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CDR
Beirut

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Protection of Jeita Spring

ADVISORY SERVICE DOCUMENT NO. 2

Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

Raifoun
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Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

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Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

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asl	Above mean sea level
BGR	German Federal Institute for Geosciences and Natural Resources
BMZ	German Ministry of Economic Cooperation and Development
CDR	Council for Development and Reconstruction
ELKA	Manufacturer of ready-mix concrete, Kaslik
GW	groundwater
KfW	German Bank for Reconstruction and Development (KfW Development Bank)
MAPAS	Company operating Jeita Grotto
MoEW	Ministry of Energy and Water
NTU	Nephelometric turbidity unit
TC	Technical cooperation
WEBML	Water Establishment Beirut and Mount Lebanon
WW	Wastewater
WWTP	Wastewater treatment plant

List of Reports prepared by the Technical Cooperation Project Protection of Jeita Spring

Report No.	Title	Date Completed
Technical Reports (TR)		
1	Site Selection for Wastewater Facilities in the Nahr el Kalb Catchment – General Recommendations from the Perspective of Groundwater Resources Protection	January 2011
2	Best Management Practice Guideline for Wastewater Facilities in Karstic Areas of Lebanon – with special respect to the protection of ground- and surface waters	March 2011
3	Guideline for Environmental Impact Assessments for Wastewater Facilities in Lebanon – Recommendations from the Perspective of Groundwater Resources Protection	November 2011
4	Geological Map, Tectonics and Karstification in the Groundwater Contribution Zone of Jeita Spring	First Draft September 2011
5	Hydrogeology of the Groundwater Contribution Zone of Jeita Spring	In progress
6	Water Balance for the Groundwater Contribution Zone of Jeita Spring using WEAP including Water Resources Management Options and Scenarios	In progress
7	Groundwater Vulnerability Mapping in the Jeita Spring Catchment	April 2012
Special Reports (SR)		
1	Artificial Tracer Tests 1 - April 2010 (prepared with University of Goettingen)	July 2010
2	Artificial Tracer Tests 2 - August 2010 (prepared with University of Goettingen)	November 2010
3	Practice Guide for Tracer Tests	Version 1 January 2011
4	Proposed National Standard for Treated Domestic Wastewater Reuse for Irrigation	July 2011
5	Artificial Tracer Tests 4B - May 2011	September 2011

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Report No.	Title	Date Completed
	(prepared with University of Goettingen)	
6	Artificial Tracer Tests 5A - June 2011 (prepared with University of Goettingen)	September 2011
7	Mapping of Surface Karst Features in the Jeita Spring Catchment	October 2011
8	Monitoring of Surface Water Runoff in the Groundwater Contribution Zone of Jeita Spring	In Progress
9	Soil Survey in the Investigations in the Groundwater Contribution Zone of Jeita Spring	First Draft November 2011
10	Mapping of the Irrigation System in the Jeita Catchment	First Draft November 2011
11	Artificial Tracer Tests 5C - September 2011 (prepared with University of Goettingen)	February 2012
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14	Guideline for Gas Stations - Recommendations from the Perspective of Groundwater Resources Protection	May 2012
15	Tritium - Helium Investigations Investigations in the Groundwater Contribution Zone of Jeita Spring	In Progress
16	Hazards to Groundwater and Assessment of Pollution Risk in the Jeita Spring Catchment	In Progress
17	Monitoring of Spring Discharge in the Groundwater Contribution Zone of Jeita Spring	In Progress
Advisory Service Document (ASD)		
1	Quantification of Infiltration into the Lower Aquifer (J4) in the Upper Nahr Ibrahim Valley	May 2012
1 - 1	Addendum No. 1 to Main Report	June 2012

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Report No.	Title	Date Completed
	[Quantification of Infiltration into the Lower Aquifer (J4) in the Upper Nahr Ibrahim Valley]	
2	Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant	June 2012
Reports with KfW Development Bank (jointly prepared and submitted to CDR)		
1	Jeita Spring Protection Project Phase I - Regional Sewage Plan	October 2011
2	Jeita Spring Protection Project - Feasibility Study - Rehabilitation of Transmission Channel Jeita Spring Intake – Dbaye WTP	May 2012
3	Jeita Spring Protection Project - Environmental Impact Assessment for the Proposed CDR/KfW Wastewater Scheme in the Lower Nahr el Kalb Catchment	In Progress

Acknowledgements

In its effort to protect the water resources in the Nahr el Kalb catchment, the project *Protection of Jeita Spring* experienced great support not only at the political and institutional level but also from many municipalities and people in the catchment area.

We are especially grateful for the backing and support of the Council for Development and Reconstruction (CDR), namely its president, Nabil Jisr, Talaat Dada (deceased) and Eng. Ismail Makki (manager), the Ministry of Energy and Water (MoEW), namely H.E. Gebran Bassil and his staff, the Water Establishment Beirut and Mount Lebanon (WEBML), namely its president, Joseph Nseir, as well as George el Kadi (technical director), Maher Chrabieh (Director of the Dbaye treatment plant) and Dr. Paul Souaid (Director of the Water Laboratory at the Dbaye treatment plant).

Some of the technical installations could not have been achieved without the help of Jeita Grotto (MAPAS). Our sincerest thanks are extended to Dr. Nabil Haddad, Ayman Ibraheem, Najeeb Najeeb and all other staff at Jeita Grotto.

Many mayors and staff of municipalities in the catchment saw the opportunities which the project hopes to provide in the near future as a chance for development. Among those which very actively assisted the project we would like to highlight the municipalities of Ballouneh (Dr. Pierre Mouzawak, Simon Daou, Tony Daou) and Jeita (Samir Baroud).

The project was made possible by grants of the German Government, allocated through the Ministry of Economic Cooperation and Development (BMZ). Our thanks therefore go to the staff of the BMZ, KfW and German Embassy. We experienced that this assistance is very much appreciated not only among the involved institutions and stakeholders but also the population living in the area.

0 Executive Summary

The Technical Cooperation (TC) Project Protection of Jeita Spring is implemented by BGR and CDR relevant for the site selection of wastewater facilities in the Nahr el Kalb catchment (to be implemented by KfW and CDR as well as other donor agencies).

This report presents investigations carried out together with WEBML staff concerning the **source of several events of high turbidity which occurred in April, May and June 2012 in Jeita Grotto and the Dbayeh drinking water treatment plant**.

These turbidity peaks constitute a major problem for raw water treatment. Since several years raw water shows a high level of microbiological contamination, clearly related to the lack of wastewater collection and treatment in the Jeita groundwater catchment. The Dbayeh drinking water treatment plant provides treatment only through sandbed filters and chlorination. **When turbidity is high, this treatment cannot be effective anymore so that the water being transferred to the drinking water network will still have a high level of microbiological contamination and turbidity.** This was the case during the seven turbidity peaks monitored by the BGR project during the time period April to June 2012. During the five last turbidity peaks monitored between 21 May 2012 and 19 June 2012, turbidity at Jeita was between 90 and 100 NTU.

The **Greater Beirut Area** receives its major share of water from Jeita spring. **The turbidity events thus constitute a major risk for the population being served by drinking water from the Jeita catchment**.

Through field observations the source of contamination could finally be located. The **HAJJ Contractors sandstone quarry in Bqaatouta** releases large quantities of a sand/water mixture from water ponds into the surface water course at Boqaata, commonly on Sunday and Monday night or during the early morning hours. This release is probably related to the operational routine. It is assumed that the sand is separated from fine material (silt, clay) by washing.

The straight-line distance to the Daraya tunnel monitoring station is 9,600 m, and 13,500 m to the Jeita monitoring station. The released sludge will infiltrate in the J4 (Keserwan Formation) aquifer somewhere between Kfar Debbiane and Deir Chamra. Turbidity was observed downstream of the HAJJ Contractors quarry in the entire river course.

Estimating the horizontal and vertical flow velocities between injection point and Jeita Grotto, it is believed that a **mixed groundwater and surface water flow path** is the most likely explanation. The turbidity peaks can therefore also be used as an indication that a **massive infiltration in the upper part of the J4 aquifer** occurs in this area, and not just at the perte de Deir Chamra.

Flow velocity in the surface water course is around 1 m/s (3,600 m/h). As previous tracer tests conducted by the project have shown, groundwater flow velocity is around 100 to 200 m/h. Travel time is approx. 24 h between the injection site and the Jeita monitoring station. It is assumed that there are several locations of high infiltration along the surface water course of Nahr es Zirghaya, and groundwater flow probably follows a large diameter conduit.

Apart from water quality, **the release of high sediment loads from quarries may, also impact on water quantity**, because the flushed fine material will deposit further downstream in areas of low flow velocity and may cause a clogging of fracture porosity. Lower porosity results in lower permeability and lower flow through, and could thus result in **less discharge at Jeita spring**.

Apart from its major impact on water supply, **the events of high turbidity have also an impact on the operation of Jeita Grotto (MAPAS) as the most important touristic site in Lebanon**.

1 Introduction

The work presented in this report was conducted in the framework of the German-Lebanese Technical Cooperation project *Protection of Jeita Spring*.

The German-Lebanese Technical Cooperation (TC) Project *Protection of Jeita Spring* is funded by a grant of the German Government (Ministry of Economic Cooperation and development, BMZ). Its aim is to "reduce important risks for the drinking water supply of Beirut through measures implemented in the Jeita catchment". On the German side, the project is implemented by the Federal Institute for Geosciences and Natural Resources (BGR). The project partners on the Lebanese side are the Council for Development and Reconstruction (CDR), the Ministry of Energy and Water (MoEW) and the Water Establishment Beirut Mount Lebanon (WEBML). Important components of the TC project are:

1. Integration of water resources protection aspects into the investment planning and implementation process in the wastewater sector;

2. Integration of water resources protection aspects into landuse planning and improved spring capture and water conveyance;

3. Establishment of a monitoring system;

4. Proposal for an improved Jeita spring capture and conveyance system to Dbayeh.

Jeita spring constitutes around 70 % of the water supply for the Greater Beirut Area has thus an immense importance. Jeita water is being treated at the Dbayeh treatment plant where it arrives via a canal and tunnel system. This conveyance system is already more than 100 years old, leaky and also highly vulnerable to pollution.

Because of the dependency on Jeita water, a major pollution event in the groundwater catchment of Jeita spring can impact heavily on the health of the population being served by Jeita water.

Between 23 April and 19 June 2012 seven turbidity peaks were observed. Turbidity in Jeita reached almost 100 NTU. At such high turbidity treatment cannot be efficient. In the Dbayeh outflow to the water supply network a max. turbidity of 5 NTU was measured.

2 Description of Turbidity Event

Six individual turbidity peaks were observed between 23 April and 11 June 2012 (Figure 1). These events were monitored by the BGR project using multiparameter probes (InSituTroll 9500) in Jeita (E 35.648579°, N 33.946155°) and in the Daraya Tunnel (siphon terminale or Jeita 140; E 35.690799°, N 33.951422°).

The first two events (Figures 4, 5) reached a smaller turbidity level (25 and 32 NTU), while the following five peaks (Figures 6, 7, 8, 9, 10) reached higher levels of very similar magnitude of turbidity (91, 99, 90 and 91 NTU). None of the turbidity events is related to rainfall events (Figure 2). There was no response in temperature or electric conductivity at the monitoring stations.

Similar but fewer and less regular events occurred in April 2011 (Figure 11) and June 2011 (Figure 12).

The comparison of all seven turbidity events shows that there were mostly two separate peaks with a time separation of almost 24 h. The first peak typically reached Jeita monitoring station on Monday between 0:00 and 09:00, the second peak between Monday 22:00 and Tuesday 01:00. The reason for this similar spacing in time and magnitude is believed to be an operational routine. It is assumed that the sand is separated from fine material (silt, clay) by washing. Water may be taken from the irrigation canal from Naber al Labbane (SAADEH et al., 2011).

