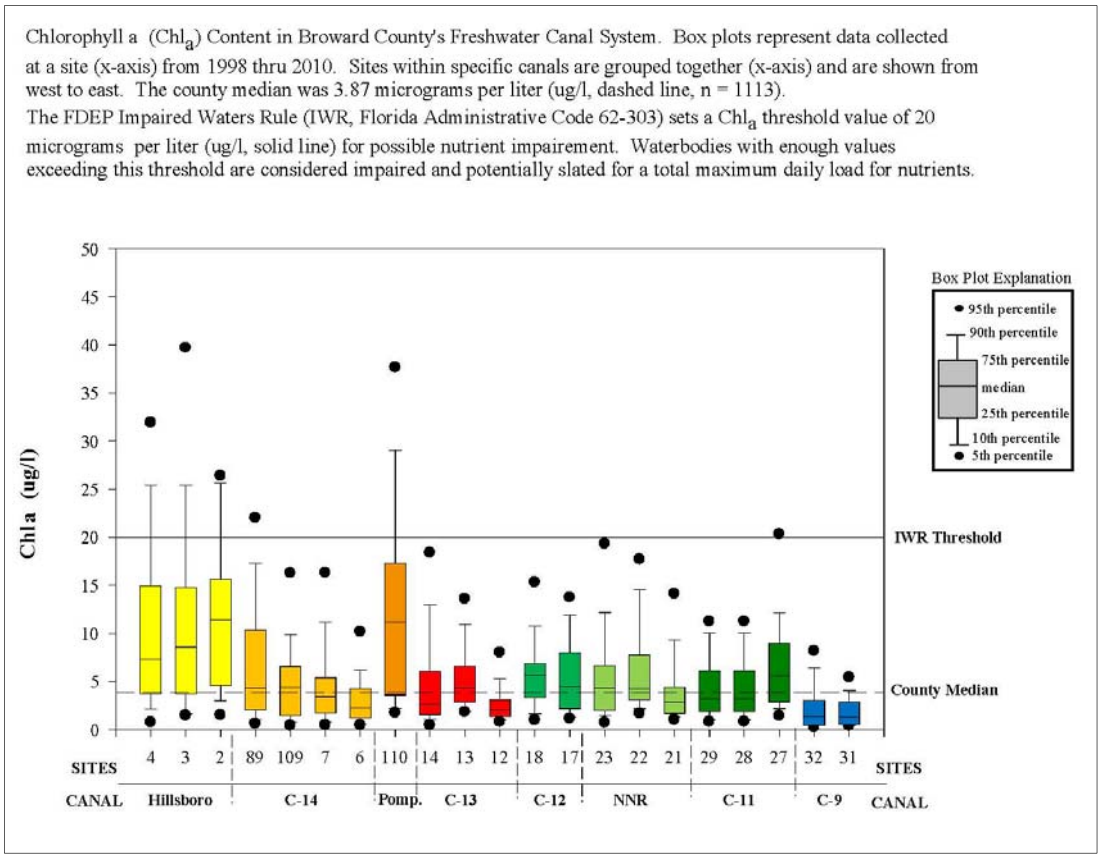

Figure 19. Chlorophyll-*a* concentrations measured in freshwater canals in Broward County

measured in Broward County. However, these analyses have also confirmed major differences between background water quality measured in the LWDD and Broward County systems for TP.

Water Management Considerations

These data and the identified water quality impairments in the LWDD system underscore the need for thoughtful development and testing of routing and operational alternatives, and any water quality improvements that might reduce the potential for water quality degradation resulting from regional C-51 canal deliveries and recharge activities. Any such impacts could potentially create liabilities for Broward County under the State's Impaired Water Rule. Broward County's water resources regulations are implemented to prevent such circumstances, with an emphasis on protecting existing water quality. Broward County's regulations prohibit any actions determined to cause or contribute to adverse water quality impacts. Section 27-193 (a) prohibits the discharge of *any substance* in such quantities as may cause receiving waters to be of quality less stringent than the water quality standards set forth in Section 27-195 or that cause pollution of water or a nuisance. Section 27-193 (b) further addresses substances that cause algal blooms by prohibiting the introduction of materials attributable to discharges producing color, odor and other floating materials that create a nuisance. It will therefore be important to conduct the necessary water quality monitoring and perform the requisite modeling to support the development of operational methods that support these requirements and avoid conflicts with state and local water quality regulations.

Cost Estimates

Reservoir and Associated Infrastructure Improvements

The following information on cost estimates was compiled from various sources. Previously, the cost of a 48,000 ac-ft reservoir, with 500 cfs pumping capacities and related conveyance infrastructure was estimated at 451.1 million in 2009 dollars (Hazen and Sawyer, 2010). Based on additional refinements to the project, which include increasing storage and pumping capacity to capture more water that is currently being discharged to tide, better estimates of future demand projections, modeling results and discussions, a reservoir of 75,000 ac-ft with 1,000 cfs pumping capacities is proposed. Current estimates for various project components of this reservoir and related conveyance infrastructure were provided by Palm Beach Aggregates, LLC, Burns & McDonnell Inc., SFWMD, LWDD and entities in Broward County. The purpose of this section is to provide updated information based upon the current configuration of the reservoir and conveyance infrastructure. This information is needed by participating parties in order to conduct additional feasibility analyses. This cost estimate is preliminary in nature and subject to adjustment as the process goes forward.

