Report No. 76416-LB

The Inspection Panel

Final Report and Recommendation

Lebanon: Greater Beirut Water Supply Project (IBRD Loan No. 7967-LB)

April 8, 2013

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Final Report and Recommendation

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A. The Request

1. On November 4, 2010, the Panel received a Request for Inspection concerning the Lebanon: Greater Beirut Water Supply Project (GBWSP or the "Project") submitted by Mr. Fathi Chatila (the Requesters' Representative) on behalf of himself and 50 residents of the Greater Beirut area, who feared that alleged failures and omissions of the Bank in the design and preparation of the Project would likely cause them harm. As elaborated in the Panel's previous reports (see below) the Request highlights three important issues of relevance to Bank's operational policies and procedures.

2. Firstly, the Requesters claim that the raw water to be used by the Project is not fit as a source for potable water. The Request states that independent analyses conducted on the water stored at the Qaraoun Dam, the main source of water for the Project, confirmed that the water is heavily polluted with high levels of chemicals and bacteria. The Request states that analyses also indicate that the water carries carcinogens. The Requesters are concerned that standard water treatment techniques would not deliver potable water to Greater Beirut, as promised, if such contaminated water is the source.

3. Secondly, with respect to the economic analysis, the Requesters state that it is not clear whether the Project is the least costly option because, in their view, certain investment costs, including the cost of treating highly contaminated water and the future need to build a dam on the Awali River, were not taken into consideration. As a result of this, the total cost of the Project will almost double in their estimation. This raised price tag, the Requesters believe, will force water tariffs to increase by 10 to 15 percent annually, making the service unaffordable for poorer people. According to the Requesters' Representative, an alternative option to the Project – construction of a dam at Damour River with an alleged storage capacity of 90 million m^3 – would be a cheaper and cleaner source of water than the GBWSP for the Greater Beirut area.

4. Thirdly, the Request also argues that the Project, as designed, will deprive farmers in the south of Lebanon and/or the Upper Litani River Basin of water for irrigation. It is claimed that the Qaraoun Dam is not storing enough water to meet the demands for both the Project and irrigation schemes under development. This could harm the livelihood of agriculture-dependent communities living in these areas.

B. Purpose of the Report

5. The purpose of this Report, the Panel's Final Report and Recommendation, is to convey the Panel's determination on whether an investigation of the above matters relating to the Project is warranted taking into account the information provided in Management's Report on the Implementation of Enhanced Supervision Actions of January 25, 2013 (the "Progress Report", see below). The Requesters and their claims have already been determined eligible in the Panel's first Report and Recommendation, as per the criteria in Paragraph 9 of the 1999 Clarifications guiding the Panel's operations.

C. The Project

6. The Project's objective is to "*increase the provision of potable water to the residents in the project area* [Greater Beirut and Mount Lebanon region] *including those in the low-income neighborhoods of Southern Beirut, and to strengthen the capacity of the Beirut Mount Lebanon Water Authority in utility operations*." [1] The Project aims to meet the demand for 250,000 cubic meters per day (m^3/d) of potable water in the project area. The Project consists of three components: (1) bulk water supply infrastructure, (2) supply reservoir distribution network and metering, and (3) project management, utility strengthening and national studies.

7. Component 1 provides for the construction of water supply infrastructure including two water tunnel conveyors of 3 and 21 km respectively, transmission pipelines, storage reservoirs and a water treatment plant. Component 2 provides for the construction of 16 supply reservoirs and pumping stations, the design and construction of a distribution network of 187 km of pipelines and installation of household meters (approx. 200,000) in selected areas and bulk water meters at reservoirs and distribution chambers. Component 3 is focused on strengthening the capacity of the water utility Establishment of the Water of Beirut and Mount Lebanon– (EBML) and of the Ministry of Energy and Water (MoEW), which is responsible for implementation.

8. According to Management, the GBWSP was identified as the immediate next-step required meeting the pressing short-term water need in the Greater Beirut area. The Project, which is also known as the Awali Conveyor Project, will supply the Greater Beirut area with potable water by gravity. The raw water, to be transported by the use of tunnels to a water treatment plant at Ouardaniye, is from three sources flowing into the Joun Reservoir. The main source is the artificial Qaraoun (Karaoun in Management Response) Lake on the Litani River in the Bekaa valley. Water from this reservoir is currently transferred by tunnels to generate electricity at three

[1] The Beirut Lebanon Water Authority is also called as Water of Beirut Mount Lebanon Establishment (EBML) or Beirut Mount Lebanon Water Establishment (BMLWE). Both acronyms are used in this Report.

hydropower plants before being released into the sea through the Awali River. The Awali Conveyor will connect to this system of tunnels below the second hydropower plant at Joun. The water from Qaraoun Lake is mixed with water from the Awali River (the second source of water) at the Joun Reservoir. Seepage of groundwater into the main tunnel from the Qaraoun Dam is the third source adding to the raw water supply for the Project. The Project will require land acquisition and involuntary resettlement for building surface structures and for establishing easement rights of way along the corridor of the water conveyor.

9. MoEW is the agency responsible for Project implementation through a Project Management Unit established within the EBML. MoEW has delegated the implementation of Component 1 to the Council for Development and Reconstruction (CDR) and will maintain responsibility through EBML for Components 2 and 3.

10. The total project costs are US$ 370 million, of which US$200 million are funded by an IBRD Investment Loan to the Government of Lebanon. The EBML is to finance US$140 million and the Government of Lebanon (GoL) will finance US$30 million for land acquisition and the front-end fee. The World Bank Board of Executive Directors approved financing of the Project on December 16, 2010. The closing date of the loan is June 30, 2016. The Project was declared effective in December 2012.

D. Chronology

11. **Panel's (first) Report and Recommendation** The Panel registered the Request on November 10, 2010, and on December 13, 2010, Management submitted its Response to the Request. On January 20, 2011, the Panel submitted its (first) Report and Recommendation to the Board of Directors. The Panel recommended that the Board authorize an investigation into the matters raised in the Request because it believed that the Request raised "*serious concerns about potential harm and serious non-compliance…*" The Panel specified that "*the Panel's investigation would deal with issues of compliance and potential harm related to water quality, tariffs and water availability, and also report on any steps and actions taken by Management during the course of the investigation to address the issues of compliance and the concerns raised by the Requesters*." [2]

12. **Board discussion and decision**. Members of the Board requested a full Board discussion of the Panel's recommendation. This Board meeting took place on March 8 and 10, 2011. In advance of this meeting, the Panel issued a written statement clarifying questions some Board members had raised with respect to the Panel's determination of eligibility.

[2] Inspection Panel, Report and Recommendation Lebanon-Greater Beirut Water Supply Project (IBRD Loan 7967-LB) January 20, 2011, INSP/R2011-0003, (hereinafter "First Report and Recommendation") , ¶ 66/67.

13. After the Panel had submitted its First Report and Recommendation to the Board and a Board discussion had been requested, Management commissioned an Independent Technical Review of Source Water Quality by the Water Institute of the University of North Carolina. Prior to the Board meeting, it provided the Panel with an Interim Report containing preliminary findings of this Technical Review, indicating that the final report of the Review would be completed by May 2011. During the Board meeting, Management committed to expand the breadth of the review to also cover water availability and costs issues.

14. At the conclusion of the Board meeting, the Board of Directors determined that "*acknowledging the legitimacy of the requesters' concerns, the Board invited the Inspection Panel to return by July after considering and taking into account the analysis of the study commissioned by Management on the water quality, availability, and cost, in order to inform the Board on whether or not subsequent investigation is warranted, and if so, on its precise focus*."

15. **Management-commissioned studies and Panel's Follow-up Report**. On June 9, 2011, Management provided the Panel with the final reports of the three studies it had commissioned: an Independent Technical Review of Source Water Quality; an Independent Technical Review of Source Water Quantity, and a Study of Project Cost Estimates, Financial and Economic Analyses.

16. On July 29, 2011, the Panel issued its "Report Follow-up to Board Decision of March 20, 2011" (the "Follow-Up Report").[3] This report benefitted from the assessment by three independent experts retained by the Panel. The Panel noted that the three studies/reviews commissioned by Management provided valuable additional analyses of the issues identified in the Panel's eligibility report, namely water quality and safe drinking water, Project costs, and water availability and the reliability of water supply. The Panel further noted that the three studies, taken together, concluded that the Project, as designed and described in the PAD, did not entail unacceptable risks with respect to future guarantees of water quality, availability of water, and financing.

17. The Panel identified, nevertheless, important issues that it believed warrant further consideration in order to ensure the robust determination of risks associated with the Project, and the development of corresponding steps to avoid and mitigate such risks. In particular the Panel referred to:
    - the nature and extent of future measures to improve source water quality in the upper Litani River Basin and, in this respect, the need for nutrient control and the containing of risks for the Project associated with eutrophication in the Qaraoun Lake and upstream;
    - the need for better analysis of revenue forecasts for EBML and its likely capacity to contribute towards debt servicing; and

[3] Inspection Panel, Follow-Up to Board Decision of March 10, 2011, July 29, 2011, INSP/SecM2011-0005 (hereinafter "Follow-Up Report").

- the need for better analysis and forecasting of future water inflow and water use in the upper Litani River Basin to have a reliable basis for managing competing demands on the water resources of the river basin.

18. **Management's Action Plan and Progress Report**. Prior to issuing its Follow-up Report, the Panel informed Management that in the Panel's view the above issues merited additional analysis. Management issued a Note that included a summary of the identified risks and risk management measures and a proposed action plan to address these risks (the "Management Note").[4]

19. The Management Note stated that, while the three commissioned studies reconfirmed the Project's design details and implementation arrangements, some potential implementation risks had been identified. The Note indicated that Management had reviewed these risks, took them very seriously, and was fully committed to addressing them satisfactorily. It also indicated that Management would report to the Board within 18 months (i.e., by end January 2013) on progress in project implementation and in the implementation of the risk mitigation and management measures.

20. In light of the actions proposed by Management, the Panel decided to await further developments to address key issues and risks. In discharge of its responsibilities, the Panel decided to report back to the Board by early 2013 on whether subsequent investigation is warranted.

21. The Panel received Management's Report on the Implementation of Enhanced Supervision Actions on January 28, 2013 (the "Progress Report"), which is attached to this Report as Annex I. Salient aspects of this report, as relevant for the Panel's assessment, are summarized in Section E below.

22. The Progress Report indicates that the GBWSP's implementation is delayed due to political and security events in Lebanon.[5] The Project was declared effective only in December 2012 but in the meantime, under the retroactive financing clause of the Loan Agreement, efforts were carried out to hire technical and institutional experts for the Project Management Unit (PMU), to advance the preparation of the bidding processes and to continue the water quality monitoring of the Project source waters.[6] In addition, the Progress Report notes that a number of Bank missions were carried out since October 2011, which comprised technical, fiduciary and safeguard staff, and close communication was maintained with PMU staff, with task teams of other Bank-financed projects in Lebanon and with donors.

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[4] Request for Inspection of the Lebanon: Greater Beirut Water Supply Project – Note addressing issues following submission of studies commissioned by Management, July 28, 2011, (hereinafter "Management Note")

[5] Report on the Implementation of Enhanced Supervision Actions in Response to Inspection Panel Report (Report no. 63546-LB) on the Lebanese Republic Greater Beirut Water Supply Project (IBRD Loan no. 7967-LB) , January 28, 2013, p. iv (hereinafter "Progress Report").

[6] Progress Report, p. 10.

23. According to the Progress Report, the Bank has also retained experts to reinforce project supervision, and to review design and tender documents. It also hired an international water quality expert to review the water quality monitoring results and the bid specifications for the Project's water treatment plant. Management notes that it further monitors other Government projects including the Canal 800 Irrigation Project and the Business Plan for Combating Pollution of the Litani River.

E. Panel review of additional information provided

24. This Report presents the Panel's final determination on whether subsequent investigation is needed into the issues of water quality, Project costs and water availability, in light of the information in the Progress Report. The Panel has also taken into account further information provided by the Requesters as well as additional studies available.

25. On each of the three issues, this section provides a brief summary of the Panel's initial concerns, the conclusions of the Management-commissioned studies, and the remaining concerns expressed by the Panel in its Follow-up Report (July 2011). This is followed by a review of the additional information made available to the Panel through recent reports.

1) On the issue of water quality

26. **Summary of previous reports.** In its (first) Report and Recommendation the Panel noted that "*the mixed origin of the pollutants and the seasonal variability of pollutant levels*" in the GBWSP source waters raised a question about the adequacy of the water treatment provided for under the Project. The Panel added that this, in turn, raised the issue of "*whether the various assessments supporting the design of the Project have adequately, and in compliance with Bank Policy, analyzed the water quality issue and related implications in terms of strategies (e.g. treatment at source of pollution), design and costs of water treatment.*"[7] Issues of compliance identified by the Panel related to the policy on Environmental Assessment (OP/BP 4.01), particularly with respect to the analysis of potential environmental risks and impacts in its area of influence.

27. The Panel retained an expert, Perry McCarty, to examine the Review of Source Water Quality prepared by a team from the University of North Carolina. The Panel expert agreed with the Review's key findings, but emphasized that these findings rested on the key assumption that the Government's proposals to improve source water quality would indeed be implemented – i.e. the Business Plan for Combating Pollution in the Litani Basin. The expert also highlighted that the high concentrations of organic matter in the Qaraoun Lake and the Joun reservoir were cause for concern and noted that eutrophication could be the cause of such high levels. Thus, in its July 2011 Follow-up Report, the Panel concluded that, with respect to water quality, important

[7] First Report and Recommendation, ¶ 60.

issues remained. It identified "*the nature and extent of future measures to improve source water quality in the upper Litani River Basin and, in this respect, the need for nutrient control and the containing of risks for the Project associated with eutrophication in the Qaraoun Lake and upstream*" as warranting further consideration.[8]

28. The action plan prepared by Management proposed four sets of actions: (1) follow up on the implementation of the Ministry of Environment (MoE) Business Plan for Combating Pollution in the Litani Basin, (2) water quality monitoring of Project source waters, (3) expert review of the water treatment plant design and bid documents, and (4) study on the causes and mitigation measures for eutrophication in Qaraoun Lake.

29. **Review of additional information**. Management reports that it has maintained an active dialogue with the GoL regarding the implementation of the Business Plan for Combating Pollution of the Litani Basin and supported a number of activities to mitigate the impacts of waste pollution in the Litani River. Among these activities is the preparation of a Loan to the GoL for pollution abatement in the Litani Basin (the proposed Lebanon Environmental Pollution Abatement Project) aimed at strengthening the monitoring and enforcement capacity of the Ministry of Environment and at establishing mechanisms to support pollution abatement investments in the Litani Basin. In addition, the Progress Report indicates that the Bank has assisted the MoE in the preparation of a National Wastewater Strategy – to reduce discharges of untreated domestic and industrial waste into Lebanon waters – and of environmental legislation, based on Bank safeguards, focusing among other things on environmental impact assessments.

30. The BMLWE capacity to monitor water quality has been enhanced through a partnership with the Department of Civil and Environmental Engineering of the American University in Beirut. Water samples from the Joun reservoir, Qaraoun Lake, Awali River and Anane pool are collected and analyzed on a bi-monthly basis. Management states that the quality of the water has not changed between April 2011 and November 2012. In addition, the analysis concludes that metal contamination is of no concern. Although the Qaraoun Lake is contaminated from farming and industrial activities, the Joun reservoir water quality is characteristic of rivers waters moderately affected by human activities, and conventional water treatment can mitigate against these concentrations. The analysis indicated concentrations of nitrite in Joun, Anane and Qaraoun, and the tender documents for the WTP were updated accordingly.

31. With respect specifically to the GBWSP and the design of the water treatment plant (WTP), Management notes that bidders can propose different designs to treat the water at the required international standards (i.e. a Design-Build-Operate contract). Project tender documents include a "baseline design" developed by an expert firm and then reviewed by an expert in water quality retained by the Bank. In addition,

[8] Follow Up Report, ¶ 49.

Management has carried out further activities, including confirming that the water quality specialist within the PMU has the necessary experience to review the bids for the WTP and ensuring that the WTP tender documents include evaluation criteria specific to water quality effluent standards.

32. The Progress Report further notes that Management has commissioned a study on causes, impacts and mitigation options of eutrophication of Qaraoun Lake. This study proposed a strategy in four points to manage the consequences of eutrophication in Qaraoun Lake. The strategy provides for reducing nutrient inputs, minimizing algae in source water, ensuring adequate water treatment, and developing and implementing a comprehensive risk management strategy.

33. **Conclusion**. In light of the foregoing, the Panel is satisfied that Management has provided evidence that it has complied with OP 4.01 on Environmental Assessment and, as a result, actions aimed at addressing the Requesters' concerns have been undertaken.

2) On the issue of Project costs

34. **Summary of previous reports.** In its (first) Report and Recommendation the Panel questioned whether the assumption that water tariffs would not increase as a result of the Project was realistic. The subsequent Study of Project Cost Estimates, Financial and Economic Analyses, commissioned by Management, concluded that the Project represented the least cost solution to achieve the Project objective of providing potable water to the residents of the Greater Beirut area. In terms of costs, according to the Study, the financial analysis overstated the incremental energy costs so it was deemed that utility net revenues would likely be stronger than estimated. On the other hand, the Study found that the economic analysis significantly overestimated the Project expected net present value. As a result, the Project would have less room for cost overruns or benefit delays than originally envisioned.

35. The Panel retained a financial expert, Roberto Mosse, to evaluate the Management-commissioned study. The Panel's expert noted a need for better analysis of revenue forecasts for EBML and its likely capacity to contribute towards debt servicing.

36. Management's action plan included three sets of actions: (1) technical expert to review the tunneling work tenders and join Bank supervision missions; (2) assistance to GoL to mobilize additional financing for the Project if practical and timely; and (3) confirmation of cash availability of BMLWE to finance GBWSP costs as planned.

37. **Review of additional information**. The Progress Report indicates that the Bank retained an engineering firm to carry out a review of the tunnel tender document and the contractor prequalification evaluation report for the tunnel and the pipeline.

38. Management further states that it "*monitors project cost estimates closely*" and that in preparing the Progress Report it reappraised the project costs, which were "*assessed*

to be unchanged as compared to the 2010 appraisal figures."[9] Therefore, Management concludes that additional financing is not needed at this time. Further, BMLWE will contribute USD140 million towards Project costs but will not service the loan, the agreement for which is between the Bank and the GoL. Management states that the Bank continues to monitor BMLWE financial performance and its ability to provide its funding for the Project.

39. **Conclusion**. In light of the foregoing the Panel is satisfied that Management has provided evidence that it has complied with relevant policies and that actions were undertaken to address concerns raised in the Request with respect to the financial strength of BMLWE and potential effects on water tariffs.

3) On the issue of water availability

40. **Summary of previous reports.** In its (first) Report and Recommendation the Panel stated that data provided to the Panel during its visit indicated that the total annual inflow of water to the Qaraoun Lake, the main water source for the GBWSP, showed great fluctuations. This, the Panel noted, raised the question of whether water availability in the Qaraoun Lake in dry periods would be sufficient to supply water to Beirut under the Project as well as meet all other demands for water, including those by new irrigation schemes and the requirements for hydropower.

41. The 2011 Study of Source Water Quantity, commissioned by Management, concluded that based on a review of historic flow data "*there is adequate water available to meet the goals of the GBWSP*" and that "*there is ample water available*" for the Project, existing irrigation and other potable water projects.[10] These conclusions, however, lay on a number of key assumptions, including in particular that recent historic water availability data are representative of future patterns. The conclusions were also based on the Presidential Decree No. 14522 of May 16, 1970, which assigns 50 million cubic meters (MCM) of Litani river water and other sources to potable water. Other assumptions were that the GBWSP is designed to meet short term water needs of the Greater Beirut area until 2016, that current demands for irrigation were at the highest recently observed, and that the Canal 800 irrigation project would begin to withdraw water only in 2021 and would reach maximum withdrawal value in 2031. According to the Study, Canal 800 "*will account for about 65 percent of the usable storage of the Karaoun Reservoir (170 MCM), and its feasibility can only be determined in the context of a broader analysis of Lebanon's total water resource availability*."[11]

[9] Progress Report, ¶ 45.
[10] Dr. Jamie Bartram, Director of the Water Institute at UNC, Joseph Lo Buglio P.E., Greater Beirut Water Supply Project, Independent Technical Review of Source Water Quantity, University North Caroline, The Water Institute, May 31, 2011, (hereinafter "Review of Source Water Quantity") p.1.
[11] Review of Source Water Quantity, p.2.

42. The Panel contracted Jose Rafael Cordova, expert on hydrology, to review the Management-commissioned study. His analysis concluded that the water demands of GBWSP would be met if the estimates of water yield accurately depicted future water availability. He raised, however, questions about the methodologies used to estimate stream flow and the reliability of the data for all water sources, and observed that a project as important as GBSWP would benefit from an updated hydrologic study of all water sources. In its Follow-up Report, the Panel thus noted "*the need for better analysis and forecasting of future water inflow and water use in the upper Litani River Basin to have a reliable basis for managing competing demands on the water resources of the river basin*."[12]

43. In several communications with the Panel, the Requesters remarked on the fact that the GBWSP and the Canal 800 project[13] depend on the same water source, the Qaraoun Lake. The Requesters remain of the opinion that the water available in the Qaraoun Lake will not suffice to meet the demands of both GBWSP and Canal 800, without implementing a concurrent water augmentation project, e.g. the Bisri dam project on the Awali River.

44. Management in its action plan identified two sets of risks with respect to availability of water: (a) that water demand in the upstream portion of the Litani River basin could impact availability of water for the Project, and (b) that additional demand from downstream users could exceed the supply from the Litani/Awali Rivers.[14] In this context, the Management action plan proposed (1) working closely with the GoL to ensure timely implementation by 2016 of the Project, and (2) supporting the Government to examine future supply augmentation projects. Management also indicated that it was (3) assisting the GoL to develop its National Water Sector Strategy, and as part of this, (4) would also support the development of a plan to manage and monitor irrigation consumption trends, climate change impacts and adaptation measures, and opportunities for irrigation efficiency.

45. **Review of additional information**. In the Progress Report, Management notes that the Project is delayed but 2016 is still the target deadline for completion of Project implementation. To assist in the review of recent information the Panel again retained Jose Rafael Cordova, expert in hydrology.

46. Management reports that GoL, with the Bank's technical assistance, has prepared a National Surface Water Storage Strategy, listing a number of dams as high priorities of the Government. GoL has also developed a National Water Sector Strategy including an updated country water balance reflecting all infrastructure projects planned in the Litani and Awali basins. The Litani River Authority has continued monitoring the flow of the Litani River.

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[12] Follow-Up Report, ¶ 10.

[13] The Canal 800 project is located upstream from Markabe power plant, and downstream of Qaraoun Dam. The conveyor's capacity will be of 8.69 m^3/s, 8 m^3/s will be used to irrigate 14,700 has, and the rest will be for domestic use.

[14] Management Note, p. 2.

47. Management also reconfirms that the presidential Decree No. 14522, which allocates specific volumes of water of Litani River (and some adjacent sources) for irrigation purposes, potable water and industrial needs, is still in force. The Decree specifies that "*an amount of 50 million m³ shall be reserved for Beirut city and industrial projects*".[15]

48. Management reports that GoL has commissioned an Environmental and Social Impact Analysis (ESIA) of future water supply augmentation infrastructure for the Greater Beirut area. The Panel understands that the GoL-commissioned draft ESIA report recommends construction of the Bisri Dam on the Awali River as the preferred first priority option. According to this study, the Bisri Dam alternative has two major advantages: (1) the volume of the reservoir and its annual recharge is sufficient to meet the predicted needs of Greater Beirut to 2030 and beyond; and (2) the Bisri-Awali valley is located such that the scheme can utilize GBWSP transmission lines, treatment plant and bulk storage reservoirs, thus maximizing both water supply efficiency and the return on investment. The study concludes, with respect to the Damour Dam alternative, that the West reservoir option on Damour has storage one-third that of Bisri, while the East reservoir option (claimed to have a potential volume approaching that of the proposed Bisri Dam) has disadvantages of excessive land take, high lateral leakage, and the potential for rock falls.

49. According to the Progress Report, this analysis of alternatives was submitted to the Bank in November 2012 and is currently under Management review. Management also indicated to the Panel that the Bank has yet to make a decision on whether project financing is possible for the Government's preferred augmentation alternative.

50. With respect to competing water demands in the Litani River basin, the Progress Report notes that Management commissioned University of North Carolina Water Institute to recommend measures to monitor and manage climate change impacts through effective water resource management and to monitor and manage agricultural consumption through irrigation efficiency improvements. The Progress Report refers to some ongoing initiatives supported by the Bank echoing recommendations of the 10-point action plan.

51. As part of its review the Panel met with Management in March 2013 requesting further clarification on the medium and long-term scenario for supply of water to the Project (the Awali Conveyor), in view of further possible delays in implementation of the Project, and irrigation projects that are under implementation and rely on supplies from the Qaraoun Lake. Following the meeting, Management provided further written clarifications to the Panel. The "Responses to Questions Raised by the Inspection Panel"[16] are referred to in this Report and attached as Annex II.

[15] Management Response, Annex 12.
[16] Lebanon Greater Beirut Water Supply Project, Responses to Questions Raised by the Inspection Panel, April 5, 2013 (hereinafter "Responses").

52. The Panel understands that the National Water Sector Strategy envisages further expansion in the future of irrigated lands based on the Qaraoun Lake by enlarging the existing Canal 900 scheme (the South Bekaa Irrigation project upstream of Qaraoun Dam) and developing the new Canal 800 scheme (downstream of Qaraoun Dam).

53. Management indicated during the meeting with the Panel that the construction of the first phase of Canal 800 – the conveyor – has begun. Extraction of water, however, is to start only after 2021 with completion of the second phase (the transmission system). With gradual expansion of the distribution network (the third phase), maximum withdrawal of water is expected a decade later. In the written Responses Management also notes that the implementation of Canal 800 is behind schedule, thus delaying the start of withdrawals from the Qaraoun Dam.[17] Management reiterated that Canal 800 would thus not pose a potential conflict between competing demands for water in the short and medium term. In the longer term, the Panel's expert is of the view that new flow augmentation infrastructures have to be developed to meet all projected demands. This view is consistent with the analysis of the 2011 Review of Source Water Quantity, which did not consider the Canal 800 and further expansion of Canal 900 in order to perform the water balance in the Litani River system.

54. Management states that the GBWSP is the least cost option to secure additional water supply to the Greater Beirut area in the short term. To develop fully the irrigation projects that will require Lake Qaraoun waters, Management clarified that the GoL will also have to develop new flow augmentation infrastructures, including the Bisri dam. In the long term, Management noted, an appropriate sequence of investments is needed to meet competing water demands in the Greater Beirut region and in the Southern Lebanon. Furthermore, Management confirmed, should a drought occur in the future, Presidential Decree No 14522 guarantees that drinking water supply will have first priority.[18]

55. **Conclusion.** In light of the information included in the Progress Report, additional responses by Management, new planning documents, information received from the Requesters and the review of the Panel's expert, the Panel is of the view that the availability of water for the Project and any impacts on other users have been adequately considered. Management has provided sufficient information to show that the relevant policy and procedures were complied with.

F. Recommendation

56. The Panel is pleased to note Management's commitment in the course of the Panel process to ensure that the issues raised in the Request and identified by the Panel as warranting further consideration were seriously taken into account to ensure that the Project is in compliance with Bank policies. As a result, important steps are being taken to address potential harm to the Requesters and other Project affected people.

[17] Responses, p. 1.
[18] See also Responses, p. 1.

57. In light of the foregoing and taking into account paragraph 5 of the 1999 Clarifications, which provides that "*the Inspection Panel will satisfy itself as to whether the Bank's compliance or evidence of intention to comply is adequate, and reflect this assessment in its reporting to the Board*", the Panel concludes that subsequent investigation of whether the Bank has complied with its operational policies and procedures with respect to the allegations contained in the Requests for Inspection is not warranted. If the Board of Executive Directors concurs with this recommendation the Panel will advise the Requesters and Management accordingly.

Biography

Jose Rafael Cordova received his PhD, in Water Resources and Hydrology, from Massachusetts Institute of Technology (M.I.T) in 1979; a Masters degree in Civil Engineering from Massachusetts Institute of Technology (M.I.T) in 1977; and a first degree from Universidad Central de Venezuela. He is a former professor of Simón Bolívar University in Venezuela, and currently is a professor of graduate studies in Hydraulic Engineering at Universidad Central de Venezuela. He is also the Director of CGR Engineering consulting firm in Venezuela. He has published more than 50 papers in Journals, Book Chapters and Conferences Proceedings; more than 250 technical reports related to hydrological and hydraulics studies; and has presented more than 60 papers in national (Venezuela) and international Congress, Conferences and Seminars. Dr. Córdova has participated in more than 275 engineering projects and consulting activities in Venezuela, Argentina, Bolivia, Bonaire, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, Egypt, El Salvador, Greece, Guatemala, Honduras, Paraguay, Peru, México, Nicaragua and Yugoslavia.

ANNEX I

INTERNATIONAL BANK FOR RECONSTRUCTION AND DEVELOPMENT
INTERNATIONAL DEVELOPMENT ASSOCIATION

PROGRESS REPORT

ON THE

IMPLEMENTATION OF ENHANCED SUPERVISION ACTIONS

IN RESPONSE TO

THE INSPECTION PANEL REPORT (REPORT No. 63546-LB) ON THE

LEBANESE REPUBLIC

GREATER BEIRUT WATER SUPPLY PROJECT

(IBRD LOAN No. 7967-LB)

January 31, 2013

ABBREVIATIONS AND ACRONYMS

AUB	American University of Beirut
BMLWE	Beirut Mount Lebanon Water Establishment
CDR	Council for Development and Reconstruction
CNRS	Centre National de la Recherche Scientifique (National Center for Scientific Research)
CPS	Country Partnership Strategy
CWSAS	Country Water Sector Assistance Strategy
DBO	Design Build Operate
GBWSP	Greater Beirut Water Supply Project
GEF	Global Environment Facility
GoL	Government of Lebanon
ICB	International Competitive Bidding
LRA	Litani River Authority
MNA	Middle East and North Africa
MOE	Ministry of Environment
MOEW	Ministry of Energy and Water
NASA	National Aeronautics and Space Administration
NWSS	National Water Sector Strategy
PER	Prequalification Evaluation Report
PMU	Project Management Unit
RFP	Request for Proposals
SEA	Strategic Environmental Assessment
SESIA	Strategic Environmental and Social Impact Assessment
USAID	United States Agency for International Development
WTP	Water Treatment Plant

Lebanese Republic

Greater Beirut Water Supply Project

(IBRD Loan No. 7967-LB)

Progress Report

On the Implementation of Enhanced Supervision Actions

In Response to the Inspection Panel Report (Report No. 63546-LB)

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EXECUTIVE SUMMARY

- The Greater Beirut Water Supply Project (GBWSP) aims to increase the provision of potable water to over 1.2 million residents in the project area within the Greater Beirut region of Lebanon, including low-income neighborhoods of Southern Beirut, and to strengthen the capacity of the Beirut Mount Lebanon Water Establishment (BMLWE) in utility operations.

- On December 16, 2010, the World Bank Board approved a USD 200 million Specific Investment Loan to the Government of Lebanon (GoL) to finance a portion of GBWSP costs. The Project became effective on December 4, 2012 and is currently under implementation.

- On November 10, 2010, the Inspection Panel (the Panel) registered a Request for Inspection of the GBWSP. Following the receipt of the Management Response, the Panel issued its initial Eligibility Report, which was discussed by the Bank's Board of Directors on March 10, 2011. During the meeting, Management proposed to expand a study already undergoing on water quality issues to cover water availability and costs. The Board invited the Inspection Panel to return by July 2011 after considering and taking into account the analysis of the study commissioned by Management on the water quality, availability, and cost, in order to inform the Board as to whether or not subsequent investigation was warranted, and if so, on its precise focus.

- Following this Board discussion and the submission of three independent studies on issues raised by the Panel (i.e. water quality, water availability and project cost, economic and financial analyses), Bank Management committed to the implementation of an 18-month Action Plan for enhanced project supervision, risk mitigation and management.

- On July 29, 2011, in its Eligibility Report, the Panel committed to report back to the Board by January 2013 with a recommendation as to whether subsequent investigation of the GBWSP is still warranted following the Panel's review of a report from Management detailing the implementation of the agreed Action Plan.

- **The objective of the present report is to inform the Board of the status of ongoing project implementation and the results of the 18-month Action Plan for enhanced project supervision.**

Project Implementation

- Loan Documents were signed on February 8, 2012. The project was however only declared effective on December 4, 2012. This delay was caused by a series of major political and security events in Lebanon, which hindered the GoL's efforts in meeting the effectiveness conditions as planned.

- Efforts by the Project Management Unit (PMU) and Bank Task Team over the past two years have been instrumental in offsetting some of the delay. Financed by the GoL under the retroactive financing clause of the Loan Agreement, these efforts have included:

    - **Project water quality monitoring**;
    - **Prequalification of 13 contractors and shortlisting of 6 construction supervision firms** for the tunnel and pipeline works per the Bank's Procurement Guidelines;
    - **Review of tender documents for the tunnel and pipeline by an independent tunneling expert**;
    - **Contracting of a design firm** to update designs and tender documents of distribution network;

- **Incorporation of results of water quality monitoring and comments** of a Bank independent water quality expert in tender documents of water treatment plant;
- **Advanced preparation of land acquisition decrees**; and
- **Training** on environmental and social safeguards.

- The Bank's project supervision was bolstered by the independent technical experts retained to review the project's tunneling and water treatment infrastructure. Management actively monitors the implementation of project-specific environmental and social safeguards, and further liaises with various GoL agencies and donors implementing other water sector projects in Lebanon.

- Despite delays in the schedule of implementation, the GBWSP continues to be responsive to project beneficiaries' short-term demand for additional water that meets all Lebanese and international health standards.

Action Plan for Enhanced Supervision Activities

- The 18-month risk mitigation and management Action Plan centered on: (i) water quality; (ii) water availability; and (iii) project cost, economic and financial analyses. The plan comprised the following activities:

  - **Action Item 1:** Follow up on implementation of the Ministry of Environment (MOE) "*Business Plan for Combating Pollution in the Litani Basin*";
  - **Action Item 2:** Monitor water quality of the project source waters;
  - **Action Item 3:** Review water treatment plant (WTP) design by water quality expert;
  - **Action Item 4:** Study causes and mitigation measures for eutrophication in Lake Karoun;
  - **Action Item 5:** Support the GoL in project implementation and in examination of future water supply augmentation projects;
  - **Action Item 6:** Develop a plan to mitigate impacts of agriculture and climate change on water availability;
  - **Action Item 7:** Review tunneling works tender documents by an experienced tunneling expert;
  - **Action Item 8:** Mobilize additional project financing to the GoL if required; and
  - **Action Item 9:** Confirm BMLWE cash availability to finance GBWSP costs as planned.

- Management closely monitored the implementation of each of the above activities through regular project briefings and dedicated meetings with Senior Bank Management.

- The outcome of each Action Plan item is summarized in Table 1 of the report, wherein a detailed description of the implementation of each of the enhanced supervision activities is further provided. The Action Plan reconfirmed both, the original appraisal findings, as well as the results of the three independent technical studies.

- Moving forward, successful project implementation remains a Management priority. Senior Management will continue to oversee project implementation on a regular basis and has provided the necessary resources for an enhanced supervision of the project. The Bank will continue to work closely with the GoL and public and private project stakeholders to ensure the full implementation of the GBWSP.

I. Introduction

Project Summary

1. Approximately half of the Lebanese population lives in the Greater Beirut and Mount Lebanon area. Home to the capital city of Beirut, some of the country's most densely populated urban centers and a major hub for public sector, private sector and tourist activity, the Greater Beirut Mount Lebanon region plays a pivotal role in the Lebanese economy.

2. The Beirut Mount Lebanon Water Establishment (BMLWE) is one of the four regional water utilities overseen by the Ministry of Energy and Water (MOEW). Traditionally considered one of the relatively better performing water utilities, the BMLWE nonetheless reports average technical and commercial losses as high as 40 percent. While the municipal connection rate to the water network reaches 90 percent, continuity of water supply is low and drops to as little as 3 hours per day in the summer season (between May and October). This seasonal water imbalance is primarily caused by growing water demand, deficient water distribution networks and a lack of water storage infrastructure.

3. Reports and studies by the Government of Lebanon (GoL), donors and academic community concur: If no actions are taken to increase water supply, improve distribution efficiency and increase storage capacity, chronic water shortages across the Greater Beirut and Mount Lebanon region will occur by as early as 2020.

4. The Greater Beirut Water Supply Project (GBWSP) was under preparation by the Government for over 10 years. Along with other major water infrastructure projects, the GBWSP is a high priority project in the MOEW's 2012 National Water Sector Strategy (NWSS), and also features in the strategic implementation plans of the Ministry of Environment (MOE) and Council for Development and Reconstruction (CDR), the national agency responsible for the implementation of major national infrastructure.

5. The GBWSP aims to increase the provision of potable water to residents in the project area within the Greater Beirut region including low-income neighborhoods of Southern Beirut, and to strengthen the capacity of the BMLWE in utility operations. The project aims to increase short-term supply of potable water in the project area by 250,000 cubic meters per day (m^3/d) with approximately 1.2 million residents expected to directly benefit from the project, including 350,000 low-income residents of the Southern Beirut suburbs.

