EXECUTIVE SUMMARY REPORT

The Control of Algae
In the Litani River Authority's Canal 900

Small Scale Testing and Validation
and
Scope of Work (SOW)

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Cover Photo: Application of Copper Sulfate to Canal 900 Near K2 Pump Station

1.0 Executive Summary

Canal 900 is operated by the Litani River Authority and is located in south central portion of Lebanon's Bekaa Valley. The canal's source water, Lake Qaraoun, contains high amounts of nitrogen and phosphorous. Nutrients in slow moving, shallow canal water provide ideal growing conditions for aquatic weeds and algae during the summer, resulting in clogged pump screens and poor water delivery capacity.
Algae control techniques were evaluated and copper sulfate was selected as safe and effective tool for algae control. Small scale testing in May and August 2005 proved that copper sulfate is an effective algaecide. The average concentration of copper sulfate in the canal will be less than the US Environmental Protection Agency (USEPA) drinking water standard and the annual amount of copper sulfate applied to land irrigated with canal water will be less than the European Union maximum allowable concentration for organic produce. LRA staff was trained in proper copper sulfate dosing estimates, application techniques and health and safety requirements.
As part of a comprehensive algae control Scope of Work for 2006, recommended activities this winter include cleaning the canal of debris, grading canal banks, repairing bridge abutments and footings to prevent soil from entering the canal, and evaluating operational changes in water delivery scheduling.

2.0 Background

Development Alternatives International (DAI) is providing advisory support services for the improvement of water quality management and remediation of wastewater and other pollution in the Litani River and Qaraoun Lake Basin.

The objectives of this scope of work were:

1. Recommendation for solution (s) for control of algae proliferation in Canal 900 (herein referred to as the "canal").
2. Preparation of a SOW and related costs for LRA to implement the recommended solution(s);

The tasks identified as necessary to accomplish the above objectives were:

1. Review and analyze the Canal 900 algae proliferation study carried out in 2003 and the algae identification study conducted in July 2004;
2. Based on the above review and analysis and using available data for flow/channel characteristics, recommend algae control solution (s) for canal 900 and prepare a concise plan and time schedule for:
    a. testing and validation of the recommended solution(s) during spring/summer 2005 and
    b. preparation of a Scope of Work (SOW) and related costs for LRA to implement a routine algae control program based on the validated solution(s).
3. Oversee, and conduct as feasible, field work to test and validate the recommended solution (s);
4. Prepare an SOW and estimated costs for LRA to implement a routine algae control program based on the validated solution(s).

Michael S. Blankinship, of Blankinship and Associates, was retained by DAI to execute the tasks described above. Mr. Blankinship is a California licensed professional Civil Engineer (PE) and Pest Control Advisor (PCA) in California with over 15 years of experience in the assessment and control of aquatic weeds.

3.0 Canal Characteristics

The canal is operated by the Litani River Authority and is located in south central portion of Lebanon's Bekaa Valley. Refer to **Figure 1**.

