Πτηνολογικός
Σύνδεσμος Κύπρου
BirdLife Cyprus

"Determination of important hydrological features for Oroklini Lake"

Foreseen as part of the project LIFE10 NAT/CY/716 where BirdLife Cyprus is an associated beneficiary

The LIFE Oroklini project is implemented with the contribution of the LIFE financial instrument of the European Union

FINAL REPORT

November, 2012

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1. Introduction

The determination of important hydrological features for Oroklini Lake constitutes the Action A.4 of the 3-year LIFE+ project entitled "Restoration and Management of Oroklini Lake SPA (CY6000010) in Larnaka Cyprus" with the grant agreement reference no. LIFE10 NAT/CY/716. Responsible for this action is the BirdLife Cyprus which is one of the five beneficiaries of this project.

I.A.CO Environmental and Water Consultants Ltd has been contracted to carry out the tasks on the hydrological features of the Lake as per the Tender no: 1/2012.

This is the Final Report of the study as requested in the relevant Terms of Reference (TOR). The "Hydrological study" that follows covers: a) the results on the Groundwater including the drilling and results from the investigative borehole, the sampling and the analyses, and the groundwater levels, b) the results on the Surface water including sampling and analyses, and the water level recorder and its installation, c) discussion on the analytical results of the surface and groundwater including the relationship of groundwater to the sea and to the lake water, classification of the groundwater, the source of salinity of it, and recommendations on the need for organic pollution analyses, d) infiltration tests carried out in the lake area, e) the integrity of the embankment and of the dam/weir, including field observations and dam capacity evaluation for low frequency floods, f) water operation study of the lake for a series of years and for a selection of a dry, average and a wet year, and finally g) an assessment of proposed water management works including technical specification and guidelines for carrying them out.

2. The Groundwater

2.1. The investigative borehole

As per the TOR an investigative 4-inch diameter borehole to a total of 6m (5m below the groundwater level, which was 1m from ground surface), was drilled on the 14th of June. This was preceded by a site visit made on the 12th of June, during which a number of possible locations for the borehole where considered together with Mr. N. Kassinis of the Game Fund, the driller Mr. A. Shiathas, and I. Iacovides and M. Mouskoundis of I.A.CO Ltd. Finally the site was chosen on the side of the earth road between the ex "flea market" area and the main lake. This location was considered as suitable causing the least interference with the birds of the area, it is safely accessible for the heavy drilling machine and sufficiently close to the lake to provide data for the groundwater conditions affecting the lake.

Data on the composition of the soil core substrate were collected (paragraphs 2.1.1 and 2.1.2) and the permeability of the strata was examined (paragraph 2.1.3). These helped in determining any possible interaction between the ground - and the surface water.

Subsequently, from this borehole, samples of groundwater were collected for chemical analysis in June and October as discussed further below (paragraph 2.2) and the groundwater level was monitored at a number of occasions (paragraph 2.3). Besides the two drillers, the drilling operation was attended by a Geologist who was recording the lithology drilled and by I.A.CO staff (see Photos 1 and 2). The borehole was finished with concrete on top with a cover in such a way so as not to stand out in the area (see Photo 3).

The ground elevation of the borehole as provided by the topographer is 21,04m, or 3,65 m. a.m.s.l., since the reported (by M. Paraskevaides, Topographer) equivalent sea level elevation is at 17,394m.

Photo 1: Drilling at the lake

Photo 2: View of the Lake on the 12th of July 2012 from the location of the investigative borehole.

2.1.1.The borehole log

A full borehole log of the investigative borehole is presented in Diagram 1. The first meter is made up of slightly sandy clay and silt, followed by two meters of gypsiferous sandy, very clayey silt, and ending with two meters of slightly sandy clay and silt. The clayey sediments and especially the gypsiferous content are the main contributory source of the saline quality of the groundwater.

2.1.2.The particle analysis

During the drilling of the borehole, samples were taken at 0,5 m to 1,0m, 2m to 2, 5m and 4 to 4,5m which appeared as water bearing for an analysis of the particle distribution. The results of this analysis are presented in Diagram 2.

The particle size distribution for the sample collected between the depths of 0,5 to 1,0m indicates that 40% of the sample is clay and between 40 and 95% is silt. The sample collected between the depths of 2 and 2,25m appears to be slightly coarser since only some 25% is clay and between 25 and 90% is made up of silt. The remainder 90 to 100% is made up of sand. Finally, the sample collected at depths of 4,0 to 4,5m appears to be similar to the first sample with 45% being made up of clay, 45 to 95% made up of silt and the remainder of sand.

2.1.3.Permeability tests

The coefficient of permeability was determined at the lab using the “Falling head Method” for the samples of soil collected from the same horizons, at depths 0,5 to 1,0m, 2,0 to 2,50m and at 4,0 to 4,5m,. The Table 1 below gives the results.

Table 1: Coefficient of permeability for selected samples using the Falling Head Method

Depth of sample (m from surface)	Compacted to (g/cm^3)	Moisture content (%)	Coefficient of permeability (cm/day)
0,5 – 1,0	1,612	32,7	$1,47 \times 10^{-3}$
2,0 – 2,5	1,600	33,1	$1,88 \times 10^{-3}$
4,0 – 4,5	1,604	28,4	$1,11 \times 10^{-3}$

These extremely low values for permeability are consistent to the lithology described in the borehole log and determined by the particle analysis being clay and silt - silty loess.

2.2. Groundwater sampling and analysis

As per the TOR, on the 21st of June 2012 a sample was obtained from the investigative borehole for heavy metals (Pb and Hg) and for all the parameters listed in Table A2 presented in the TOR document and shown in Table 2 below. A report on this analysis was received on the 6th of July and the results are shown on Table 2. Similarly, a second sample was obtained on the 10th of October 2012 (see Photo 3) and analyzed for the same parameters except for the heavy metals (Pb and Hg). A report on this second analysis was received on the 25th of October 2012. The results are also shown on Table 2.

2.2.1. Discussion on the results of the groundwater analyses

The sampling from the groundwater was set at early June when the water-table was expected to be at its highest elevation after the winter and spring water flows, and in October, well after the summer period when the water-table would have receded. Thus, a good picture of the groundwater quality fluctuation would have been obtained.

Table 2 lists the results of the two analyses for the groundwater which are compared to average seawater values, EU Drinking standards and the Cyprus Threshold Values.

Some comments on the analytical results are as follows:

Electrical Conductivity:

The Electrical Conductivity of the groundwater is exceptionally high and refers to brine, possibly associated with halite commonly associated with other evaporate deposits. It varies between 30%, at the beginning of the dry season, to more than 300% higher than that of seawater by the end of the dry season.

Calcium:

The calcium is possibly from sediments of sulfates gypsum present in the subsurface. The presence of high amounts of calcium and sulfates indicates solution of gypsum. The increase by the end of the dry season is possibly due to the dilution of gypsum during high water-table conditions.

Sodium:

Water associated with evaporite formations generally has a very high sodium concentration. The increase by 65% by early October is again due to dissolution of evaporite formations in the subsurface during the high water-table conditions of the previous wet season. The increase is reflected in the Electrical conductivity of the groundwater of the sample of October,

Sulfate:

The groundwater as indicated by the calcium and sulfate appears to be saturated with respect to gypsum. It should be noted, from the results shown in Table 3 further below, that the surface water in the lake also presents the same analogy of Calcium to Sulfate. This suggests contact with the groundwater.

Chloride:

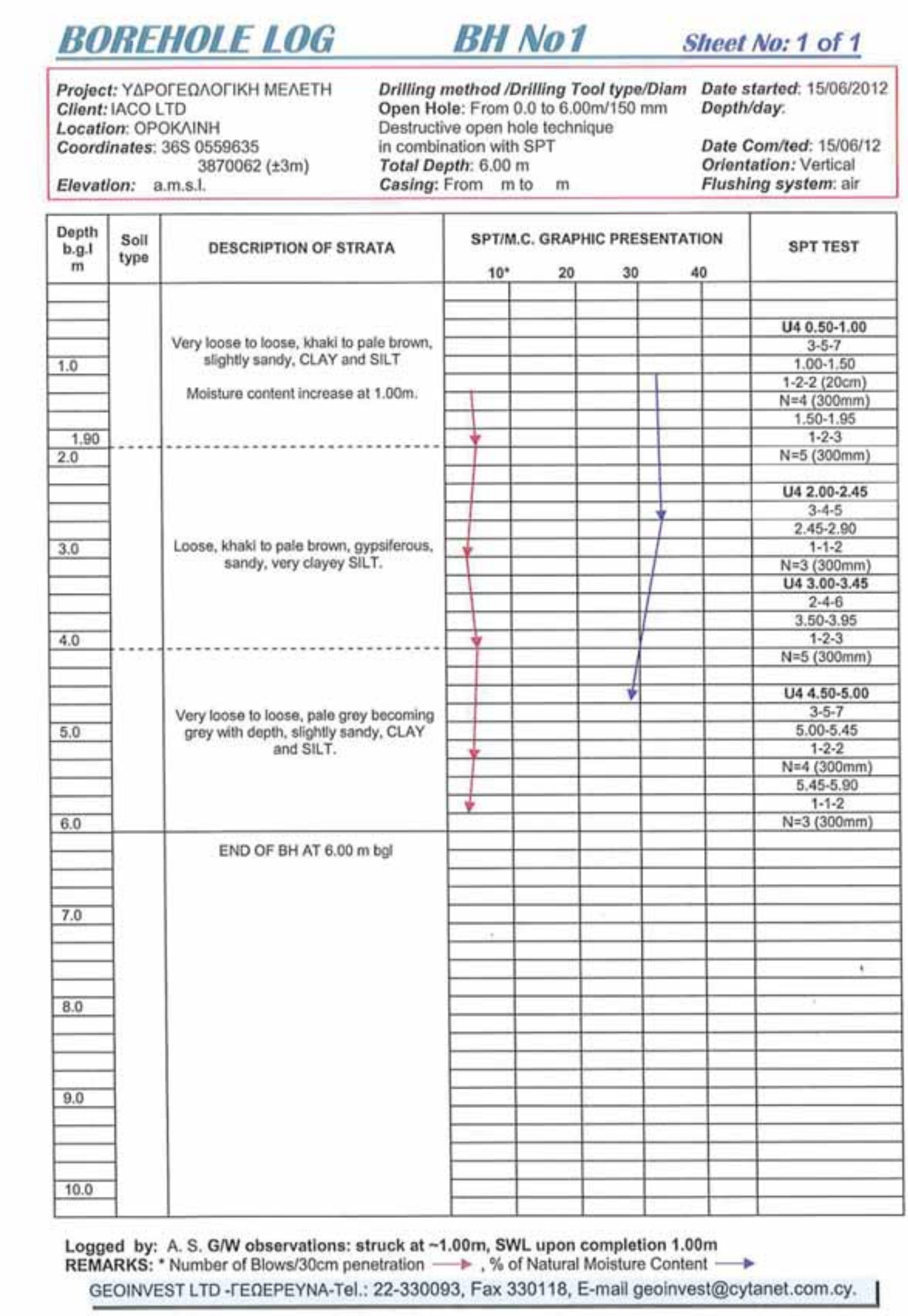
Chloride may be present in resistates as the result of inclusion of connate brine and in the cementing material and is to be expected in incompletely leached deposits laid down in the sea or in a closed drainage basin. The increase in the chloride content of the groundwater by 54% between the June and the October sample indicates, as for the other elements mentioned earlier, increased dissolution due to the high water-table conditions. This increase is well reflected in the electrical conductivity of the groundwater in the October sample.

Nitrogen:

The general absence of farms and animal husbandry and agricultural activities in the immediate area is reflected in the low amounts of Total Nitrogen and Nitrate in both the ground and the surface water.

Phosphorous:

It is a component of domestic and industrial sewage. The relatively small amounts in both the groundwater and the surface water suggest minimal pollution from sewage sources. The 100% increase between June and October is due to the reduced dilution that occurs in the dry season.



BOREHOLE LOG **BH No1** **Sheet No: 1 of 1**

Project: ΥΔΡΟΓΕΩΛΟΓΙΚΗ ΜΕΛΕΤΗ
Client: IACO LTD
Location: ΟΡΟΚΛΙΝΗ
Coordinates: 36S 0559635
3870062 (±3m)
Elevation: a.m.s.l.

Drilling method /Drilling Tool type/Diam
Open Hole: From 0.0 to 6.00m/150 mm
Destructive open hole technique
in combination with SPT
Total Depth: 6.00 m
Casing: From m to m

Date started: 15/06/2012
Depth/day:
Date Com/ted: 15/06/12
Orientation: Vertical
Flushing system: air

Depth b.g.l m	Soil type	DESCRIPTION OF STRATA	SPT/M.C. GRAPHIC PRESENTATION 10* 20 30 40	SPT TEST
		Very loose to loose, khaki to pale brown, slightly sandy, CLAY and SILT. Moisture content increase at 1.00m.		U4 0.50-1.00
				3-5-7
1.0				1.00-1.50
				1-2-2 (20cm)
				N=4 (300mm)
				1.50-1.95
1.90				1-2-3
2.0		Loose, khaki to pale brown, gypsiferous, sandy, very clayey SILT.		N=5 (300mm)
				U4 2.00-2.45
				3-4-5
				2.45-2.90
3.0				1-1-2
				N=3 (300mm)
				U4 3.00-3.45
				2-4-6
				3.50-3.95
4.0				1-2-3
		Very loose to loose, pale grey becoming grey with depth, slightly sandy, CLAY and SILT.		N=5 (300mm)
				U4 4.50-5.00
				3-5-7
5.0				5.00-5.45
				1-2-2
				N=4 (300mm)
				5.45-5.90
				1-1-2
6.0				N=3 (300mm)
		END OF BH AT 6.00 m bgl		
7.0				
8.0				
9.0				
10.0				

Logged by: A. S. **G/W observations: struck at ~1.00m, SWL upon completion 1.00m**
REMARKS: * Number of Blows/30cm penetration ⟶ , % of Natural Moisture Content ⟶

GEOINVEST LTD -ΓΕΩΕΡΕΥΝΑ-Tel.: 22-330093, Fax 330118, E-mail geoinvest@cytanet.com.cy.

Diagram 1: Substrate Log of the investigative borehole

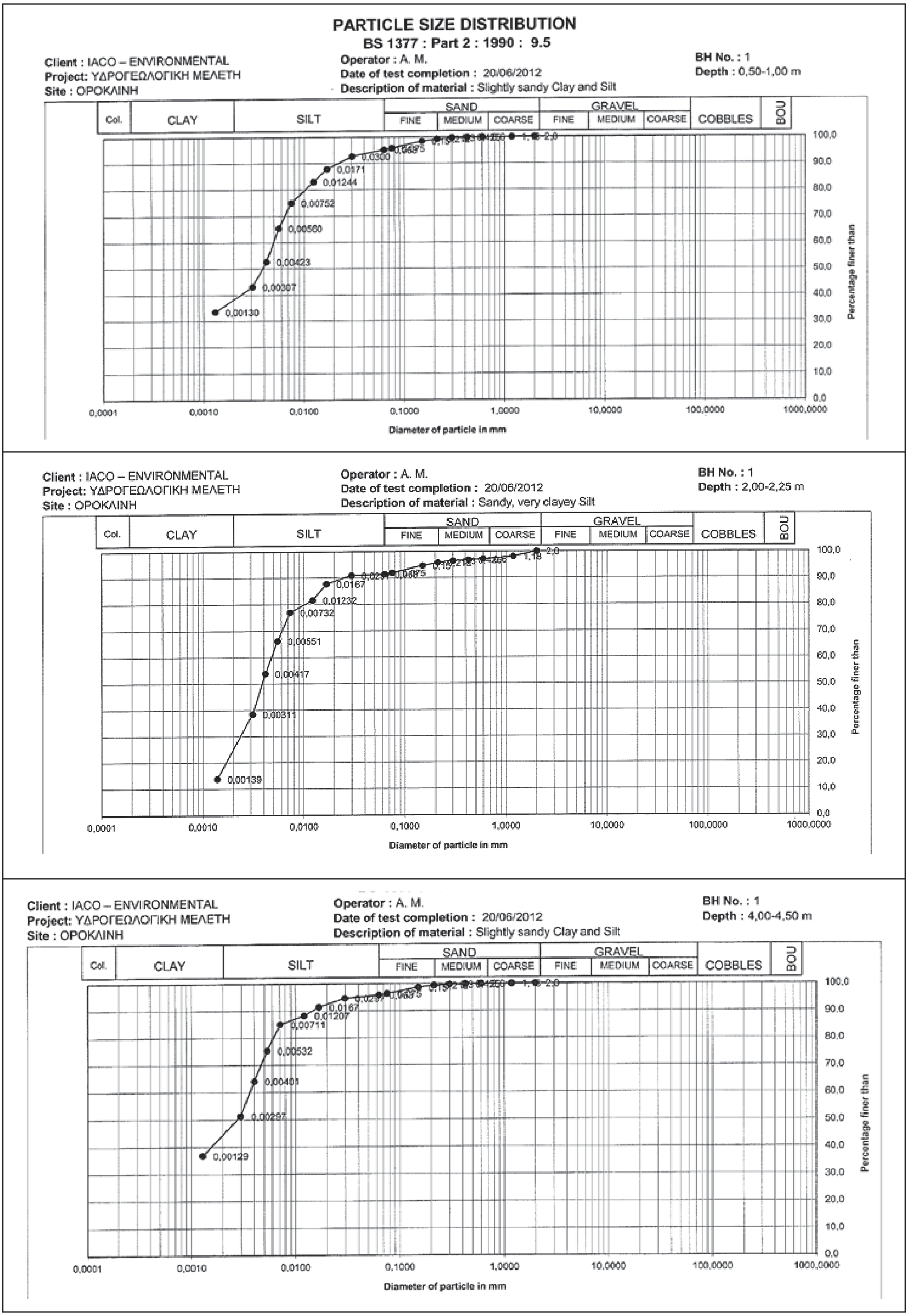


Diagram 2: Particle size distribution of samples at 0,5 – 1,0m., 2,0 – 2,25m., and at 4,0 – 4,5m.

Boron:

This is very high both in groundwater (8,69 to 10,80 mg/l) as well as in surface water (5,29 to 5,56 mg/l) and well above the sea water content (4,5 mg/l). Evaporite deposits in closed basins may contain considerable amounts of boron. Another source might be due to borax used in detergents something that is not expected to occur since this is not allowed any longer.

Mercury:

This is significant as an environmental pollutant. The amount detected is lower than 1 μg/L in both the ground and the surface water samples taken in June. Both the EU drinking Water Standards and the Cyprus TVs put it at 1 μg/L.

Lead:

Lead in groundwater and the lake water, in the samples taken in June, is 9,9 and less than 2,9 μg/L respectively which puts it below the EU drinking Water Standards and the Cyprus TVs of 10 μg/L.

The urbanized catchment and the proximity of the Larnaka – Paralimni Highway could be a source of this element through the exhaust gases due to the heavy traffic.

Table 2: Analytical results on groundwater samples collected on June 21st, 2012 and October 10th, 2012 and comparison with various standards

No	Parameter	Units	Groundwater Results		Seawater[1]	EU Drinking Water Standards[2]	Cyprus Threshold Values[3]
			21/06/2012	10/10/2012			
1	Total Nitrogen*	mg/L-N	9,4	7,8	0,67		
2	Nitrites NO_2^+	mg/L-N	0,46	<0,009***		0,50	
3	Total Ammonia Nitrogen	mg/L-N	<0,6	2,8			
4	Ammonium NH_4^+	mg/L-N	<0,59	2,6		0,50	0,50
5	Total Phosphorus	mg/L-P	0,14		0,09		
6	Soluble reactive Phosphates (SRP)	mg/L-P	<2,6	<2,6			
7	HCO_3^-	mg/L	470	352	142		
8	CO_3^{2+}	mg/L	<1	<1			

[1] *Seawater composition (after Goldberg and others 1971 – USGS Water Supply Paper 2254)*

[2] *Council Directive 98/83/EC on the quality of water indented for human consumption. Adopted by the Council, on 3 November 1998 Source: http://www.lenntech.com/applications/drinking/standards/eu-s-drinking-water-standards.htm*

[3] *ANNEX 3 to the Commission Staff Working Document accompanying the Report from the Commission in accordance with Article 3.7 of the Groundwater Directive 2006/118/EC on the establishment of groundwater threshold values. Information on the Groundwater Threshold Values of the Member States. (In most cases the drinking water standards have been adapted as TVs. With the exception of Conductivity, SO_4, and CI, naturally occurring substances are in most aquifers below TVs.) Source: http://ec.europa.eu/environment/water/water-framework/groundwater/pdf/com_swd_annex_iii.pdf Included in national legislation N.13(I)/2004 (Annex VI item III)*

9	SO_4^{2-}	mg/L	13265	14465	2700	250	250 - 3000
10	Cl^-	mg/L	28183	43426	19000	250	250 - 3000
11	NO_3^- - N	mg/L-N	4,46	<0,2	0,67	50	50
12	F	mg/L	≤3	≤3	1,3	1,5	
13	Ca^{2+}	mg/L	1022	1423	410		
14	Mg^{2+}	mg/L	2928	4937	1350		
15	K^+	mg/L	184	375	390		
16	Na^+	mg/L	16000	26500	10500	200	
17	B	mg/L	8,69	10,80	4,5	1,0	
18	El. Conductivity	µS/cm	61500	175800		2500	2500-7000
19	pH	-	7,2	7.3		≥ 6,5 and ≤ 9,5	
20	Total Hardness	mg/L $CaCO_3$	14500	23700			
21	Total Alkalinity	mg/L $CaCO_3$	470	352			
22	Colour	Hazen	28	50		****	
23	Pb**	µg/L	9,9	No analysis	0,03	10	10
24	Hg**	µg/L	<1	No analysis	0.2	1	1

*The value of Total Nitrogen is the sum of TKN, NO_3-N, NO_2-N
**only for samples of June
*** The value for nitrites is between the detection limit and the limit of quantified determination
**** Acceptable to consumers - no abnormal change

Color:

The color of natural water usually results from leaching of organic debris. The increase between the sampling in June to that of October could be due to the increase of dissolved salts.

Photo 3: Groundwater sampling (Left) and surface water sampling (Right) in June 2012 (on top) and in October 2012 (below)

2.3. Groundwater levels

The depth to the groundwater level was measured (Photo 4) on the 15th and 21st of June, on the 12th of July, on the 16th of August, on the 10th of September, on the 10th and 17th of October, and on the 13th of November 2012. The depth to the water level was at 1,0m, 1,2m, 1,35m, 1,2m, 1,42m, 1,2m, 1,2m and 1,04 respectively. The groundwater level measurements are shown in Diagram 3. The water level receded at 0,013m/day in the period of the 15th June to 12th of July. This was recovered to 1,2m below the surface on the 16th of August. There is no record of a local rainfall during this period although rain events were observed in parts of the island (Mountains, Nicosia area, but not at the Larnaka Airport). The flow of the stream towards the lake was observed to have increased on the 16th of August as compared to the last time that it was observed (12th July 2012). After this date, the water level receded again to the lowest point observed on the 10th of September (1,42m). Traces of rain observed at the Larnaka Airport Meteorological Station on the 1, 3 and 4th of October, 0,6mm on the 8th and 12,4mm on the 10th of October caused an important recovery of the groundwater level by the 17th of October to 1,2m.

The rise of the groundwater level on 16th of August was investigated. The possibility of release of treated effluent from the existing pipe network of the Larnaka Sewage Treatment Plant in the area was turned down by the Water Development Department. Mr. Andreas Theodosiou,, Community Board Secretary, expressed his view that groundwater that arises gradually to the surface at the marsh area upstream of the highway is the main reason that flow is observed at the stream at the point of the Highway culvert during the summer period (Photo 5), even without any rainy event during this period. This could have been increased somewhat during this period due to cloudy weather and reduced evaporation.

The rains of October and of early November caused runoff and a rise of the ground water level as shown Diagram 3.

The elevation at the top of the investigative borehole according to the topographic survey made for this project is 21,04m or 3,65m- a.m.s.l.

