Greater Beirut Water Supply Project:
Independent Technical Review of Source Water Quantity

May 31, 2011

Dr. Jamie Bartram, Director of the Water Institute at UNC
Joseph LoBuglio P.E.

Created for the World Bank
Sustainable Development Department
Middle East and North Africa Region
by the Water Institute at UNC

UNC GILLINGS SCHOOL OF GLOBAL PUBLIC HEALTH | THE WATER INSTITUTE

Summary and Key Findings

Summary

The Water Institute at UNC[1] was asked to provide an independent technical review concerning the availability of water for a water treatment facility serving the Greater Beirut area of Lebanon, to be built as part of the Greater Beirut Water Supply Project (GBWSP). This review is based largely on the results of an April 2011 site visit to Lebanon by a senior UNC water engineer, and on data obtained from the Litani River Authority[2] and the Council for Development and Reconstruction (CDR).

A review of historic flow data for the system providing water to the GBWSP concludes that there is adequate water available to meet the goals of the GBWSP.

Key Findings and Assumptions

Key findings

- ***GBWSP and Existing Irrigation Projects. A review of historic flow data for the system providing water to the GBWSP concludes there is adequate water available to meet the goals of the GBWSP.*** About 66 million cubic meters (MCM of storage in Karoun Reservoir is needed to meet both the needs of the GBWSP and the highest recent dry-year withdrawals for irrigation. This condition was met in 19 years out of 20 (95 percent of the time). In that one exceptional year the shortfall of 4.4 MCM accounted for about 9 percent of the value withdrawn for irrigation. So, as per Decree 14522 (see below), water could be available for the GBWSP in all years.

- ***GBWSP and Short-Term Irrigation Projects. Repeating the flow analysis with the full planned withdrawal of 25 MCM West Bekaa and Rechaya Potable Water Project (WBRPWP) reveals a high level of water availability for the GBWSP.*** The additional water withdrawals for the potable water project are not projected to begin until at least 2016. Even if the potable water project withdraws the full amount when it begins, there is ample water available for that project, existing irrigation, and the GBWSP in 18 out of the 20 study years (90 percent). The shortfalls of 9 MCM and 22.5 MCM in the exceptional years represent 14% and 34% of the combined withdrawals for irrigation and the WBRPWP.

---

[1] An institute within The UNC Gillings School of Global Public Health at the University of North Carolina at Chapel Hill. Please see annex 3.

[2] The review is also based on a preliminary flow balance created by a senior engineer, formerly head of the Planning and Design Department in the Litani River Authority, now acting as a consultant to the Authority.

Key Assumptions

- ***Lebanese Presidential Decree No. 14522, dated 16 May 1970, gives priority to drinking water supply***. Decree 14522 assigns 40 million cubic meters (MCM) of Litani water and other sources of water to "potable water and water for industrial purposes." Further, it specifies that "The State is . . . entitled to decrease the quantities allocated for irrigation as per table 2 by 25 percent and, if necessary, add this 25 percent to the 50 million m^3 allocated for potable water, household, and industrial purposes without any compensation to beneficiaries of irrigation water."[3]

- ***The GBWSP is designed to meet the short-term water needs of the Greater Beirut region until 2016***. Needed withdrawals for the GBWSP are assumed to be constant at the design level (3 cubic meters per second [CMS]) during the dry period***.***

- ***Current demands for irrigation are, to be conservative, assumed to be the highest recently observed.*** Withdrawals were identified as part of a preliminary flow balance (figure 1).

- ***Recent historic water availability is representative of future patterns.*** Of the four primary sources of water for the water treatment plant, only the Karoun Reservoir possesses significant seasonal storage. A 47-year dataset of inflows into Karoun Reservoir was used to evaluate variability in storage. Because of a statistically significant downward trend in storage over the full period, only the last 20 years of the dataset (1989-2008) was used in the analysis.

- ***Seasonal flows of the springs and Awali (or Bisri) River follow typical patters seen between 2003 and 2009 and are proportional to water availability, as determined by annual Karoun Reservoir inflow amounts.*** The three other sources of water are the Ain Zarqa spring, input from a spring into the Awali conveyor tunnel near Jezzine, and the Awali (or Bisri) River.

- ***The Dry Period is defined as April 15th to October 31st.*** This is in accordance with section 2 of the decree ("This amount can be distributed during the period as of mid-April until the end of October every year …"), and also largely agrees with actual water availability and demand patterns.

- ***The Canal 800 irrigation project will not begin to withdraw water until 2021 and will not reach maximum value until about a decade later.*** The project will account for about 65 percent of the usable storage of the Karoun Reservoir (170 MCM), and its feasibility can only be determined in the context of a broader analysis of Lebanon's total water resource availability.

[3] Excerpts are from the English version of the decree, provided in annex 2.

1. Introduction

A 250,000 cubic meter per day water treatment plant will be constructed as part of the Greater Beirut Water Supply Project (GBWSP).

The objectives of this technical review are to:

1) Determine whether there is sufficient water available from the Litani and Awali sources meet the needs of the GBWSP.
2) Assess the potential for water supply conflicts with competing uses.
3) Understand the impact of near-term planned increases in water withdrawals.

1.1 Methodology

The analysis involved the creation of monthly flow balances that include water from four main sources: the Karoun Reservoir, input from Ain Zarqa spring, input from a spring into the Awali conveyor tunnel near Jezzine, and the Awali (or Bisri) River (Figure 1).

Two flow withdrawal scenarios are reviewed in this analysis. In the first, irrigation projects currently in place (Canal 900, Kasmieh, Lebaa) are included. The second also includes anticipated withdrawals from the West Bekaa Potable Water Project, which is estimated to begin withdrawals no sooner than 2016.

2.0 Water Balance

2.1 Description of the System

A schematic of the system is shown in Figure 1.