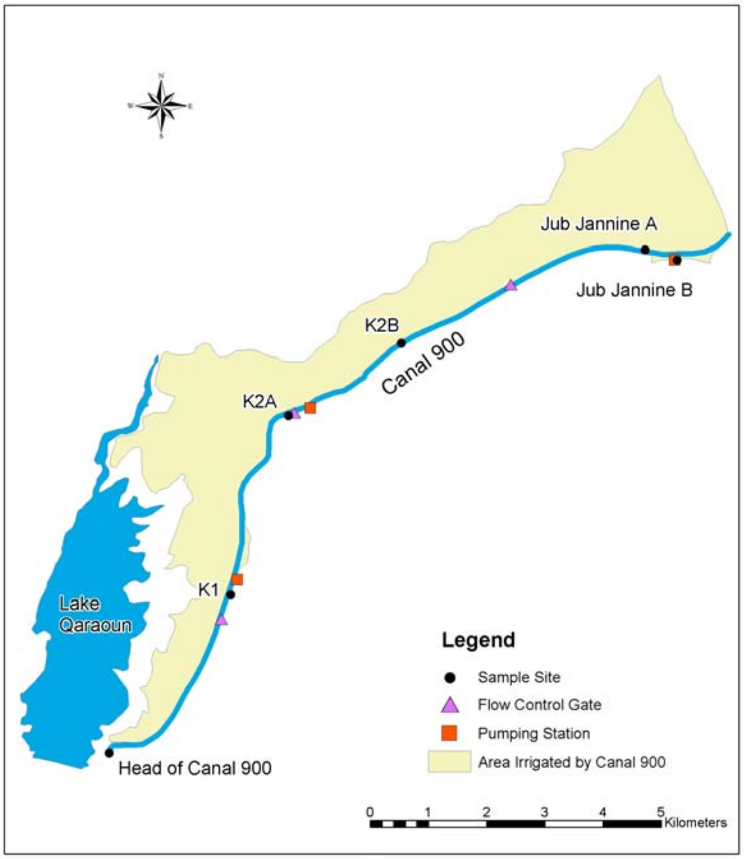

Figure 1. Project Location Map

Canal 900 an open, combination rectangular and trapezoidal, concrete-lined channel of approximately 18.5 km. It is divided roughly into 4 equal reaches of average slope of 0.2 % and delivers irrigation water from Lake Karaoun to approximately 1900 Hectares (Ha).

The canal is designed to deliver 30 million cubic meters per year (m^3/yr). Three pump stations deliver water to regulating reservoirs that subsequently service laterals that irrigate adjacent crop land totaling approximately 2,000 hectares (Ha). Water is delivered from May to September. The canal is dry the remaining 7 months of the year.

The main pump delivering water from Lake Karaoun to the south end of the canal delivers water at an average flow (Q) of 4.5 cubic meters per sec (m^3/s). Although not currently operational, the total delivery capacity of water from the 5 wells at the north end of the canal is 0.275 m^3/s. Water is delivered from regulating reservoirs to laterals at rates ranging from 0.170-0.890 m^3/s.

Crops in the Bekaa Valley irrigated by Canal 900 include, in order of predominance: wheat, potatoes, onions, water melons, tomatoes, and apples. Crops such as potatoes are sprinkler irrigated and other vegetables are drip irrigated.

4.0 Technical Documentation Review

We reviewed the following documents:

1.) Addressing Algae Proliferation in Canal 900 of the Litani River Basin in Lebanon. October 2003. DAI.
2.) Conveyor 800 Mission Report of the Algae Control Specialist. 09-12 February 2004.
3.) Litani River Authority, General Studies Department, South Bekaa Irrigation District Canal 900-Phase I (2000 Ha) Hydraulic and Technical Specifications. March 2, 2005

The following relevant facts were derived:

1.) Lake Qaraoun and the canal have hypereutrophic conditions highly conducive to the growth of algae.
2.) Reduction and/or treatment of Lake Qaraoun water to remove P and N is not feasible at this time.
3.) Unabated algae growth in the canal is blocking pumps, screens, and filters, clog drip emitters, limits water delivery to farmers, generate foul odors and attract mosquitoes
4.) LRA staff use nets and screens to manually remove algae.

5.0 Canal 900 Reconnaissance Findings

Site reconnaissance during both the May and August site visits revealed that the following aquatic weeds were present in the canal:

1. Filamentous green algae (*Cladophora* sp.) at all locations; most prevalent at and downstream of K1 pump station. Refer to **Figure 2**.

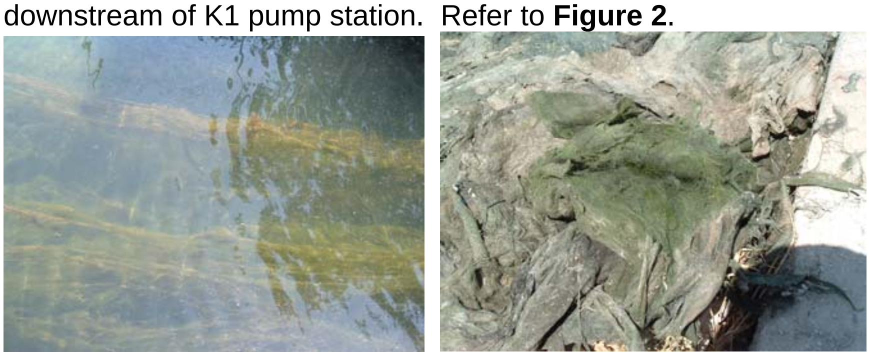

Figure 2. Filamentous Green Algae

2. Sago pond weed (*Stuckenia pectinatus*) and curly leaf pond weed (*Potamogeton crispus*) at and downstream of the K2 pump station. Refer to **Figures 3 and 4**.