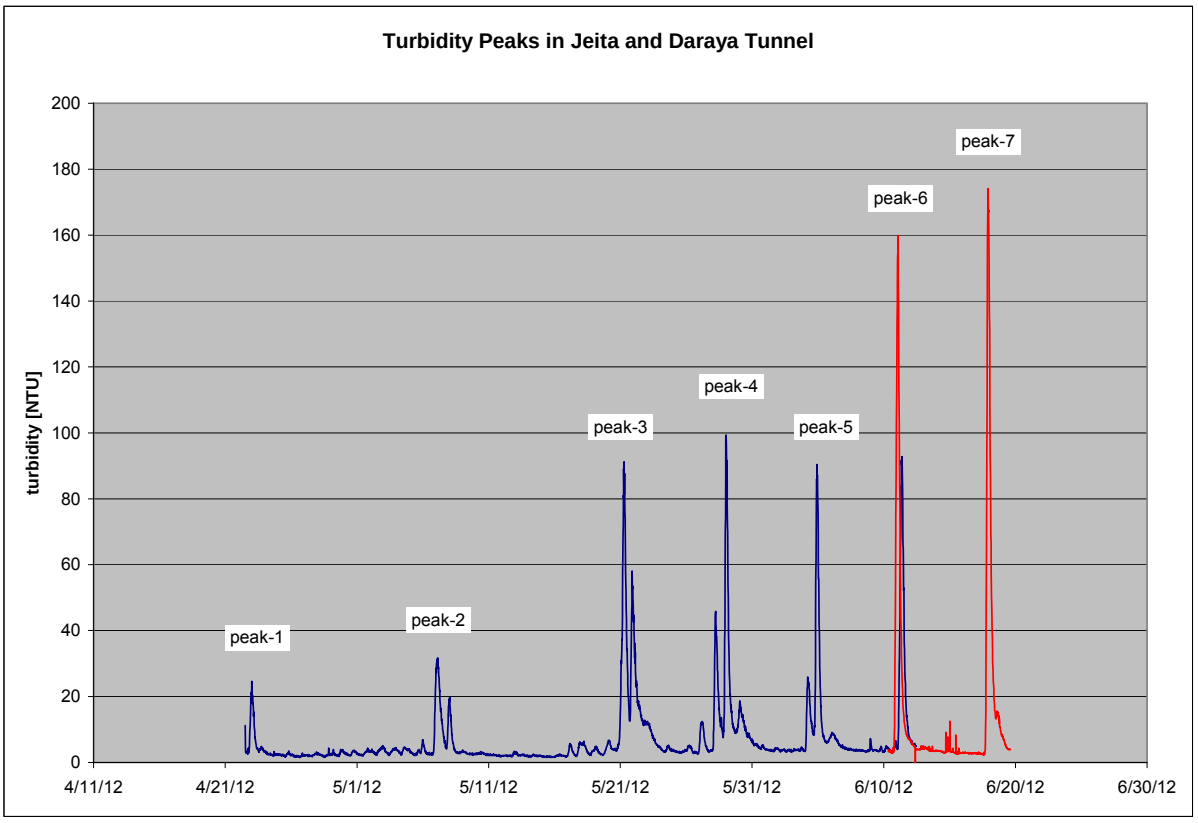

Figure 1: Turbidity Monitored in Jeita (blue) and Daraya Tunnel (red)

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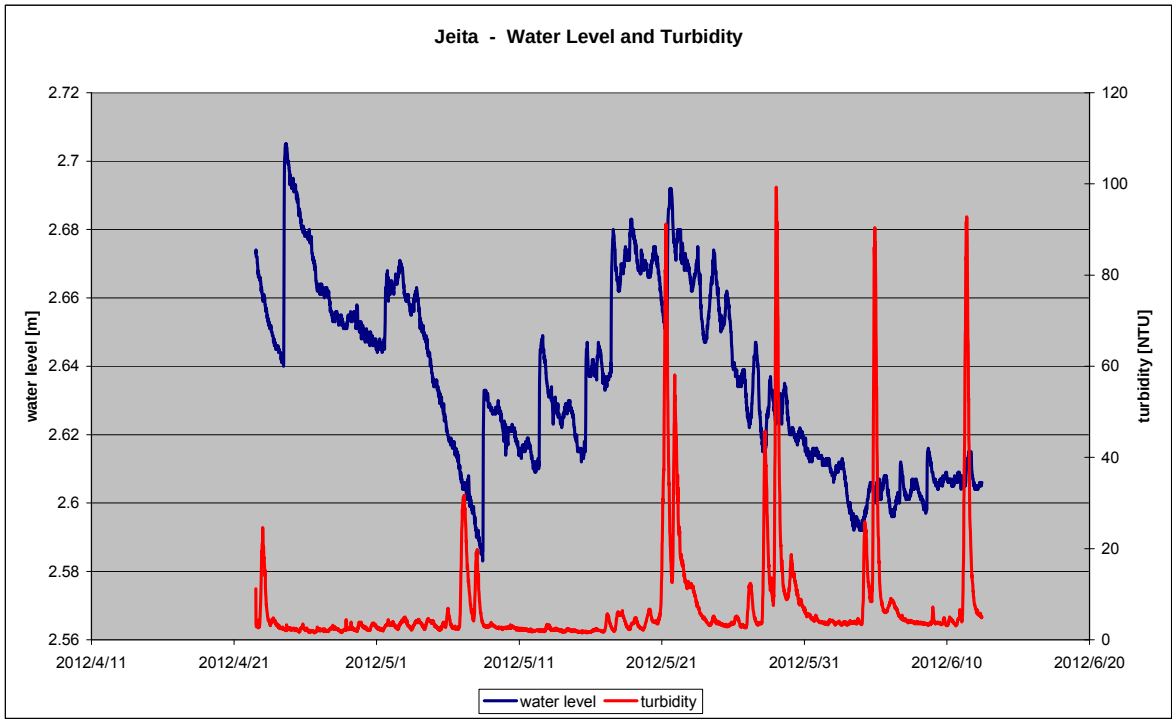

Figure 2: Correlation of Turbidity (red) and Water Level (blue) Monitored in Jeita

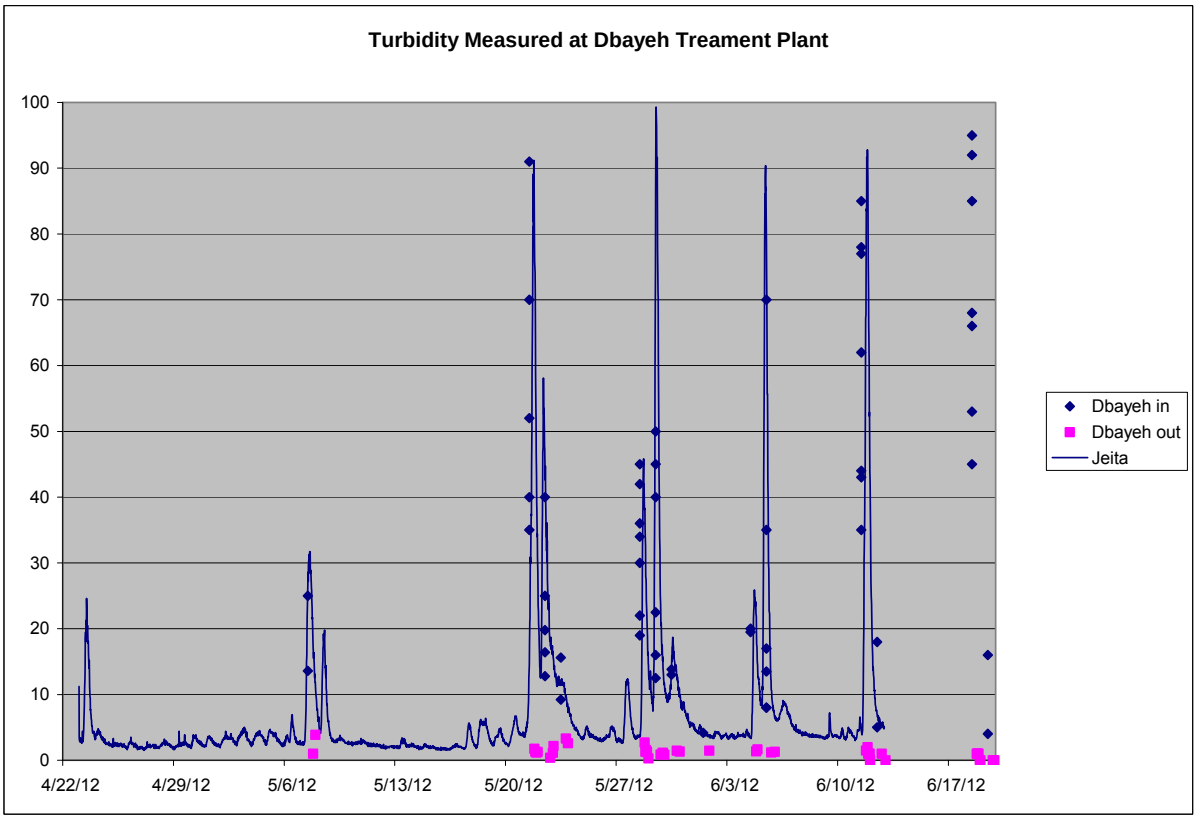

Figure 3: Correlation of Turbidity at Jeita Spring (BGR) and Dbayeh Treatment Plant

Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

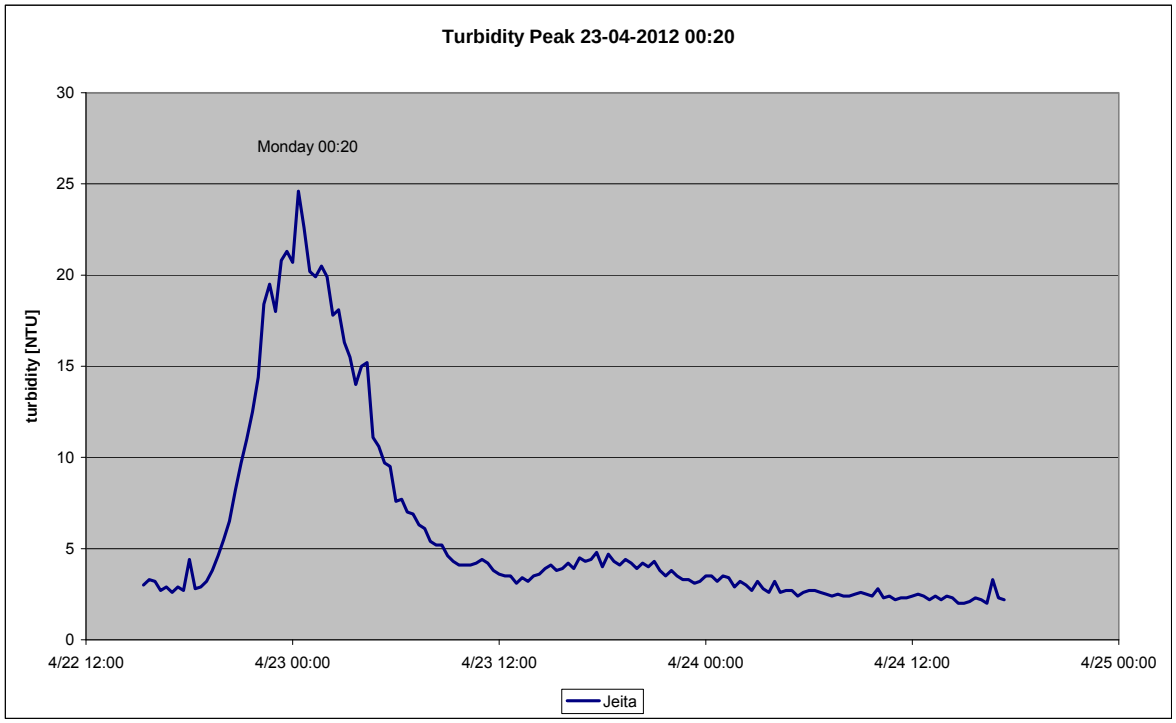

Figure 4: Turbidity Distribution in Jeita during First Event

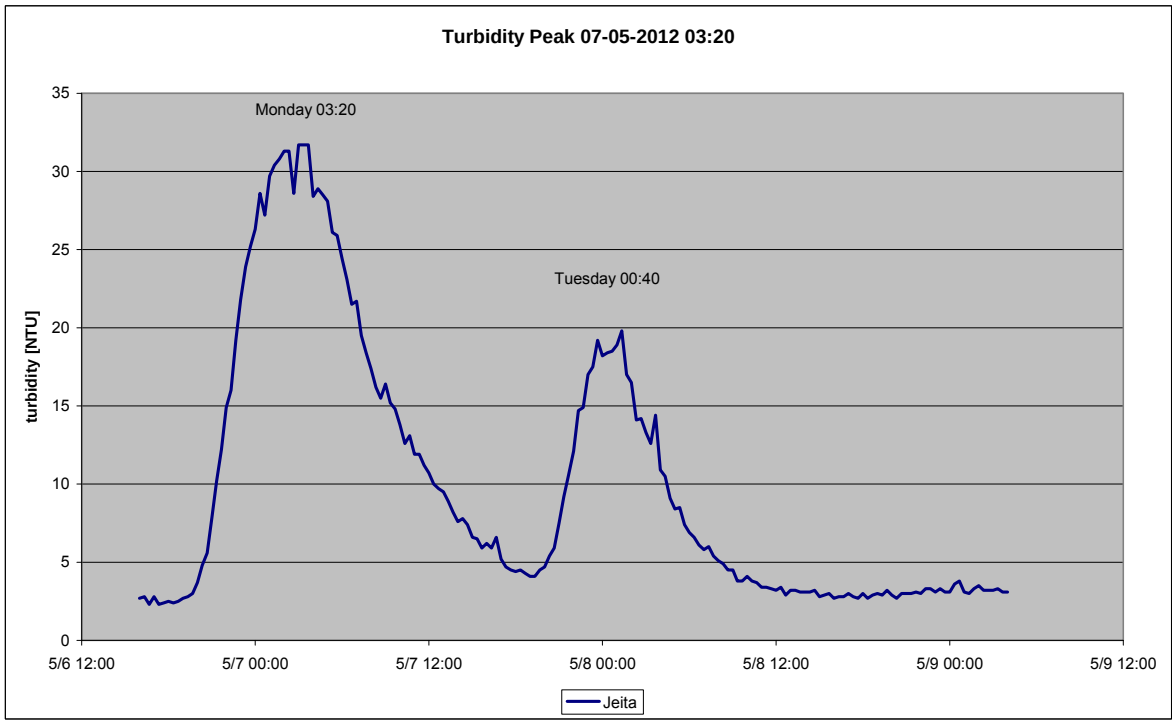

Figure 5: Turbidity Distribution in Jeita during Second Event

Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

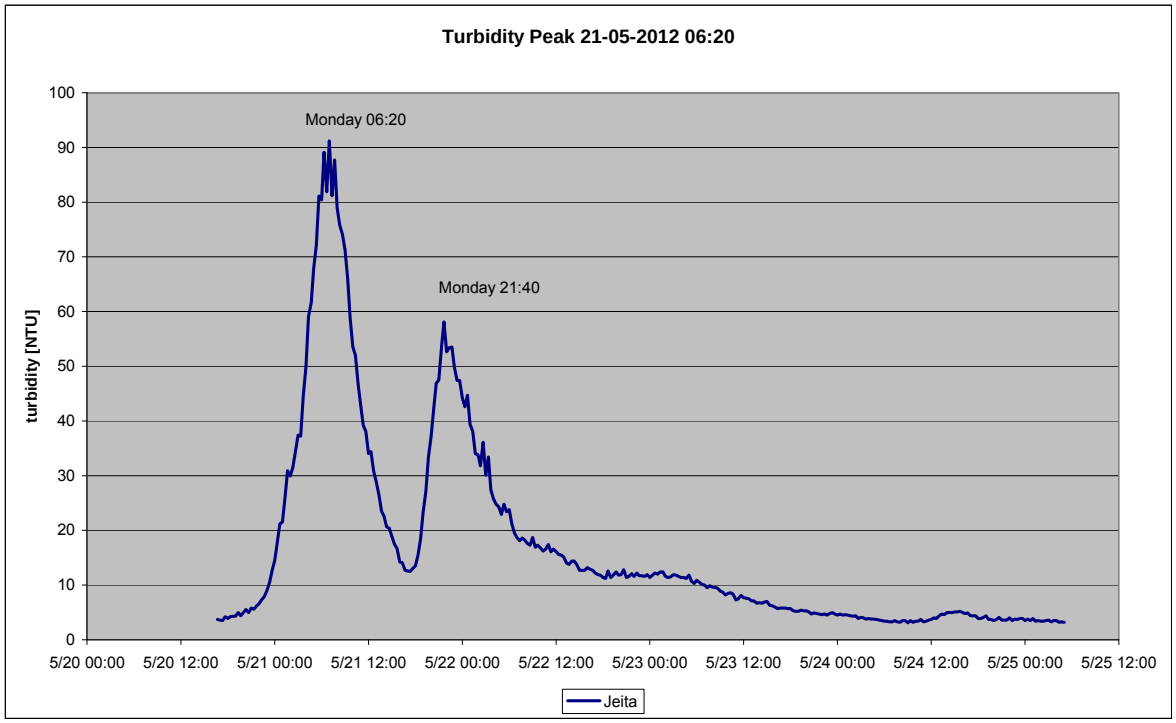

Figure 6: Turbidity Distribution in Jeita during Third Event

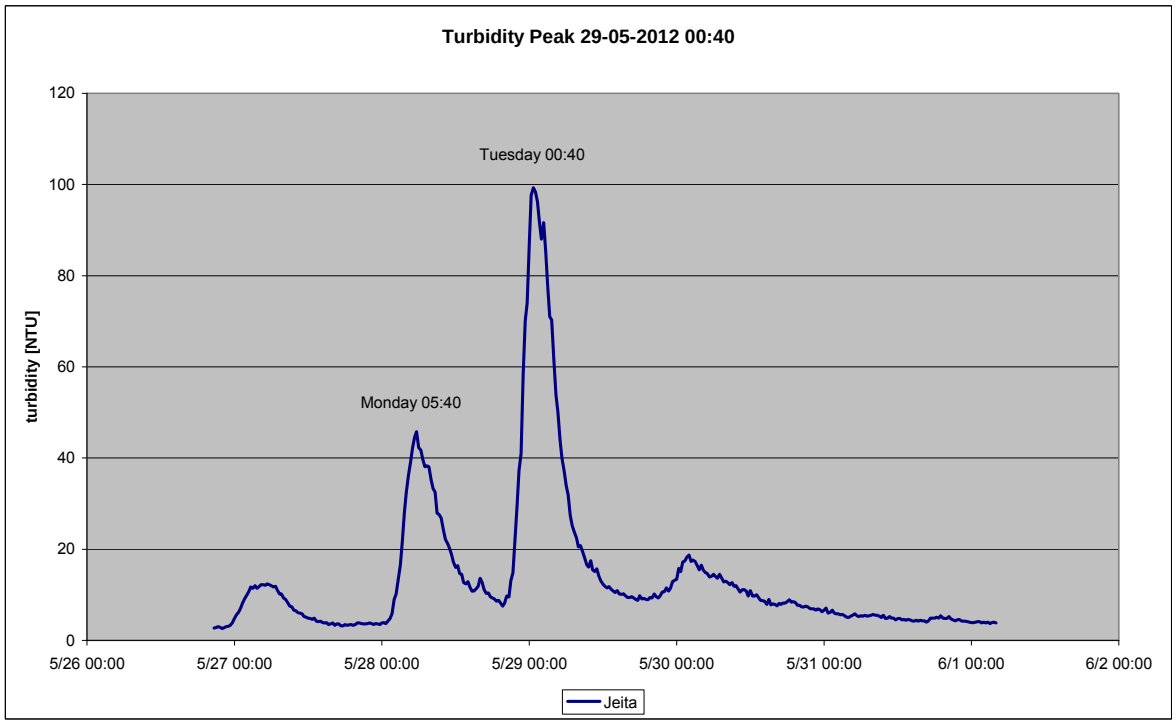

Figure 7: Turbidity Distribution in Jeita during Fourth Event

Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

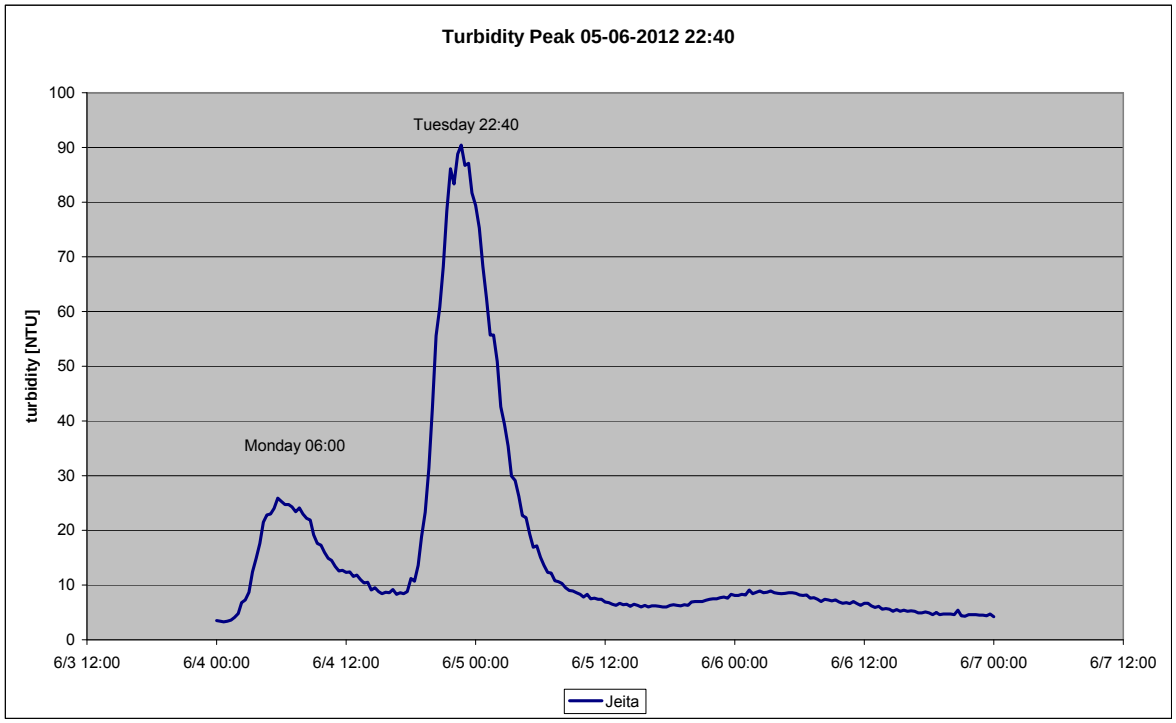

Figure 8: Turbidity Distribution in Jeita during Fifth Event

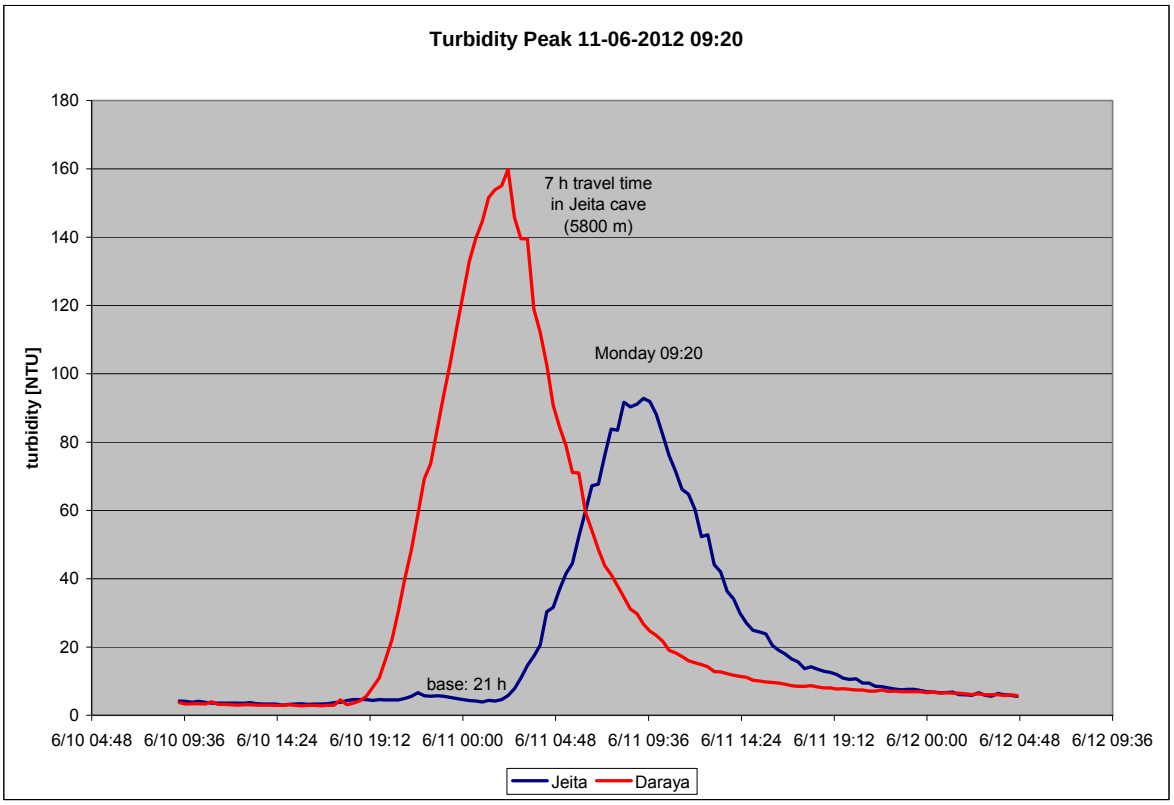

Figure 9: Turbidity Distribution in Jeita during Sixth Event

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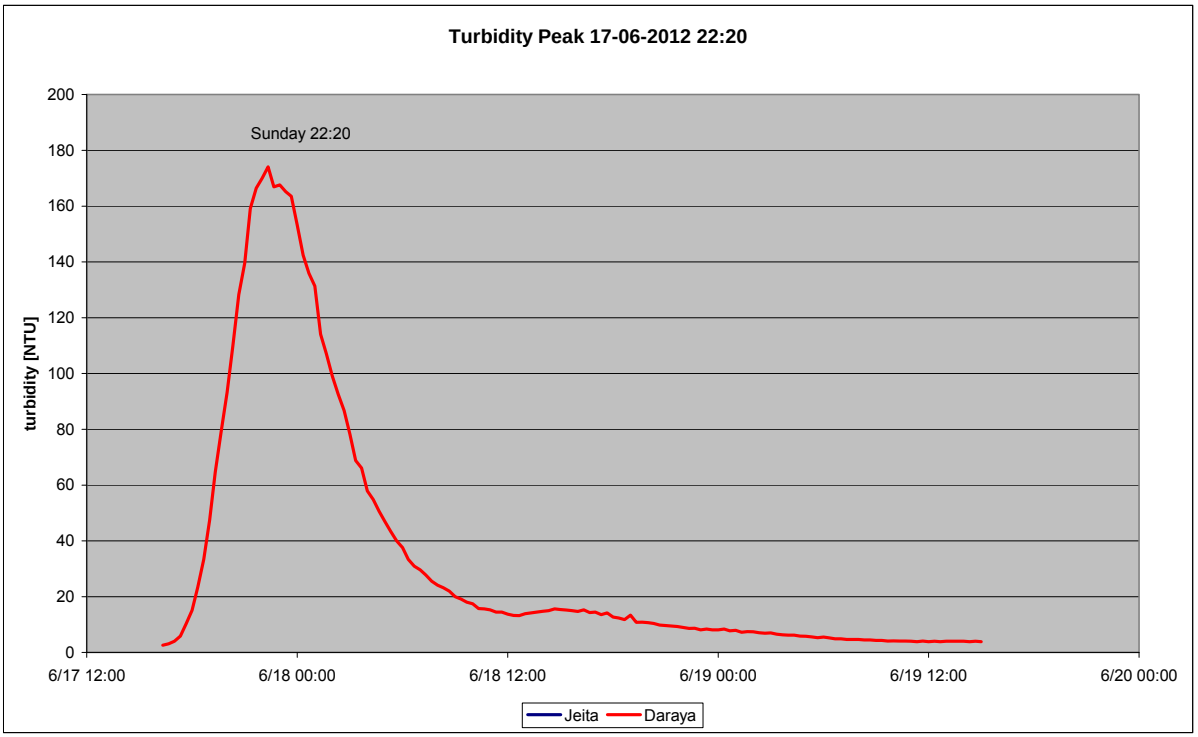

Figure 10: Turbidity Distribution in Jeita during Seventh Event

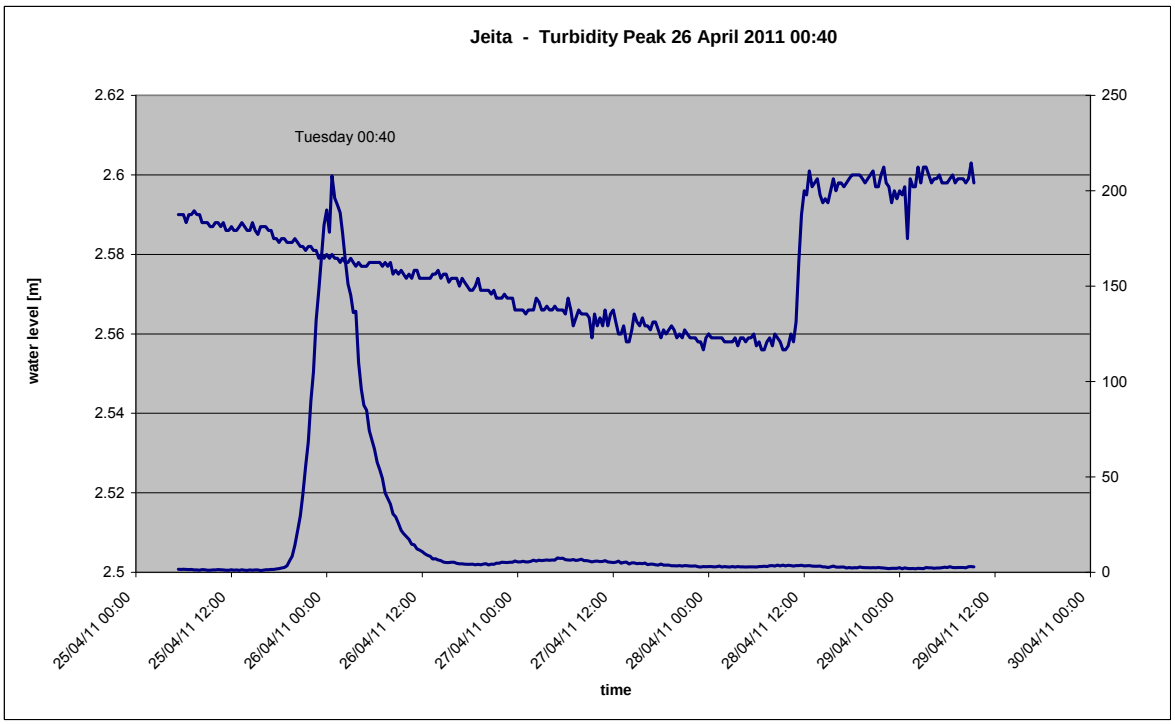

Figure 11: Turbidity Peak on 26 April 2011 in Jeita

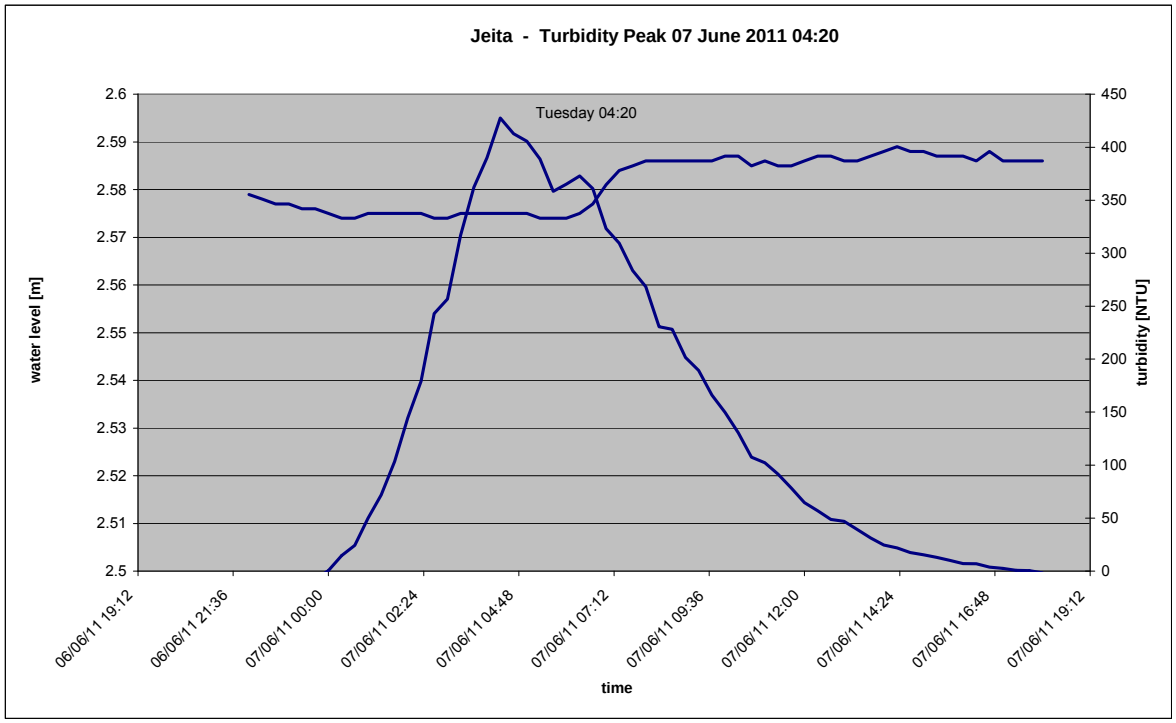

Figure 12: Turbidity Peak on 07 June 2011 in Jeita

3 Potential Pollution Sources

The turbidity peaks were observed in Jeita and Daraya tunnel with a time delay of around 7 hours (11 June 2012). The turbidity peak in Daraya was 60% higher compared to Jeita. Due to its arrival in both stations, the pollution source has to be located east of the monitoring at Daraya tunnel. It is likely that injection is done during the weekend so that public attention will be low. The injected material is believed to be sludge from a quarry or dumped construction material. The infiltration into groundwater requires that a large amount of water is available, either from surface water, public water supply, tankers, a water well or a water pond. Most likely is injection or dumping in water courses where there is surface water runoff or irrigation water (from an irrigation canal) without extra cost.

During this time period, however, there was only runoff in few water courses. On 15 June 2012 the estimated runoff was as follows:

- Nahr es Salib at Daraya bridge: ~ 3 m³/s
- Nahr el Hardoun: none
- Nahr es Zirghaya: 0.25 m³/s

All potential pollution sources were closely observed for their potential impact on water courses. The following sources were noted (Figure 13):

(1) borehole Joseph Nassar in Ballouneh (Figures 14, 15)
(E 35.680419°, N 33.950730°, ~ 675 m asl)
drilling to groundwater level, at 450 m on 15 June 2012