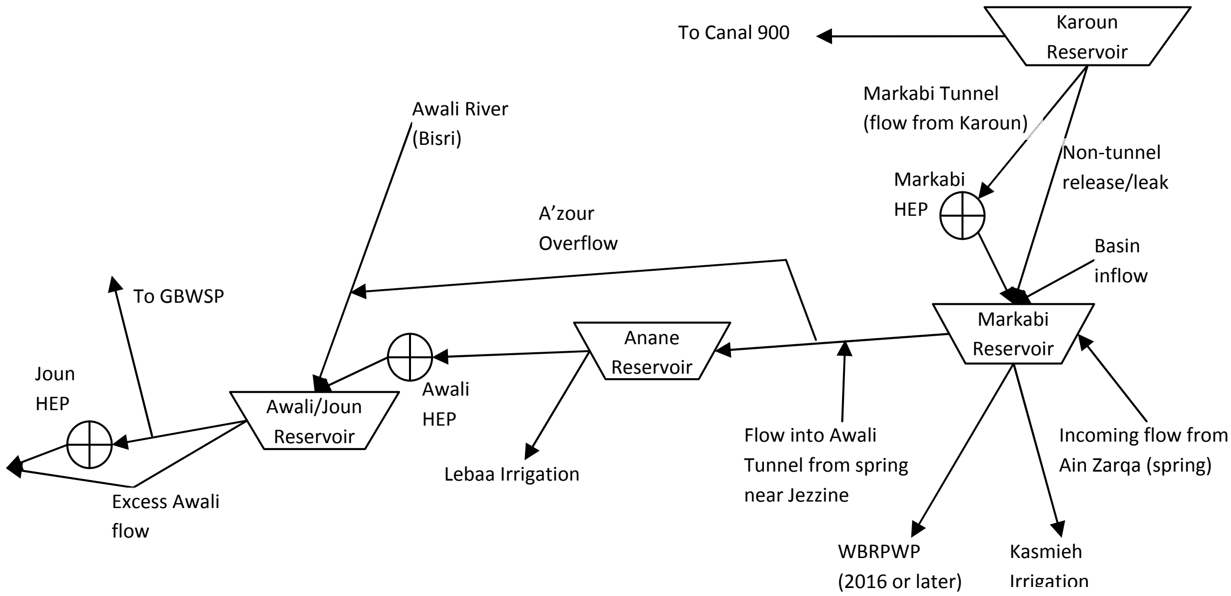
Water from Karoun Reservoir makes its way to Markabi Reservoir either through the tunnel and Markabi hydroelectric plant (HEP) or through the Litani River downstream of the dam. Water from the catchment downstream of the dam, as well as from the Ain Zarqa spring, is added to the reservoir while withdrawals for irrigation and, eventually, the WBRPWP are removed. These flows are seasonal; it is unusual for there to be flow from the Litani Basin downstream of the dam during the dry season. Separately, water from Karoun Reservoir is provided to the Canal 900 irrigation project.

Flow from the Markabi Reservoir travels through the Awali Tunnel under open-flow conditions. Water from a spring near Jezzine is added directly into the tunnel. To avoid pressurizing the tunnel, there is an overflow at A'zour which takes excess flow from the Awali Tunnel and discharges it into the Awali River.

The Awali Tunnel discharges into the Anane Reservoir. Water from the Anane Reservoir is piped under pressure to the Awali HEP. Some of the water is also used for irrigation at Lebaa. The Awali HEP discharges into the Joun Reservoir, which also receives flow from the Awali River (including any overflow from A'zour). This reservoir is piped under pressure to the Joun HEP.

Water for the GBWSP will be withdrawn at a location upstream of the Joun HEP. Excess water at the Joun Reservoir continues to flow in the Awali River where it is joined by the outflow of the Joun HEP and travels to the sea.

Figure 1. Schematic of water sources and water withdrawals affecting availability of water for the GBWSP



Source: reconstructed from flow schematic, maps, and supporting literature obtained during April site visit.

2.2 Sources of Data

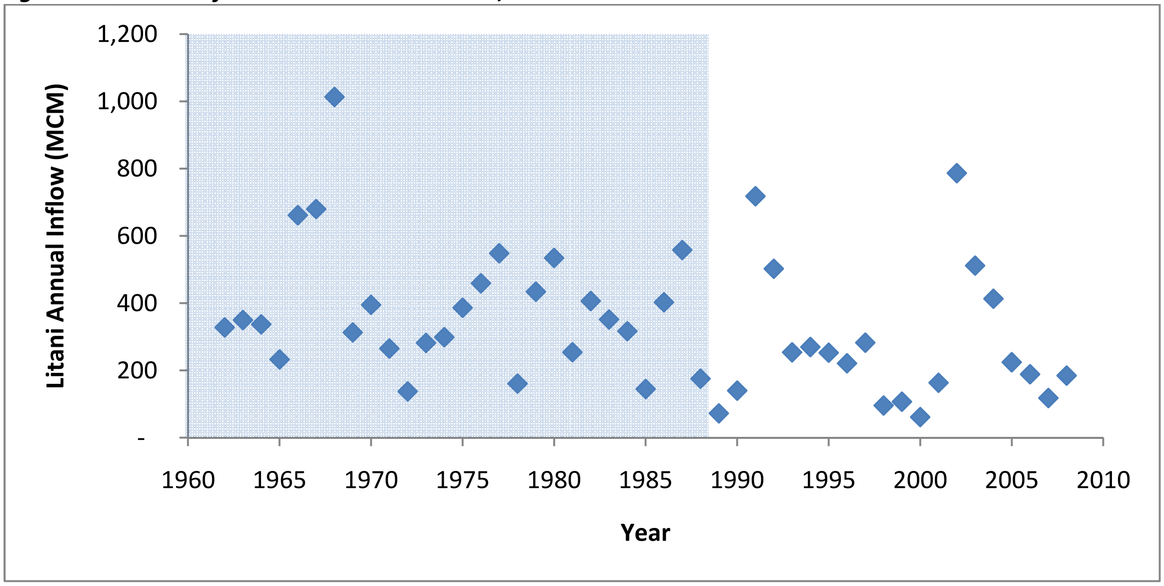
Three sources of data were used to build the model of the water system.

a) Litani River Inflows to Karoun Lake

This dataset was provided by the Litani River Authority and includes monthly storage inputs to Karoun Lake from the Litani River over a 47-year period (September 1962 to December 2009), as well as total storage for each hydraulic year (September through August). The Authority's method of calculating inflows is not to accumulate river inflows, but to use a volume-level relationship and frequent measurements of reservoir level. This was referred to as an "industrial" balance and accounts for river inflows as well as some losses (see part b of section 2.4).

Because of a statistically significant downward trend in storage over the full period, only the last 20 years of the dataset (1989-2008) were used in the analysis. This period, which shows no statistically significant trend (p=0.7), includes the lowest 5 years on record and 13 of the lowest 20 years on record (Figure 2). The reduced inflows to Karoun Lake are likely a result of higher utilization of the upper Litani River over time. Using only the later part of the dataset makes it far more likely that the data are representative of current conditions as well as providing a conservative estimate; the excluded data has higher average flows and would result in higher estimates of available water if included.