6. As per Presidential Decree No. 14522, which allocates water to various regions of Lebanon for potable and agricultural use, a portion of water from the Litani and Awali Rivers will be diverted to help meet Greater Beirut's short-term demand for water. The Litani River is the longest river in Lebanon. Dammed at Lake Karoun and supplemented by several freshwater springs, the Litani River feeds several existing irrigation and hydropower infrastructures, flows through the existing Joun Reservoir and discharges finally to the Mediterranean Sea. The Awali River (also known as the Bisri River in its upper section) also flows through the existing Joun Reservoir and discharges to the Mediterranean.

7. The GBWSP consists of three components with an estimated cost of USD 370 million:

- ***Component 1: Bulk water supply infrastructure:*** Water from the existing Joun reservoir will be transferred by gravity through underground tunnels to a water treatment plant (WTP) and onwards to three bulk storage reservoirs through twin transmission pipelines.

- ***Component 2: Supply reservoirs, distribution network and metering:*** Water stored in the bulk storage reservoirs will be distributed throughout the project area via a network of new and rehabilitated distribution pipelines and smaller supply reservoirs. Meters will also be installed in select project areas.

- ***Component 3: Project management, utility strengthening and national studies***. This component will finance the costs of the Project Management Unit (PMU), strengthening BMLWE operations and water sector studies of national relevance.

8. On December 16, 2010, the World Bank Board of Executive Directors approved a World Bank Specific Investment Loan of USD 200 million (Loan No. 7967) to finance a portion of the GBWSP. The BMLWE is financing an additional USD 140 million of project costs from its own resources. The GoL is further contributing USD 30 million towards project costs and servicing the total project debt, as per Loan Agreement documents.

9. Loan and project documents were signed on February 8, 2012. Between January 2011 and December 2012, however, several major political and security-related events significantly hindered the GoL's ability to finalize various effectiveness conditions as planned. The project was accordingly declared effective on December 4, 2012.

Project Implementation Status

10. In the period between Board approval and declaration of project effectiveness, efforts by the PMU and Bank Task Team were instrumental in offsetting some of the incurred delay. Financed by the GoL under the retroactive financing clause of the Loan Agreement, these efforts included: (i) hiring technical and institutional experts to the PMU; (ii) advance preparation for tendering of several large procurement packages and; (iii) ongoing water quality monitoring of project source waters, among others.

11. Water sector missions were carried out in October 2011, April 2012, July 2012, and January 2013. The Task Team, which comprises senior technical, fiduciary and safeguard staff, including Beirut-based staff members, maintains regular weekly communication with the various project implementing agencies and coordinates closely with task teams of parallel Bank-financed projects in Lebanon, particularly in the environment sector, as well as with other donors involved in the water sector.

12. The MOEW, CDR and the BMLWE are jointly involved in managing project implementation, through a PMU which comprises 12 technical and institutional specialists. The PMU is led by a Project Coordinator with extensive experience in the implementation of infrastructure projects under donor financing. An experienced civil engineer, with expertise in underground tunneling construction and management, oversees Component 1. An Operations Advisor at the MOEW is further responsible for overall implementation oversight, as well as the design and implementation of Component 3 activities.

13. The Bank has retained additional independent technical experts to further bolster project supervision. The design and tender documents of the underground tunnel under Component 1 have been reviewed and updated as per the recommendations of an independent firm with international experience in underground tunnels and tunnel boring machines. An international water quality expert has also reviewed water quality results and bid specifications for WTP under Component 2.

14. Management also monitors the implementation of other related GoL projects including: (i) the Greater Beirut Wastewater Project, financed by the European Investment Bank (EIB) and; (ii) the Canal 800 Irrigation Project financed by the Arab Fund for Economic and Social Development and Kuwait

Fund for Arab Economic Development, both currently under implementation by CDR as well as; (iii) the "Business Plan for Combating Pollution of the Litani River", led by the MOE.

15. Through this coordination, Management: (i) has reconfirmed appraisal findings that the wastewater collection and treatment facilities located within the Greater Beirut area will collect and treat the additional water volume delivered through the GBWSP; (ii) is currently preparing a USD 17 million loan to GoL for pollution abatement in the Litani Basin; and (iii) has reconfirmed the findings of independent studies on water quality and water availability, submitted to the Board in July 2011.

16. Management also coordinates Bank activities in the water sector with other donors. The Bank is regularly represented at the quarterly Water Sector Coordination Meetings hosted by the MOEW, and has participated in the MOE Donor Meetings for the "Business Plan for Combating Pollution of the Litani River" in September 2011 and November 2012.

17. Fiduciary controls, namely financial management and procurement, are in good standing, albeit with delays in the implementation of the procurement plan due to the delay in declaring project effectiveness as described above.

18. Demonstrating its commitment to the project even before the Loan was declared effective, BMLWE disbursed USD 2.8 million on the project against the Loan retroactive financing clause. Audited financial statements as well as interim unaudited financial reports for the BMLWE have been reviewed and accepted by the Bank. Project accounting software has also been commissioned within the PMU. The Task Team provided hands-on training to the PMU's Financial Officer and Accountant on the Bank's reporting requirements and disbursement guidelines.

19. Management continues to monitor project environmental and social safeguards compliance and has engaged in capacity building with respect to Bank requirements. With regards to social safeguards, Management has provided capacity building to the PMU on Bank requirements for stakeholder consultation, land acquisition and grievance redress mechanisms. Management also regularly reviews the status of land acquisition under the project as submitted in the PMU Quarterly Reports, as well as the implementation of the GBWSP Environmental Management Plan and Resettlement Action Plan. The most recent site visit was undertaken by Bank social and environmental specialists on December 11, 2012.

Summary of Panel Process, Independent Reviews and Board Consideration

20. On November 10, 2010, the Inspection Panel (the "Panel") registered a Request for Inspection (IPN Request RQ 10/09) of the GBWSP (RQ10/09). Following Management's response to the Request (December 13, 2010), the Panel's initial Eligibility Report (January 20, 2011), and a Board discussion (March 10, 2011), Management commissioned three independent technical reviews on: (a) source water quality; (b) water availability; and (c) project cost estimates, financial analysis and economic analysis. The three studies were submitted to the Board on June 9, 2011, translated into Arabic and publically disclosed.

21. The studies reconfirmed the adequacy of the GBWSP's design details and implementation arrangements. The studies also identified several potential risks described below. In its July 28, 2011 memorandum to the Board and Panel, Management committed to enhance plans for project supervision in an 18-month Action Plan designed to mitigate these identified risks.

22. The results of the three studies and the respective identified risks are summarized below:

(a) Source Water Quality Independent Review and Identified Risks

- ***Summary of independent review findings.*** Water available to the GBWSP was found to be: "of sufficient quality such that conventional water treatment technologies can produce potable water meeting Lebanese and international health and aesthetic based standards and guidelines."[1]

- ***Risks.*** (i) The GoL may not identify and implement adequate upstream catchment protection measures and; (ii) increased input of nitrogen and phosphorous could lead to unquantified eutrophication of Lake Karoun and impact project water quality.

(b) Water Availability Independent Review and Identified Risks

- ***Summary of independent review findings.*** "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."[2]

- ***Risks.*** Increased water demand in the upstream Litani River basin could impact the availability of water for the GBWSP. Also additional water demand from future water users could exceed the supply from the Litani/Awali Rivers.

(c) Project Cost Estimates, Financial and Economic Analysis Independent Review and Identified Risks

- ***Summary of independent review findings.*** "The appraisal team established the adequacy of the investment cost estimates, as required by OMS 2.20, though the operating cost was substantially overestimated." "The team addressed the financial aspects of the project appropriately" and "the economic analysis fundamentally meets the requirements of OP 10.00, OP10.04 and OMS 2.20."[3]

- ***Risks.*** (i) Potential cost over-runs could negatively impact project implementation; (ii) funds may not be available to service the project debt and; (iii) BMLWE might not have the necessary cash reserves for project financing

23. In its July 29, 2011 report, the Panel acknowledged the Action Plan for Enhanced Supervision and committed to review progress made to address the identified risks described above before reporting back to the Board by January 2013 with a final recommendation as to whether a subsequent investigation of the GBWSP would still be warranted.

II. Management Action Plan

24. The 18-month risk mitigation and management Action Plan centered on the three pillars of: (i) source water quality; (ii) water availability; and (iii) project cost, economic and financial analyses. The Action Plan comprised the following specific actions:

- **Action Item 1**: Follow up on the implementation of the MOE "*Business Plan for Combating Pollution in the Litani Basin*";

[1] "GBWSP Independent Technical Review of Source Water Quality" (University of North Carolina, May 2011).
[2] "GBWSP Independent Technical Review of Source Water Quantity" (University of North Carolina, May 2011).
[3] "GBWSP Study of Project Cost Estimates, Financial and Economic Analyses" (Travers, May 2011).

- **Action Item 2**: Monitor water quality of project source waters;
- **Action Item 3**: Review WTP design by a water quality expert;
- **Action Item 4:** Study the causes and mitigation measures for eutrophication in Lake Karoun;
- **Action Item 5**: Support the GoL in project implementation and in examining future water supply augmentation projects;
- **Action Item 6:** Develop a plan to mitigate the impacts of agriculture and climate change on water availability;
- **Action Item 7:** Review tunneling works tender documents by an experienced tunneling specialist;
- **Action Item 8:** Mobilize additional project financing to the GoL if required; and
- **Action Item 9**: Confirm BMLWE cash availability to finance GBWSP costs as planned.

III. Outcome of Management Action Plan Implementation

25. The outcomes of the Management Action Plan are summarized in Table 1 below and detailed in the sections thereafter. In Management's view, the 18-month Action Plan has been successfully implemented. This report concludes that the GBWSP continues to be responsive to project beneficiaries' demand for additional water that meets all national and international health standards. The project remains cost-effective and sustainably financed.

Table 1: Implementation of Management Action Plan

WATER QUALITY

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
GoL not committed to implementing upstream catchment protection measures	The GoL has reconfirmed its commitment to implementation of MoE Business Plan for Combating Pollution of Karoun Lake (reference Ministerial Declaration dated June 13, 2011) and has arranged stakeholder and donor meetings to mobilize support and financing.	**Action Item 1:** **The World Bank will maintain the ongoing dialogue with the MOE on upstream catchment protection and will participate in the Fall 2011 donor meeting to finalize the Business Plan for Combating Pollution in Lake Karoun.**	The MOE Business Plan for Combating Pollution of Lake Karoun ("the Karoun Business Plan") diagnoses sources of domestic, industrial, commercial and solid waste pollution to surface waters in the Upper Litani River catchment (i.e., upstream of Karoun Lake). The report presents detailed action plans to alleviate pollution incoming to Lake Karoun. The Bank has maintained an active dialogue with the MOE on the implementation of the Karoun Business Plan. The GBWSP Task Team meets regularly with MOE representatives during missions to Lebanon. Specifically, the Bank undertook the following activities to mitigate the impacts of domestic, industrial, commercial and solid waste pollution in the Litani Basin: (i) **Loan Preparation:** The Bank is currently preparing a USD 17 million Loan to GoL for pollution abatement in the Litani Basin. The proposed Lebanon Environmental Pollution Abatement Project (P143454) aims to assist the GoL in reducing industrial pollution. Specific objectives are to strengthen the monitoring and enforcement capabilities of the MOE and establish technical and financial mechanisms for supporting pollution abatement investments in the Litani Basin and other areas of industrial activity in Lebanon. The project is currently under preparation with an estimated Board date of July 16, 2013.

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
			(ii) **Participation in MOE Donor Meetings**: The Bank participated in the September 5, 2011 and November 6, 2012 MOE Donor Meetings, the objectives of which were to identify sources of financing for the Karoun Business Plan. (iii) **National Water Sector Strategy**: The Bank provided the Ministry of Energy and Water (MOEW) with technical assistance for the development of the National Water Sector Strategy (NWSS), which informed development of its 2012 Country Water Sector Assistance Strategy (CWSAS - Report no 68313-LB). The NWSS was approved by the Council of Ministers and by Parliament in March 2012 and builds directly on actions recommended by the MOE's Karoun Business Plan. The MOEW is currently also developing detailed implementation plans for the NWSS and has requested the Bank's continued assistance. The Bank CWSAS also informs the progress report on the Lebanon Country Partnership Strategy (CPS), currently under preparation. (iv) **NWSS Strategic Environmental Assessment**: Financed by the Global Environment Facility (GEF) Regional Governance and Knowledge Project, a Strategic Environmental Assessment (SEA) of the NWSS is currently under preparation in collaboration with the MOEW and MOE. The objectives of the SEA are to: (i) provide recommendations for optimizing the NWSS in order to fully integrate major environmental social, and economic concerns; (ii) test and demonstrate opportunities for practical application of the SEA in Lebanon including the Litani Basin; and (iii) test and demonstrate applicability of methodological and procedural SEA approach outlined in the 2012 Lebanon SEA decree. The SEA is currently under

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
			implementation. (v) **National Wastewater Strategy**: The Bank assisted the MOEW in the development of the National Wastewater Strategy, which was launched on December 13, 2012 in Beirut. The National Wastewater Strategy proposes a detailed set of priorities and activities to reduce the discharge of untreated domestic and industrial wastewater into Lebanese watercourses, and other environmentally sensitive areas including the Litani Basin. (vi) **Technical Assistance to the MOE on environmental legislation**: The Bank provided technical assistance to the MOE in the development of several pertinent environmental decrees namely: (i) Environmental Impact Assessment Decree; (ii) Draft Decree on National Environmental Police; and (iii) Draft Decree on National Environmental Fund. The Bank also assisted the MOE in drafting: (i) the draft law on integrated solid waste management and (ii) the draft law on Environmental Prosecutor, both of which are currently under discussion by Parliament. This legislation, designed based on Bank safeguards, is critical to the successful implementation of the Karoun Lake Business Plan, particularly regarding Environmental Impact Assessments (EIA). A water sector supervision mission took place in mid January 2013 to Lebanon, and included an environmental specialist to follow up on the various activities above and continue to ensure coordination with the GBWSP and water sector activities in general.

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
GoL not committed to implementing upstream catchment protection measures	GoL has reconfirmed its commitment to implementation of Ministry of Environment (MoE) Business Plan for Combating Pollution of Karoun Lake (reference Ministerial Declaration dated June 13, 2011) and has mobilized stakeholder and donor meetings to mobilize support and financing.	**Action Item 2:** **The World Bank will ensure that the findings of continuous downstream water quality monitoring are reported in a dedicated annex to supervision aide-memoires.**	The Beirut Mount Lebanon Water Establishment (BMLWE), in collaboration with the American University of Beirut (AUB), has collected and analyzed water quality samples from four locations along the Litani and Awali Rivers since December 1, 2011. The water quality data was subsequently submitted to the Bank on a bi-monthly basis. At the request of BMLWE, the Bank compiled the data into an electronic master sheet and submitted it to BMLWE, MOEW and CDR. This was agreed to be a more pragmatic way of reporting and statistically analyzing the water quality monitoring results. The Bank also retained a water quality expert to review the results of the water quality monitoring. Principal outcomes of the review include: (i) **The findings of the earlier independent review of GBWSP water quality remain valid;** (ii) **The review confirmed that a conventional water treatment plant, which comprises the treatment processes included in the GBWSP treatment plant, will treat the water from Joun Reservoir to international drinking water standards;** (iii) **Water quality monitoring data has been included in the WTP tender documents.** This will provide potential bidders with detailed information on the influent water quality, which in turn will optimize the design of water treatment processes. Furthermore, the WTP design includes a modern water quality laboratory and telemetric influent/effluent monitoring infrastructure;

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
			(iv) **BMLWE's capacity for water quality monitoring was enhanced** through its partnership with the AUB Department of Civil and Environmental Engineering. BMLWE has also rehabilitated its existing laboratory equipment to bolster the capacity for regular onsite analysis of relevant water quality parameters.
Increased input of nitrogen and phosphorous could lead to unquantified eutrophication of Lake Karoun and impact project water quality	An analysis of the causes and impacts of eutrophication in Lake Karoun will be commissioned. Implementation of the MoE Business Plan for Combating Pollution of Karoun Lake will control discharge of nitrogen and phosphorous to Lake Karoun. Downstream, the Water Treatment Plant at Ouardaniyeh, included in Component 2 of the GBWSP, will treat nitrogen and phosphorous (among other parameters) to Lebanese and international health and aesthetic based standards.	**Action Item 3:** **A water quality expert will join the supervision team to review the consistency of the technical design of the water treatment plant with the observed water quality.**	The WTP will be tendered as a Design Build Operate (DBO) contract wherein prequalified bidders can propose different technical designs to treat the water to the required international effluent standards. GBWSP tender documents will also include a "baseline design" which was developed by an expert consulting firm and which bidders can also price. The technical evaluation of DBO bids thus requires wide-ranging experience with various water treatment technologies. Accordingly, the Bank retained an expert in water quality to review the consistency of the proposed WTP technical design with observed water quality as described above. In addition, the Bank: (i) **Confirmed that the Water Quality Specialist recruited to the PMU has the requisite experience to evaluate water treatment plant bids.** The Bank's water engineer reviewed the terms of reference and candidate evaluation report in detail prior to providing the Bank's no objection to the recruitment. (ii) **Ensured that WTP tender documents include evaluation criteria specific to water quality effluent standards.** The Bank's independent water expert will review the evaluation report (as described above) to ensure both the evaluation criteria and their applications

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
			are consistent and representative. (iii) **Provided the PMU with examples of international best practice DBO contracts**. The PMU procurement specialist further participated in the International Labor Organization (ILO) procurement training and liaises regularly with the Bank's procurement specialist based in Beirut. The evaluation of technical bids for the WTP is planned for September 2013. The WTP works prequalification evaluation report will be submitted to the Bank for review in addition to the independent technical review described above.
Increased input of nitrogen and phosphorous could lead to unquantified eutrophication of Lake Karoun and impact project water quality	An analysis of the causes and impacts of eutrophication in Lake Karoun will be commissioned. Implementation of the MoE Business Plan for Combating Pollution of Karoun Lake will control discharge of nitrogen and phosphorous to Lake Karoun. Downstream, the Water Treatment Plant at Ouardaniyeh, included in Component 2 of the GBWSP, will treat nitrogen and phosphorous (among other parameters) to Lebanese and international health and aesthetic based standards.	**Action Item 4:** **The World Bank will work with MoE and MOEW to conduct an analysis on the causes, impacts and mitigation options for possible eutrophication in Lake Karoun.**	The Bank commissioned a study on the causes, impacts and mitigation options for eutrophication of Lake Karoun. The study reconfirmed the findings of the GBWSP Independent Technical Review of Source Water Quality (May 2011) and confirmed that "water from the Joun reservoir is of sufficient quality such that conventional water treatment technologies can produce potable water meeting Lebanese and international health and aesthetic based standards and guidelines." The study further proposed a four point strategy to manage the consequences of eutrophication on Lake Karoun and confirmed that the GoL has taken important steps within the GBWSP and associated activities towards implementation of each of these strategies as described below: (i) **Reduce nutrient inputs:** MOE's Lake Karoun Business Plan identifies point and non-point nutrient inputs in detail and offers remediation measures that address the causes of eutrophication in Lake Karoun.

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
			With the implementation of various activities in the Business Plan as described above, nutrient inputs are drastically reduced in the Litani watershed. (ii) **Minimize algae in source water:** The GBWSP will utilize waters from Lake Karoun, as well as water from the Awali River and 3 freshwater springs. As such the GBWSP minimizes the source of algae. (iii) **Ensure adequate water treatment:** The GBWSP WTP "baseline design" comprises conventional treatment technologies that include coagulation, filtration, and ozonation, which have proved effective in removing cyanobacteria and associated toxins. Bidders on the WTP will have the opportunity to propose varying technical proposals for water treatment as per the DBO contract proposed above. (iv) **Develop and implement a comprehensive risk management strategy**. The Lake Karoun Business Plan and National Water Sector Strategy both comprise comprehensive monitoring of the Litani Basin for nutrient levels, algal concentrations, and algal composition – all of which are recommended to assist with planning and evaluating the success of eutrophication mitigation.

WATER AVAILABILITY

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
Increased water demand in the upstream Litani River basin could impact the availability of GBWSP water. Additional water demand from future water users could exceed the supply from the Litani / Awali rivers	The GBWSP will be implemented by 2016. The GoL is currently in various stages of preparation for future medium- and long-term water projects that utilize Litani and Awali rivers. The GoL has confirmed that these projects will not be fully implemented until 2021 and beyond. The GoL has also begun the preparation of various supply augmentation projects that will supplement Litani and Awali river waters in the future.	**Action Item 5:** **The World Bank will work closely with the GoL, and through project supervision activities, to ensure that the GBWSP is implemented on schedule by 2016.** **The Bank will also support the GoL in examining future supply augmentation projects**. **In Management's December 2010 Response to the Request for Inspection, Management committed to carry out a Strategic Environmental and Social Impact Assessment (SESIA) to review the feasibility studies, environmental and social impacts and costs of the various GoL alternatives for longer-term water supply to the Greater Beirut Region including the Bisri, Damour and Janna Dams.**	The Bank continues to coordinate closely with GoL to avoid further implementation delays moving forward. The GoL has retained a consulting firm to undertake an Environmental and Social Impact Analysis (ESIA) of future water supply augmentation infrastructure in the Greater Beirut Region. The draft ESIA was submitted to the Bank for review on November 28, 2012. The Bank has communicated to the GoL that a decision to proceed with preparation of a new water supply augmentation project will be considered after the Bank's review of an evidence-based ESIA that assesses the technical, social, environmental and economic aspects of all dam and non-dam options for water supply augmentation in the Greater Beirut Region. The Bank undertook a detailed review and comparison of: (i) international best practice standards for a Strategic Environmental and Social Impact Assessment (SESIA) and the terms of reference and workplan for the new water supply augmentation project. The results confirmed that the SESIA committed to by Management is being implemented by the GoL as required and as per international standards of best practice. Management further confirmed that: (i) **MOEW has developed a National Surface Water Storage Strategy** which details national demand for water and sources of supply through augmentation. The National Surface Water Storage Strategy lists many dams (including the dams mentioned by the GBWSP Requesters) to be high priority infrastructure projects

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
			required by the GoL; (ii) **Continuous flow monitoring of the Litani would remain a principal activity of the Litani River Authority (LRA).** The LRA is the water establishment responsible for the regulation of the Litani river and the operation of the Karoun Dam and the 3 downstream hydropower plants; (iii) **The MOEW's recently approved NWSS is informed by an updated country water balance which reflects all infrastructure projects planned on the Litani and Awali rivers;** and (iv) **Presidential Decree No 14522 on Litani and Awali River water allocation remains in force**. The decree allocates specific volumes of Litani and Awali river waters to various areas across Lebanon for potable and agricultural use.
Increased water demand in the upstream Litani River basin could impact the availability of GBWSP water. Additional water demand from future water users could exceed the supply from the Litani/Awali rivers	The GBWSP will be implemented by 2016. The GoL is currently in various stages of preparation for future medium- and long-term water projects that utilize the Litani and Awali rivers. The GoL has confirmed that these projects will not be fully implemented until 2021 and beyond. The GoL has also begun the preparation of various supply augmentation projects that will supplement the Litani and Awali river waters in the	**Action Item 6:** **As part of the World Bank's ongoing technical assistance to GoL for the development of the NWSS, a plan will be developed to monitor and manage consumption trends, opportunities for irrigation efficiency improvements and climate change mitigation and adaptation measures, among others. This process would include**	A plan was developed to monitor and manage consumption trends in the Litani basin, capitalize on opportunities for irrigation improvements and put in place plans for climate change mitigation and adaption measures. The plan comprises a 10-point action plan to monitor and manage: (i) climate change impacts through effective water resources management and; (ii) agricultural consumption through irrigation efficiency improvements: **Plan to Monitor and Manage Climate Change Impacts through Effective Water Resources Management** • Strengthen analytical tools for more precise assessments of climate change impacts;

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
	future.	**specific recommendations for management of the Litani/Awali rivers and their basins.**	• Mainstream climate change impacts and adaptation measures into the planning, design and implementation of water and agriculture projects in a coordinated approach; • Further develop drought and flood mitigation and adaptation plans; and • Increase net water supply by further developing water collection and storage infrastructure and promote the use of alternative water resources in planning and investment programs. **Plan to Monitor and Manage Agricultural Consumption through Irrigation Efficiency Improvements** • Upgrade agricultural technologies; • Invest in high value crops; • Monitor water availability and use; • Enforce regulations and policies; • Establish Water User Associations; • Pilot demonstration projects as a means to raise awareness; and • Invest in research In addition to developing the plan, the Task Team liaised with another World Bank project (P117170) currently under implementation in Lebanon in partnership with the National Aeronautics and Space Administration (NASA). The Regional Coordination on Improved Water Resources Management and Capacity Building Project (TF012052) is implementing many of the plan's recommendations, including those related to flood and drought modeling and mapping, measurement of evapotranspiration and groundwater recharge among others.

PROJECT COST, FINANCIAL AND ECONOMIC ANALYSES

Description of Risk	Risk Management Measures	World Bank Action Plan	Summary of Outcomes
Potential cost over-runs could negatively impact project implementation.	A USD 20 million contingency budget has been incorporated into project costs. The PMU will also be staffed by experienced professionals that will assist the BMLWE in project implementation and supervision.	**Action Item 7:** **An experienced technical specialist (with demonstrated experience in tunneling infrastructure) will join the World Bank supervision team, review the tenders for the tunneling bids and will participate in select Bank supervision missions.**	The World Bank retained an engineering firm with extensive tunnel experience that undertook a technical review of the tunnel tender documents and assisted the Bank with the technical review of the contractor prequalification evaluation report for the tunnel and pipeline contract. The firm joined the January 2013 World Bank supervision mission and will join upcoming World Bank supervision missions as required to provide CDR with technical assistance in the evaluation of bids received for the complex tunneling and pipeline contract.
Potential cost over-runs could negatively impact project implementation.	20 million USD of contingency budget has been incorporated into project costs. The Project Management Unit will also be staffed by experienced professionals that will assist the BMLWE in project implementation and supervision.	**Action Item 8:** **The World Bank will assist GoL in mobilizing additional financing for the project if practical and timely.**	Additional financing is not required at this time. Management will continue to monitor project costs as part of supervision activities and will work with the GoL to mobilize additional financing if required.
Funds may not be available to service the project debt. **BMLWE has not confirmed availability of cash reserves for project financing and could thus negatively impact project implementation**	The GoL has committed to servicing the World Bank loan of USD 200 million. The Beirut Mount Lebanon Water Establishment has confirmed availability of cash reserves to finance USD 140 million of project costs. The remaining USD 30 million will be financed by the GoL.	**Action Item 9:** **Letter from BMLWE is available upon request**.	The BMLWE will contribute USD 140 million towards project costs. The BMLWE will not service the USD 200 million Bank Loan. Loan and project documents between the Bank and the Lebanese Borrower (i.e., the Ministry of Finance) confirm these arrangements. The Bank monitors BMLWE financial performance as part of normal supervision. By the end of 2011, cash reserves stood at USD 198.9 million versus the appraisal level of USD 170 million. Performance in 2012 has met expectations.

Source Water Quality

Action Item 1: Follow up on the Implementation of the MOE: "Business Plan for Combating Pollution in the Litani Basin"

26. Bank representatives participated in the September 2011 and November 2012 MOE Donor meeting to prepare for the implementation of the Business Plan for Combating Pollution of the Karoun Lake. Through the proposed "Lebanon Environmental Pollution Abatement Project," currently under preparation by the Bank, several activities under the MOE Business Plan will be financed and focus specifically on industrial pollution abatement within the Litani Basin.

27. Management has also actively engaged with various GoL stakeholders to bolster activities within the water sector in general. Over the past 24 months, the Bank has engaged with GoL on the investment projects and Economic and Sector Work (ESW) activities described below:

- ***Proposed Bank Loan for the "Lebanon Environmental Pollution Abatement Project."*** The GoL requested Bank financing (USD 17 million) for the project, to assist in reducing industrial pollution which causes adverse health effects and/or environmental degradation, strengthen MOE monitoring and enforcement capabilities and establish technical and financial mechanisms for supporting pollution abatement investments. This Loan is under preparation and is scheduled for submission to the Board by July 16, 2013.

- ***National Water Sector Strategy (NWSS).*** Developed over 2011/2012 by the MOEW and with the technical assistance of the Bank and other donors, the NWSS was adopted by the Council of Ministers in March 2012 and aims to "ensure water supply, irrigation and sanitation services throughout Lebanon on a continuous basis and at optimal service levels, with a commitment to environmental, economic and social sustainability." Among the six key NWSS outcomes are: (i) the creation of an enabling environment for integrated water resources management and sector regulation, combined with development of water resources infrastructure; (ii) improving irrigation infrastructure to improve water control and to increase efficiency through modern water-saving irrigation technology, as well as improving the performance and sustainability of the irrigation sector; (iii) putting wastewater on a sustainable footing[4] and protecting the environment, and (iv) strengthened sector capacity for oversight and reform implementation.

- ***Country Water Sector Assistance Strategy (CWSAS).*** In partnership with the MOEW, the Bank further developed the CWSAS for Lebanon to support implementation of the NWSS including the prioritization of reform measures and investment opportunities. The CWSAS was completed in April 2012 and defines an operational plan for Bank involvement in Lebanon's water sector for 2012-2016.

- ***Environmental Legislation.*** The Bank provided technical assistance to the MOE in the development of several pertinent environmental decrees, namely: (i) Environmental Impact Assessment Decree, approved by the Council of Ministers in March 2012; (ii) Draft Decree on National Environmental Police; and (iii) Draft Decree on National Environmental Fund. The Bank further assisted MOE in drafting: (i) the draft law on integrated solid waste management; and (ii) the draft law on Environmental Prosecutor, both of which are currently under discussion by Parliament for ratification. This legislation, designed based on Bank safeguards, is critical to

[4] I.E., that cost recovery in wastewater be achieved. Currently water tariffs only cover the cost of provision of potable water supply.

the successful implementation of the Karoun Lake Business Plan, particularly regarding Environmental Impact Assessments (EIA).

- ***National Wastewater Strategy:*** The National Wastewater Strategy, which was officially launched by the GoL on December 13, 2012, proposes a detailed set of priorities and activities to drastically reduce the discharge of untreated domestic and industrial wastewater into Lebanese watercourses and other environmentally sensitive areas including the Litani Basin.

Action Item 2: Water Quality Monitoring of Project Source Waters

28. In order to monitor the quality of GBWSP source water, the BMLWE, in partnership with the American University of Beirut (AUB), collects and analyzes water samples on a bi-monthly basis. Water samples are being taken every two weeks as of December 2011from: (i) the Joun Reservoir (the GBWSP source water); (ii) Lake Karoun; (iii) Awali River; and (iv) Anane pool.

29. The Bank retained a water quality expert from the Massachusetts Institute of Technology (MIT) and Massachusetts Water Resources Authority (MWRA), to review the water quality sampling results. The report concluded the following:

- The findings of the GBWSP Independent Technical Review of Source Water Quality (May 2011) are still valid. There is no indication that water quality deteriorated from April 2011 to November 2012.

- Metal contamination is not of concern. Only barium and beryllium were detected with regularity and these were at very low levels. Further, coagulation/flocculation/settling followed by filtration (i.e. the treatment processes included in the GBWSP WTP design) are very effective in lowering particulates such as those in heavy metals, should concentrations increase in the future.

- Lake Karoun shows the highest concentration of organic parameters, and has more compounds detected, compared to the three other downstream locations. These chemicals are indicative of farming and industrial contamination. Conventional water treatment, such as that included in the Greater Beirut water supply treatment plant, which includes ozone treatment and carbon filtration, can mitigate against these compounds.

- Nitrite concentrations at Joun, Anane and Lake Karoun are indicative of farming activity in the watershed. Nitrite can be treated with ozone followed by Granular Activated Carbon (GAC) filtration. Management facilitated a discussion between the expert, CDR and the WTP design engineers, who have updated the WTP tender documents accordingly.

- Water quality at Joun Reservoir, where the WTP intake will be located, is characteristic of river waters moderately impacted from human activities. Many of these rivers have been used as a source for potable water and do not present any unusual challenge to conventional water treatment technologies.

- Watershed protection and source water control remain imperative as confirmed in the MOE Business Plan for Combating Pollution in the Litani River, described above.

30. The water quality data have further been compiled into a master document which the PMU has included in the WTP tender documents to characterize influent water quality. The inclusion of these

recent and comprehensive water quality data in the WTP tender documents will ensure that bidders design responsive treatment processes in the Design Build Operate (DBO) contract planned for the WTP.

Action Item 3: Expert Review of the Water Treatment Plant Design and Bid Documents

31. The GBWSP water treatment plant will be tendered as a DBO contract, documents for which are in advanced stages of preparation by the PMU. Contractor prequalification for the DBO works is planned for September 2013. Construction supervision consultants will be solicited shortly thereafter and will assist the PMU in the prequalification of contractors as well as the evaluation of bids received. The Bank has provided regular assistance to the PMU in the finalization of the DBO contract documents.

32. The Bank has further retained an international expert, as described above, to assist the supervision team in evaluating the PMU's WTP prequalification and bid evaluation reports. This is particularly important given that under DBO contracts, contractors will propose different technologies to treat the influent source water. Experience in water treatment processes is therefore required for the full technical evaluation of DBO bids.

33. Going forward, progress on procurement of the WTP will continue to be an item of focus during supervision missions and will be reported specifically in a dedicated section of aide memoires.

Action Item 4: Study on the Causes and Mitigation measures for Eutrophication in Lake Karoun

34. The Bank commissioned the Water Institute of the University of North Carolina (UNC) to assess the trophic status of Lake Karoun and the impact of its water quality on the GBWSP. The report, included in Annex 4, concluded the following:

- Eutrophication is a natural process that occurs in freshwater lakes and is characterized by increased algal growth. Like many other lakes around the world whose waters are used for potable water supply, Lake Karoun can be categorized as eutrophic.
- The report reconfirms the findings of the GBWSP Independent Technical Review of Source Water Quality (May 2011), noting that "water from Joun Reservoir is of sufficient quality such that conventional water treatment technologies can produce potable water meeting Lebanese and international health- and aesthetic-based standards and guidelines."
- Through the implementation of the NWSS and the Business Plan for Combating Pollution in the Litani, the GoL has already taken concrete steps to implement the recommended four-point strategy to manage the impacts of eutrophication on Lake Karoun as a source of potable water supply. These steps include: (i) reducing nutrient pollution inputs; (ii) minimizing algae in project source water; (iii) ensuring adequate drinking-water treatment; and (iv) developing and implementing a comprehensive risk management strategy.

Water Availability

Action Item 5: GBWSP Implemented on Schedule by 2016 and Support for GoL in Examining Future Supply Augmentation Projects

35. Faced with delays in declaring Loan effectiveness, the PMU nonetheless submitted to the Bank's review various bid documents for major infrastructure contracts (namely, the tunnel and pipeline contract,

WTP tender and distribution network packages). As a result, several large contracts are in advanced stages of preparation for tender. This has offset a portion of the incurred delays.

36. The GoL requested Bank financing of a proposed New Water Supply Augmentation Project. This longer-term project would supplement volumes of water available to the Greater Beirut area. The GoL further confirmed that it had retained, at its own cost, a consulting firm to undertake the Analysis of Alternatives and Environmental and Social Impact Assessment (ESIA) of the new water supply augmentation project.

37. The Bank has informed the GoL that financing the New Water Supply Augmentation Project will only be considered after a thorough review of an evidence-based ESIA which considers the technical, economic, social and environmental project alternatives. The GoL submitted an endorsed draft of the Analysis of Alternatives and ESIA to the Bank on November 26, 2012. The Draft ESIA is currently under review by the Bank.

Action Item 6: Plan to Mitigate the Impacts of Agriculture and Climate Change on Water Availability

38. The Bank commissioned the University of North Carolina Water Institute (UNC) to develop a plan to identify and exploit opportunities for irrigation efficiency improvements and develop climate change mitigation and adaptation measures for the Litani Basin in particular. The report, included in Annex 3, details the following Action Plan based on international best practice and the 2012 World Bank MENA Development Report, "Adaptation to a changing climate in the Arab countries: A case for adaptation governance and leadership in building climate resilience." (World Bank Report no. 73482):

- ***Plan to Monitor and Manage Climate Change Impacts through Effective Water Resources Management***
  - Strengthen analytical tools for more precise assessments of climate change impacts;
  - Mainstream climate change impacts and adaptation measures into the planning, design and implementation of water and agriculture projects in a coordinated approach;
  - Further develop drought and flood mitigation and adaptation plans; and
  - Increase net water supply by further developing water collection and storage infrastructure and promoting the use of alternative water resources in planning and investment programs.

- ***Plan to Monitor and Manage Agricultural Consumption through Irrigation Efficiency Improvements***
  - Upgrade agricultural technologies;
  - Invest in high value crops;
  - Monitor water availability and use;
  - Enforce regulations and policies;
  - Establish Water User Associations;
  - Pilot demonstration projects as a means to raise awareness; and
  - Invest in research.

