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Protection of Jeita Spring

SPECIAL REPORT NO. 16

Hazards to Groundwater and Assessment of Pollution Risk in the Jeita Spring Catchment

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Hazards to Groundwater and Assessment of Pollution Risk in the Jeita Spring Catchment

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asl	above mean sea level
AFD	Agence Française pour le Développement
BMZ	German Ministry of Economic Cooperation and Development
CDR	Council for Development and Reconstruction
COM	Council Of Ministers
EDC	endocrine disrupting compounds
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency, USA
FAO	Food and Agriculture Organization
FC	Financial Cooperation
GW	groundwater
IGN	Institut Geographique National
JC	Jeita spring catchment (= groundwater catchment)
KfW	German Bank for Reconstruction and Development
LPD	Landuse Planning Department (Ministry of Public Works)
LRA	Litani River Authority
MCL	maximum contaminant level
MCM	Million cubic meters
MoE	Ministry of Environment
MoEW	Ministry of Energy and Water
MoIM	Ministry of Interior and Municipalities
MoIT	Ministry of Industry and Trade
MoPH	Ministry of Public Health
MRDLG	Maximum residual disinfectant level goal
NGO	Non-governmental organization
SW	surface water
TC	Technical Cooperation
UNDP	United Nations Development Program
UTM	Universal Transverse Mercator
WEBML	Water Establishment of Beirut and Mount Lebanon
WW	wastewater
WWTP	wastewater treatment plant

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1 - 1	Addendum No. 1 to Main Report [Quantification of Infiltration into the	June 2012

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* prepared in cooperation with University of Goettingen

Acknowledgements

In its effort to assess the existing hazards sources in the Jeita Spring Groundwater catchment, the project *Protection of Jeita Spring* experienced great support not only at the political and institutional level but also from many municipalities and public society in the catchment area.

We are especially grateful for the backing and support of: the Council for Development and Reconstruction (CDR), the Ministry of Energy and Water (MoEW), the Ministry of Environment (MoE), the Ministry of Agriculture (MoA), the Ministry of Health, the Landuse Planning Department (LPD) at Jounieh, the heads, mayors and board members of municipalities, Arc en Ciel (NGO), the UNDP project for Reducing Healthcare Wastes, the Mount Lebanon Governorate and last but not least the population living in the Jeita Spring Groundwater catchment area. Some of important information would not be collected without their collaboration.

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.

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 among the involved institutions (ministries, municipalities, operators, etc.) and stakeholders (area deputies, local NGOs, etc.) but mainly by the population living in the area. In addition, seeing the work accomplished many stakeholders of different parts of the country (Bekaa, etc.) expressed their deep interest in having such project repeated in their areas.

0 Executive Summary

This report presents an overview on the existing potential contamination sources (groundwater hazards) in the Jeita spring groundwater catchment, compiled through a field assessment conducted by the Technical Cooperation (TC) Project Protection of Jeita Spring.

Important in this respect are the groundwater hazards related to the uncontrolled discharge of wastewater, gas stations, quarries, building stones factories, solid wastes illegal dumpsites, illegal dumping of contaminated effluents in the environment, storm water, storage and handling of diesel and oils in generators and residential heating systems, feedlots, slaughterhouses, and agricultural practices.

The main consequence of these investigations is that there is a very high risk of severe contamination of the groundwater resources of Jeita spring. The rapid and uncontrolled development in the study area has led to a considerable contamination load at this vital drinking water source. Due to the nature of the rocks and the very fast flow in the groundwater system, there is virtually no attenuation or adsorption of contaminants. The groundwater resources are therefore highly vulnerable to pollution.

Current land use licensing regulations and practices are inadequate. There is not yet a proper collection and treatment system for wastewater in the catchment despite its generation of significant organic pollution.

Improperly manufactured (single layered, badly sealed) and installed petroleum products storage reservoirs (diesel, fuel, oils, etc.) are assumed to be leaking to the groundwater.

There are many illegal waste dumps, especially containing commercial and construction waste.

The responsible governmental institutions are urgently called to take action before this important water resource is entirely lost due to pollution. The area where Jeita spring groundwater is most vulnerable has been previously delineated by the project. Water resources protection in this area is most important. It is urgent to implement landuse restrictions for water resources protection, as proposed in an earlier report concerning the delineation of groundwater protection zones in the groundwater catchment of Jeita spring (MARGANE et al., 2013). The implementation of wastewater schemes and banning hazardous human activities should have highest priority in the area of high groundwater vulnerability (equivalent to groundwater protection zone 2).

While only physical and organic contaminations are treated by the Water Establishment of Beirut and Mount Lebanon, all other contaminations (petroleum, chemical, radioactive, etc.) are neither regularly monitored nor treated.

The present report aims at giving an account of the current situation of risks affecting Jeita spring. It can be used by relevant governmental entities and other stakeholders to undertake specific water analyses and define the actual existing contamination and then take the necessary steps to stop pollution.

A close investigation of current practices in the establishment and operation of each human activity presenting an environmental risk to groundwater was accompanied

by a study of laws and guidelines governing the permitting system, the operation and the supervision and control by governmental agencies as well.

Currently, It is widely recognized that the permitting systems and guidelines do not sufficiently include necessary measures of pollution prevention, enforcement and control able to address specific pollution pathways and time scale (travel time). The vulnerability of groundwater resources needs to be interpreted in active measures.

Recommendations are given to help decision makers closing the gaps in the existing legislation and recommend efficient enforcement and amendments. Furthermore, recommendations for best design and management practices were provided to mitigate the risk of groundwater contamination considering the groundwater vulnerability.

Furthermore, based on this assessment and on its previous elaboration of groundwater vulnerability maps, the BGR project evaluated the Jeita spring groundwater contamination risk related to each of the major identified groundwater hazards. This risk assessment and evaluation were detailed in a separate report named Special Report No. 19 where groundwater management and protection policy measures were recommended.

1 Introduction

The work presented in this report was conducted by BGR staff, in the framework of the German-Lebanese Technical Cooperation BGR project *Protection of Jeita Spring*, funded by a grant from the German government (Ministry of Economic Cooperation and development, BMZ). This project aims at reducing 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), on the Lebanese side, the project partners are the Council for Development and Reconstruction (CDR), the Ministry of Energy and Water (MoEW) and the Beirut and Mount Lebanon Water Establishment (WEBML).

In this respect, several hydrological, geological and environmental assessments were conducted by the project. The present study assesses the hazards existing in the Jeita Spring groundwater catchment (JC), and evaluates its related risk of groundwater contamination.

In addition to a field assessment covering the Jeita catchment area (405.6 km^2), this study includes a deep literature review pertaining to the legal framework and international practices related to each encountered potential contamination source. In meetings with relevant stakeholders and interviews with the population living in the area the potential environmental impact was discussed. The governing regulatory framework of each hazard source was deeply studied besides the actual practices, e.g. concerning the permitting process, the supervision of implementation as well as checking the environmental status of each site and the related contamination risk.

While the groundwater hazards related to gas stations were detailed in a separate report, the present report looks at all other major contamination sources (both point and diffuse), in particular: wastewater, stormwater, generators, residential heating systems, diesel tanks, car repair workshops, dry cleans, clinics and hospitals, industries, agriculture (crops and animals production: cattle, poultry and pig farms), quarries, building stone and rock cutting factories, dumpsites of commercial, municipal and construction wastes.

The assessment revealed a high density of contamination sources on a highly karstified limestone, leading to a high contamination potential for the groundwater resources of Jeita spring constituting the major source for the drinking water supply of the Greater Beirut Area.

Wastewater presents the most noted contamination risk but is not the only major health risk. While biological and physical contaminations are monitored by WEBML's laboratory at Dbayeh, the hazards generated by petroleum, heavy metals, chemicals, pesticides, and radioactive elements, are neither monitored nor treated in disregard of their major potential impacts on human health. The reason is the lacking laboratory capacity of WEBML.

Despite the presence of a quite developed regulatory framework and environmental guidelines, the practices are far from being environmentally sound. Absence of environmental awareness at the public society level, joined with the absence of a dedicated local governmental entity able to enforce the proper application of environmental laws and guidelines, have led to an environmental anarchy, a situation dangerous to the local population and to the population supplied by drinking water from Jeita spring.

While the Ministry of Environment (MoE) works on issuing guidelines and laws, their application is faced by overlapping responsibilities between governmental institutions, and severe lack of staff and means (vehicles, monitoring and sampling equipment, laboratory, etc.) so that this ministry is practically unable to achieve any change in this desolate situation. Also, following law 221 the responsibility of protecting water resources falls under the authority and duties of the MoEW. While this ministry in lacking of staff able to take action in such issues.

Furthermore, the municipalities are not aware of the major role they must play as stated in the municipal law, and are practically not able to assume their role due to lack of staff, know-how, facilities and financial means, in addition to the political issues related to the election of the municipal boards in the country. These boards are elected for a period of six years then changed with their affiliated staff following the political situation. Also, political and social factors play a major role in limiting law enforcement and consistent planning.

The present report starts by displaying the characteristics of the study area and its water resources with a particular attention to the vulnerability of the groundwater resources of Jeita spring.

According to WORLD BANK (2012), water sector inefficiencies and environmental damages are costing the Lebanese economy nearly 3% of GDP per year. Groundwater pollution has direct effects on public health and health-related expenditures. In 2000, the costs of the health impacts of water pollution in Lebanon were estimated at USD 7.3 million per year and the costs of excess bottled water consumption at about USD 7.5 million, noting that these are conservative estimates that do not account for all associated direct and indirect costs (MoE, 2001). Despite this fact the National Water Sector Strategy (NWSS; MoEW, 2012) lacks of enforced proposals to reduce pollution risks.