The following sections include current cost estimates for the reservoir and immediately adjacent conveyance infrastructure and pumps, a new pump station generally at the location of the S-155A structure, four pump stations in the LWDD canal system and additional infrastructure improvements in the Broward County canal system. If Miami-Dade County utilities participate in the project, additional work will be needed to address any conveyance infrastructure improvements in the Miami-Dade canal network that may be required.

Burns & McDonnell Engineer's Opinion of Probable Construction Cost (OPCC) for a 75,000 Ac-Ft Reservoir – January 2011

The engineering firm of Burns & McDonnell through Galen Miller, P.E., has prepared an independent Engineer's Opinion of Probable Construction Cost (OPCC) for the 75,000 ac-ft reservoir based on the 30% Construction Plans prepared for PBA by BCI Engineers, Inc. and a Basis of Design for certain conveyance infrastructure and pump stations prepared for PBA by Zan Kugler, P.E. Burns & McDonnell was retained by PBA for this purpose based upon its extensive experience with SFWMD and U.S. Army Corps of Engineers (USACE) projects such as the Conceptual Design for the Everglades Restoration Plan, the existing stormwater treatment areas, the Everglades Long-Term Plan, the Everglades Conveyance and Regional Treatment project, and with preparing OPCCs for government infrastructure projects.

The OPCC was developed in accordance with the requirements of Design Criteria Memoranda (DCM) – 7, jointly published by the USACE and SFWMD. Given the preliminary nature of the current design, the OPCC has been developed as a Class 3 estimate as defined in DCM-7. As explained in the OPCC, the project cost has been estimated as if the land were vacant farmland.

A complete copy of the OPCC is included in **Appendix B**, along with the *curriculum vitae* of Galen Miller, P.E. The following summary is based on the OPCC. The OPCC was developed using the USACE's MCASES/MII cost estimating software, and the detailed summaries of costs for the reservoir earthwork

and hydraulic conveyance facilities, using that software are included as additional appendices within the OPCC (**Appendix B**). Labor rates and fringe benefits were applied consistent with the most current Federal Davis Bacon wage rate determination for heavy construction in Palm Beach County. The OPCC explains the specific line items that are included and how they were developed, the assumptions, and also includes the detailed calculations for the line items as appendices.

The following summaries are taken from the OPCC. Please note that the "Estimated Unit Cost" figures are calculated from the totals in the "Estimated Total Cost" column, and as such include rounding to two decimal points. **Table 7** summarizes costs related to the reservoir itself, including the items as listed.

Table 7. Summary of Burns & McDonnell Engineer's Opinion of Probable Construction Cost for proposed reservoir earthwork.

Item #	Description	Estimated Quantity	Unit	Estimated Unit Cost	Estimated Total Cost
	Mobilization	1	LS	$4,964,760.00	$4,964,760
1	Cell excavation, peat	2,769,000	CY	$2.97	$8,231,163
2	Cell excavation, overburden	23,307,000	CY	$2.97	$69,282,671
3	Cell excavation, limestone	51,056,000	CY	$10.38	$530,044,840
4	Cell excavation, below limestone	2,501,000	CY	$7.06	$17,663,304
5	Embankment foundation excavation	2,246,189	CY	$2.97	$6,677,051
6	Perimeter embankment compaction	4,429,373	CY	$0.33	$1,456,847
7	Interior embankment compaction	320,808	CY	$0.33	$105,518
8	Soil bentonite cutoff wall	228,318	CY	$73.25	$16,723,394
9	Geocomposite drainage layer	336,266	SY	$9.58	$3,222,837
10	RCC construction, plate(int. slope & roadway)	199,602	CY	$54.76	$10,930,528
11	RCC construction mass (spillway structure)	134,699	CY	$54.76	$7,376,274
12	Limerock road base	2,404	CY	$22.34	$53,705
13	Relief drain	5,900	LF	$24.01	$141,684
14	Blanket drains (downstream)	27,800	LF	$69.39	$1,928,999
15	Toe drain (upstream)	42,200	LF	$90.81	$3,832,185
16	Topsoil, seed & mulch	653	AC	$6,994.85	$4,567,634
17	Breech excavation	1,401,247	CY	$3.48	$4,882,385
18	Erosion control	90,155	LF	$10.13	$913,607
19	Dewater completed cells (C&C of water)	1	LS	$300,000.00	$300,000
20	Fine grading of cell floors	7,521,360	SY	$0.19	$1,452,826
21	Demobilization	1	LS	$3,309,840.00	$3,309,840
	Subtotal Direct Cost				**$698,062,051**
	Home office overhead	5%		of direct cost	$34,903,103
	Bonds and insurance	2%		of direct cost	$13,961,241
	Profit	10%		of direct cost	$69,806,205
	Subtotal				**$816,732,600**
	Contingency (cell excavation)				$62,522,198
	Contingency (all other construction)				$20,306,287
	Subtotal Estimated Cost in Current Dollars				**$899,561,085**
	Allowance for escalation				$74,740,219
	Subtotal Opinion of Probable Construction Cost				**$974,301,303**