39. A regional Bank-financed Global Environment Facility (GEF) project (TF10252, USD 1.05 million) currently under implementation by the GoL in partnership with the United States National Aeronautics and Space Administration (NASA), is implementing several of the UNC report recommendations. Led by the Conseil National de la Recherche Scientifique (CNRS – National Council for Scientific Research), the project objective is to better manage local and regional water resources and reduce the threat of land degradation and climate change to vulnerable agricultural production systems

and water resources through the use of remote sensing and Earth observation tools and methods. Specifically the project is: (i) providing a compilation of past, current and potential future water balances in the Litani watershed and other areas of Lebanon; (ii) estimating current water storage conditions; and (iii) evaluating potential increases and decreases in irrigation water requirements under various climate change scenarios and helping in the planning of agricultural practices.

40. On November 13, 2011, and in partnership with 12 GoL agencies and several academic institutions, including the MOEW, MOE, Ministry of Agriculture (MOA), Disaster Risk Management Center, Lebanese Agriculture Research Institute, Civil Defense and American University of Beirut, the CNRS held a national end-user engagement project workshop in Beirut. The workshop objective was to disseminate preliminary findings of the GEF project and to facilitate active collaboration by various counterparts on implementation of climate change mitigation and agriculture development plans. The workshop was held in partnership with the World Bank, NASA and USAID. The GBWSP and GEF Project are led by the same Task Team Leader, which ensures that cross-dissemination of knowledge and coordination at the national level continues.

41. In parallel, the Bank continues to assist MOEW in developing implementation plans for the NWSS, which echoes the recommendations of the Action Plan described above.

Project Cost Estimates, Financial and Economic Analyses

Action Item 7: An Experienced Tunneling Specialist to Review the Tunneling Works Tenders and Join Select Bank Supervision Missions

42. The Bank hired Arup Ltd, a consulting firm with broad international experience in tunneling infrastructure, to review tender documents, contractor bids and the GoL bid evaluation report of the tunneling and pipeline infrastructure under Component 1. The draft tender documents have been reviewed by Arup and its technical comments incorporated by the PMU in revised documents.

43. Arup remains under contract to the Bank to assist with the review of the PMU's bid evaluation reports and to provide technical advice on works and construction supervision activities during Bank supervision missions in the future. The Associate Director of Tunneling at Arup joined the World Bank supervision mission to Beirut in January 2013.

Action Item 8: Assist GoL in Mobilizing Additional Financing for the Project if Practical and Timely

44. On any large infrastructure project, including the GBWSP, project cost estimates can only be confirmed at the time of contract award. Management therefore monitors project cost estimates closely. The PMU further updates the disbursement and procurement plans on a quarterly basis in order to reflect updated industry figures. These are submitted to the Bank accordingly for review and discussion.

45. As part of preparation of this report, Management undertook a re-appraisal of project costs as detailed under Action 9 below. The project costs are assessed to be unchanged as compared to the 2010 appraisal figures.

46. Additional financing for the project is thus not required at this time. The Bank will consider any request from GoL for additional financing in the future if required.

Action Item 9: Confirm Cash Availability of BMLWE to Finance GBWSP Costs as Planned

47. A review of the project cost components compared to the baseline appraisal period in mid-2010 shows them basically unchanged. The Lebanese cement industry has begun to experience a significant fall in prices. Steel prices have increased for some components, particularly bar and rod, but after climbing globally in 2011, have fallen well below their peak. With low global growth and recent production capacity increases, the cost of steel should not put significant upward cost pressure on the project. A key cost driver is that of tunnel boring machines. The Bank tunneling consultant reports that tunnel boring machine prices have been stable over the past two years. These factors lead the Bank to maintain the appraisal cost estimates at this time.

48. The water supply and demand in the BMLWE service area continue to develop as forecast in the Project Appraisal Document. Population growth in the BMLWE service area continues at a modest rate, increasing overall water demand. Good rainfall over the winter of 2011/2012 did improve the yield of BMLWE's existing wells and helped to slow aquifer drawdown in the main well fields, but supply volumes still cannot meet seasonal demand and intermittent service continues throughout the system. This continued imbalance between demand and supply as documented at appraisal leaves the estimated economic value of the proposed incremental water supply under the project unchanged. The estimated economic cost to deliver that incremental supply also remains unchanged. The expected net economic value of the project therefore has not changed since appraisal.

49. Adequate BMLWE cash reserves are available as confirmed by BMLWE financial statements. The Bank continues to track the overall financial performance of BMLWE, with particular attention to the ability to finance the counterpart USD 140 million contribution to the project.

50. Analysis of the 2010 and 2011 annual financial statements shows that the main financial performance indicators continue at appraisal levels. The tariff collection rate remains stable at approximately 90 percent over a two year collection period. The annual net operating cash surplus was USD 27.3 million in 2010 and USD 24.4 million in 2011, values that are consistent with past performance.

51. The year-end cash and bank balance has increased from the USD 170 million level reported at appraisal to USD194 million in 2010 and USD198.9 million in 2011. BMLWE thus has a growing ability to meet its counterpart funding obligation.

IV. Next Steps

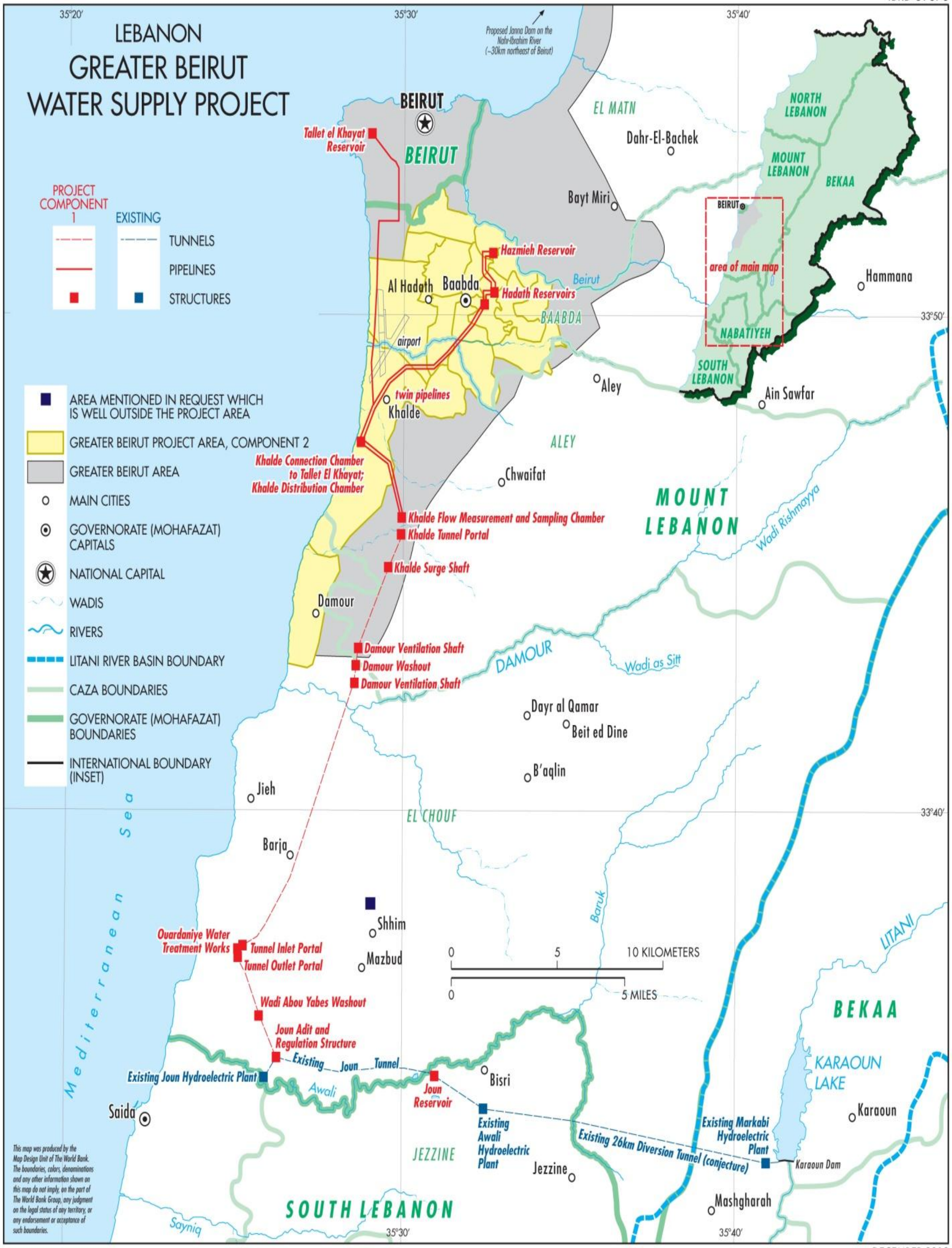
52. Management notes that successful implementation of the 18-month Action Plan, as detailed above, has strengthened implementation of the GBWSP in general. On Components 1 and 2, the recommendations of independent water quality and tunnel engineering experts have been incorporated into plans for the construction and operation of project infrastructure. On Component 3, the capacity of both the PMU and the BMLWE to account for technical, social, environment, legal and fiduciary aspects of project management and implementation has also further been strengthened.

53. Impacts beyond the GBWSP have also been realized as a result of the Bank studies commissioned on eutrophication, water quality and water availability. A formal water quality monitoring regime has been integrated into BMLWE operations and analytical findings have been shared with relevant GoL counterparts and donors active in the Lebanese water and environment sectors. The monitoring outputs have further informed and enhanced parallel Bank projects and activities in the Lebanese water and environment sectors.

54. Moving forward, successful project implementation remains a Management priority. Senior Management will continue to oversee project implementation on a regular basis and has provided the resources needed for intensive supervision of this sensitive project. The Bank will continue to work closely with the GoL and public and private project stakeholders to ensure the full implementation of the GBWSP.

Annex 1: Project Map

IBRD 39675



DECEMBER 2012

Annex 2: Management Memo - July 28, 2012

THE WORLD BANK/IFC/MIGA

OFFICE MEMORANDUM

DATE: July 29, 2011

TO: Roberto Lenton, Chairperson, IBRD/IDA Inspection Panel

FROM: Sri Mulyani Indrawati, Managing Director, MDI

EXTENSION: 88109

SUBJECT: **Request for Inspection of the Lebanon Greater Beirut Water Supply Project (P103063)– Note/Action Plan addressing identified risks following submission of three studies commissioned by Management**

Following my memo to you dated June 9, 2011 which enclosed the three studies commissioned by Management, please find attached for your reference (i) a note addressing the identified project risks along with an action plan to mitigate the risks, and (ii) a cover memo from Ms. Shamshad Akhtar, Regional Vice President MNA.

Attachment

THE WORLD BANK/IFC/MIGA

OFFICE MEMORANDUM

DATE: July 28, 2011

TO: Roberto Lenton, Chairperson, IBRD/IDA Inspection Panel

FROM: Shamshad Akhtar, Regional Vice President, MNAVP

EXTENSION: 84477

SUBJECT: **Request for Inspection of the Lebanon: Greater Beirut Water Supply Project – Note addressing issues following submission of studies commissioned by Management**

1. Following the Board meeting of March 8, 2011 on the Inspection Panel Report regarding the Greater Beirut Water Supply Project, MNA Management commissioned three independent reviews of: (i) Project Water Quality; (ii) Project Water Availability; and (iii) Project Cost, financial analysis and economic analysis.

2. While the three independent studies reconfirmed the project's design details and implementation arrangements, some potential implementation risks were identified and are described in the attached note.

3. MNA Management has reviewed these risks and is confident that they can be managed within the confines of an enhanced supervision regime for the project. I would also like to reiterate that we take the potential risks very seriously and are fully committed to satisfactorily addressing them. Instructions will be issued to my senior management team, both in Washington and in Beirut, to closely monitor the implementation of the risk mitigation and management measures outlined in the attached note. I also commit to personally reviewing the progress.

4. In addition, MNA Management will report to the Board within 18 months (i.e., by end January 2013) on: (i) progress in project implementation; and (ii) progress in the implementation of the attached risk mitigation and management measures.

Attachment

Greater Beirut Water Supply Project
Summary of Risks, Management Measures and Proposed Action Plan with respect to Inspection Panel Request

On November 10, 2011, the Inspection Panel registered a Request concerning the Greater Beirut Water Supply Project (GBWSP). Following the Management Response dated December 13, 2011 and the Inspection Panel's report dated January 21, 2011, a Board discussion was held on March 8, 2011, after which MNA Management commissioned three independent studies: (i) a Water Quality Study by The Water Institute at the University of North Carolina, (ii) a Water Availability Study also by The Water Institute at the University of North Carolina, and (iii) a Project Cost, Financial Analysis and Economic Analysis Study undertaken by Mr. Lee Travers, former Lead Water Economist at the World Bank. The three studies were submitted to the Inspection Panel on June 9, 2011, publicly disclosed and have been translated into Arabic.

While the three independent studies reconfirmed the project's design details and implementation arrangements, some potential risks were also identified and are described below. MNA Management accordingly commits to revising plans for supervision of project implementation to include the risk management measures described below and summarized in Table 1.

Water Quality

Identified Risks:

- The provision of water quality that meets all applicable health and aesthetic-based standards and guidelines is contingent on the implementation of upstream catchment protection measures in addition to the water treatment infrastructure planned under the GBWSP.

- An increased input of nitrogen and phosphorous could lead to eutrophication of Qaraoun Lake. This could pose a risk to the quality of project source water.

Risk Management Measures:

- In its Ministerial Declaration dated June 13, 2011, GoL committed to: (i) "the implementation of strategies and action plans for river basin management and solid waste management" and (ii) "the involvement of non-governmental organizations in the implementation of such plans" among other high-priority actions.

  The Ministry of Environment's (MoE) "Draft Business Plan for Combating Pollution of Qaraoun Lake" is an action plan commissioned based on the recommendation of an Inter-Ministerial Committee. The Inter-Ministerial Committee included the MoE, Ministry of Energy and Water, Ministry of Agriculture and Ministry of Industry, among others. The Committee was tasked with diagnosing the state of the Litani River basin, and the Plan is to be finalized in September 2011. The Plan will subsequently be presented to the Environmental Parliamentary Commission and to the Council of Ministers for final approval, provisionally by December 2011. A donor meeting to identify potential sources of Plan financing will also be held this Fall. The MoE has confirmed that the World Bank will be invited to participate in this meeting.

  The World Bank will continue to work closely with GoL in managing the preparation of upstream catchment protection activities. The World Bank will also ensure that the findings of continuous downstream water quality monitoring are reported in a dedicated annex to supervision aide-memoires. A water quality expert will join the supervision team to review the consistency of the technical design of the water treatment plant with the observed water quality.

- The risk of eutrophication will be managed by upstream catchment protection measures (as included in the Business Plan for Combating Pollution of Qaraoun Lake) as well as effective downstream water treatment, mitigating the risk to water quality.

  The World Bank will work with MoE and the Ministry of Energy and Water to analyze and better understand the potential causes of eutrophication of Qaraoun Lake and proposed management and mitigation measures to prevent and/or limit its impacts.

  The World Bank will also assist MoE with preparation and implementation of upstream pollution abatement programs specific to the agricultural sectors and will ensure that monitoring data on nitrogen, phosphorous and dissolved oxygen is included in the tender for the Design/Build/Operate contract for the water treatment plant.

Water Availability

Identified Risks:

- Increased water demand in the upstream portion of the Litani River basin could impact the availability of water for the GBWSP.
- Beyond the water demand from the present GBWSP, additional demand from future downstream water users could exceed the supply from the Litani/Awali Rivers.

Risk Management Measures:

- As part of the World Bank's ongoing technical assistance to GoL for the development of the National Water Sector Strategy, a plan will be developed to monitor and manage consumption trends, identify and exploit opportunities for irrigation efficiency improvements, and develop climate change mitigation and adaptation measures, among others. This process would include specific recommendations for management of the Litani/Awali Rivers and their basins.

- The GBWSP has been designed to meet the short-term water demand needs of the project area. GoL has confirmed that no other projects utilizing the Litani/Awali Rivers will be implemented before 2021. Beyond 2021, any additional demand from future water users will be met by various supply augmentation projects, already under consideration by GoL.

  The World Bank will support GoL in examining future supply augmentation projects as requested.

Project Cost, Financial Analysis and Economic Analysis

Identified Risks:

- The project has less room for cost overruns than originally envisioned. Cost overruns could pose a risk to the positive net present value of the project as well as to the viability of the financing plan.
- The BMLWE may not have the cash reserves of USD 170 million, stated to exist at the time of project appraisal.

Risk Management Measures:

- The GBWSP is a technically complex project which comprises extensive tunneling, water treatment and distribution infrastructure. As such, the project has been designed to incorporate USD 20 million in contingencies. The project will also finance independent construction supervision contracts for various works package as well as a dedicated procurement specialist position within the Project Management Unit.

  In addition, the World Bank will recruit a technical expert with demonstrated experience in tunneling infrastructure (the highest-cost project component) to join select supervision missions and review the tenders for tunneling works. Furthermore, if cost overruns above the existing project contingency do occur, the World Bank will work with GoL to mobilize additional financing resources.

- The BMLWE has submitted documentation to the World Bank confirming that the available balance held in its dedicated account at the Central Bank exceeds USD 170 million.
- The total project cost is USD 370 million. The BMLWE will finance USD 140 million of these costs from its cash reserves as described above. The remaining USD 30 million will be financed by GoL which has also assumed responsibility for debt servicing of the World Bank loan of USD 200 million.

	Description of Risk	Risk Management Measures	World Bank Action Plan
Water Quality	**GoL not committed to implementing upstream catchment protection measures**	GoL has reconfirmed its commitment to implementation of Ministry of Environment (MoE) Business Plan for Combating Pollution of Qaraoun Lake (reference Ministerial Declaration dated June 13, 2011) and has mobilized stakeholder and donor meetings to mobilize support and financing	The World Bank will maintain the ongoing dialogue with the MoE on upstream catchment protection and will participate in the Fall 2011 donor meeting to finalize the Business Plan for Combating Pollution in Lake Qaraoun. The World Bank will ensure that the findings of continuous downstream water quality monitoring are reported in a dedicated annex to supervision aide-memoires.
	Increased input of nitrogen and phosphorous could lead to unquantified eutrophication of Lake Qaraoun and impact project water quality	An analysis of the causes and impacts of eutrophication in Lake Qaraoun will be commissioned. Implementation of the MoE Business Plan for Combating Pollution of Qaraoun Lake will control discharge of nitrogen and phosphorous to Lake Qaraoun. Downtream, the Water Treatment Plant at Ouardaniyeh, included in Component 2 of the GBWSP, will treat nitrogen and phosphorous (among other parameters) to Lebanese and international health and aesthetic based standards.	The World Bank will ensure that the findings of continuous downstream water quality monitoring are reported in a dedicated annex to supervision aide-memoires. A water quality expert will join the supervision team to review the consistency of the technical design of the water treatment plant with the observed water quality A water quality expert will join the supervision team to review the consistency of the technical design of the water treatment plant with the observed water quality The World Bank will work with MoE and the Ministry of Energy and Water (MOEW) to conduct an analysis on the causes, impacts and mitigation options for possible eutrophication in Lake Qaraoun.
Water Availability	**Increased water demand in the upstream Litani River basin could impact the availability of water for the GBWSP. Also Additional water demand from future water users could exceed the supply from the Litani/Awali rivers**	The GBWSP will be implemented by 2016. GoL is currently in various stages of preparation for future medium and long-term water projects that utilize Litani and Awali rivers. GoL has confirmed that these projects will not be fully implemented until 2021 and beyond. GoL has also begun the preparation of various supply augmentation projects that will supplment Litani and Awali river waters in the future.	The World Bank will work closely with GoL, and through project supervision activities, to ensure that the GBWSP is implemented on schedule by 2016. The World Bank will also support the GoL in examining future supply augmentation projects. As part of the World Bank's ongoing technical assistance to GoL for the development of the National Water Sector Strategy, a plan will be developed to monitor and manage consumption trends, opportunities for irrigation efficiency improvements and climate change mitigation and adaptation measures among others. This process would include specific recommendations for management of the Litani/Awali rivers and their basins.
Project Cost,Financial Analysis and Economic Analysis	**Potential cost over-runs could negatively impact project implementation.**	20 million USD of contingency budget has been incorporated into project costs. The Project Management Unit will also be staffed by experienced professionals that will assist the BMLWE in project implementation and supervision.	An experienced technical specialist (with demonstrated experience in tunneling infrastructure) will join the World Bank supervision team, review the tenders for the tunneling bids and will join select Bank supervision missions. The World Bank will assist GoL in mobilizing additional financing for the project if practical and timely.
	Funds may not be available to service the project debt. BMLWE has not confirmed availability of cash reserves for project financing and could thus negatively impact project implementation	The GoL has committed to servicing the World Bank loan of USD 200 million. The Beirut Mount Lebanon Water Establishment has confirmed availability of cash reserves to finance USD 140 million of project costs. The remaining USD 30 million will be financed by the GoL.	Letter from Beirut Mount Lebanon Water Establishment is available upon request.

Annex 3: Agriculture and Climate Change in Lebanon Action Plan Moving Forward

Agriculture and Climate Change in Lebanon
Action Plan Moving Forward

November 2012

Created for the World Bank
by the Water Institute at UNC

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Key Findings

Approximately 50% of Lebanon's agricultural land area is located in the Upper Litani River Basin of the Beka'a Valley wherein agriculture consumes 82% of total water demand. Climate change models have further predicted an increase in runoff, less snowpack, and a longer dry season, which could decrease water availability and increase water demand, particularly in the summer months.

The objective of this report is thus to develop a plan to: (i) identify and exploit opportunities for irrigation efficiency improvements; (ii) develop climate change mitigation and adaptation measures among others and (iii) monitor and manage water consumption trends with a specific focus on agricultural water based on a review of existing data and literature on water use in the Litani River basin.

This report thus presents an overview of the impact of climate change and agriculture on water resources in Lebanon and makes recommendations, based on international best practice examples, on ways in which the Government of Lebanon and its partners can build a more climate-resilient agriculture sector namely:

Plan to Monitor and Manage Climate Change Impacts through Effective Water Resources Management

- Action 1: Strengthen the scientific analytical tools for more precise assessments of climate change impacts;
- Action 2: Mainstream climate change impacts and adaptation measures into the planning, design and implementation of water and agriculture projects in a coordinated approach;
- Action 3: Further develop drought and flood mitigation and adaptation plans;
- Action 4: Increase net water supply by further developing water collection and storage infrastructure and promote the use of alternative water resources in planning and investment programs

Plan to Monitor and Manage Agricultural Consumption through Irrigation Efficiency Improvements

- Action 1: Upgrade agricultural technologies;
- Action 2: Invest in high value crops;
- Action 3: Monitor water availability and use and enforce regulations and policies;
- Action 4: Establish Water User Associations;
- Action 5: Pilot demonstration projects as a means to raise awareness; and
  Action 6: Invest in research

Building off of the Ministry of Energy and Water's National Water Sector Strategy, the Ministry of Environment's active policy and work program as well as parallel academic, scientific and public sector activities, the proposed action plan complements important work already underway in and across Lebanon. The action plan further highlights immediate next steps as identified in national documents that will optimize water resources management across Lebanon, and the Litani Basin in particular, in the short to medium terms.

Water Resources in Lebanon

1. Despite its perceived abundance of freshwater relative to the Middle East and North Africa (MENA) region, Lebanon is already using two thirds of its available water resources, with temporal and spatial mismatch between supply and demand. Factors exacerbating this seasonal water imbalance include: (i) the low water storage capacity (6% of total resources, compared to the MENA average of 85%), (ii) deficiency of water supply networks and (iii) on the demand side, significant consumption in agriculture and rising demand from the municipal and industrial sectors. If no actions are taken to improve efficiency, manage demand and increase storage capacity, these seasonal imbalances are likely to lead to chronic water shortages in the country[1].

2. As shown in Figure 1 below, renewable water resources per capita in Lebanon (926 m^3/capita/year in 2009) are already below scarcity threshold (defined as 1000 m^3/capita/year), with expected decrease in coming years[2]. The Ministry of Energy and Water (MOEW) further anticipates total demand will rise 22% by 2035, increasing from 1473 to 1802 million cubic meters (MCM), using a "moderate" modeling scenario.

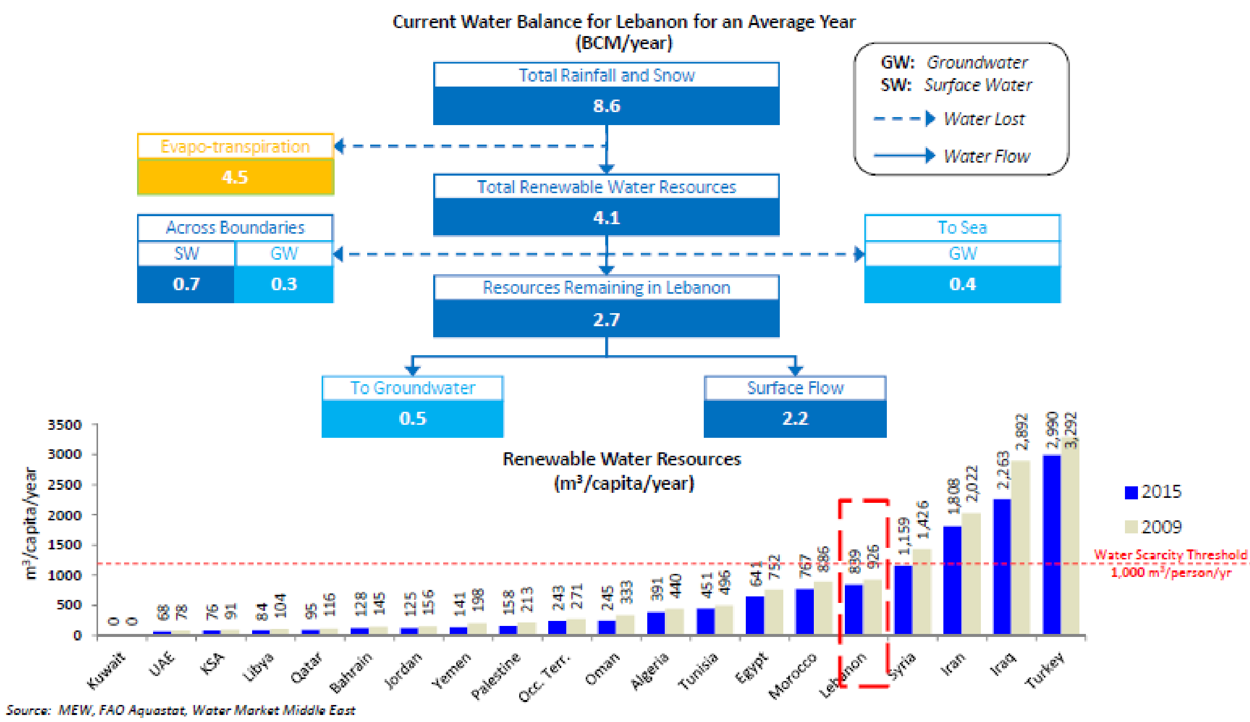

Figure 1: Lebanon 2012 Water Balance (Reproduced from MOEW 2012)

3. The agricultural sector is the largest water user across Lebanon (representing approximately 60% of all demand) and has the largest projected increase in water demand by 2035. Table 1 summarizes the breakdown of current water demand by sector on a national level.

[1] World Bank Country Water Sector Assistance Strategy, 2012
[2] Government of Lebanon, National Water Sector Strategy, 2012

Table 1: Percentage of National Water Demand by Sector (MOEW, 2010)

	Demand
Industrial	10%
Domestic	34%
Agricultural	59%

4. Roughly 2000 MCM of the total precipitation falling within Lebanon is available each year as surface or groundwater[3]. The MOEW subsequently reports that only about 1850 MCM may be available by 2035 due to the impacts of climate change. The MOEW also shows that the high demand scenarios may exceed the available water (Figure 2).

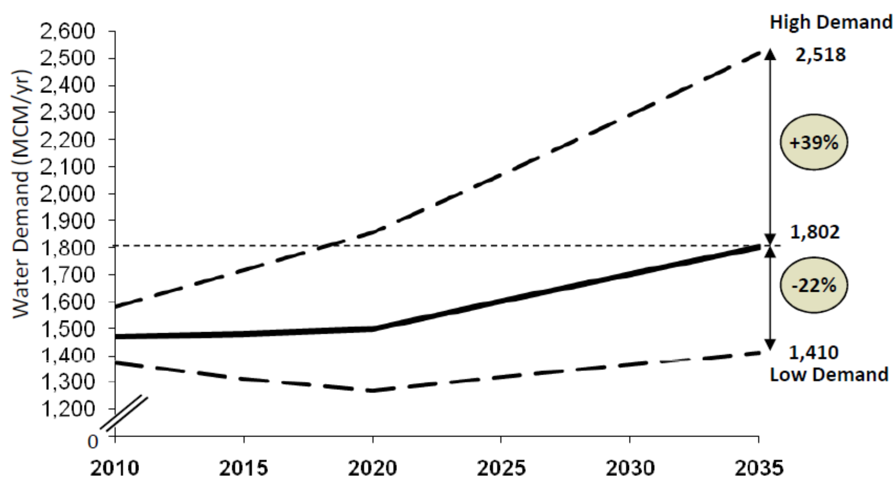

Figure 2: National Water Demand in Low-, Moderate- and High-demand Scenarios. (Reproduced from MOEW, 2010)

5. The Lebanese government has thus made reform of the water sector a national priority and adopted the National Water Sector Strategy (NWSS) in March 2012. The NWSS goal is 'to ensure water supply, irrigation and sanitation services throughout Lebanon on a continuous basis and at optimal service levels, with a commitment to environmental, economic and social sustainability'. The NWSS is organized around six key outcomes, described in Box 1 below.

6. Implementation of the NWSS has further been given high priority by the Government and a Strategic Roadmap for implementation has been developed in detail. A summary of the Roadmap is provided in Figure 3 below.

[3] El Fadel et al, 2000

Box 1: National Water Sector Strategy: Six Key Outcomes
(Adapted from World Bank Country Water Sector Assistance Strategy, 2012)

1. **Improved, sustainable and affordable water supply.** The NWSS targets improved, sustainable and affordable water supply by: (i) developing infrastructure to ensure continuous access to high-quality service through increased coverage, reduced unaccounted-for water and optimized network management; (ii) transformation of water establishments (WE's) progressively into autonomous and accountable utilities by moving them to a service orientation, strengthening their administrative and financial autonomy, and involving them in project planning and implementation; (iii) moving the WEs towards financial sustainability by applying over time tariff structures that cover costs and contribute to demand management; and (iv) increasing the role of private capital and management by developing an enabling environment for PPP.

2. **Sustainable water resources management and allocation to priority uses**. The NWSS proposes creation of an enabling environment for integrated water resources management and sector regulation, combined with development of water resources infrastructure. MOEW will be responsible for strategic planning, major investment, conservation and regulation; the WEs and Litani River Authority (LRA) will be responsible for water monitoring and distribution. The target is to (i) maximize the potential and improve the quality of surface water resources; (ii) improve the management and protection of groundwater as a strategic reserve, control and manage its abstraction, and promote conjunctive use of surface and groundwater, including artificial recharge; and (iii) to meet deficits through ground and surface water, prioritizing surface water storage wherever possible.

3. **Putting wastewater on a sustainable footing and protecting the environment.** The NWSS proposes a series of investments and measures to put wastewater on a sustainable footing and to protect the environment: (i) developing wastewater infrastructure to increase coverage of collection networks and treatment capacities, optimizing treatment processes and sludge disposal, and ensuring reuse where possible; (ii) improving wastewater management by implementing an institutional and business model for wastewater collection, treatment and reuse; and (iii) environmental protection by promoting and improving water quality management, and protection of recharge zones. In addition, climate change will be factored into water resources planning and operations, and flood control and mitigation integrated into strategies for recharging depleted or stressed groundwater aquifers.

4. **Profitable and sustainable irrigated agriculture.** Investments and measures proposed in the NWSS to encourage profitable and sustainable irrigated agriculture include: (i) improving irrigation infrastructure to improve water control and to increase efficiency through modern water-saving irrigation technology; (ii) improvements in the performance and sustainability of the irrigation sector, through decentralization, stakeholder participation, demand management and cost recovery; and (iii) possible expansion on 15-30,000 ha.

5. **Strengthened sector capacity for oversight and reform implementation.** The NWSS addresses the need for strengthened sector oversight and reform implementation by setting out measures for restructuring and equipping MOEW to take on policy-making, planning and regulatory roles, and by building human capacity in the sector through recruitment and staff development and training.

6. **Improved efficiency of public investment.** In the short term, better horizontal coordination is needed to ensure an effective sequencing of investments and alignment of capital and O&M expenditures. In the longer term, the NWSS proposes increasing the role of the WEs and the LRA in investment planning and implementation.

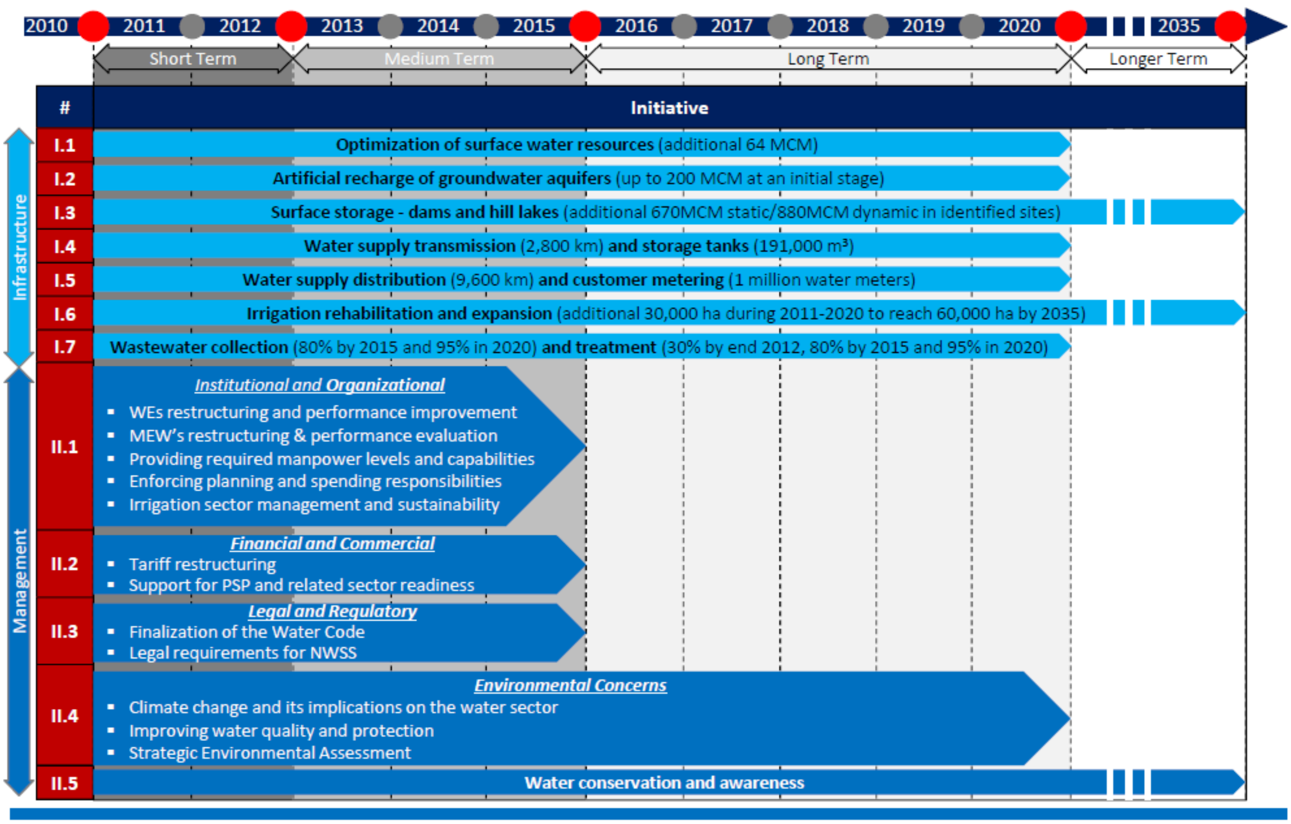

Figure 3: National Water Sector Strategy – Strategic Roadmap Actions (NWSS, 2012)

7. The Intergovernmental Panel on Climate Change Fourth Assessment Report (IPCC 2007a) states that "Warming of the climate system is unequivocal", that there is high confidence of increased runoff and earlier spring peak discharge in many glacier- and snow-fed rivers, and that "climate change is expected to exacerbate current stresses on water resources from population growth and economic and land-use change, including urbanization." Moreover, "Runoff is projected with high confidence to decrease by 10 to 30% [by the end of the 21st century, see Figure 4] over some dry regions at mid-latitudes and dry tropics, due to decreases in rainfall and higher rates of evapotranspiration. There is also high confidence that many semi-arid areas (e.g. the Mediterranean Basin, western United States, southern Africa and north-eastern Brazil) will suffer a decrease in water resources due to climate change."

8. Climate models further predict a significant reduction in precipitation in much of Mediterranean Africa, northern Sahara, and the eastern Mediterranean, ranging from 10-30% by the next century[4]. Climate change impacts for the MENA region thus include intensification of the following trends: (i) decreased precipitation (ii) lower yields on major food crops (iii) accelerated saltwater intrusion to coastal freshwater aquifers from sea-level rise and (iv) increased duration and intensity of droughts among other factors. Figure 5 below[5] demonstrates the effect of sea level rise in the MENA Region as an example of exacerbated impact of climate change in Lebanon and the surrounding region.