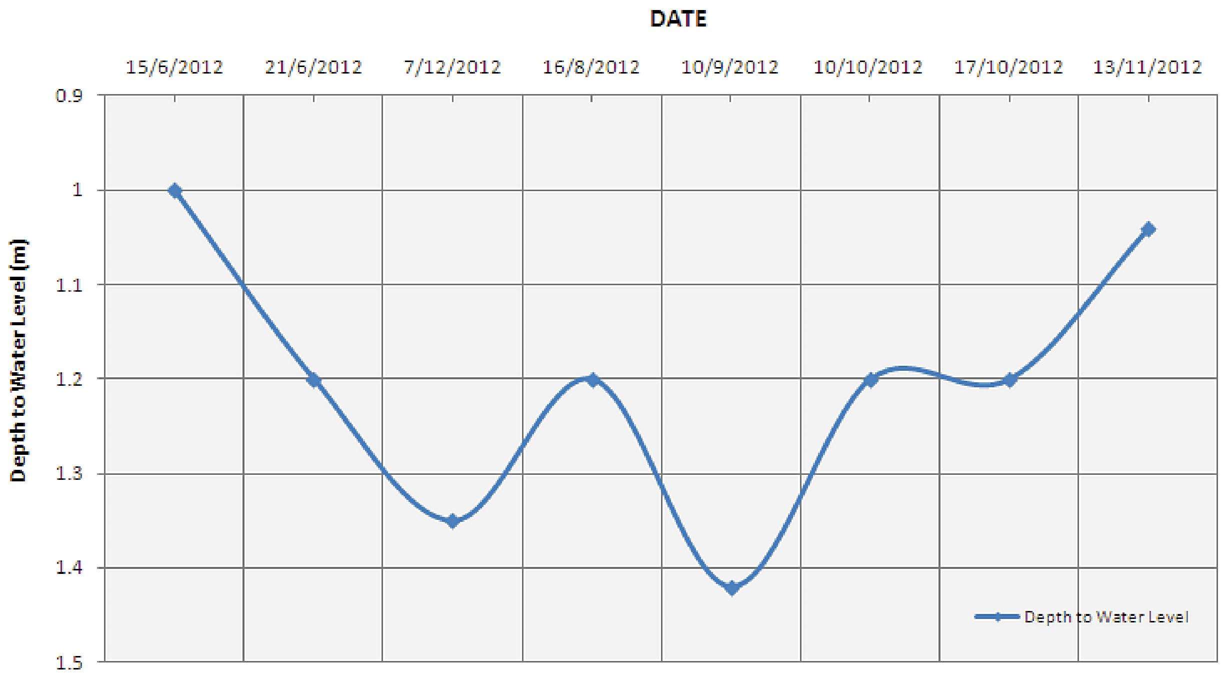


Diagram 3: Depth to Groundwater level at the investigative borehole

Photo 4: Groundwater Level monitoring on the 12th of July 2012

Photo 5: Stream flow towards the Lake on 16th August 2012

3. The Surface Water

3.1. Surface water sampling and analysis

On the same dates as for the groundwater sampling, June and October 2012, samples were obtained from the surface water standing in the lake. For the sample taken in June, an analysis was performed for heavy metals (Pb and Hg) and for all the parameters listed in Table A2 of the TOR document as well as for dissolved oxygen, BOD and COD (Photo 3). For the sample taken in October the analysis was performed for the same parameters, including dissolved oxygen, BOD and COD, except for the heavy metals (Pb and Hg). The results are also shown in Table 3.

3.1.1. Discussion on the results of the surface water analyses

Table 3 lists the results of the analysis of the Lake surface water sampled on the 21^{st} of June and 10^{th} of October 2012 and compares them to average river water values, the EU Drinking standards and the Cyprus Threshold Values.

It should be noted that a lake with a surface water outlet represents a holding and mixing basin for the stream flow that flows into it. The detention time of water in the lake provides an opportunity for slow reactions to come closer to completion than they can in the rapidly moving water of a stream. Closed-basin lakes become saline owing to evaporation of water and continued influx of solutes.

Some additional comments on the surface water analytical results, to those already mentioned when discussing the results on the groundwater analyses, are as follows:

pH

The increase of the pH in the Lake water, compared to that of the local groundwater, might be due to the taking up of dissolved carbon dioxide by photosynthesis by aquatic organisms during daylight and release at night. Surface water in areas not influenced by pollution generally has a pH in the range of 6,5 to 8,5.

Calcium

The fresh water sediment deposit called “marl” which is formed in the lake is made up partly of calcium carbonate. The presence of high amounts of calcium and sulfates indicates solution of gypsum, as found in the groundwater sample, suggesting interconnection of the groundwater to the surface water.

Dissolved Oxygen

A normal value at 30 ^{0}C is around 7,5 mg/l. Aquatic life requires oxygen for survival and the DO determination is used widely in evaluations of the biochemistry of lakes. The value of 6,6 mg/l detected for the lake water (at 25^{0}C when the sample was collected in June) appears slightly lower than normal but the value of 9,5 mg/l in the October sample is well above normal.

BOD_5

The lake pollution level presented by the sample of June, being the situation at high water level after the wet season, as expressed by the BOD of 12 mg/l, is considered as quite low. The ten-fold increase (118 mg/l) by the end of the dry season (the sample of October), indicates increased pollution possibly caused by inflow from the urbanized catchment area without undergoing much dilution with rain water, the decay of vegetation, and the increased presence of feces compared to the water content of the lake having undergone evaporation.

COD

This determines the pollution or oxidizable material loads expressed as oxygen equivalent. To a certain degree these correspond to the BOD. The COD value determined for the lake water in June is considered low (25mg/l) whilst for the same reasons as for the BOD, discussed earlier, by October the value has increased considerably, reaching the value of 188 mg/l.

Table 3: Analytical results on surface water sample collected on June 21st, 2012 and October 10th, 2012 and comparison with various standards

No	Parameter	Units	Surface water Results		Mean composition of world river water [4]	EU Drinking Water Standards[2]	Cyprus Threshold Values[3]
			21/06/2012	10/10/2012			
1	Total Nitrogen	mg/L-N	7,8	10,1			
2	Nitrites NO_2^+	mg/L-N	0,1	0,03		0,50	
3	Total Ammonia Nitrogen	mg/L-N	<0,6	4,2			
4	Ammonium NH_4^+	mg/L-N	<0,58	4,0		0,50	0,50
5	Total Phosphorus	mg/L-P	0,20	0,09			
6	Soluble reactive Phosphates (SRP)	mg/L-P	<2,6	<2,6			
7	HCO_3^-	mg/L	308	355	58		
8	CO_3^{2+}	mg/L	<1	<1	7		
9	SO_4^{2-}	mg/L	4092	4498	11	250	250 - 3000
10	Cl^-	mg/L	2942	3120	7,8	250	250 - 3000
11	NO_3^- - N	mg/L-N	3,25	1,68	1	50	50
12	F	mg/L	<1,2*	<1,2*		1,5	
13	Ca^{2+}	mg/L	441	511	15		
14	Mg^{2+}	mg/L	657	759	4,1		
15	K^+	mg/L	23	36			
16	Na^+	mg/L	2240	2587	6,3	200	
17	B	mg/L	5,29	5,56		1,0	
18	El. Conductivity	μS/cm	13700	16250		2500	2500-7000
19	pH	-	8,3	8,0		≥ 6,5 and ≤ 9,5	
20	Total Hardness	mg/L $CaCO_3$	3780	4375	54		
21	Total Alkalinity	mg/L $CaCO_3$	308	355			

[4] Source: J. HEM Study and Interpretation of the Chemical Characteristics of Natural Water USGS WS Paper 2254 with further reference to I. Oltman 1968 USGS Water Supply Paper 1964

22	Colour	Hazen	30	68		**	
23	Pb	µg/L	<2,9	No analysis		10	10
24	Hg	µg/L	<1	No analysis		1	1
25	Dissolved oxygen	mg/LO_2	6,6	9,5			
26	BOD_5	mg/L	12	118			
27	COD	mg/L	25	188			

* The value for F is within the detection limits and the limit of quantitative determination
** Acceptable to consumers - no abnormal change

3.2. The Lake water levels

3.2.1. The Selection of automatic water level recorder

The site conditions of the lake and the possible location for the installation of the automatic recorder, to take the maximum advantage and longest record of water level at every cycle, were considered. It was concluded that the optimum site would be near the spillway of the lake where access can be found via the bank of the dam from the western direction or possibly from the main asphalt road once the vegetation is cleared out.

Bearing in mind the above, a number of recorder providers were explored and quotations were obtained. These were included in a short report named "Proposal for an automatic water level recorder" which was attached to the monthly progress report of June. BirdLife Cyprus on the basis of the above, approached a local agent for the provision of the type of water level recorder that was proposed by the consultant, and a quotation had been obtained. During this period the consultant assisted in clarifying items and terms of the quotation. The instrument recommended is made of ceramic materials that are able to withstand semi-saline and/or sea water.

Finally, the water level logger "CeraDiver" together with the "Baro-Diver" of "Eijkelkamp Agri-search equipment of Netherlands" was purchased together with a reading unit for a total of €2420 + VAT. The cost for the housing unit which has been designed by the Consultant and manufactured locally, including installation, was €470+V.A.T.

The "CeraDiver" with a ceramic housing and ceramic pressure sensor of 22 mm diameter and length 90 mm has a memory capacity of 48.000 measurements. The "Baro-Diver" has the function to register barometric pressure. Compensation for atmospheric pressure variations is carried out with the use of the available Diver- Office software program.

3.2.2. Installation of the water level recorder

The automatic water level recorder was handed to the Consultant by Birdlife Cyprus on the 10th of October. The site for the installation of the equipment was finalized after the weir was cleared of the vegetation on the 10th of October. The BirdLife Cyprus expressed its agreement for this site by an email message on the 25th of October 2012. The instrument is placed just upstream of the weir (see Photo 6), this being the optimum location with access via the bank of the dam and where the deepest part of the lake can be reached. A design of the housing installation of the water level recorder with the appropriate fittings, features, protective measures and specifications was made (see Photo 6 below), quotations were obtained and BirdLife Cyprus gave its consent to proceed with its preparation.

The water level recorder was installed on the 13th of November 2012 (Photo 7) and programmed for recording observations every 12 hours (6:00 a.m. and 6:00 p.m). The results of the first week of measurements, until the 19th of November (water column above Diver, Pressure and Temperature) are shown on the software template (Plate 1). The lake was over-spilling throughout this period and the water column fluctuation was of the order of 1cm which could be attributed either to increased flow and/or wave action.

A training session on the use of the recorder and its interface software was carried out on the 12th of November at the premises of I.A.CO Ltd and on the field on the 19th of November to an Officer of BirdLife Cyprus.

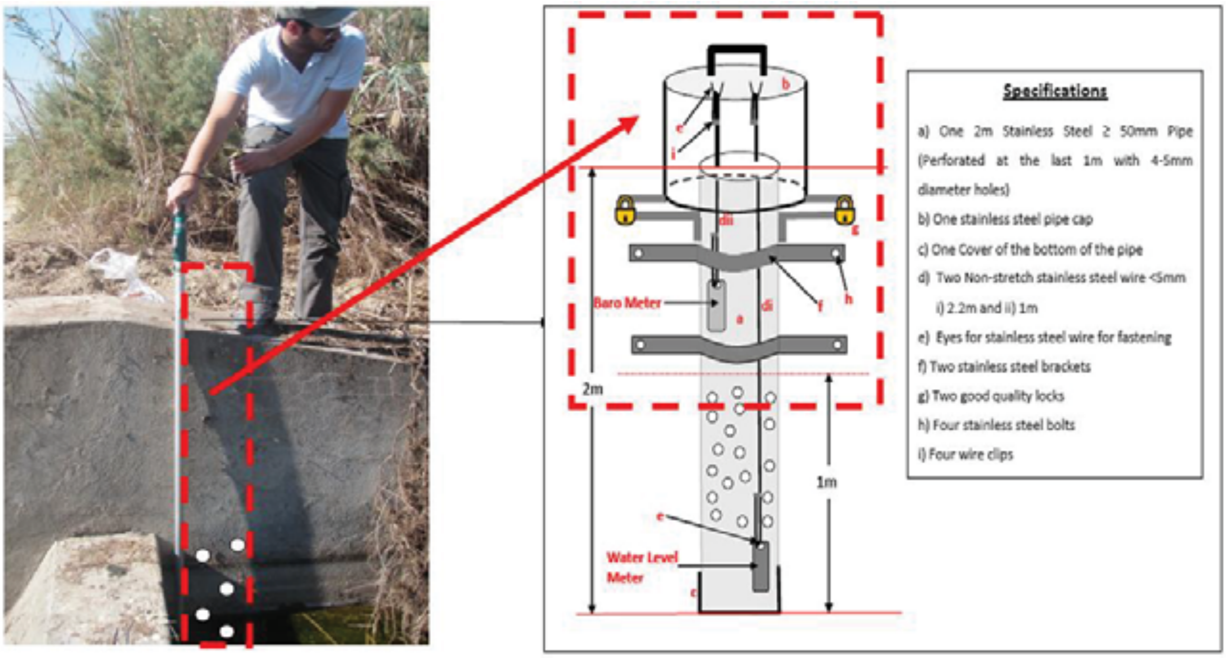


Photo 6: The selected location for the installation of the water level Recorder and design of the housing setup for its secured installation

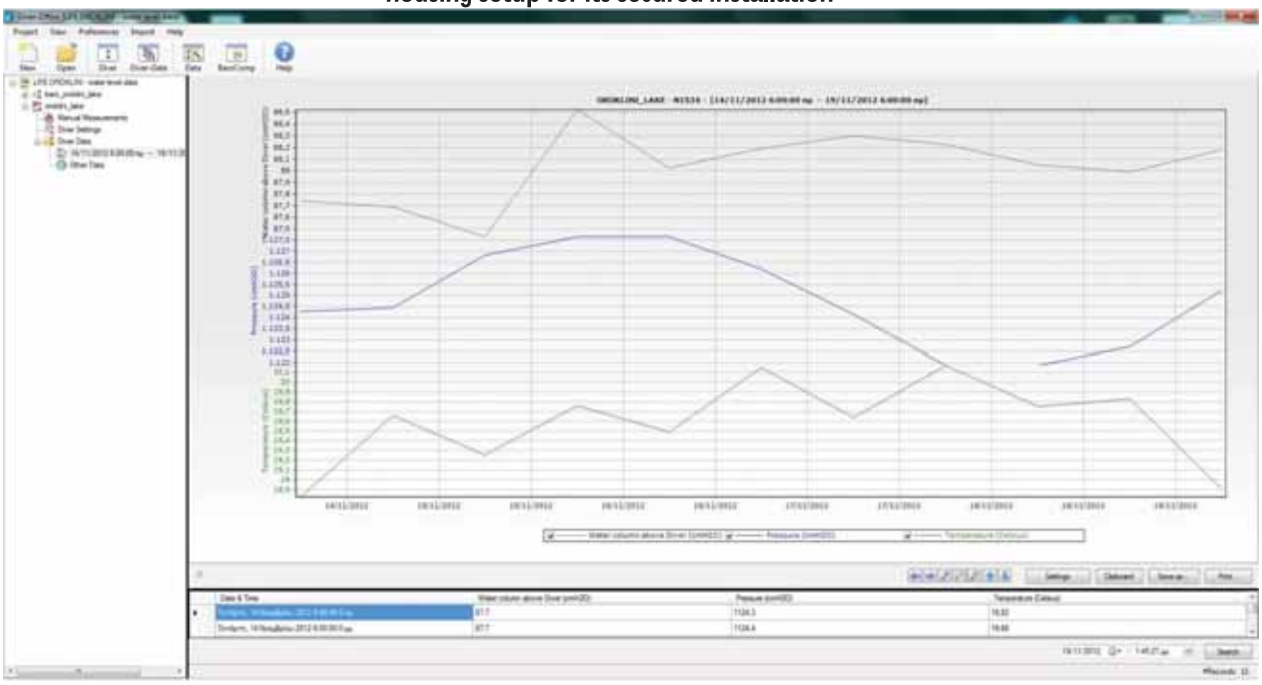


Plate 1: Software Template of water level recorder (sample output)

4. Discussion on the analytical results of surface and groundwater

4.1. Relationship of groundwater to the sea and the lake water

A crucial question arises as to the relationship of the groundwater to that of seawater and even of greater importance to that of the lake water. The latter would be useful in determining the extent of the contribution of the groundwater to the lake water balance.

In an area where no other source of saline contamination exists, high chloride concentrations in groundwater can be considered a rather definite proof of seawater contamination. Important amounts of chloride could come from other sources, such as the case of the evaporites at the bottom of the lake; however, the establishment of definite proof of the seawater source may be difficult.

Photo 7: The water level recorder and its housing

A low calcium/magnesium ratio may sometimes be indicative of seawater contamination. In our case Ca:Mg ratio for seawater is 0,303 and for the local groundwater is 0,349 (for the sample of June) and 0,288 (for October). The lake water has a much larger ratio, this being 0,671 and 0,673 for the June and October samples, respectively.

The presence of sulfate similar to that of seawater might also be indicative. It should be noted that sulfate for seawater is 2.700 mg/l whilst for the local groundwater is 13.265 and 14.465 mg/l for June and October respectively, and for the lake water is 4.092 and 4.498 mg/l for June and October respectively. This shows dissimilarity between seawater and groundwater but closer relationship of Lake Water to the Groundwater.

Boron may also be used to aid in determining whether a particular aquifer has been contaminated by seawater or by some other saline source. In our case the values are 4,5 mg/l for seawater, 8,69 to 10,8 mg/l or groundwater, and 5,29 to 5,56 mg/l for lake water leading to the same conclusion as for the sulfates above.

On a Piper Diagram when waters are the result of mixing of two different end member waters, then the compositions of the waters should plot along a straight line in each of the fields of the diagram. On the other hand, if the compositions do not plot along a straight line on the Piper diagram, then the waters cannot be related by simple mixing between the two end members. In our case the groundwater and the typical seawater sample do not plot on a straight line. In fact not even the lake water plots sufficiently well on a straight line with the groundwater sample (see Diagram 4).

Other parameters that lead to the conclusion that there is no sea water intrusion in the area and that sew water is not the cause of the increased salinity of the local groundwater and of the lake water are the following:

- Absence of the necessary hydraulic conditions such as lowering of the water-table below the mean sea level, usually caused by over-pumping. In the present case there is no any pumping of groundwater due to the poor water bearing formations and poor quality of the water, let alone over-pumping. It should be noted that the water level observations made on the investigative borehole drilled for this project show a water-table above mean sea level (see paragraph 2.3 and Diagram 3). On the 10th of September the groundwater level was at its lowest for the observed period, being at 2,23m a.m.s.l. showing a positive hydraulic slope towards the sea.
- The view that the groundwater of the area is not affected by sea intrusion is supported also by the results of the chemical analyses and more specifically by an important index of salinization, that of the ratio of Na/Cl, which could be employed to determine whether the presence of salinity in the groundwater is due to sea water or not. On the occasion of sea intrusion this ratio is less than 0,86 (molar ratio) while in the present case it is greater (0,88).
- Also, pollution by sea water could be characterized by the ratio Cl-/ HCO3- + CO32- (Simpson’s ratio).According to this ratio the characterization of pollution by sea water is subdivided in 5 classes: 0,5 for good quality water, 1,3 for slightly polluted water, 2,8 for moderately polluted water, 6,6 for seriously polluted and 15,5 for very seriously polluted water (usually at the coast). In the case of the groundwater at Oroklini lake, this ratio is more than 100, something that shows that the very high salinity in the water, which is greater than of sea water, is not related to sea intrusion, but rather to the soil type and other “operating conditions” of the aquiferous zone of the area.

All the above lead to the conclusion that there is no sea intrusion in the area and that the chemical composition of the groundwater is affected directly by the presence of sediment deposits which are very rich in salts something that is greatly supported by the investigative borehole log. This, in association with the poor permeability of the area which does not allow any leaching of the salts causes the high salinity of the groundwater.

4.2. Classification of the groundwater and Lake water

An attempt to classify the hydrochemical facies of the groundwater and of the Lake water using the trilinear plotting technique on Piper diagram (see Diagram 4 and 5) results to the following classification:

- The groundwater is of "Chloride type, Sodium type and $Cl+SO_4$";
- The Lake Water is of "No Dominant type, Sodium type and $Cl+SO_4$".

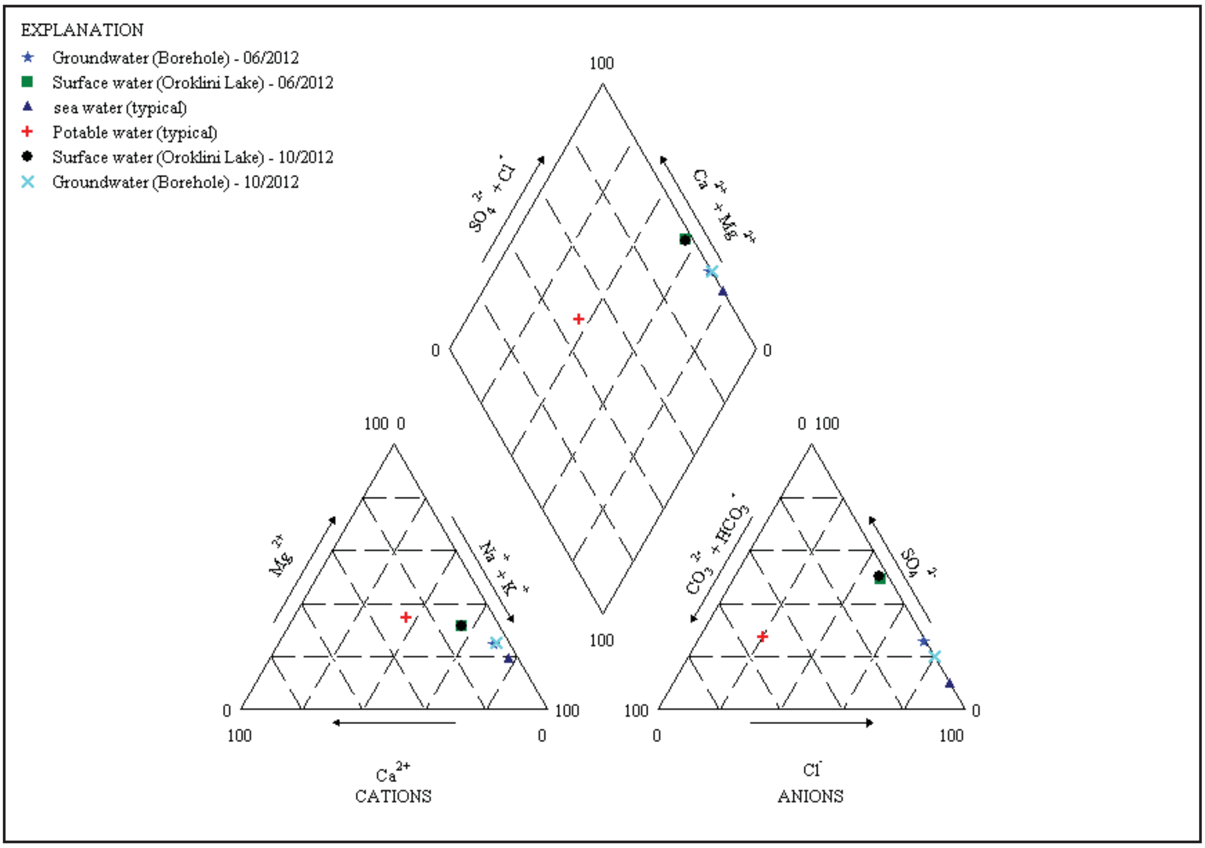


Diagram 4: Piper diagram for the groundwater and lake water samples of June and October 2012 as compared to an average seawater type of water and for potable water

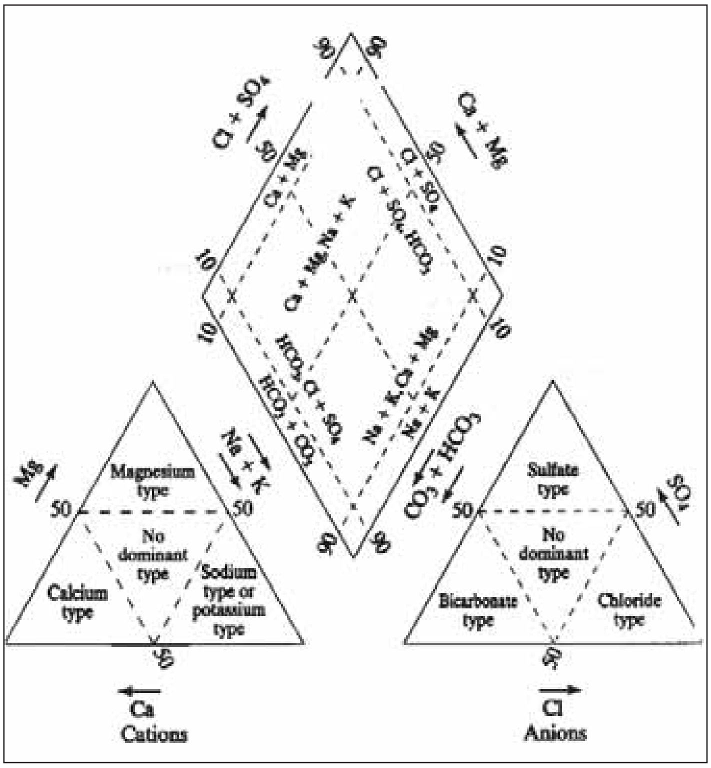


Diagram 5: Classification of hydrochemical facies using the Piper plot (A. Kehew 2001: Applied chemical hydrogeology)

4.3. Source of the salinity of the groundwater

The source of salinity of the groundwater which appears to be higher than that of seawater is the soil type of the area. The largest part of the Oroklini lake area is made up of soils of the «gleyic Solonchalks» type. The common international name of such soils is "saline soils" or "soils affected by salinity". These soils have a high content of dissolved salts[5]. They are salty soils at various gradations depending on the presence of water. Gleyic Solonchaks are widespread within the context of waterlogged areas as back swamps. These soils are present in dry and semi-dry climates and at coastal areas in seasonally waterlogged areas with grasses and/or halophytic herbs as in the case of the area of the Oroklini Lake. In low-lying areas with a shallow water table, salt accumulation is strongest at the surface of the soil.