The summary in **Table 8** includes the 1,000 cfs conveyance crossing from the C-51 canal under Southern Boulevard, a new pump station having a pumping capacity of 1,000 cfs on the north side of Southern Boulevard, a 1,000 cfs conveyance crossing under the existing L-8 canal, a 1,000 cfs east-west conveyance canal from the L-8 conveyance crossing to the north-south conveyance canal, a 2,000 cfs north-south conveyance canal, a 1,000 cfs conveyance crossing from the L-12 canal under Southern Boulevard to the north-south conveyance canal, and inflow structure and a C-51 reservoir inflow and

Table 8. Summary of engineer's Opinion of Probable Construction cost for hydraulic conveyance facilities

Item #	Description	Estimated Quantity	Unit	Estimated Unit Cost	Estimated Total Cost
1	C-51 reservoir pump station	Job	LS	LS	$21,212,779
2	Fine grading of cell floors	Job	LS	LS	$13,352,423
3	Culverts and conveyance canals	Job	LS	LS	$16,640,315
	Subtotal Direct Cost				**$51,205,517**
	Home office overhead	5%		5%	$2,560,276
	Bonds and insurance	2%	Of Direct Cost		$1,024,110
	Profit	10%	Of Direct Cost		$5,120,552
	Subtotal				**$59,910,455**
	Contingency (all other construction)			30%	$15,361,655
	Subtotal Estimated Cost in Current Dollars				**$75,272,110**
	Allowance for sscalation			4.80%	$3,613,061
	Subtotal Opinion of Probable Construction Cost				**$78,885,171**

water supply pump station having a gravity capacity of 2,000 cfs and a pumping capacity of 1,000 cfs as well as a control and command center for remote operation and monitoring. The OPCC totals $1.054 billion by phase as follows (rounded from the detailed OPCC in **Appendix B**):

- Phase 1 - $311 million, composed of $232 million for reservoir earthwork and $79 million for the hydraulic conveyance facilities.
- Phase 2 - $365 million
- Phase 3 - $378 million

The OPCC was developed on the basis of currently available design information, which is preliminary in nature and subject to potentially significant change.

The OPCC does not include certain items that would be part of the total project costs. As identified in the OPCC, these items generally include the relocation of canals and roadways serving the adjacent agricultural uses, the mitigation area as shown on the plans, the 1,000 cfs pump station at S-155A in the C-51 canal, expenses to date, additional surveys, additional subsurface investigation, planning, engineering and design, bid solicitation or negotiation and construction contract award, construction management, permanent power supply for the pump stations, project commissioning and turnover. The OPCC also excludes land acquisition, permitting, financing, owner's cost for project management and administration, owner's risk and insurance, and the operation and maintenance of the completed facilities. The OPCC does not include processing of the excavated rock to a salable product or any consideration of owner revenues resulting from such possible sales over time.

Palm Beach Aggregates, LLC (PBA) Current Cost Estimates for 75,000 Ac-Ft Reservoir

Palm Beach Aggregates, LLC (PBA) provides the following preliminary estimate to assist all interested parties in conducting subsequent feasibility analyses, as set forth in the Memorandum of Understanding. This summary estimate is provided for review and further discussion, recognizing that it is based upon 30% construction plans and includes the following assumptions.

Design Assumptions. The PBA preliminary estimate for additional feasibility analysis purposes includes all of the items included in the Burns & McDonnell Opinion of Probable Construction Cost (discussed

above and included in **Appendix B**). The PBA preliminary estimate also includes land, the relocation of agricultural roadways and drainage canals, construction of the mitigation area, expenditures to date for planning, site investigation, conceptual and preliminary design, additional surveys and subsurface investigations necessary for completion of design, further planning, engineering and final design, bid solicitation or negotiation and construction contract award, construction management, project commissioning and turnover, dredging of Phase 1 to achieve a consistent bottom elevation, dredging of phases 2 and 3 as needed, engineering and professional services, owners costs for overall project management and administration, owners risk and insurance, performance risk and execution risk. The PBA preliminary estimate is based upon PBA's wage rates rather than Federal Davis Bacon wage rates as the project is not anticipated to include Federal funds.

The PBA preliminary estimate includes a reduction for the net present value of the rock materials that will be excavated and stockpiled, with consideration of the management of these stockpiled materials for the 25 + years they are currently estimated to be stored (to meet the project construction schedule of 7 years, rather than the 25 + years of currently anticipated market driven excavation timetable).

Recognizing that additional detail and description, along with independent verification by the utilities or other participants, would be needed for the project to proceed beyond the current additional feasibility analysis stage, PBA's current preliminary estimate to deliver the reservoir and adjacent infrastructure, within the seven-year construction schedule, is $695,000,000.

The above estimate assumes that PBA would construct the project on behalf of the project sponsor, pursuant to an agreed upon construction draw schedule, without the need for PBA to obtain construction or other financing. Under that type of structure, the project sponsor, utilities or other participants would be responsible for obtaining the funding for the project.

The PBA preliminary estimate is based upon the current design and 30% construction plans, which are subject to change. One possible change for near-term discussion is the intersection of the C-51 canal, L-8 canal, L-12 canal and the conveyance canal to the C-51 reservoir, which could result in a simpler design and perhaps a lower cost. As these preliminary estimates, current plans and design are reviewed and discussed, other alternatives may become apparent, which could impact these estimates.