Figure 3. Sago Pond Weed

Figure 4. Curly Leaf Pond Weed

The primary purpose of algae removal is to keep pump screens clean. Screens are located at each of the three pump stations and screen water prior to it being pumped to one of the three storage reservoirs.

Prior to reaching the screens, algae is currently removed from the canal by hand using rakes and boards placed across the canal. This technique is labor-intensive and must be repeated regularly.

6.0 Analysis of Suggested Control Options

Observations made during the site reconnaissance and data provided in the technical documentation reviewed suggest that a variety of aquatic weed control techniques may be considered. Each of these techniques is briefly discussed and evaluated below. Evaluation is based on past experience with these techniques in similar canal environments in California. A summary of the algae control options discussed above are presented in **Table 1**.

TABLE 1. Summary of Control Options

METHOD	POSITIVES	NEGATIVES	CONCLUSION
Chemical			
Various	See Table 2	See Table 2	Consider. See Section 5.0 below.
Mechanical			
Hand Removal	Available labor, past experience	Limited effectiveness, Labor intensive	Implement
Remove Canal Debris	Removes dirt, improves flow, prevents weeds next	Must be repeated every year	Implement
Bank Grading	Prevents Soil in Canal	None	Implement
Biological			
Apply Barley Straw	May slow algae production	Not proven; may clog pump screens	Do Not Implement
Use of Fish (Carp or Tilapia)	May eat algae and weeds	Must be repeated every year; may be removed by residents	Do Not Implement
Exclusion of Light (Trees)	May prevent algae from growing	Takes time to grow, only partial shade	Do Not Implement
Operational			
Agricultural Practices to Limit N & P	May prevent algae from growing	Control of the source of N & P is difficult	Implement if Possible; Provide education, extension and outreach
Exclusion of Light (Shade Structure)	May prevent algae from growing	Expensive, hinders canal maintenance	Do Not Implement
Improved Canal Flow Management	May prevent algae from growing	Current insufficient water demand to justify sustained high volume flow	Implement if Possible

7.0 Recommended Algae Control Solutions

Based upon the analysis of control options presented above, an IPM approach to the control of aquatic weeds in Canal 900 is recommended. Components of the recommended IPM approach include:

Mechanical Control:

1. The canal bottom should be thoroughly cleaned of all soil and debris. Weed seed may be present in canal cracks and joints and should be removed using pressure washing equipment or other suitable device
2. Retaining walls should be constructed at bridge abutments to prevent soil from entering the canal.
3. Ground on the side of the canal should be graded away from the canal so that during rain events no soil is washed into the canal.
4. Residents adjacent to the canal should be instructed on how to prevent soil from entering the canal from their property. Further, they should not be allowed to house animals close to the canal to prevent nutrients and bacteria in animal waste from entering the canal.
5. Algae should continue to be removed by hand from the canal and pump intake structures

Operational Control:

1. Consider decreasing flow during evening hours and increasing flow during daylight hours to decrease daytime water temperatures and increase shear stress on algae adhered to the canal banks.

Chemical Control:

1. Screen and select appropriate herbicide(s) based upon factors including ease of use, efficacy, toxicity to non-target organisms, and risks to applicators and residents near the application area.

8.0 Analysis of Chemical Control Options

As previously discussed, the climate, topography and growing season of Lebanon's Bekaa Valley is similar to that of the central Valley of California. Management of aquatic weeds in irrigation canals in California have historically relied on an IPM approach that includes the use of herbicides. Several herbicides have proven effectiveness and based on the screening and selection factors mentioned above, are evaluated and summarized in the **Table 2** below.