2 Scope of Work

This assessment aims at providing to the relevant stakeholders a comprehensive practical study underlining the main pollution sources in the groundwater catchment of Jeita spring (Jeita catchment) and their related risk of groundwater contamination in addition to specifying the ways to detect such contamination and minimize the pollution risk.

The present report displays the assessed practices and related contamination risks of major hazard sources in the Jeita catchment, in addition to an overview of the

related regulatory framework, guidelines, and stakeholders. The pollution sources are displayed on maps in a way to allow decision makers to undertake proper measures to reduce their impact. Hazardous elements related to each contamination source are clearly specified in addition to an evaluation of their potential risk on public health. Relevant contamination indicators are also emphasized.

An evaluation of the risk assessment to Jeita spring groundwater is provided in a separate report (Special Report No. 19; RAAD & MARGANE, 2013), based on the groundwater vulnerability at the site and the contamination risk generated by each source of contamination.

Displaying the ruling regulatory framework intends to underline its gaps and enforce recommendations in a way to reach a proper monitoring and control of the contamination sources that are endangering one of the major water sources in Lebanon, and putting at risk the health of the population in the Greater Beirut Area (50% of the residents in Lebanon).

Currently the impact of pollution is not monitored by WEBML, except for selected microbiological constituents (MARGANE et al., 2013). This is because the laboratory of WEBML is too small and lacking instrumentation and staff to analyze critical parameters in the raw water. Microbiological analyses were done on average only every 4 days over the past 5 years. Most relevant parameters of the Lebanese drinking water standard were not analyzed at all even once a year. A normal quality control of raw water for such a high number of consumers would need analyses at least every hour. Due to frequently high turbidity in the raw water (MARGANE, 2012a), the practiced filtering through sand beds and chlorination are inadequate to eliminate pollutants such as heavy metals or organic substances. The high level of chlorination can result in the formation of chlorinated hydrocarbons.

Analysis conducted by Dr. Mey Jurdi from Environmental Health Department at the American University of Beirut revealed the presence of Cd and Cu in Kashkoush and Jeita springs (presentation at MoEW on 19 January 2012). However, the number of samples analyzed was not sufficient to draw conclusions. A further investigation of the occurrence of heavy metals in Jeita and Kashkoush springs is urgently needed considering the related danger on Public health.

The current practice is such that individual water sources used for drinking water are inspected physically on site at best once a day and that water supply from a contaminated source is shut off for short time when the inspection shows a high visible turbidity (most turbidity sensors, if having been installed at all, were never maintained and calibrated). This means that contaminations frequently reach the drinking water treatment plant and pass into the network without a contamination having been identified or treated.

Academic institutions are also called to benefit from this report and contribute to a better environment by implementing further investigations concerning water quality especially concerning those elements that are currently not monitored but are

assumed to be present in groundwater due to the presence of related contamination sources and the practiced disposal of contaminants in the environment, such as heavy metals (generated by hospital wastes, chemicals (generated by industries and dry cleans), petroleum products (oils, fuel and diesel), and pesticides (agriculture). At the same time, WEBML is called to enhance its monitoring, laboratory and treatment capacities.

NGOs working on the environmental sector may use this report to work on specific identified issues that can bring about a major improvement in the area.

This study could be used as a pilot to cover the entire Lebanese territory in a similar way and to prepare a national environmental strategy able to control the liquid and solid waste management at the country level. Not only at the regulatory framework level but at its application by empowering the local governmental institutions (technically and financially) concerning control and supervision capacities and mostly by raising the public environmental awareness at schools, municipalities, universities, industries, gas stations, and relevant commercial businesses.

The present report can be a tool for the population living in the groundwater catchment of Jeita spring, to understand better the potential impact of each human activity on the quality of water resources, especially on groundwater. People must understand that any environmentally unsound practice can lead to a major health risk to each person drinking from this water source (even after treatment by WEBML).

3 Study Area

The groundwater contribution zone of Jeita spring (Jeita catchment) has been delineated by the BGR project using tracer tests. It covers an area of 405.6 km² (MARGANE et al., 2013). Its northern boundary stretches to east of Tannourine (max. distance from Jeita 42 km) and covers more than 50% of the Upper Cretaceous plateau areas in the Lebanon mountain range (C4 geological unit; Figures 1, 2 and 3). Jeita spring receives about 46% of its water from an infiltration zone in the Upper Nahr Ibrahim Valley. The shape of the groundwater contribution zone (Figure 4) is considerably different from the surface water catchment. Previously it was believed that both were nearly identical (MARGANE, 2012a, 2012b).

The Jeita catchment is of steep topography and elevation ranges from 60 (at Jeita) to 2,628 m asl (at Mount Sannine)

3.1 Geology

Due to the non-availability of adequate and precise geological maps, the geology of the Jeita catchment was mapped by the BGR project (HAHNE, 2011; MARGANE

et al., 2013). For further details it is referred to these documents. The new geological map is presented in Figure 5.

Geologically the Jeita catchment consists of formations which are part of the Jurassic (J) or Cretaceous (C), with more than 70% of the outcrop area being covered by limestone with high degrees of karstification. Karstification is extreme at higher altitudes, especially on the high plateau, in the Sannine Formation (C4). There are more than 2,000 dolines on this plateau and therefore almost no surface water drainage network. Rain and snow rapidly infiltrate into these dolines, resulting in an extremely high groundwater recharge of around 81% (MARGANE et al., 2013; SCHULER & MARGANE, 2013).

Figure 1: Karstification in the Mdairej Formation (C2b) at Faqra

Figure 2: Scarce vegetation and soil cover on the C4 lead to high infiltration

Figure 3: Satellite image (Google earth) showing the dolines in the Sannine Formation (C4)

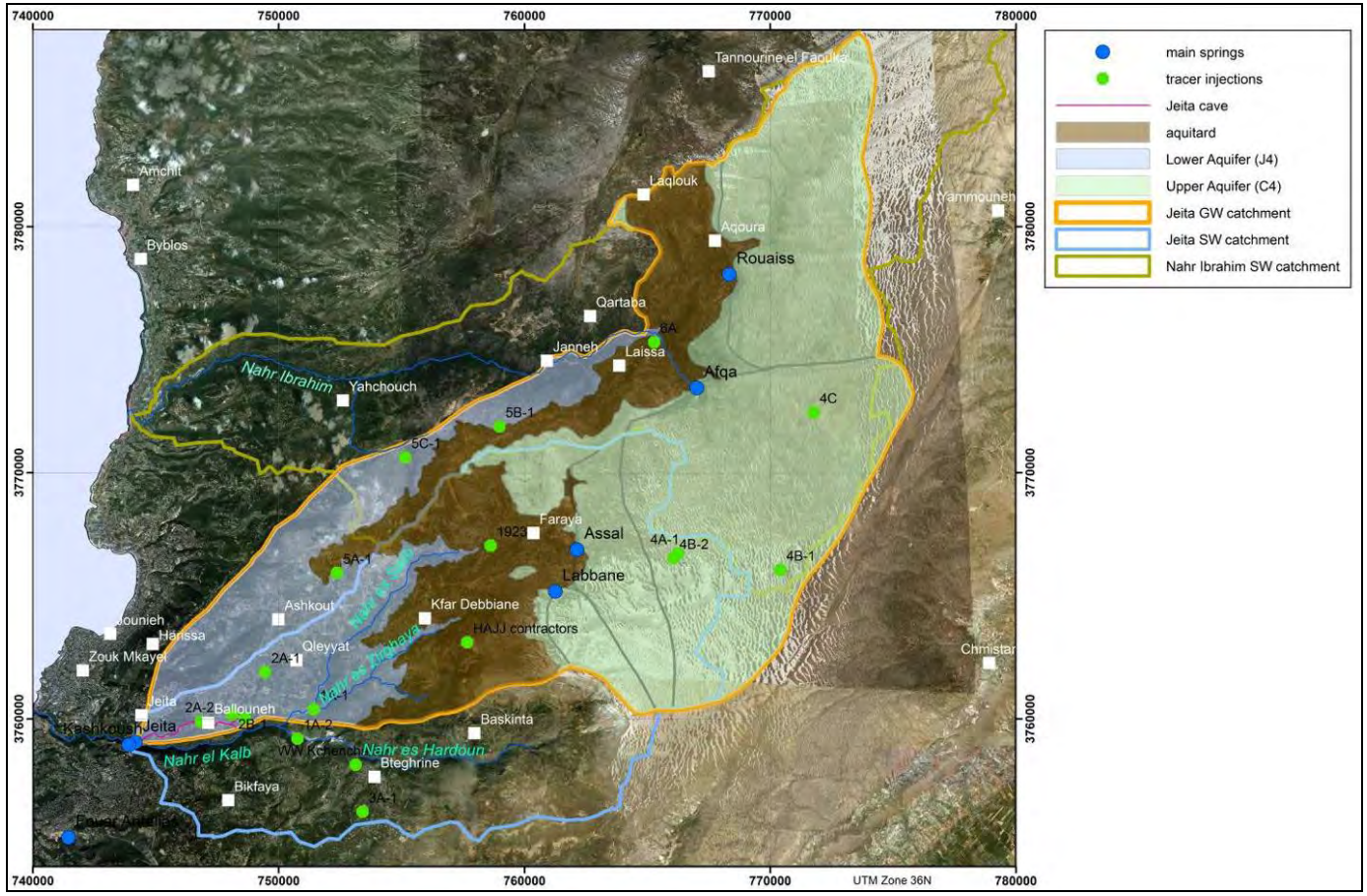


Figure 4: Hydrogeological classification in Jeita catchment groundwater contribution zone of Jeita spring (MARGANE et al., 2013)