The PBA preliminary estimate does not include the SFWMD pump station at the S-155A structure, any improvements within the LWDD and Broward County canal systems, financing expenses, capitalized interest during construction, expenses for operations and maintenance of the completed facilities, capital expenditures over time or any costs or expenses incurred by parties other than PBA with respect to the project.

Design Features. The particulars include a reservoir having 75,000 ac-ft of storage, a 1,000 cfs conveyance crossing from the C-51 canal under Southern Boulevard, a new pump station having a pumping capacity of 1,000 cfs on the north side of Southern Boulevard, a 1,000 cfs conveyance crossing under the existing L-8 canal, a 1,000 cfs east-west conveyance canal from the L-8 conveyance crossing to the north-south conveyance canal, a 2,000 cfs north-south conveyance canal, a 1,000 cfs conveyance crossing from the L-12 canal under Southern Boulevard to the north-south conveyance canal, and inflow

structure and a C-51 reservoir inflow and water supply pump station having a gravity flow capacity of 2,000 cfs and a pumping capacity of 1,000 cfs.

The current design increases the size of the north-south conveyance canal from 1,000 cfs to 2,000 cfs, the pumping capacity of the C -51 reservoir pump stations from 500 cfs to 1,000 cfs, includes a connection to the L-12 canal for additional operational flexibility and includes a control and command center for remote operation and monitoring of all system controls and pumps.

The reservoir itself will have storage 44 feet deep, with the majority below ground and a portion above ground. With a ground elevation between approximately 10 and 15 feet NAVD (rising south to north), the below ground storage will be between approximately 30 and 35 feet (to a maximum depth of -20 NAVD) and the above ground storage will be between approximately 9 and 14 feet. The below ground portion of the storage is limited to depths where the chloride concentrations are lower than drinking water standards, based upon extensive soil borings and water quality sampling as part of the FDEP permitting process for the mining operation. The containment structure has been designed to "post-Katrina" standards for above ground impoundments, approximately 22 and 25 feet above ground. All elevations will be tied to NAVD for consistency and to account for the gradient of the ground elevations.

The reservoir construction is proposed in 3 phases. Phase 1 will include approximately 10,000 ac-ft of storage, a portion of the embankments and spillways, all pump stations and conveyance canals connecting to the C-51 and L-12 canals. Phase 1 will therefore be fully operational at the completion of construction. Relocation of drainage canals and access roads serving the agricultural land uses adjacent to the project is included.. Phase 1 is projected for completion 2.5 years after notice to proceed. Phase 2 will include approximately 20,000 ac-ft of additional storage (for a cumulative total of about 30,000 ac-ft), additional portions of the embankments and spillways. Phase 2 is projected for completion 5 years after the initial notice to proceed. Phase 3 will add approximately 45,000 ac-ft of storage, for a cumulative total storage of about 75,000 ac-ft. Phase 3, and will include the final portions of the embankments and spillways and is projected for completion 7 years after the initial notice to proceed.

The surface area of the storage cells of the completed reservoir will total approximately 1,500 acres. The project will also include the land needed for the areas between the storage cells, the containment structure surrounding the reservoir, spillways, conveyance canals and pump stations.

S-155A Structure Costs

The cost for the proposed 1000 cfs S-155A pump station was estimated by SFWMD staff based on the actual cost for a similar facility built at another site in western Palm Beach County (**Table 9**).

Table 9. Estimated 2008 costs for construction of a 1000 cfs pump station.

Year Built	Structure + Equipment Cost	Capacity CFS	Construction Cost Index History	2012 Escalated Price	2012 Price Per CFS
2008	28,418,289	1120	8090	31,650,035	28,259

The cost of land is not included because the exact site has not been determined. Some additional adjacent land will be required, but It may be possible to build much of the structure within existing

SFWMD right-of way. Assuming the new location is closer (less transportation and access costs), the approximate 2012 cost for 1000 cfs pump station (not including land for the western site used for comarison) would be about $25,000/cfs or $25 million.

LWDD Improvements

Introduction

The following summary provides the basis of the opinion of probable costs developed for the proposed hydraulic structures of the Lake Worth Drainage District (LWDD) for delivery of stored C-51 reservoir water to Broward County. These costs were described in a document entitled, "C-51 Reservoir Project - LWDD Water Supply Structures, December 30, 2011 Preliminary Cost Estimate." A copy of this document is included in **Appendix B, Part 2**. The costs represent a conceptual level estimate for the construction of the project's pump stations and control structures for LWDD E-1 canal. The detail of the estimate was limited to the extent necessary to produce an initial budget for the selected alternative.

Scope of Work

The project involves the supply of water stored in the C-51 reservoir via South Florida Water Management District's C-51 canal to the LWDD E-1 canal. It is proposed the E-1 canal convey a total capacity of 225 cfs (145 mgd) south to Broward County's conveyance system. The proposed facilities include:

Pump Station No. 1: A (150 cfs) pump station is to be constructed east of the existing LWDD CS-2 gated spillway located at the confluence of the E-1 and C-51 canals.