The most extensive occurrences of Solonchaks are in inland areas where evapotranspiration is considerably greater than precipitation, at least during a greater part of the year. Salts dissolved in the soil moisture remain behind after evaporation/transpiration of the water and accumulate at the surface of the soil or at some depth.

The solubility of salts, which is temperature-dependent, is greater in the warm dry season when there is a net upward water flux from the groundwater table to the surface soil, than

[5] FAO CORPORATE DOCUMENT REPOSITORY
http://www.fao.org/DOCREP/003/Y1899E/y1899e09.htm

in the cooler wet season when salts are leached from the surface soil by surplus rainfall. Solonchaks form in depression areas with strong capillary rise of saline groundwater.

The soils in the area have a "gleyic" horizon (from the Russian local name of "gley" which means mucky mud) since they are almost completely saturated by groundwater, due to the low topography in relation to the subsurface water horizon (partly drying up only for a short duration of few weeks but not always) and show a coloured form of "gleyic" type. This mucky mud in the lake water is obvious throughout the fringe of the lake (see Photo 3 showing the sampling from the lake and the black color of the bottom water).

4.4. Need for organic pollution analyses

Organic pollutants originate from domestic sewage, urban run-off, minor industrial/trade effluents and farm wastes. Sewage effluents are the greatest source of organic materials discharged to freshwaters.

The stream flowing into the lake gathers the entire storm and other waters from the catchment which is all practically covered by the urbanized development of Oroklini. A large number of organic pollutants from a wide range of sources may enter this stream and find its way to the lake of Oroklini.

The organic pollutants may include: a) surfactants, being the main active agents in all washing and cleaning agents, b) pollutants from food and household related products, c) solvents from a large range of products such as car shampoos and degreasing products from vehicle maintenance, household cleaners etc., d) a number of organic pollutants from vehicle washing, and e) pesticides and herbicides from road weed treatment, and from gardens and parks.

Of great importance in the area, in view of the urban environment and the heavy traffic highway that crosses the stream, are the organics that are expected to be dominated by petroleum hydrocarbons, which arise from motor oil and tyres from road surfaces. A term used for a mixture of these organics is "Total petroleum hydrocarbon (TPH)".

It is requested, in the TOR, that advice be provided to BirdLife Cyprus on whether analysis of organic pollutants originating from runoff from the surrounding fields and/or roads are needed. A similar concern for the quality of water entering the lake originating both from the main stream and from the area of the Petrol Station next to the lake has also been expressed by the Community Council of Voroklini.

The two samples taken from the lake water in June and October show a ten-fold increase of the BOD_5 from 12 to 118 mg/l. The sample of October indicates increased pollution possibly caused by inflow from the urbanized catchment area which did not have any dilution with rain water. Other sources could be from the decay of vegetation, and the increased presence of feces in a reduced quantity of water in the lake having undergone evaporation. The COD shows a similar increase, 25 to 188 mg/l, between June and October. In the other hand the Dissolved oxygen, 6,6 mg/l in June and especially 9,5mg/l in the October sample suggests good conditions for the lake.

As described earlier the potential for organic pollution entering the lake from the stream draining the urbanized catchment, and from TPH from the heavy traffic in the area, is high. It is thus considered important to monitor the water flowing into the lake mainly from the main stream but also from the small amounts of water flowing from the area of the Petrol Station. The sampling should be done during the first flash floods, in the early winter, when the pollution load is expected to be at its highest, and in the summer season when the dilution of urban storm runoff would be lowest.

The analyses should include BOD_5, COD, DO and Hg and Pb (about €200 per sample). Also, analysis for TPH should be undertaken (about €50 per sample). Thus, a total cost of about €1000 for analyses should be envisaged.

Collecting samples for organic pollution, alone, is not considered though sufficient. An "*integrated study of the likely pressures on water quality degradation of the surface runoff within the catchment area*" is deemed a must if measures are to be taken to safeguard the quality of the lake water. Such a study is considered to be particularly useful for the determination of measures for the management of the lake and the maintenance of a good quality condition and its operation as a habitat, since within the catchment area there are and could be developed other infrastructure works and small industries in the presence of intense urban development. Similarly, issues such as the existing storm water network or further plans for this as well as sewage network etc. could be examined.

5. Infiltration tests

On the 14th of June, two soil infiltration tests were carried out within the drying reservoir bottom area of the Oroklini Lake aiming to arrive to some indicative value not only for the surface water infiltration but also for the uprising groundwater, when conditions allowed.

The tests were carried at the dry bed of the lake 7 and 15 meters southeast from the drilled investigative borehole, called site 1 and site 2 respectively (Photo 8). The test sites are considered representative for the bottom of the reservoir throughout, although in the deeper parts of the lake finer material is expected to occur due to longer suspension and deposition of sediments resulting to even lower infiltration rates.

For the needs of the test, a plastic pipe (ring) of 200mm diameter (188mm internal diameter) was used. The ring was gently driven for a few centimetres into the soil in such a way so as to avoid any disturbance of the soil (Photo 9).

A quantity of 0,5 L of water was first added on a plastic wrap, lining the ring and, which was pulled out at the start of the time measurement. This helped avoid any disturbance of the top of the soil. This type of test is used by the USDA for the soil infiltration and it is as per the standards of the Agricultural Department of the U.S.A. The time required for the infiltration of water within the ring constitutes an estimate of the infiltration rate of water into the soil in mm/hr.

For the Oroklini Lake the infiltration rates as shown in the calculations in Table 5 are 3 and 3,5 mm/hr. It should be noted that after 1 hr, only 3mm of water had infiltrated at the site 1 and 3,5 at the site 2 respectively and the calculations are based on these measurements. On the basis of these infiltration rates, which could even be lower if the test lasted until all the water in the ring had infiltrated, the soil type could be classified as clay.

Photo 8: Site 1 - 7m due southwest of borehole and Site 2- 15m due southwest of borehole

Photo 9: Carrying out an infiltration test at a dried part of the lake bottom.

Both the permeability and the infiltration values help to determine any possible interaction between ground and surface water.

Table 4: Calculations for the infiltration test at Oroklini Lake area

Inside diameter 188 mm Inside area of ring = πr^2 = 3,14 * $(94)^2$ = 27.759 mm^2 For 500 ml or 500.000 mm^3 Height of water in ring = 500.000mm^3/27.759 mm^2 = 18 mm Column 3=[(col2)/(col1)]*3.600				
Test results				
Location	**Time for Test (seconds)** **1**	**Height of water column infiltrated (mm)** **2**	**Infiltration Rate (mm/hr)** **3**	**Comments** **4**
Site 1, 7m SE of well	3600	3	3	Infiltration rate could be much lower since only part of the water was infiltrated
Site 2, 15m SE of well	3600	3.5	3.5	As above

6. Integrity of the embankment and the dam/weir

According to the TOR, the integrity of the dam (or concrete spillway weir) and of the bank (or earth embankment) controlling the water of the lake at section S3 (see map of Appendix I) had to be examined for leakages. The results of this examination and whether the dam needs reinforcement or just an installation of a sluice gate that will enable the control of water are reported in the text that follows.

No record exists or could be located either of the embankment and or the spillway weir design and built details. There is also no record as to when and why the retention embankment was constructed. It is known though that the drainage ditches further to the south were dug to drain the area between 1930 and 1950 due to issues with Malaria[6].

In view of the absence of design or construction plans and impossibility for on-site measurements in view of the dense vegetation, the following assumptions were made and reviewed for the weir, after the vegetation was cleared on the 10th of October.

The embankment at the lake, of 292m length and about 2m width at the crest, is considered as an "Earthfill Dam" type containing more than 50 percent, by volume, earth fill materials, soil and rock materials that are predominantly gravel sizes or smaller. It is also assumed that the embankment is of rolled-fill type where materials from borrow pits and suitable materials from excavations for other structures were delivered to the embankment and spread in layers, each layer having been thoroughly compacted and bonded with the preceding layer by power-operated rollers.

The spillway of the embankment, as shown on Photo 10-left and Photo 17-left, is made up of a concrete broad crested weir of 9m length[6]. The spillway crest level is 0,9m from the embankment crest level.

The vegetation on the upstream side of the embankment is so dense that made any site survey extremely difficult. The most difficult part was the area of the weir itself where the vegetation was very dense something that made it impossible to check the weir for leakage or consider the need for a sluice gate (Photo 10 – right and Photo 11). The situation before the clearing of the vegetation is given by Photo 10–right, which can be compared with a photograph taken in 2008 (Photo 10 – left).

BirdLife Cyprus, followed the Consultant's recommendation that it was imperative, not only for the needs of this study, to have the area around the weir cleared of the vegetation which was totally obscuring it, but also for providing the conditions of the weir to work efficiently as a spillway and, arranged the clearing of the vegetation from the area within and around the weir on the 10th of October. The weir was uncovered and details of its condition were revealed (Photo 16 and 17).

[6] Heycock N. and Heath Tom (27th June 2008): "Hydrology Report of Oroklini Marsh, Cyprus,"


Photo 10: Weir during wet year, looking West (After Haycock Hydrology report, Oroklini Marsh, 2008) (Left) and same area on the 21st of June 2012 (Right)


Photo 11: Conditions at the Weir on 16th August 2012, South view (Left) and same area, North view (Right)

6.1. Field inspection on the integrity of the bank and the weir

On the 12th of June a site field survey was carried out along the whole extent of the embankment (bank) examining its integrity for leakages up to the spillway concrete weir.

On the 17th of October a site visit was carried out at the site of the weir which was cleared of all the vegetation on the 10th of October and the whole structure was revealed. The needs for reinforcement of the structure, identification of deficiencies or concerns that may potentially affect the safety of it as well as the need for an installation of a sluice gate for controlling the flow of the water were considered.

Some points of interest are:

6.1.1. The embankment

The surface area of the embankment (top and southern part) has been checked by walking over the slopes and crest systematically in order to see the exposed surface area clearly. The northern part towards the lake is covered by dense vegetation and could not be observed.

At regular intervals while walking the slope and crest of the embankment:

- The earth surface and its alignment was observed

- Distortions and other anomalies of the embankment surfaces and subtle changes in vegetation were noted.
- The areas where the embankment contacts the abutments could not be fully checked because of the dense vegetation at the weir. Only the western abutment was observed.
- Minor erosion/ slides at the surface, and traces of flow were noted.
- Seepage points, cracking, instability, settlement and maintenance concerns were noted (such as inadequate slope protection, surface runoff erosion, inappropriate vegetative growth and animal burrows).

The observed conditions of the embankment are as follows:

- No embankment cracking (longitudinal, transverse and desiccation cracking) was observed either at the crest or the slopes.
- The earthen bank appears to be quite stable without any serious instability situations such as slides displacements etc.

Other observations made are the following:

- At least one point was observed where leakage occurred this being at the lower berm, at a location 170 meters from the most western starting point of the embankment (Photo 12).
- Increased ant burrows along lines of minor cracks at 45m (Photo 13-left) and 225m from western most point of bank (Photo 15- left).
- A minor subsidence has been observed between the point 120 and 230 m from the western starting point of the embankment (Photo 14). Increased vegetation was noticed on the bank in this area (Photo 14-left). On the basis of this observation the topographic survey carried out under this project, considered the embankment and revealed the extent of this subsidence, shown on Diagram 6. The maximum subsidence is about 0.35m, the average being about 0,20m over a distance of about 100-110 meters. This subsidence should be corrected by raising the embankment to its previous level using earth material similar to the rest of the bank and be compressed by roller.
- In certain areas of the bank, traces of flow with salt deposition on the top soil were noted with minor erosion of the downstream side of the bank (Photo 13-right and 15-right)
- The vegetation on either side of the bank acts as a stabilizing agent.

All embankment dams are meant to pass some water through them in the form of leakage or seepage. The leakage observed will be a problem only if embankment material is moved by the water flow. This does not appear to be the case. The presence of vegetation along all the southern slope of the embankment indicates that some seepage occurs which maintains the vegetation (see Photo 13– right). The only point of definite leakage in the form of minor spring operating at some high water level in the lake was the one detected at the point 170 m from the western most point of the embankment (Photo 12). This leakage point needs to be particularly checked and monitored. If the flow increases then remedial works need to be undertaken.

The above remarks are the only ones that can be made on the basis of the detailed field inspection of the embankment.

Photo 12: Non active (12/6/2012) seepage point at the lower berm of the bank at 170m from western most point

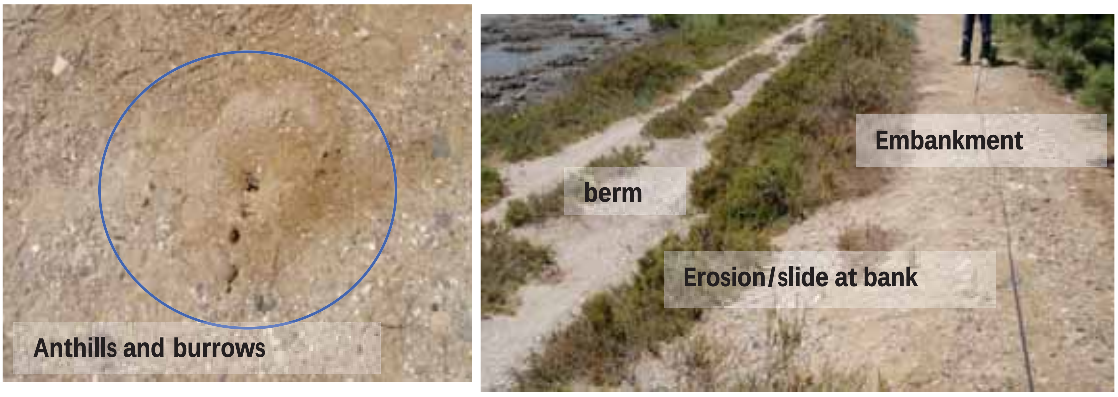


Photo 13: Photo 3: Burrows and anthills at 45m from western most point on embankment (Left) and erosion/slide at 75m (Right)

Photo 14: At 135m from western most point showing subsidence between 120 -230 m with increased vegetation in subsided area

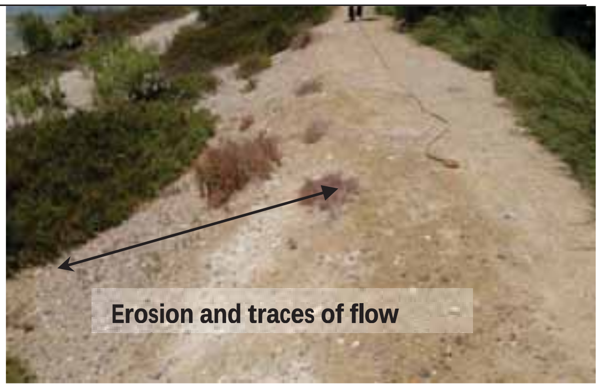


Photo 15: Anthills and possible minor crack on bank at 225m (Left) and erosion and traces of flow (salt deposition) at 250m (Right).

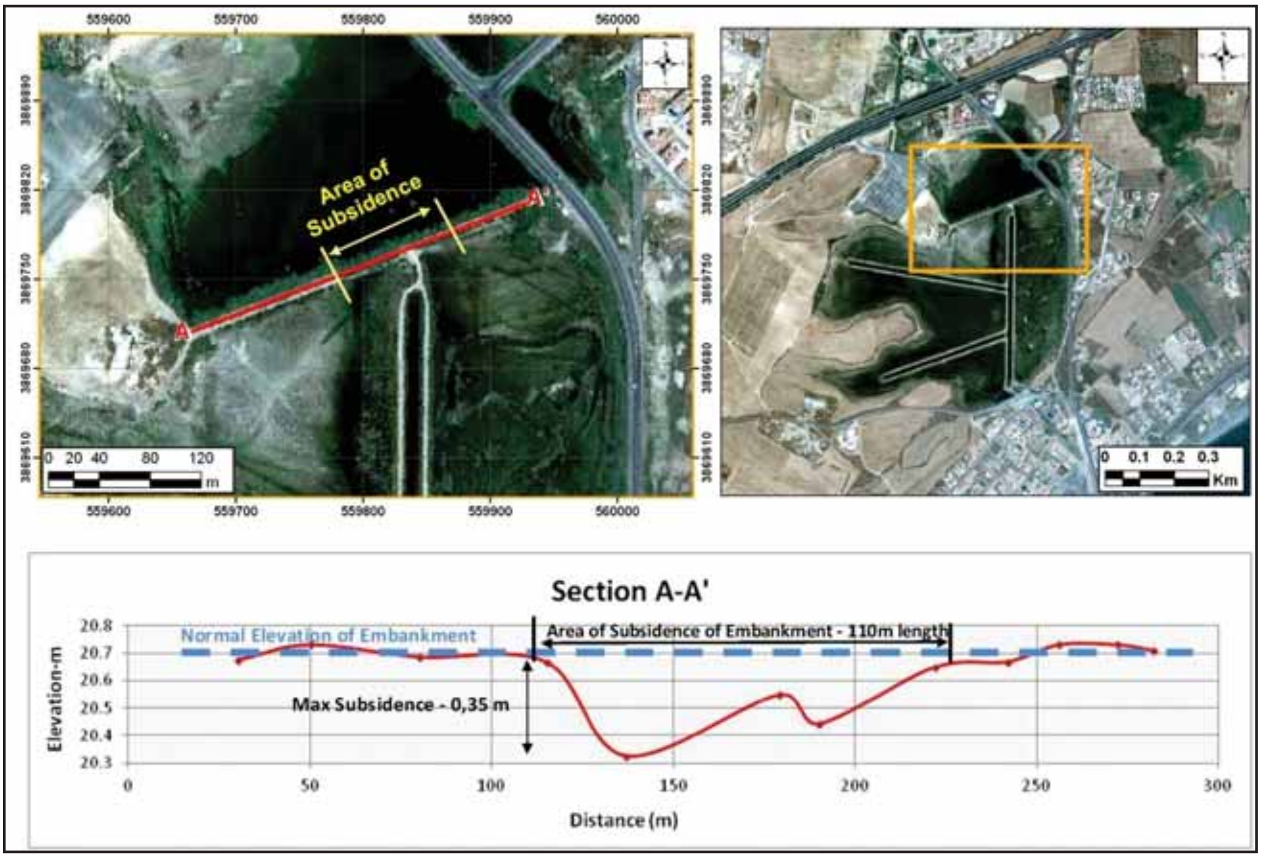


Diagram 6: Subsidence of the embankment observed in the field and measured by the topographic survey

6.1.2. The weir

A survey of the weir was made on the 17th of October after the vegetation was cleared away.

The following observations were made:

- The wing-wall in the eastern part of the weir, next to the public road, has been removed and the easternmost two meters of the spillway crest of the structure have been removed when the weir was breached in 2008 to enable the draining of the lake "due to Bird flu fears".
- The concrete in this part has been replaced by earth material (see Photo 17).

- The remaining elements of the concrete structure appear to be relatively in good condition. Minor seepage occurs on the spillway wall as shown on Photo 16.
- The 1,5 -2,0 meters of the easternmost part of the concrete spillway crest appears to have been tampered with and the top 15-20 cm of concrete has been removed.
- The highest water mark on the western wing-wall is about 15 – 20 cm lower than the spillway crest corresponding to the lowered by the same amount spillway crest in the easternmost 1,5 – 2,0 meters.
- A v-notch at the centre of the spillway crest is in good condition but taken up by roots. This must be kept clear.
- The width of the spillway crest of the weir is 32 cm.
- A minor crack at the downstream side of the western wing-wall does not pose any danger. The rest of the wing-wall is in excellent condition and has a width of 40 cm.
- The location for the water level recorder was chosen at the corner of the upstream side of the spillway crest and the western wing-wall. On the 17th of October the water level at this point was 70 cm whilst the top water level was evaluated to be 90 cm. The total height to the top of wing wall is 1,90 cm.

Photo 16: Minor seepage shown on the spillway wall during the spill of the lake on November 14th 2012

As a result of the above observations it is recommended that:

- The eastern wing-wall should be constructed to the same shape and size as the standing western wing-wall.
- The breached part of the weir must be reinstated in concrete.

- Allowance should be made for a sluice gate as shown in detail in the section further below under the proposed management works.
- The lowered by 15-20 cm of the 1,5 – 2,0 meters eastern part of the spillway crest should be reinstated to its original elevation.
- The seepage on the spillway wall should be fixed during the construction works that will be undertaken at the weir. Insulating material (asphalt or other more suitable material should be placed on the upstream part of the spillway. Cement injection may also be considered.
- The CYTA wire which was found to cross the weir and the bottom of the lake (Photo 17-right) should be further investigated with CYTA and be removed.
- The weir should be maintained clear of the vegetation so that the spillway operates effectively.

Photo 17: Conditions at the Weir on the 10th October 2012, West view (Left) and north-west view (Right)

6.2. Weir capacity evaluation for low frequency floods

As part of the testing of the integrity of the weir which acts as a spillway for the lake and in view of the deliberate breaching that was effected in 2008, as discussed earlier, it was considered useful to check the capacity of this weir, as is at present, for low frequency flood events.

Thus, the capacity of the spillway weir to accommodate flows with return period of 2, 5, 10, 20, 50, 100, 200 and 500 years was tested by working the hydrology and peak flows at such frequencies and examining the capacity of the weir to route them downstream without over-topping the earthen embankment.

This evaluation for flood accommodation by the weir was carried out using the HEC-RAS model as applied to "in-line structures" along a river reach, assuming full lake conditions. The parameters for a broad crested weir were used with a geometry assumed as presented above.

The rainfall record (depth/duration/intensity) at Meteorological Station 731 at Larnaka Airport was used for determining the rainfall events at various return periods.

The characteristics of the catchment area used for the determination of the time of concentration of flow were determined as presented in Table 5 that follows.

The selected time of concentration is 1,5 hours being slightly less than the average of the Turazza-Giandotti method of 2,2 hours and of the SCS Lag method of 1,3 hours, for a conservative approach.

The magnitude of flow events at various return periods was based on the use of the Rational Formula. The Table 6 below presents the storm intensities and peak flows at the various return periods for the assumed time of concentration of 1,5 hours. The runoff factor used for this is 0,37 based on the criteria discussed further below.

Table 5: Characteristics of the catchment area of the stream flowing into Oroklini Lake

Basin	Basin Area (Km^2)	Mean slope of Basin (m/m)	Longest Flow Path (m)	Mean Basin Elevation (m)	Min Basin Elevation (m)	Max Basin Elevation (m)
Oroklini River	2,95	0,1	2500	39	1,7	171

Table 6: Storms and peak flows at various return periods for the Oroklini Lake

Oroklini River				Return Period (years)							
				2	5	10	20	50	100	200	500
Time of Concentration (T_c)	**Runoff Factor (C)**	**Basin Area (Km^2)**	**C*A**	**Storm Intensity (mm/hr)**							
				14,7	19,7	23,0	26,1	30,2	33,2	36,3	40,3
1,5	0,37	2,95	1,09	**Peak Flow* (m^3/s)**							
				4,5	6,0	7,0	8,7	11,0	12,6	14,3	16,5

**For 20, 50, 100, 200 and 500 yr return period, the peak flows are multiplied by an adjustment factor which is 1,1 1,2, 1,25 1,3 and 1,35 respectively. Less frequent, higher intensity storms require adjusted runoff coefficients because infiltration and other losses have a proportionally smaller effect on runoff.*

The estimation of the runoff factor has been based on a mix of land use analysed into 68% residential area and 32% other type (16% cultivated and 16% forest). The hydrologic soil group on the basis of the classification by the NRCS has been determined as of "Group B", being silt loam or loam.

For a slope of >6% the runoff coefficient for the rational formula for Residential area (single house plots) is 0,44, for cultivated land is 0,28 and for forest is 0,18. These figures for the mix of land use as given above result to a coefficient of runoff of 37%.