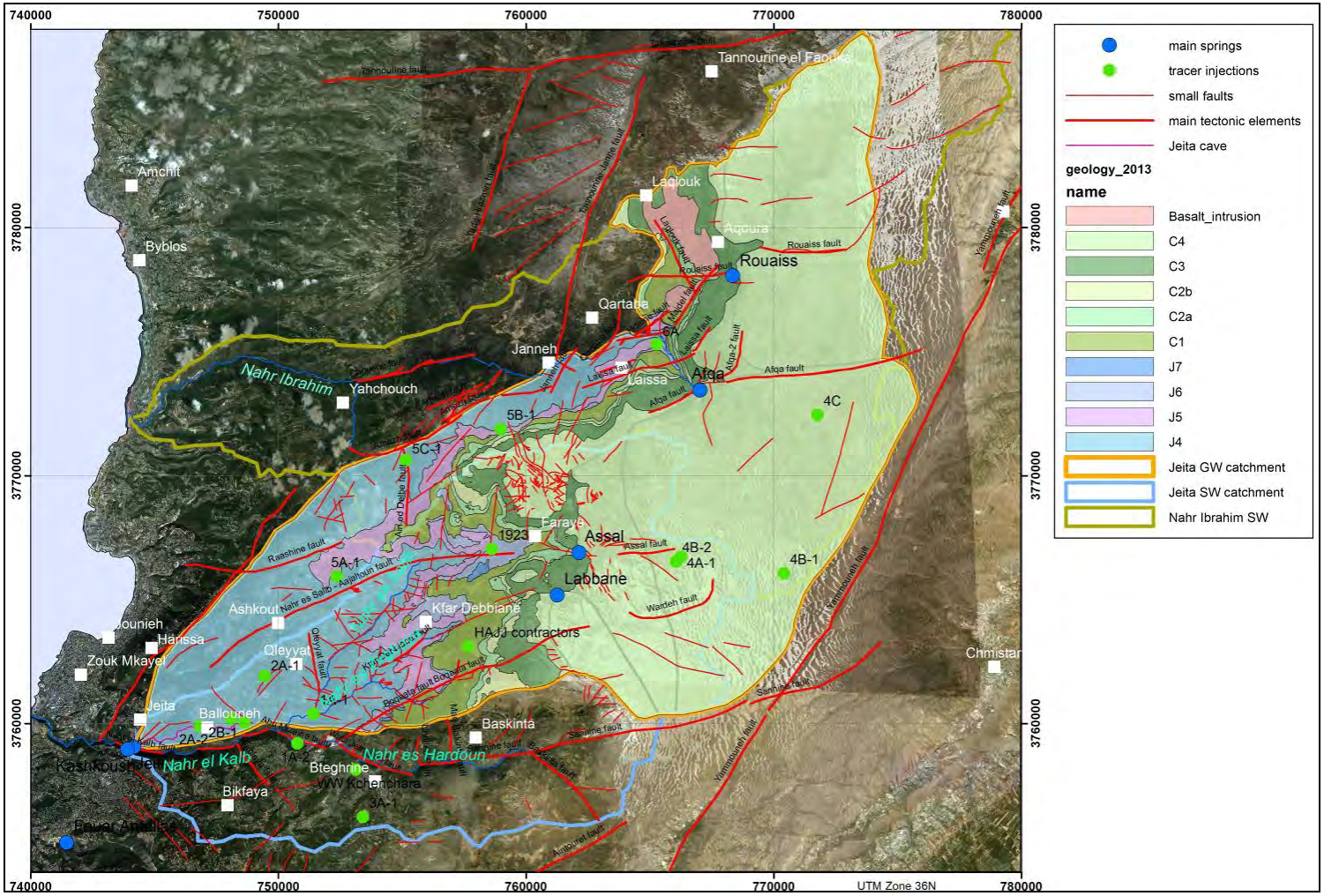


Figure 5: Geological map of the groundwater catchment of Jeita spring (MARGANE et al., 2013)

3.2 Climate

The catchment area of Jeita Spring GW is characterized by a Mediterranean climate with precipitation from November to April and a dry season in the summer lasting from June to September. The study area benefits from a relatively high rainfall of on average 1529 mm/a.

Mild temperatures prevail in the upper catchment during summer making this area attractive for tourism.

In winter, precipitation is mainly falling as snow in the upper part of the Jeita catchment, exceeding 1,200 m. The Upper Cretaceous plateau (1,800 – 3,000 m asl) is covered by approx. 4 m of snow (in 2012: up to 10 m and more) from December till April (Figure 6). This area is the main GW recharge area (Figure 7). Climate data for the area is generally scarce, especially related to snow cover, snow height and snow density. The project has currently installed 5 meteorological stations in the catchment area in order to provide accurate reliable climatic data.

The snow cover is very important for groundwater recharge (81 %) and this snow can be considered the lifeline of Lebanon. Such extended areas of snow cover, exceeding 1,600 m asl, do only occur in the Lebanon and Anti-Lebanon mountain ranges (Figures 8, 9). Climate change may lead to significantly lower groundwater resources availability as regional climatic scenarios predict less rainfall (15-30%), higher summer and winter temperatures (up to 5°C), and thus less snow and runoff, with more evaporation and less groundwater recharge (MARGANE & MAKKI, 2012). What is most important is that higher temperatures will lead to a considerable reduction of the snow cover as these would be followed by a considerable upward shift of the orographic snow line of between 300 and 400 m in the coming few decades, assuming a 2°C rise during this time (MARGANE et al., 2013).

Figure 6: Snow cover on the Upper Cretaceous plateau in the groundwater catchment of Jeita spring

Figure 7: Direct groundwater recharge in dolines during snowmelt in Upper Cretaceous plateau of Jeita spring