Pump Stations No. 2, 3, and 4: Three additional pump stations (225 cfs) are proposed to convey water from C-51 canal south via the E-1 canal through the LWDD.

Additional Costs

In addition to the above new required infrastructure, two existing LWDD control structures, #3 and #20, will need to be replaced.

Methodology

The preliminary cost estimate was prepared using quantity take-offs from the facility concept drawings. No structural design has been performed to date. The preliminary cost estimate includes direct labor costs as part of the construction item total. The cost total for the construction component line item was reviewed as an overall unit rate and compared to historic data where available. Also a budget level quote was obtained for the reservoir station pumping equipment from MWI Pump Company.

Indirect Costs

Local sales tax was assumed to be included as part of the materials or equipment rental direct costs. A 1.5% overall mark-up was included to cover builder risk, general liability, and vehicle insurance and 6% overhead mark-up was added to cover costs such as home office expenses.

Contingency

Due to the conceptual level nature of the design, a 30% contingency was added to the overall construction cost total.

Summary of Estimated Costs

The costs shown in **Figure 10** represent an initial concept design for the proposed facilities. See **Appendix B** for additional details.

Table 10. Summary of construction costs for improvements to Lake Worth Drainage District infra-structure needed to convey additional water from the C-51 reservoir south to Hillsboro canal.

Description	Date: 12-30-2011
1. Pump station no.1	**$5,788,264**
2. Pump station no.2	**$6,737,361**
Ps no.2 spillway	**$2,278,373**
3. Pump station no.3	**$6,737,361**
Ps no.3 spillway	**$2,278,373**
4. Pump station No.4	**$6,737,361**
Ps no.4 spillway	**$2,278,373**
5. Existing control structure replacement	
Control no. 3	**$250,000**
Control no. 20	**$250,000**
PROJECT TOTAL	**$33,335,466**

Operation and Maintenance

Operation and maintenance cost may vary greatly. A preliminary estimate of these costs was developed in 2009 as follows, which that can be used as a basis to calculate annual O&M costs, after additional project details have been defined:

Maintenance of gated structures	$5,000.00 per year
Operation of gated structures (man power)	$115,200.00 per year per pump
Maintenance of pump stations	$5,000.00 per year per pump
Electricity to operate pump stations	$30,000.00 per year

Broward County Improvements

Costs for potential projects and improvements within the water control districts managed by Broward County in the northern part of the county are shown in **Table 11**

Table 11. C-51 proposed project list for water control districts managed by Broward County and adjoining Pinetree Water Control District.

Map Ref.	Scope of Project	Cost Estimate
1	New 2-9,000 GPM pumps at CS 45 at Hillsboro canal	$300,000
2	New 2-9,000 GPM pumps for Pinetree WCD at Hillsboro canal	$350,000
3	Basin interconnection of C-4 canal through Tradewinds North Park	$750,000
4	Basin interconnection of C-5 canal from Sample Road to Wiles Road	$600,000
5	Basin interconnection of C-1 canal under Sample Road	$300,000

Total	**$2,300,000**

Regional System Improvements [Being investigated by SFWMD]

Combined Preliminary Cost for all Improvements and Unit Calculations

The compilation of these current estimated costs for the 75,000 ac-ft reservoir, according to the categories used by Hazen and Sawyer (2010), is set forth in **Table 12** below:

Table 12. Current estimated capital costs for infrastructure needed for the C-51 reservoir project.

Reservoir and Related Infrastructure (Using Palm Beach Aggregates Estimate)	
(1) C-51 reservoir construction and property	
(3) Southern Boulevard conveyance crossing	
(4) S5AE pump station (between C-51 and L-8 conveyance crossing)	
(5) L-8 canal conveyance crossing	
(6) C-51 reservoir conveyance canal and inflow structure	
(7) C-51 reservoir inflow and water supply pump station	
Sub Total	**$695.0 million**
C-51 Canal Improvements SFWMD	
(2) S155A pump station	$ 25.0 million
Broward County Canal Improvements	
(8) Broward County 298 district improvements	$ 2.3 million
LWDD Improvements	
(9) LWDD improvements	$ 33.3 million
Total	**$755.6 million**

Per Unit Cost Calculations

All of the calculations below are provided as an "apples to apples" comparison to the methodology included in the Hazen and Sawyer (2010) Report. The methods used by Hazen and Sawyer (2010) convert the total project cost into unit costs per gallon in three ways:

(1) cost per raw water offset, which is the amount of raw water in mgd that would result from the reservoir storage;

(2) cost per raw water provided, which is the amount of raw water in mgd that could be withdrawn from the surficial aquifer by the utilities based on the raw water offset obtained from (1) above and a recharge-to-withdrawal ratio of 0.75; and

(3) cost per potable water provided, which is the amount of treated water in mgd expected from (2) above using a treatment ratio of 0.85.

This methodology estimates the annual operations and maintenance (O&M) costs and converts the total capital and O&M costs to a total cost per 1,000 gallons. This total cost per 1,000 gallons assumes that 100% of the capacity is reserved in advance, with capital costs financed over a 20-year time frame at an average tax-exempt interest rate of 6% structured with level debt service. These calculations make no provisions for capitalizing interest costs through construction, funding necessary debt service reserves, O&M reserves or stabilization reserves, capital expenditures over time or O&M inflation.