Using the HEC-RAS, the peak flows for the various return periods were routed through the weir as shown in the Diagram 7. It appears from this Diagram 7 that the weir capacity (9m long and 0,9m deep) can cope with floods up to 12,6 m^3/s which occur at a return period of 100 years (or even up to 150 year events). Floods of greater magnitude than this will overtop the embankment and pose serious danger to the structure.

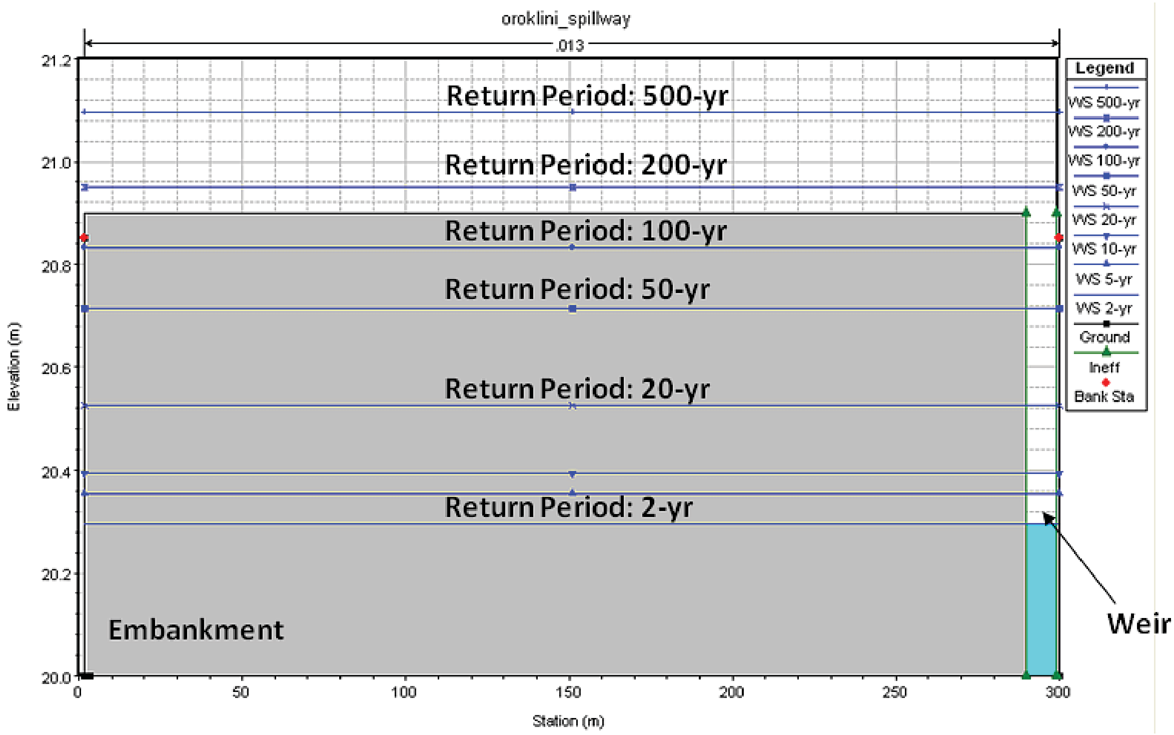
It should be noted that the vertical axis of the Diagram 6 is exaggerated compared to the horizontal axis for clarity purposes.

A summary of the results of the flood capacity evaluation of the weir is presented in Table 7 where the water surface depth, the flow and the weir flow area for each return period are given.

The velocity is of the order of 1,7 to 2,0 m/s which are quite low and not expected to produce any erosion effects. Besides, the weir is made of reinforced concrete which can withstand much larger velocities.

Table 7: Summary of the results for the weir capacity evaluation for routing various flood events

River Name	Flood Event (years)	Weir		
		Peak flow (m3/s)	Water Surface Depth (m)	Weir Flow Area (m^2)
Oroklini River	2	4,5	0,29	2,61
	5	6,0	0,36	3,24
	10	7,0	0,39	3,51
	20	8,7	0,53	4,77
	50	11,0	0,71	6,39
	100	12,6	0,83	7,47
	200 or More	14,3 or more	Embankment Overflow	



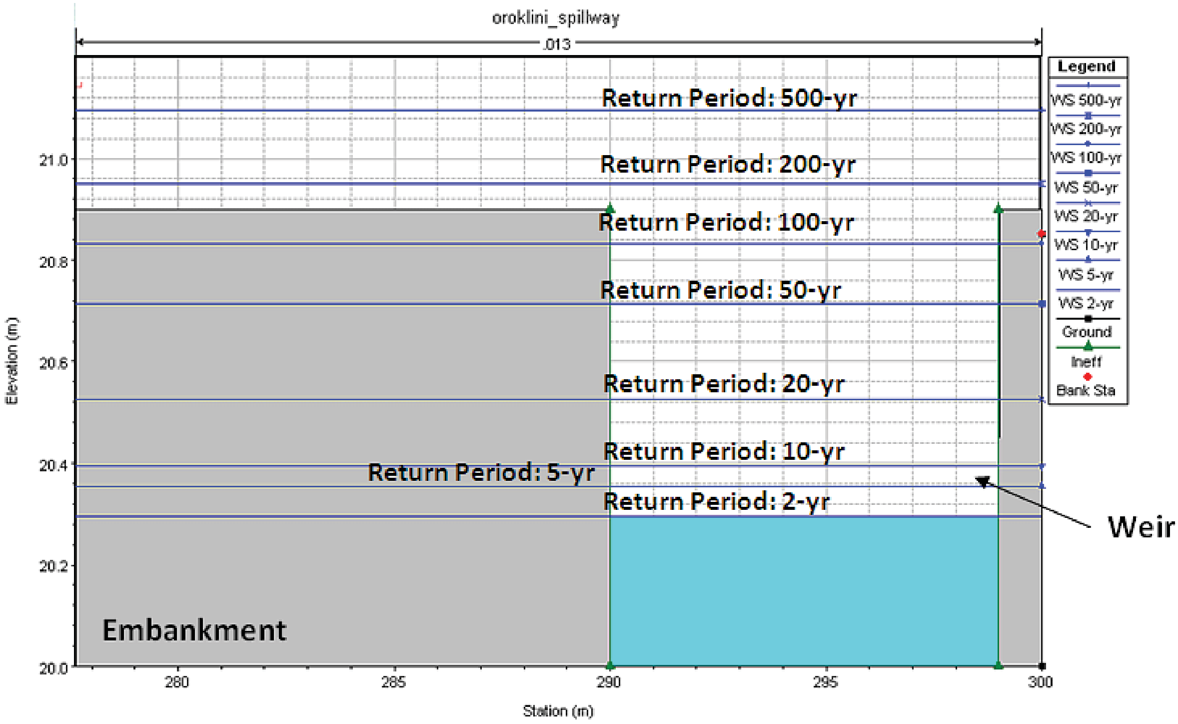


Diagram 7: View of the embankment and weir cross section in full size (above) and in blow up for the weir (below) with water surface profiles for the floods at various return periods

6.3. Concluding remarks on the integrity of the embankment and the spillway weir

Some concluding remarks are:

- The embankment is found in good condition and should withstand the pressure of the water stored in the reservoir.

- No serious leakage was found except in one case which should be monitored and be corrected if the flow is increased.
- A minor subsidence of an average of 20cm is observed between 120 and 230 m from the western starting point of the embankment. This has to be reinstated to the previous level using earth material similar to the rest of the bank and compressed by roller.
- Minor downstream areas of the bank which show signs of erosion could be reinstated.
- The weir needs major construction works, namely:
    - The eastern wing-wall needs to be constructed at the same dimensions as the western wall.
    - The spillway crest should be established at the same level, throughout. The eastern 2 meters which have been excavated to some 20 cm lower, should be reinstated.
    - A sluice gate is needed to be established as shown on the section of proposed management works (Figure 4).This will allow a better management of the water in the lake. If this management proposal is pursued, then a foot-bridge will also be required as is also shown on Figure 4. The weir should be kept free of vegetation at all times so that its operation is not hindered. The size of the spillway weir allows the routing of 100 year flood events (even 150 years)

7. Water Operation Study of Oroklini Lake

7.1. The Water Operation Study for the available observed series of years

A detailed monthly water operation study of the Oroklini Lake, as defined by the embankment at the area of S3 (see Appendix I), has been worked out on the basis of the hydro-climatological conditions of the years 1968 to 2011 (Appendix II).

This water operation study of the lake, and the model developed as an “excel spreadsheet” for it, can be used in the future when environmental objectives (i.e. selected water level at the lake, volume required or surface area of the lake etc.) are determined.

This water operation study has been based on the monthly rainfall record of the Meteorological Station 713 (being at the elevation of 45 m. a.m.s.l.) at Aradippou which is the closest, being only 6,5 km away, and most representative in terms of altitude to the catchment area of Oroklini. The available mean monthly evaporation rate (1991-2005) as measured at the Meteorological Station 731 (at the elevation of 1 m. a.m.s.l.) at Larnaka Airport was used.

The study takes into account all sources of inflow such as runoff, direct precipitation, and rising groundwater, and losses such as evaporation, and outflow.

The model works as follows:

The calculations are carried out in three stages:

a) Inflow computations before evaporation is applied,

b) Outflow calculation including evaporation loss, and

c) Evaluation of final balance computations

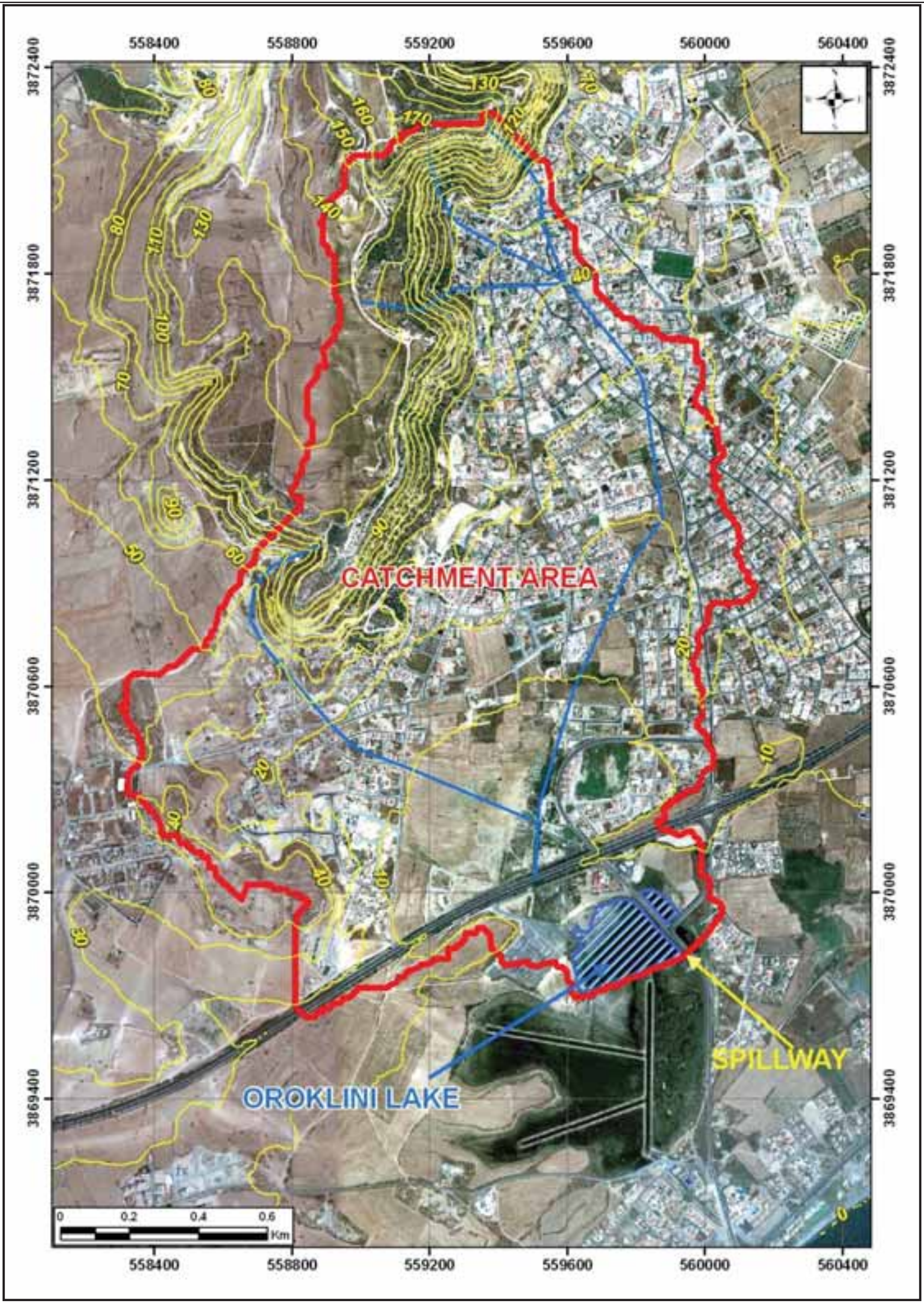
<u>Inflow computations before evaporation is applied</u>

- The model starts on October 1968 (October being the first month of the hydrologic year when the first runoff may usually be observed) with initial water content in the lake set at zero.
- The rainfall for the month is multiplied by the area of the lake (60.459 m^2) to provide the volume of water due to direct rainfall on the lake (see Map 1).
- The rainfall for the month is multiplied by the catchment area (2.895.668 m^2) and by the runoff coefficient (0,37 as described further below) to provide the volume of runoff (see Map 1).
- The Water Volume of the Lake before spills and evaporation (m^3) is the sum of the volume due to direct rainfall on the lake, the volume due to runoff, the groundwater contribution as described further below, and the volume of the previous month.
- The total volume of the month is checked and if less than the maximum capacity, that volume is set for the month. If higher than the maximum capacity then the maximum volume is set for the month.

- The volume of water over-spilled is determined as the excess of the maximum capacity of the lake.

<u>Outflow computations including evaporation loss</u>

- On the basis of the volume set for the content of the lake, the water stage is determined through the use of the “capacity vs. stage” curve of the lake (Diagram 8).
- Using the stage of the water level the corresponding water surface area of the lake is determined using the “stage vs. area of the lake” curve (Diagram 9).
- The potential loss of water by evaporation is calculated using the water surface area multiplied by the mean evaporation for the month.
- If on the same month there is spill then the loss by evaporation is replaced by the spill.
- The spill for the month is adjusted accordingly.



Map 1: Satellite photo (2003) of the lake area and the catchment area of the streams flowing towards it

Computations of final water balance

- The finally estimated quantity lost by evaporation is subtracted from the water content of the lake (estimated before evaporation) with the minimum content set at zero (not below zero).

- On the basis of the resulting volume set for the content of the lake (after evaporation) the water stage is determined through the use of the “capacity vs. stage” curve of the lake (Diagram 8).
- Using the stage of the water level the corresponding water surface area (after evaporation) of the lake is determined using the “stage vs. area “of the lake curve (Diagram 9).

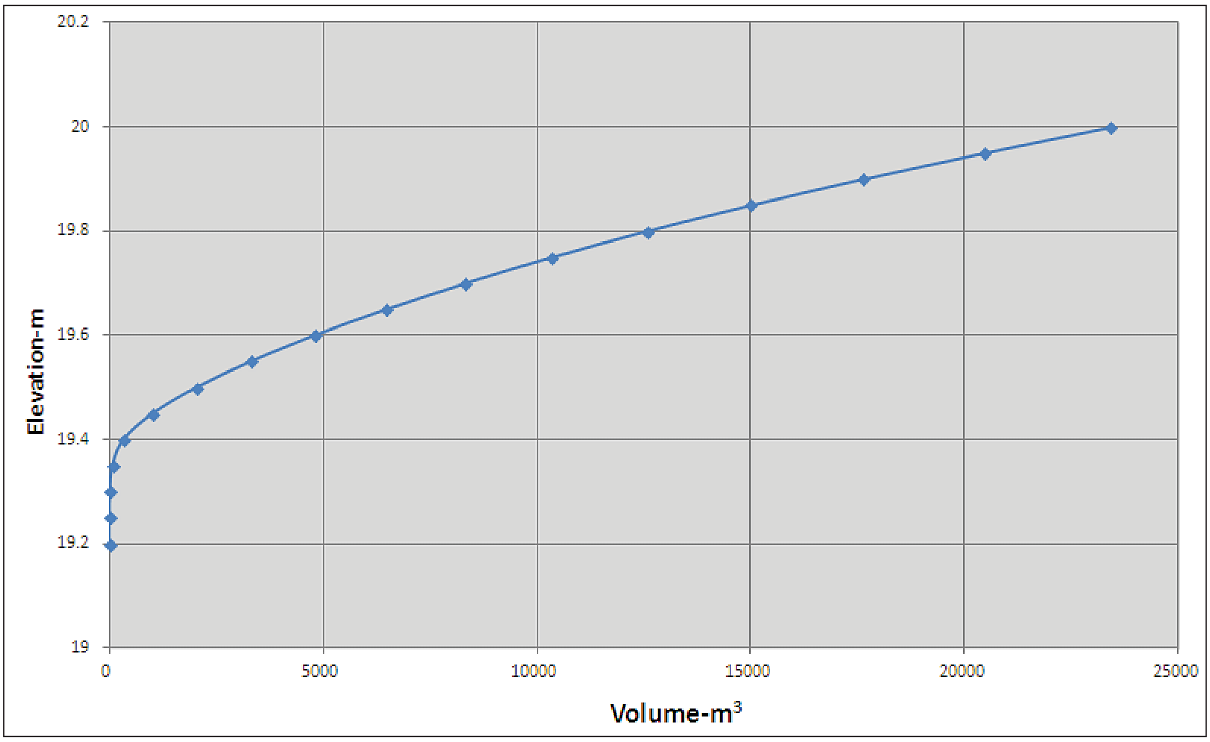


Diagram 8: Storage capacity curve vs. water level in the lake

<u>Runoff coefficient</u>

The estimation of the runoff factor as described earlier has been based on a mix of land use making up the catchment and analysed into 68% residential area and 32% other type (16% cultivated and 16% forest). The runoff coefficient for a general of slope > 6% is assumed 0, 44 and 0,23 respectively giving an overall coefficient of runoff of 37%.

<u>Groundwater contribution</u>

Evaluating the contribution of groundwater to the water balance of the lake is quite difficult with the available information. Topographically, and having in mind the groundwater level fluctuation as has been observed in the period of June to October groundwater is expected to contribute as “rising” water to the lake. Another evidence to this, is the fact that runoff (in very small quantities) was observed throughout the summer period at a time that no rainfall occurred. This runoff is believed to originate from the marsh area upstream the main highway where groundwater is gradually “seeping” as rising water. This has also been the long time observation of Mr. Andreas Theodosiou, Community Board Secretary, in that the groundwater arises gradually to the surface at the marsh area upstream of the highway.

This, in his opinion, is the main reason that flow is observed at the stream under the Highway culvert during the summer period.

In evaluating the amount of groundwater contribution, the coefficient of permeability as per the top layer of the investigative borehole of 1,8 x 10-3 cm/day was used. When this is applied over an area of about 0,45km^2 of marsh area upstream the highway and the lake and marsh area around it, it results to about 250 m^3/month

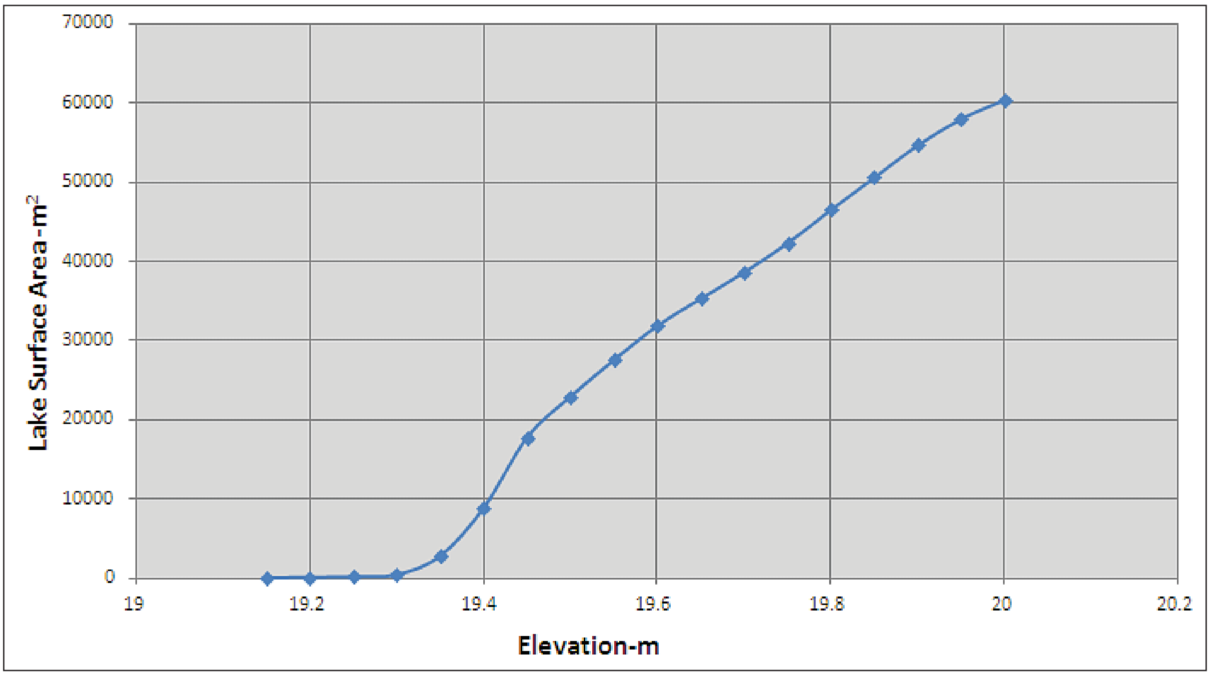


Diagram 9: Lake water surface area vs. Water level in the lake

The monthly water operation study of the Oroklini Lake based on the hydro-climatological conditions of the years 1968 to 2011 (Appendix II) has shown that due to the small capacity of the lake compared to the annual runoff of the Oroklini stream, the lake collects water every year exhibiting spills in most months.

In Table 8 the frequency of months at which the lake appears to be totally dry, as a result of the water operation study using the hydro-climatologic record of 1968 to 2011 is shown. The month of August has the highest frequency (76,7%) followed by July (55,8%) and September (55,8) and June (11,6). The month of October could also be expected to be dry, but very rarely (2,3%).

Table 8: Frequency in % of months with occurrence of dry conditions in the Lake in the period of 1968 – 2011 (43 years)

Number of Years	Frequency of months with occurrence of dry conditions in the lake (1968-2011) in (%)											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
1	2,3											
5									11,6			
24										55,8		55,8
33											76,7	

Table 9 shows the frequency of months at which the lake appears, as a result of the water operation study using the hydro-climatologic record of 1968 to 2011, to spill over the weir. In the months of December, January and February the lake is always full and exhibits spills. The months of October November, March and April, also exhibit spills at high frequency, 86,0, 95,3, 93,0 and 95,3%, respectively. The month of May also results to spills quite often (at a 76,7% frequency). In the months of June, July, August and September the lake occasionally may have spills at 32,5, 7,0, 13,9 and 23,2% frequency, respectively.

Table 9: Frequency in % of months with occurrence of wet conditions with quantities spilled from the Lake in the period of 1968 – 2011 (43 years)

Number of Years	Frequency of months with occurrence of spills from the lake (1968-2012) in (%)											
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT
3										7,0		
6											13,9	
10												23,2
14									32,5			
33								76,7				
37	86,0											
40						93,0						
41		95,3					95,3					
43			100	100	100							

7.2. The Water Balance under drought, average, and wet conditions

The water balance has also been performed on a monthly basis under the three scenarios of drought, average rainfall and wet conditions.

The total annual rainfall for the period 1968 -2011 was statistically analysed and:

a) The year 1976-77 with rainfall of 320 mm being very close to the mean value of rainfall (347,7 mm) was selected to be used for the monthly water balance under average conditions;

b) The year with rainfall of the average (347,7 mm) minus one standard deviation (106,3) or 241,4 mm was used to represent the year under drought conditions. For this, the year of 1995- 96 with a total rainfall of 247,5 mm was selected, and

c) The average rainfall plus one standard deviation, or 454,0 mm, was used to represent the year under wet conditions. For this, the year 2001-02 with a total rainfall of 437,4 mm was selected.

The years used for the scenarios have been selected as stated above and on the basis of the annual total rainfall. The monthly distribution of rainfall could affect the distribution of water availability in the lake.

The water balance derived in the same manner as discussed in paragraph 7.1 for each scenario is presented in Appendix III.

The monthly water balance under the three scenarios is shown in Figures 1 to 3. Each figure shows the monthly water level in the lake, the monthly volume stored and the water surface area of the lake.