Figure 2. Annual inflows to Karoun Reservoir, 1989-2008



Note: Data within the shaded area are not included in the analysis.

b) Water Flow Data 2003-2005, 2007-2009

The Litani River Authority publishes a summary of monthly flows from the Karoun Reservoir, through three hydroelectric plants, and to the sea. The following are included in their data:

Table 1. Description of flow parameters in water system

Location	Description
Water through Markabi HEP	Released from Karoun Reservoir through the Markabi HEP
Canal 900 withdrawals	Water released from Karoun Reservoir for Bekaa irrigation (Canal 900)
Inflow from Karoun Basin	Water inflow from the Karoun Basin (location of the Litani River) downstream of the dam. The water could be from rainfall or incidental springs; it is collected in a reservoir just downstream of the Markabi HEP (Markabi Reservoir) and is available for downstream uses.
Loss from dam	There are losses through the dam that forms Karoun Reservoir, due to overflows during wet times and leakage through the dam. This water is not lost; as it is collected in the portion of the Litani River downstream of the dam and feeds the Markabi Reservoir.
Ain Zarqa	A spring that also feeds the Markabi Reservoir
Kasmieh irrigation	Water released for irrigation from the Markabi Reservoir
Loss at Markabi	Losses from Markabi Reservoir
Lebaa irrigation	Withdrawals for irrigation
Input from spring near Jezzine into Awali Tunnel	The Awali Tunnel, connecting Markabi Reservoir with Anane Reservoir, goes through a spring that contributes flow to the tunnel.

A'zour Overflow	The Awali Tunnel is not meant to be pressurized or run full. When upstream capacities are greater than the capacity of the tunnel or Anane Reservoir, the excess flow is diverted to the Awali (or Bisri) River. This flow does not go through the Awali HEP but is available for the GBWSP, as it can feed the Joun Reservoir.
Water through Awali HEP	Water through the Awali HEP is from Anane Reservoir, which is fed from all the upstream sources.
Losses to Awali Basin	The Joun (or Awali) reservoir is fed from the output of the Awali HEP and the Awali River. When more water than needed is available, it continues into the downstream portion of the Awali River.
Awali (Bisri) River	This river feeds the Joun Reservoir. It may contain flow from the Karoun Reservoir whenever A'zour overflow exists.
Used for Joun HEP	Water going through the Joun HEP.

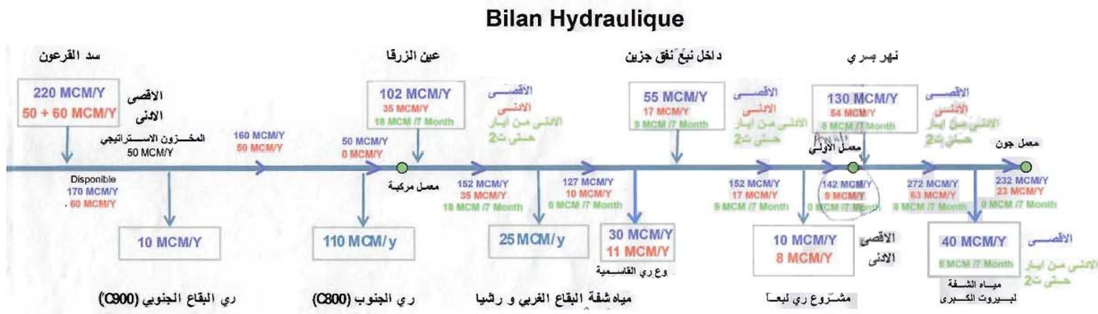
Source: Litani River Authority, based on data for 2003-2005 and 2007-2009.

c) Preliminary Water Balance

A preliminary annual water balance was created by the Litani River Authority, the main part of which is shown in Figure 3. During the site visit, it was recognized that this flow balance could be improved by including a timeline showing when the various projects become active. For example, withdrawals for Canal 800 are not expected to begin until 2021 and will not reach the full amount until 2030. As this withdrawal will amount to roughly 65 percent of Karoun Reservoir's usable capacity, it should not be included in a flow balance that doesn't include wider consideration of Lebanon's water resources.

The water balance created for this technical review looks at monthly flow variations using data described in section 2.2b, and looks at the frequency of dry years using data described in section 2.2a. Monthly variations are important because there is no significant storage downstream of the Karoun Reservoir. This means, for example, that excess flows from the Awali River in May cannot be stored for use in August. The water balance also considers years other than the one with the lowest inflow into Karoun Reservoir.

Figure 3. Preliminary flow balance



Source: Litani River Authority.

Note: Annual average amounts shown in purple; annual amounts for driest year in red; amount for dry season of driest year in green

2.3 Values Used in the Analysis

The water balance calculated on a monthly basis, using both dry-year and average-year values (Table 2).

Table 2. Source of values describing water availability and use for monthly flow balance

Location	Dry-Year Value	Average-Year Value	Monthly Data
Karoun Reservoir	61 MCM, Driest year from 47-year record	Average value from 20 year record	Not used. Storage is available as needed up to total annual inflow amount, not to exceed active storage volume of 170 MCM
Canal 900 withdrawals	10 MCM [a]	Same as dry-year value	Proportioned to average monthly flows observed from 2003 to 2009
West Bekaa and Rechaya Potable Water Project	25 MCM [a]	Same as dry-year value	Because of uses other than irrigation, assume half of allotment is uniformly distributed over year, and half follows irrigation pattern of Kasmieh
Ain Zarqa spring	35 MCM [a]	102 MCM [a]	Proportioned to average monthly flows observed from 2003 to 2009
Kasmieh irrigation	30 MCM (dry season only) [a]	Same as dry-year value [b]	
Spring Inflow to Awali Tunnel	17 MCM [a]	55 MCM [a]	
Lebaa irrigation	10 MCM (dry season only) [a]	Same as dry-year value [b]	
Awali River	54 MCM [a]	130 MCM [a]	

Source: Derived from data provided by the Litani River Authority.

a. From preliminary water balance

b. Although the preliminary water balance shows lower withdrawals in average years, higher dry-year values were used to make the analysis conservative.