4 Evans 2008, 2009
5 Sowers – Weinthal, 2010

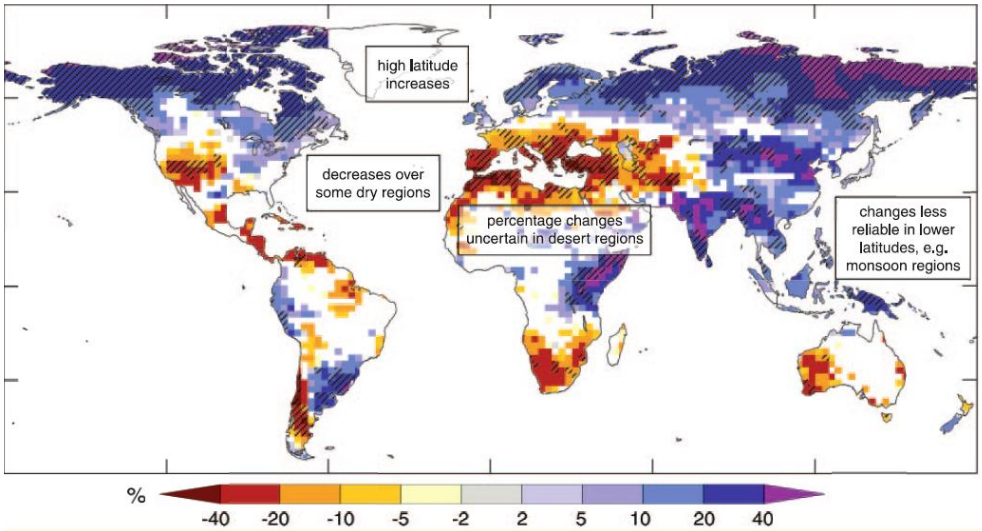

Figure 4: Projections and Model Consistency of Relative Changes in Runoff by the End of the 21st Century (Reproduced from IPCC, 2007)[6]

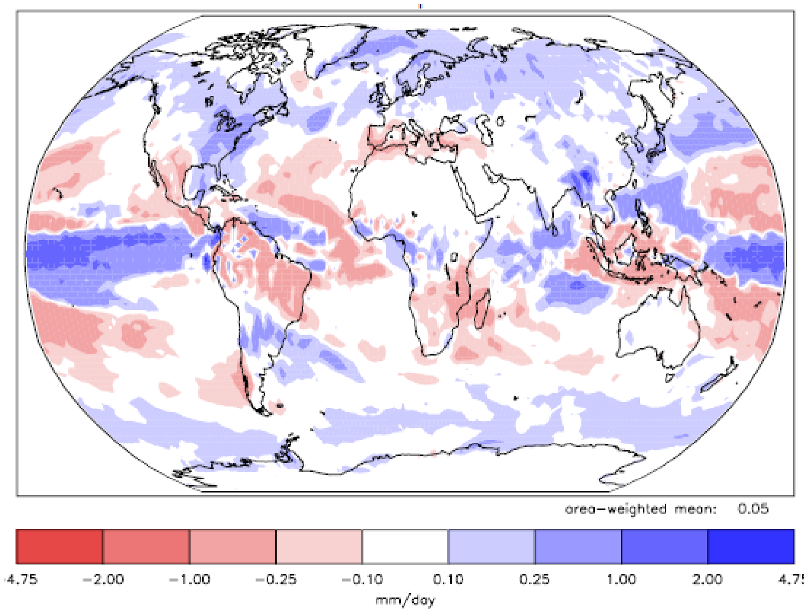

Figure 5: Changes in annual average precipitation due to increasing greenhouse gases 1993-2012 vs pre-industrial (Courtesy of NASA)[7]

9. Confident predictions concerning the impact of climate change on Lebanon specifically however are difficult to make because estimates from climate models are at low geographic resolution and

[6] Note: Caption from IPCC (2007) reads "Large-scale relative changes in annual runoff (water availability, in percent) for the period 2090-2099, relative to 1980-1999. Values represent the median of 12 climate models using the SRES A1B scenario. White areas are where less than 66% of the 12 models agree on the sign of change and hatched areas are where more than 90% of models agree on the sign of change. … The global map of annual runoff illustrates a large scale and is not intended to refer to smaller temporal and spatial scales. In areas where rainfall and runoff is very low (e.g. desert areas), small changes in runoff can lead to large percentage changes. … In some areas with projected increases in runoff, different seasonal effects are expected, such as increased wet season runoff and decreased dry season runoff. …"

[7] Note: the Middle East is at the southeastern edge of a large area of drying around the Mediterranean. This was a robust feature in AR4-era GCMs historical runs and is caused largely by a northerly shift in the North Atlantic storm tracks (which is why Northern Europe gets wetter while the south gets drier).

assume long timeframes. Low precision impairs the ability to predict changes at smaller geographical scales; but, global and regional trends may be discerned and applied to the country level.

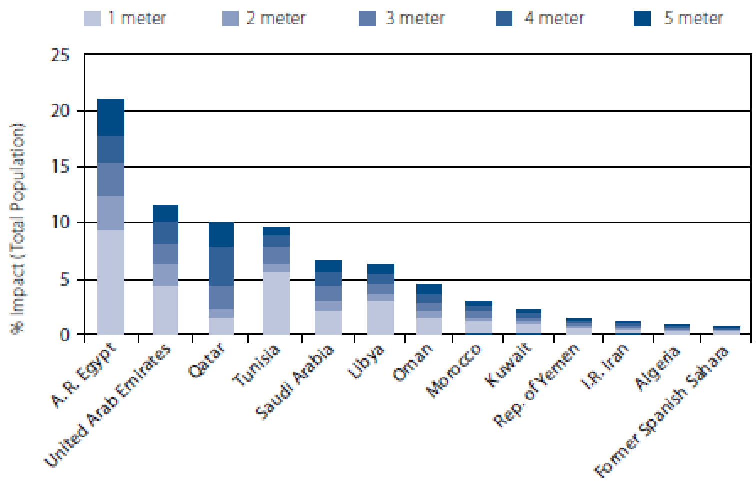

Figure 6: Effect of sea level rise on select MENA countries

10. Bou-Zeid and El-Fadel (2002) discuss four different climate change models that estimate the impact of climate change on Lebanon's average temperatures and precipitation (Table 2). Evaporation was found to increase under all scenarios. The results suggest a possible increase in irrigation demand in the Bekaa Valley of up to 6% by the 2020s. However, when averaged across Lebanon, climate-driven changes in renewable surface and groundwater are modest (<300 Mm^3/yr) in comparison to the projected impacts of population and economic growth by 2025. Thus, while the models suggest an increase in mean summer temperatures, the models also suggest either minimal or no change in rainfall.

11. Nevertheless, the dry season in Lebanon is predicted to become longer. An expected rise in temperatures across the region, combined with high evaporation rates and lower storage rates in snowpack, could further increase the risk of flooding. Lebanon has a moderate risk for flood damage due to the high proportion of densely populated areas situated within close proximity to rivers (Giupponi & Shechter, 2003). The loss of storage capacity in snowpack also equates to less snowmelt during the dry season, effectively reducing an important freshwater storage mechanism for the Beka'a. As seawater level is predicted to rise (Figure 6), Lebanon's groundwater supplies in low-lying areas would also be at risk of saltwater intrusion.

Table 2: Predicted Climate Change Impact on Lebanon's Weather from Various Models. (El-Fadel et al., 2000)

	HadCM2	GFDL-R15	CGCM	Echam4	Maximum
Jan-March Mean Temp Increase (°C)	0.6	1.2	1.3	1	1.3
Jun-Aug Mean Temp Increase (°C)	0.8	1.8	0.9	1.4	1.8
Oct-April Mean Rainfall Ch Rainfall Change (mm/day)	0	-0.1	0	0	-0.1

Box 2: *Biophysical Impacts of Climate Change on Agriculture Systems*
Adapted from: (Increasing Resilience to Climate Change in the Agricultural Sector of the Levant, A Case study of Jordan and Lebanon, The World Bank 2010)

It is widely expected that climate change will impact agricultural systems in Lebanon. This will happen through changes in temperature, moisture and CO_2 levels, increased exposure to pests and diseases, and the interactions among all of these factors. It can be challenging to make concrete predictions of future impacts because of the complexity of agricultural systems and a lack of data on key environmental thresholds for many crops. Still, there is sufficient information available to identify general impacts and expected trends.

Effects from Temperature Changes

Predicting specific crop responses to temperature is complex. The reasons for this are because: different species have different minimum and optimal temperatures for development; different processes occur at different times (e.g., photosynthesis only occurs during light hours, while respiration occurs all day); and many of these processes are not related linearly to temperature (Gregory et al., 2009). For example, increased temperatures during the colder winter months in Jordan and Lebanon could mean that crops grown during these seasons mature sooner (Wilby, 2010). While these changes could be beneficial in systems where the growing season is limited, in others, it could actually result in reduced yields. Temperature increases can accelerate a crop's development, which in turn can reduce the amount of time that crops like wheat or barley spend during the grain-filling stage (e.g., producing grains), leading to smaller harvests (Khresat, 2010). In addition, higher nighttime temperatures can increase overall crop respiration, potentially offsetting gains from increased day temperatures (Khresat, 2010). Temperature increases can also affect the nutritional value of crops. High temperatures, pre- and post-harvest, can affect the quality of many fruit and vegetable crops, including reduced nutritional value as vitamin or antioxidant levels decrease and faster ripening and softening occurs (Moretti et al. 2009).

Effects from Precipitation Change

Drought stress occurs as a combination of two factors: when plants cannot access sufficient water through their roots (e.g., if soil moisture levels are low) and when water losses are too high from transpiration (the loss of water through the stomata in leaves), which occurs if air temperatures are high or humidity levels are low. These two conditions often occur in semi-arid climates like those of Jordan and Lebanon, and are consistent with the predicted climatic changes in both countries (Reddy et al., 2004).

A complementary approach to irrigation management is to choose or develop drought-tolerant crops that have high water-use efficiency. The Fertile Crescent region was the birthplace of domesticated wheat thousands of years ago. Today, locally-evolved crop varieties, or landraces, are generally cultivated in areas with high elevation and environmental stress, where dry farming is performed. They tend to be well adapted to these environmental conditions since they are exposed to many years of selection in the specific area and therefore more likely to survive the harsh climatic conditions during seasons of extreme variability. These plants can serve as genetic stock for future crop breeding. Key traits leading to high water-use efficiency include: retaining water in the plant, rather than allowing it to evaporate at the soil surface; gaining more carbon per unit of water transpired by the crop; and storing a greater fraction of biomass in the plant component that will be harvested (Condon et al., 2004). These traits are interdependent; while one trait might be key in a given environment, it may be less important in another (Condon et al., 2004).

Box 2: Continued

Effects from Changes in CO_2 Levels

The increases in atmospheric CO_2 concentrations that are largely responsible for changes in temperature and precipitation are also expected to have direct effects on plant growth. If atmospheric CO_2 concentrations increase, the pressure of this tradeoff is reduced − more growth can occur with less water loss. This "CO_2 fertilization effect" is particularly important for the group of plants that use this pathway for photosynthesis. Commonly produced crops in Jordan and Lebanon such as vegetables, fruit trees, and wheat and barley all use this pathway, while sugarcane, sorghum, maize, and some millets use a different ("C4") pathway and are therefore less sensitive to CO_2 fertilization. Jablonski et al. (2002) performed a meta-analysis of studies of CO_2 fertilization effects, and found that overall, plants produced 19 percent more flowers, 18 percent more fruits, and 25 percent greater seed mass under elevated CO_2 levels.

While the CO_2 fertilization effect could potentially be beneficial, there are still key questions. These include whether it will be sufficient to offset any negative effects on yield due to temperature and water stress, how much it will be limited by other constraints such as nutrient availability (Oren et al., 2001), and whether it will favor crops over weeds (Fuhrer, 2003). Research is just beginning to answer these questions and examine these complex interactions. Therefore, it will be some time before the positive or negative effects from increased CO_2 concentrations are understood with high levels of certainty.

Pest and Pathogen Management

The impact of plant pathogens or pests on crops depends on three factors: the pathogen and its characteristics; the crop and its susceptibility or health; and the environment and whether it benefits the crop or the pest. Changes to any of these three factors can have an impact on disease severity and its net effects. As climate changes, the types and numbers of pests and diseases prevalent in a given area will change. Effects on insect pests are as complicated as the effects on their host plants, and can be hard to predict their net impact on crops (Fuhrer, 2003). Insects, being cold-blooded creatures, are often heavily influenced by temperature (Abdel-Wali, 2010). Increases in temperatures may increase the number of insect generations possible each year, both due to the length of the possible growing season and the insect's accelerated development (Harvell et al., 2002). For example, a 2°C increase could result in 1-5 more life cycles per season (Abdel-Wali, 2010). Extreme events, such as the predicted increases in droughts and floods from climate change, can act as triggers for insect outbreaks (Fuhrer, 2003).

Precipitation and moisture levels are also important for the occurrence of many plant diseases. For example, leaf wetness duration is a key factor for the occurrence and spread of many leaf diseases (Juroszek and Tiedemann, 2011). The germination of fungal spores and their successful infection of the plant often requires close to 100% relative humidity, which usually occurs during night-time dew. In addition, fungicides are often less effective under high rainfalls (Juroszek and Tieddman, 2011). This reiterates the fact that most plants require a moderate level of moisture, with too much or too little both being damaging.

Box 2: Continued

Effects on Livestock

Animals are at risk from climate change in the Arab Region. This is for two reasons: first, through direct physiological impacts due to high temperatures or dry conditions, and second, through the indirect effects of climate change on their food and water supplies (Easterling and Apps, 2005). For example, it is known that increases in temperature beyond optimal levels lead to decreased growth rates, feed efficiency, eggshell quality, and the overall survival of poultry (Teeter and Belay, 1996). Temperature stresses on dairy animals can reduce dry matter intake, leading to weight loss and increased water intake. This leads to less meat and decreased milk production (Farajalla, 2010). Wolfenson et al. (2000) estimate that heat stress causes economic losses in about 60 percent of dairy farms around the world. Nardone et al. (2010) show that the mean adult weight of sheep is 13.5 percent lower in Asian breeds as compared to European breeds, while weights for African breeds are 40.6 percent lower. For goats, Asian breeds are 14.4 percent lighter, and African breeds 31.7 percent lighter. While there are many factors that would affect these trends, Nardone et al. (2010) predict it is because of increasing temperatures.

Animal production can be highly water-intensive (Chapagain and Hoekstra, 2003). It is estimated that the water it takes to produce 30 grams of animal protein (the daily requirements for humans) is 3.7 tons for beef, 1.9 tons for sheep, and 0.7-1.9 tons for milk (these are based on values for industrial as well as grazing production systems) (Nardone et al., 2010). Rainfed grazing systems have a much lower water impact, but are also more sensitive to water shortages. Animals need to drink more water under heat-stressed conditions. This increased water intake can have negative effects in and of itself, if the water is high in contaminants such as heavy metals, is at an unoptimal pH level, or contains excess nutrients (Nardone et al., 2010).

Fortunately, sheep and goats, key animals for both Jordan and Lebanon, are relatively heat-resistant, compared to other livestock. However, at extreme or prolonged high temperatures they still experience heat stress, reducing milk yields (Nardone et al., 2010). Improving local breeds through selection and breeding is one potential approach to addressing this challenge (Al-Jaloudy, 2006).

12. It is therefore recommended that the Government of Lebanon and its partners ***consider pursuing*** the following recommended actions as steps towards safeguarding nationwide water availability and building a more climate resilient Lebanese agriculture sector. Such recommendations are drawn from international best practice in national strategies on climate change from Indonesia, Mexico and Yemen. In addition, recommendations are drawn from a World Bank commissioned study to better understand the interaction between climate change, water resources and agricultural production in the Huanghe-Huaihe-Haihe (3H) region.[8]

[8] "China: Measuring and Coping with Climate Change and Its Impacts on Water and Agriculture in the 3H (Huanghe-Huaihe-Haihe) Region (By 2030)" Washington, DC: The World Bank (June 28, 2010)

Plan to Monitor and Manage Climate Change Impacts through Effective Water Resources Management

Action 1: Strengthen the scientific analytical tools for more precise assessments of climate change impacts on water and agriculture

13. The ability to make more precise predictions of climate change impacts is a valuable tool in building more resilient water and agriculture sectors. Examples of valuable knowledge derived from such predictions include the estimated impact of extreme weather events on agricultural production, determination of the critical climate thresholds for various regions and sectors, as well as needs assessments and sector-specific information on climate change impacts and vulnerabilities. Such assessments enable policymakers to design effective adaptation policies, in addition to monitoring water availability and use.

14. A number of nations are making efforts in this regard. In Mexico, the National Strategy identifies as a priority the design and implementation of a program for climate modeling (as part of a national climate information system). In Indonesia, the National Strategy seeks to institutionalize the utilization of climate information in agriculture-related decision making, while Yemen has begun efforts to consolidate climate data in a "climate observation network." While providing new insights into the impacts of climate change, and their implications for water allocation decisions, cropping patterns, agricultural practices as well as prices and trade, the study recommended that large-scale programs be launched to strengthen data collection and scientific analytical work for more sophisticated, precise, and reliable assessments of climate change impacts on water and agriculture.

15. In Lebanon, capacity building efforts are already underway to utilize remote sensing and earth observation tools to better monitor water availability and use – in the context of a changing climate. Continuing such action will be a positive step in bolstering Lebanon's capacity to make data-informed decisions in water management, especially in the agriculture sector.

Action 2: Further mainstream climate change impacts and adaptation measures into the planning, design and implementation of water and agriculture projects in the Beka'a region (and other regions in Lebanon) in a coordinated approach with different government agencies

16. As climate change will impact all sectors of the Lebanese economy, it is critical that the government pursue a comprehensive approach in addressing the phenomenon. Aside from Law 359/1994 and Law 738/2006 (which ratify the United Nations Framework Convention on Climate Change and the Kyoto Protocol respectively), no major legislation in Lebanon directly addresses climate change. While Lebanon has demonstrated its commitment to address climate change through the enactment of Law 690/2005 (which includes climate change in the Ministry of Environment's main mandate), the Ministry of Environment's Second Communication to the UNFCCC states that the process of integrating climate measures into existing and planned policy frameworks and strategies "is still at its very early stages." [9]

[9] Lebanon Ministry of Environment. (February 2011) *Second National Communication to the UNFCCC*. Beirut.

17. In order to mainstream climate adaptation practices in a coordinated and comprehensive manner, it is important to establish the institutional mechanism to enable cohesive and synergetic response measures to climate change. Under the Protection of the Environment section in the 2009 Ministerial Declaration, the idea of establishing a National Committee for Climate Change and Desertification (NCCCD) was put forward. This report recommends that the Government of Lebanon pursue this activity further. In the MoE Second National Communication to the UNFCCC, it is proposed that the NCCCD be composed of key line ministries as well as Lebanese academia, research groups and NGOs working in climate change. Each ministry would work within its mandate as assigned by laws and regulations to mainstream climate change concepts into sectoral development plans and policies.

18. Recommended actions therefore include the following: (a) provide relevant information to appropriate stakeholders on the ground; (b) engage local communities and stakeholders to promote the inclusion of autonomous and community-based adaptations into national policy frameworks; (c) establish a climate change adaptation fund to finance adaptation projects; and (d) adopt a regional-specific development policy to adapt to climate change. Implementing such measures will better ensure local stakeholder engagement and participation in climate adaptation efforts.

Action 3: Further develop drought and flood mitigation and adaptation plans

19. Drought and flood mitigation and adaptation plans are essential for the water and agriculture sectors, which are expected to suffer from increasingly intense climate change related events. However, such plans should not be produced as standalone documents but must be in line with national sustainable development strategies and policies. International donor and government resources should be mobilized to formalize these connections.

20. Drought and flood mitigation and adaptation plans will likely entail the development of early warning systems as well as increased allocation of funds for insurance against natural disasters – amongst other measures. Agricultural insurance, for example, could be further developed with initial piloting of various schemes which include standard insurance coverage and index-based insurance. International donors and government agencies could potentially mobilize finances for the development of effective natural hazard insurance schemes.

21. Lebanon is one of 4 MENA countries (Jordan, Lebanon, Morocco, and Tunisia) participating in a regional World Bank-financed Global Environment Facility (GEF) project carried out in partnership with the Arab Water Council, NASA, and USAID. The project objective is to better manage local and regional water resources and reduce the threat of land degradation and climate change to vulnerable agricultural production systems and water resources in and across the project areas through the use of remote sensing and Earth observation tools and methods.

22. Under this project, the Bank and NASA have partnered to operationalize various remote sensing and earth observation tools across remote sensing agencies in MENA including the Conseil National de la Recherche Scientifique in Lebanon. Specifically, these tools are being used in applications that include (a) providing a compilation of past, current and potentially future water conditions; (b) providing maps of soil wetness and estimates of irrigation water use; (c) estimating current water storage conditions; and (d) evaluating potential increases and decreases in irrigation

water requirements under various climate change scenarios and help in the planning of agricultural practices. These activities are a critical first step in implementing this report's proposed actions on mainstreaming climate change research into water and agricultural planning and in strengthening Lebanon's preparedness for flood and droughts.

Action 4: Increase net water supply by further developing water collection and storage infrastructure and promote the use of alternative water resources in planning and investment programs

23. A number of developing countries have made efforts to increase net water supply through public investments in water collection and storage infrastructures as well as placing greater emphasis on the use of alternative water sources in the national planning and investment programs. In the Lebanese context, such investments could offer great potential in forging more climate-resilient water and agriculture sectors.

24. Lebanon's water collection and storage capacity can be expanded with the construction of large, medium, small, and farm scale dams and rainwater harvesting infrastructure. Desalination, artificial groundwater recharge, use of brackish water, and reuse of treated wastewater are additional methods which can also be considered. While various technologies can be pursued to achieve such aims, it is essential that technologies appropriate to the local and national contexts be determined upon thorough environmental, social and cost-benefit analysis.

Plan to Monitor and Manage Agricultural Consumption through Irrigation Efficiency Improvements

25. As describe above, the National Water Sector Strategy calls for "*Profitable and Sustainable Irrigated Agriculture*". This is particularly relevant given that agriculture accounts for 60% of water used nationally.

26. Within the Beka'a Valley of Lebanon (see map), the agricultural sector consumes 82% of the total water demand. An estimated 44-52% of the country's agricultural land area is situated within the Upper Litani River Basin[10] of the Beka'a Valley. Demand is expected to increase because of increasing population and the economic incentive of farming more of the arable land.

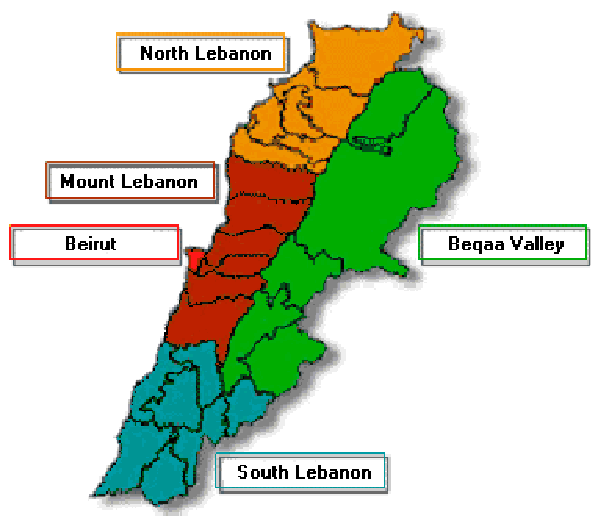

Figure 10: Map of Lebanon, by Region

27. Reducing water use through behavioral and technological adaptations will be essential in order to adapt to a changing climate and the accompanying changes in water availability. Moreover, due to demographic pressures of a growing population, Lebanon's agriculture sector will be expected to produce more food with less water – especially if availability decreases. And as agriculture accounts for 82% of the water used in the Beka'a, even a small efficiency improvement could

[10] Karaa et al., 2004 and ELARD, 2011

result in large water savings. In a study on water use in the MENA agriculture sector, it is argued that technical improvements at the farm level (rather than the basin or project levels) offer the greatest possible water savings and efficiency potential (Tuijl, 1993). This report, therefore, focuses on possible water savings at the farm level.[11]

Action 1: Upgrade Agricultural Technologies

28. Four key factors influence the amount of water required for irrigation and include: (1) irrigation method, (2) crop type, (3) irrigation scheduling and (4) water source (Mirata & Emtairah, 2011).[12]

29. The volume of water used for farm irrigation depends heavily on the technology used. Surface irrigation is the use of open channels to bring water to fields and uses the most water. Sprinkler systems and drip irrigation can use about half as much water as surface irrigation, but are more expensive and require a reliable source of relatively clean water. According to FAO (2008), 9% of Lebanon uses drip technology and 28% uses sprinklers. However, the NWSS reports 6% and 24% for each irrigation technology respectively. Table 3 details the predicted water use in situations when only surface irrigation or only drip irrigation technologies are utilized. The difference in water usage between the surface irrigation only scenario (455 MCM / yr) is more than twice the drip irrigation only scenario (218 MCM / yr). Comparing these figures to actual water use reported by the NWSS (405 MCM/year) would suggest a relatively low adoption rate of the drip irrigation method. Appendix A gives a more detailed comparison of the suitability and risks associated with each technology.

Table 2: Predicted Water Use by Surface vs. Drip Irrigation Methods

	Area of land irrigated by each water source (ha)		Total Irrigated Land (ha)	Using Only Surface Irrigation (10,000) m^3/ha^1	Using Only Drip Irrigation (4,800) $m3/ha^2$
	Surface Water	Ground Water		MCM/yr	MCM/yr
North Beka'a	11,867 ha	9,000 ha	20,867 ha	209 MCM / yr	100 MCM / yr
South Beka'a & Rahaya	7,080 ha	17,516 ha	24,596 ha	246 MCM / yr	118 MCM / yr
TOTAL			**45,463 ha**	**455 MCM / yr**	**218 MCM / yr**

1. Efficiencies from El-Fadel et al. (2000)
2. Efficiencies from BAMAS (2003)

30. The dominant method of irrigation within Lebanon is thus surface irrigation, which uses furrows, open channels, and basins (Hamdy, 2002). Efficiency is a measure of the effectiveness of an irrigation system in delivering water to plants. While traditional to the region, surface irrigation tends to be inefficient due to issues with the irrigation conveyance system. Under such a system,

[11] The NWSS also provides recommendations on household and industrial efficiency improvements, such as incorporations of high-efficiency plumbing mechanisms and clothes washers, retrofits for large industrial and commercial water consumers, and water audits of households and establishments. While such recommendations are significant, the report does not focus on such actions as they will have greater impact in more urban areas of Lebanon.

[12] In addition to the benefits of decreasing agricultural water demand, improvements in irrigation have also shown to increase crop yields, improve soil quality, and reduce the amount of fertilizers needed (Mirata & Emtairah, 2010).

water supplies are often unreliable – characterized either by having too low of a flow, resulting in seepage, or too large of a flow, resulting in runoff. Other reasons for the inefficiency are due to a lack of knowledge amongst farmers about proper water application rates and uneven fields, which lead to pooling (Tuijl, 1993).

31. Surface irrigation can be improved by leveling the land to enable a more even distribution of irrigation water and to prevent water logging (Tuijl, 1993). However, experiences from many MENA countries would suggest that the relatively high water demand per hectare associated with surface irrigation (as well as the uneven application rate of water to the soil) warrants a transition into more efficient irrigation technologies – namely, sprinkler and / or drip irrigation technologies

32. Sprinkler irrigation imitates natural rainfall through the spraying of water either by overhead or ground level spray guns. The systems can be stationary or set on rotational apparatuses. The technology is suitable for large and small-scale irrigation schemes (Clements, 2011). Crops that are best suited to sprinkler systems include those that are grown in rows or close together (i.e. cereals, pulses, wheat, vegetables, and spices) as well as trees (Clements, 2011).[13] Within the Beka'a Valley, sprinkler systems are used to irrigate wheat, potatoes, sugar beets, and forages (Karaa, 2008).

33. Efficiencies for sprinkler systems vary with the surrounding climate, with the FAO suggesting efficiencies ranging from 65-80% for cool to desert climates (Clements, 2011). Published efficiencies range from 60-90% (Tuijl, 1993), 75-90% (The National Academy of Sciences, 1999), and up to 95% in certain cases (Mirata & Emtairah, 2010). Other benefits to sprinkler systems include protection from unexpected low temperatures, even distribution of water on fields, flexibility (permanent or mobile structures), and a lower risk of soil erosion. Fertilizers can also be applied through sprinkler systems resulting in a more efficient application and a decrease in overall costs.

34. Disadvantages associated with sprinkler systems include susceptibility to weather conditions and capital costs. In cases where the systems are mobile, labor is required to move the sprinklers (Clements, 2011). It also requires that the water source be clean and nearby in order to minimize the risk of blockage and ensure steady supply. Sprinkler systems can also be energy intensive, which should be taken into consideration before installation.[14] Another major disadvantage involves evaporation losses. While sprinkler irrigation systems entail a lower rate of evaporative loss (relative to surface irrigation systems) as sprinklers eliminate the need for conveyance infrastructure, the loss rate is nevertheless higher than that of drip irrigation systems. According to the June 2005 BAMAS report, 94% of interviewed farmers utilize sprinkler systems for some of their crops in the Upper Litani, while 22% use drip irrigation.

35. Drip irrigation technology involves small emitters, which can provide exact amounts of water directly to the roots of crops and results in high water use efficiencies of up to 95% compared to surface and sprinkler techniques with 60% and 75-90% respectively (Clements, 2011). The reported efficiencies of drip or micro-irrigation is up to 90% and can result in water savings of 40-80% over traditional methods (Mirata & Emtairah, 2010; Clements, 2011). Besides the advantage

[13] Various crops have shown an increase in crop yield due to switching to sprinkler technology.
[14] In Morocco, Tuijl reports costs being a barrier to sprinkler systems in Morocco due to the high price of energy. (Tuijl 1993)

in water savings, drip irrigation offers other benefits including run-off reduction, more efficient application of fertilizers and agrochemicals, and even increased crop yields.[15] Whereas sprinkler distribution is affected by weather patterns such as rain and wind, drip technology remains unaffected (Clements, 2011). Additionally, drip systems work well with source water from wells and can nearly eliminate water runoff.

36. Drip irrigation can be applied on small- and large-scale farms and is well suited for regions with permanent or seasonal water scarcity. Typical crops grown in the Beka'a Valley (i.e. citrus, olives, apples, and vegetables) have agreed well with drip irrigation (Clements, 2011). In the Upper Litani, farmers have used drip technology specifically for trees and vegetables (Karaa, 2008). In 2005, approximately 60% of farmers relying on Canal 900 local agricultural infrastructure employed drip irrigation systems (BAMAS, 2005).

37. The cost of installing a drip irrigation system ranges from 800 USD-3,000 USD/ha depending on the sophistication of the technology (Clements, 2011 and National Academy of Sciences, 1999). However, while drip technology has a relatively high capital cost, the reduction in water and fertilizer required would result in lower annual costs to farmers.

38. Another drawback involves the lack of technical knowledge required to properly maintain the system. Piping, emitters, and tubing can become clogged or could develop leaks when users do not ensure that source water is of a high quality.[16] Drip irrigation has also suffered from a lack of basic knowledge and understanding of what the technology entails. For example, Darwish et al. (2005) examined the reasons behind some farmers switching from drip systems to sprinklers in the Upper Litani. In the study, it was discovered that farmers perceived that the degradation of soil quality and increase in salinity were associated with the new systems. Nevertheless, while the decision may have been misinformed, the initial willingness of farmers to invest in drip technology reveals that despite barriers, farmers are willing to transition to new technologies.

Box 3: Successful Water Savings Strategies in Lebanon

Improvements in irrigation technology and policy have shown to be successful in Lebanon – specifically in the Qasmieh and South Beka'a Irrigation scheme. Located on the country's southern coast, the Qasmieh scheme had an original water demand of 16,700 m^3/ha/yr. However, after rehabilitation, the demand dropped to 11,575 m^3/ha/yr. In combination with the improvements, the Litani River Authority used differential water pricing to encourage irrigators to switch to higher efficiency technology (Karaa, 2008). The South Beka'a scheme initially used 6,100 m^3/ha/yr and after rehabilitation the number dropped to 5,534 m^3/ha/yr, resulting in a 9.28% decrease in consumption after one year (Karaa, 2008).

39. Adaptations such as switching to more efficient irrigation systems could result in significant water savings, thereby enabling goals for demand and use scenarios in the NWSS to be met. In order to identify specific changes and evaluate the resulting water savings, efficiency for each irrigation technology and the fraction of land that currently employs each technology must be known.

[15] If in the future, Lebanon begins to directly use reclaimed wastewater, drip irrigation has a lower risk compared to sprinklers for pathogen transmission (Christen, 2006).

[16] In 2008, the American University of Beirut conducted an agricultural survey to assess the economic impact of the water quality on drip farming schemes in the Bekaa (AUB, 2008). The study revealed that on average the cost to unclog an emitter was $1.90 USD/1000 m^2.

Table 4 compares the three irrigation methods across a few key parameters based upon MENA-wide information.

Table 4: Comparison of Irrigation Methods in MENA (Adapted from Tuijl, 1993)

	Surface	Sprinkler	Drip
Cost (USD/ha)	-	$600-$2500	$800-$3000
Relative cost of moving complex parts	Low	medium	high
Efficiency	50-60%	60-75%	65-95%
Technical expertise needed by farmer	medium	high	very high
Inflexible water delivery system	moderately tolerant	sensitive	sensitive
Min. Economical field Size (ha)	4	50-100	2
Fertigation ease	Good	excellent	excellent

40. Published studies on the Lebanese agriculture sector, specifically, indicate a range of efficiencies for surface, sprinkler, and drip technologies as well as a range of values for the percentage of existing acreage currently irrigated with each technology in Lebanon (Table 5).

Table 5: Efficiency Ranges of Various Irrigation Technologies in Lebanon as Published in Literature

Technology	Efficiency Estimate (%)	Existing Fraction of Acreage (%)
Surface	60	53-70.4
Sprinkler	70-80	23.4-28
Drip	80-95	6.2-19

41. Based upon these ranges, changing the fraction of land that employs each type of irrigation technology could enable the water savings goal of reducing agricultural water use from 9000 to 7000 m^3/ha/yr as stated in the NWSS**.**

42. A feasible scenario is shown in Table 6 wherein the overall water usage attained is 7,495 m^3/ha/yr, which exceeds the NWSS target, but still represents a 17% decrease in water usage from the current 9000 m^3/ha/yr. Although this is a modest percentage, based on the overall agricultural consumption in the Beka'a of 405 MCM/year, the savings would amount to roughly 69 MCM per year.

Table 6: Reduction in Irrigation Water Use

Technology	Efficiency Estimate (%)	Assumed Existing Fraction of Acreage (%)	Fraction of Acreage Under Possible Future Scenario (%)
Surface	60	70.4	25
Sprinkler	80	23.4	35
Drip	95	6.2	40
Overall Average Water Use (m^3/ha/yr)		9000 (assumed)	7495 (Calculated)

Box 4: Cost Savings Associated with More Efficient Water Use in Syria

In 2001, a FAO report by Varela-Ortega and Sagardoy, offered policy recommendations to reduce the water demand in the agricultural sector within Syria. The country had a water deficit of 3,104 MCM/yr, 85% of which was consumed in agricultural practices. By adopting new technology in 2000, Syria was able to reduce their initial average water usage of 12,434 m^3/ha to 8,000 m^3/ha. As a result, the national government decided to switch all irrigated land (1,276,068 ha) to modern irrigation technology within four years. In order to meet this goal, the government decided to create opportunities for farmers to purchase new equipment through conditional bank loans. The media was also mobilized by advertising the new technologies to farmers throughout the country. A FAO study (Varela-Ortega & Sagardoy, 2001) was also solicited to evaluate success of such efforts. Among its key findings were that cost savings on the farm level differed by technology and farm size.

For large farms (~14 ha) using river water, the switch from surface irrigation resulted in a net profit increase of 4,712 SYP/ha for sprinkler and 3,704 SYP/ha for drip. For large farms using groundwater about 100m deep, the net profit increase was 18,375 SYP/ha for sprinkler irrigation and 17,460 SYP/ha for drip. Within Syria, river water is charged at 3,500 SYP/ha as well as a basin-specific fee ranging from 2,000-6,000 SYP/ha. For well water, extraction costs are 0.8-2.37 SYP/m3, which is why an improvement in irrigation technology can result in such high cost savings for groundwater users (Varela-Ortega & Sagardoy, 2001).

For medium sized farms (~5 ha), the study showed that drip irrigation was slightly more profitable than sprinkler (about a 3% difference in income increase). A 33% and 36% profit increase for sprinkler and drip irrigation was shown on farms using river water for irrigation, while a 64% and 67% profit increase was reported when the source water was from a well (Varela-Ortega & Sagardoy, 2001).