drilling started approx. 20 days earlier using rotary rig with drilling mud, since 14 June 2012 percussion rig
continuous operation, weekly injection unlikely
ca. 960 m W of Daraya tunnel (downstream)

(2) construction waste dump site next to Mar Roukoz school (Figures 16, 17)
(E 35.702113°, N 33.960792°, ~ 820 m asl)
continuous operation since many years, no water available for flushing, weekly injection unlikely
ca. 1500 m NE of Daraya tunnel (upstream)

(3) cement brick fabrication in lower Nahr es Salib (Figures 18, 19)
(E 35.702113°, N 33.960792°, ~ 555 m asl)
approx. 20 m from river, dumping into river observed
flushing with river
ca. 2500 m E of Daraya tunnel (upstream)

(4) abandoned limestone quarry in Nahr es Zirghaya (Figures 20)
(E 35.729715°, N 33.957227°, ~ 680 m asl)
directly at river
ca. 3700 m ENE of Daraya tunnel (upstream)

(5) decoration stone cutting factories in Deir Chamra (Figures 21, 22, 23, 24)
(E 35.711043°, N 33.945585°, ~570 m asl)
approx. 100 m from river, dumping into river observed
flushing with river
flow in Nahr es Hardoun almost zero,
not part of Jeita groundwater catchment
ca. 2100 m E of Daraya tunnel (upstream)

(6) ELKA cement limestone quarry in Abou Mizane (Figures 25, 26, 27)
(E 35.729925°, N 33.942568°, ~ 620 m asl)
directly at river, dumping into river likely
flow in Nahr es Hardoun almost zero,
not part of Jeita groundwater catchment
ca. 3700 m E of Daraya tunnel (upstream)

(7) rock cutting factory in Boqaata Ashkout (Figure 28)
(E 35.730474°, 34.000871°, ~ 1205 m asl)
no surface water, no pond available
ca. 6,600 m NE of Daraya tunnel (upstream)

(8) cement brick fabrication in the upper Nahr es Salib at Mayrouba (Figures 29)
(E 35.779583°, N 34.011525°, ~ 1185 m asl)

200 m N of river, observed discharge into river
ca. 10,600 m NE of Daraya tunnel (upstream)

(9) sandstone quarry of HAJJ contractors in Bqaatouta (Figure 30)
(E 35.791707°, N 33.975972°, ~ 1,485 m asl)
large water ponds (total capacity ~ 5,000 m³)
observed sludge discharge into surface water course

The river courses and activities at each indicated site were observed during the weekends before submission of this report. Because of certain criteria a number of sites could be ruled out in the course of the investigation:

Site (1), borehole Joseph Nassar in Ballouneh, is located too far downstream of Daraya tunnel and could therefore not reach this monitoring location. Therefore this site can be ruled out as a source.