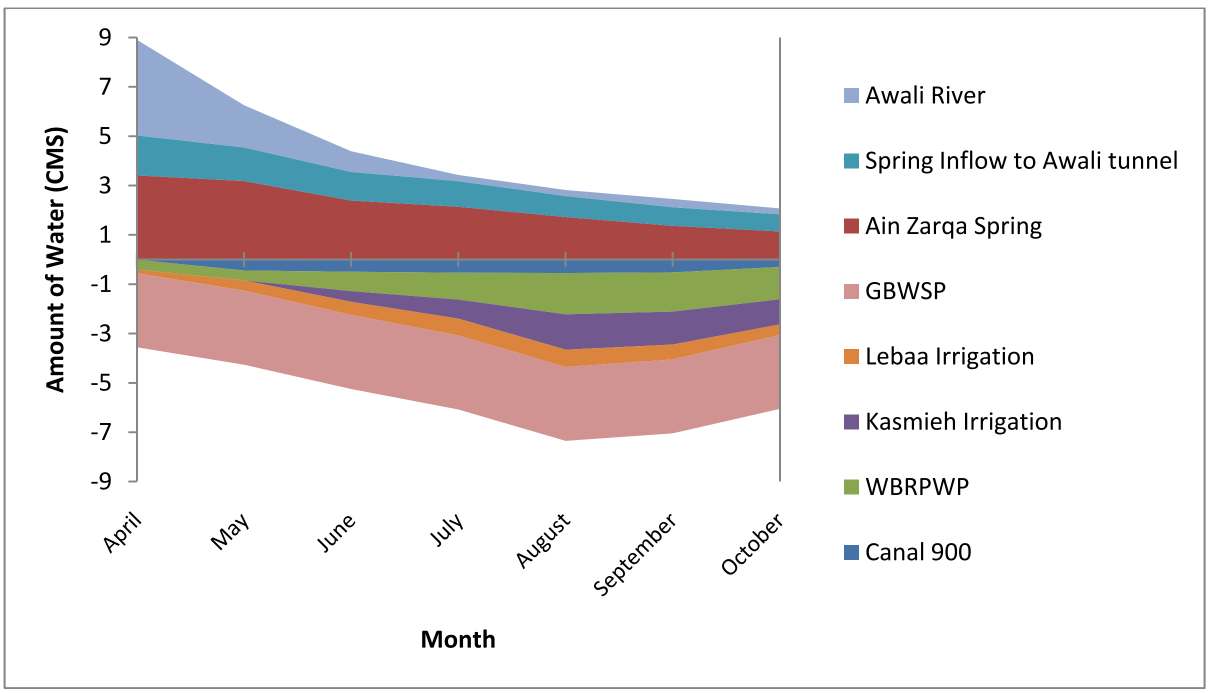
Some of the values were not used in this calculation (Table 3).

Table 3. Values not needed to calculate monthly flow balance

Location	Reason for Non-Inclusion
Water through Markabi HEP	Not a source of water or source of loss
Inflow from Karoun Basin Loss from dam	Included in Karoun Reservoir release
Loss at Markabi	Does not generally occur during dry season
A'zour Overflow	Included in flow from the Awali entering Joun Reservoir
Water through Awali HEP	Not a source of water or source of loss
Loss to Awali Basin	Occurs only if excess in Joun Reservoir, in which case there is no shortage of water
Used for Joun HEP	Not a source of water or source of loss

The monthly pattern of flows used to scale annual data is obtained by averaging the monthly water flow data from all sources (Table 1) for all available years. Withdrawals for the Greater Beirut Water Supply Project are assumed to be constant at the design level (3 CMS) for the dry period (April 15 to October 31). These flows are plotted for the dry-season months in Figure 4.

Figure 4. Average monthly inflows and withdrawals in water system from all sources



Note: Inflows are positive values above x-axis; withdrawals are negative values below x-axis.

2.4 Other Considerations in the Analysis

The analysis also took account of the following factors and assumptions:

a) Assumption of lowest inflows from Awali (or Bisri) River and two springs when storage in Karoun Reservoir is lowest

The flow balance assumes the highest withdrawals in every case. Inputs from the Awali River, the spring at Ain Zarqa, and the spring feeding the Awali Tunnel near Jezzine are assumed to be lowest for years in which storage in the Karoun Reservoir is lowest. Although this may not be true in all cases—one can imagine a year with low flows during the wet season but average flows during the dry season—it is the most conservative assumption.

b) Accounting for unknown losses

As noted in section 2.2a, the data reflect flows that were observed as part of the operation of the current system (designated by the engineer as "industrial flows") rather than derived from a hydrologic water balance. A hydrologic water balance would involve a more rigorous accounting of inflows and losses, such as evaporation and seepage, while the "industrial" flows represent net flow values. To illustrate, consider a standard water balance for a reservoir, calculated as:

Increase in Storage = Inflows – Outflows – Losses

Since storage increases and some outflows were measured, this can be rearranged so that the known values are on the right side and those unknown are on the left:

Inflows – Losses = Increase in Storage + Known Outflows

The left hand side "Inflows – Losses" is a single quantity and the two subcomponents cannot be separated as the losses are unknown. The left-hand side can be characterized as "net inflows" since it represents flows inclusive of losses. The principle in this simple case also applies when computing a water balance for a more complex system.

c) Canal 800

Canal 800 is not included in this review because the planned withdrawal of 110 MCM will not start until 2021 and will not reach the maximum value until about a decade later. As noted in section 2.2c, this withdrawal will account for about 65 percent of the usable storage of the Karoun Reservoir (170 MCM), and its feasibility can only be determined in the context of a broader analysis of Lebanon's total water resource availability and the cost effectiveness of efficient irrigation practices.

The amount of water needed for irrigation is dependent on many factors, including the crop, the soil type, and the irrigation method. Water use can be optimized when the yield of crops under differing irrigation conditions is understood (for example, see the work of Karam and others[4]). Efficiencies of irrigation methods also vary; traditional methods are about 50% efficient while sprinkler irrigation can reach 70%-80% efficiency and drip irrigation can exceed 80%. FAO data show that, as of 2000, 64% of the irrigated land in Lebanon received water from surface irrigation, 28% from sprinkler irrigation and 8% from drip irrigation[5], so there may be opportunities to reduce the overall withdrawal for irrigation.