Based upon modeling conducted by SFWMD, the 75,000 ac-ft reservoir would be capable of producing 185 mgd of water. Using the same calculations as in the report by Hazen and Sawyer (2010), 185 mgd from the reservoir would result in 246 mgd of raw water that could be withdrawn (0.75 ratio) and 209 mgd of potable water that could be provided (0.85 ratio). These calculations will be used below, recognizing that the final recharge-to-withdrawal ratio will depend upon the specific utilities participating, and that the final amounts will be based upon additional work to be conducted. The updated cost estimates are based upon 30% construction plans, some increases in the reservoir pump capacity, and more detailed investigation of the current cost of the reservoir and conveyance.

The format and formulas of Table 3.2 from the Hazen and Sawyer (2010) report are depicted in **Table 13**. **Table 13** uses current estimates by PBA, SFWMD, LWDD and Broward County, with an increase of O&M costs from the Hazen and Sawyer (2010) report to $2.4 million a year.

Table 13. Updated unit costs using the format of Table 3.2 from the Hazen and Sawyer (2010) report. Estimated capital, O&M and unit costs of proposed 75,000 ac-ft C-51 reservoir in 2011 dollars, financed for 20 years, using LWDD conveyance alternative. 100% of reservoir capacity is used.

Type of Cost	mgd	Capital Cost (millions $)	Annual O&M Cost (million $)	Capital Cost ($/Gal of Water)	Annual O&M Cost ($/1,000 Gal. of Water)	(20 yr Term) Total ($/1,000 Gal. of Water (a)
(1)		(2)	(3)	(4) (2) / mgd	(5) ((3) x 1,000)/ (mgd x 365)	(6)
Cost per water offset (185 mgd)	185	$755.6	$2.4	$4.08	$0.04	$1.01
Cost per raw water provided (246 mgd)	246	$755.6	$2.4	$3.07	$0.03	$0.76
Cost per potable water produced (209 mgd)	209	$755.6	$2.4	$3.62	$0.03	$0.90

(a) **Based on 20 year municipal bond at 6 percent annual interest, with limitations as explained below.**

(b) **The 246 mgd was based on a recharge-to-withdrawal ratio of 0.75 based on the findings in the 2010 H&S Report and is a weighted average that will vary depending on the utilities included and the unmet demands of these utilities.**

(c) **Does not include the cost of water treatment and distribution, which will depend upon whether stranded treatment capacity exists for individual utilities and other individual circumstances.**

This cost per 1,000 gallons assumes that 100% of the capacity is reserved in advance, with capital costs financed through 20 year tax-exempt financing and an average interest rate of 6% structured with level debt service. Please note that these calculations are for comparative purposes only to the Hazen and Sawyer (2010) report and make no provisions for capitalizing interest costs through the 7 year construction period, funding debt service reserves, O&M reserves or stabilization reserves, capital expenditures over time or O&M inflation. These and other financing components would need to be analyzed and added to the above calculations and to the Hazen and Sawyer (2010) calculations.

For reference purposes, **Table 14** shows costs of using 30 years as the financing term instead of 20 years. **Table 15** and **Table 16** compare costs using 80% reserved capacity instead of 100% reserved capacity, for 20-year and 30-year terms, respectively. Additional analyses will be needed of the design alternatives for the various project components (reservoir, SFWMD, LWDD, Broward 298 Districts), annual O&M costs of the various project components, the number of participants and the percent capacity to be reserved, the length and cost of financing and various structure and governance options.

Table 14. Updated costs for a 75,000 ac-ft reservoir as in Table 12, financed over a 30-year term.

Type of Cost	mgd	Capital Cost (millions $)	Annual O&M Cost (million $)	Capital Cost ($/Gal of Water)	Annual O&M Cost ($/ 1,000 Gal. of Water)	(30 yr Term) Total ($/1,000 Gal. of Water) (a)
(1)		(2)	(3)	(4) (2) / mgd	(5) ((3) x 1,000) / (mgd x 365)	(6)
Cost per water offset (185 mgd)	185	$755.6	$2.4	$4.08	$0.04	$0.85
Cost per raw water provided (246 mgd)	246	$755.6	$2.4	$3.07	$0.03	$0.64
Cost per potable water produced (209 mgd)	209	$755.6	$2.4	$3.62	$0.03	$0.75

Table 15. Updated costs for a 75,000 ac-ft reservoir as in Table 12, financed for 20 years, using 80% instead of 100% reserved capacity.

Type of Cost	mgd	Capital Cost (millions $)	Annual O&M Cost (million $)	Capital Cost ($/Gal of Water)	Annual O&M Cost ($/ 1,000 Gal. of Water)	(30 YR Term) Total ($/1,000 Gal. of Water) (a)
(1)	(x0.8)	(2)	(3)	(4) (2) / mgd	(5) ((3) x 1,000) / (mgd x 365)	(6)
Cost per water offset (185 mgd)	148	$755.6	$2.4	$5.11	$0.04	$1.26
Cost per raw water provided (246 mgd)	196.8	$755.6	$2.4	$3.84	$0.03	$0.95
Cost per potable water produced (209 mgd)	167.2	$755.6	$2.4	$4.52	$0.04	$1.12

Table 16. Updated costs for a 75,000 ac-ft reservoir as in Table 12, financed for 30 years, using 80% instead of 100% reserved capacity.