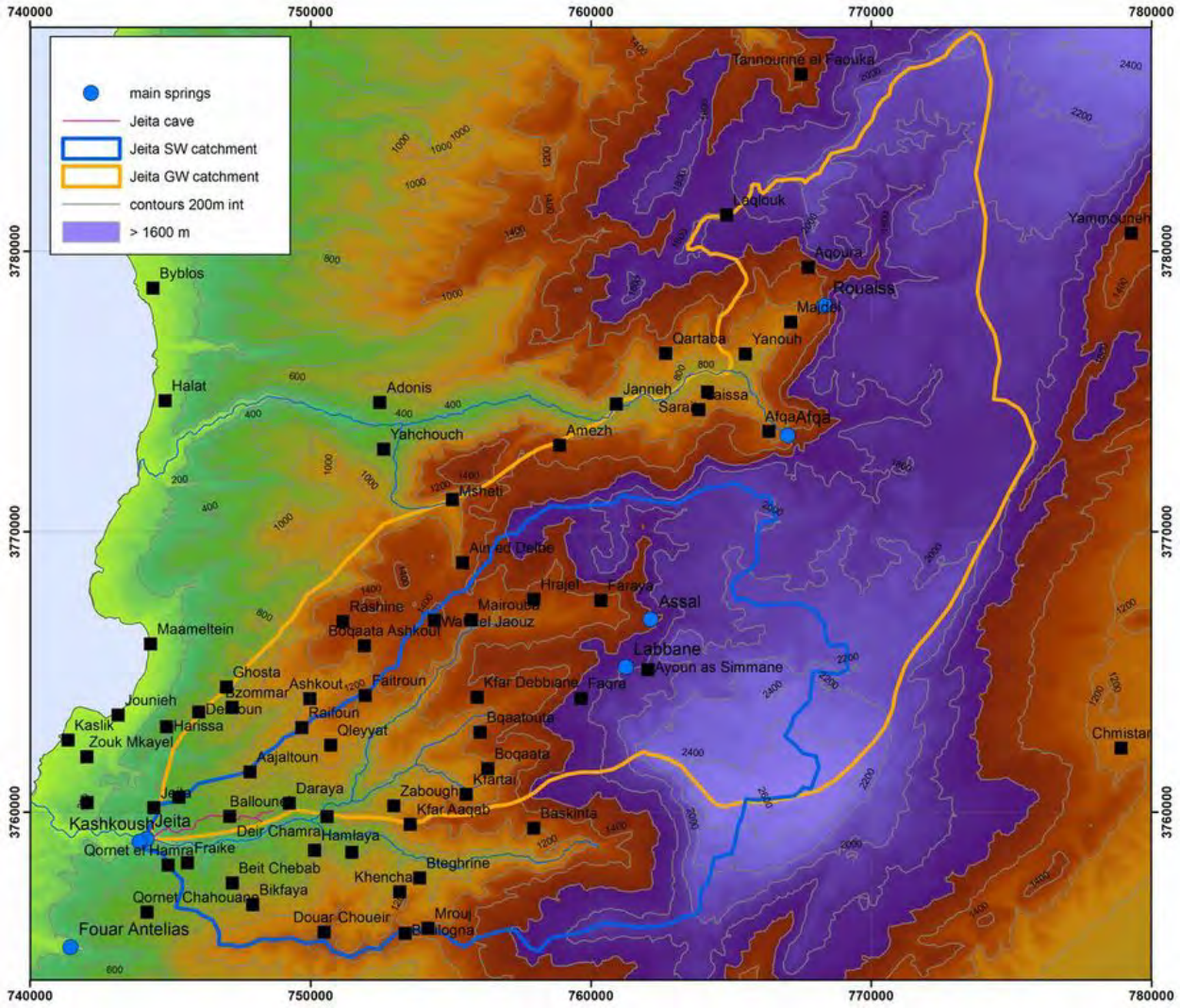


Figure 8: Areas in Jeita catchment mountain ranges exceeding 1,600 m

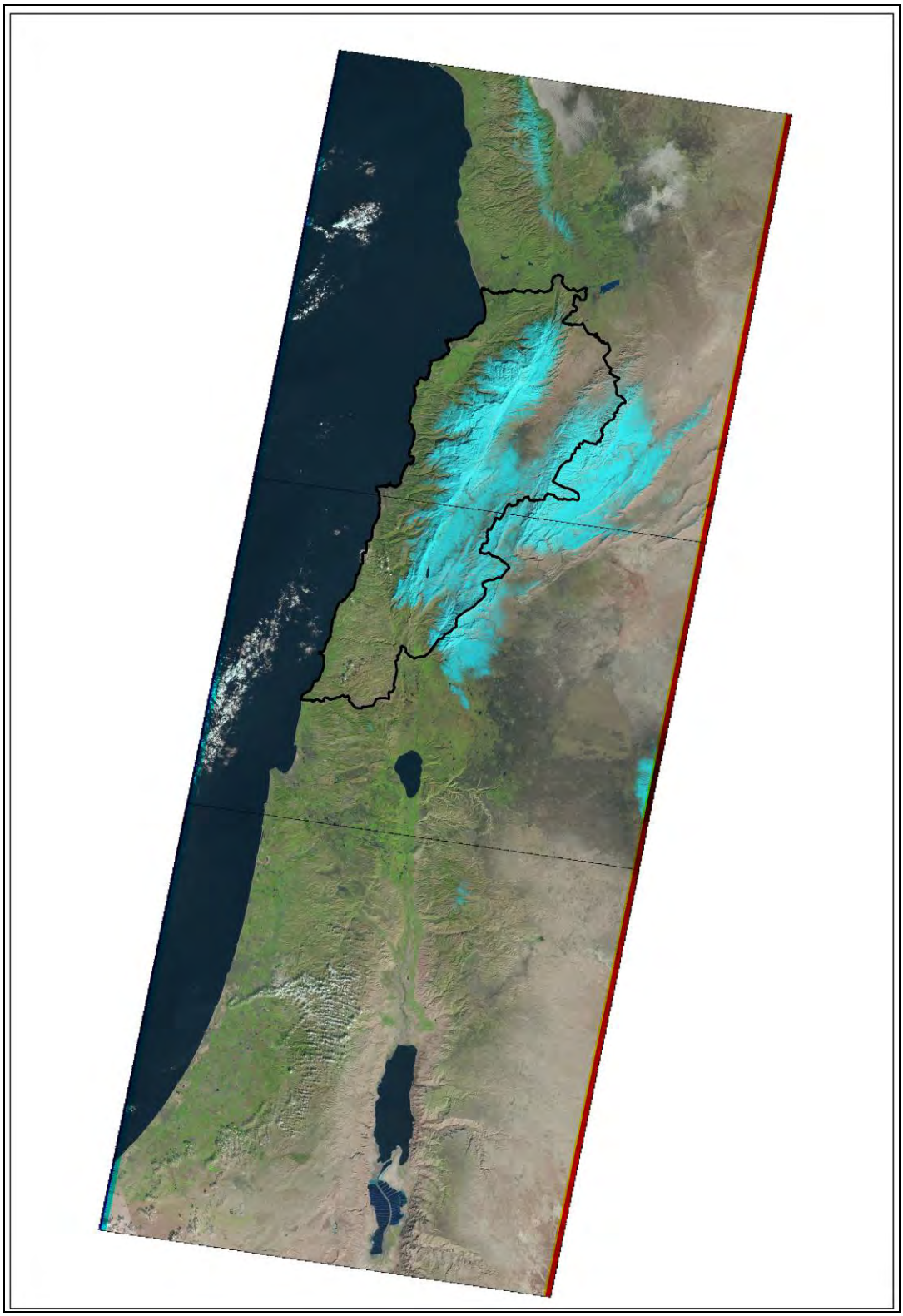


Figure 9: Typical distribution of snow cover in the Levant
(Landsat TM7 satellite image of 19.01.2002)

3.3 Hydrology

Hydrological measurements conducted by BGR showed that more than half of the long-term annual discharge of Jeita spring comes from the Nahr Ibrahim surface water catchment (Afqa and Rouaiss springs), the remainder from the northern part of the Nahr el Kalb surface water catchment (Figure 10).

Within the Jeita catchment three major subcatchments of periodic streams in the Nahr el Kalb surface water catchment can be distinguished: Nahr es Salib (92.3 km²), Nahr El Msann (Nahr Zirghaya = 47.8 km²), and Nahr el Hardoun (48.8 km²). There are two surface water gauging stations monitored by Litani River Agency (LRA)

The groundwater catchment of Jeita spring also comprises the entire groundwater catchments of the Afqa, Assal, Labbane and Rouaiss springs. This mechanism of indirect groundwater recharge from the Upper Aquifer to the Lower Aquifer was proven through differential discharge measurements in the Upper Nahr Ibrahim (MARGANE, 2012a, 2012b) and stable isotope analyses carried out by the project. Water from this infiltration in the Upper Nahr Ibrahim Valley contributes about 46% to Jeita spring discharge.

3.3.1 Rivers

The Nahr el Khalb is the main river in the catchment, flowing from east to west, and discharging into the Mediterranean Sea. It originates at the confluence of Nahr el Salib and Nahr Zirghaya and receives considerable amounts of water from the Jeita and the Kashkoush springs on its way down. Approximately 2 km downstream of the confluence it is fed by a third ephemeral river: Nahr el Hardoun. Compared to Nahr el Salib and Nahr el Msann, Nahr el Hardoun seems to be of minor importance for the generation of total river discharge as it does not receive inflow from the Upper Aquifer (C4). In general river beds are in a natural shape and not rectified, containing big stones and boulders of diameters up to 3 meters (MARGANE, 2011). Surface water flow of the Nahr el Kalb surface water catchment is measured by LRA at three locations (Figure 10). Long-term average flow at the seamouth is 170 MCM/a (WY 1997/98 - 2009/10; MARGANE & STOECKL, 2013).

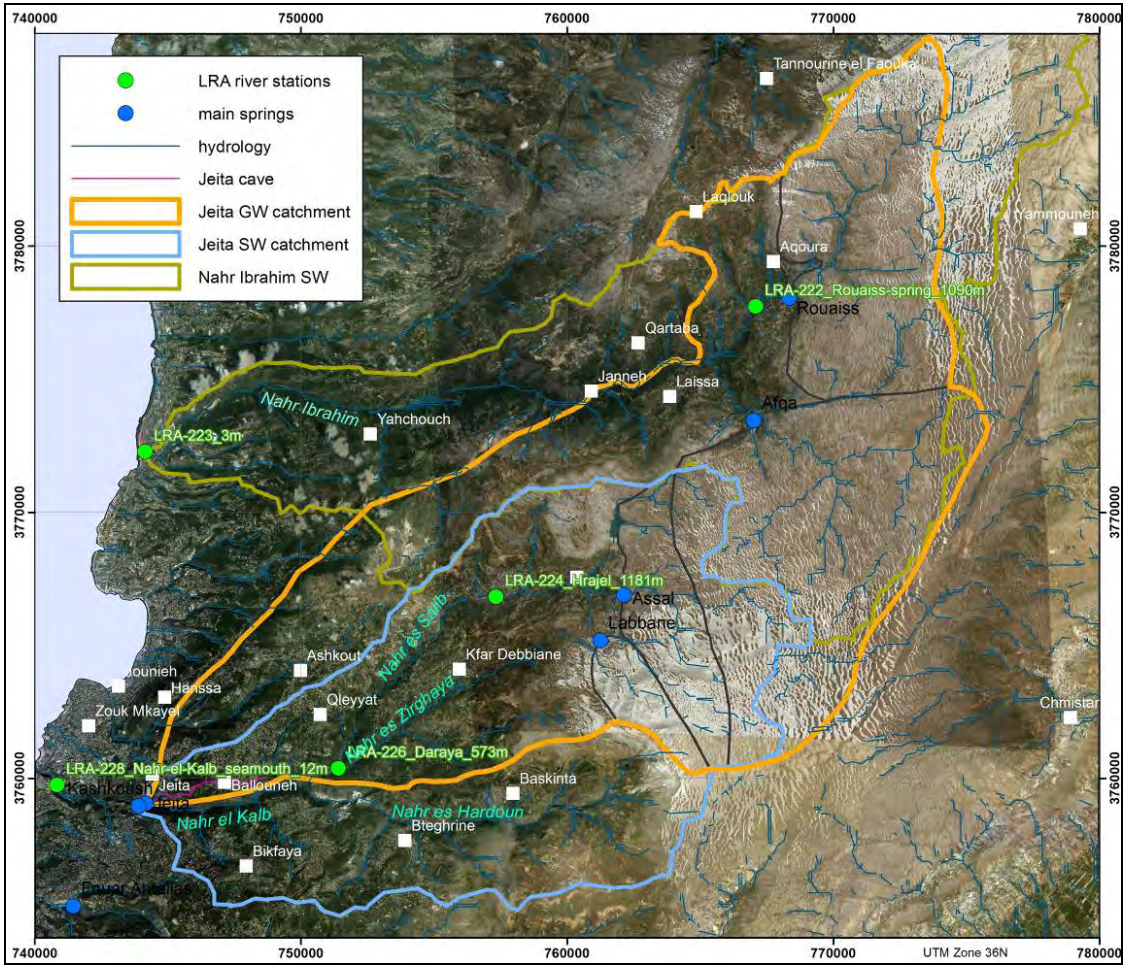


Figure 10: Hydrology of the Jeita spring groundwater catchment

(MARGANE & STOECKL, 2013)

3.3.2 Dams

So far Chabrouh Dam (Figure 11) is the only dam located in the groundwater catchment of Jeita spring. Its storage capacity is 9.0 MCM. However, about 30% of water stored in the dam are believed to be leaking either through the dam structure itself or through the C4 geological unit, contributing to increased spring discharge of the Hadeed, Qana and Terrache springs (BOU JAOUDE et al., 2010). It receives only little direct runoff from its own catchment. The major quantity of water is acquired through a channel from Labbane spring. Water from Chabrouh dam provides potable water for the upper Keserwan district. Boqaata dam is currently under construction. It is located right at the contact between the J5 (basalt) and J4 (limestone) geological units. The uppermost part of the J4 is highly karstified, which is the reason why the same site has been proposed by GITEC & BGR (2012) as a managed aquifer recharge dam.