Site (2), construction waste dump site next to Mar Roukoz school, does not have sufficient water to flush the pollution. Dumping seems random and continuous. Therefore this site can also be ruled out as a source.

Site (3), cement brick fabrication in lower Nahr es Salib, too small, no current dumping activities; site can be ruled out as a source.

Site (4), abandoned limestone quarry in Nahr es Zirghaya, too small, no current dumping activities; site can be ruled out as a source.

Site (5), decoration stone cutting factories in Deir Chamra, discharge of fairly large quantity of sludge from limestone cutting into surface water course, but currently no runoff in Nahr es Hardoun; not inside groundwater catchment (MARGANE et al., in progr.).

Site (6), ELKA cement limestone quarry in Abou Mizane, discharge of fairly large quantity of fine material from limestone quarry into surface water course, but currently no runoff in Nahr es Hardoun; not inside groundwater catchment (MARGANE et al., in progr.).

Site (7), cement brick fabrication in upper Nahr es Salib, can be excluded because the potential amount of sludge to be discharged would be too little and the dilution by surface water runoff too high. Secondly the amount that would infiltrate is too low, as measurements conducted in April 2011 have shown (MARGANE et al., in progr.).

Site (8), rock cutting factory in Boqaata Ashkout, site too small, potential amount of sludge to be discharged too little; site can be ruled out as a source.

Site (9), very large and active quarry; storage of large amounts of water; discharge of sludge/water mixture observed.

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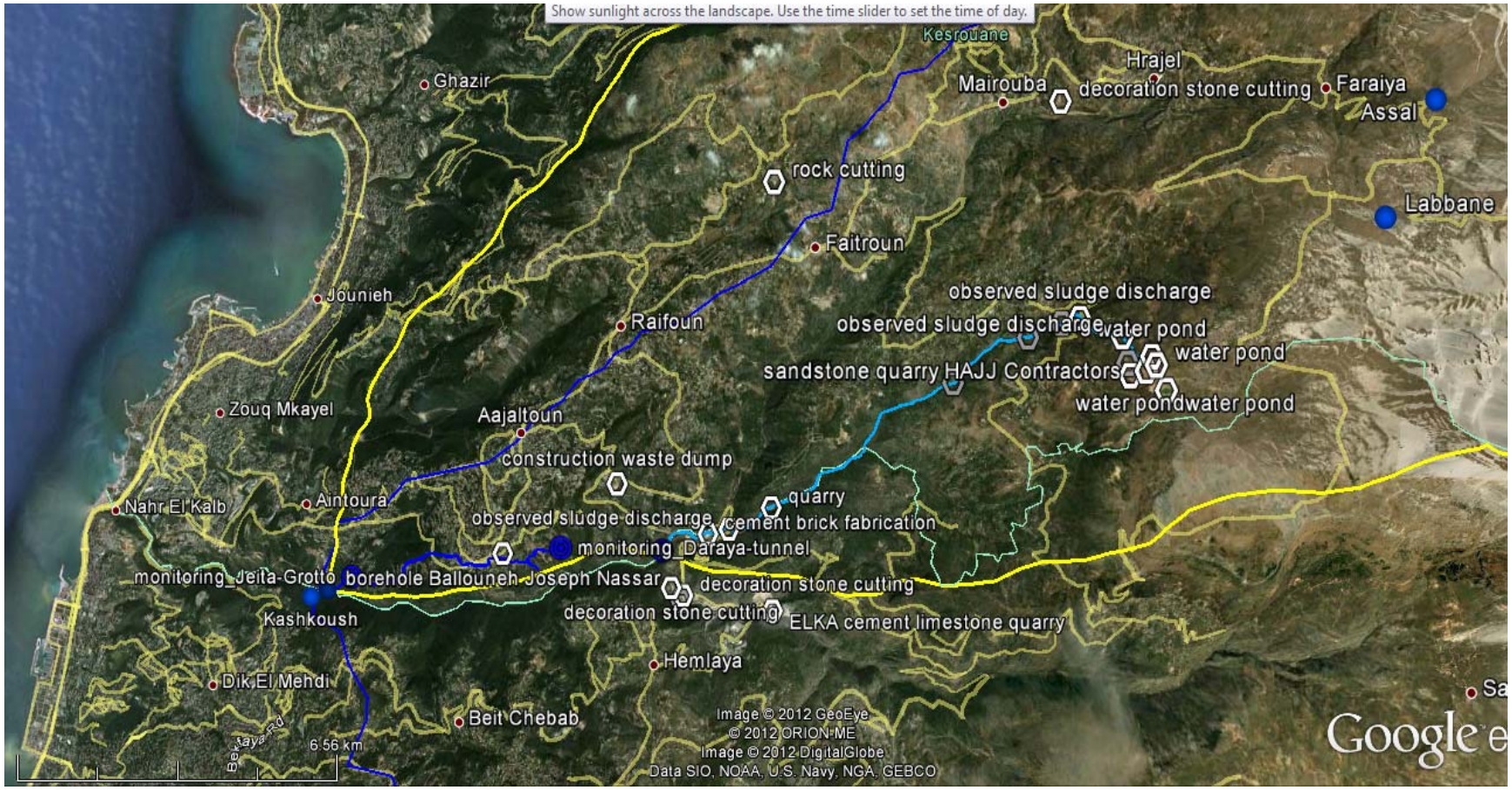


Figure 13: Investigation Area

Figure 14: Drilling of Joseph Nassar Water Well in Ballouneh

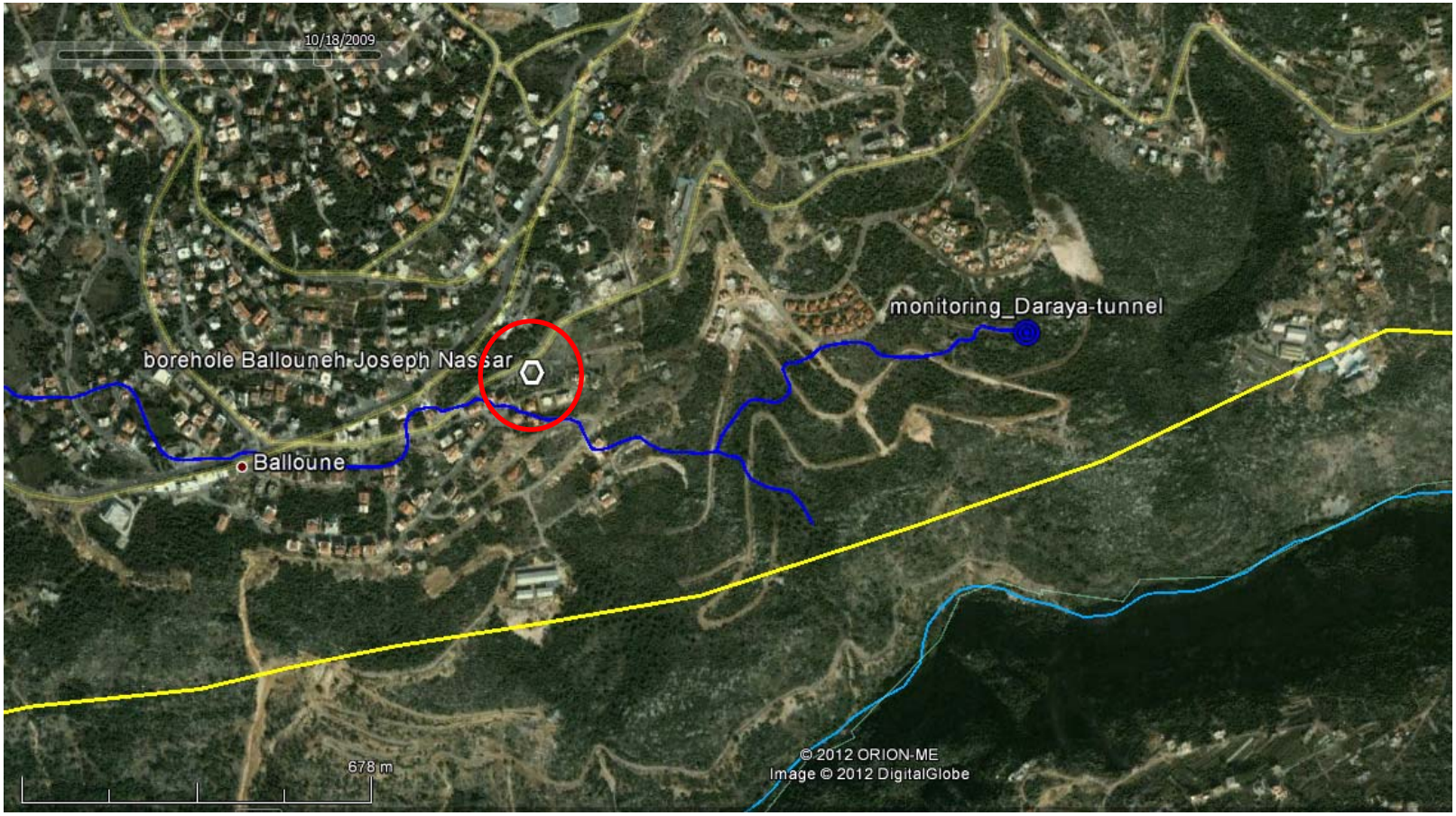


Figure 15: Potential Pollution Site (1): Borehole Ballouneh/Joseph Nassar

Figure 16: Construction Waste Dump at Mar Roukoz School

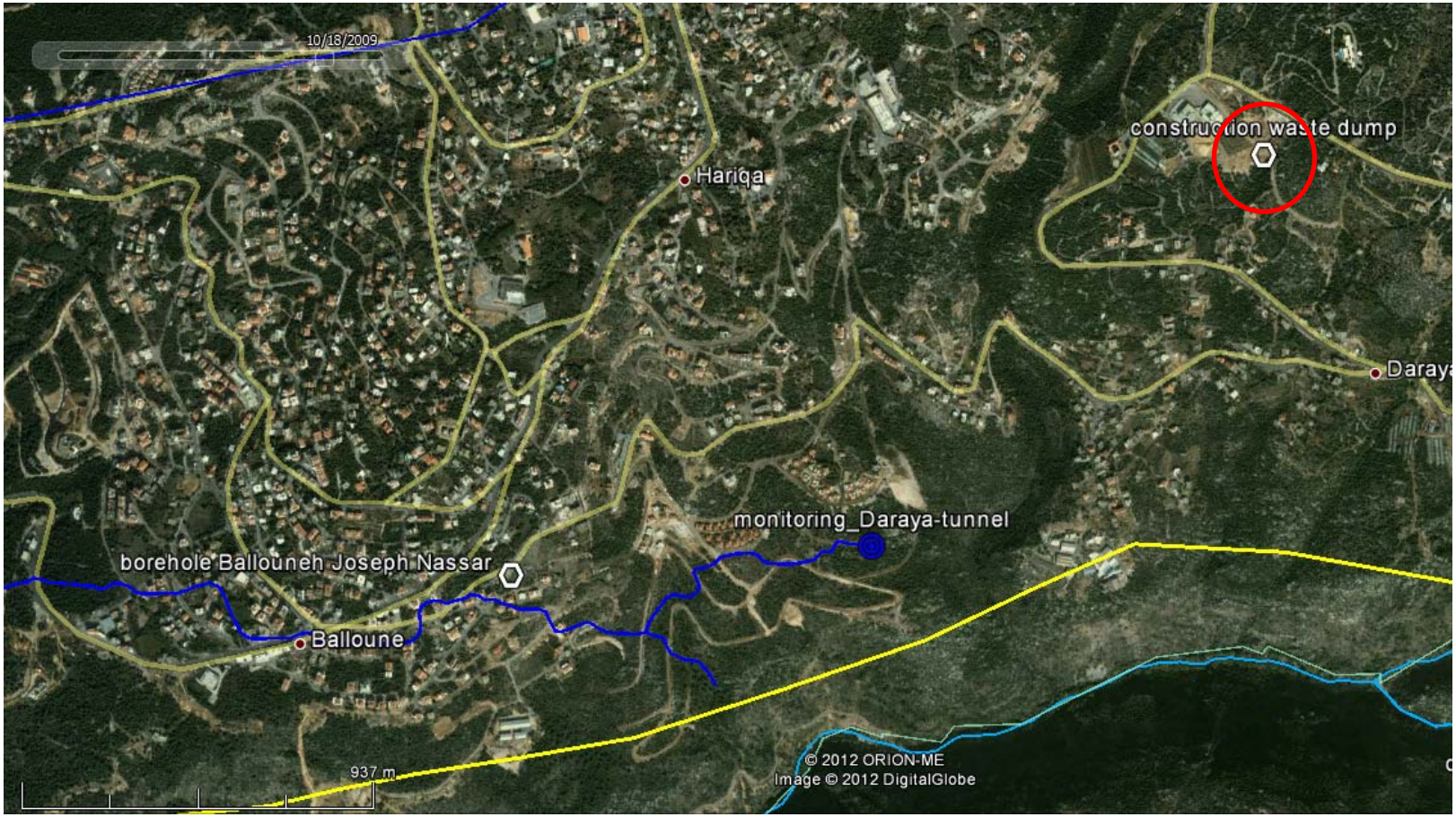


Figure 17: Potential Pollution Site (2): Construction Waste Dump at Mar Roukoz School