For smaller farms (~1.5 ha), sprinkler and drip technology resulted in profit increases of 38% and 67% respectively for river source based irrigation. If groundwater is the main source, savings reached 67% and 111% for sprinkler and drip respectively. For smaller farms in Syria using wells, the investment in drip technology is actually very economical. The FAO report also stressed the importance of farmer training to ensure that the modern equipment is used properly and that best practices are followed when it comes to water application rates (Varela-Ortega & Sagardoy, 2001)

Action 2: Invest in Lower Water Demand Crops

43. According to available data, there are few water intensive crops grown within Lebanon. For example, bananas, which have nearly a year-long growing season and high water need, account for only 2.68% of the irrigated land in Lebanon. Transitioning out of current water intensive crop production, therefore, may only result in modest gains. Nonetheless, water-conscious decisions regarding crop choice can increase efficiencies. In the upper Litani region, the main crops grown include fruit trees, olives, nuts, potatoes, sugar beets, vegetables, cereals, and grapes. Figure 5 displays the rough distribution of crops within the Beka'a Valley.

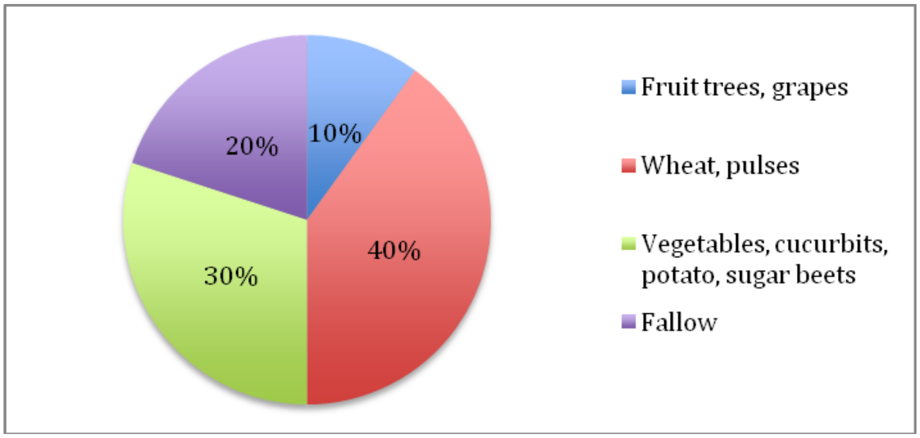

Figure 5: ***Distribution of Crops within the Beka'a Valley (Karam et al., 2004)***

44. Olives and grapes are specifically suited to a water stressed climate and do not require substantial amounts of irrigation. Areas in the northern Beka'a have planted 2 million cherry and apricot trees which require significantly less water than other traditional crops (Houri, 2006). The Lebanese Agricultural Research Initiative (LARI) recommended an increase in sugar beets and soybeans grown within the Beka'a (2005). The LARI research has shown that soybeans have a low water consumption compared to other regionally grown crops. Sprinkler technology is well suited for wheat, doubling the crop benefits in some cases. Drip irrigation almost doubles crop benefits for cotton, and has been shown to be beneficial for orange trees as well.

Using FAO's categories and national crop statistics from 2003, Figure 6 breaks down the distribution of crops planted by water demand. Table 9 compares various crops' water needs to standard grass. There is a potential for water savings if farmers switched from mid-range water intensive crops like wheat and pulses to lower water demand crops like grapes, olives, squash, cucumbers, and radishes. Such a transition could be achieved through farmer-targeted educational programs.

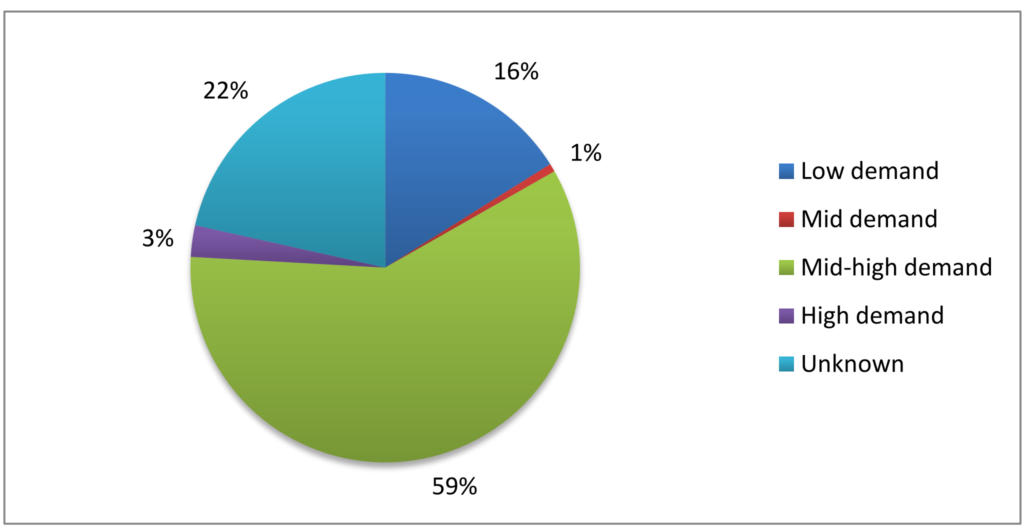

Figure 6: Distribution of Crops Planted (By Water Demand) within Lebanon

Table 9: Daily Water Needs for Various Crops Compared to Standard Grass (FAO, 1997)

30% less	10% less	same	10% more	30% more
4.6 mm/day	**5.9 mm/day**	**6.5 mm/day**	**7.2 mm/day**	**8.5 mm/day**
citrus olives grapes	cucumbers radishes squash	carrots crucifers lettuce melons onions peanuts peppers spinach tea cacao coffee clean cultivated nuts & fruit trees (apples)	barley beans maize flax small grains cotton tomato eggplant lentils millet oats peas potatoes sorghum soybeans sunflower tobacco wheat	banana nuts & fruit trees with cover crop

Action 3: Monitor Water Availability and Use and Enforce Regulations and Policies

45. Successful monitoring requires that basic infrastructure be mobilized to gather, analyze and manage relevant data. Many of these activities are already conducted by the MOEW, the Litani River Authority, local universities as well as the Beka'a Regional Water Authority. However, ensuring that monitoring activities are coordinated and data is shared across institutions is essential.

46. Regulations and policies related to water usage should be established based on sound scientific data and reports while mechanisms should be employed to enforce rules. In Indonesia, enforcement is heavily participative – at the community level. Lebanon could consider devolving specific enforcement activities to local institutions (i.e. water user associations) as a means to effectively enforce water regulations and policies on the ground.

Action 4: Establish Water User Associations

47. As irrigation is the single largest water consumer in Lebanon it is especially crucial to create water institutions such as Water Users Association (WUA). As proposed by the NWSS, WUA's would facilitate stakeholder participation in the design and management of projects according to best practices, oversee and monitor irrigation schemes, as well as set and adjust water tariffs according to the proposed "Tariff Initiatives", thereby ensuring participatory management in governance and cost recovery.

48. A WUA would also confront the lack of awareness about water consumption and conservation by carrying out public awareness campaigns and initiatives. In Yemen, similar water user associations

have demonstrated themselves to be especially effective in raising farmer awareness on similar issues as well as spearheading community management of groundwater and improving irrigation conveyance / delivery systems.

Action 6: Pilot Demonstration Projects as a Means to Raise Awareness

49. Capacity building at the local farm level will be important to ensure sustainable and effective uptake of new technology. The 2005 BAMAS report recommends the development of an extension program to disseminate training and best farming practices to local famers.

50. In Yemen, similar efforts are underway to pilot demonstration projects as a means to ensure that responsible water management measures can be demonstrated to farmers. Such actions can help serve as a catalyst for wider changes in behavior.

Action 7: Invest in Research

51. National Action Plans from Indonesia, Mexico and Yemen have all placed significant emphasis on the need to invest in research – be it of superior seed and crop varieties or localized cost benefit analyses of various irrigation technologies. In Lebanon, localized studies have been conducted and highlight the importance of location specific research to discover best practices regarding irrigation methods as well as fertilizers application rates and techniques.[17] LARI has performed numerous studies within the Beka'a Valley regarding best agricultural practices specific to the region since its establishment in 1964. Such efforts should continue and be bolstered. Studies and reports already published offer a starting point for shaping new efficient and water saving farming methods within the upper Litani region.

Summary

52. Climate change poses an important threat to the temporal and spatial distribution of water resources across Lebanon. In a country where agriculture already consumes a significant majority of available freshwater resources, it is therefore critical to develop and implement targeted action plans which simultaneously reduce water demand while also optimizing supply.

53. Building off of the Ministry of Energy and Water's National Water Sector Strategy, the Ministry of Environment's active program as well as other parallel activities underway throughout Lebanon's academic, scientific and public sector, this report thus offers action plans for each of climate change mitigation measures as well as agricultural optimization.

54. Based on international best practices for similar action plans, these recommendations provide the Lebanese Government and its counterparts a synopsis of immediate next steps that will optimize water resources management across Lebanon in the medium to long terms, and in the Litani River Basin in the shorter term.

[17] Studies have shown that improvements in agricultural practice along with advancements in irrigation technology can produce higher crops yields while using less water. Darwish et. al. (2004) conducted research related to N-P-K fertilizer application rates and found the most efficient rates for growing potatoes using drip technology in the Beka'a Valley. Karam et al. (2006) reported that higher amounts of irrigation water actually had a negative impact on cotton lint yields grown in the Beka'a Valley.

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Appendix A

Table A1. Technology suitability based on various parameters.

	Drip		Sprinkler		Surface
	Buried	Surface	Fixed pivot	Traveler	Furrow
Moderate soil salinity	H	H	M**	M	M
Suitability for loam soil	H	H	M	M	H
Suitibility for crop establishment					
Small seeded crops	L	M	H	L	M
Large seeded crops	L	H	H	M	H
Transplants or cuttings	H	H	M	M	M
Special considerations					
Soil/sand blowing	L	L	H	H	M
Dust control	L	L	H	H	M
Cooling	L	L	H	H	M

H= highly suitable, M=moderately suitable, L=low level of suitability
** leaf burn becomes a problem

Table A2. Level of risk associated with each technology.

	Drip		Sprinkler		Surface
	Buried	Surface	Fixed pivot	Traveler	Furrow
Pathogen risk					
ingestion risk	L	M	M	H	M
contact risk	L	H	H	H	H
aerosol risk	L	L	H	H	L
Disease risk					
large surface crops	L	H	H	M	M
root crops	L	M	M	M	M
cucurbits, tomatoes, etc	L	H	H	H	M
trees, vines, cane, fruit	L	H	M	M	M
clogging, corrosion risk					
high Suspended solids	L	L	M	-	H
high potential precipitates	L	L	M	-	H
high biological activity	L	L	M	-	H
pH< 6, >9	L	L	L	-	M
risk of runoff- soil type loam	L	L	M	H	M
deep percolation risk - loam soil	L	L	L	H	H

H= high risk, M = moderate risk, L= low risk

Annex 4: Report on water quality challenges to Lake Karoun, especially those relating to eutrophication

Study on Eutrophication, Upstream Management of Water Availability,

and Impact of Climate Change

Report on water quality challenges to Lake Karoun, especially those relating to eutrophication

August 2012

Prepared for the World Bank
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Executive Summary

Eutrophication is a natural process that occurs in freshwater lakes and is characterized by increased algal growth. It is associated with excess nutrients and can be accelerated by human activities in the watershed which increase the nutrient load to the lake. Use of eutrophied water bodies as drinking water sources is widespread and includes large lakes such as Lakes Okeechobee and Erie in the United States, Lake Taihu in China, Eğirdir Lake in Turkey and Lake Muggelsee in Germany. Without adequate safeguards, algal growth associated with eutrophication can increase the costs of drinking-water treatment, may be associated with taste and odour problems, and can be of health concern.

Karoun Lake is the largest lake in Lebanon and is located in the Bekaa valley, the country's principal agricultural and industrial area. Karoun Lake is eutrophic, as reflected by high levels of total phosphorus and total nitrogen in water samples. Reports on the Upper Litani have identified several nutrient pollution sources. Point sources include the direct disposal of municipal and industrial waste into the Litani River. Non-point sources are primarily composed of agricultural run-off exacerbated by overuse of fertilizers. Consequences of eutrophication include algal proliferation. The presence of blue-green algae (cyanobacteria) has been documented in Lake Karoun. Some cyanobacteria are of health concern because of their ability to release toxins however, the removal of toxins can be achieved through drinking water treatment.

The Greater Beirut Water Supply Project (GBWSP) will deliver drinking water to over 1.2 million residents of the Greater Beirut area. Influent to the GBWSP water treatment plant comprises of waters from Karoun Lake as well as higher quality water from the Bisri River and 3 large springs. The effect of eutrophication in Karoun Lake on the Greater Beirut Water Supply Plan GBWSP is thus significantly reduced.

Based on a thorough review of the yearlong water quality sampling undertaken by the Government of Lebanon, this report, which is specific to Karoun Lake, is consistent with the findings of the Greater Beirut Water Project Independent Technical Review of Source Water Quality (May 2011), which concluded that: "Water from Joun Reservoir is of sufficient quality such that conventional water treatment technologies can produce potable water meeting Lebanese and international health- and aesthetic-based standards and guidelines. Although microbial contamination exists in the source waters, standard water treatment should be able to reduce contamination and result in product water meeting drinking water quality standards."

A *four point strategy* is recommended to manage the consequences of eutrophication on Lake Karoun as a source of water for drinking-water supply. The Government of Lebanon and its partners have begun to take steps toward implementing these recommendations as described below:

1. *Reducing nutrient pollution inputs.* Pollution from point and non-point sources can be reduced through pollution mitigation measures and appropriate water basin management. Adding flocculation and chemical precipitation to wastewater treatment prior to discharge into the Litani River may be achievable in the short-medium term and would help limit nutrient (specifically phosphorus) levels in point sources. More efficient application of fertilizer can reduce the nutrient loads from non-point sources, while also reducing fertilizer costs. The Ministry of Environment's Draft Business Plan for Combating Pollution of Qaraoun Lake

produced by Earth Link and Advanced Resources Development S.A.R.L., which examines point and non-point nutrient inputs, offers remediation measures that would address the causes of eutrophication in Lake Karoun. The Business Plan is under implementation by an Inter-ministerial committee appointed by the Prime Minister. The Ministry of Environment has mobilized national and international financing for several pollution abatement projects within the Plan, including a World Bank Loan for Pollution Abatement within the Litani Basin, currently under preparation.

2. *Minimizing algae in the drinking-water source water*. With a continuous monitoring system in place that detects algal blooms in the lake, offtake design and operation can be adopted to allow the operator to select water depths for intake at which algal presence is low. This is common practice in many other systems. The GBWSP has been designed to utilize waters from Lake Karoun as well as water from Bisri river and 3 springs.
3. *Ensuring adequate drinking-water treatment*. Treatment should remove intact algal cells without damage. Removal of whole cells in early stages of treatment minimizes the potential risk of transmission of toxins or disinfection byproduct precursors into later treatment stages. Conventional treatment processes including coagulation, filtration, and ozonation have proved effective in removing cyanobacteria and associated toxins. Reserve capacity for removal of toxins or disinfection byproduct precursors is an additional safeguard that should be available for use if an algal bloom occurs. The GBWSP comprises a water treatment plant which the Beirut Mount Lebanon Water Establishment is tendering as a Design-Build-Operate (DBO) contract in which contractors will propose a variety of conventional water treatment technologies to treat influent water quality.
4. *Developing and implementing a comprehensive risk management strategy*. A system-wide 'Water Safety Plan' or equivalent that includes catchment monitoring and management should be implemented. Comprehensive monitoring of the Litani Basin for nutrient levels, algal concentrations, and taxanomic algal composition is recommended to assist with planning and evaluating the success of eutrophication mitigation as a component of the plan. The Ministry of Environment's Business Plan for Combating Pollution in Lake Qaraoun (currently under implementation as described above) comprises specific actions to monitor, manage and reduce nutrient levels in Lake Karoun. The recently approved National Water Sector Strategy further identifies Lake Karoun pollution mitigation as a specific priority and presents a plan for action.

Study Objectives

The Water Institute at UNC was asked by the World Bank to perform a review of published literature and data regarding the Upper Litani Basin and Lake Karoun to assess the trophic status of Lake Karoun and the impact of the quality of the water on the Greater Beirut Water Supply Project (GBWSP). Weekly water quality data obtained from Lake Karoun over one year beginning in April 2010 were examined along with water quality from the Litani Basin Management Advisory Services (BAMAS), the United States Agency for International Development (USAID), the Draft Business Plan created by Earth Link and Advanced Resources Development (ELARD), and other reports. The Water Institute has previously reviewed weekly water quality data from April 2010 to April 2011 and produced a report focusing on water at the intake for the GBWSP, which is composed partly of water from Karoun Lake (Bartram and LoBuglio 2011).

Another objective of the study was to review the recommended remediation measures in the ELARD business plan to reduce the effects of eutrophication. This included understanding the effectiveness of the recommended measures in cases where they were implemented in other eutrophic water bodies.

1. Eutrophication

Eutrophication can be defined as an increase in nutrients (particularly nitrogen and phosphorus) that leads to the proliferation of algae and plants in natural waters. The change in the trophic status of a lake from a low level (oligotrophic), to a high level (eutrophic) is a naturally occurring process in freshwater lakes, and is often seen as a progression as a lake ages. Most commonly, lakes move from oligotrophic to eutrophic as nutrients are both cycled internally and introduced to the system from external inputs.

During the 1940s and 1950s, the increase in eutrophication due to anthropogenic activities came to the forefront of surface water quality issues. Human activities within a watershed can dramatically accelerate the rate and intensity of eutrophication. Discharging municipal waste into tributary rivers and agricultural run-off increases the amount of nutrients entering the lake. Deforestation can result in higher run-off rates which also lead to increased leaching of soil nutrients into surrounding freshwater bodies (BAMAS, 2005b).

A survey completed in the 1990s reported the proportion of lakes considered eutrophic by geographic region and found proportions equal to 54 per cent, 53 per cent, 48 per cent, 41 per cent, and 28 per cent in the Asia Pacific Region, Europe, North America and South America and Africa respectively (ILEC/Lake Biwa Research Institute, 1988-1993). Eutrophication of lakes and reservoirs that are used for drinking water is widespread. Lakes Okeechobee (Schelske, 1989) and Erie (Reutter, 1989) in the United States, Lake Taihu in China (Jin et al., 2006), Eğirdir Lake in Turkey (Sömek et al., 2008), and Lake Muggelsee in Berlin, Germany (Welker et al., 2003) are only a few of the documented eutrophied water bodies that local populations depend on for drinking water.

1.1 Trophic Status of Lake Karoun

The trophic status of a lake or reservoir is most often categorized by specific parameters of water quality including: total phosphorus, total nitrogen, dissolved oxygen (DO), transparency, and chlorophyll *a*. Based on a review of water quality data (Table 1), Lake Karoun can be classified as eutrophic to hypereutrophic.

Table 1: Nutrient levels, biomass and productivity at each trophic category

Indicator	Source of Data (see references)	Measured level in Lake Karoun	Number of Samples Collected	Eutrophication Level (Chapman, 1996)
Total Phosphorus (mg/m3)	MVM 2000	0.0-220.0 with a mean of 33.95	27	Eutrophic
	IWRM, Oct 2003	570-1,170 with a mean of 810	10	Hypereutrophic
	ELARD 2011	290-330 with a mean of 305	4	Hypereutrophic
	Weekly sampling April 2010-April 2011	30-680 with a median of 110	45	Hypereutrophic
Total Nitrogen (mg/m3)	IWRM, Oct 2003	<5,000-9,000 with a mean of 5,000	10	Eutrophic/Hypereutrophic
	ELARD 2011	6,700-10,100 with a mean of 8,100	4	Hypereutrophic
	WB weekly sampling April 2010-April 2011	7,693-23,581 with a mean of 13,303*	45	Hypereutrophic
Annual Mean Chlorophyll (mg/m3)		Not Measured		
Chlorophyll maxima (mg/m3)		Not Measured		
Secchi Disc Transparency (m)	IWRM, Oct 2003	3.5-4.5 with a mean of 4.1	10	Mesotrophic
Dissolved Oxygen (% saturation)	IWRM, Oct 2003	15-59 with a mean of 36.9	10	Eutrophic

* Total Nitrogen estimated by adding NH4, NO2, NO3 which would less than total nitrogen, however these parameters combined are already substantially over the lower bound for hypereutrophic classification

1.2 Effects of Eutrophication

As a lake becomes eutrophic, there is an increase in biomass production, mostly in the form of algae. Once the algae die, they settle to the bottom of the lake where DO is consumed in the decomposition process. Oxygen depletion can lead to unpleasant odors and tastes as well as unwanted algal growth due to complex feedback mechanisms. The combination of anoxic conditions and high pH can result in the generation of ammonia gas (BAMAS, 2005b). The depletion of oxygen can also lead to a change in chemical dynamics near the sediment of the lake, with a resulting potential to release of manganese, iron and phosphorus from the lake bottom (Chapman, 1996). The additional phosphorous can, in turn, intensify the eutrophication process (Chorus & Bartram, 1999).

One of the major impacts of eutrophication is the loss of DO within the water column. When the concentration falls below 80% of its maximum value (saturation), an issue of odor and taste may occur

(Chapman, 1996). Low DO can lead to other water quality issues including the generation of methane and sulfide as well as the mobilization of trace metals. (IETC, 2000).

Eutrophic lakes with adequate sunlight availability, temperature, and phosphorus loading may be favorable environments for the formation of nitrogen-favoring algae. If algae growth is dominated by one species it is usually referred to as an algal bloom (Chorus & Bartram, 1999) and these blooms can generate numerous negative effects on the water quality of a reservoir. They can clog water treatment filters and produce undesirable odors and taste in the water (Okafor, 2011). Algal blooms can also impair agricultural equipment, impede delivery of irrigation water through canals, and attract unwanted insects (BAMAS, 2005a).

Eutrophication can lead to the production of cyanobacteria, also known as blue-green algae, which are cause for particular concern. If the walls of the cyanobacteria cells are broken, harmful toxins (cyanotoxins) can leak into the water. Health effects associated with these toxins range from gastrointestinal and hepatic illnesses, while chronic exposure has been shown to cause liver damage and possible tumors (Chorus & Bartram, 1999). Chorus and Bartram (1999) acknowledge "problems with cyanobacteria are likely to increase in areas…with agricultural practices causing nutrient losses to water bodies through over-fertilisation and erosion".

Cyanobacteria are a problem throughout the U.S.; an EPA assessment of over 1000 lakes identified 27% of lakes as having moderate to high risk of cyanobacteria, and 30% had detectable levels of the cyanotoxin microcystin (USEPA, 2009). Atoi et al. list several instances of cyanobacteria identified in drinking water sources in the Mediterranean region (Table 2).

Table 2: Observed cases of Cyanobacteria in drinking water sources in the Mediterranean Region (adapted from Atoi et al.)

Lake or Reservoir	*Reference*
Eğirdir in Turkey	Sömek et al. 2008
Marathonas reservoir in Greece	Lymperopoulou et al. 2011
Arcos reservoir in Spain	Quesada et al. 2006
Lake Oubeira in Algeria	Nasri et al. 2004
Hjar reservoir in Tunisia	El Herry et al. 2007
Lake Tiberias / Lake Kinneret Reservoir (Israel)	Banker et al. 1997

2. Water Quality Effect in Lake Karoun

Based on the data in previous reports studying Lake Karoun, the three major effects of eutrophication in Lake Karoun are algal growth, a loss of DO, and an increase in turbidity. Assessing the exact effects of eutrophication on the Karoun Reservoir is difficult due to the variability in sampling methodologies of the past reports. The limnological attributes of the reservoir vary at different depths, and depth information was not reported in all of the studies, although most sampling regimes measured parameters at varying locations throughout the reservoir at mid-depth. Since the withdrawal from the reservoir does not occur at the surface, these mid-depth measurements should provide some indication of lake water quality relevant to the GBWSP and thus are referred to in analysis.

2.1 Algal Production

A recently published paper (Atoi et al, 2012) reports that, in May 2009, for the first time, cyanobacterial blooms have been identified in Karoun Lake. The blooms persisted from May through

December for two consecutive years. In this study samples were taken from a depth of 0.5 meters, in the north-east portion of the lake (figure 1) and analyzed using microscopic techniques.

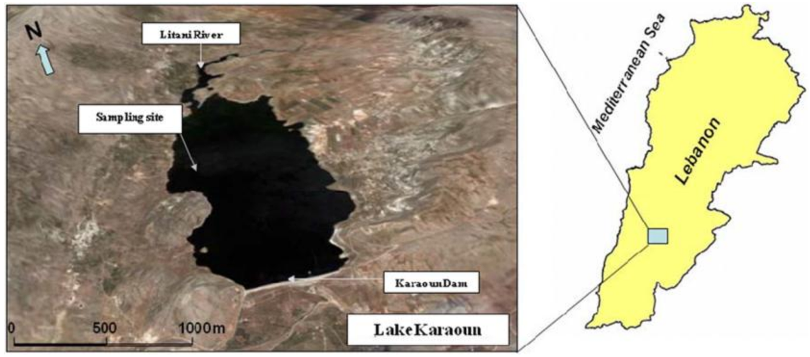
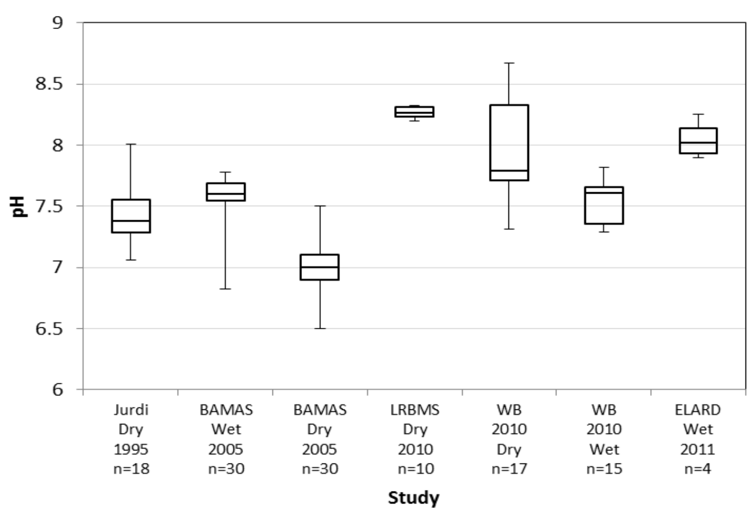


Figure 1: Sampling location for cyanobacteria study (copied from Atoi et al. 2012)

Algae growth was not the focus on any of the previous reports but some data indicate algal growth before 2009. The BAMAS 2005b report, which focused primarily on Canal 900, reported significant algae proliferation along the water channel and attributes it directly to the anthropogenic activities in the Upper Litani River Basin (BAMAS, 2005a). The BAMAS 2005b reported there was no algae growth in Lake Karoun, however the same report stated, "the water in the Lake [Karoun]…has elevated concentrations of phosphorous and nitrogen that are conducive to algal bloom under appropriate environmental conditions". The 2010 LRBMS report assessed that the DO levels were reflective of a suspended algae growth. The authors also observed algae proliferation in the lower and upper area of the river closer to Lake Karoun. The IDRC report also noted "high levels of algal production" at the outlet of Lake Karoun during the summer season (IRDC, 2007).

From 1995 to 2011 there is a trend of increasing pH in Lake Karoun shown in Graph 1. Based on these reports, the pH range in Lake Karoun is approaching the range cited by Okafor as ideal for cyanobacteria growth (2011).

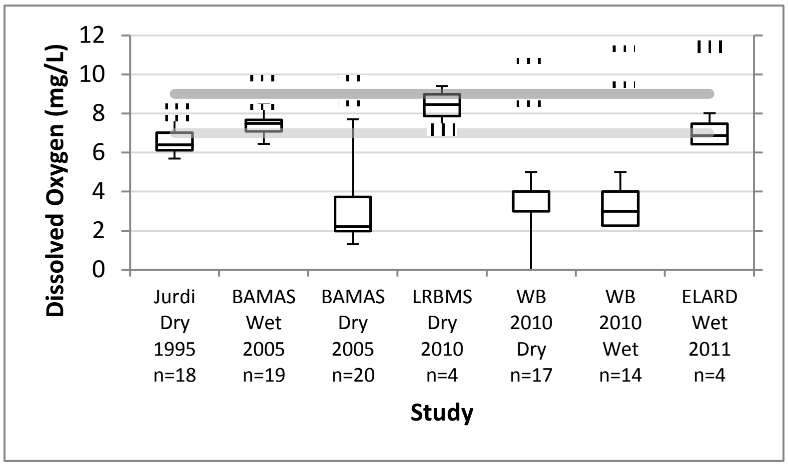


Graph 1: Measured levels of pH in Lake Karoun from various studies conducted between 1995 to 2011.

Note: Ministry of Environment acceptable range for aquatic life (ELARD, 2011) is between 6 and 9. Boxes show the median, 25th, and 75th percentiles, whiskers show the extreme values in the dataset.

2.2 Dissolved Oxygen

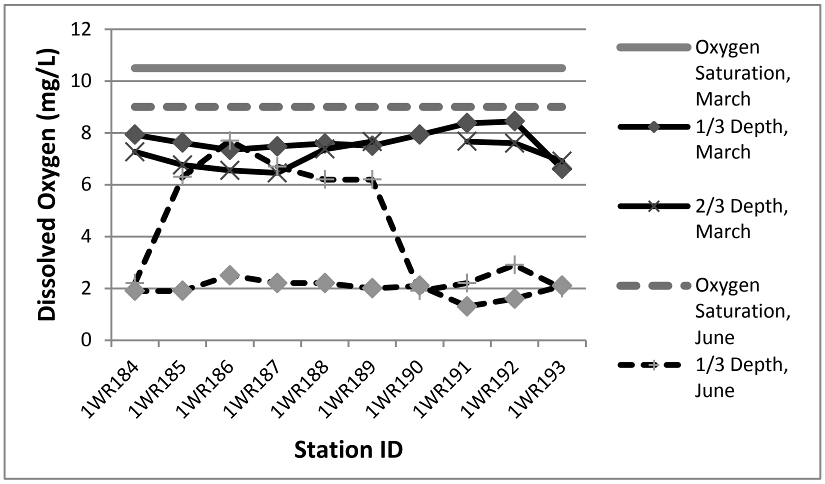
The Ministry of Environment (MOE) guideline for freshwater aquatic life is for 50% of samples to be above 9 mg/L O_2 and all samples to be above 7 mg/L (ELARD, 2011). Dissolved oxygen is highly dependent on temperature, with maximum "saturation" values varying from 12.8 to 7.0 mg/L for a temperature range of 5 to 35 C respectively. The year-long sampling campaign by the Government of Lebanon from April 2010 to April 2011 reported a range of 2-5 with a mean of 3.6 mg/L O_2. Graph 2 shows the variation of DO from five water quality studies. Recent data do not appear to meet guidelines for freshwater aquatic life.



Graph 2: Measured levels of DO (mg/L O_2) in Lake Karoun collected from various studies.

Note: Boxes show the median, 25^{th}, and 75^{th} percentiles, whiskers show the extreme values in the dataset. MOE guidelines shown at 7 and 9 mg/L. Horizontal dashed lines show saturation values at minimum and maximum temperatures. BAMAS Wet 2005 value of 0.868 not included because the value is inconsistent with the dataset and is likely a measurement or typographical error. LRBMS DO levels are not consistent with saturation values at reported sample temperatures ranging from 32.2 to 34.7 C. A non-detect in the WB 2010 Dry data is shown as 0.

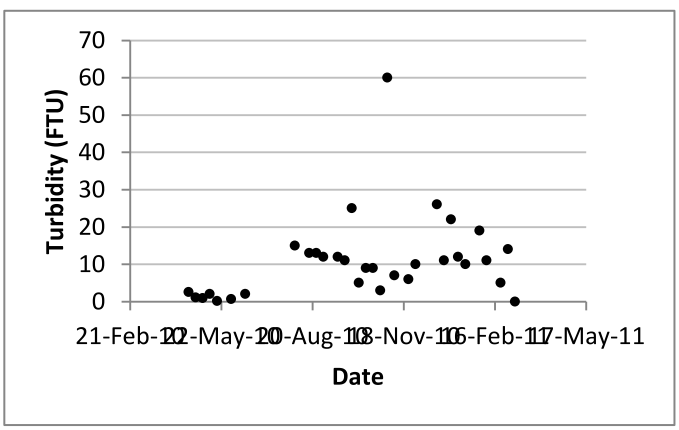
Under eutrophic conditions it would be expected to see high DO concentrations at the surface due to photosynthesis and lower DO concentrations with increasing depth due to decay of algae that have died off. The BAMAS reports (2005b,c) recorded samples at varying depths and demonstrate this pattern as shown on Graph 3. DO levels appear adequate in the wet season but fall dramatically during the dry season. The variation at the 1/3 depth during the dry season could be due to patchiness of algal growth or uneven disturbance of the surface.



Graph 3: DO concentrations at two depths in Lake Karoun during the wet season (BAMAS , 2005b,c)
Note: BAMAS March 2005 value of 0.868 at 1WR190 not included because the value is inconsistent with the dataset and is likely a measurement or typographical error. Oxygen saturation levels shown are at average sample temperature.

2.3 Turbidity

There are numerous compounding effects that would impact the turbidity within Lake Karoun. If eutrophication is the cause of increased turbidity we would expect to see higher levels during the summer months when algae growth occurs. The weekly data (see Graph 4) shows that turbidity is actually lower in the dry season compared to the wet season, which would suggest that the increase in turbidity is due to an increase in sediments from winter precipitation. Other reports lacked a comparison of turbidity between the wet and dry seasons.



Graph 4: Weekly measured turbidity in Lake Karoun from the Government of Lebanon's year-long sampling campaign.
Note: Data from samples upstream of the Reservoir are omitted.

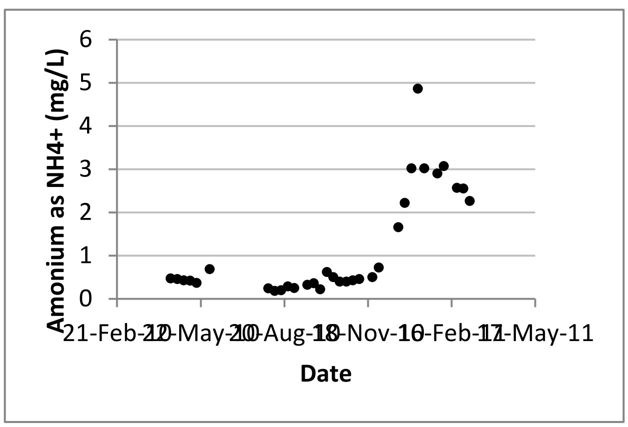
2.4 Metals

None of the reviewed reports specifically examined the mobilization of trace metals from the lake sediment as a result of anoxic conditions. According to Wetzel (2001), there is an increase in phosphorus, iron, and manganese released by sediments due to low oxygen levels in the bottom of lakes.

Past water quality reports of Lake Karoun have not recognized iron or manganese in the lake sediment as being released due to anoxia in the reservoir. All levels of manganese were below detection in the water quality tests as well as the lake sediment tests in the following reports: MVM 2000, BAMAS 2005 summer and winter, ELARD 2011. Metals were a focus of the Greater Beirut Water Supply Quality Report (GBWSQR), which addressed issues of metals in the source water (Bartram & LoBuglio, 2011). This report concluded, based on data from eight measurements on samples from the Joun Reservoir taken between 1999 and 2011, that metals removal is not a high concern. No instances were found of levels above the allowable maximum contaminant level.

2.5 Ammonia

As a consequence of anoxic conditions, nitrogen present within the lake body tends to be in ammonia form. The ammonia levels within Lake Karoun show a clear seasonal trend (Graph 5), with higher levels measured in the wet season. Due to the amount of variables within the watershed, the ammonia present within the reservoir could not be attributed specifically to eutrophication. It is possible that ammonia levels are lower in the summer due to consumption by algae and higher in the winter when algae are not present in the lake. However two reports, Jurdi et al., 2002 and BAMAS 2003a, directly attributed the ammonia to wastewater discharge upstream rather than from excess phosphorus and nitrogen. The GBWSQR discussed ammonia levels in the reservoir and should be referred to for treatment options.



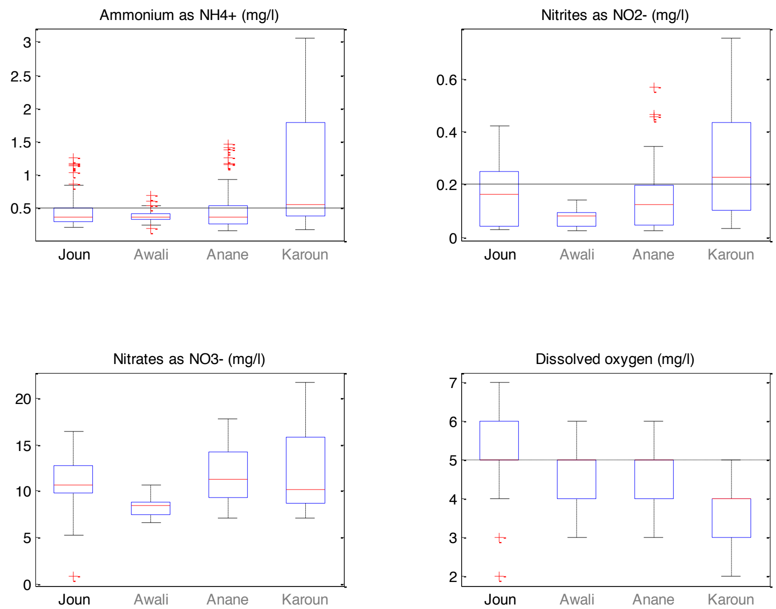
Graph 5: Weekly measured Amonium in Lake Karoun from Government of Lebanon's year-long sampling campaign.