In the dry year scenario as per (b) above (Figure 1), the lake appears to be dry in the months of July, August and September. All the other months appear to provide a full lake except for June at which the lake is less than half full.

In the average year scenario as per (a) above (Figure 2), the lake is dry only in the months of June, July and August. The rest of the months, show full conditions for the lake except for the month of May when the lake is only nearly half full.

In the wet year scenario as per (c) above (Figure 3), the lake is never dry. In all the months the lake is full except for the month of July during which it is a quarter full.

It should be stressed again that the due to the capacity of the lake (23.400 m^3) being rather small compared to the inflow potential of the catchment, even at the dry scenario there is water in the lake.

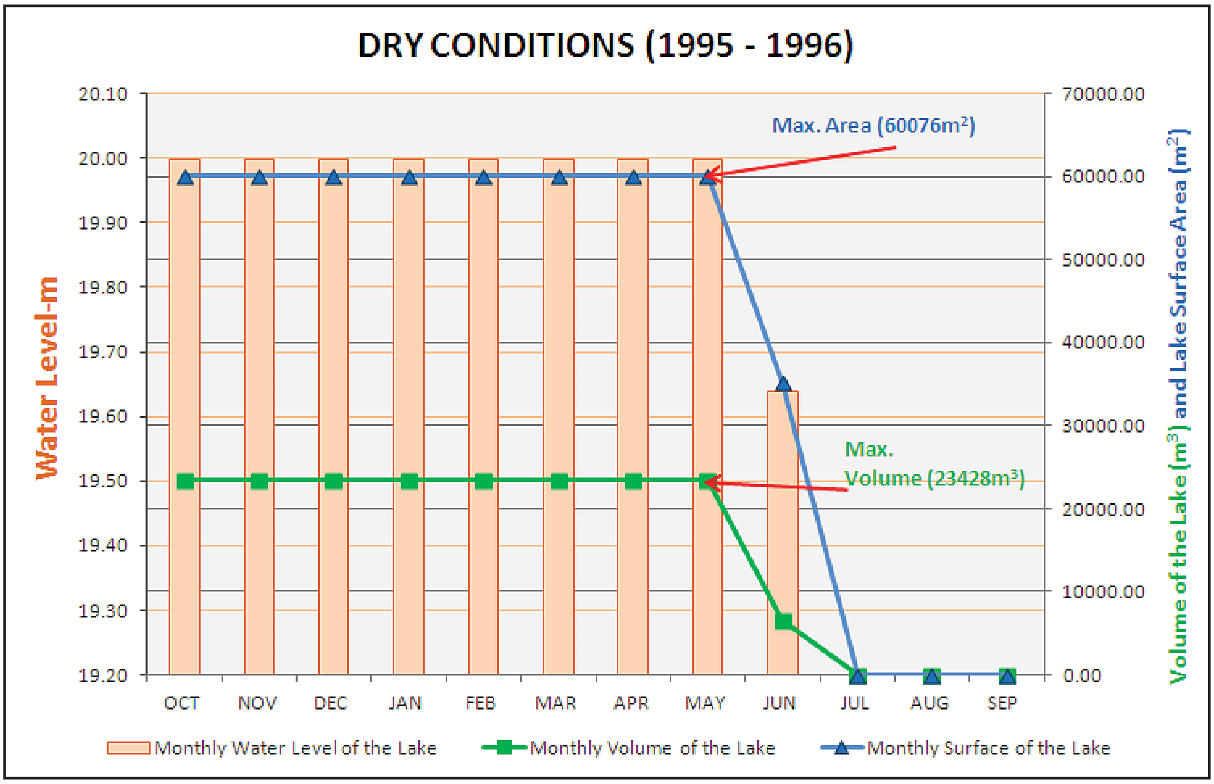


Figure 1: Water balance of the lake under dry conditions (Average minus 1 standard deviation)

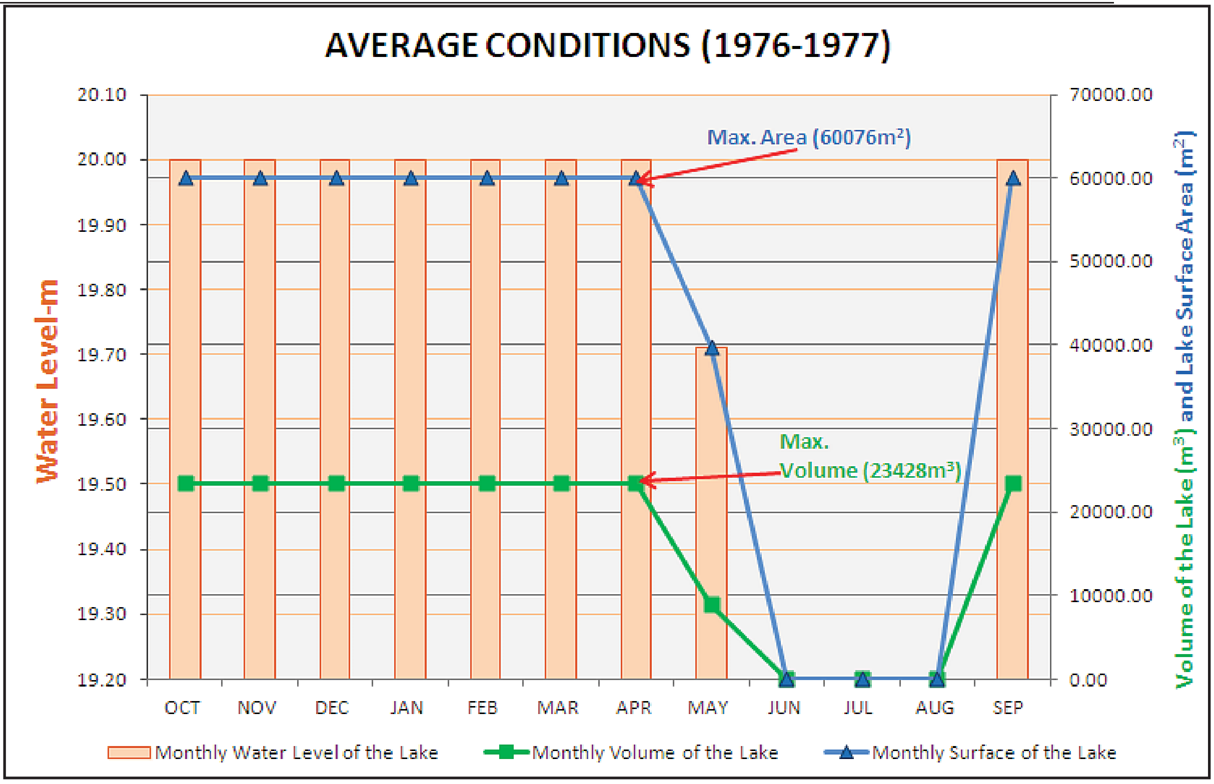


Figure 2: Water balance of the lake under average conditions

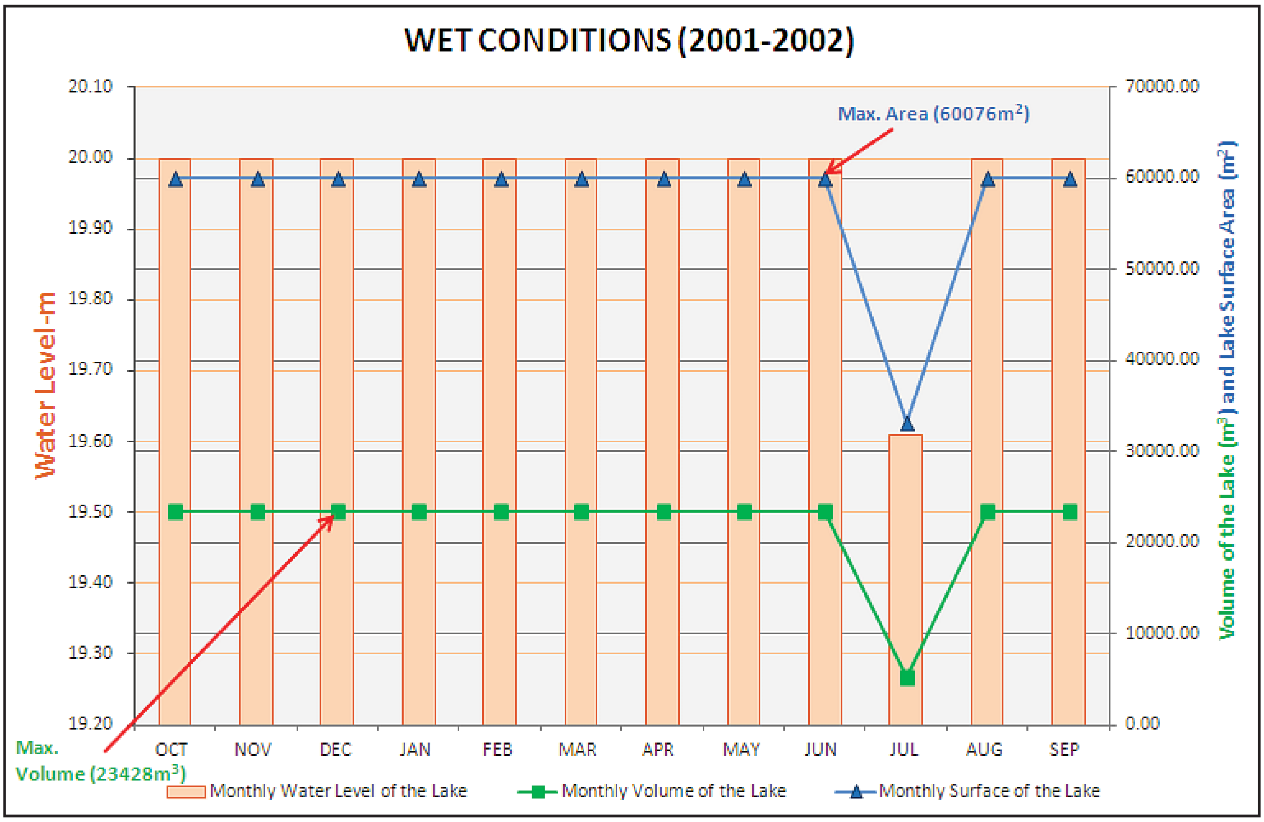


Figure 3: Water balance of the lake under wet conditions (Average plus 1 standard deviation)

7.3. Proposed prescriptions for the management of the water in the lake

A set of prescriptions are made for the management of the water in the lake, based on the water operation study, and on the proposed water management works which are outlined and discussed later in the text. These, which could be used for the Action Plan for Oroklini Lake which is expected to be developed at a later stage during the Life project implementation, are the following:

The lake tends to dry up completely in the summer months depending on the quantities of the water accumulated in the wet period and depending on the dryness of the summer months.

Some notable points for consideration for the management of the water in the lake are:

- The continuing urbanization of the runoff catchment area (Photo 18) suggests that runoff into the lake should be expected to increase in the future since the coefficient of runoff will be increasing due to more impermeable areas (roads, roofs, parking areas etc.). At the same time some deterioration of the quality of the surface runoff should be expected.
- At present there is no urban sewage network in the catchment. Once the Community Council proceeds with the establishment of a sewage network, then a reduction of the available runoff and at the same time an improvement of the quality of the surface runoff should be expected.
- A study for the pressures within the catchment area that affect or could affect the quality of the surface runoff should be initiated. This could involve identification of sources (with sampling and chemical analysis if required) and proposals for measures to reduce or eliminate them.

Photo 18: The urbanized area of the runoff catchment (68% of the total)

- In the southern part of the Oroklini marsh area, along the coastal road, a pipe network exists, for the irrigation of the gardens of the coastal Hotels, with an extension up to the old pump house at the end of the main canal. This brings tertiary treated effluent water from the Larnaka Sewage Treatment Plant to the area.

Tertiary treated water was released in the past in the Oroklini Lake. The possibility of having access to this network and use of certain quantities of this water for maintaining the lake and marsh area when needed should be investigated. The expected concentration of the main quality parameters of the re-cycled water are[7] : 10 mg/l for BOD5, 70 mg/l for COD, 10 mg/l for SS, TN≤ 5 mg/l, 1 mg/l for TP and 2.1 mS/cm for Electrical Conductivity.

- Another source of water for occasional use for the Oroklini Lake would be the water from the Southern Conveyor which runs along the main highway towards the Kokkinochoria. The Water Development Department should be approached to consider: accessibility to an outlet and, terms and quantities of water that could be used from this source.
- Other management prescriptions and proposed water works are presented and discussed in the text that follows. Selection of any of these will depend on the environmental objectives that will be set up by the Action Plan.
- A detail water operation model will need to be set up and operated to deal effectively with any management plan and prescribed environmental objective. This will have to operate on a daily basis involving thus a daily rainfall-runoff model and daily operation rules to meet set management objectives once decided.

[7] WDD, MANR&E (2010) Feasibility study for the use of the recycled water of Larnaka

8. Assessment of proposed water management works

A number of water management works have been proposed in the Terms of Reference for which a short assessment report was required to be made.

The assessment indicates which of these water works are needed in managing the water levels in the different sectors of the lake and prevent the drying out of the lake during dry seasons, to fit the needs of the target species. This assessment will be taken into consideration by the “Reserve management” expert when giving advice on how to proceed, taking into account the species needs.

For each of these water works tentative technical specifications/guidelines and draft schematic drawings for their implementation are provided.

8.1. Reinforcement of the dam surrounding sector S3 (Appendix I) and installation of a sluice in the southeastern side

The spillway weir is reported[8] to have been deliberately breached during the wet season of 2007 – 2008 in an effort to empty it “due to Bird Flu fears” at the time. According to the reports, the easternmost 80cm was removed allowing the lake to drain downstream in a single day. It is also reported that the weir was reconstructed using rock and mud and no concrete. Fears were expressed at the time that the spillway structure may not hold up during the next major flood event.

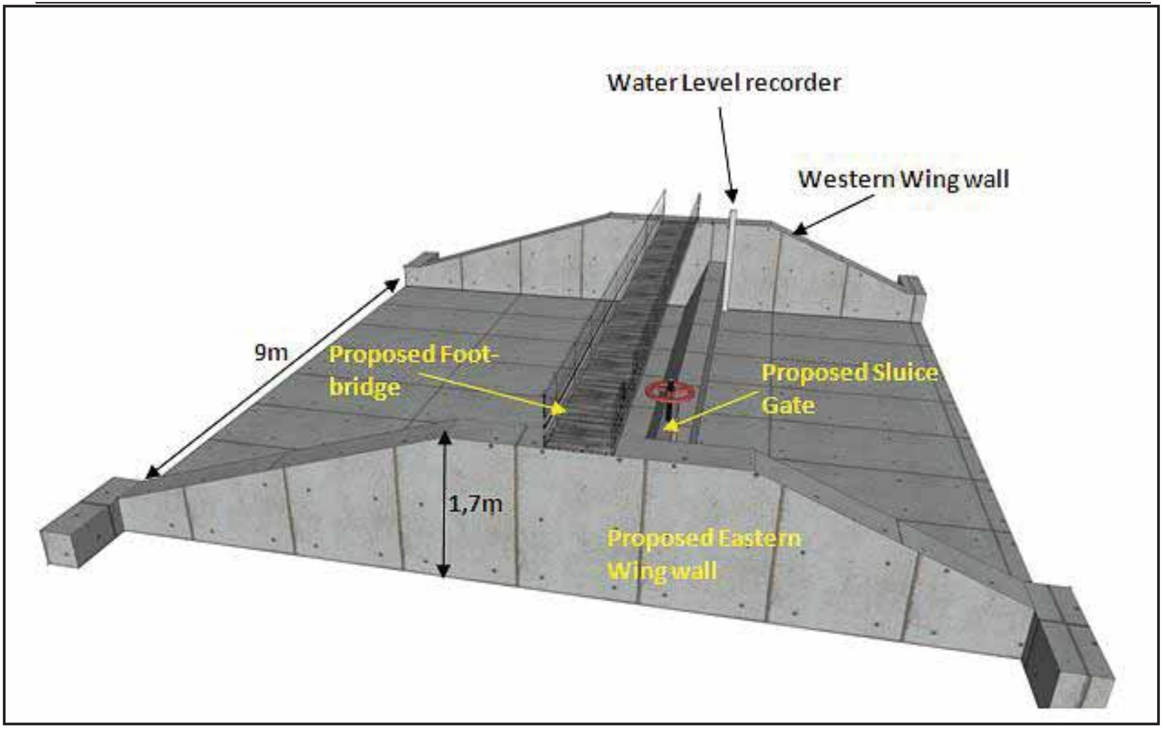
After the removal of the dense vegetation and uncovering of the weir structure on the 10th of October 2012, it became obvious that indeed the easternmost part of the structured had been removed and replaced by earth.

A reinforced concrete side – wing-wall similar to the one that exists at the western end of the weir should be constructed at the eastern part to bind the whole weir and protect the major road that passes 2 – 3 meters to the east. In between the two wing-walls the overflow weir should be reconstructed, especially the part that has been reduced in height by some 10 to 20 cm at the eastern third part of the overflow weir. At the eastern third part of the overflow weir a sluice gate is proposed to be established that could be controlled manually on the occasion that the lake needs to be drained. Furthermore, a simple foot- bridge structure joining the eastern to the western wing-wall will be useful in providing access to both the water level recorder which has been established on the western side of the weir but also to the controls of the sluice gate. A gate allowing access to the bridge and protection rails will be necessary.

<u>The eastern wing-wall</u>

A schematic sketch for the eastern wing-wall together with dimensions (similar to the existing western wing-wall is presented in Figure 4. The structure should be made of reinforced concrete and fair-faced with footing foundations sufficient for the conditions of the area.

[8] Heycock N. and Heath Tom (27th June 2008): “Hydrology Report of Oroklini Marsh, Cyprus”.



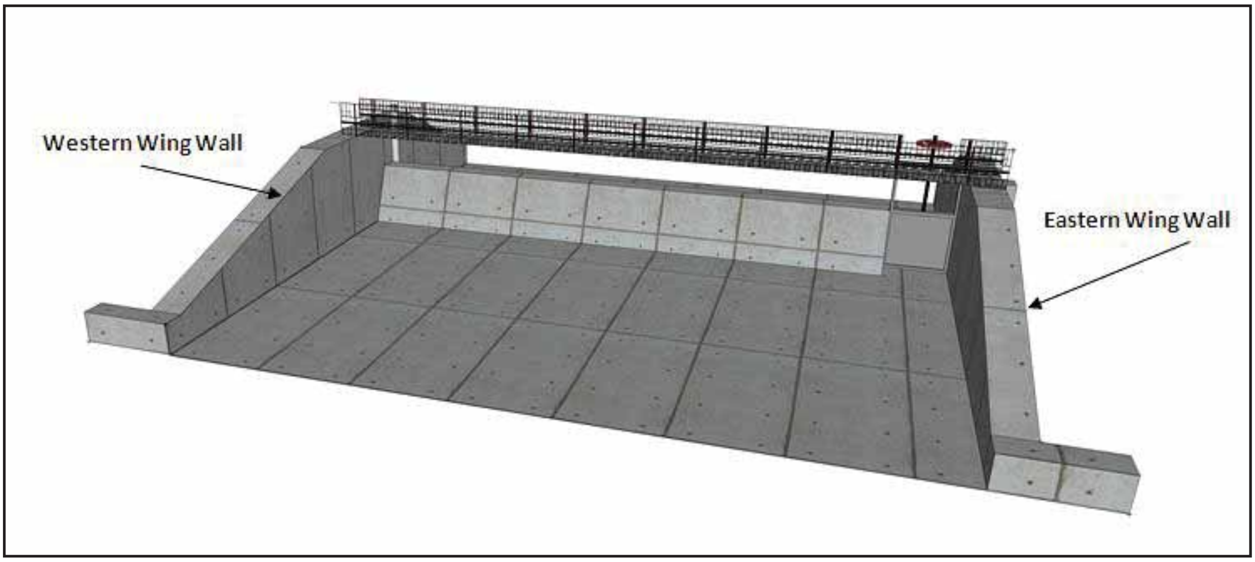


Figure 4: View of the weir with the sluice gate, the foot-bridge and the water level recorder a) from upstream (u/s) to downstream (d/s) looking west (top) and b) from d/s to u/s looking north (below)

<u>The sluice gate</u>

Sluice gates use a sliding panel to regulate flow through an aperture. Sluice gates provide excellent water level control as the aperture size can be adjusted as required to suit management objectives. Furthermore, the position of the aperture can be varied to further enhance water level control.

For the Oroklini Lake, the sluice gate will be installed at the easternmost part of the spillway weir and will be manually controlled. It will slide within frames fitted in groves of the concrete structure (see Figure 4 and tentative sketch in Figure 5 below). It is expected to be made of anticorrosive material (stainless steel, aluminum or cast iron) in view of the aggressive nature of the water of the lake. Its purpose would be to enable the release of water from the S3 Lake to areas downstream for management purposes and even allow complete draining of the lake if required within a single day.

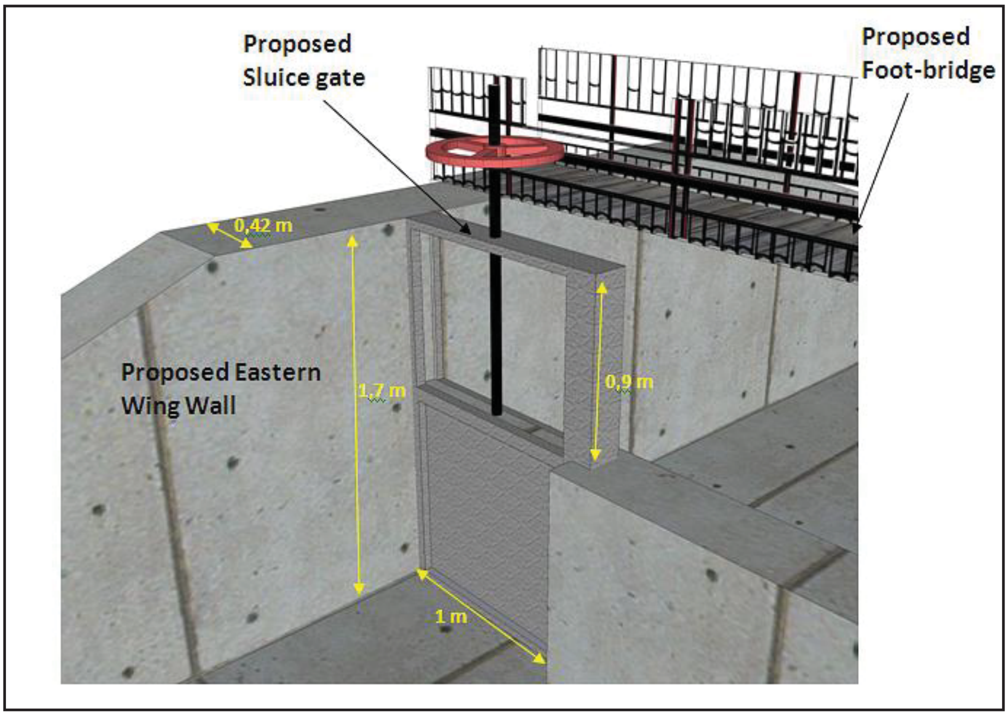
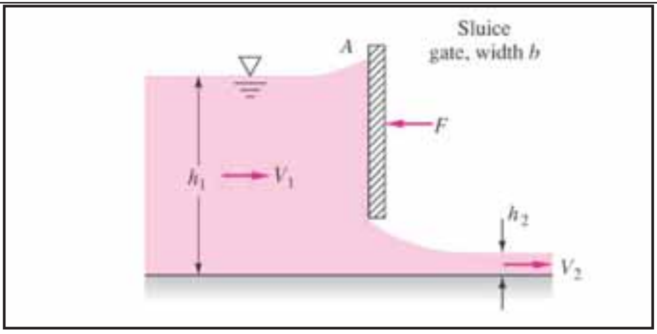


Figure 5: Close up of sluice gate (up) and sample sluice gate made of stainless steel (down)

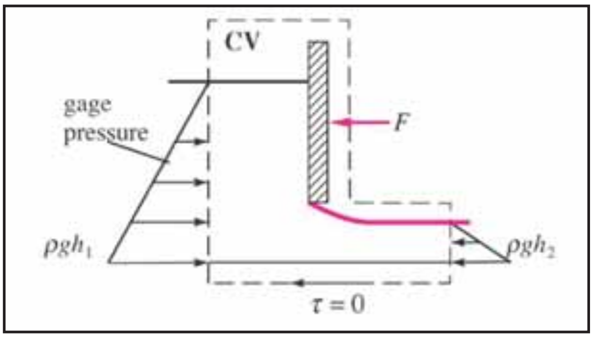
A rough design is made below based on assumed dimensions of 100cm width by 120cm height for controlling a maximum water level height of 90 cm and operating at an aperture of 20cm. The aperture of course can be varied according to the selected management operation.