---

[4] Karam, F., R. Lahoud, R. Masaad, Rabih Kabalan, J. Breidi, C. Chalita, Y. Rouphael. (2007). Evapotranspiration, seed yield and water use efficiency of drip irrigated sunflower under full and deficit irrigation conditions. Agricultural Water Management Volume 90, Issue 3, 16 June 2007, Pages 213-223

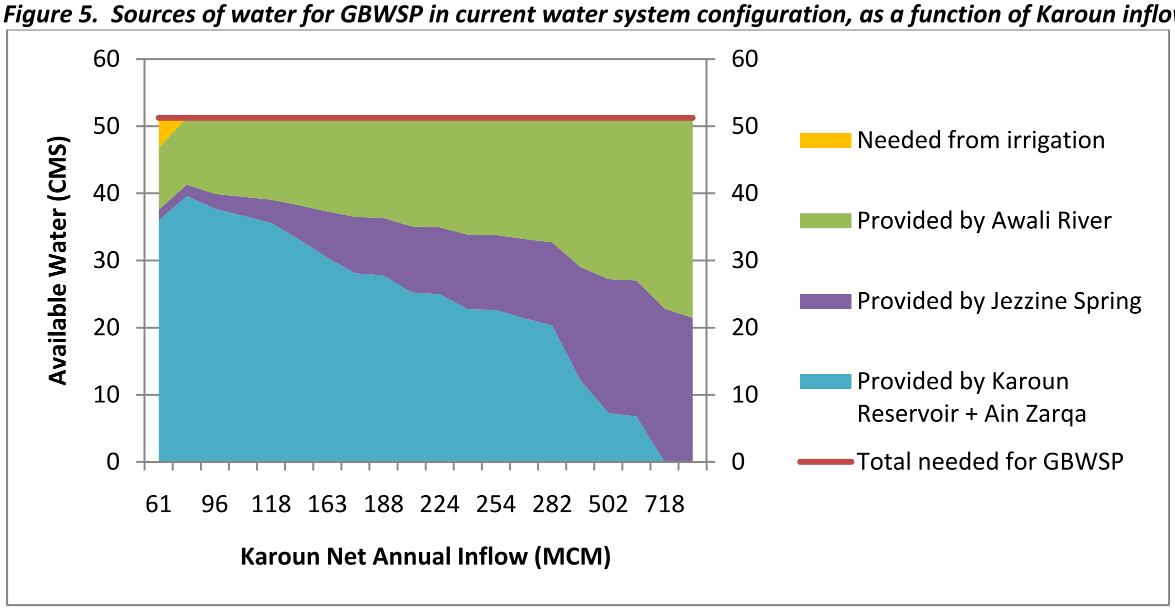
[5] I. Hamdan, T. Oweis and G. Hamdallah (eds.) AARINENAWater Use Efficiency Network: Proceedings of the Expert Consultation Meeting, 26-27 November 2006, Aleppo, Syria. ICARDA, Aleppo, Syria. iv + 244 pp. (http://www.icarda.org/docrep/Books/AARINENA.pdf#page=107)

3.0 Results

This review of historic flow data for the system providing water to the GBWSP concludes that there is adequate water available to meet the goals of the GBWSP.

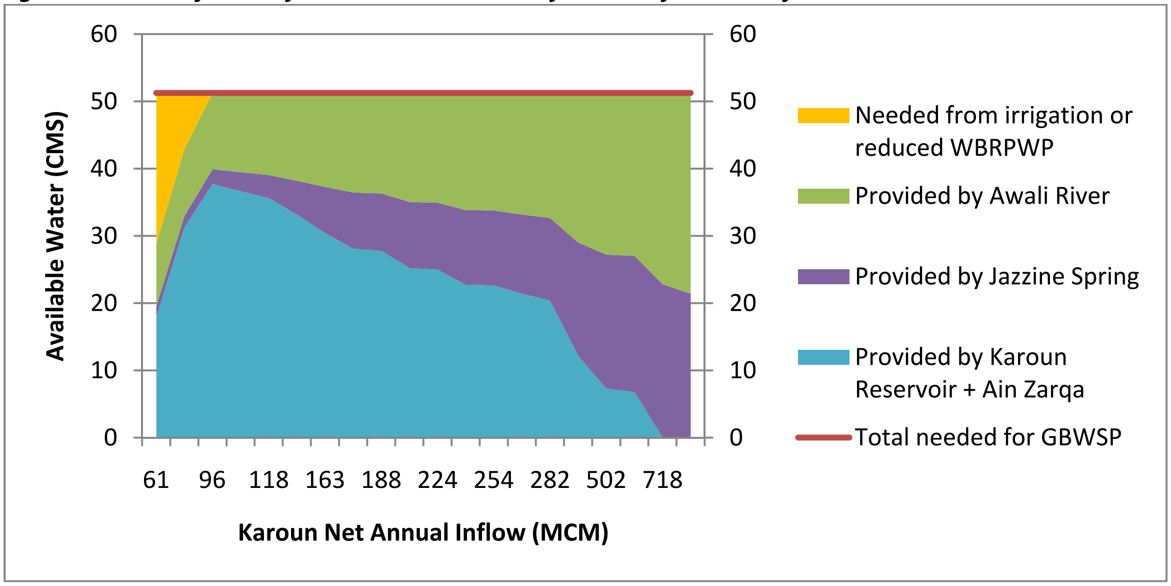
About 66 MCM of storage in Karoun Reservoir is needed to meet the needs of both the GBWSP and the highest recent dry-year withdrawal for irrigation (Figure 5 shows the estimated amount from each source). This condition was met in 19 of the 20 years reviewed (95 percent of the time). In the one exceptional year, the shortfall (4.4 MCM) amounted to about 9 percent of the total withdrawn for irrigation. Therefore, as allowed by Decree 14522, water could be available for the GBWSP in all years. This historical data show that as conditions get wetter, more water is available from the Awali River and springs, and less is required from Karoun Reservoir. In the driest years, about 70 percent comes from sources within the Litani Basin and the rest from the Awali River and the spring near Jezzine. In the driest year, about 70 percent comes from sources within the Litani Basin and the rest from the Awali River and the spring near Jezzine, with the sources of withdrawal from irrigation depending on how those withdrawals are made.

Figure 5. Sources of water for GBWSP in current water system configuration, as a function of Karoun inflows



The Inclusion of the full planned West Bekaa and Rechaya Potable Water Project in the analysis shows a continued high level of water availability for the GBWSP (Figure 6). The additional water withdrawals for the potable water project (25 MCM per year) are not projected to begin for at least five years. Even if the project withdraws the full amount from the start, there is ample water available for that project as well as the GBWSP and existing irrigation in 18 of the 20 study years (90 percent). The shortfalls of 9 MCM and 22.5 MCM represent 14 and 34 percent of the combined withdrawals for irrigation and the WBRPWP in the two years where shortfalls exist. In all cases, withdrawals from Karoun Reservoir plus Ain Zarqa spring for the GBWSP are at or below 40 MCM—within the allocation amount specified in Decree 14522 for potable water and industry.