Note: Data from samples upstream of the Reservoir are omitted.

3. Consequences for Drinking Water

The water supplied to the GBWSP, which will come from the Joun Reservoir, is characteristically different than that from Karoun Lake because the Joun Reservoir combines water from Karoun Lake with that from the Bisri River and several springs. Graph 6 shows, for example, that the range of weekly measurements (April 2010 to April 2011) of nitrogen components is lower in the Joun Reservoir than it is in Karoun Lake. Dissolved oxygen is substantially higher.

This report does not change the findings of the GBWSQR, notably that "Water from Joun Reservoir is of sufficient quality such that conventional water treatment technologies can produce potable water meeting Lebanese and international health- and aesthetic-based standards and guidelines. Although microbial contamination exists in the source waters, standard water treatment should be able to reduce contamination and result in product water meeting drinking water quality standards." The following sections provide more detail on the treatment challenges for contaminants related to eutrophication.



Graph 6: Distribution of weekly Nitrogen levels in the Joun Reservoir and contributing waters, April 2010 to April 2011.

Note: On each box, the central mark is the median, the edges of the box are the 25th and 75th percentiles, the whiskers extend to the most extreme data points not considered outliers, and outliers are plotted individually. Outliers are those points falling more than 1.5 times the difference between the 25th and 75th percentiles from either edge of the box. This corresponds to approximately 99.3 percentile coverage if the data are normally distributed.

3.1 Algae Formation

The main concerns arising from algal proliferation are taste and odor issues, damage to treatment filters and addressing toxins related to cyanobacterial blooms. Algal blooms can block filters and impair water treatment operations such as coagulation and filtration (WHO, 2011). Protection measures against algae fall into three broad categories: mitigation measures to protect source waters, in-reservoir monitoring and treatment, and water treatment options.

The main mitigation technique for algal blooms (and thus cyanobacteria) is to limit the inflow of phosphorus to the water body (Chorus and Bartram, 1999). Jeppesen et al. (2005) summarize the long-term responses of 35 (mostly European) lakes to nutrient reduction and found that reducing total phosphorus loading resulted in lower indicators for algal growth, although the response time was typically 10 to 15 years. The business plan (ELARD 2011) contains detailed information on sources of nutrients and practical reduction strategies. These are discussed in more detail in section 5 of this report.

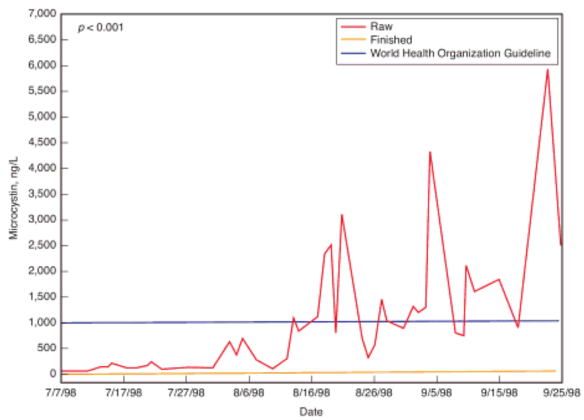
There are in-reservoir treatment options such as water circulation, application of algaecides, phosphorus precipitation, and reoxygenation, however these should be additional measures implemented along with a strong nutrient reduction strategy (Chorus and Bartram 1999). Water circulation, which involves using mechanical means to circulate water throughout the depth of a reservoir, may be beneficial. Hudnel et al. (2010) reported recirculation to be effective in two of three reservoirs in Wisconsin where cyanobacteria are a persistent problem; these two reservoirs were also routinely treated with algaecides. Algaecides have been employed as a treatment option by themselves, but they have the potential to rupture cells resulting in the release of toxins. To reduce these effects, they can be used where careful monitoring allows the identification of the start of a bloom and are applied when the overall population is low. Copper sulfate has already been employed as a mitigation strategy for algae within Canal 900, however there are negative environmental impacts associated with this type of treatment (BAMAS, 2003b).

Upstream monitoring of algal blooms should also be incorporated through using an in-situ probe that can obtain continuous readings. The probe would measure chlorophyll *a*, which can be measured at two distinct frequencies to distinguish between algae species. Samples should be taken at varying heights throughout the water column since some species of cyanobacteria utilize buoyancy to regulate insolation. If algae are present, then the water treatment plant can adjust the intake height or other plant parameters to minimize algal content of the abstracted water. Such monitoring was shown to be effective in several drinking water reservoirs in North Carolina (Werblow 2008). Screens have been employed in order to deter algae from blocking filters; however caution should be taken since these can lead to shear forces that can rupture cells of cyanobacteria. Blending affected water with alternative sources is also a common practice (AWWA 2010) and happens for the GBWSP when water from Karoun Lake is mixed with water from the Bisri River and springs on the way to the Joun Reservoir.

Removal of harmful cyanotoxins can be achieved during drinking water treatment but these processes should be implemented along with the mitigation strategies discussed above. Treatment process such as filtration and flocculation can remove whole cells, although care must be exercised to ensure cells are not ruptured and that the disposal of backflow effluent and settled floc is done judiciously. Rapala et al. (2002) studied nine waterworks where cyanobacteria have been a problem and which used difference drinking water treatment processes. They found that the most significant reduction occurred during coagulation, settling, and sand filtration. They saw little effect from carbon filtration, chlorination, and ozonation. The highest reduction value (95–97%) was observed for the most complex treatment processes (A, B, and C in Table 3). Hoeger et al. (2005) studied a plant using ozonation, filtration, flocculation, and active carbon and found it to be very effective in removing both cyanobacterial cells and toxins. In five water treatment plants in Wisconsin, where microcystin toxins were repeatedly found in the raw water, Karner et al. (2001) found that conventional water treatment practices used by the facilities effectively removed microcystins by 1-3 logs (Graph 7). The WHO (2011) also suggests oxidation, using either ozone or chlorination at high enough concentrations, granular activated carbon (GAC), or powdered activated carbon (PAC).

Table 3: Water treatment processes and endotoxin reductions at nine treatment plants (reproduced from Rapala et al. 2002)

	Treatment process	Endotoxins		
		Raw water (EU ml^{-1})	Treated water (EU ml^{-1})	Reduction (%)
A	Al-coagulation–clarification–sand filtration–ozonation–slow sand filtration–chlorination	356	15	96
B	Fe-coagulation–clarification–powdered activated carbon–Fe-coagulation, chlorination with chlorine and chlorine dioxide–parallel flotation and settling–activated carbon filtration–disinfection with chloramine	227	12	95
C	Fe-coagulation–clarification–sand filtration–Fe-coagulation–flotation–activated carbon filtration–chlorination	164	5	97
D	Al-coagulation–parallel flotation and settling–disinfection with chlorine dioxide–activated carbon filtration–chlorination	42	9	79
E	Al-coagulation with contact sand/anthracite filtration–activated carbon filtration–chlorination	67	5	93
F	Al-coagulation–flotation–sand filtration–chlorination	33	3	91
G	Al-coagulation–flotation on sand filter–UV-disinfection–chlorination	18	4	78
H	Al-coagulation–flotation on sand filter–chlorination	34	14	59
I	Sand filtration–Al-coagulation–chlorination–mixing with ground water	85	10	88



Graph 7: Microcystin concentrations for raw and finished waters at the Oshkosh, Wisc., water treatment plant during the summer of 1998. (reproduced from Karner et al. 2001)

3.2 Dissolved Oxygen, Turbidity, Metals, and Ammonia

Low dissolved oxygen, in itself, is not a health concern for drinking water. The low levels of oxygen in drinking water can lead to issues in taste and odor of drinking water. These can be addressed through aeration and other standard water treatment processes. Processes such as flocculation, coagulation, filtration, and aeration also address turbidity and ammonia, as is discussed in the 2011 Greater Beirut Water Supply Project: Independent Technical Review of Source Water Quality.

4. Mitigation Strategies

Eutrophication is an increasing worldwide problem as population surges and anthropogenic activities increase in watershed basins. Numerous treatment options exist and have proven successful although they can be expensive and require proper planning and execution. The best long-term mitigation strategy for addressing eutrophication within Lake Karoun is to reduce nutrient inputs into the water system from the Upper Litani Basin, which is discussed in detail in the Business Plan. Recovery from over enrichment has been proven possible, however it can be an expensive process. Past water quality reports focusing on the Upper Litani River Basin have identified specific point and non-point sources of pollution within the basin: municipal wastewater, industrial wastewater, and agricultural run-off. By addressing these sources of pollution, there is the potential to substantially impact the amount of nutrients entering Lake Karoun.

Ontario, Canada: A famous study published in 1974 by Schindler showed that substantial phosphorus loading to Lake 226 in Ontario significantly increased algal production and led to eutrophication. Upon discontinuing the addition of phosphorus, the lake was able to quickly return to near prefertilization conditions (Wetzel, 2001).

4.1 Point Pollution

Studies conducted over the past decade have identified the direct dumping of waste into the river system as the major source of pollution in the Upper Litani Basin. Elevated nitrogen and phosphorus levels have been attributed to the wastewater discharge occurring in the Upper Litani Basin (BAMAS, 2005b).

The following reports have all made mention of the need to address the issue of wastewater management in the Upper Litani: BAMAS 2005b, BAMAS 2005c, MVM 2000. The construction of the Temnin El Tahta, Zahle, and Jeb Jaannine Wastewater Treatment plants (WWTPs) will help to alleviate the pollution stress, however other areas of concern have yet to be addressed through wastewater treatment and sewers. The Government of Lebanon and the Council for Development and Reconstruction have proposed building 8 WWTPs in the Upper Litani, which would include both secondary and tertiary treatment (BAMAS, 2003a). In Brazil and Zimbabwe, tertiary treatment has been effective in reducing phosphorus inputs.

The BAMAS 2003a report suggested that “10 large scale wastewater treatment plants … using secondary treatment” would be an ideal plan. The report also highlighted advanced wastewater treatment processes that would remove nitrogen, phosphorus and ammonia nitrogen from the water. In addition to increased wastewater treatment, the issue of direct dumping of sewage and other dump sites close to the river should be addressed (BAMAS, 2003a).

The BAMAS 2005c summer report identified the major sources of pollution as domestic wastewater discharge, industrial effluent, and solid waste from landfills. The Draft Business Plan identified specific areas within the Upper Litani Basin that are severe threats to the surface water quality due to direct dumping of municipal waste.

Panaro Lake, Brazil: In Brazil, tertiary sewage treatment was able to reduce phosphorus inputs into Panaro Lake by two thirds. However additional efforts have been required to decrease the total phosphorus within the water body (IETC, 2000).

Lake Chivero, Zimbabwe: Investing in tertiary wastewater treatment facilities also showed positive results in the case of Lake Chivero, Zimbabwe. However, as new communities were built along the lake, they only utilized primary wastewater treatment, which resulted in Lake Chivero regressing to a eutrophic state (IETC, 2000).

In terms of industrial wastewater, the 2011 Draft Business Plan identified the industries within the Upper Litani Basin that pose the greatest pollution threat. These include distilleries, meat processing, olive oil processing, and paper manufacturing. Food processing, which is a significant industry in the Upper Litani, is a significant source of phosphorous input according to Wetzel (2001). In The Great Lakes region of the United States, high levels of phosphorus in Lake Erie were reduced by first addressing point and then non-point pollution sources.

A combined effluent treatment plant is recommended due to the high cost of individually treating wastewater by the small industries within the Upper Litani, The plant would directly address the issue of excessive nutrients by using microorganisms in the treatment process that would consume nitrogen and phosphorus (ELARD, 2011). Within the Draft Business Plan, they encourage pre treatment of industrial waste and offer recommendations tailored to individual manufacturing processes (2011). These pre-treatment processes include chemical precipitation, sedimentation, neutralisation, and biological treatment (ELARD, 2011).

Adding flocculation or chemical precipitation to waste water treatment is a cheap and effective way to reduce phosphorus levels (up to 85-95%). Used in combination, they can be 90-98% effective at removing phosphorous, however if only flocculation is used the efficiency is only 30-60%. Other issues like color, turbidity and bacteria would also be addressed through this method (IETC, 2000).

Other solutions suggested from the IRDC report include phosphorus inactivation, adjusting the water offtake location, hypolimnetic aeration, sediment oxidation and sediment removal. The most viable of these recommendations is the chemical inactivation of phosphorus however it will require advanced technical knowledge (BAMAS, 2003b).

4.2 Non-Point Pollution

Additional notable sources of pollution are results of the current agricultural practices within the Upper Litani Basin. The Draft Business Plan determined that 52.5% of the land in the basin is used for agricultural activities (2011). The IDRC final report declares, "much of the high nitrate concentrations observed in the Litani River are thus believed to originate from poor fertilizer practice." (2007). This conclusion was supported by the Draft Business Plan, which found that 1.4 times the amount of needed phosphorus and nitrogen were applied to crops such as lettuce, tomatoes and melons. For potato and grape crops, up to 3 times the amount of needed nitrogen and twice the amount of phosphorus were added to the soil (ELARD, 2011). Reducing over-fertilization typically involves engagement of civil society and educational programs about best management practices. Such programs focus not only on the environmental benefits but also the economic benefits of reduced fertilization costs and better yields from more informed application of fertilizers.

> **Great Lakes, United States:** Controlling phosphorus loading to Lake Erie was vital in the ecosystems' recovery from eutrophic conditions in the 1970s. Phosphorus loading due to detergents and wastewater were tackled first followed by runoff and non point sources (EPA, 1995). Basin wide legislation and enforcement of the new policies were crucial in the recovery of Lake Erie. Improvements within the lake were evident within a few years after executing reductions in phosphorus loading (IETC, 2000).

While fertilizers can serve as a large non-point source of phosphorus, the predominant soils within the Upper Litani are calcareous which render applied phosphorus immobile (BAMAS, 2005b). The BAMAS 2003a and LRBMS 2010 reports both cited run-off from agricultural fields and over fertilization as the source for the extensive amounts of nitrite and nitrate in the Upper Litani Basin.

Based on their findings, the Draft Business Plan advises an “Environmental Farm Plan” that would help to decrease the harmful effects of over fertilizing that is occurring within the Upper Litani Basin (2011). Adopting the “Environmental Farm Plan” would help educate farmers about the importance of proper application rates of fertilizers and when to apply them during the growing cycle. Previous reports (BAMAS 2005b) also recommended the development of an educational program to decrease over fertilization practices.

5. Additional Recommendations

As recommended in the IRDC 2007 report, an in depth limnological study of the Karoun Reservoir including a full temperature and DO profile should also be conducted in order to gain a better understanding of the lake dynamics. A detailed study of the reservoir characteristics would help determine the seasonal effects of algal growth and nutrient loading within the lake. A major Lebanese university could provide assistance in this area of research as suggested by the IRDC report (2007).

In order to ascertain the true extent of eutrophication, a consistent water quality-monitoring program should be adopted. This has been recommended by numerous reports including: BAMAS 2005, M Jurdi et al (2001). Parameters such as DO, total nitrogen, and chlorophyll *a* should be monitored and examined together to determine whether the trophic status of the reservoir is improving.

In assessing how to combat eutrophication, it is important to note that often times it can take up to 10 years for an ecosystem to noticeably respond to restorative efforts. This is due to retention time and internal recycling of phosphorus already present in the lake system. Most often the first sign of achievement in a mitigation strategy will be a decrease in total phosphorus levels (Chorus & Bartram, 1999). Such mitigation strategies need to be coupled with careful monitoring and water treatment processes to ensure a continuous supply of safe water.

As previously suggested in the GBWSQR, incorporating a water safety plan (WSP) would help to assess whether adopted management strategies are in fact impacting the water quality in Lake Karoun. WSPs are a way to ensure safe drinking water from the source to the customer. Monitoring the quality of the source, treatment, and distribution of the water manages the risk of contamination at each step. Areas that have implemented WSPs have also incorporated an independent audit from a private or governmental organization to certify that the plans are being fully executed.

6. References

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Annex 5: Greater Beirut Water Supply Project – Independent Water Quality Review

Windsor Sung, Ph.D, PE
Program Manager, Massachusetts Water Resources Authority
Lecturer, Massachusetts Institute of Technology

Memo

To: Claire A. Kfouri

From: Windsor Sung

Date: November 26, 2012

Re: Greater Beirut Water Supply Project – Independent Water Quality Review

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Summary

Water quality data from Joun, Bisri (Awali river), Anane and Qaraoun (Karoun) Reservoirs were reviewed. These were collected from December 2011 to November 2012 and includes 24 rounds of physical, chemical and microbiological data; 3 rounds of metals and organics.

Though the results show contamination from farming and industrial activities, in particular at Qaraoun Reservoir, the water quality at Joun Reservoir, where the water treatment plant intake will be located, is characteristic of river waters moderately impacted from human activities. Many of these waters have been used as a source for potable water and do not present any unusual challenge to conventional water treatment technologies.

Water at Joun Reservoir is relatively hard (due to calcium and magnesium). It has a fair amount of solids and bacterial loading. The data collected during this period was compared to the results reviewed by Bartram and LoBuglio[1] (April 2010 to April 2011). The results of that study remain valid and there is no indication that water quality has deteriorated from April 2011 to November 2012.

A conventional water treatment plant, which comprises the treatment processes included in the treatment plant of the Greater Beirut Water Supply Project, will treat the water from Joun Reservoir to international drinking water standards.

In particular, it is recommended that Granular Activated Carbon (GAC) be substituted for anthracite in the filtration step. Ozonation followed by GAC filtration will help to lower nitrite levels and mitigate against the low levels of organics. An optimum pH for residual disinfection and to minimize calcium scale formation potential should also be investigated during the design phase. Every effort should be made to protect the watershed from further contamination.

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[1]Bartram, Jamie and Joseph LoBuglio. Greater Beirut Water Supply Project: Independent Technical Review of Source Water Quality. Final Report. Chapel Hill, NC: The Water Institute at the University of North Carolina, 31 May 2011

These recommendations have been discussed with the design engineer and have been accepted by the implementing government agency and Project Management Unit.

Date Reviewed and Observations

Physical, chemical and microbiological results from Joun, Bisri (Awali River), Anane and Qaraoun (Karoun) Reservoirs were reviewed. 24 rounds of analysis were collected every 2 weeks starting on 8 December 2011 and continued through 20 November 2012[2]. In addition there were 18 rounds of sampling for BOD, COD, CN, DO and TOC.

Qaraoun Reservoir has the highest values of COD and TOC, followed by Anane and then Joun Reservoir with Bisri having the lowest level. The organic analysis (discussed later) also followed this trend. On the other hand, color, turbidity hardness and total suspended solids were higher for Joun and Bisri Reservoirs than Anane and Qaraoun. These parameters showed large seasonal variability with 2 high episodes in February. The smaller variability of these parameters for Anane and Qaraoun is likely due to reservoir size.

Nitrite at Joun, Anane and Qaraoun Reservoirs are elevated and is a contaminant of concern. However, ozone followed by GAC filtration should be able to treat this. Bisri has low nitrite but is elevated for bacterial load (total and fecal coliform, and E coli). While bacterial loads are high, conventional water treatment followed by chlorine disinfection should provide 4 log removal and inactivation.

Three rounds of metal analysis conducted on 25 February 2012, 25 April 2012 and 18 July 2012 from the same 4 sources were reviewed. Only barium and beryllium were detected with regularity and these were at very low levels. Most heavy metals are associated with particulates and conventional water treatment with coagulation/flocculation/settling followed by filtration is very effective in lowering particulates. Thus metal contamination should not be a concern.

Three rounds of organics analysis conducted on 28 January 2012, 21 July 2012 and 13 October 2012 from the same 4 sources were reviewed. Compounds that were detected include polynuclear aromatic hydrocarbons (PAH), phthalates (plasticizers), pesticides, chloro-benzenes, trihalomethanes and xylenes. Of these compounds, typically Qaraoun Reservoir shows the highest concentration of detects and has more compounds detected. Xylenes were detected at the highest concentration of 11 mg/L at Joun Reservoir on 21 July 2012. These chemicals are indicative of farming and industrial contamination. Conventional water treatment, such as that included in the Greater Beirut Water supply treatment plant, can mitigate against many of these compounds, especially since ozone treatment and carbon filtration are part of the original conceptual design. Pollution prevention always remains preferred over treatment. Therefore watershed protection and source water control is imperative.

All the data has been entered into a master spreadsheet to facilitate additional analysis by interested parties. Box and whisker plots (Figures 1- 27) have been produced for aid in visual comparison of water quality by source. Some key water quality parameters are presented as time series plots in Figures 28 – 33. High values of particulates were associated with February and March 2012 and most likely rain related. High nitrite values were observed in July and August 2012.

In conclusion, the water from Joun Reservoir, which will be used as the influent to the water treatment plant in the Greater Beirut Water Supply Project, is of a quality that is treatable by the conventional water treatment technologies in the treatment plant design.

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[2] Data from 28 March 2012 was missing

Disclaimer

The statements above are my personal professional opinions and do not reflect official views of Massachusetts Institute of Technology or Massachusetts Water Resources Authority.

References

1. Greater Beirut Water Supply Project Project Appraisal Document
2. Bartram, Jamie and Joseph LoBuglio. *Greater Beirut Water Supply Project: Independent Technical Review of Source Water Quality. Final Report.* Chapel Hill, NC: The Water Institute at the University of North Carolina, 31 May 2011
3. Montgomery Watson Harza (MWH) Conceptual Design for the GBWSP Water Treatment Plant

Figures

The following figures compare the four water quality sources as a series of box and whisker plots. The middle line in the box is the median value, and the top and bottom boxes are the 25th and 75th percentile values. The top and bottom "whiskers" are 1.5 times the IQR above the third quartile value and 1.5 times IQR below the first quartile value. IQR is the difference between the third and first quartile. Red asterisks are used to denote outliers and these are values greater than or less than the top and bottom whiskers.

It should be noted that these are raw water values. Typical water treatment can remove 1.5 to 2 logs of physical parameters (93 to 99% removal) and up to 4 logs of microbiological counts (99.99%). For example, the median color of Joun Reservoir water was 16.6 (average of 74), it could easily be treated to less than 5 color units. Similarly for turbidity and suspended solids.

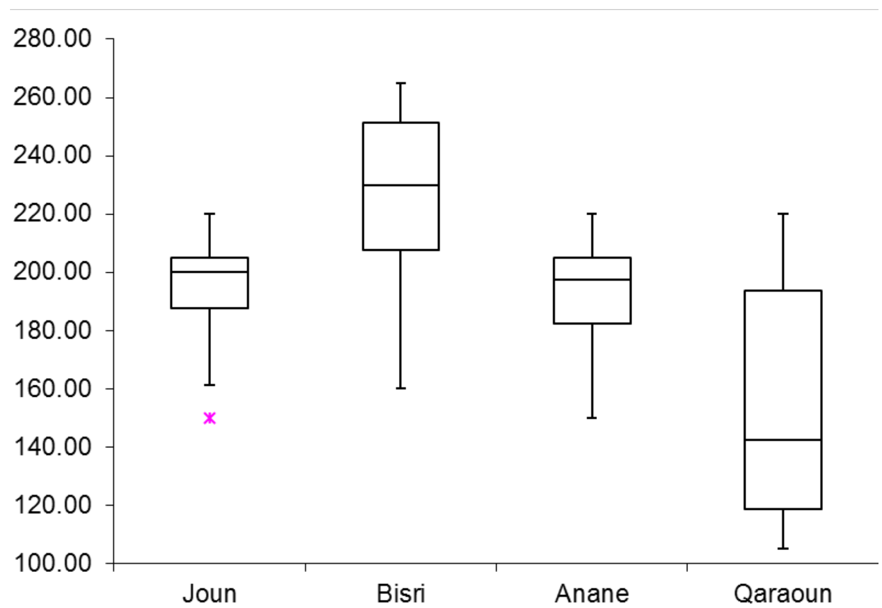

Figure 1 Total Alkalinity (mg/L as $CaCO_3$)

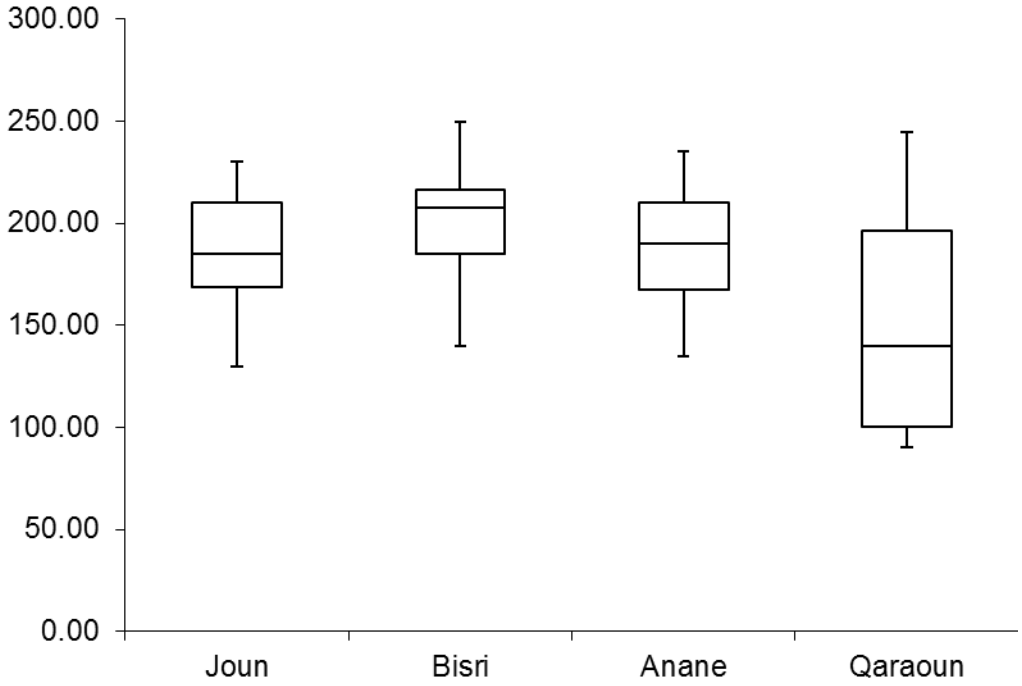

Figure 2 Calcium Hardness (mg/L as $CaCO_3$)

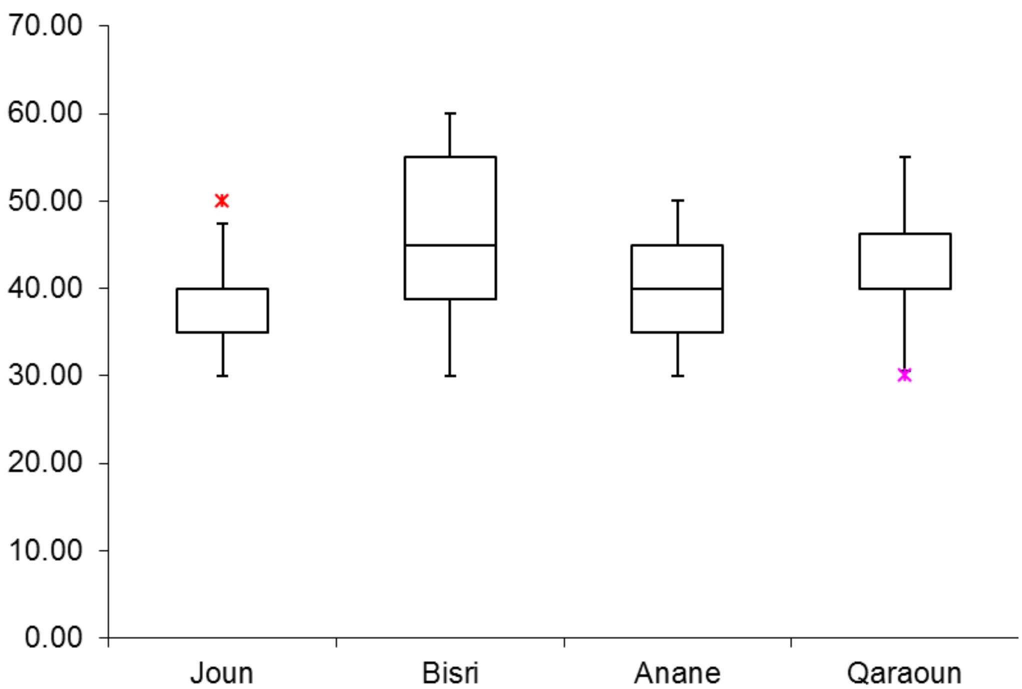

Figure 3 Magnesium Hardness (mg/L as $CaCO_3$)

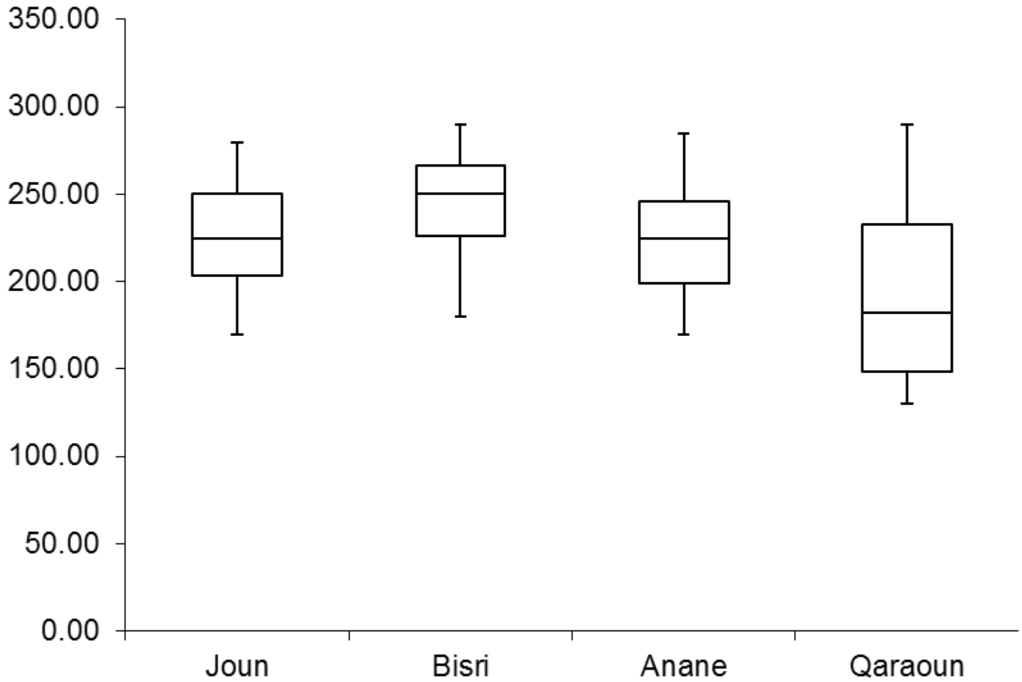

Figure 4 **Total Hardness (mg/L as $CaCO_3$)**

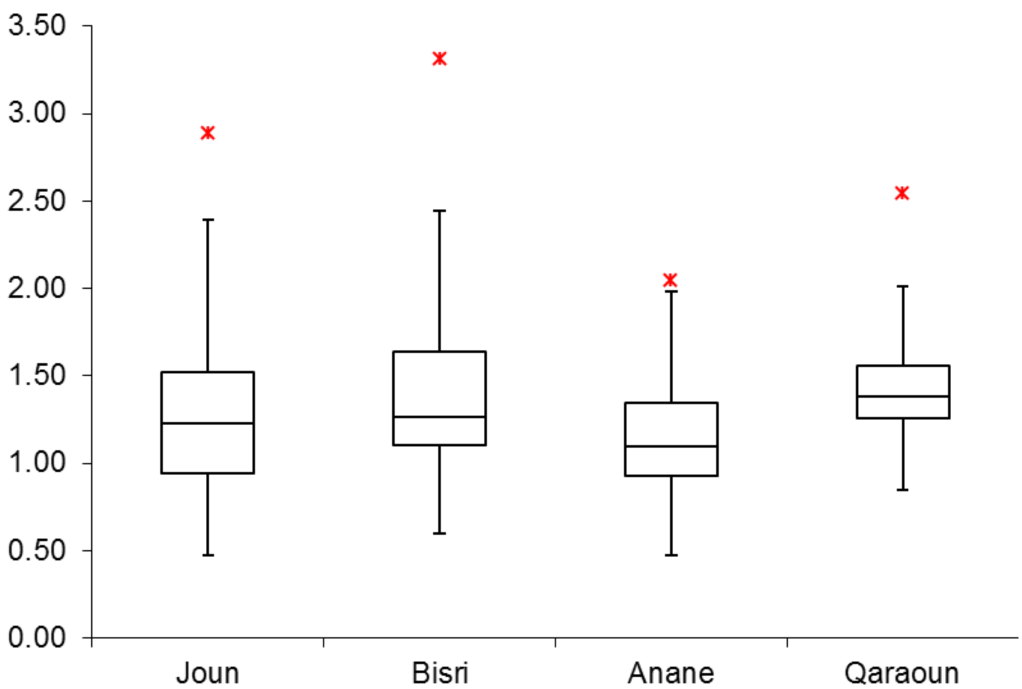

Figure 5 **Log_{10} Color (TCU)**

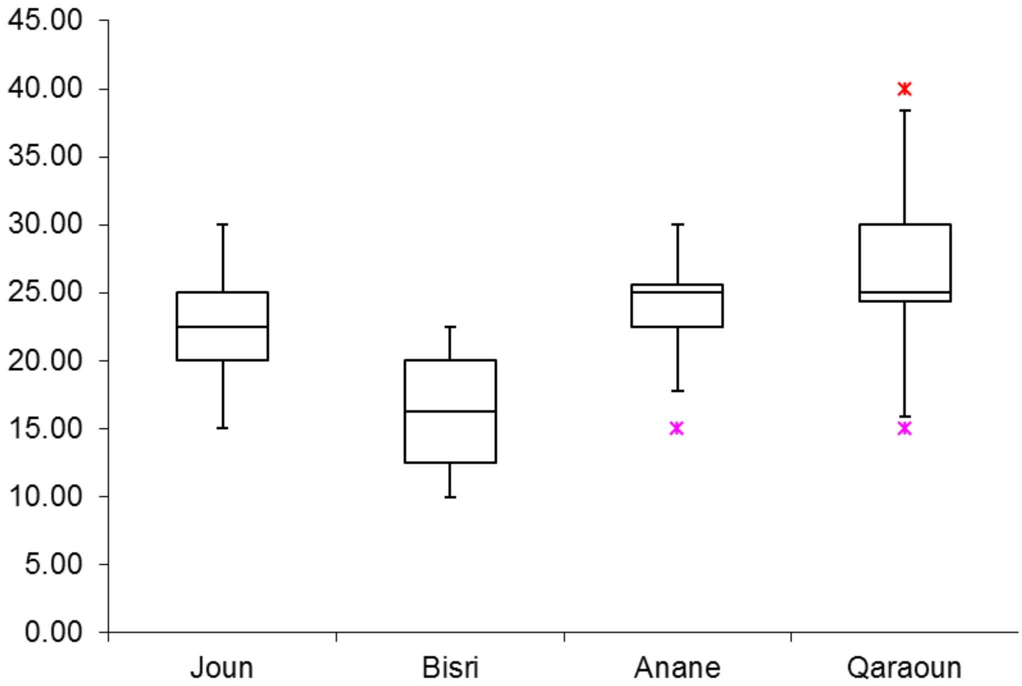

Figure 6 Chloride (mg/L)

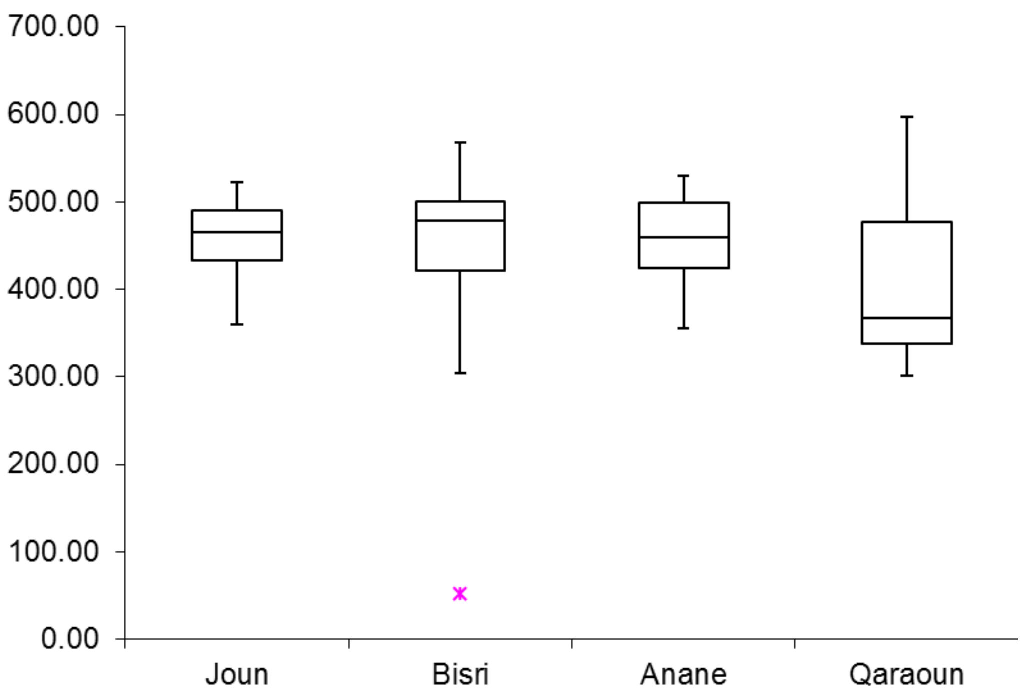

Figure 7 Conductivity (μS/cm)