TABLE 2. Summary of Herbicide Control Options

Herbicide	Ease of Use	Efficacy on Algae	Toxicity to Non-Target Organisms	Risk to Applicators	Risk to Residents
Copper Sulfate	Easy	Good	None	Low	Low
Chelated Copper	Moderate	Good to Very Good	Low	Low	Low
Acrolein	Difficult	Excellent	High	High	High
Hydrogen Peroxide	Difficult	Good	High	Moderate	Low

At this time, copper sulfate is readily available to the LRA, has proven efficacy on the algae species present in the canal, and when used according to label directions will not likely cause adverse impact to aquatic environments in which it is used. It is a dry solid that is easy to handle and does not possess acute or chronic human health risks. Because the canal is concrete-lined and the water that it carries is not used for habitat for any species, the use of copper will adversely impact water quality. Further, when copper-treated water is used for crop irrigation, it is not known to be phytotoxic to the crops currently grown in the area.

In addition, the target concentration of copper in the canal will not exceed the US Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) for drinking water of 1.3 mg/L.

Last, the anticipated amount of copper delivered annually per irrigated hectare of land per irrigation year is less than the maximum amount suggested by the European Union (EU) that can be added to soil annually for organic food production.

9.0 Algae Control Testing and Validation

Small scale testing and validation of algae control using herbicides was accomplished from 16-26 May 2005. Testing took place at three locations in the canal. A target concentration of between 0.5 and 1 milligram per Liter (mg/L or parts per million [ppm]) was initially targeted to evaluate the degree of algae control. Good to very good control of algae was noted in 3 days. Refer to **Figures 5 and 6**.

Figure 5. 20 May 2005

Figure 6. 23 May 2005

During the site reconnaissance done from 1-5 August, 2005, significant amounts of algae were noted, particularly from at and downstream of the K2 regulating reservoir. As a result, the dosing target was increased to 1 mg/L for the month of August.

On both the May and August field reconnaissance visits, LRA staff were trained to estimate the amount of copper sulfate required per location and date in order to achieve target copper concentrations. In addition, LRA staff were trained in appropriate techniques for safely and effectively measuring and applying copper sulfate to the canal.

10.0 Water, Crop and Soil Testing

Based upon water quality testing performed by DAI and LRA staff, canal water temperature increases from spring to summer and increases in chlorophyll concentration appears to precede observed algae counts. In addition, relative to other locations in the canal, high algae densities and chlorophyll concentrations were observed at the end of the canal at Jub Jannine and K2. This finding is consistent with the high water temperature and slow or non-existent flow that is present in these locations.

DAI staff performed soil and crop sampling. The data suggest that the soil in the area irrigated by Canal 900 has copper at a concentration that appears to be statistically significantly higher than the soil in background areas not irrigated by Canal 900. The reason for this is not known. This data does, however, provide background information for LRA staff so that the impact to area soils as a result of using copper in Canal 900 irrigation water can measured.

11.0 Cost Estimation

11.1 Summer Activities: Chemical Control

The estimated annual copper sulfate use is 1286 Kg and the estimated unit cost of copper sulfate of $3 USD/Kg, the cost to implement the control of algae in the canal is estimated at $3/Kg x 1286 Kg = $3,858.

Estimated labor costs for past manual control of algae were based on 10 men at a rate of $10 USD/day/man. This equates to a cost of approximately $15,000 USD for the 5 month irrigation season. Labor costs, however, are expected to less than this value when copper sulfate is used. Nonetheless, the need, if any, of continued manual removal of algae in conjunction with the use of coppers sulfate is not known and depends on the degree of control achieved with copper sulfate.

Therefore, a conservative estimate for the cost of implementing chemical control in the summer is $3,858 + $15,000 = $18,858 USD.

11.2 Summer Activities: Operational Control

Additional staff time will be required to execute changes in the operation of the canal to aid in the control of algae. The level of effort is not known.

11.3 Winter Activities: Mechanical Control

Additional staff time will be required to perform these tasks. Assuming 10 men at a rate of $10 USD/day/man for a 2 month mechanical control program, this equates to a cost of approximately $6,000 USD. In addition, the equipment such as skip loaders ($150/day) and backhoes ($150/day) will be required at a cost of $18,000 for the same 2 month period.

Therefore, a conservative estimate for the cost of implementing winter mechanical control is $6,000 + $18,000 = $24,000 USD.

This cost does not include the cost to design and build retaining walls around bridge abutments and footings. The cost for this work will vary and depend on the length, size and type of structure that is selected.