Type of Cost	mgd	Capital Cost (millions $)	Annual O&M Cost (million $)	Capital Cost ($/Gal of Water)	Annual O&M Cost ($/ 1,000 Gal. of Water)	(30 YR Term) Total ($/1,000 Gal. of Water) (a)
(1)	(x0.8)	(2)	(3)	(4) (2) / mgd	(5) ((3) x 1,000) / (mgd x 365)	(6)
Cost per water offset (185 mgd)	148	$755.6	$2.4	$5.11	$0.04	$1.06
Cost per raw water provided (246 mgd)	196.8	$755.6	$2.4	$3.84	$0.03	$0.80
Cost per potable water produced (209 mgd)	167.2	$755.6	$2.4	$4.52	$0.04	$0.94

Cost Comparison of Water Supply from the Reservoir vs Water from Other Alternative Sources

The current estimated cost of the 75,000 Ac-Ft C-51 reservoir and infrastructure improvements, based upon 30% construction plans, current preliminary design, and using the LWDD conveyance alternative is $755.6 million in 2011 dollars. Estimated unit costs using the Hazen and Sawyer (2010) report methodologies are shown in **Table 17.**

Table 17. Estimated cost per gallon of water obtained from the 75,000 ac-ft C-51 reservoir and infrastructure improvements

Cost Components	Recharge Capacity (185 mgd)	Resulting Estimated Potable Water (209 mgd)[1]
Capital cost in $/gallon	$4.08	$3.62
Annual O&M cost in $/1,000 gallons [2]	$0.04	$0.03
Total cost in $/1,000 gallons based on Hazen and Sawyer (2010) methods[3]	$1.01	$0.90

[1] Resulting Estimated Potable Water is based upon Recharge Capacity, then average recharge-to-withdrawal ratio of 0.75 from the Hazen and Sawyer (2010) report, then average treatment efficiency of 0.85 (Hazen and Sawyer, 2010. The actual amount of potable water provided by reservoir capacity will vary depending on the utilities included, individual circumstances and well field locations.

[2] Does not include the cost of water treatment and distribution, O&M inflation or future capital-expenditures, which will vary by utility. These costs will also depend upon whether stranded treatment capacity exists for individual utilities.

[3] Converts one time capital cost of $4.08 per gallon of reservoir capacity (or $3.62 per gallon of estimated resulting potable water) to a total cost per 1,000 gallons using the Hazen and Sawyer (2010) report methodology for comparative purposes. The Hazen and Sawyer (2010) report methodology financed the capital costs over a 20 year time frame at an average interest rate of 6.00% , structured with level debt service, assuming that 100% of reservoir capacity was reserved in advance. Note that neither of these calculations nor the Hazen and Sawyer (2010) report calculations include provisions for capitalizing interest costs through the seven year construction period, funding debt service reserve, O&M or stabilization reserve funds. Costs are in 2011 dollars.

Table 18 and **Table 19** provide a side-by-side comparison of various alternative water supply options, using information from this report, the previous Hazen and Sawyer reports, and other information as noted, based generally on the methods used by Hazen and Sawyer (2010). Although these examples are from different size systems, producing different capacities of potable water and with different total capital costs, the capital cost in dollars per gallon of water capacity, the annual O&M cost in dollars per thousand gallons of water and the total cost per thousand gallons of water figures provide a rough comparison among various alternatives.

Table 18. Alternatives for producing raw water for recharge -- estimated mgd of potable water that could result from each source, based upon a recharge to withdrawal ratio of 0.75 and a treatment efficiency of 0.85, and cost calculations for each.

Project	Potable Water (mgd)	Capital Cost (million $)	Annual O&M Cost (million $)	Capital Cost ($/Gal of Water)	Annual O&M Cost ($/1,000 Gal. of Water) (a)	Total Cost ($/1,000 Gal. of Water (b)
C-51 reservoir 75,000 ac-ft (PBA 2011, Appendix B, Part 2)	209	$755.6	$2.4	$3.62	$0.03	$0.90
C-51 reservoir 75,000 ac-ft B&M 2011 OPCC, Appendix B, Part 1) (c)	209	$1,054.0	$2.4	$5.04	$0.03	$1.24
Reclaimed water recharge (d)	75	$683.0		$9.13	$1.94 (d)	$4.12
Miami-Dade ground water recharge - reclaimed water (e)	18.6	$357.5 (e)		$19.22 (e)	$1.94 (d)	$6.53
Miami Dade canal recharge using reclaimed water (e)	21.0	482.0 (e)		$22.95(e)	$1.94 (d)	$7.42

(a) Does not include the cost of water treatment and distribution, which will depend upon whether stranded treatment capacity exists for individual utilities and other individual circumstances, or any impacts relating to additional water quality standards.

(b) Based on 20 year municipal bond at 6 percent annual interest, with limitations as explained herein.

(c) Burns & McDonnell OPCC does not include land or other items as explained above and in the OPCC.

(d) Conceptual Feasibility of a Sub-Regional Lower East Coast Water Supply Solution, prepared by Hazen & Sawyer in association with MacVicar, Federico & Lamb, Inc (2009).