Figure 11: View of Chabrouh Dam from Mzaar

3.4 Groundwater System

Although a number of studies have been conducted on water resources in the Nahr el Kalb catchment, no major groundwater investigation such as conducted by the Protection of Jeita Spring project has ever been conducted in Lebanon. A UNDP study conducted mainly by civil engineers in the late 1960s (UNDP, 1973), studying Jeita spring did not care to look at its groundwater catchment and the real origin of Jeita spring water. It only stated that the groundwater catchment of Jeita must be somehow similar to its surface water catchment, without elaboration from where this wisdom was deducted.

Between 2010 and 2013, the groundwater catchment of Jeita spring was finally delineated based on numerous tracer tests and other hydrogeological investigations conducted by the BGR project. It covers an area of 405.6 km² (MARGANE et al., 2013) and stretches in the north to almost Tannourine. A large share of Jeita water comes from higher elevations (C4 geological unit) and that is the (only) reason why it is not more polluted than it already is.

The groundwater system was subdivided into (from up to down; Figure 4):

- Upper Aquifer: C4 geological unit (Sannine Formation); discharging at the Rouaiss, Afqa, Assal and Labbane springs; thickness of up to 1,000 m.
- Aquitard Complex: comprising of J5-C3 geological units; without major springs; combined thickness of up to 800 m
- Lower Aquifer: J4 geological unit (Keserwan Formation); thickness up to 1,050 m and more

Four major springs discharge from the Upper Aquifer (C4): Rouaiss, Afqa, Assal and Labbane. The natural quality of these springs is much better than in the Lower Aquifer (Jeita, Kashkoush, Faouar Antelias) because only few contamination sources exist yet. This, however, is unfortunately starting to change with the development of resorts directly on the very highly vulnerable Sannine Formation (C4). Microbiological contamination is therefore expected be rise, especially at Assal and Labbane spring, which are immediately downstream of the resort area.

Groundwater flow velocities in both, the Upper and Lower Aquifers are very high (Figure 12). Tracer tests showed a mean flow velocity of between 70 and 200 m/h, but in large conduits flow velocity can reach up to 2,000 m/h during winter.

3.4.1 Springs

Jeita is the main spring with annually highest discharge in the catchment. It is the main source of water supply for the Greater Beirut Area and is of major strategic importance for the whole country. At Jeita high spring discharge peaks are observed during January to April (up to 60 m³/s), and low flow are noticed during the dry season (min. ~1 m³/s). There are several other springs in the catchment, from which some of them are ephemeral. Two more springs in the Nahr el Salib are

of relevance for water supply: Labbane and Assal. The discharge rates of some springs in the Jeita catchment have previously been assessed by LRA through long-term monitoring but this monitoring faces several shortcomings. Discharge rates of springs in Jeita catchment were monitored by the BGR project between 2010 and 2013. A new assessment of spring discharge was given in Special Report No. 8 (MARGANE & STOECKL, 2013).

Jeita Spring

Jeita spring exits from the Lower Aquifer (J4 geological unit; Keserwan Limestone Formation) at an elevation of 60 m asl. Jeita spring collects water recharged directly on the Lower Aquifer and a considerable amount of indirect GW recharge coming from the infiltration of surface water in the Upper Nahr Ibrahim Valley, the Upper Nahr es Salib Valley and the Upper Nahr El Msann (Zirghaya) Valley. Direct measurements of spring discharge were never done at Jeita spring. The BGR project installed two different flow monitoring systems (MARGANE & STOECKL, 2013) and collected measurements since July 2010, arriving at a discharge of 115 MCM for water year 2010/11 and 183 MCM for water year 2011/12. Average long-term discharge of Jeita spring in the WEAP model prepared for the entire groundwater catchment of Jeita spring (405.6 km²) was assessed to be 172 MCM/a.

Afqa Spring

Afqa Spring is located at 1,280 m asl. Its subsurface catchment has a total size of approximately 101.5 km² (MARGANE et al., 2013) and reaches up to 2,628 m asl. Afqa is completely fed through the C4 unit; discharge varies highly throughout the year with a maximum normally between March and May. Water discharged from Afqa spring flows westward in Nahr Ibrahim, however near the confluence of the Rouaiss and Afqa branch an extensive surface water infiltration zone was identified. Here an estimated 23 % of all surface water contributes to feed Jeita spring (total contribution to Jeita spring discharge: 29 % or 50 MCM) through riverbank infiltration into the Lower Aquifer (J4) (SCHULER & MARGANE, 2013; MARGANE et al., 2013).

The water supply installations at Afqa spring are in a poor condition and should be upgraded. The spring capture should be established in a professional way. Currently, water use is completely uncontrolled and the spring is not protected against pollution. At least the perimeter 50 m upstream, 15 m to each sides and 10 m downstream of the spring must be protected (MARGANE & SCHULER, 2013).

Assal Spring

Assal Spring is located at 1.540 m asl. Its groundwater catchment has a total size of approximately 14.6 km² and reaches up to 2.628 m asl. Assal is completely fed through the C4 unit. Assal spring discharges from two separate captures, with only

the western spring being measured, both by BGR and LRA. Discharge from the western spring is estimated to constitute approx. 75% of total flow from Assal spring. Based on measurements of the BGR project, a flow of 15 MCM for water year 2010/11 and of 22.4 MCM for water year 2011/12 was assessed for the western spring (MARGANE & STOECKL, 2013). Flow measured with another, more accurate system (ADCP) since November 2012 indicates a total flow of the western spring for water year 2012/13 of approx. 18 MCM. Total spring discharge from Assal spring is therefore estimated at 24 MCM/a.

Assal spring is polluted with sewage water particularly from resorts, chalets and dwellings in Aayoun es Simane area (CDR, 2006) and needs to be protected as proposed by MARGANE & SCHULER (2013).

Labbane Spring

Labbane Spring is located at 1.644 m asl. Its groundwater catchment has a total size of approximately 9.5 km² and reaches up to approx. 2.550 m asl. Labbane spring is completely fed through the C4 unit. Highest discharge occurs in May, as response to snowmelt. Discharge from Labbane spring has a high seasonal variability, falling almost dry between September and December. Water from Labbane Spring is conveyed to Chabrouh dam where it is treated (aeration, rapid sand bed filtration and chlorination) before distribution in the Upper Keserwan district. A part of water from Labbane spring is conveyed into an irrigation canal that feeds the area of Kfar Debbiane irrigation scheme, mainly between May and September.

Rouaiss Spring

Rouaiss spring is fed by the C4. Its groundwater catchment has a size of about 65.8 km^2

The capture of Rouaiss spring is in a poor condition and should be upgraded. Measurement of spring discharge takes place by LRA not at the spring but some 1.6 km further downstream. The station is almost completely destroyed, which leads to unreliable monitored values at this site (MARGANE, 2012a). The long-term average discharge is unknown but fairly high, probably around 97 MCM/a (MARGANE & STOECKL, 2013). This water could be used much more efficiently. The spring capture should be established in compliance with monitoring standards. Currently, water use is completely uncontrolled and the spring is not protected.