At sections 1 and 2, the flow is uniform and the pressure is hydrostatic. Neglecting bottom friction and atmospheric pressure, decide the velocities v_1 and v_2, and the horizontal force F required to hold the gate if h_1= 0,9 m, h_2= 0,2 m, and b= 1 m



Section 1: Cross-section of a sluice gate

A control volume that cuts through known regions is chosen (section 1 and section 2, the bottom and the atmosphere) and that cuts along regions where unknown information is desired (the gate, with its force F).



Section 2: The sluice gate

Steady incompressible flow with no variation across the width b is assumed. The inlet and outlet mass flows balance:

$$\dot{m} = \rho V_1 h_1 b = \rho V_2 h_2 b$$

or

$$V_2 = \frac{h_1}{h_2} V_1$$

We may use gage pressures for convenience because a uniform atmospheric pressure causes no force. With x positive to the right, the net horizontal force is equated to the x-directed momentum change:

$$\sum F_x = -F_{gate} + \bar{p}_1 A_1 - \bar{p}_2 A_2 = \dot{m}(V_2 - V_1)$$

or

$$-F_{gate} + \gamma \frac{h_1}{2}(h_1 b) - \gamma \frac{h_2}{2}(h_2 b) = \dot{m}\left(\frac{h_1}{h_2} V_1 - V_1\right)$$

$$\dot{m} = \rho h_1 b V_1$$

Solve for F_{gate} and eliminate V_2 using the mass flow relation. The desired result is:

$$F_{gate} = \frac{1}{2} \rho g b h_1^2 \left[1 - \left(\frac{h_2}{h_1}\right)^2\right] - \rho h_1 b V_1^2 \left(\frac{h_1}{h_2} - 1\right)$$

Now, if the energy (Bernoulli) equation is applied to the two points at the free surface ($p_1=p_2=0$ before and after the gate:

$$\frac{p_1}{\gamma}+\frac{V_1^2}{2g}+h_1=\frac{p_2}{\gamma}+\frac{V_2^2}{2g}+h_2$$

If V_2 is eliminated using the mass flow relation, then:

$$V_1=\sqrt{\frac{2g(h_1-h_2)}{(h_1/h_2)^2-1}}=\sqrt{\frac{2gh_2}{1+h_1/h_2}}$$

Where, h_1 / h_2= 0.9/0.2=4.5

And g= 9.81 m/s^2

Then:

V_1 = 0.845 m/s

$V_2 = (h_1/h_2)\ V_1$= 3.80 m/s

And the gate force is:

$$F_{gate}=\frac{1}{2}\rho g b h_1^2\left[1-\left(\frac{h_2}{h_1}\right)^2\right]-\rho h_1 b V_1^2\left(\frac{h_1}{h_2}-1\right)$$

=(1/2)x998x9.81x1x(0.9)^{2}x[1-(0.2/0.9)2–998x0.9x1x(0.845)^{2}x((0.9/0.2)-1) = 1524.54 = 1.5kN (or kP) [9]

At this exit velocity (V_2), the pond should be effectively drained well within a day. The draining of the lake at such speed would be optimal since it would not be expected to develop any scouring or flooding impacts.

The sluice gate could be imported from abroad[10] or made to measure locally if properly designed. A local quotation[11] for a sluice gate in stainless steel as shown in Figure 5 is of the order of €1200 to €1300.

The Foot-bridge

The foot-bridge (see sketch in Figure 4) will be secured on the top of the wing-walls through two I-beams which could be of galvanized iron, since the bridge is above the water level, and with a wooden timber floor with spaces in between. The total width of the bridge could be 60cm, and with aluminum rails on both sides, 120 cm high. The length of the weir and thus

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[9] *SI unit of pressure (the newton per square metre) is called the pascal (Pa). A pressure of 1 Pa is small; it approximately equals the pressure exerted by a Euro bill resting flat on a table. Everyday pressures are often stated in kilopascals (1 kPa = 1000 Pa).= 1kN.*

[10] *- Hydro Gate 7010 Broadway Suite 400 Denver, CO 80221 (www.hydrogate.com)*

- Rodney Hunt Company, 46 Mill Street, Orange, Massachusetts 01364 USA (www.rodneyhunt.com)

- Waterfront Fluid Controls, The Hub (Unit 8), Digital Media Quarter, Pacific Drive, GLASGOW, G51 1EA (www.waterfrontengservices.co.uk)

- Aquatic Control Engineering Ltd, Hall Farm, Main Street, Rampton, Nottinghamshire, DN22 0HR.(info@aquaticcontrol.co.uk)

[11] *Costas Akhas, Yeri Industrial Area*

of the footbridge will be 9 meters and for this reason appropriate trussing of the footbridge may be required. The bridge will be bolted on the concrete wing-walls of the weir. Locking gates at both ends will deter uninvited guests.

The footbridge will provide access to the water level recorder and to the manually operated sluice gate.

8.2. Digging of new channels and low features in S3 (Appendix I) in order to create ideal nesting habitat surrounded by water

Most wading birds nest in woody vegetation either submerged or surrounded by water. Water is essential for nesting colonies because it provides a safety buffer against land predators. The water level in the Oroklini Lake varies both seasonally and annually. The stability of the water level in the areas surrounding the nesting habitats might be an issue. Created nesting islands that maintain water levels when the lake is full of at least 0,5m and, during droughts and dry seasons a quantity of water replacing the amounts lost by evaporation (far less than 500m^3) could be supplied to provide a water level of the order of 0,5m which could be particularly valuable during years of low rainfall.

Since no suggestion still exists as to the preferred shape of the nesting habitat to be developed, a sinuous shaped channel dug to the elevation of 19,5m and following the topographic contour of 20,3m at a depth of up to 0,80m has been considered in the area of Sheet/Plan 41/25 plot 582 which is government land and it lies at the south-western part of the S3 area. The channel will be of similar type as the drainage channels of S6 and S7 area (see Photo 19).

The channel is proposed to be trapezoidal, unlined, of about 5 meters width and up to 0,80m deep. The slopes will be 1:3. The total length of the channel could be up to 200 meters as shown on Figure 6. No protection of the slopes is considered as necessary since the water is normally stagnant and no erosive flows will exist. Nonetheless, a stabilization of the slopes with light rip-rap will secure a long life of the channel. The final width and extent of the channel will be decided by the 'Reserve management' expert.

Water will be expected to flow into the channel once the water level reaches the 19.50m elevation (when the lake is full the water level is at 20.0m). Groundwater also may seep into the channel at the time of high water- table.

Photo 19: Sections of the North –south main channel showing characteristics of the geometry and protection of the slopes.

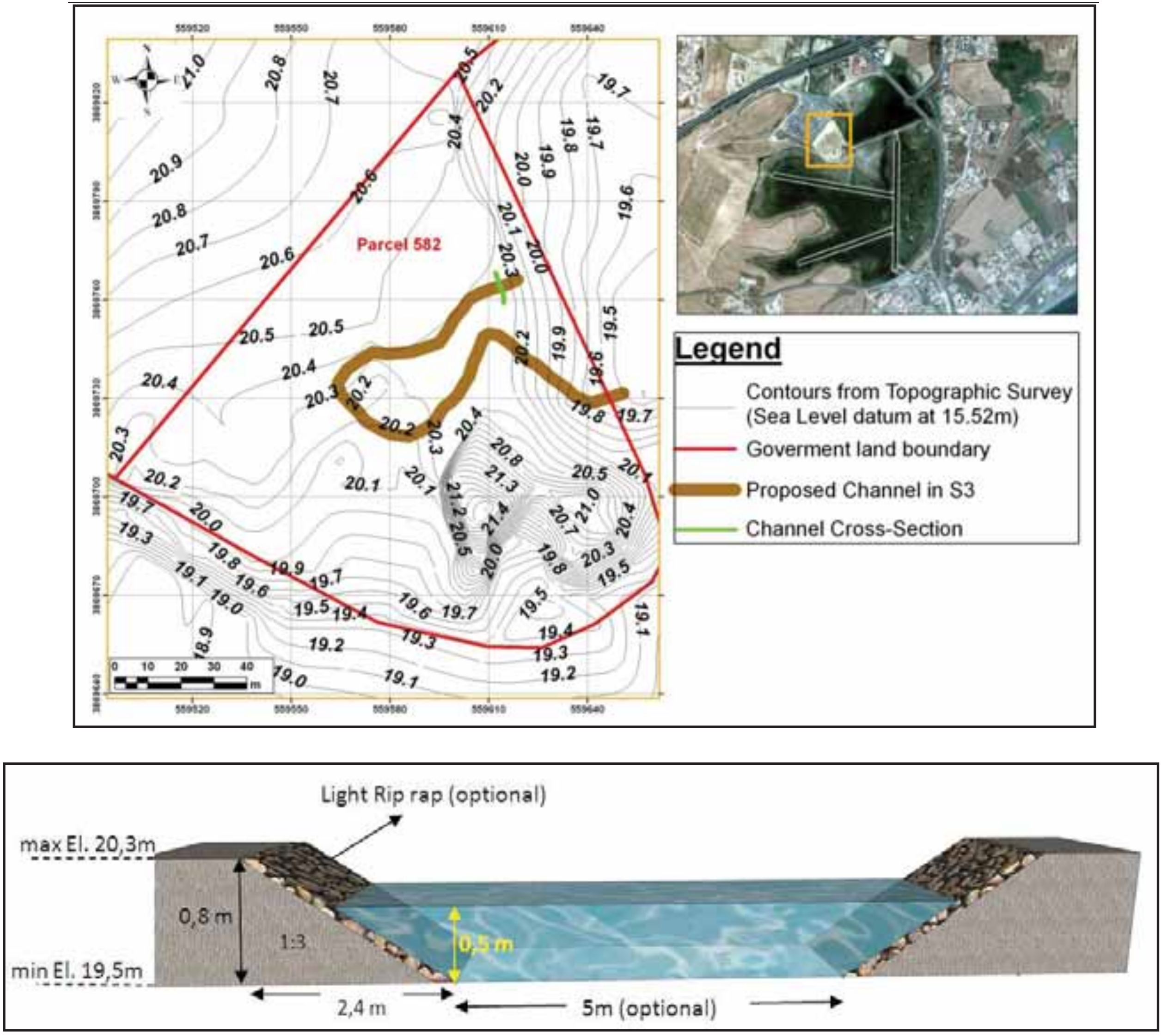


Figure 6: Draft location of the channel for the creation of nesting habitats and a schematic cross section.

8.3. Installation of sluice at south end of main ditch (north/south canal) and ensure drainage is clear beyond

The main north-south canal (See Photo 20) of about 8m width drains the marshland downstream the main lake to the sea. At the southern end there exist the remnants of a redundant pumping station which was used to expedite the draining of the marshland. Presently the canal at this point is taken up by lush vegetation and roots (Photo 21).

According to the Haycock report[6] the long N-S ditch has never completely dried up in the period of at least 2000 to 2008 with a pool forming towards the south in dry years.

According to the recent topographic survey a point on the water edge of the ditch at 26 metres north of the redundant pump house was 0,25m lower than the entrance of the culvert at 32,6 m south of the pump house. The exit of the same culvert 10 m further south is at even higher elevation by 0,07m. In our opinion the ditch drains to the sea until the water level in it drops below the entrance elevation of the culvert in the south. A pool remains below that level and dries only if evaporation is high enough for a sufficient period to dry it up. This explains also why pumping was required when the decision for a pump was made.

The depth from which the pumping was made is not known. Had it been from below sea level either through a pit or the bottom of the ditch at that point being below sea level, explains why this pumping operation had to be abandoned, since pumping inverted the hydraulic gradient and caused more sea water to be pumped into the area. It is reported[6] that "during the pumping more water came back possibly due to salinity gradient".

As per the same reference (Haycock report[6]): "the site is drained to the south by a recent road culvert which has a diameter of 0,9 m and is connected to the bridge and thence to the sea. However the culvert appears to be blocked by sand and rubble. There are potential drainage issues for the site, and as a result it is very unlikely the site will be connected to the sea. ".

The purpose of a sluice being installed at the south end of the main N-S ditch is not clear. If the purpose of the sluice is to enable the control of the flow either for increased storage upstream or release of water (for draining the area) then a weir with a sluice gate as suggested for the Oroklini lake (S3 area) would be needed (see Figures 4 and 5).

Bearing in mind the present width of the main ditch, an overflow weir with a sluice gate with the same specifications as the one at the Oroklini Lake will be sufficient. The proposed height of the spillway level is suggested to be smaller than 90cm from the existing elevation of the bottom of the channel at the south end point so that the dirt roads on either side of the ditch are not flooded. Access to the sluice gate mechanism will be required. This could be accomplished by a foot-bridge across the weir or a shorter access only to the sluice gate.

To ensure that the drainage is clear beyond the point of the south end of the N-S ditch (taken at the location of the old pump house) one would need either to provide a topographic gradient towards the sea, by lowering the topography downstream of the southern end (including the culvert(s) accordingly, or raise the elevation of the bottom of the ditch at a reasonable gradient from the south end of the ditch up to a point about 30m to the north.

Photo 20: The main north-south ditch and the south end at which the sluice could be installed

Photo 21: Present conditions of main north- south ditch at the location of the old pumping station and where the overflow weir and sluice gate is envisaged.

8.4. Installation of sluice and splitter on northern drainage ditch input to S3, diverting peak flow to S6 and S7 (Appendix I)

In the Consultant’s opinion an installation of sluice and splitter on the northern drainage ditch input to S3 for diverting peak flow to S6 and S7 are not needed for the following reasons:

- Flow, including peak flow, from the northern drainage ditch that enters the S3 Lake overspills downstream to S6 and S7 when the lake is full.
- If release of water is needed to be made from the S3 Lake before it overspills, this can be accomplished with the proposed sluice gate to be installed at the weir of this Lake.
- Controlling and diverting peak flows through a sluice and splitter is a demanding operation for which relatively expensive structures will be required, whilst the same could be accomplished through the Lake and its spillway and or sluice gate that will be established as detailed earlier in this text.

8.5. Installation of a wind pump to feed new compartment(s) of S3;

Wind pumps are fairly large tower-mounted multi-bladed wind rotors particularly suitable for pumping fairly large quantities of water at low lifts from a well or for water level control in fish ponds, salt pans and natural wetland creation. Wind pumps requiring wind velocities as low as 3m/s could be useful for the site.

Since the indications are that no sufficient groundwater is available for pumping at the site of the Oroklini Lake, it is assumed that the wind pump is to be used for pumping water from the Lake itself and, most likely, it will be installed at its deepest part near the weir.

Wind pumps are quite site-specific, requiring a steady moderate wind to start up and keep turning, so the site needs to be monitored and evaluated to properly size it. In Table 10 to 12 the available monthly data on: a) mean daily wind-run at 2m, b) the maximum mean hourly wind speed at 10m for the period of 1991-2000 and c) the same as in (b) including the direction for the period of 1976 – 1985, all at the nearby Larnaka Airport are presented.

Wind pumps have a relatively low capital cost and long lifetime (about 25 years) but the aggressive nature of the water of the Lake to metals should be kept in mind when selecting tower materials. A wind pump is entirely mechanical. A 6-monthly service will be required. A wind pump may cost about €5.000 to €10.000 with complete installation but it could be a cost-effective solution if a large scale application is considered. A 3,5 metre diameter rotor operating in a wind speed of 3 m/s will pump 50 m^3/day through a head of 5 metres.

Photo 22: A typical wind mill pump

The impact on the environment should be of prime concern when purchasing and installing a wind pump. Possible impacts such as noise, air turbulence and effect on birds, effect on fish and other aquatic species caused by the impeller of the pump etc. would need to be examined.

There are a large number of manufacturers[12] that one could consider for purchasing a windmill pump suitable for the specific needs of the Lake operation.

Table 10: Mean daily windrun at 2m in km at Larnaka (Airport) Station Number 731 (Latitude 340 53', Longitude 330 38' elev.: 1m) – 1991-2000

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
187	204	219	233	237	253	274	258	220	181	184	172	219

Table 11: Maximum mean hourly wind speed (m/s) at 10m at Larnaka (Airport) - 1991 - 2000

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
19.6	22.7	16.5	18.5	15.5	18.5	19.6	17.5	15.5	18.5	15.5	17.5	22.7

Table 12: Mean daily value of wind at 10 m (direction in tenths of degrees and speed in m/s) at Larnaka - 1976-1985

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
31	30	31	31	21	21	21	20	30	30	31	31	direction
4.12	4.12	4.12	4.12	4.12	4.12	4.64	4.12	3.60	3.60	4.12	4.12	speed

[12] Aquatic Control Engineering Ltd, Hall Farm, Main Street, Rampton, Nottinghamshire, DN22 0HR, info@aquaticcontrol.co.uk

Calculations

Calculations of the required wind pump will depend on the rotor diameter selected, the head from which water will be pumped and transmitted and the quantities to be pumped. The formulas for carrying out estimates on the basis of the head and quantities needed to be pumped could be based on the mean wind speed at the site given in Table 10 to 12.

The formula used for calculating the power in the wind is shown below:

$$P_W = \tfrac{1}{2}\, \rho\, A\, V^3$$

Where, P_W is power in watts available in the wind (W)
ρ is the air density in kilograms per cubic metre (kg/m^3)
A is the swept rotor area in square metres (m^2)
V is the wind speed in metres per second (m/s)

A wind mill can extract only some 30 -40% of the power from the wind therefore a coefficient of performance should be added to the formula for “power in the wind”:

$$P_M = \tfrac{1}{2}.Cp\, \rho\, A\, V^3$$

Where, P_M is power (in watts) available from the machine
Cp is the coefficient of performance of the wind machine

Furthermore, a wind machine will only operate at maximum efficiency for a fraction of the time it is running, due to variations in wind speed. A rough estimate of the output from a wind pump can be obtained using the following equation;

$$P_A = 0,1\, A\, V^3$$

Where, P_A is the average power output in watts over the year
V is the mean annual wind speed in m/s

A Simple "rule-of-thumb" approach:

A simpler rule of thumb may be more appropriately used than attempting any detailed analysis. The rule of thumb assumes that a wind pump system will, on average, be 17% efficient in converting wind energy into hydraulic output, which in many cases is probably not a bad estimate. The average hydraulic output power for a windpump of about 17% average efficiency will be:

$$P = 0.17x1/2\, \rho V^3 \qquad W/m^2 \text{ of rotor area}$$

Because the density of air at sea level is approximately 1.2kg/m^3, it follows that:

$$P= 0.17x1/2x1.2xV^3 = 0.1\, V^3 \quad W/m^2$$

or $$P= 0.1x1/4\ \pi D^2 \quad V^3 \text{ watts for a rotor diameter D meters}$$

If 0,1V^3 is multiplied by the time interval in hours applying to the average wind speed used, then the output can be calculated. For example, if V is the daily mean wind speed (based on 24 hours), then the daily hydraulic energy output will be:

$$E = 24x0.1V^3av \qquad Wh/m^2 \text{ of rotor area}$$

If this is multiplied by the rotor area in square metres, it gives the daily hydraulic energy output. Dividing the number of watt-hours per day by 2.725 converts this to a daily "cubic metres-metre" product, or m3.m (i.e. output in cubic metres times head in metres). This can readily be converted to a daily output of water at any particular pumping head; eg.:

1,000 Wh/day (or 1kWh/d) (hyd) = 1,000/2.725 =367 m^3.m

, which is 36,7m^3/day if lifted through 10m, or 3,67m^3/day through 100m, etc.

8.6. Installation of new low bunds in north western part of S3 with overflow sluice

The installation of new low bunds in the north-western part of S3 is assumed that it is intended for enlarging the wet-land in excess of the Lake when full, which brings water to the 20,0m contour.

A bund is simply an embankment-like structure, constructed across the land slope.

A possible location of this bund/dyke and schematic sketch of a section of the bund are shown on the topographic map shown in Figure 7. The bund and the overflow weir and sluice will need to be located more accurately once a detailed topographic survey is carried out in the immediate area surrounding the bund, and the pool that will be formed when full of water.

The double culvert and the “dirt” road that connects the area where the illegal flea-market was and the parking area of “Oops” are to be removed and the stream bed is to be re-established. Thus, the height of the overflow sluice and the possibility of submerging the double culvert and the “dirt” road are not of concern.

The choice of the location of the bund is such so that the structure controls the water within the main drainage system which drains water into the Lake and there is a reasonable spread of land that could be maintained as a wet-land for a longer period in a year due to the raised water level. High flows (floods) are regular, so the spillway of the structure needs to be sufficiently robust to withstand this, and have enough overflow capacity to allow excess water to exit the site quickly when required.

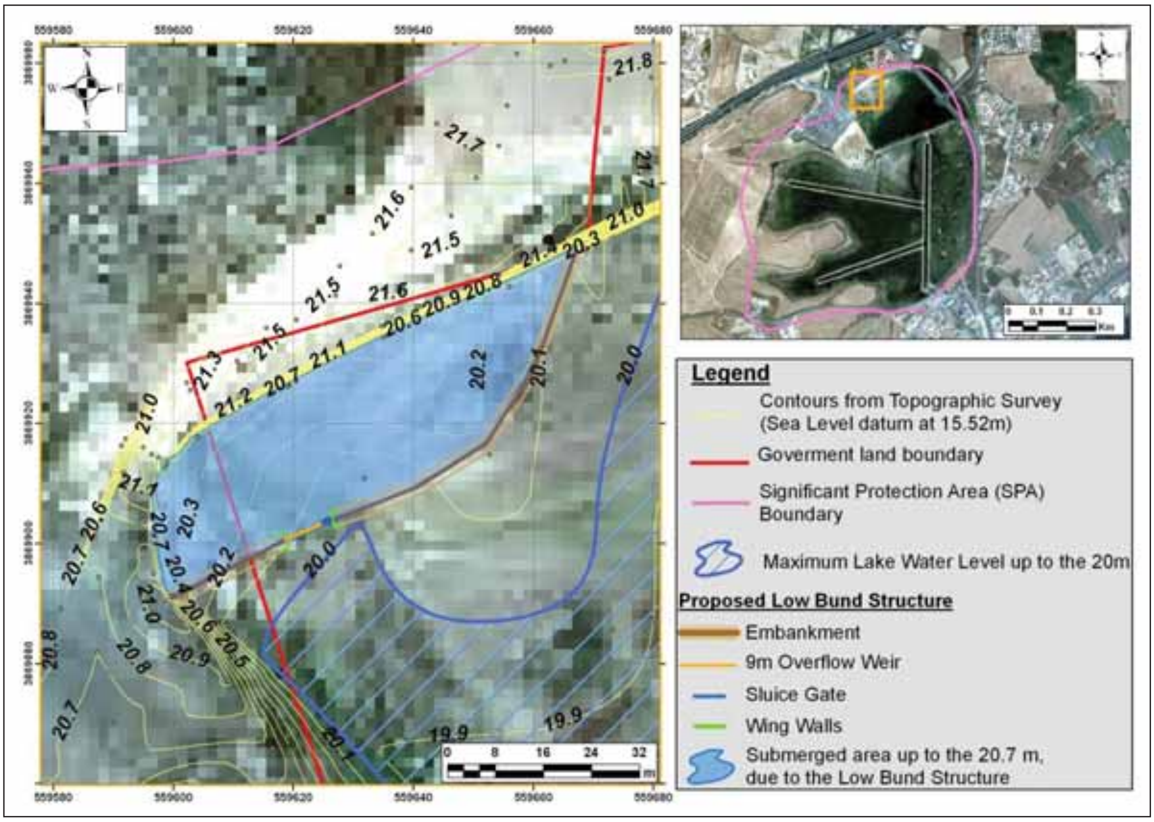
The structure and the overflow sluice will allow set water levels to be maintained which is important to the overall site management plan objectives and for flow control.