Figure 18: Cement Brick Factory in Lower Nahr es Salib

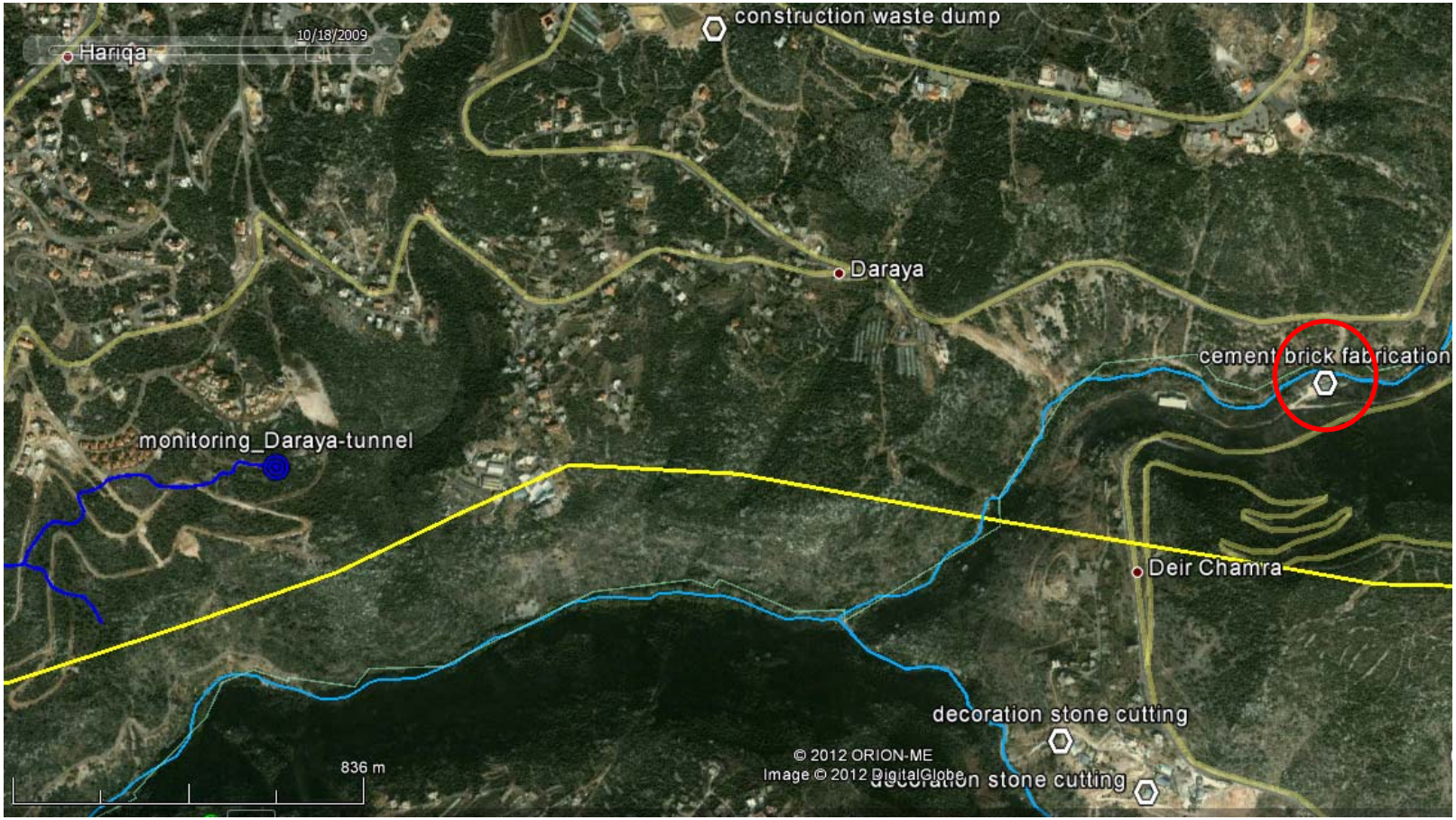


Figure 19: Potential Pollution Site (3): Cement Brick Factory in Lower Nahr es Salib

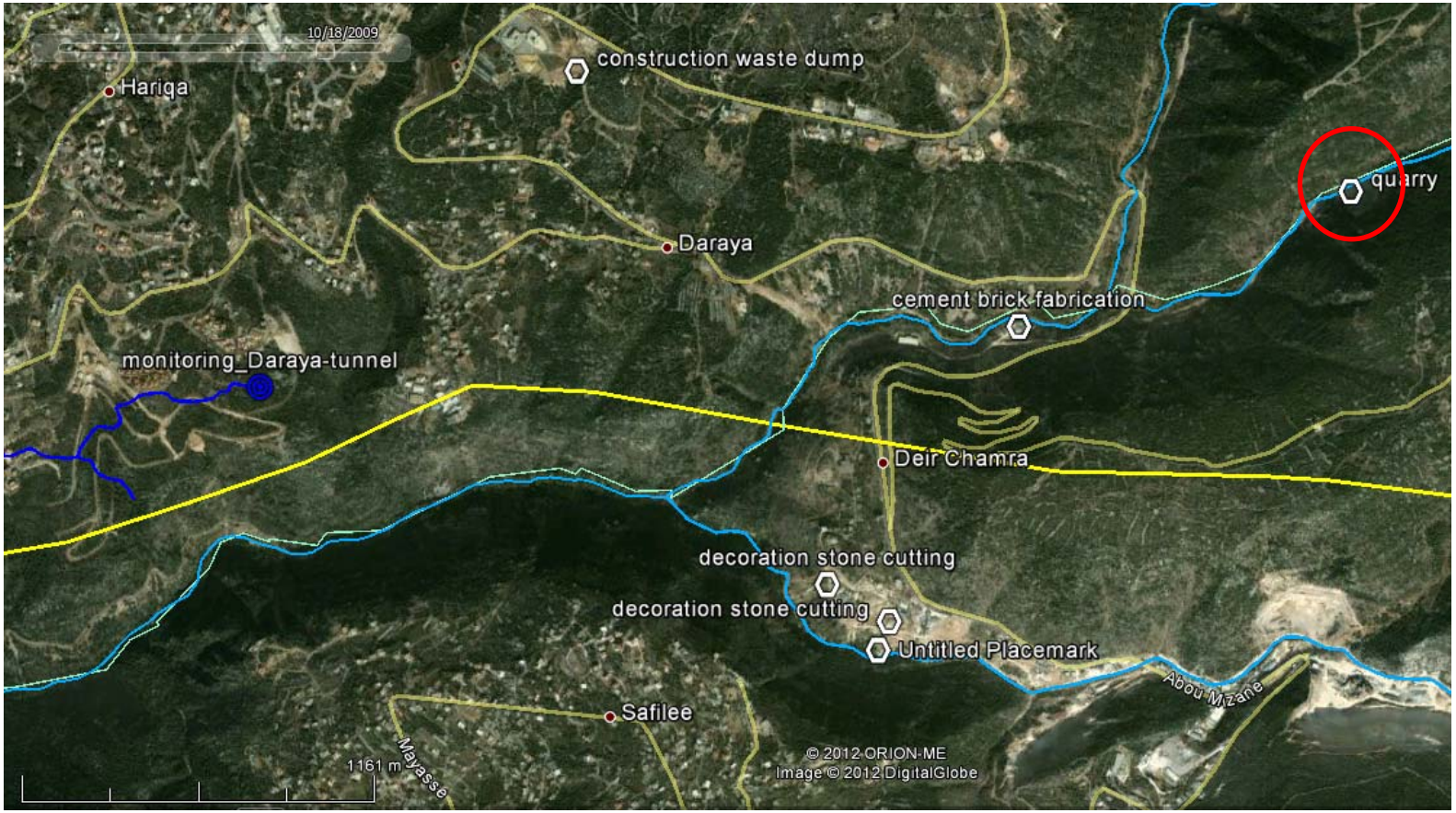


Figure 20: Potential Pollution Site (4): Abandoned Quarry in Nahr es Zirghaya

Figure 21: Decoration Stone Cutting Factories in Deir Chamra

Figure 22: Discharge of Limestone Sludge into Nahr es Hardoun from Decoration Stone Cutting Factories in Deir Chamra

Figure 23: Discharge of Limestone Sludge into Nahr es Hardoun from Decoration Stone Cutting Factories in Deir Chamra

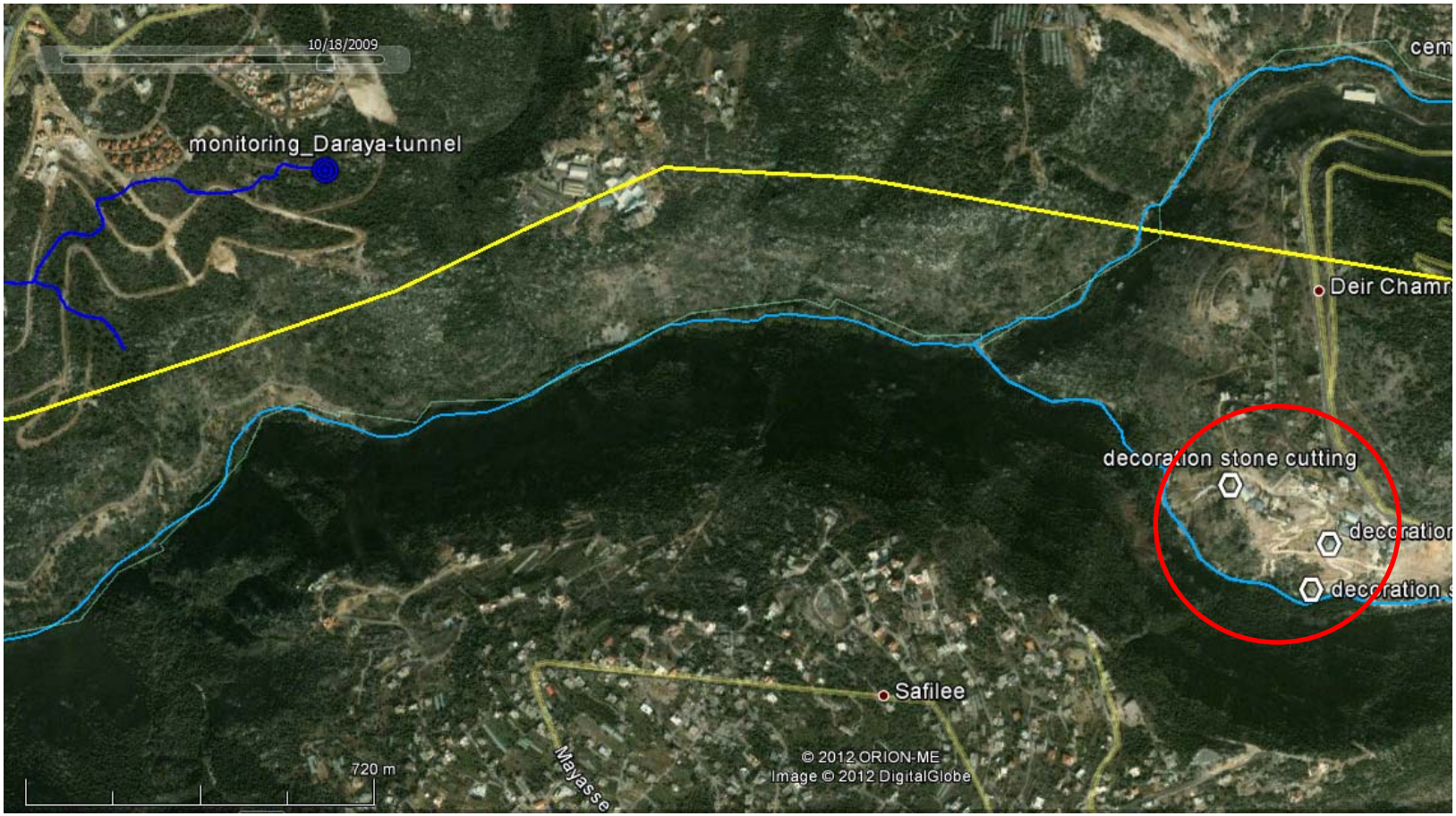


Figure 24: Potential Pollution Site (5): Decoration Stone Cutting Factories in Deir Chamra