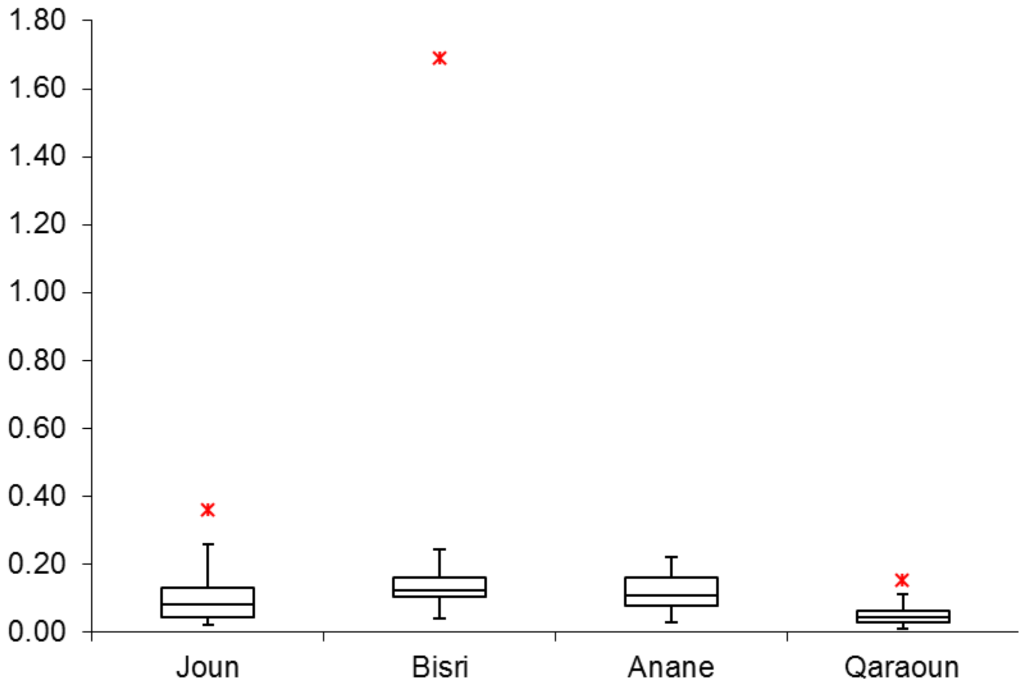

Figure 8 Ferrous Iron Fe^{2+} (mg/L)

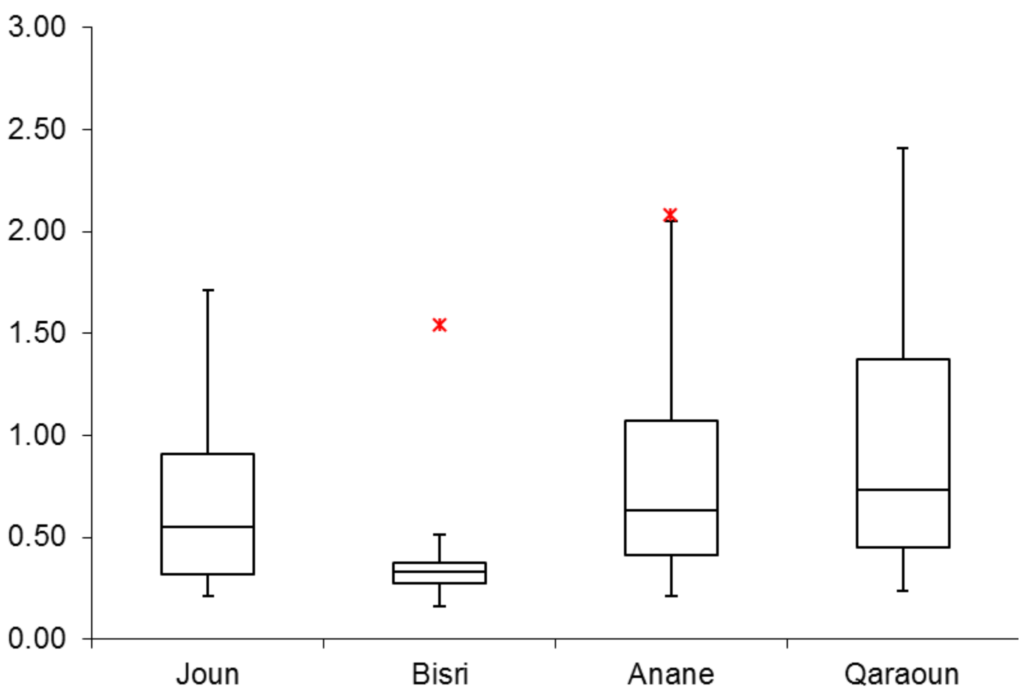

Figure 9 Ammonium Ion NH_4^+ (mg/L)

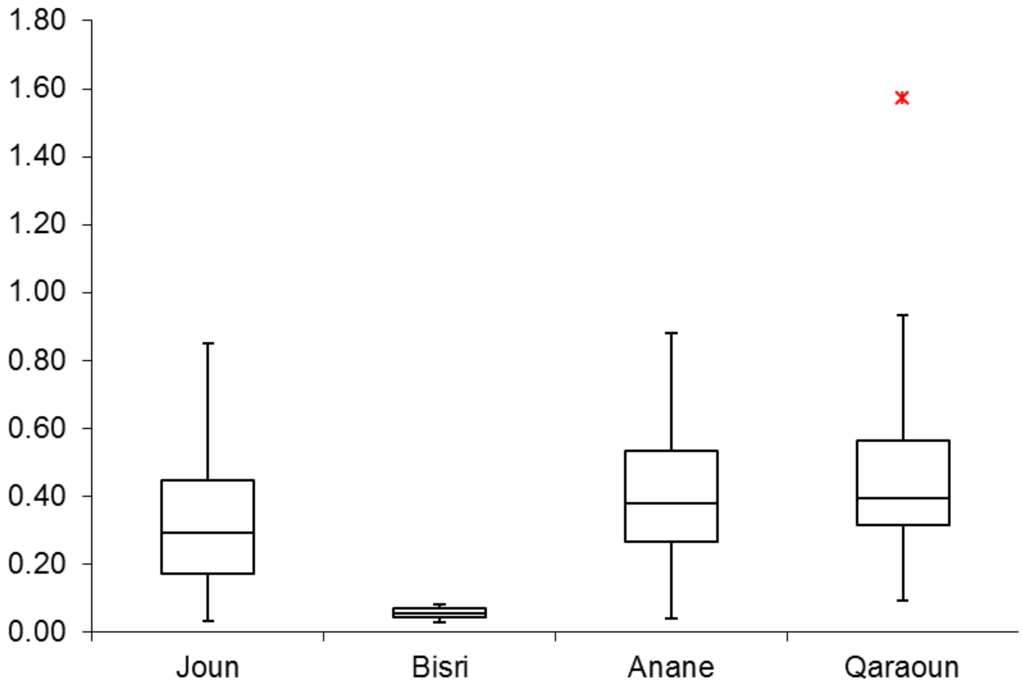

Figure 10 **Nitrite NO_2^- (mg/L)**

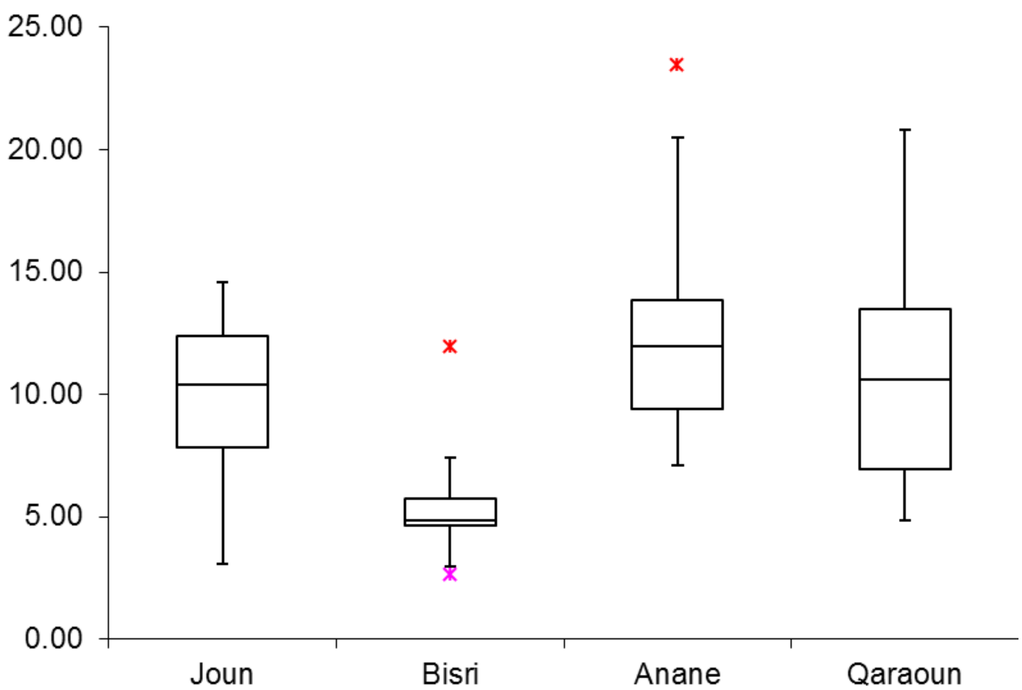

Figure 11 **Nitrate NO_3^- (mg/L)**

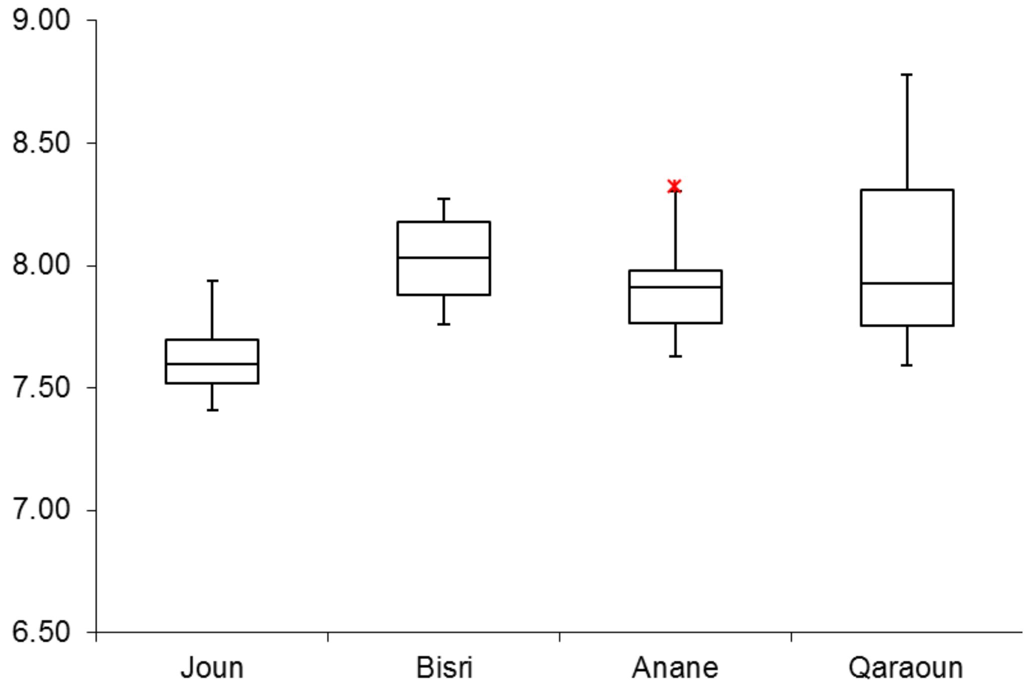

Figure 12 pH

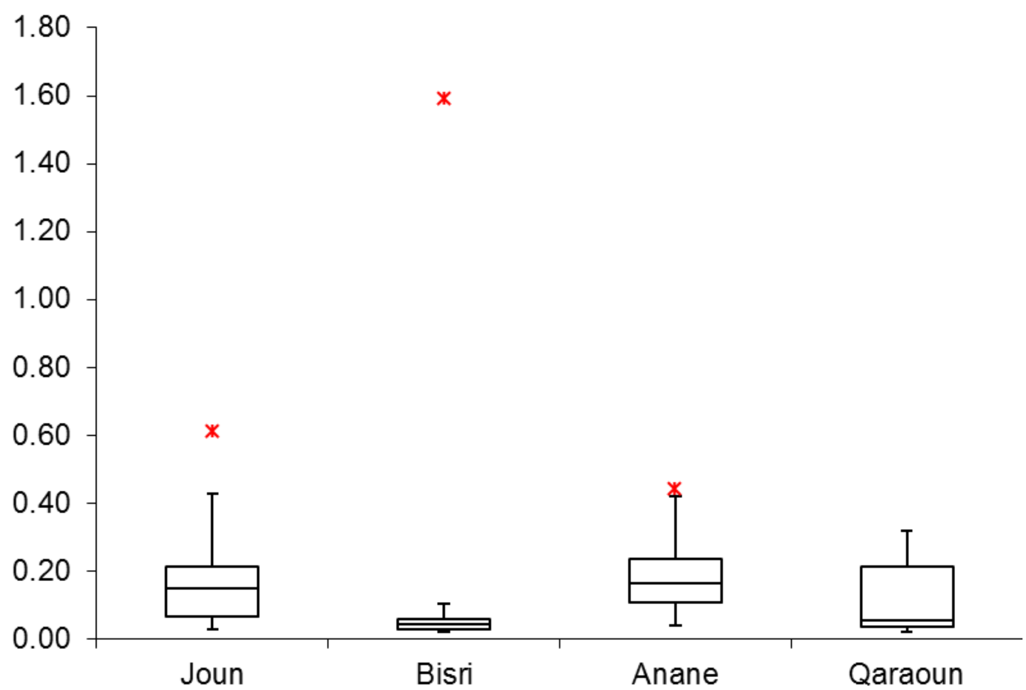

Figure 13 Phosphorus (mg/L)

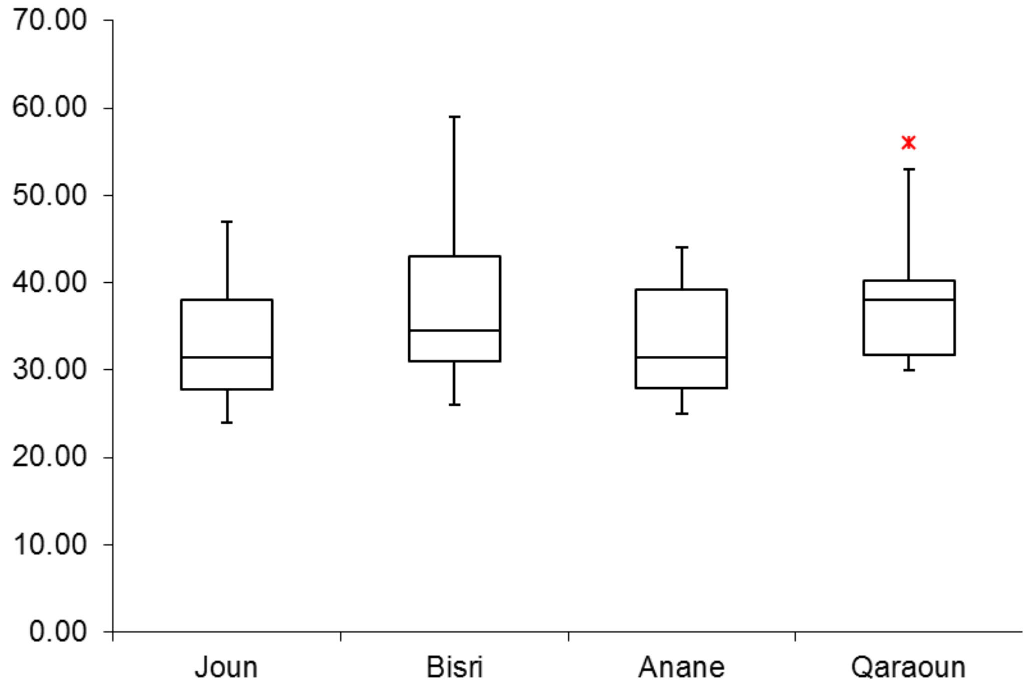

Figure 14 Sulfate (mg/L)

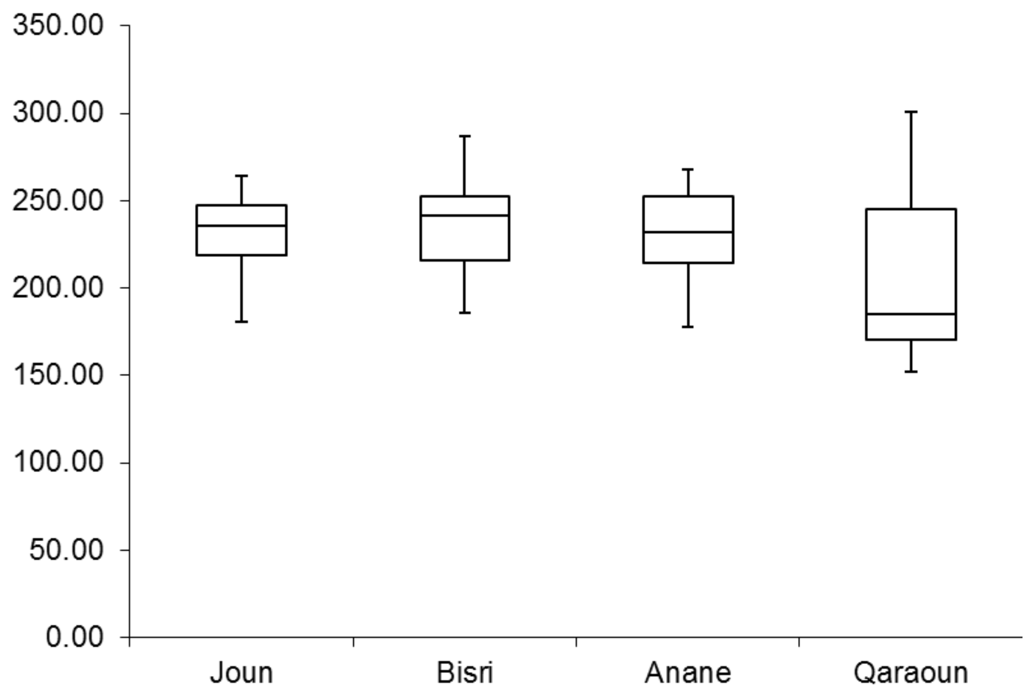

Figure 15 Total Dissolved Solids (mg/L as NaCl)

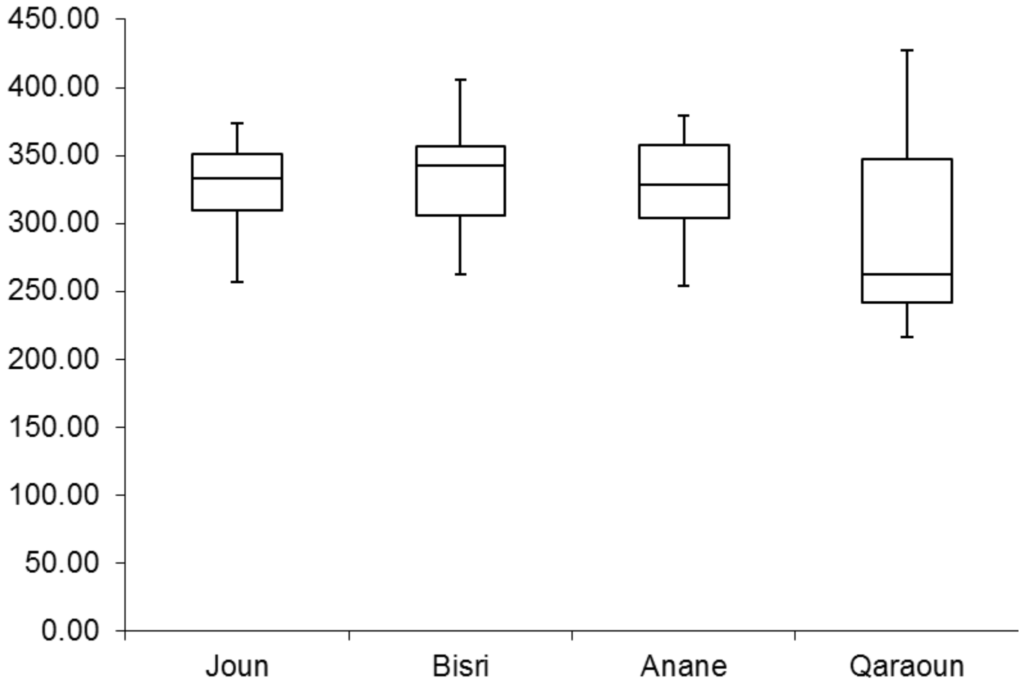

Figure 16 Virtual Mineralization (mg/L)

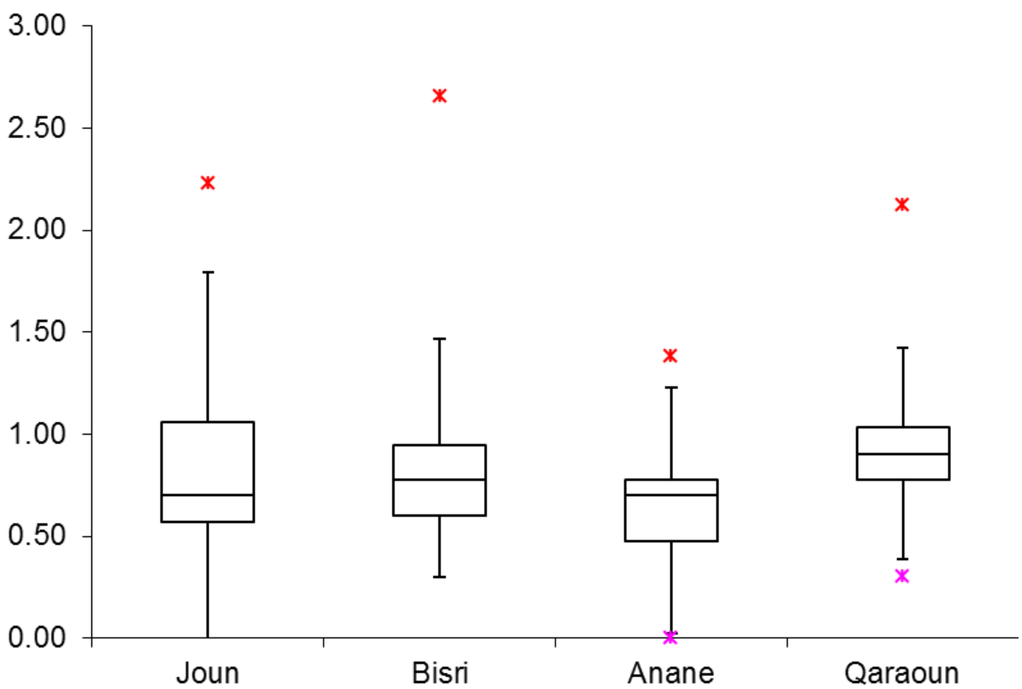

Figure 17 Log_{10} Total Suspended Solids (mg/L)

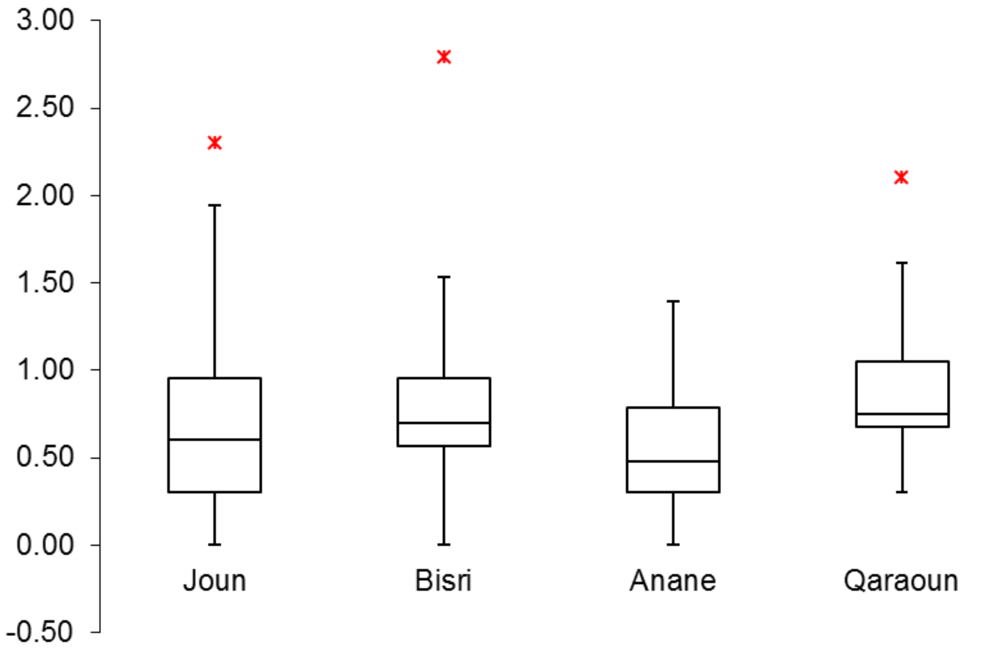

Figure 18 **Log_{10} Turbidity (NTU)**

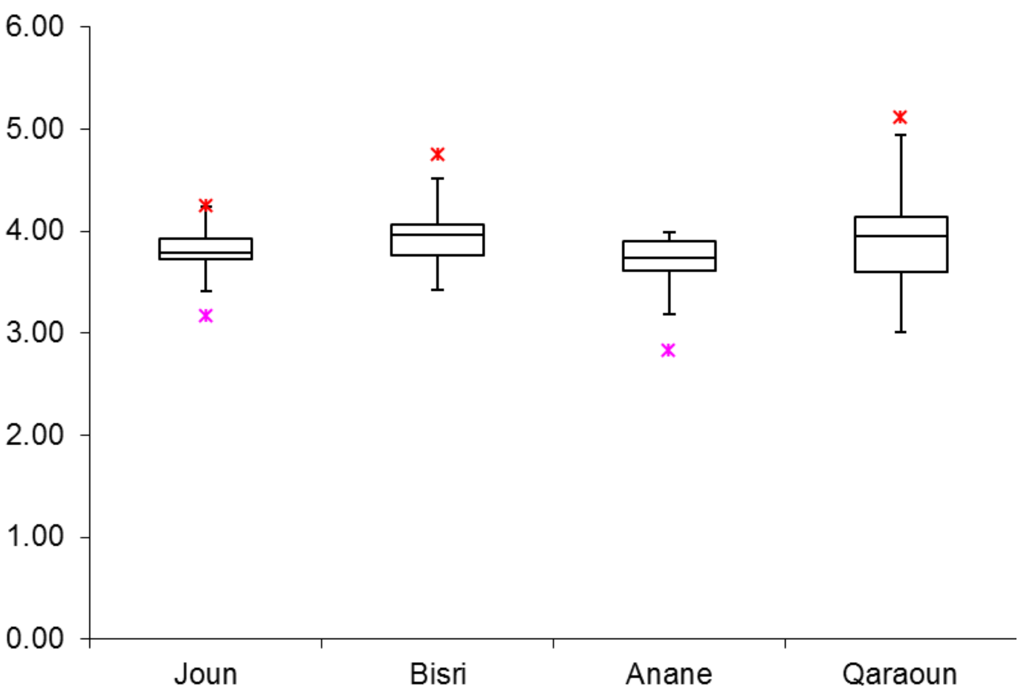

Figure 19 **Log_{10} Total Coliform (CFU/100mL)**

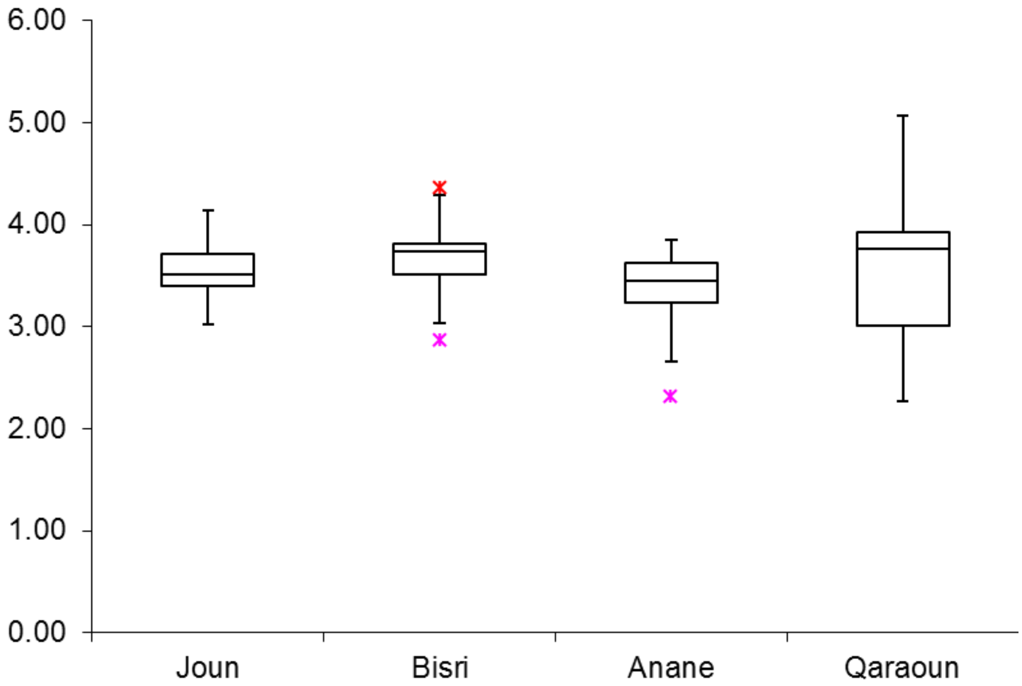

Figure 20 Log$_{10}$ Thermal Tolerant Total Coliform (CFU/100mL)

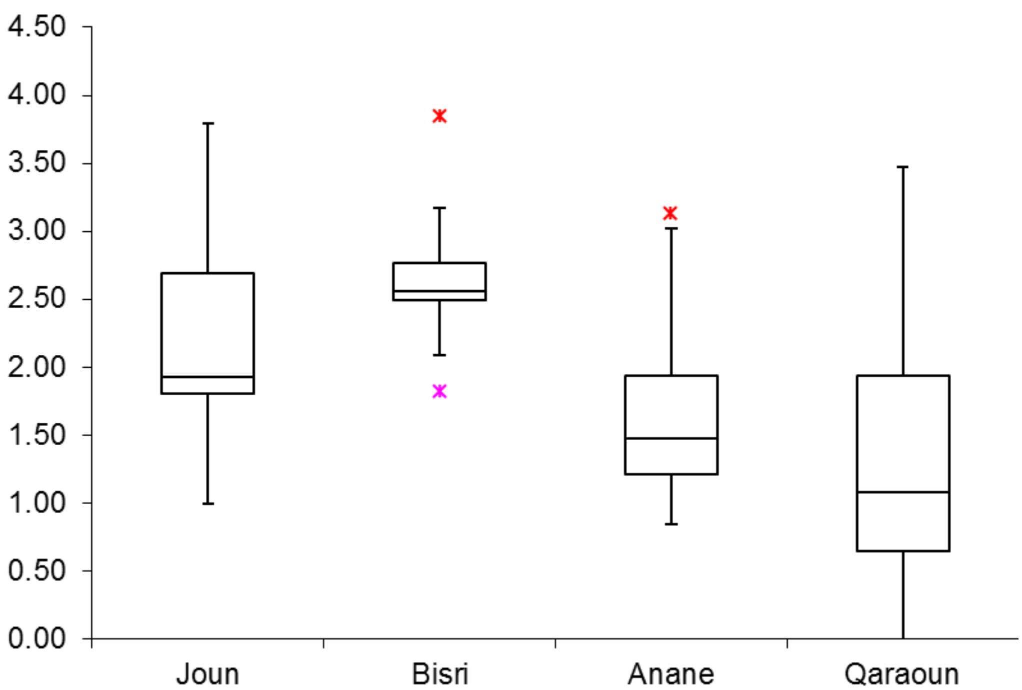

Figure 21 Log$_{10}$ Escherichlia Coli (CFU/100mL)