Figure 6: Source of Water for GBWSP in 2016 as a function of Karoun inflows



4.0 Impact of the GBWSP on Climate Change and Aquifers

a) Climate change

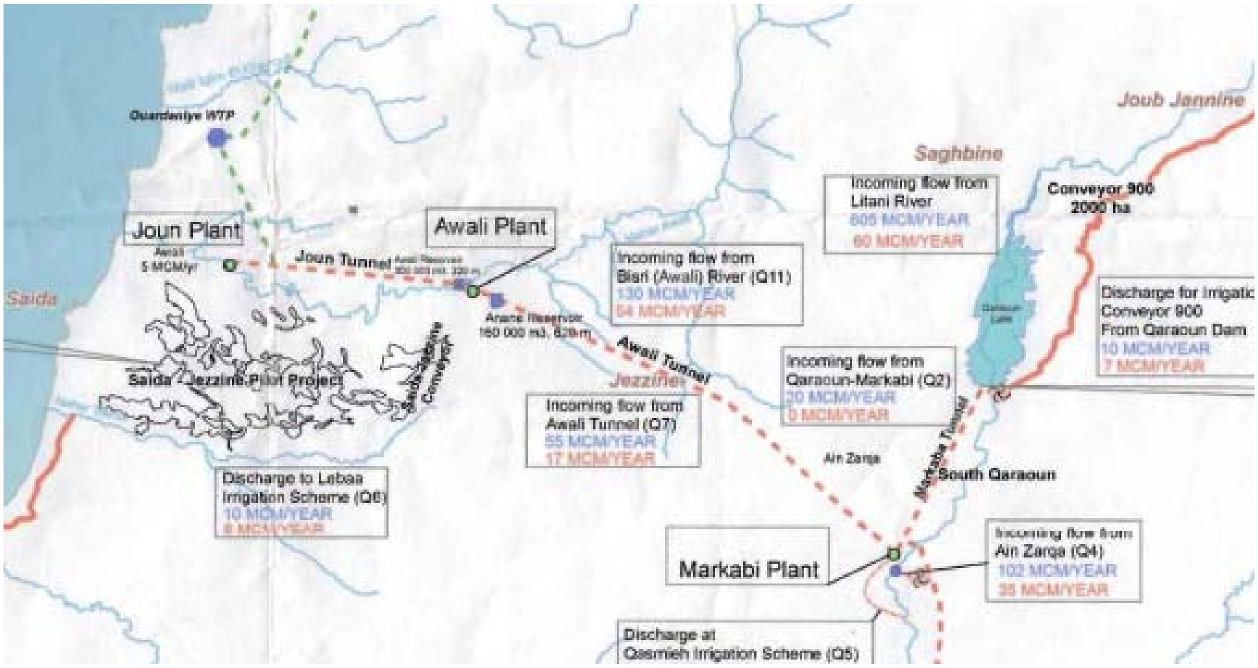
Climate change effects, observable on the order of decades, are beyond the scope of this analysis. Although these effects are accounted for, to some extent, in the decision to use data from only the past 20 (rather than 47) years to calculate Karoun Reservoir net inflows, an accurate picture of these effects also depends on an analysis of long-term trends in population growth and water utilization patterns.

b) Aquifer storage and recharge

The GBWSP is targeted towards providing water to the Greater Beirut area in the seven dry months of the year. During the five wet months, the area is supplied with groundwater from a variety of aquifers, some of which are closely coupled with surface sources and wax and wane with the wet and dry seasons; and some of which are more isolated and could potentially serve as seasonal reservoirs. By providing water during the wet months, the GBWSP could potentially replenish or preserve the supply in many of these aquifers. This would enable the aquifers to supply water further into the dry period, and thereby lessen demand on the Litani and Awali (Bisri) rivers during times of reduced availability.

Annex 1: Images

Map of system



Facilities at Markabi (from Google Maps)

Anane Basin

Joun Resoir

Annex 2: Decree in English

Ministry of Hydraulic and Electric Resources

Decree No. 14522

Distributing the water of the Litani River and other sources of water in the area between the road of Beirut-Damascus and the springs of Anjar- Chemsine and underground water in Terbol area north of this road in the central Beqaa for irrigation purposes.

The President of the Republic,

Based on

- the Lebanese Constitution;
- decision No. 3 of the board of directors of the National Authority of the Litani River, minutes No. 475 on July 18, 1968 in respect of distributing the water of Litani River for irrigation purposes;
- studies made by Ministry of Planning [sic] on this subject;
- the report of World Bank mission dated April 30, 1969;
- the report of the joint mission of the FAO and the International Bank for Reconstruction and Development No. 69/41 on Oct. 16, 1969;
- recommendation by Minister of Hydraulic and Electric Resources; and pursuant to
- the approval of the Council of Minister on April 8, 1970.
-

Decreed

Article 1

The term "western foothills" in this decree means the Lebanese territories between Beirut River, the Mediterranean and the south borders at an altitude of 800 m above sea level.

The term "South Beqaa" refers to the area from the Beqaa plain from the dam of Albert Naccache in the south to the road of Beirut-Damascus in the north and the section in the north of this road between the course of the Litani River and the irrigation channel at an altitude of 900 m till Ryak.

Article 2

The total amount of water which can be used in an average water year in the regions covered in this decree is determined at 510 million m^3 . This amount can be distributed during the period as of mid-April until the end of October every year as shown in table 1 attached to this decree.

Article 3

This volume of water shall be distributed over the regions shown in table 2 attached to this decree, as summarized below:

South Beqaa	140 Million m^3
Western foothills	320 Million m^3
Potable water and water for industrial purposes	50 Million m^3
TOTAL	510 Million m^3

The irrigation water currently used in these regions is included in this amount.

Article 4

Pending the construction of Khardala Dam, storing water therein, and using it for irrigation purposes, the above quantities (as shown in table 2) shall be reduced as follows:

South Beqaa	120 Million m^3
Western foothills	270 Million m^3
Potable water and water for industrial purposes	40 Million m^3
TOTAL	430 Million m^3

Article 5

In case new water resources are available, the government of Lebanon will distribute them to the western foothills, taking into consideration technical rules and future water needs based on the distribution guidelines by virtue of this decree.

Article 6

Water quantities mentioned in article 2 of this decree shall not be deemed a vested right vis-à-vis the State. These quantities can be decreased in drought years depending on water availability. The State is also entitled to decrease the quantities allocated for irrigation as per table 2 by 25% and, if necessary, add this 25% to the 50 million m^3 allocated for potable water, household, and industrial purposes without any compensation to beneficiaries of irrigation water.