Figure 25: Limestone Quarry for Cement Production (ELKA) in Abou Mizane (08/2011)

Figure 26: Limestone Quarry for Cement Production (ELKA) in Abou Mizane

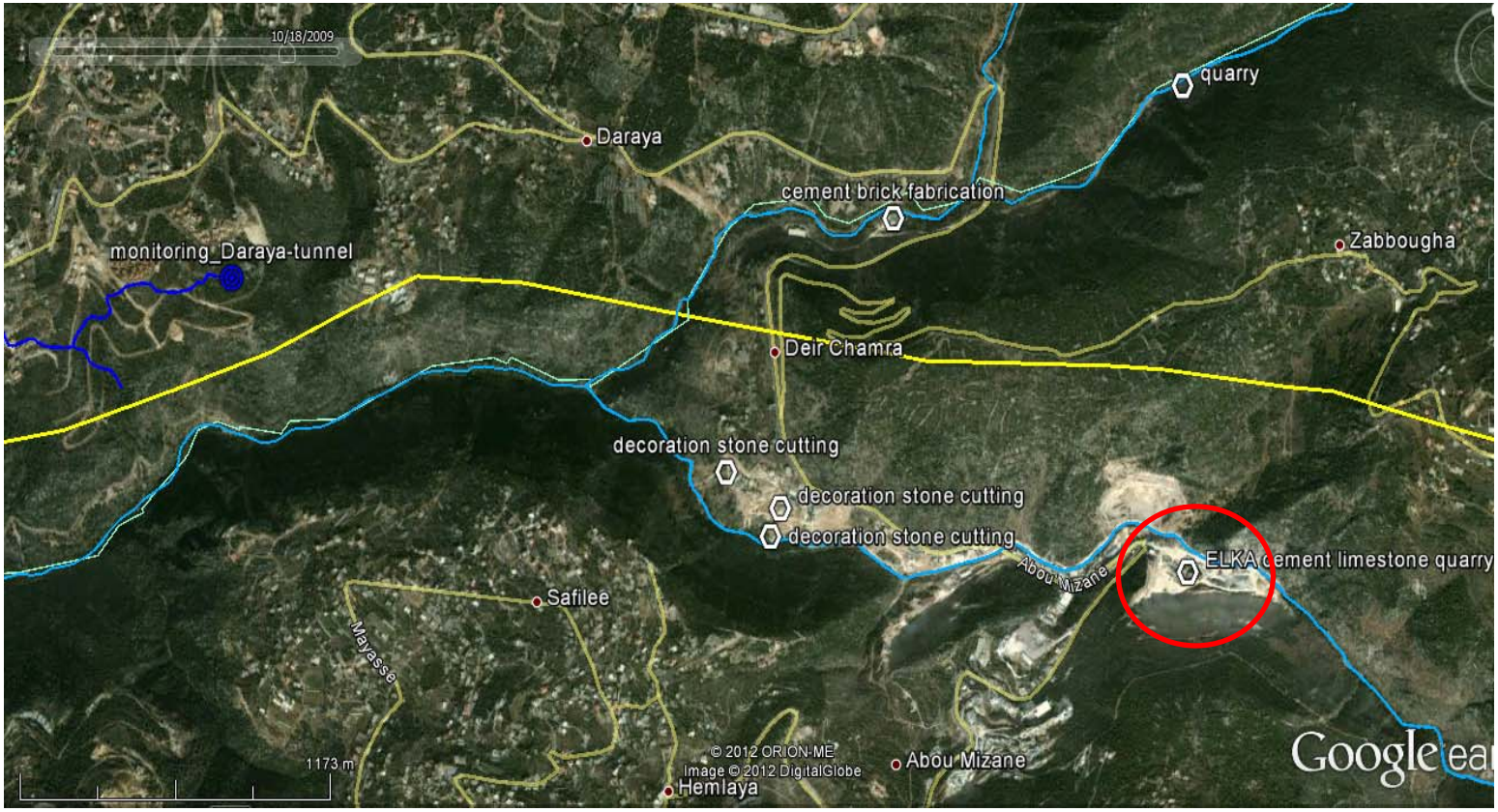


Figure 27: Potential Pollution Site (6): Limestone Quarry for Cement Production (ELKA) in Abou Mizaine

Figure 28: Rock Cutting in Boqaata Ashkout

Figure 29: Cement Brick Factory in the Upper Nahr es Salib at Mayrouba

Figure 30: Sandstone Quarry of HAJJ Contractors in Bqaatouta

3 Results of Investigation

During15-19 June 2012 the source of high turbidity in Jeita Grotto and the Dbayeh drinking water treatment plant could undoubtedly be identified. The river courses and potential pollution sources were monitored closely during that weekend. While on Saturday, 16 June, no turbidity was observed in the lower Nahr es Salib, Nahr es Hardoun and Nahr es Zirghaya valleys, high turbidity was noted on Sunday, 17 June, morning at 07:15 (Figure 31: location 1; E 35.721823°, N 33.953970°). While the surface water runoff upstream of the confluence with Nahr es Salib was clear (Figure 30a), it became highly turbid after the confluence (Figure 32b, location 1). Following the turbidity upstream it could first be identified at location 2 (Figures 34, 35), near Kfar Debbiane, then further up at location 3 (Figures 36, 37), close to the HAJJ Contractors quarry. The sediment flushed with the river course was composed of sand and silt. Along this river course there is no other potential source for that kind and amount of material.

The sandstone quarry has several large water ponds with a combined capacity of at least 5,000 m³ (Figures 36, 37, 38 39, 40). On Sunday, 17 June 2012, some of them were found empty with clear water level marks indicating that they had been containing water shortly before (Figures 38, 39). Also the pond shown in Figure 39 clearly functions as a sediment flushing facility. The Google Earth images show that sediment flushing from ponds at the HAJJ Contractors sandstone quarry must have been practiced at least since the year 2003.

The regular occurrence of high turbidity peaks after the rainy season is founded in the operation of the sandstone quarries. Flushing seems to take place commonly on Saturday and Sunday in the early morning hours, sometimes only on one of these days.

Over the first kilometer, the sediment/water mixture runs mainly over the aquitard (J5 to C3 geological formations) so that infiltration cannot take place. Downstream of location 2 (Figures 32, 43) the Keserwan Formation (J4) starts to crop out in the valley and continues to be at outcrop until the so-called perte de Deir Chamra, located at the southern boundary of the Jeita groundwater catchment. Here a tracer test had been done in 1973, proving the connection of the Nahr es Salib river with Jeita spring (HAKIM et al., 1988).

The upper part of the J4 is commonly highly karstified and shows a high infiltration capacity (MARGANE et al., in progr.; MARGANE, 2012a, b).

The straight-line distance from the HAJJ Contractors sandstone quarry to the Daraya tunnel monitoring station is 9,600 m, and 13,500 m to the Jeita monitoring station. The released sludge will infiltrate in the J4 (Keserwan Formation) aquifer somewhere between Kfar Debbiane and Deir Chamra). It is assumed that most of the infiltration of the sediment/water mixture takes place along the course of Nahr es Zirghaya between locations 1 and 2. Turbidity was observed downstream of the HAJJ

Contractors quarry in the entire river course until the perte de Deir Chamra and even in Nahr el Kalb at Jeita (Figure 42).

The turbidity peaks can therefore also be used as an indication that a massive infiltration in the upper part of the J4 aquifer occurs in this area. Flow velocity in the surface water course is assumed to be around 1 m/s (3,600 m/h). Previous tracer tests conducted by the BGR project have shown (DOUMMAR et al., 2010a, b; DOUMMAR et al., 2011 a, b, c) that groundwater flow velocity in the J4 aquifer is around 100 to 200 m/h, depending on the season. Travel time between Daraya and Jeita monitoring stations (5,300 m) was 7 h (760 m/h).

Currently it is not possible to determine flow velocities because the exact timing of injection is not known. However, a travel time of approx. 24 h between the injection site and the Jeita monitoring station means that flow will take place through a mixed surface water and groundwater path (see table below). Groundwater flow through a conduit of a fairly large diameter, such as Jeita Grotto, where flow velocities are much higher than in smaller conduits, is very likely. It is assumed that there are several locations of high infiltration along the surface water course in Nahr es Zirghaya.

Path	Distance (m)	Velocity (m/h)	Time (h)
Quarry to J4 outcrop	1200	3600	0.33
Nahr es Zirghaya - Perte de Deir Chamra Groundwater path	V: 300-800 H: 7600	V: 20 H: 150	H: 27 V: 50
Nahr es Zirghaya - Perte de Deir Chamra Surface Water path	7800	3600	2.2

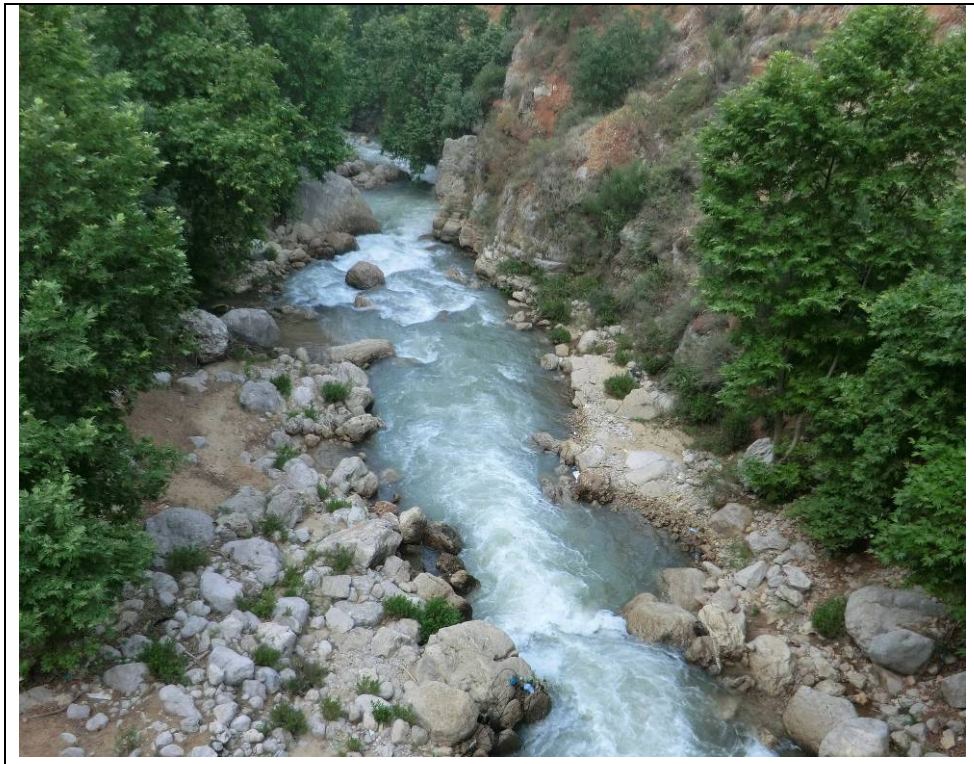
V: vertical, H: horizontal

Events of high turbidity had also occurred in Jeita in April and June 2011, however, not as regular as now.

The input of sediment from sandstone and other quarries may not only have a major impact on the quality of water but also on the permeability of the aquifer. A reduced permeability will result in a lower discharge at Jeita spring. Fractures filled with such fine material are observed throughout the lower parts of the Nahr el Kalb and Nahr es Salib valleys. This process occurs also naturally through erosion of the C1 sandstone but is accelerated by the operation of sandstone quarries.

Apart from those impacts on water quality and quantity the events of high turbidity have a major impact on the operation of the touristic site of Jeita Grotto (MAPAS).