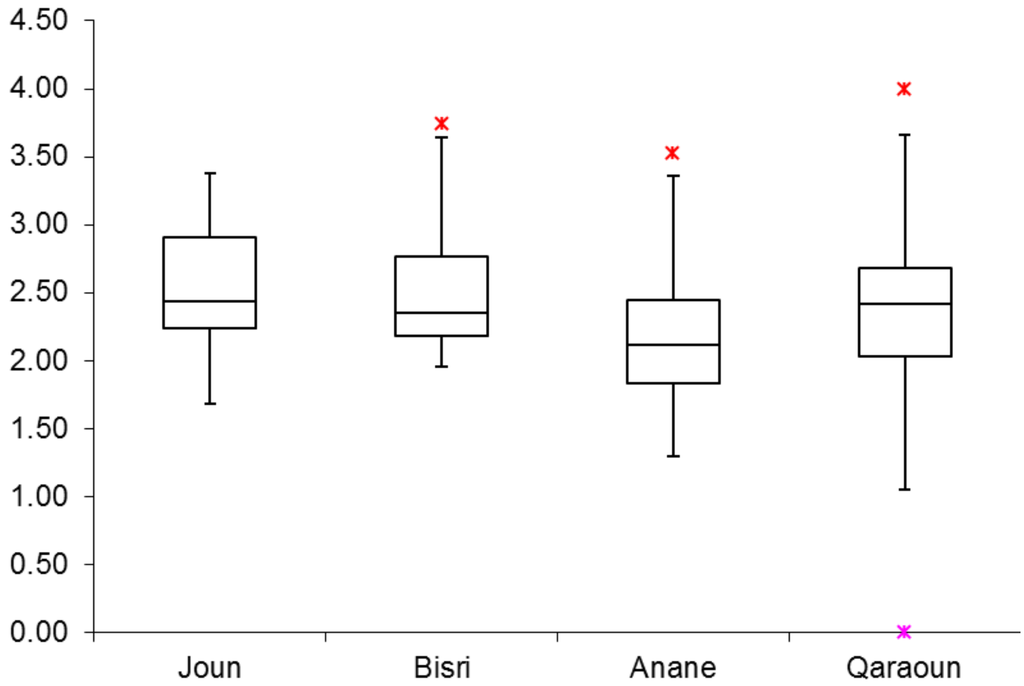

Figure 22 **Log_{10} Citrobacter Freundi (CFU/100mL)**

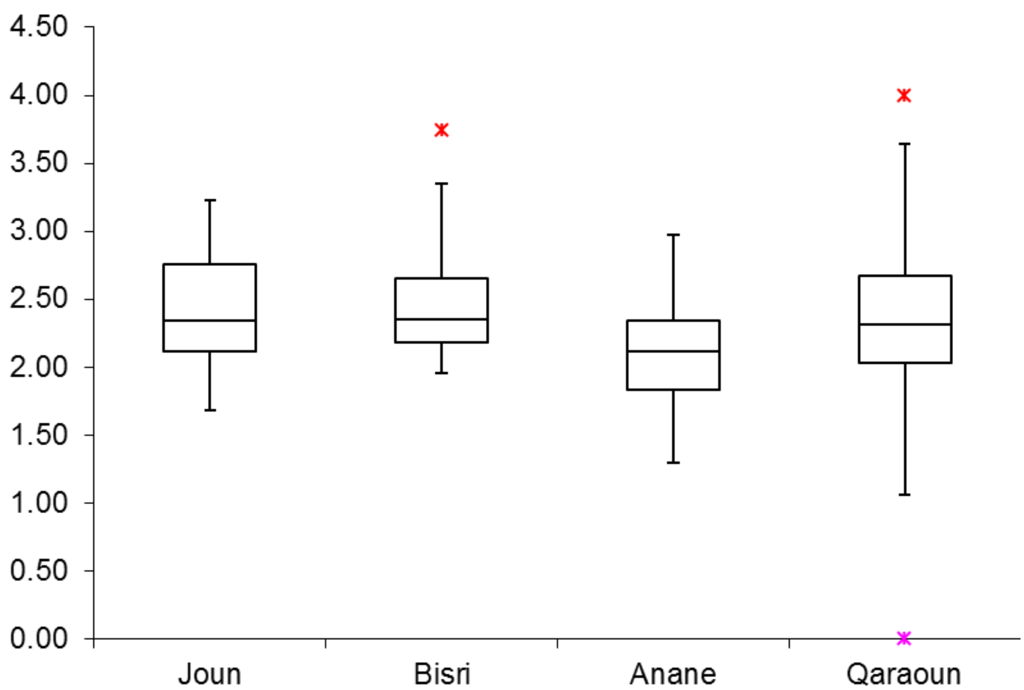

Figure 23 **Log_{10} Enterobacter Cloacae (CFU/100mL)**

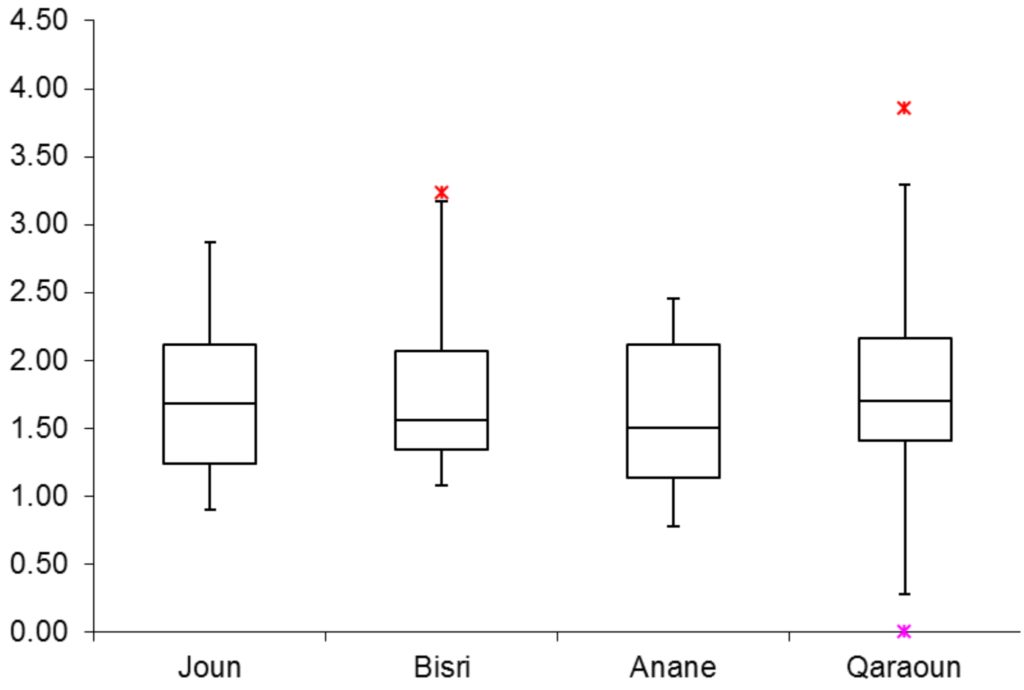

Figure 24 **Log_{10} Kleb. Pneum. Ozaenae (CFU/100mL)**

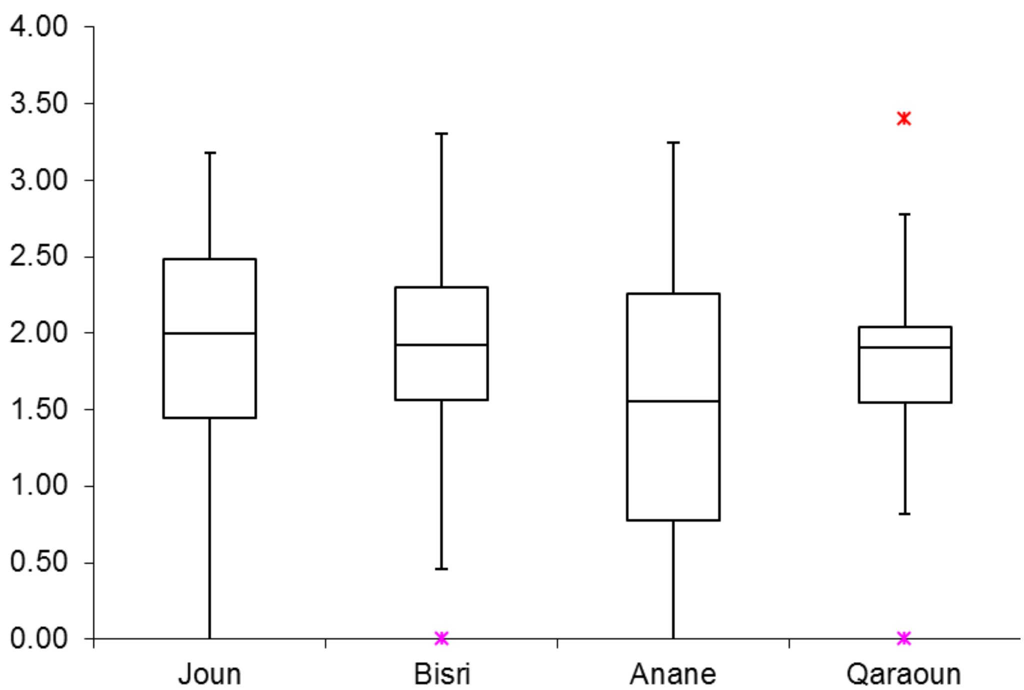

Figure 25 **Log_{10} Chryseomonas Luteola (CFU/100mL)**

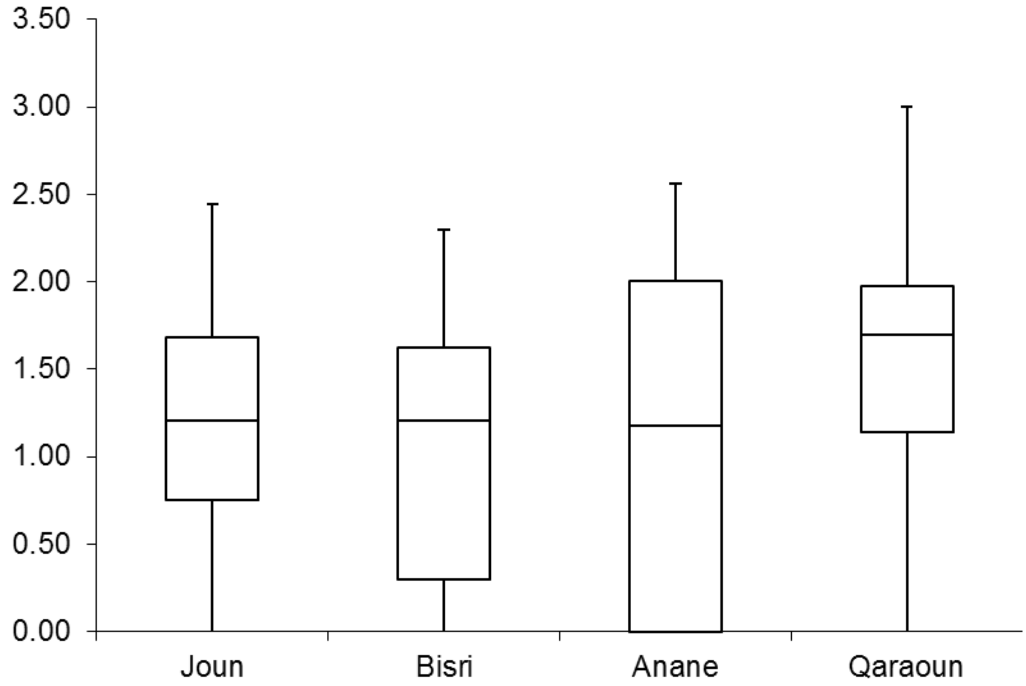

Figure 26 **Log_{10} Non fermenter spp (CFU/100mL)**

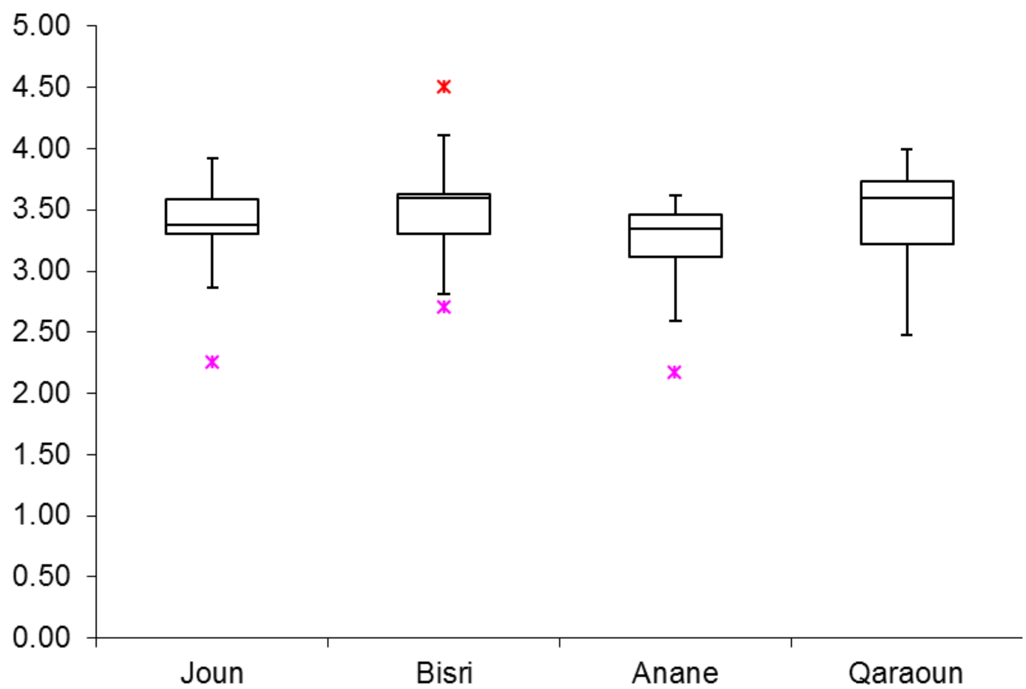

Figure 27 **Log_{10} Flavi. Oryzihabitans (CFU/100mL)**

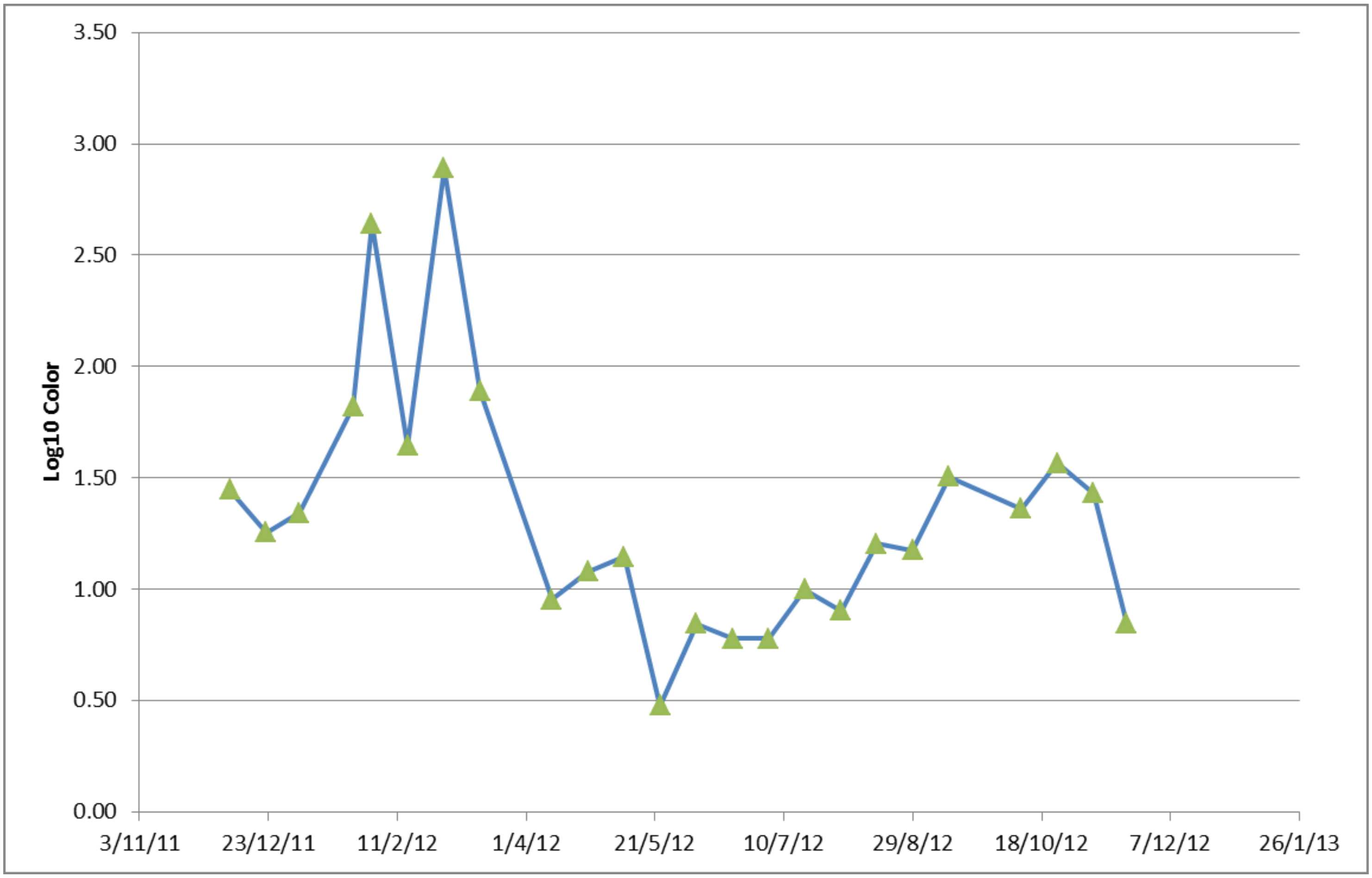

Figure 28 Time variation of Log_{10} Color at Joun Reservoir

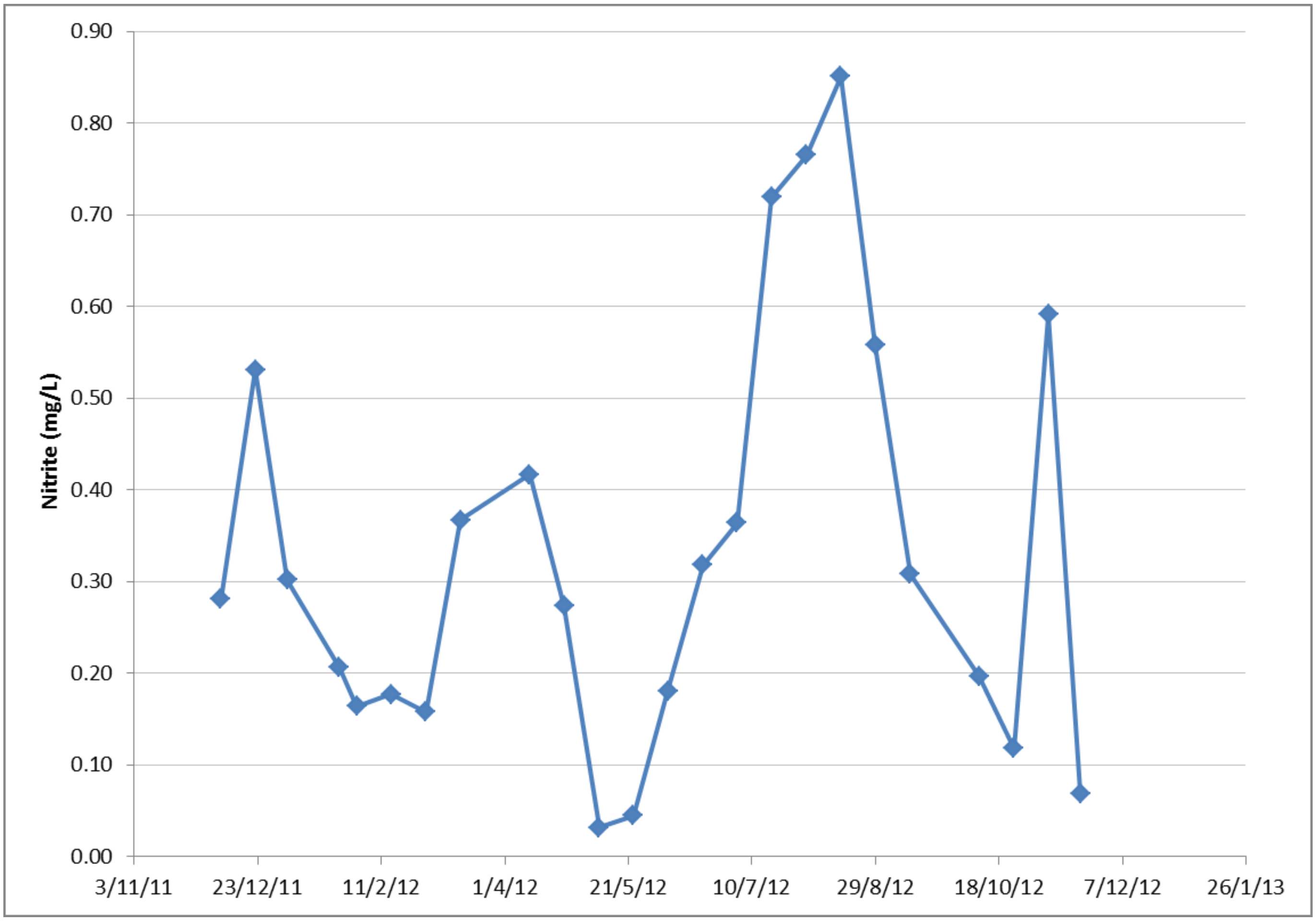

Figure 29 Time variation of Nitrite at Joun Reservoir

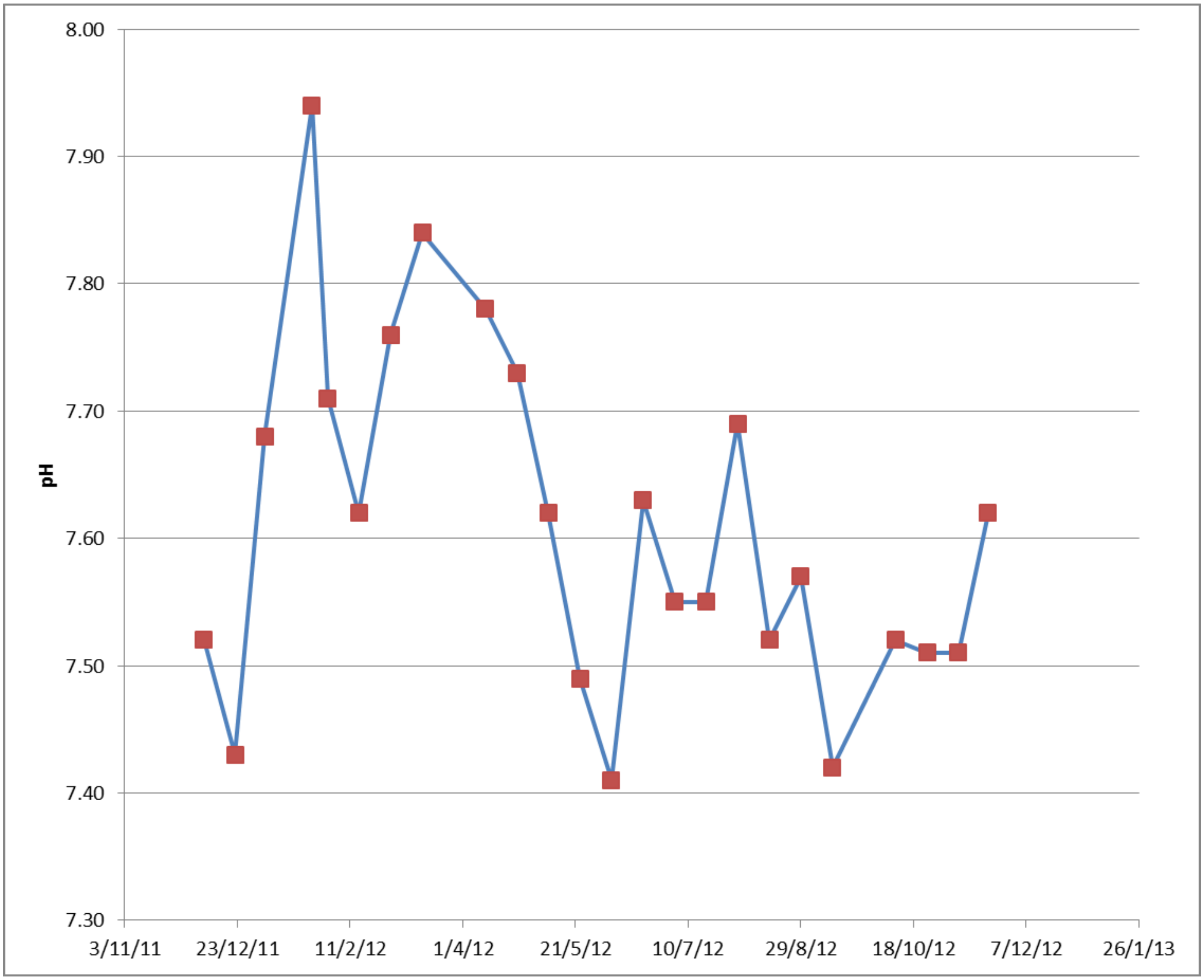

Figure 30 Time variation of pH at Joun Reservoir

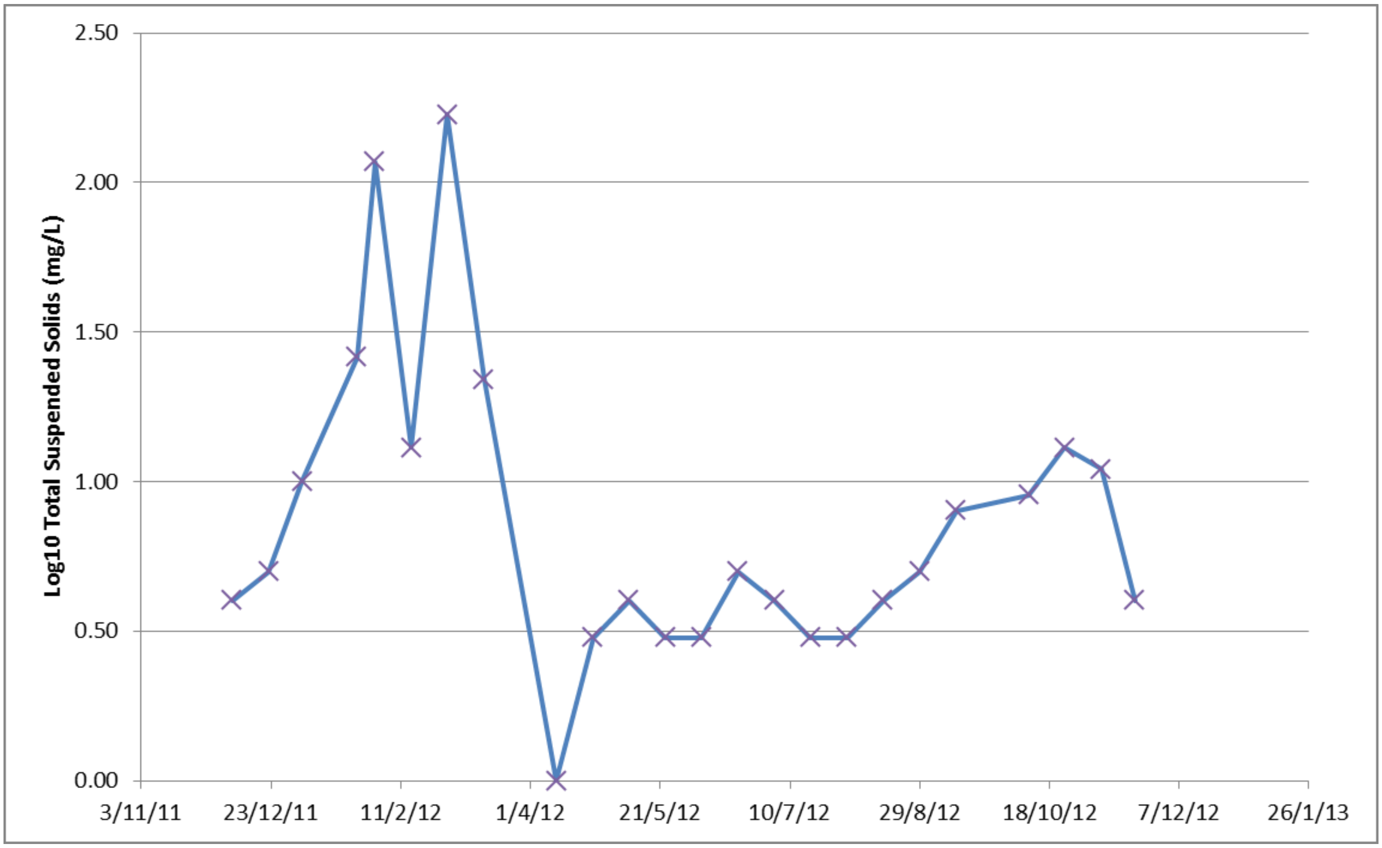

Figure 31 Time variation of Log_{10} Total Suspended Solids at Joun Reservoir

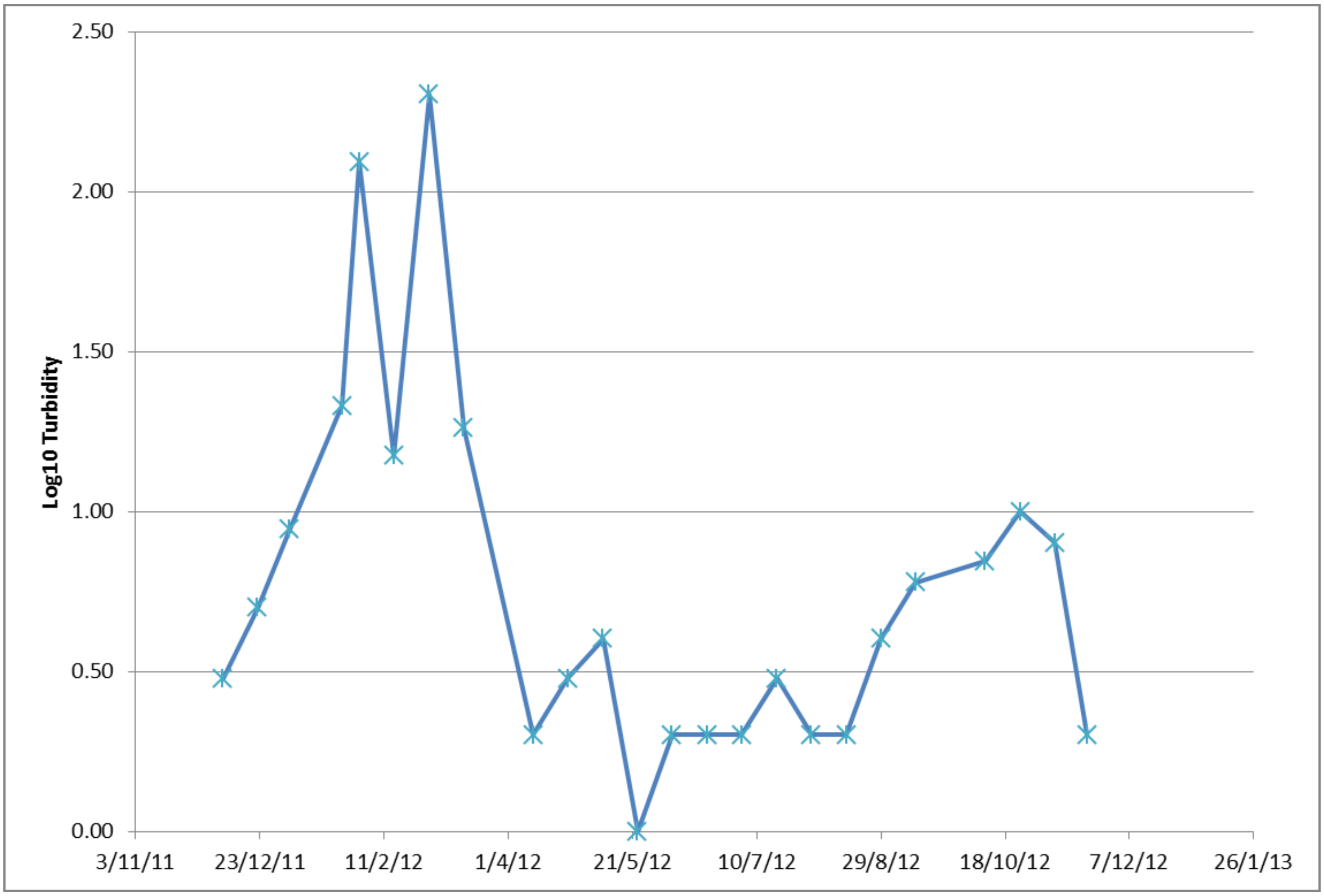

Figure 32 Time variation of Log_{10} Turbidity at Joun Reservoir

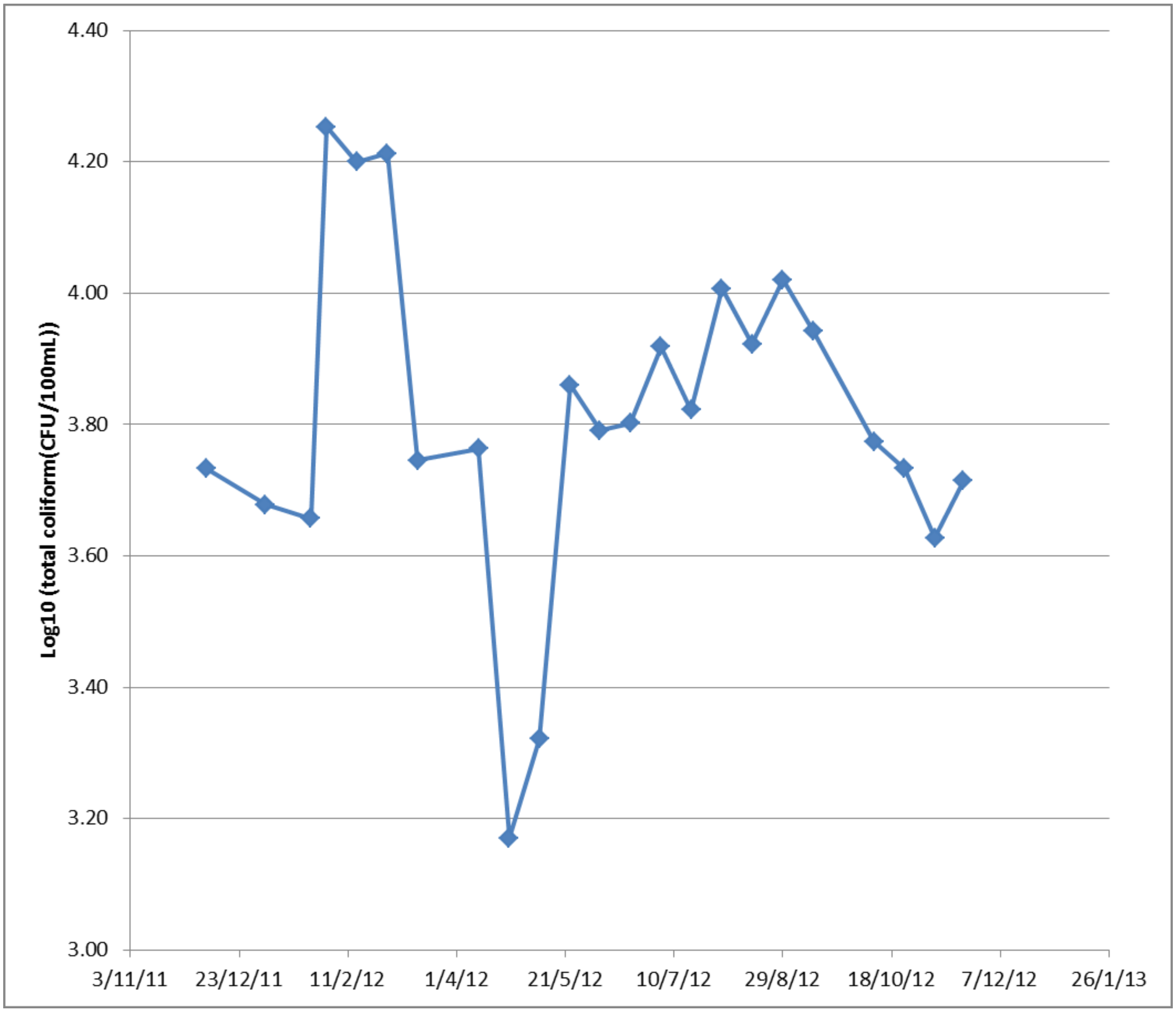

Figure 33 Time variation of Log_{10} Total Coliform at Joun Reservoir

ANNEX II

Lebanon: Greater Beirut Water Supply Project
Responses to Questions Raised by the Inspection Panel
April 5, 2013

- **When will Canal 800 start extracting water from the Qaraoun reservoir? Does Management see a risk that there may be conflict between demands for water to Beirut and water for Canal 800?**

Canal 800 will not begin to withdraw water from the Qaraoun reservoir until at least 2021 and will not reach its maximum value of withdrawals until at least 2031. Canal 800 is a three-phased project of which only Phase I is currently financed and under implementation. Phases II and III remain under design, with no confirmed source of funding. Further, the implementation of Canal 800 - Phase I is currently behind schedule, further delaying the start of water withdrawals from the Qaraoun reservoir.

The Greater Beirut Water Supply Project (GBWSP) will alleviate water shortage in the project area, currently receiving an average of 3 hours of water per day between May and October. The GBWSP is one of several actions planned by GoL to provide long-term solutions for water supply augmentation in the Greater Beirut region.

The GBWSP and Canal 800 projects are not mutually exclusive as per the results of the 2011 Independent Review of Water Availability which confirms that sufficient water is available to meet the objectives of the GBWSP. The Independent Review was informed, in part, by the Ministry of Energy and Water's (MOEW) hydraulic balance for the Litani Basin. The Independent Review noted that Canal 800 will not begin withdrawals until at least 2021 and should be reflected in the hydraulic balance accordingly. The Independent Review of Water Availability also confirmed that GBWSP will convey water from two large underground springs (Jezzine and Ain Zarqa) in addition to water from the Qaraoun reservoir.

MOEW's National Water Sector Strategy (NWSS) and Surface Water Strategy (both provided to the Inspection Panel) detail GoL's plan for the various infrastructure investments required to increase the volume of water provided to the various areas of Lebanon, including Greater Beirut. The NWSS includes the GBWSP, Canal 800, Bisri Dam, Damour Dam and many other investment and policy reform actions currently under implementation by GoL. The Sector Strategy was informed by nationwide public consultations and was approved by Parliament in March 2012.

Further, Presidential decree 14552 which distributes Litani water, allocates specific volumes of water to each of the Beirut and Southern Lebanon areas and is being observed in each of the GBWSP and Canal 800 projects respectively.

Overall, Lebanon is managing future water needs over the long term through a combination of policy measures, infrastructure investments, and different types of management measures and has historically adjusted to changing water and climactic conditions which are often difficult to predict with certainty, through a combination of measures outlined in the NWSS.

- **What is the long term plan for supply of water to the Awali conveyor tunnel?**

The GBWSP will convey 3 m^3/sec of water to the Greater Beirut Region. As confirmed in the Management Response (December 2011), the tunnel is over dimensioned to carry an ultimate total flow of 9 m^3/sec. This project-design decision was informed by GoL's plans, as described above, to implement Bisri Dam, among other long-term water augmentation solutions to the Greater Beirut region.

As documented in the GBWSP PAD, GoL undertook a detailed alternative analysis review of the options for conveyance of water under the GBWSP. Constructing an underground tunnel, with tunnel boring machines, was found to be the best option to: (i) convey water by gravity (thereby reducing operations costs); (ii) reduce over-ground disturbances; (iii) reduce expropriations costs and; (iv) ensure higher security of the infrastructure.

- **Management reports that GoL has requested Bank financing of a proposed New Water Supply Augmentation project. Does this mean that additional water resources are necessary to meet project needs?**

The request for a New Water Supply Augmentation project is not related to the GBWSP.

As described above, GoL is currently implementing the NWSS, as approved by the Lebanese Parliament in March 2012, which includes dams at Bisri and Damour among others, in addition to a series of policy reforms, and rehabilitation of existing infrastructure.

The Action Plan for Enhanced Supervision committed to mobilizing additional financing to the GBWSP if required. As reported in Management's Report on the Action Plan for Enhanced Supervision (January 31, 2013), no additional financing is required to meet the objectives of the GBWSP.

- **The Bisri dam seems to be the preferred augmentation alternative. When can this dam realistically be commissioned? Is the Bank considering financing for this dam?**

GoL undertook a detailed analysis of alternatives for supply augmentation to the Greater Beirut region which included Bisri, two sites at Damour and Janna dam. The analysis also included non-dam alternatives including groundwater, desalination and loss and leak reductions.

GoL submitted the analysis of alternatives to the Bank for review in December 2012. The Bank has not made a decision to date on whether project financing will be possible.

- **Does Management have a study of future (beyond 2021) availability of water in the Litani River basin, taking into account any further projected utilization of this water, as well as trends that may be exacerbated by climate change ?**

  The Action Plan for Enhanced Supervision of the GBWSP committed to developing a plan to monitor and manage: (i) Climate Change Impacts through Effective Water Resources Management; and (ii) Agricultural Consumption through Irrigation Efficiency Improvements. As detailed in Management's Report on the Action Plan for Enhanced Supervision (January 31, 2013), both plans were developed and further provided specific implementation actions, already under implementation by GoL.

  The Bank also granted GoL a Global Environment Facility (GEF) Grant of 1,050,000 USD for a project that utilizes remote sensing and earth observation tools and methods to improve water resources and agricultural management. This project, currently under implementation in partnership with the United States National Aeronautics and Space Administration (NASA) is providing GoL with technical assistance in climate downscaling, evapotranspiration mapping and runoff modeling and is not limited to 2021.