(e) Miami-Dade Water Consolidated PWS Consumptive Use Permit 13-00017-W November 1, 2010, File Information from Exhibit 28 attached to letter dated December 21, 2009.

Table 19. Alternatives that would result in treated water - estimated capital and O&M costs of desalinating brackish water from the Floridan Aquifer. Table depicts mgd of potable water .

Project	Potable Water (mgd)	Capital Cost (millions $)	Annual O&M Cost (million $)	Capital Cost ($/Gal Potable Water)	Annual O&M Cost ($ / 1,000 Gal. of Potable Water)	Total Cost ($/1,000 Gal. of Water) (a)
Floridan reverse osmosis (b)	136	$952.0		$6.00 (c)	$1.40 (c)	$2.83
Floridan reverse osmosis using $10 capital cost/gal	136	$1,360.0		$10.00 (d)	$1.40 (c)	$3.79
Miami Dade Hialeah reverse osmosis estimate	8.5	$93.0 (e)		$10.94 (e)	$1.40 (c)	$4.01

(a) Based on 20 year municipal bond at 6 percent annual interest, with limitations as explained herein

(b) This project would result in 136 mgd of potable water. Cost includes pumping from Floridan aquifer, concentrate disposal and treatment to potable water quality. Source: Conceptual Feasibility of a Sub- Regional Lower East Coast Water Supply Solution, Phase 2A, Hazen and Sawyer in association with MacVicar Federico and Lamb, Inc. for the City of Fort Lauderdale and participating utilities, January 2010.

(c) Conceptual Feasibility of a Sub- Regional Lower East Coast Water Supply Solution, prepared by Hazen and Sawyer in association with MacVicar Federico and Lamb, Inc. for the City of Fort Lauderdale and participating utilities, February 2009.

(d) Estimate based upon recent project costs.

(e) Miami-Dade Water Consolidated PWS Consumptive Use Permit 13-00017-W November 1, 2010, File Information from Exhibit 28 attached to letter dated December 21, 2009.

Conclusions and Recommendations

1. The planning investigations documented in this report provide initial information necessary to assess the feasibility of the C-51 reservoir as a potential source of water for future regional public water supply needs of Palm Beach and Broward counties. The report and the modeling tools developed for this planning exercise may be used as the basis for future work on the C-51 reservoir to determine regulatory feasibility.

2. SFWMD should facilitate meeting the permitting criteria necessary for developing water supply from the C-51 reservoir. Participating utilities will actively engage with SFWMD in discussions regarding the requirements of existing regulatory framework.

3. Jointly with LWDD staff and the local water management agencies in Broward County, SFWMD should determine operational feasibility and a strategy for conveying water from the C-51 reservoir and coordination with the current deliveries from the existing regional system. This effort should lead to the development of new facilities required to convey water which may be used for the detailed design phase of the project.

4. Participating stakeholders should develop a detailed design report and further refine the cost estimates for the C-51 reservoir projects as well as a plan for recovering the capital costs and the payments for the operations and maintenance of the facilities of the C-51 project.

5. Options to retrofit Interstate Highway-595 should be examined in a subsequent investigation.

6. If it is determined that project benefits should be extended further south to include some portion of the Miami-Dade County service area, the canal identified as being the most advantageous for such deliveries is the C-11S canal. Once again the issue of conveying water from the North New River to southern canals would have to be addressed. In addition, potential impacts of increased water deliveries on groundwater levels in low-lying areas of southwest Broward County must be considered. In these areas, canal stages are held at lower control elevations due to specific water management operations in support of drainage and flood control needs.

7. Analyses conducted for both Palm Beach and Broward counties have dealt primarily with conveying water from north to south. In order to provide effective recharge to coastal wellfields, improved capabilities must be provided to move water east through existing canals or alternative conveyance means such as pipelines.

8. SFWMD should reexamine the wet season and dry season water levels maintained in coastal Broward County canals above the salinity structures to determine if they are already at the maximum allowable levels or if there is opportunity to hold more freshwater in the upstream canals and coastal aquifer.

9. More extensive water quality data are needed for LWDD. Part of this need may be addressed by systematically compiling and analyzing available historical data sets from other agencies and

entities, including SFWMD, USGS, FDEP, Palm Beach County and local municipalities. Due to potential water quality issues and concerns, implementation of a systematic monitoring program should be considered as a component of operation/maintenance of the C-51 reservoir project to determine water quality at critical locations throughout the water capture, storage and distribution systems.

10. Broward County and LWDD need to determine how best to resolve water quality issues that may impede the ability to move water within and between primary and secondary canal networks.

11. Capital costs of the project range from $755.6-$1,054 million, operations and maintenance costs are estimated as $2.4 million/year, and usage is estimated at 185 mgd from the reservoir. The cost of water from the reservoir ranges from $0.90 to $1.24/1000 gallon. This compares to costs of $4.12 to $7.42/1000 gallons for groundwater recharge methods, and $2.83 to $4.01 for reverse osmosis technologies.

12. Based on the total estimated capital cost for the system components analyzed so far, costs of obtaining water from the C-51 reservoir appear to be lower than costs of water from other commonly-used alternative water supply sources.

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