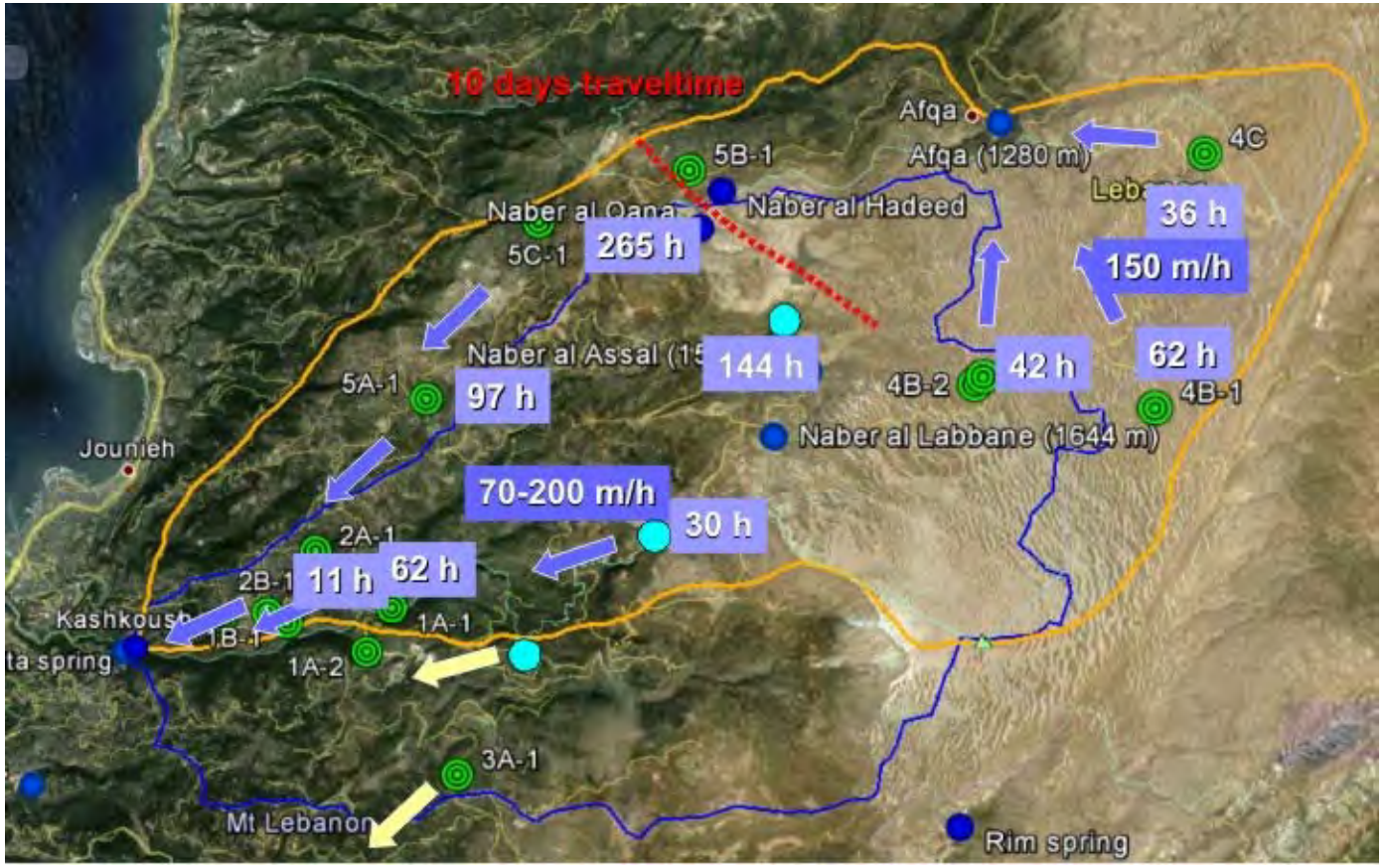


Figure 12: Groundwater flow velocities determined by tracer tests

(MARGANE et al., 2013)

3.4.2 Wells

According to SHABAN (2009), groundwater discharges have declined. A relatively high number of water wells were drilled all over the catchment area. Most of them are illegal and were drilled without any kind of permit. Despite severe rules to obtain well drilling permits, people are managing to drill their private wells and uptake groundwater without any control or limitations. This fact poses major risks on this groundwater which is used for drinking purposes and is supposed to be protected from any contamination source.

For most existing wells in the Jeita catchment the location, depth and abstraction is unknown. Some of the wells are not used for water abstraction but rather for wastewater discharge (ACE, 1995; MoE, 2001: Lebanon State of the Environment Report 2001, Chapter 15). A new well survey has recently been undertaken by the UNDP project at the Lebanese Centre for Water Conservation and Management (LCWCM).

3.5 Water Supply Infrastructure

Currently available water supply network components in Jeita catchment are illustrated in Figure 13. The existing water supply infrastructure is very old. It requires urgent rehabilitation. No protection measures are in place at any spring. Even large springs, important for domestic water supply, such as Labbane spring, are not surrounded by a fence and virtually any water source can be accessed without problem. This constitutes a major health risk. During the field assessment, pesticides containers were found dumped at few meters of the Labbane spring reservoir (Figure 34).

Spring captures of all major springs are in a poor condition. Currently, at none of them accurate spring discharge measurements and water quality monitoring are undertaken by the Lebanese authorities, due to a major lack of maintenance, equipment and laboratory capacities. Therefore, neither the available amount nor the quality was known before the start of the BGR project. The continuous measurements undertaken by the BGR project at Jeita, Kashkoush, Assal and Labbane springs are the first attempt to come to real and continuous (however partial) quality (Turbidity, pH, EC, DO) and quantity assessments. The same is valid for surface water monitoring and the monitoring of meteorological data. Due to massive gaps in historical and present data records, until now, reliable water resources assessments have not been possible. Imprecise or false assessments will lead to wrong water infrastructure planning.

It is urgently recommended to improve the monitoring of all components of the water balance. As springs are the main source of water supply, the project recommends the implementation of an advanced discharge monitoring for all springs yielding more than 10 MCM/a.

Moreover, conveyors such as the Jeita-Dbayeh canal and tunnel system, which is partly more than 140 years old, constitute a severe risk to public health. The Jeita -

Dbayeh conveyor is not fenced so that access is open to everybody. People have drilled into the canal and are pumping water from it. The canal is used as a car park and for storage of material, etc. **It is strongly recommended to rehabilitate the dilapidated Jeita-Dbayeh conveyor system** also because the Greater Beirut Area may be out of water for months if the system, which consists only of a single line, is interrupted by landslide, rock fall, collapse (tunnel) or intentional damage. A related proposal was made by the project (GITEC & BGR, 2012).

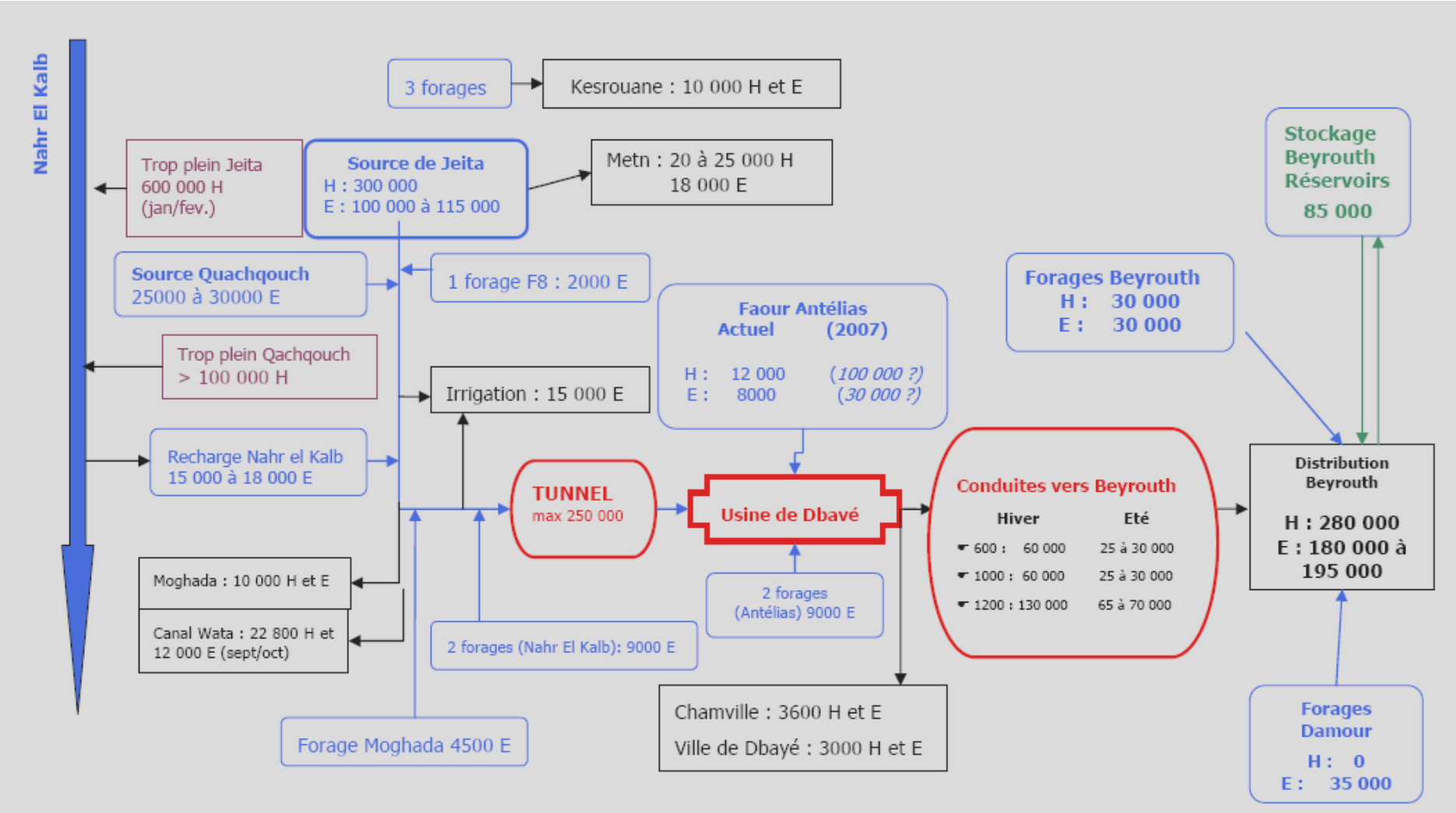


Figure 13: Diagram of the water supply network providing drinking water to Greater Beirut area (CORAIL & ICEA, 2005)