In view of the foregoing, the State is entitled to identify the areas that can be cultivated using permanent irrigation water, while the remaining areas shall be cultivated on a seasonal basis.

The State, temporarily, may distribute unneeded potable water and water allocated for household and industrial purposes to irrigation.

Shortage of water in drought years and due to meeting the needs for potable water and water for household and industrial purposes shall be distributed over all regions pro rata to allocated quantities.

Article 7

In line with water distribution scheme and new irrigation projects developed for different regions, priority shall be given to fertile soil most fit for irrigated agriculture.

Article 8

All other decisions and decrees in conflict with this decree shall be revoked and deemed null and void.

Article 9

This decree shall come into force upon publication in the official gazette.

Baabada, May 16, 1970

Charles Helou, (singed)

Issued by the President of the Republic

Prime Minister, Rachid Karame (signed)

Minister of Hydraulic and Electric Resources, Anouar Khatib (signed)

Table 1

Distribution of Litani River water for irrigation purposes
Quantities of water currently available and used for irrigation purposes

First:

Quantities of water annually available during the irrigation season in the period as of mid-April until the end of October - from different sources in the areas between the road of Beirut-Damascus, the southern borders, and between the springs of Anjar- Chemsine, and the underground water in Terbol area north of this road in the central Beqaa - amount to 510 million m^3. This amount of water is detailed in the following table:

SOURCE	ALTITUDE (m)	QUANTITY (mm^3)	Notes
1. Spring of south Beqaa	870-890	50	
2. Underground water in the south Beqaa	840	60	
3. Water available in the Qaraoun Lake	820	160	
4. Ain al Zarqa (Water Litani Course)	600	20	
5. Tunnel of Markaba-Jezzine	600	10	
6. Qasmieh River (estuary)	5	17	
7. Nahr el Awali	30	10	
8. Different small and scattered springs	-	5	
9. Damour River	445	5	
10. Beirut River (Daychounieh)	50	5	
11. El Zahrani & Abou Assouad	180-400	10	
12. Ras el Ain (Tyr)	18	10	
13. Underground water in the southern coastal plains	-	20	
14. Khardala Dam	270	80	
15. Marjeyoun	-	3	
16. Springs in the lower Litani River from Markabi to Mansoub	3	45	
TOTAL		510	

Notes:

Latest studies show that the quantities of water that could be extracted from the underground in the south Beqaa exceed the amount of 60 million m^3 mentioned in line item 2 in the table above to at least 70 million m^3.

1. The springs of the upper Litani currently used for irrigation between Tell-Amara and the road of Damascus are not counted in this table, despite the fact that water currently used in other regions particularly in the western foothills and south Lebanon are included in distribution over different regions.

2. Possible construction of a dam in Kamed El laouz area was not taken into consideration, though such dam can be filled with water taken form underground water in Rashaya area (Aiha –Kfarkouk) through a tunnel.

3. The Khardala Dam has not been constructed yet, and untill this date, it is not known how to benefit from the springs of the lower Litani.

4. The above four notes show that the proposed water quantity allocated for irrigation purposes in south Beqaa is sufficient for this area with a large reserve of no less than 50 m^3 remaining.

<u>Second:</u>

The quantities of water currently used in irrigation and the irrigated areas are as follows:

A. In south Beqaa 76 million m^3 is currently used to irrigate approx. 9,500 ha. An irrigation project at an altitude of 900 m shall maintain an overall and standard-based reorganization of irrigation system in south Beqaa, and hence, the irrigated area shall be subject to such reorganization.

B. In the western foothills, 112 million m^3 is used to irrigate 8,600 ha. as detailed in the table below. It is worth noting that a huge amount of water is wasted and the water allocated for the currently irrigated areas should be rationalized and lowered to only 86 million m^3.

	Beirut River	Damour River	Nahr el Awali	Qasmieh Project	Ras El Ain	Underground Water	Litani River	Marjayoun	Other sources	Total Area	Quantities of water allocated
Region	ha	ha	ha	Ha	ha	ha	ha	ha	ha	ha	million m3
The area between Beirut River and Ghadir River	350	-	-	-	-	-	-	-	50	400	4.5
The area between Ghadir River and Damour River	-	400	-	-	-	-	-	-	50	450	4.5
The area between Damour River and Nahr el Awali	-	-	250	-	-	400	-	-	50	700	7.5
The area between Nahr el Awali and Al Zahrani River	-	-	450	300	-	600	-	-	50	1400	14
The area between Al Zahrani River and Litani River	-	-	-	2000	-	100	-	-	100	2200	22
The area between Litani River and Borders	-	-	-	900	1100	850	300	300	-	3450	34.5
Total	350	400	700	3200	1100	1950	300	300	300	8600	86
Quantity of water currently used for irrigation	5	5	9	50	10	20	5	3	5	112	
Quantity of water to be allocated	3.5	4	7	32	10	20	3	3	3	86	

N.B:

Water savings because of reorganization of irrigation systems in western foothills and south Lebanon amount to 112 – 86= 26 m^3. This quantity has been allocated for irrigating new lands despite great difficulties facing reorganization of old irrigation systems and taking out water savings from farmers.

Table 2

Distribution of Litani water for irrigation

Distributing the water of the Litani River and other sources of water in the area between the road of Beirut-Damascus, the southern borders, and the springs of Anjar- Chemsine and underground water in Terbol area north of this road in the central Beqaa during the irrigation season from the middle of April until the end of October of every year

First: Lands of the region

Areas of lands in each region are shown below:

A. **Lands of South Beqaa**
   The areas of land down the channel at an altitude of 900 m amount to 30480 ha, of which 22500 ha for irrigation, and the remainder is for roads, housing, and wasteland. An area of 9,500 is currently irrigated in this region.
B. **Lands of the western foothills:**
   The total area of the western foothills within the domain area of the National Authority of the Litani River and between an altitude of 800 m and the sea level amount to 211,000 ha, of which only 7,400 ha are being irrigated.

Second: Method of distributing water for irrigation purposes

Since the available amount of water in the Litani River is not sufficient to irrigate all arable and irrigable lands, water can be distributed by either of these two methods:

1. Irrigating arable and irrigable lands nearby water, accordingly, depriving remote areas from irrigation; or

2. Irrigating sections of lands in each region by a reasonable and fair amount of water to ensure equity among regions and avoid deprivation of any region from the benefits of irrigation from Litani water.