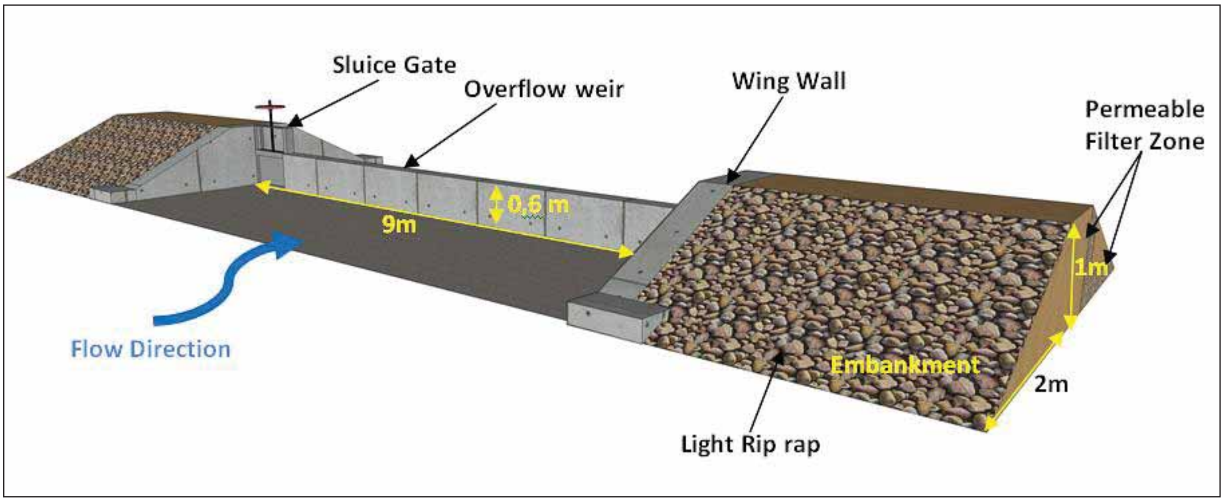
The low bund structure is to be made of soil material preferably local (due to the high content of clay and marl which makes it quite impermeable). The soil material dug from the new channel to be established in the S3 area, in order to create nesting habitats surrounded by water (as per “paragraph 8.2” above), would be suitable. The soil material will need to be consolidated at various levels with a small road- roller.

The dimensions of the water retaining structure will be 1 m high and 1m width at the top. The slopes will be at 1:2 ratio protected with light riprap from local rock material (sandstone) in the inside area. The outside slope should preferably be covered with a more permeable material. The total length of the bund is estimated to be about 95 meters.

The 9m overflow weir to a height of 60cm needs to be constructed in reinforced concrete with protection wing-walls at both sides. A sluice gate similar and to the same dimensions to the one planned for the Lake (see Figure 5) would enable management of the water in the upstream side of the retention bund. At maximum water level (60cm) at the weir, the flooded area will be, on the basis of the recent topographic survey, as shown on the map of Figure 7.

The size of the overflow weir (9 meters) has been kept the same as for the lake since the structure should be able to cope with floods of the same severity.





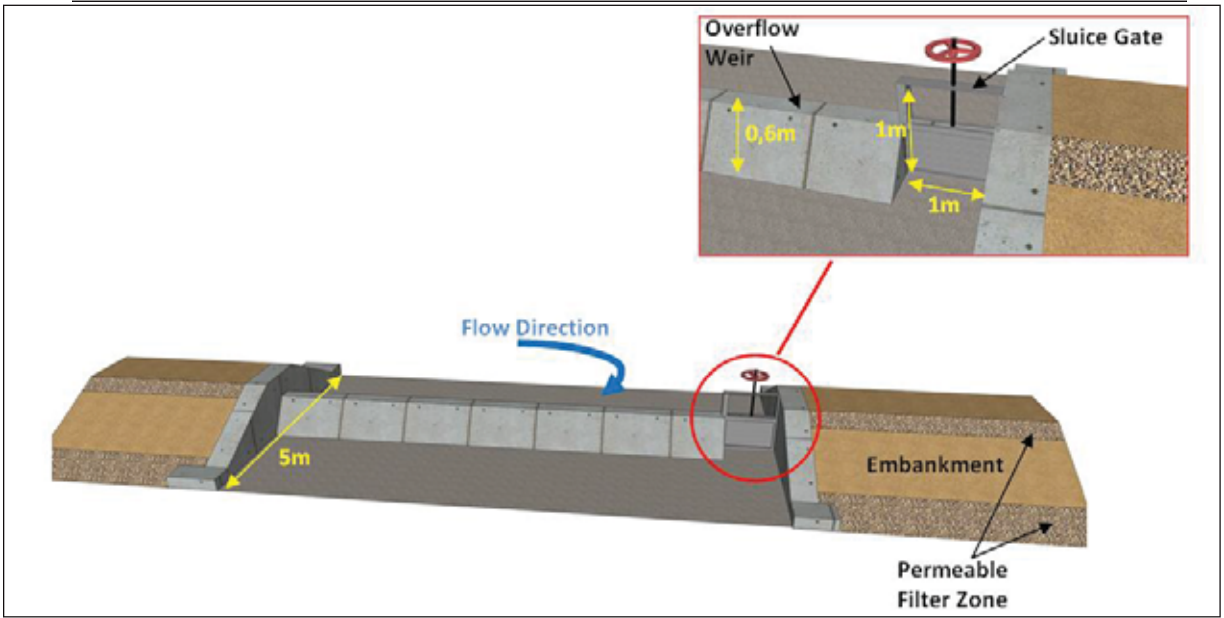


Figure 7: Draft location of the low bund for enlarging the wetland and schematic cross sections of the bund (looking downstream at top and, upstream at bottom) and the overflow sluice

9. APPENDICES

Appendix I: Map of Oroklini Lake

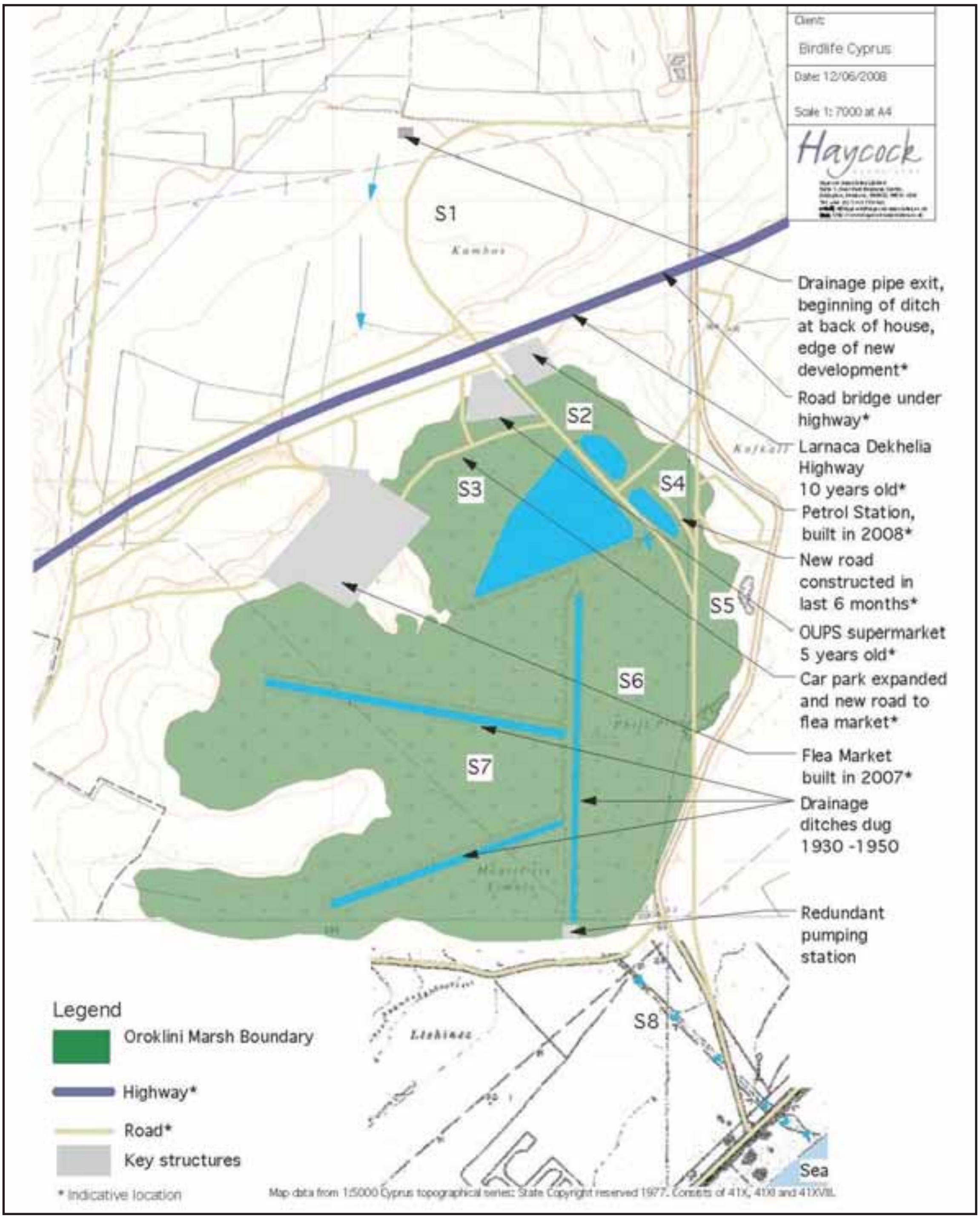
Appendix II: The Oroklini Lake monthly water operation study (1968 - 2011)

Appendix III: The water balance under the three scenarios

APPENDIX I

– Map of Oroklini Lake

Overview of key features at Oroklini Lake (from the Hydrology Report of Oroklini Marsh, Cyprus, Dr. Nick Haycock & Tom Heath)


Client:
Birdlife Cyprus
Date: 12/06/2008
Scale 1: 7000 at A4
Haycock
S1
Kambos
S2
S3
S4
S5
S6
S7
S8
Drainage pipe exit, beginning of ditch at back of house, edge of new development*
Road bridge under highway*
Larnaca Dekhelia Highway 10 years old*
Petrol Station, built in 2008*
New road constructed in last 6 months*
OUPS supermarket 5 years old*
Car park expanded and new road to flea market*
Flea Market built in 2007*
Drainage ditches dug 1930 -1950
Redundant pumping station
Sea
Legend
Oroklini Marsh Boundary
Highway*
Road*
Key structures
* Indicative location
Map data from 1:5000 Cyprus topographical series: State Copyright reserved 1977. Consists of 41X, 41XI and 41XVIII.

APPENDIX II

The Oroklini Lake monthly water operation study (1968 -2011)

CONSTANT PARAMETERS					
MEAN MONTHLY EVAPORATION (FROM METEOROLOGICAL STATION OF LARNACA AIRPORT FOR THE YEARS 1991-2005)		Area of the Lake (m^2)	Groundwater Inflow (m^3/month)	Runoff Factor	Catchment Area (m^2)
MONTH	Mean Monthly Evaporation (mm)	60459	250	0,37	2895668
OCT	189,1				
NOV	117				
DEC	80,6				
JAN	80,6				
FEB	92,4				
MAR	136,4				
APR	183				
MAY	244,9				
JUN	285				
JUL	306,9				
AUG	294,5				
SEP	249				

MONTH	1968-1969					1969-1970					1970-1971					1971-1972				
	Monthly Rainfall (mm)*	Elevation of Water Level (m) **	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	8,4	20,0	23428	60076	60537	29,2	20,0	23428	60076	295964	1	19,6	3077	28956	0	4,10	20,00	23428	60076	13766
NOV	79,0	20,0	23428	60076	887387	68,4	20,0	23428	60076	767411	39,5	20,0	23428	60076	419954	30,10	20,00	23428	60076	333910
DEC	130,6	20,0	23428	60076	1473612	347,3	20,0	23428	60076	3926344	50,8	20,0	23428	60076	570391	48,20	20,00	23428	60076	540963
JAN	169,6	20,0	23428	60076	1915036	28,1	20,0	23428	60076	313459	54,4	20,0	23428	60076	611138	47,90	20,00	23428	60076	537567
FEB	4,3	20,0	23428	60076	43369	64,3	20,0	23428	60076	722482	102,4	20,0	23428	60076	1153720	20,60	20,00	23428	60076	227861
MAR	55,5	20,0	23428	60076	620236	51,5	20,0	23428	60076	574962	13,3	20,0	23428	60076	142592	47,90	20,00	23428	60076	534215
APR	2,5	20,0	23428	60076	17552	12,7	20,0	23428	60076	133002	85,1	20,0	23428	60076	952466	27,90	20,00	23428	60076	305044
MAY	5,1	20,0	23428	60076	43262	33	20,0	23428	60076	359050	1,5	20,0	23428	60076	2515	3,00	20,00	23428	60076	19493
JUN	0,0	19,6	6556	35367	0	0	19,6	6556	35367	0	1,3	20,0	21270	60328	0	7,40	20,00	23428	60076	66886
JUL	0,0	19,2	0	0	0	0	19,2	0	0	0	0	19,6	3009	28743	0	0,00	19,61	5241	33176	0
AUG	0,0	19,2	0	0	0	0	19,2	0	0	0	2,5	19,8	13863	48722	0	9,10	20,00	23428	60076	67369
SEP	0,0	19,2	0	0	0	0	19,2	0	0	0	0	19,5	1898	23189	0	0,00	19,70	8719	39382	0

APPENDIX II

MONTH	1972-1973					1973-1974					1974-1975					1975-1976				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	*26,2*	*20,0*	*23428*	*60076*	*262008*	*0,4*	*19,6*	*4381*	*31798*	*0*	*54,9*	*20,0*	*23428*	*60076*	*586851*	*20,4*	*20,0*	*23428*	*60076*	*196360*
NOV	*54,6*	*20,0*	*23428*	*60076*	*611215*	*29,1*	*20,0*	*23428*	*60076*	*303544*	*25,4*	*20,0*	*23428*	*60076*	*280713*	*57,4*	*20,0*	*23428*	*60076*	*642907*
DEC	*33,6*	*20,0*	*23428*	*60076*	*375712*	*71,2*	*20,0*	*23428*	*60076*	*801289*	*146,1*	*20,0*	*23428*	*60076*	*1649050*	*106,3*	*20,0*	*23428*	*60076*	*1198571*
JAN	*96,0*	*20,0*	*23428*	*60076*	*1081990*	*82,7*	*20,0*	*23428*	*60076*	*931453*	*42,3*	*20,0*	*23428*	*60076*	*474183*	*65,2*	*20,0*	*23428*	*60076*	*733378*
FEB	*35,7*	*20,0*	*23428*	*60076*	*398772*	*169,8*	*20,0*	*23428*	*60076*	*1916591*	*25,2*	*20,0*	*23428*	*60076*	*279927*	*10,8*	*20,0*	*23428*	*60076*	*116939*
MAR	*35,8*	*20,0*	*23428*	*60076*	*397260*	*5,7*	*20,0*	*23428*	*60076*	*56571*	*55,2*	*20,0*	*23428*	*60076*	*616840*	*19,0*	*20,0*	*23428*	*60076*	*207108*
APR	*20,8*	*20,0*	*23428*	*60076*	*224682*	*34,4*	*20,0*	*23428*	*60076*	*378615*	*36,7*	*20,0*	*23428*	*60076*	*404647*	*35,7*	*20,0*	*23428*	*60076*	*393329*
MAY	*2,0*	*20,0*	*23428*	*60076*	*8174*	*54,1*	*20,0*	*23428*	*60076*	*597871*	*31,8*	*20,0*	*23428*	*60076*	*345468*	*0,0*	*19,7*	*8965*	*39852*	*0*
JUN	*10,9*	*20,0*	*23428*	*60076*	*106501*	*2,2*	*20,0*	*23428*	*60076*	*8029*	*0,0*	*19,6*	*6556*	*35367*	*0*	*0,0*	*19,2*	*0*	*0*	*0*
JUL	*0,0*	*19,6*	*5241*	*33176*	*0*	*0,0*	*19,6*	*5241*	*33176*	*0*	*0,3*	*19,2*	*0*	*0*	*0*	*0,0*	*19,2*	*0*	*0*	*0*
AUG	*16,5*	*20,0*	*23428*	*60076*	*151126*	*0,0*	*19,2*	*0*	*0*	*0*	*0,0*	*19,2*	*0*	*0*	*0*	*0,0*	*19,2*	*0*	*0*	*0*
SEP	*0,0*	*19,7*	*8719*	*39382*	*0*	*0,0*	*19,2*	*0*	*0*	*0*	*0,0*	*19,2*	*0*	*0*	*0*	*5,2*	*20,0*	*23428*	*60076*	*20720*

MONTH	1976-1977				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	20,4	20,0	23428	60076	196360
NOV	57,4	20,0	23428	60076	642907
DEC	106,3	20,0	23428	60076	1198571
JAN	65,2	20,0	23428	60076	733378
FEB	10,8	20,0	23428	60076	116939
MAR	19,0	20,0	23428	60076	207108
APR	35,7	20,0	23428	60076	393329
MAY	0,0	19,7	8965	39852	0
JUN	0,0	19,2	0	0	0
JUL	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0
SEP	5,2	20,0	23428	60076	20720

MONTH	1977-1978				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	0,0	19,8	12318	46286	0
NOV	5,0	20,0	23428	60076	38703
DEC	163,7	20,0	23428	60076	1848256
JAN	102,2	20,0	23428	60076	1152165
FEB	40,0	20,0	23428	60076	447441
MAR	93,7	20,0	23428	60076	1052605
APR	1,5	20,0	23428	60076	6234
MAY	0,6	19,9	15756	51002	0
JUN	0,0	19,5	1388	18500	0
JUL	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0
SEP	0,4	19,2	0	0	0

MONTH	1978-1979				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	15,7	20,0	23428	60076	143163
NOV	13,5	20,0	23428	60076	146022
DEC	204,8	20,0	23428	60076	2313449
JAN	32,3	20,0	23428	60076	360997
FEB	31,6	20,0	23428	60076	352365
MAR	36,3	20,0	23428	60076	402919
APR	5,9	20,0	23428	60076	56036
MAY	21,6	20,0	23428	60076	230018
JUN	12,8	20,0	23428	60076	128006
JUL	0,0	19,6	5241	33176	0
AUG	0,0	19,2	0	0	0
SEP	7,8	20,0	23428	60076	50148

MONTH	1979-1980				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	32,0	20,0	23428	60076	351084
NOV	16,1	20,0	23428	60076	175450
DEC	111,8	20,0	23428	60076	1260823
JAN	29,7	20,0	23428	60076	331569
FEB	112,6	20,0	23428	60076	1269169
MAR	24,7	20,0	23428	60076	271624
APR	35,9	20,0	23428	60076	395592
MAY	6,0	20,0	23428	60076	53449
JUN	0,0	19,6	6556	35367	0
JUL	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0
SEP	0,0	19,2	0	0	0

MONTH	1980-1981					1981-1982				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	12,7	20,0	23428	60076	109207	0,0	19,2	0	0	0
NOV	1,0	20,0	23428	60076	4540	58,8	20,0	23428	60076	635324
DEC	50,2	20,0	23428	60076	563600	28,0	20,0	23428	60076	312328
JAN	167,7	20,0	23428	60076	1893531	26,4	20,0	23428	60076	294218
FEB	85,2	20,0	23428	60076	959040	49,4	20,0	23428	60076	553836
MAR	34,9	20,0	23428	60076	387073	50,6	20,0	23428	60076	564775
APR	7,0	20,0	23428	60076	68486	12,4	20,0	23428	60076	129606
MAY	9,0	20,0	23428	60076	87404	0,0	19,7	8965	39852	0
JUN	58,8	20,0	23428	60076	648660	2,1	19,9	15863	51125	0
JUL	0,0	19,6	5241	33176	0	0,0	19,3	332	3640	0
AUG	0,0	19,2	0	0	0	0,0	19,2	0	0	0
SEP	0,0	19,2	0	0	0	0,0	19,2	0	0	0

MONTH	1982-1983					1983-1984				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	3,4	20,0	23428	60076	3945	11,2	20,0	23428	60076	92229
NOV	20,9	20,0	23428	60076	229779	68,6	20,0	23428	60076	769674
DEC	40,1	20,0	23428	60076	449282	39,6	20,0	23428	60076	443623
JAN	57,1	20,0	23428	60076	641698	39,9	20,0	23428	60076	447018
FEB	23,3	20,0	23428	60076	258421	80,8	20,0	23428	60076	909239
MAR	29,8	20,0	23428	60076	329349	31,2	20,0	23428	60076	345195
APR	20,1	20,0	23428	60076	216759	34,3	20,0	23428	60076	377483
MAY	3,0	20,0	23428	60076	19493	0,0	19,7	8965	39852	0
JUN	0,0	19,6	6556	35367	0	0,0	19,2	0	0	0
JUL	0,0	19,2	0	0	0	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0	0,0	19,2	0	0	0
SEP	0,0	19,2	0	0	0	0,0	19,2	0	0	0

APPENDIX II

MONTH	1984-1985					1985-1986					1986-1987					1987-1988				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	4,0	20,0	23428	60076	10736	48,4	20,0	23428	60076	513668	5,8	20,0	23428	60076	35774	21,3	20,0	23428	60076	206547
NOV	286,4	20,0	23428	60076	3234857	40,0	20,0	23428	60076	445964	11,9	20,0	23428	60076	127912	2,3	20,0	23428	60076	19254
DEC	99,9	20,0	23428	60076	1126132	59,0	20,0	23428	60076	663203	51,4	20,0	23428	60076	577182	116,9	20,0	23428	60076	1318548
JAN	45,4	20,0	23428	60076	509271	68,6	20,0	23428	60076	771861	20,6	20,0	23428	60076	228570	75,5	20,0	23428	60076	849959
FEB	32,4	20,0	23428	60076	361420	39,5	20,0	23428	60076	441782	23,7	20,0	23428	60076	262949	77,1	20,0	23428	60076	867360
MAR	30,8	20,0	23428	60076	340667	26,2	20,0	23428	60076	288602	157,3	20,0	23428	60076	1772465	118,6	20,0	23428	60076	1334437
APR	0,5	19,9	18343	54964	0	5,8	20,0	23428	60076	54904	18,3	20,0	23428	60076	196386	8,3	20,0	23428	60076	83200
MAY	0,0	19,6	5001	32797	0	78,1	20,0	23428	60076	869517	6,4	20,0	23428	60076	57976	54,2	20,0	23428	60076	599003
JUN	0,0	19,2	0	0	0	20,6	20,0	23428	60076	216291	0,0	19,6	6556	35367	0	6,5	20,0	23428	60076	56699
JUL	0,0	19,2	0	0	0	0,0	19,6	5241	33176	0	7,4	20,0	23428	60076	48698	0,0	19,6	5241	33176	0
AUG	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,6	5986	34385	0	0,8	19,2	0	0	0
SEP	1,0	19,4	388	4442	0	1,6	19,6	4665	32263	0	0,0	19,2	0	0	0	0,9	19,2	0	0	0

APPENDIX II

MONTH	1988-1989					1989-1990					1990-1991					1991-1992				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	42,9	20,0	23428	60076	451028	90,7	20,0	23428	60076	997208	2,8	20,0	20582	59768	0	9,0	20,0	23428	60076	67329
NOV	54,8	20,0	23428	60076	613478	34,6	20,0	23428	60076	384843	22,0	20,0	23428	60076	239383	65,6	20,0	23428	60076	735719
DEC	133,6	20,0	23428	60076	1507568	32,1	20,0	23428	60076	358734	19,7	20,0	23428	60076	218384	312,9	20,0	23428	60076	3536986
JAN	90,6	20,0	23428	60076	1020870	26,7	20,0	23428	60076	297613	61,5	20,0	23428	60076	691499	9,5	20,0	23428	60076	102934
FEB	18,4	20,0	23428	60076	202960	131,5	20,0	23428	60076	1483090	32,5	20,0	23428	60076	362552	49,7	20,0	23428	60076	557231
MAR	26,0	20,0	23428	60076	286338	10,5	20,0	23428	60076	110900	43,4	20,0	23428	60076	483281	8,3	20,0	23428	60076	86000
APR	0,0	19,8	12684	46921	0	3,5	20,0	23428	60076	28871	21,1	20,0	23428	60076	228078	6,0	20,0	23428	60076	57167
MAY	26,2	20,0	23428	60076	271340	1,0	20,0	20284	59285	0	0,0	19,7	8965	39852	0	31,6	20,0	23428	60076	343204
JUN	0,0	19,6	6556	35367	0	0,0	19,6	3520	30130	0	0,0	19,2	0	0	0	12,0	20,0	23428	60076	118951
JUL	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,6	5241	33176	0
AUG	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0	18,8	20,0	23428	60076	177159
SEP	1,7	19,6	5153	33037	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,4	19,8	13246	47828	0

APPENDIX II

MONTH	1992-1993				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	0,5	19,7	8416	38806	0
NOV	51,7	20,0	23428	60076	563379
DEC	94,0	20,0	23428	60076	1059353
JAN	60,0	20,0	23428	60076	674522
FEB	29,5	20,0	23428	60076	328597
MAR	54,0	20,0	23428	60076	603258
APR	5,5	20,0	23428	60076	51508
MAY	5,5	20,0	23428	60076	47789
JUN	12,0	20,0	23428	60076	118951
JUL	0,0	19,6	5241	33176	0
AUG	0,0	19,2	0	0	0
SEP	0,0	19,2	0	0	0