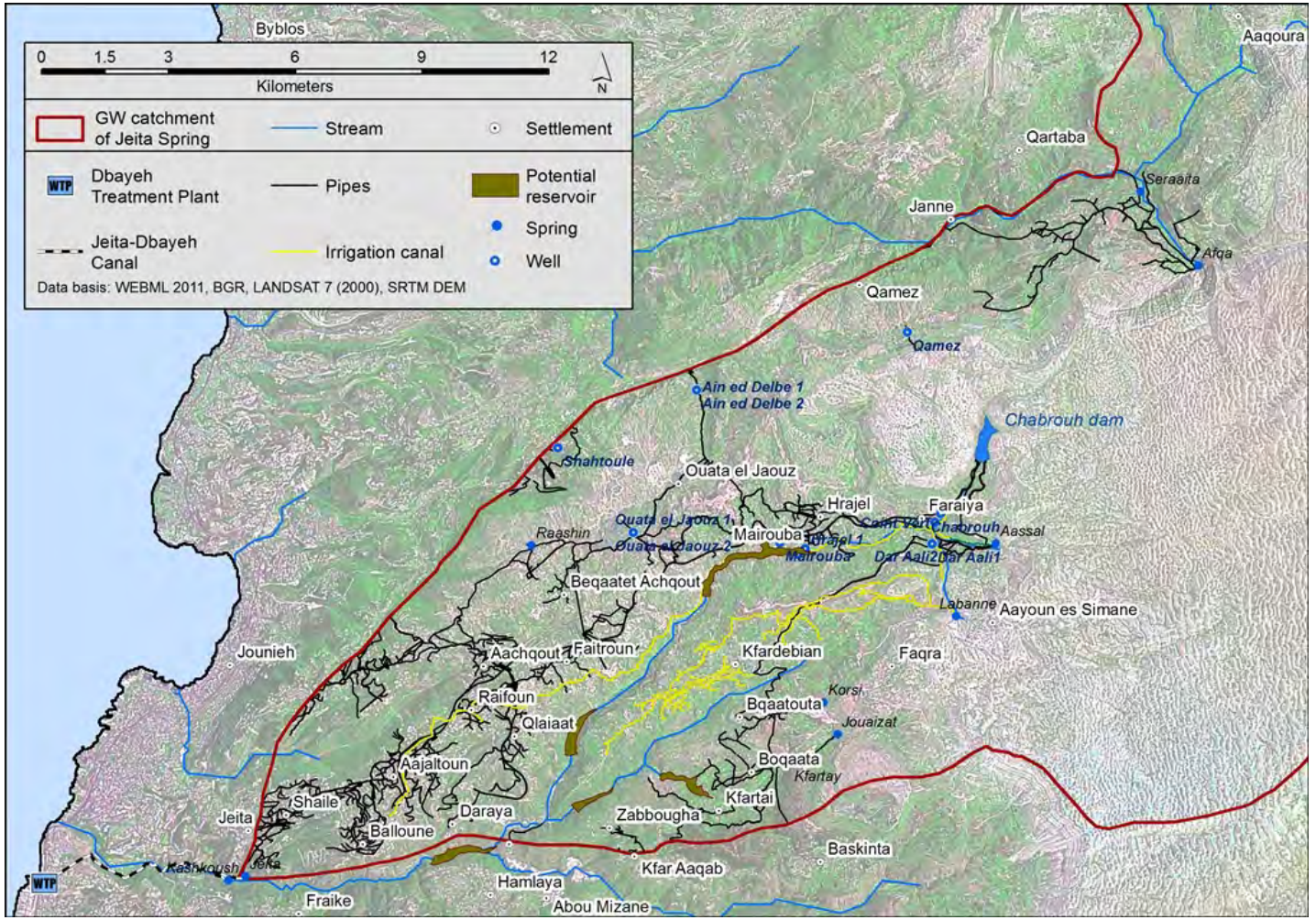


Figure 13: Water supply network in the Jeita catchment

3.6 Urban Context

The study area expands mainly within the district (caza) of Keserwan, the remaining part being located in the districts of Jbeil and Metn, all located in the governorate (mohafazat) of Mount Lebanon. A full list of all municipalities of Jeita spring catchment is exhibited in Annex 1.

The population is distributed unevenly among regions. Around 75% of the total number of population is living in the lower part of the catchment. The villages located at higher elevations are mainly populated during summer time (Table 1, 2 and 3; SCHULER & MARGANE, 2013) which put these areas under severe pressure in absence of planning and infrastructure (i.e. wastewater collection and treatment facilities). Meanwhile, the population does not seem to vary in the villages of lower altitudes such as Jeita and Ballouneh.

In recent years the population numbers have risen significantly as more and more houses are built at mid altitudes (600 - 1000 m asl). An increasing number of people are commuting in summer between this area and Beirut.

Urban expansion poses a major challenge for this vulnerable area. With landuse planning practically non-existent, this rapid and unmanaged urban expansion has a severe impact on the landscape, water resources, environment and quality of life.

Table 1: Summer and Winter Population in the Villages on the Upper Aquifer

Municipality/village	Population	
	October-March	May - September
Cretaceous		
Faqra	3,000	3,378
Aayoun es Simane*	1,689	3,000

Source of data: * GITEC (2011)

Table 2: Summer and Winter Population in the Villages on the Aquitard

Municipality/village	Population	
	June- September	October-May
Aquitard North		
Faraya	4,000	4,000
Hrajel	8,000	4,000
Mairouba	4,000	4,000
Wata el Jaouz	3,000	600
Aquitard South		
Baskinta (10%)	1,600	1,568
Boqaata	2,800	1,200
Bqaatouta	2,400	2,400
Kfardebian	12,000	12,000
Kfartai*	1,000	1,000
Ouadi el Karm	-	-

Source of data: * GITEC (2011)

Table 3: Summer and Winter Population in the Villages on the Lower Aquifer

Municipality/village	Population	
	June- September	October-May
J4 North-West		
Afqa	-	-
El Ghabat	3,000	600
Laissa	3,000	300
Seraita	-	-
J4 West		
Aajaltoun*	12,000	6,000
Aachqout	8,024	5,617
Ain el Delbe	400	20
Ain el Rihane	4,000	4,000
Balloune	15,000	12,000
Beqaata Aachqout	2,800	1,200
Bzoummar	500	250
Daraya*	1,500	1,500
Dlebta	900	450
Faitroun*	3,400	1,800
Ghosta	3,500	2,500
Hiyata	-	-
Jeita	5,000	5,000
Kfar Debbiane*	12,000	12,000
Qamez	1,200	50
Qleyyat*	11,000	5,500
Raashine	6,000	4,500
Raifoun	5,000	1,000
Shaile	6,000	6,000

Source of data: * GITEC (2011)

The catchment area holds several schools, hotels and touristic resorts.

There are a number of large touristic resorts with apartments, mainly occupied during the weekends: Faqra Club, Mzaar, Satellity, Al Irani, SunCity, Les Villettes de Kfardebian, Aajaltoun village etc.

Furthermore, Jeita catchment holds many restaurants especially at Qleyyat, Roumieh, Mayrouba, and Hrajel. These are mainly active during summertime and the skiing season when many tourists frequent the area (Figure 14).

There are 18 large schools in the main part of the Jeita catchment (Table 4).

Table 4: Schools in the Jeita spring catchment

Name of School	Village
Notre Dame de Loueizeh	Zouk Mosbeh
Saint Joseph	Aintoura
Saint Sauveur	Jeita
Aajaltoun International School (AIS)	Aajaltoun
Saint Louis	Aajaltoun
Notre Dame des Rochers	Aajaltoun
Lycée officiel	Aajaltoun
Ecole TS officielle	Aajaltoun
Ecole technique officielle	Aajaltoun
Saint Rock	Qlaiaat
Saint Paul	Faitroun
Louaize	Faitroun
SSCC	Kfar Debbiane
Lycee officiel	Kfar Debbiane
Ecole officielle	Kfar Debbiane
Soeurs de La Croix	Hrajel
Ecole officielle	Hrajel
Ecole officielle	Mayrouba

Source: BGR field assessment

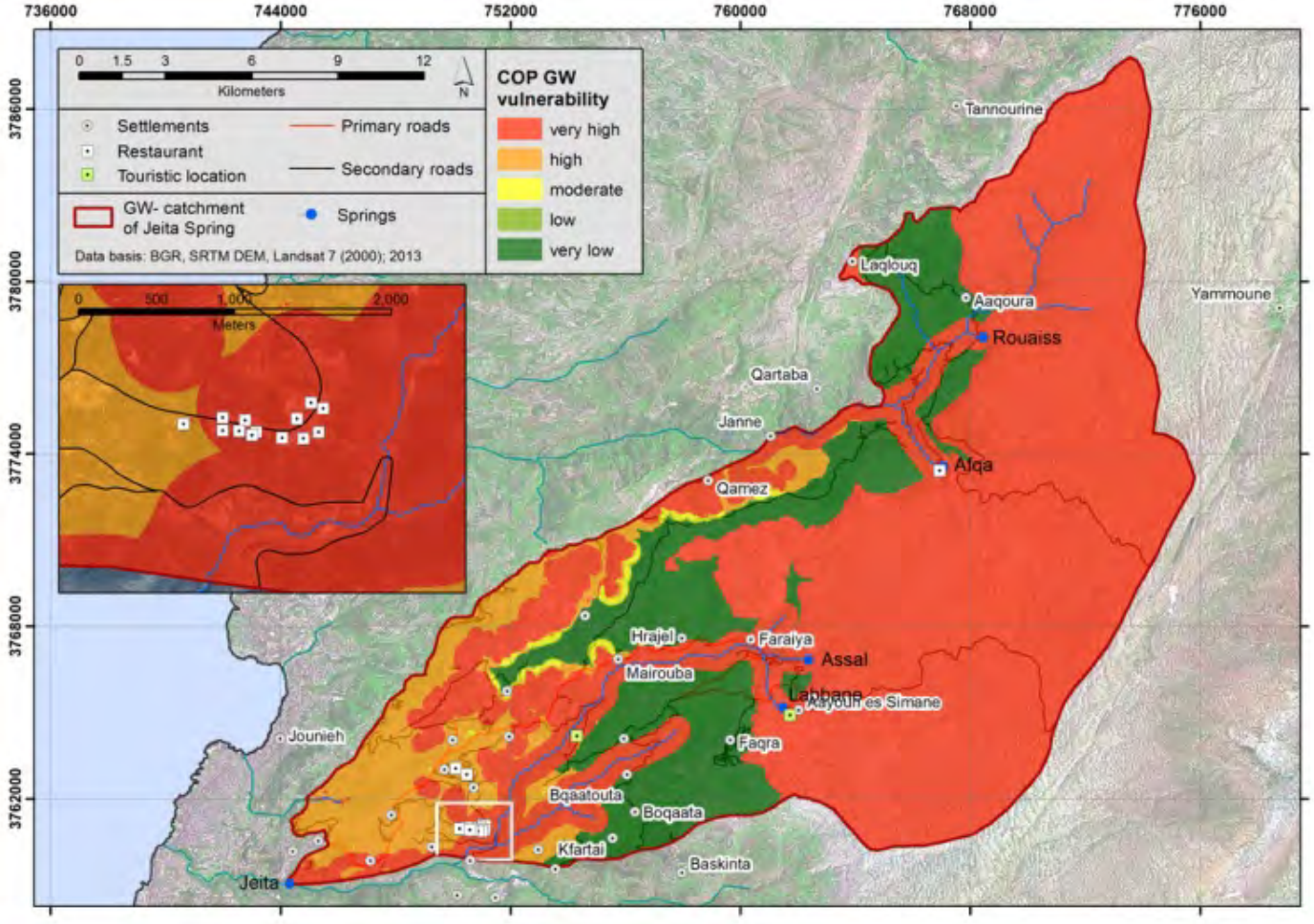


Figure 14: Restaurants and touristic resorts assessed by BGR in Jeita catchment with highlight to the GW vulnerability