Since the second method secures more social equity and does not deprive any regions nearby Litani river from benefiting from its water, it is used to distribute water over the western foothills, taking into consideration the currently irrigated areas. Decreasing the regions, which currently include irrigated areas by the same percentage of new water allocated to regions not including currently irrigated areas leads to full establishment of the right of the irrigated areas and giving them additional right. Moreover full inclusion of the currently irrigated areas into distribution account as if such areas are not irrigated areas deprive them totally from their vested right, and the new irrigated areas shall be very minimal, accordingly people living there shall not feel the benefits of the project. Therefore, for distributing new water, half of the irrigated areas is considered while the other half is deemed as having a vested right and not included in the distribution account.

In south Beqaa, the quantities of water available in springs and underground water are hardly enough to irrigate the whole region, therefore, to be able to request finance from the International Bank for Reconstruction and Development, the amount of water deemed enough for full irrigation was allocated to lands most fit for irrigation in the region.

Third: Water distribution

A. Irrigation of south Beqaa

An mount of 140 million m^3 shall be allocated to south Beqaa, and this amount is enough for full irrigation during the period from April to October according to the reports of the International Bank for Reconstruction and Development and FAO. This water is taken from these sources:

1. Underground water in south Beqaa	60 m^3
2. Springs in south Beqaa	50 m^3
3. Qaraoun Lake	30 m^3
Total	140 m^3

B. Irrigation of western foothills:

An mount of 320 million m^3 shall be allocated to western foothills. This amount shall be taken from different sources located in the western foothill and the quantity of water available for irrigation in Qaraoun Lake (i.e., 130 m^3). This amount shall be divided over the areas currently irrigated and new irrigation projects as follows:

- Currently irrigated areas

86 m^3

- New areas

234 m^3

Total 320 m^3

C. Reserve for potable water and industrial needs

An mount of 50illion m^3 shall be reserved for Beirut city and industrial projects.

50 m^3

510 m^3

Fourth: Lands to be irrigated

A. Lands covered by the project in south Beqaa:

14000,000 m^3 = 23,500 ha approx.

The percentage of irrigated land: 6000 m^3 per ha

22,500 = 78%

30,000

This for full irrigation, the remainder lands are for roads, housing, and wastelands.

B. Lands covered by the project in western foothills

New areas that can be irrigated:

$$\frac{23,400,000}{7000m^3/ha} = 33,000 \text{ ha}$$

- Percentage of distribution per regions (with a total area of 211,140 ha):

33,000+$^{1/2}$ % x 8,600 = 17.7%

211,140

This percentage shall apply to the area of each region, and then half of the currently irrigated area shall be taken out of such region.

Region	Total Area under an altitude of 800 m	17.8% of this area	50 % of the currently irrigated area	New area which will benefit from allocated water	Total amount of water allocates	Total irrigated area	% of irrigated area to total irrigated area under an altitude of 800 m
	ha	ha	ha	ha	mm3	ha	
The area between Beirut River and Ghadir River	7880	1400	0.5% X 400	1200	7	1600	20.3%
The area between Ghadir River and Damour River	17240	3000	0.5% X 450	2775	20	3225	18.7%
The area between Damour River and Nahr el Awali	23040	4100	0.5% X 700	3750	27	4450	19.3%
The area between Nahr el Awali and Al Zahrani River	25040	4400	0.5% X 1400	37000	26	51000	20.3%
The area between Al Zahrani River and Litani River	44740	7000	0.5% X 2200	6900	49	91000	20.3%
The area between Litani River and Lebanese borders	93200	16400	0.5% X 3450	14675	104	18125	13.4%
Total	211140	37300	0.5% X 8600	33000	234	41600	19.7%

The official gazette, issue 49, June 18, 1970, pages 1029, 1030, 1031, 2032, 1033, 1034, 1035, and 1036

Annex 3: About the Authors

The Water Institute at UNC is part of the Environmental Sciences and Engineering Department within the UNC Gillings School of Global Public Health. These institutions are internationally recognized for decades of leadership in water, health, and the environment and strive to address critical issues using collaborative and cross-disciplinary approaches. The Institute fosters partnerships among faculty, students and collaborators from North Carolina and across developed and developing nations worldwide. Current research activities focus on sustainability of WASH systems in response to climate change and other threats, impediments to improved water and sanitation coverage, health sector involvement in WASH promotion, water safety plans, water quality monitoring, and how information informs WASH policy. The School has additional WASH expertise in water treatment technology, WASH enterprise development, wastewater treatment, microbiology, economics, and water resources.

Dr. Jamie Bartram has been a Professor at the University of North Carolina at Chapel Hill since 2009 and is the Director of the 'Water Institute at UNC'. He was awarded the IWA (International Water Association) 'Grand Award' in 2004 and holds Honorary Professorships at the University of Wales at Aberystwyth, University of Bristol and University of Surrey, UK. Dr. Bartram has over 20 years experience of international policy, research and advisory work in public health and disease prevention, especially in relation to environment and health and water supply and sanitation; and in more than 30 developing and developed countries worldwide. He is author of more than 60 academic papers and more than 40 book chapters, and editor of around 25 books including on aspects of global monitoring, water supply, sanitation and hygiene. He spent 10 years as coordinator of Water, Sanitation, Hygiene and Health at the World Health organization (WHO) headquarters where he lead reform of its international monitoring and standard-setting activities, coordinated the WHO Guidelines for Drinking Water Quality Volume 3: Surveillance and control of community supplies, and led the development of the Water Safety Plan approach to ensuring safe drinking water supply.

Joe LoBuglio, P.E. is a research specialist working with the Water Institute at UNC in the Gillings School of Global Public Health at the University of North Carolina at Chapel Hill. Mr. LoBuglio has over ten years of experience in environmental management, water supply planning, and drinking water quality and has additional expertise in uncertainty analysis and modeling. Mr. LoBuglio led a drinking water analysis for the National Strategy for Environmental Health for the United Arab Emirates at UNC. He has worked for the Massachusetts Water Resources Authority, the agency responsible for drinking and wastewater services in the Boston metropolitan area, helping develop processes for obtaining, managing, and reporting on river and marine water quality data associated with the Boston Harbor Cleanup Project. He has contributed to projects for the North Carolina State legislature promoting North Carolina's economic development through strategic water resource management. Recent work helped frame and analyze policy options for water allocation considering social, ecological, economic, and institutional systems. He has engineering degrees from Princeton and Stanford Universities.