MONTH	1993-1994				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	20,0	20,0	23428	60076	191833
NOV	17,1	20,0	23428	60076	186768
DEC	6,8	20,0	23428	60076	72374
JAN	140,5	20,0	23428	60076	1585666
FEB	60,1	20,0	23428	60076	674944
MAR	48,2	20,0	23428	60076	537610
APR	3,4	20,0	23428	60076	27739
MAY	2,0	20,0	23428	60076	8174
JUN	0,0	19,6	6556	35367	0
JUL	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0
SEP	0,0	19,2	0	0	0

MONTH	1994-1995				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	44,1	20,0	23428	60076	464610
NOV	200,6	20,0	23428	60076	2263725
DEC	46,4	20,0	23428	60076	520589
JAN	28,7	20,0	23428	60076	320251
FEB	19,4	20,0	23428	60076	214279
MAR	13,4	20,0	23428	60076	143724
APR	13,0	20,0	23428	60076	136397
MAY	8,2	20,0	23428	60076	78350
JUN	1,2	19,9	20139	59009	0
JUL	5,2	20,0	23428	60076	37380
AUG	0,0	19,6	5986	34385	0
SEP	0,0	19,2	0	0	0

MONTH	1995-1996				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	4,4	20,0	23428	60076	15263
NOV	39,1	20,0	23428	60076	435777
DEC	6,4	20,0	23428	60076	67847
JAN	94,2	20,0	23428	60076	1061616
FEB	45,6	20,0	23428	60076	510825
MAR	21,5	20,0	23428	60076	235405
APR	33,0	20,0	23428	60076	362769
MAY	3,2	20,0	23428	60076	21757
JUN	0,0	19,6	6556	35367	0
JUL	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0
SEP	0,1	19,2	0	0	0

MONTH	1996-1997					1997-1998					1998-1999					1999-2000				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	41,8	20,0	23428	60076	438577	43,7	20,0	23428	60076	483511	0,1	19,8	13449	48134	0	5,7	20,0	23428	60076	39828
NOV	1,7	20,0	23428	60076	12463	39,2	20,0	23428	60076	436909	27,5	20,0	23428	60076	294503	34,1	20,0	23428	60076	379184
DEC	41,9	20,0	23428	60076	469656	61,4	20,0	23428	60076	690368	93,8	20,0	23428	60076	1057089	25,7	20,0	23428	60076	286295
JAN	7,0	20,0	23428	60076	74638	46,5	20,0	23428	60076	521721	49,2	20,0	23428	60076	552281	58,8	20,0	23428	60076	660939
FEB	29,1	20,0	23428	60076	324069	10,2	20,0	23428	60076	110148	42,0	20,0	23428	60076	470079	46,0	20,0	23428	60076	515353
MAR	44,4	20,0	23428	60076	494600	29,6	20,0	23428	60076	327085	21,5	20,0	23428	60076	235405	26,3	20,0	23428	60076	289734
APR	45,5	20,0	23428	60076	504251	1,1	20,0	23428	60076	1706	39,1	20,0	23428	60076	431812	55,1	20,0	23428	60076	612909
MAY	1,3	20,0	23428	60076	251	21,2	20,0	23428	60076	225491	0,0	19,7	8965	39852	0	5,4	20,0	23428	60076	46658
JUN	0,0	19,6	6556	35367	0	0,0	19,6	6556	35367	0	0,0	19,2	0	0	0	0,3	19,7	9952	41755	0
JUL	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0	0,0	19,2	0	0	0	5,5	20,0	23428	60076	21382	0,0	19,2	0	0	0
SEP	15,5	20,0	23428	60076	137301	7,2	20,0	23428	60076	43357	0,1	19,7	9851	41559	0	34,7	20,0	23428	60076	354617

APPENDIX II

MONTH	2000-2001					2001-2002					2002-2003					2003-2004				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	35,7	20,0	23428	60076	392962	28,7	20,0	23428	60076	290304	5,2	20,0	23428	60076	47746	31,4	20,0	23428	60076	340111
NOV	119,0	20,0	23428	60076	1340130	24,7	20,0	23428	60076	272790	6,5	20,0	23428	60076	66792	6,9	20,0	23428	60076	71319
DEC	138,9	20,0	23428	60076	1567556	152,6	20,0	23428	60076	1722620	111,5	20,0	23428	60076	1257427	159,7	20,0	23428	60076	1802982
JAN	47,6	20,0	23428	60076	534171	61,6	20,0	23428	60076	692631	51,2	20,0	23428	60076	574918	217,1	20,0	23428	60076	2452668
FEB	27,7	20,0	23428	60076	308223	33,2	20,0	23428	60076	370475	63,8	20,0	23428	60076	716823	74,9	20,0	23428	60076	842459
MAR	0,5	20,0	21143	60290	0	38,9	20,0	23428	60076	432348	114,8	20,0	23428	60076	1291426	0,0	19,9	15484	50690	0
APR	24,7	20,0	23428	60076	266539	26,6	20,0	23428	60076	290330	43,4	20,0	23428	60076	480482	1,9	20,0	23428	60076	2817
MAY	44,2	20,0	23428	60076	485818	10,5	20,0	23428	60076	104382	0,0	19,7	8965	39852	0	0,5	19,8	14625	49696	0
JUN	0,0	19,6	6556	35367	0	20,4	20,0	23428	60076	214027	10,5	20,0	23428	60076	87510	0,0	19,4	627	8081	0
JUL	0,0	19,2	0	0	0	0,0	19,6	5241	33176	0	0,0	19,6	5241	33176	0	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0	21,6	20,0	23428	60076	208851	0,0	19,2	0	0	0	0,0	19,2	0	0	0
SEP	0,0	19,2	0	0	0	18,6	20,0	23428	60076	195816	3,0	19,9	19247	57009	0	0,0	19,2	0	0	0

APPENDIX II

MONTH	2004-2005					2005-2006					2006-2007					2007-2008				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	3,9	20,0	23428	60076	9604	7,3	20,0	23428	60076	48087	73,5	20,0	23428	60076	797376	9,7	20,0	23428	60076	75252
NOV	31,7	20,0	23428	60076	352019	50,5	20,0	23428	60076	564808	35,0	20,0	23428	60076	389371	28,3	20,0	23428	60076	313536
DEC	65,3	20,0	23428	60076	734510	6,3	20,0	23428	60076	66715	5,6	20,0	23428	60076	58792	45,0	20,0	23428	60076	504743
JAN	73,1	20,0	23428	60076	822795	76,8	20,0	23428	60076	864673	18,5	20,0	23428	60076	204801	23,0	20,0	23428	60076	255735
FEB	11,0	20,0	23428	60076	119203	29,3	20,0	23428	60076	326333	142,3	20,0	23428	60076	1605330	25,0	20,0	23428	60076	277663
MAR	10,6	20,0	23428	60076	112032	26,8	20,0	23428	60076	295393	24,3	20,0	23428	60076	267097	2,0	20,0	23428	60076	14693
APR	37,7	20,0	23428	60076	415966	10,1	20,0	23428	60076	103573	26,3	20,0	23428	60076	286934	6,4	20,0	23428	60076	61695
MAY	27,7	20,0	23428	60076	299061	4,5	20,0	23428	60076	36471	66,6	20,0	23428	60076	739354	17,9	20,0	23428	60076	188140
JUN	0,3	19,7	9952	41755	0	1,8	20,0	23428	60076	3502	0,0	19,6	6556	35367	0	0,0	19,6	6556	35367	0
JUL	0,0	19,2	0	0	0	0,5	19,8	10900	43609	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0
AUG	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0
SEP	0,0	19,2	0	0	0	0,0	19,2	0	0	0	0,0	19,2	0	0	0	16,6	20,0	23428	60076	149751

MONTH	2008-2009					2009-2010					2010-2011				
	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)	Monthly Rainfall (mm)	Elevation of Water Level (m)	Volume of Water (m^3)	Surface Area of Water (m^2)	Volume of Water Over-Spilled (m^3)
OCT	12,2	20,0	23428	60076	126976	9,2	20,0	23428	60076	93020	4,7	20,0	23428	60076	42087
NOV	19,2	20,0	23428	60076	210537	25,8	20,0	23428	60076	285240	0,0	19,9	16649	52097	0
DEC	53,7	20,0	23428	60076	603215	143,3	20,0	23428	60076	1617358	53,8	20,0	23428	60076	597568
JAN	76,8	20,0	23428	60076	864673	118,5	20,0	23428	60076	1336657	121,8	20,0	23428	60076	1374009
FEB	61,5	20,0	23428	60076	690790	105,9	20,0	23428	60076	1193335	43,2	20,0	23428	60076	483661
MAR	41,0	20,0	23428	60076	456117	0,0	19,9	15484	50690	0	32,2	20,0	23428	60076	356513
APR	19,9	20,0	23428	60076	214495	6,7	20,0	23428	60076	57146	12,5	20,0	23428	60076	130738
MAY	8,0	20,0	23428	60076	76086	17,5	20,0	23428	60076	183612	9,8	20,0	23428	60076	96459
JUN	0,0	19,6	6556	35367	0	2,3	20,0	23428	60076	9161	40,0	20,0	23428	60076	435871
JUL	0,0	19,2	0	0	0	2,6	20,0	23428	60076	11241	0,0	19,6	5241	33176	0
AUG	0,0	19,2	0	0	0	0,0	19,6	5986	34385	0	4,0	20,0	23428	60076	9644
SEP	29,3	20,0	23428	60076	293497	10,4	20,0	23428	60076	85562	4,0	20,0	23428	60076	30565

** The rainfall is based on MS 713 at Aradippou.*

*** The elevation is based on the topographic survey carried out for this project; the mean sea level elevation is at 17,39m.*

APPENDIX III

The water balance under the three scenarios

DRY CONDITIONS (1995-1996)

MONTHLY RAINFALL			INFLOW (before evaporation)					OUTFLOW (calculation/adjustment of evaporation loss)					FINAL BALANCE		
YEAR	MONTH	Monthly Rainfall (mm)	Rainfall volume falling directly in to the Lake (m^3)	Catchment Runoff (m^3)	Water Volume of Lake before evaporation loss (m^3)	Water Volume of Lake before evaporation (m^3) (and after overspill)	Volume over-spilled (m^3)	Stage (m) from Storage capacity curve	Area of lake (m^2) corresponding to stage *(using area vs.stage equation)*	Potential Volume of water lost by Evaporation (m^3)	Adjustment of loss by evaporation, replaced by Spill	Net Volume Over-Spilled (m^3)	Final Water Volume of the Lake (m^3)	Final Stage (m) from Storage capacity curve)	Final Area of lake (m^2) corresponding to stage *(using area vs. stage equation)*
			1	2	3=1+2+gwt+11[a]	4=3 -5	5	6	*7*	8 =7×Evap	9=8-5[b]	10=5-(9)[c]	11=4-9	12	*13*
1995-1996	OCT 95'	4,4	2660	47141	57010	23428	33582	20	60076	11360	0	22221	23428	20	60076
	NOV 95'	39,1	23639	418916	466234	23428	442806	20	60076	7029	0	435777	23428	20	60076
	DEC 95'	6,4	3869	68569	96117	23428	72689	20	60076	4842	0	67847	23428	20	60076
	JAN 96'	94,2	56952	1009256	1089887	23428	106645 9	20	60076	4842	0	1061616	23428	20	60076
	FEB 96'	45,6	27569	488557	539804	23428	516376	20	60076	5551	0	510825	23428	20	60076
	MAR 96'	21,5	12999	230350	267027	23428	243599	20	60076	8194	0	235405	23428	20	60076
	APR 96'	33,0	19951	353561	397191	23428	373763	20	60076	10994	0	362769	23428	20	60076
	MAY 96'	3,2	1935	34285	59897	23428	36469	20	60076	14713	0	21757	23428	20	60076
	JUN 96'	0,0	0	0	23678	23428	250	20	60076	17122	16872	0	6556	19,64	35367
	JUL 96'	0,0	0	0	6806	6806	0	19,64	35812	10991	10991	0	0	19,2	0
	AUG 96'	0,0	0	0	250	250	0	19,33	2542	749	749	0	0	19,2	0
	SEP 96'	0,1	60	1071	1382	1382	0	19,47	18435	4590	4590	0	0	19,92	0

AVERAGE CONDITIONS (1976-1977)

MONTHLY RAINFALL			INFLOW (before evaporation)					OUTFLOW (calculation/adjustment of evaporation loss)					FINAL BALANCE		
YEAR	MONTH	Monthly Rainfall (mm)	Rainfall volume falling directly in to the Lake (m^3)	Catchment Runoff (m^3)	Water Volume of Lake before evaporation loss (m^3)	Water Volume of Lake before evaporation (m^3) (and after overspill)	Volume over-spilled (m^3)	Stage (m) from Storage capacity curve	Area of lake (m^2) corresponding to stage *(using area vs.stage equation)*	Potential Volume of water lost by Evaporation (m^3)	Adjustment of loss by evaporation, replaced by Spill	Net Volume Over-Spilled (m^3)	Final Water Volume of the Lake (m^3)	Final Stage (m) from Storage capacity curve)	Final Area of lake (m^2) corresponding to stage *(using area vs. stage equation)*
			1	2	3=1+2+gwt+11[a]	4=3 -5	5	6	*7*	8 =7×Evap	9=8-5[b]	10=5-(9)[c]	11=4-9	12	*13*
1976-1977	OCT 76'	20,4	12334	218565	238107	23428	214679	20	60076	11360	0	203318	23428	20	60076
	NOV 76'	57,4	34703	614982	673363	23428	649935	20	60076	7029	0	642907	23428	20	60076
	DEC 76'	106,3	64268	1138895	1226841	23428	1203413	20	60076	4842	0	1198571	23428	20	60076
	JAN 77'	65,2	39419	698551	761648	23428	738220	20	60076	4842	0	733378	23428	20	60076
	FEB 77'	10,8	6530	115711	145918	23428	122490	20	60076	5551	0	116939	23428	20	60076
	MAR 77'	19,0	11487	203565	238731	23428	215303	20	60076	8194	0	207108	23428	20	60076
	APR 77'	35,7	21584	382489	427751	23428	404323	20	60076	10994	0	393329	23428	20	60076
	MAY 77'	0,0	0	0	23678	23428	250	20	60076	14713	14463	0	8965	19,71	39852
	JUN 77'	0,0	0	0	9215	9215	0	19,72	40331	11494	11494	0	0	0	0
	JUL 77'	0,0	0	0	250	250	0	19,33	2542	780	780	0	0	0	0
	AUG 77'	0,0	0	0	250	250	0	19,33	2542	749	749	0	0	0	0
	SEP 77'	5,2	3144	55713	59107	23428	35679	20	60076	14959	0	20720	23428	20	60076

WET CONDITIONS (2001-2002)

MONTHLY RAINFALL			INFLOW (before evaporation)					OUTFLOW (calculation/adjustment of evaporation loss)					FINAL BALANCE		
YEAR	MONTH	Monthly Rainfall (mm)	Rainfall volume falling directly in to the Lake (m^3)	Catchment Runoff (m^3)	Water Volume of Lake before evaporation loss (m^3)	Water Volume of Lake before evaporation (m^3) (and after overspill)	Volume over-spilled (m^3)	Stage (m) from Storage capacity curve	Area of lake (m^2) corresponding to stage *(using area Vs stage equation)*	Potential Volume of water lost by Evaporation (m^3)	Adjustment of loss by evaporation, replaced by Spill	Net Volume Over-Spilled (m^3)	Final Water Volume of the Lake (m^3)	Final Stage (m) from Storage capacity curve)	Final Area of lake (m^2) corresponding to stage *(using area vs. stage equation)*
			1	2	3=1+2+gwt+11[a]	4=3 -5	5	6	7	8 =7×Evap	9=8-5[b]	10=5-(9)[c]	11=4-9	12	13
2001-2002	OCT 01'	28,7	17352	307491	332051	23428	308623	20	60076	11360	0	297262	23428	20	0.80
	NOV 01'	24,7	14933	264635	303246	23428	279818	20	60076	7029	0	272790	23428	20	0,80
	DEC 01'	152,6	92260	1634952	175089 1	23428	1727463	20	60076	4842	0	1722620	23428	20	0,80
	JAN 02'	61,6	37243	659981	720901	23428	697473	20	60076	4842	0	692631	23428	20	0,80
	FEB 02'	33,2	20072	355704	399454	23428	376026	20	60076	5551	0	370475	23428	20	0,80
	MAR 02'	38,9	23519	416773	463970	23428	440542	20	60076	8194	0	432348	23428	20	0,80
	APR 02'	26,6	16082	284992	324752	23428	301324	20	60076	10994	0	290330	23428	20	0,80
	MAY 02'	10,5	6348	112497	142523	23428	119095	20	60076	14713	0	104382	23428	20	0,80
	JUN 02'	20,4	12334	218565	254577	23428	231149	20	60076	17122	0	214027	23428	20	0,80
	JUL 02'	0,0	0	0	23678	23428	250	20	60076	18437	18187	0	5241	19,61	0,41
	AUG 02'	21,6	13059	231422	249971	23428	226543	20	60076	17692	0	208851	23428	20	0,80
	SEP 02'	18,6	11245	199280	234203	23428	210775	20	60076	14959	0	195816	23428	20	0,80

a) Adjusted for steady monthly groundwater (gwt) contribution of $250m^3$, October assumes initial conditions of $6958m^3$, being the mean value of all months of September as per balance of Appendix II, the remaining months take up the value of the end of the previous month.

b) The adjustment to the loss by evaporation is made by replacing it by an amount of spill (or to the maximum if available).

c) The net volume over-spilled is adjusted by the amount by which the evaporation loss was adjusted.

Summary and Conclusion

The study "Determination of important hydrological features for Oroklini Lake" was prepared in the period between 25 May 2012 to 15 November 2012 and as part of the project LIFE10 NAT/CY/716. This study has provided valuable information on the hydrology of the site and forms the baseline for Oroklini Lake's water management. Information from this study will be included in the Action Plan that will be prepared as part of the LIFE Oroklini project. In other words the site's water management could not have been achieved without the baseline provided by the hydrological study.

The study included the following elements:

1. Investigative Borehole
2. Infiltration tests
3. Groundwater levels
4. Surface and Groundwater sampling, analysis and key results
5. Installation of the water level recorder
6. Integrity of the embankment and the spillway weir
7. Spillway weir capacity evaluation for low frequency floods
8. Water Operation Study of Oroklini Lake
9. Assessment of proposed water management works
10. Notable points for consideration for the management of the water in the lake
11. Further Studies considered necessary

Main findings:

1. *Investigative Borehole*

The groundwater level is 1meter below ground.

The Borehole Log - Lithology:

The first meter is made up of slightly sandy clay and silt, followed by two meters of **gypsiferous** sandy, very clayey silt, and ending with two meters of slightly sandy clay and silt.

The Particle Analysis:

0,5 - 1,0m	40% Clay and 55% Silt and 5% Sand
2,0 - 2,5m	25% Clay and 65% Silt and 10% Sand
4,0 – 4,5m	40% Clay and 55% Silt and 5% Sand

Permeability tests:

The extremely low values for permeability are consistent to the lithology described in the borehole log and determined by the particle analysis being Clay and Silt - silty loess.

2. *Infiltration tests*

The tests were carried at the dry bed of the lake 7 and 15 meters southeast from the drilled investigative borehole.

Infiltration rate: 3mm/hr and 3,5 mm/hr (*Infiltration rate could be much lower since only part of the water was infiltrated*)

3. Groundwater levels

The groundwater levels fall steadily in June while a rise is noted in mid-August. This rise is not due to a rainfall event or release of treated effluent from the existing pipe network of the Larnaka Sewage Treatment Plant in the area. The reason for this increase of groundwater levels in August needs to be further investigated.

The levels drop again in September and October but the rains of October and of early November caused runoff and a rise of the ground water level again.

4. Surface and Groundwater sampling, analysis and key results

The sampling from the surface and groundwater was carried out in early June and October. The two samples (June and October) were analyzed for the same parameters, except for the heavy metals (Pb and Hg) which were analyzed only in June. Dissolved Oxygen, BOD and COD were analysed only for the surface water.

Exceptionally high values of **EC**, **major ions** (Cl^-, SO_4^-,HCO^{3-}, $Ca2^+$,Mg^{2+}, K^+, Na^+) and **Boron:**

- Linked with connate salts (evaporate deposits - gypsum) and repetitive cycles of evaporation, rather than sea intrusion.
- High amounts in both GW & SW suggest interconnection between them.

Low NO_3-N (Nitrates) and **P (Phosphorus)**, both in both GW & SW:

- absence of agricultural activities and suggest minimal pollution from sewage.

Hg (Mercury): below detection limit (<1 μg/l) in both GW & SW.

Pb (Lead) in both GW & SW is 9,9 and 2,9 μg/l respectively ➔below the EU drinking Water Standards (10μg/l).

The significant increase of BOD (from 12 to 118 mg/l – June to October) and COD (25 to 188 mg/l – June to October) indicates increased pollution possibly caused by inflow from the urbanized catchment area without undergoing much dilution with rain water, the decay of vegetation and increased presence of faeces.

Relationship of groundwater to the sea and the lake water

- The study showed that sea water is not the cause of the increased salinity of the local groundwater and of the lake. *Thus, there is no sea intrusion in the area and the chemical composition of the groundwater is affected directly by the presence of sediment deposits which are very rich in salts.*

5. Installation of the water level recorder

The water level recorder was placed just upstream of the weir, in S3. It is programmed for recording observations every 12 hours (6:00 a.m. and 6:00 p.m). Water level data will be retrieved on a monthly basis. These data will provide information for the management of the site in the future.

6. Integrity of the embankment and the spillway weir

The embankment is found in good condition. No serious leakage was found except in one case which should be monitored and be corrected if the flow is increased. A minor subsidence of an average of 20cm is observed between 120 and 230m from the western starting point of the embankment. This has to be reinstated to the previous level. Minor downstream areas of the bank which show signs of erosion should be reinstated.

7. Spillway weir capacity evaluation for low frequency floods

The eastern wing-wall needs to be constructed at the same dimensions as the western wall.
The spillway crest should be established at the same level, throughout.
The weir should be kept free of vegetation at all times.

The seepage on the spillway wall should be fixed during the construction works.
A sluice gate is needed to be established. This will allow for a better management of the water in the lake.

8. Water Operation Study of Oroklini Lake

A detailed monthly water operation study of the Oroklini Lake, has been worked out on the basis of the hydro-climatological conditions of the years 1968 to 2011 (Meteorological Station 731, Aradippou).
This water operation study of the lake, and the model developed as an "excel spreadsheet" for it, can be used in the future, i.e. when environmental objectives (i.e. selected water level at the lake, volume required or surface area of the lake etc.) are determined.
The study takes into account all sources of inflow such as runoff, direct precipitation and rising groundwater, and losses such as evaporation, and outflow.
The calculations are carried out in three stages:
Inflow computations before evaporation is applied, Outflow calculation including evaporation loss, and Evaluation of final balance computations.
The Water Operation Study has shown that due to the small capacity of the lake compared to the annual runoff of the Oroklini stream, the lake collects water every year exhibiting spills in most months.
Frequency of months at which the lake appears to be totally dry: August, July, September and June.
December, January and February the lake is always full and exhibits spills.
March, November, and April, exhibit spills at high frequency
October, May, June and September exhibit spills at low frequency

9. Assessment of proposed water management works

The study assessed proposed water management works like installing control structures at some areas of the site and digging new channels and low features in S3. However, the design of works will be made by experts on managing wetlands for birds. The assessment carried out as part of this study did not take into account the wildlife of the site.

10. Notable points for consideration for the management of the water in the lake

- The continuing urbanization of the runoff catchment area suggests that runoff into the lake should be expected to increase in the future. At the same time some deterioration of the quality of the surface runoff should be expected.
- Once the Community Council proceeds with the establishment of a sewage network, then a reduction of the available runoff and at the same time an improvement of the quality of the surface runoff should be expected.
- The possibility of having access to the existing pipe network, which brings tertiary treated effluent water from the Larnaka Sewage Treatment Plant to the area and use of certain quantities of this water for maintaining the lake and marsh area when needed, should be investigated.
- Another source of water for occasional use for the Oroklini Lake would be the water from the Southern Conveyor which runs along the main highway towards the Kokkinochoria.

11. Further Studies considered necessary

The "*Lakewater Operation Model under environmental objectives*" should be set and ran when environmental objectives are available, involving a daily rainfall-runoff model, so that operation rules can be defined and needs for further water management works can be prescribed and modeled.

An *“integrated study of the likely pressures and impacts on water quality degradation of the surface water runoff within the catchment area”* is deemed a must, if measures are to be taken to safeguard the quality of the lake water.
Such a study is considered to be particularly useful for the determination of measures for the management of the lake and the maintenance of a good quality condition and its operation as a habitat, since within the catchment area there are and could be developed other infrastructure works and small industries in the presence of intense urban development. Similarly, issues such as the existing storm water network or further plans for this as well as sewage network etc. could be examined.