Figure 31: Observed High Turbidity in Lower Nahr es Zirghaya (location 1)



a) Nahr es Salib at Daraya bridge; 17 June, 07:10

b) Confluence of Nahr es Zirghaya with Nahr es Salib 17 June, 07:15

Figure 32: Observed High Turbidity in Lower Nahr es Zirghaya (location 1)

Figure 33: Observed High Turbidity in Lower Nahr es Zirghaya (location 1, looking upstream from bridge)

Figure 34: Observed High Turbidity in Upper Nahr es Zirghaya (location 2)

Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

Figure 35: Observed High Turbidity in Upper Nahr es Zirghaya (location 2 near Kfar Debbiane, looking downstream from bridge)

Figure 36: Observed High Turbidity in Upper Nahr es Zirghaya (location 3 NE of Bqaatouta)

Figure 37: Observed High Turbidity in Upper Nahr es Zirghaya (location 3 NE of Bqaatouta, looking upstream from bridge)

Figure 38: Water Ponds in Sandstone Quarry of HAJJ Contractors in Bqaatouta

a) emptied water pond with water level marks

b) nearly empty water pond with water level marks

Figure 39: Flushed Water Ponds in Sandstone Quarry of HAJJ Contractors in Bqaatouta

Figure 40: Flushed Water Pond in Sandstone Quarry of HAJJ Contractors in Bqaatouta

Figure 41: Water Pond used for Sand Washing and Flushing of Fine Material in Sandstone Quarry of HAJJ Contractors/Bqaatouta

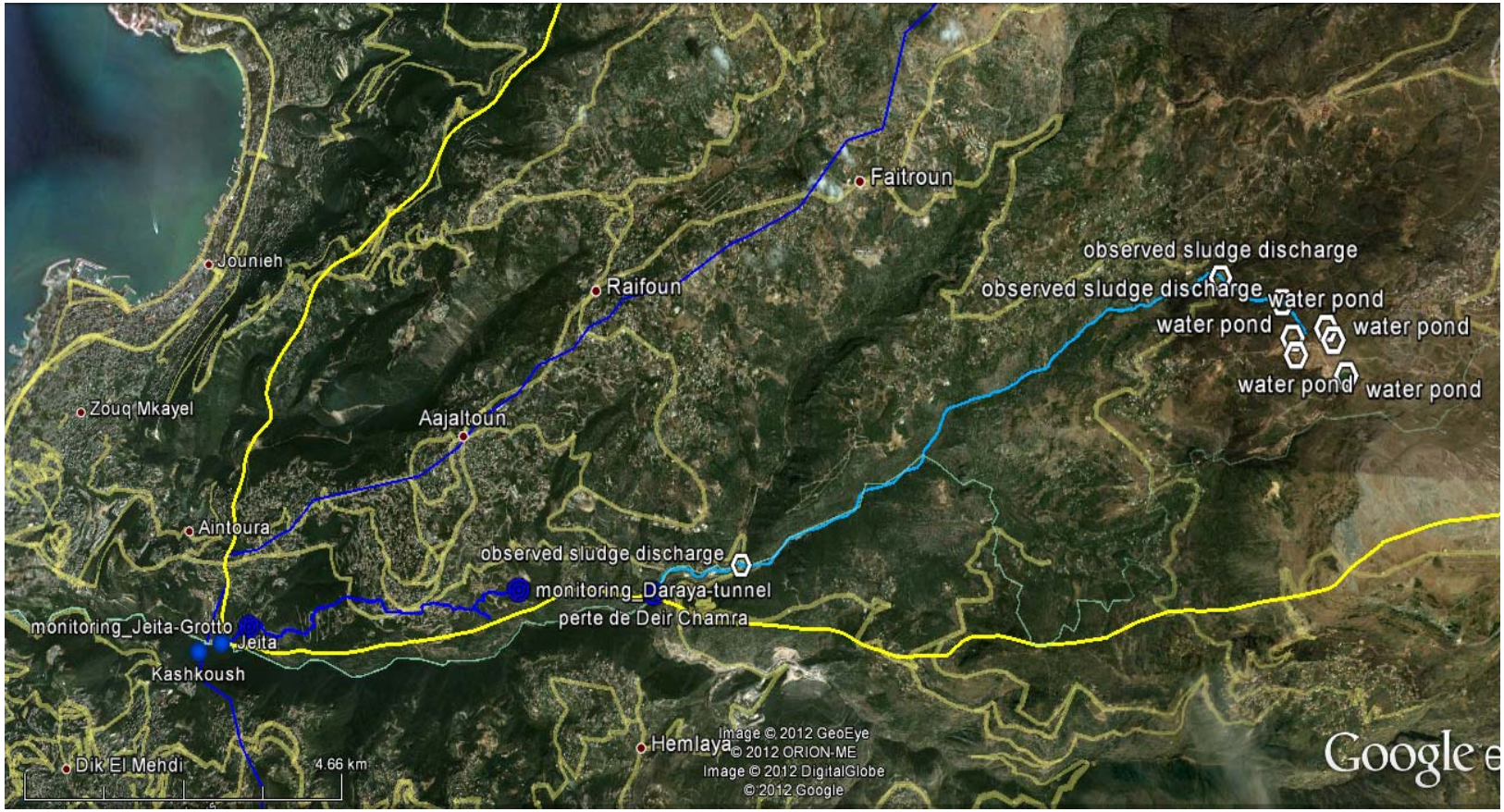


Figure 42: Surface Water Flow Path from Contamination Site to Jeita
(blue line: boundary of Jeita surface water catchment)

Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

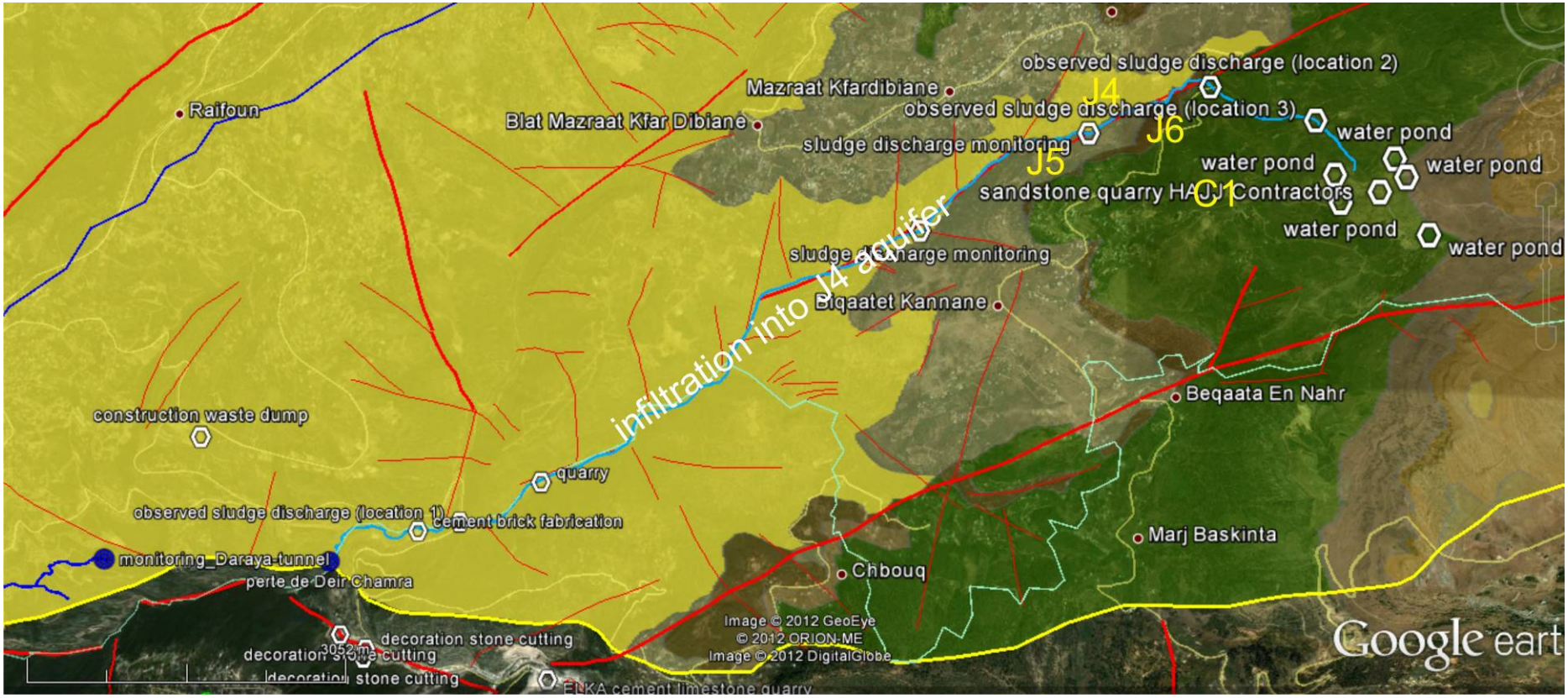


Figure 43: Groundwater Flow Path from Contamination Site to Jeita
(yellow line: boundary of Jeita groundwater catchment)

5 Conclusions and Recommendations

The observed events of high turbidity together with the observed practice at all other mentioned quarries, rock cutting companies and brick manufacturers show that there is almost no environmental consciousness and ignorance of environmentally sound practices. There is a complete lack of supervision and enforcement by governmental regulators in this sector.

Luckily the ELKA limestone quarry and decoration stone factories of Deir Chamra/Abu Mizane are not located in the Jeita groundwater catchment. Otherwise the environmental impact would even be much more severe.

However, the encountered impact on the Jeita water resources from the operation of the HAJJ Contractors sandstone quarry is severe enough and there is an urgent need to act.

The Lebanese Government is well advised to introduce an environmental police, such as introduced and efficiently working in Jordan since 2006. Only a well trained and equipped police force will be able to stop a further deterioration of the environment and the precious water resources of Lebanon.

Awareness building is still at the beginning in Lebanon. Both, MoEW and WEBML should focus on this issue because otherwise many important water resources will be lost due to contamination.

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ANNEX 1: Measurements Conducted by WEBML at the Dbayeh Drinking Water Treatment Plant Intake and Outlet

DBAYEH	In	In	Out	Out
Date+Time	NTU	NTU	EC	EC
4/23/2012 6:00				
5/7/2012 08:00	25	1	412	424
5/7/2012 11:30	13.6	3.84	412	424
5/21/2012 04:30	35			
5/21/2012 08:00	70	1.72	417	429
5/21/2012 09:30	91	1.32	413	426
5/21/2012 11:00	52	1.15	440	426
5/21/2012 13:00	40	1.26	437	437
5/22/2012 00:00	40			
5/22/2012 06:00	25			
5/22/2012 08:00	16.4	0.39	432	438
5/22/2012 12:00	19.8	1.14	431	438
5/22/2012 13:00	12.8	2.14	432	441
5/23/2012 07:30	15.6	3.3	432	439
5/23/2012 11:00	9.22	2.59	432	438
5/28/2012 06:00	45			
5/28/2012 07:15	42	2.69	429	434
5/28/2012 08:30	36	1.3	432	436
5/28/2012 09:30	34	1.54	430	436
5/28/2012 10:45	30	1.28	431	437
5/28/2012 12:15	22		430	
5/28/2012 13:00	19	0.29	431	435
5/29/2012 00:00	50			
5/29/2012 07:30	45	0.86	428	436
5/29/2012 08:00	40		428	
5/29/2012 09:00	22.5		430	
5/29/2012 11:00	16	1.11	731	436
5/29/2012 13:00	12.5	0.84	432	438
5/30/2012 08:00	13.8	1.44	427	436
5/30/2012 12:30	13	1.33	430	438
6/1/2012 09:30	4.16	1.46	433	439
6/4/2012 08:30	20	1.34	432	439
6/4/2012 10:30	19.5	1.65	431	436
6/5/2012 00:00	70			
6/5/2012 06:30	35			
6/5/2012 07:30	17	1.19	426	435
6/5/2012 08:30	13.5		431	
6/5/2012 11:30	8		432	
6/5/2012 13:00	8	1.27	432	438

Locating the Source of the Turbidity Peaks Occurring in April - June 2012 in the Dbayeh Drinking Water Treatment Plant

DBAYEH	In	In	Out	Out
Date+Time	NTU	NTU	EC	EC
6/11/2012 07:30	44	1.49	432	437
6/11/2012 09:45	43	2	432	438
6/11/2012 10:45	78	1	432	439
6/11/2012 11:45	85	1	432	438
6/11/2012 12:45	77	1	431	437
6/11/2012 13:30	62	0	432	437
6/11/2012 18:00	35			
6/12/2012 07:15	18	1	430	435
6/12/2012 13:00	5	0	432	436
6/18/2012 05:00	45			
6/18/2012 07:20	68	1	434	442
6/18/2012 08:00	85	1	434	439
6/18/2012 09:00	95	1	433	439
6/18/2012 10:00	92	1	431	440
6/18/2012 12:00	66	0	426	433
6/18/2012 13:00	53	0	428	432
6/19/2012 07:45	16	0	424	435
6/19/2012 10:00	4	0	433	440