Urban development in the Jeita catchment has mainly followed the urban planning legislative Decree N° 69 dated 09/09/1983 which regulates the designs and systems of towns and villages and the classification (zoning) of territories within the National Land Use Master Plan (Schéma Directeur d'Aménagement du Territoire Libanais), as well as the balance that must be maintained between the development of urban areas on one hand and the preservation of the natural sites, agricultural activities and forest areas on the other, in addition to the upholding of public health and traffic safety, esthetics and a sustainable living environment (MOUBAYED et al., 2012). This decree did not include any consideration of groundwater resources protection.

A Regional Landuse Master Plan for protecting Nahr El Kalb valley was issued in 1997 (Decision N° 49 of the General Directorate of Urbanism, dated 17/12/1997). Also this plan did not properly consider protecting groundwater resources.

The last National Physical Master Plan issued in 2005 by CDR and approved in 2009 (Decree 2366 dated 20/6/2009) lacks clear groundwater protection considerations. Water resources protection is restricted in this Master Plan only by restricting urban activities, quarries and industries at very high mountains above 1900 m asl (DAR IAURIF 2005). Following this Master Plan, Nahr Ibrahim and Nahr El Kalb valleys are required to be protected by not allowing solid and liquid wastes disposal and preserving the steep slopes from soil erosions mainly through reforestation. However, this was considered from the perspective of safeguarding the natural characteristics of the valleys and not specifically the groundwater. Protection of the latter was mentioned separately (water resources vulnerability). This part needs an update specifying groundwater protection areas of important springs, with a clear specification of the activities to be banned or to be allowed and the related required infrastructure and operation guidelines. The necessity to protect vulnerable groundwater such as in the zones of faults and fractures was highlighted in this Master Plan, differentiating between already urbanized areas where effluents treatment plants must be mandatory in addition to a proper solid waste management. However, the areas considered as presenting high water vulnerability in Jeita catchment are significantly underestimated in comparison to the groundwater vulnerability as mapped by BGR (MARGANE & SCHULER, 2013), this was due to the absence of a corresponding groundwater vulnerability map at the time. The Master Plan promulgates that organic agriculture should be replacing the use of chemical fertilizers and pesticides in vulnerable zones and that environmental impact assessments should be obligatory for permitting of human activities (DAR IAURIF 2005). Vulnerable areas are yet to be specified considering groundwater vulnerability. It is recommended to integrate the groundwater vulnerability map prepared by BGR into the National Physical Master Plan.

The field assessment conducted by BGR shows that the environmental criteria for permitting the construction of buildings within the protection zones of rivers established by the Ministry of Environment through decision No. 90/1 of 2000, (which states environmental criteria to permit the construction of buildings within the protection zones of rivers set by the Ministry of Environment article 2, paragraphs 1&2), were not considered in the urban development of the area. Buffer setbacks from water streams and springs are mostly not respected and wastewater infrastructure is lacking. Buffer

setbacks from water streams are not always clear to decision makers (such as engineers of municipalities, etc.). The modification of many laws, decrees, and decisions, which are often contradictory to one another render the urban planning criteria unclear even to decision makers.

For example, Figures 15 and 16 show that many chalets in Aayoun es Simane are located at few hundred meters directly upstream of Labbane spring. From Labbane spring, one can clearly see the chalets' located immediately above the spring (Figure 17). These chalets have only open cesspits as means of wastewater evacuation.
It is important to mention that Jeita Spring catchment includes several "Protected Natural Sites:

- Natural bridge of Nabaa el Labbane : Site protected by Decree N° 434 dated March 28, 1942 (amended by Decree N° 836 of 09/01/50), based on the Law of July 8, 1939 related to the protection of natural landscapes and sites. Protection consists of a zoning regulation on construction rights as well as prospect regulations. A buffer zone of construction ban until a distance of 200 m from all sides of the natural Faqra bridge is imposed.
- Riverbeds: Nahr Ibrahim; Nahr el-Kalb and its tributaries Sannine (Nahr es Hardoun), Nahr el Salib and Msann (Nahr Zirghaya): Sites protected by Decision 97/1 of the Ministry of Environment (MoE) issued on July 2, 1998, based on the law on natural sceneries and sites of 1939, Decree 9501, dated November 7, 1996, and Article 12 of Law 667, dated December 29, 1997. River protection consists in general of a 500 m wide zone following the centerline of the river, within which all activities are subject to MoE authorization. This zone extends to 3000 m for the authorization of quarries. (DAR IAURIF, 2005).

Figure 15: Intercontinental Hotel & resort at Aayoun es Simane located above Labbane spring

Figure 16: Snapshot from Google Earth emphasizing the short distance between Labbane spring and the chalets area

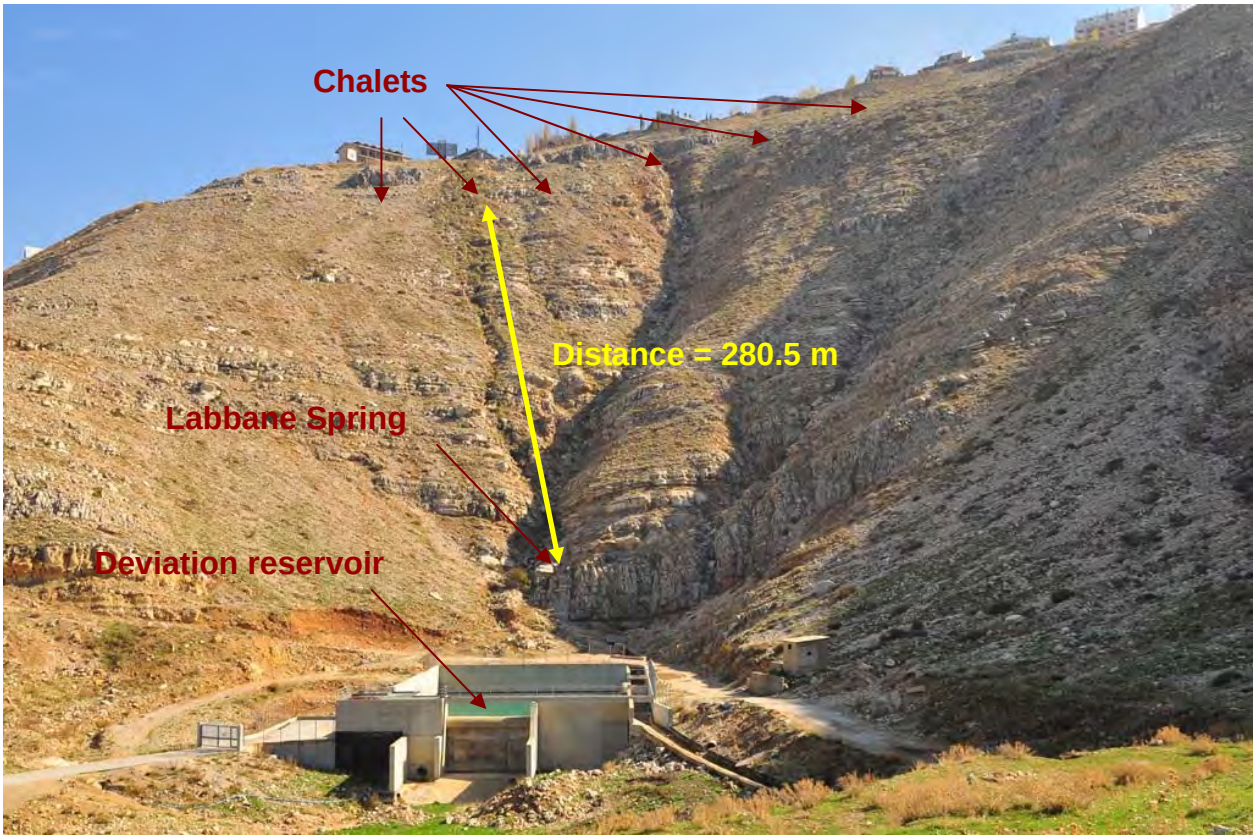


Figure 17: Position of the chalets straight above Labbane spring

3.7 Vulnerability to Contamination

Several characteristics of the study area lead to consider it as highly vulnerable to groundwater contamination of which we mention:

- The highly karstified geological context with shallow or sometimes absent soil covers that lead to a high infiltration rate and low retention capacity.
- Uncontrolled expansion of residential areas (approx. 200.000 inhabitants, living mainly in scattered habitations) and environmentally unsound practices in existing human activities.

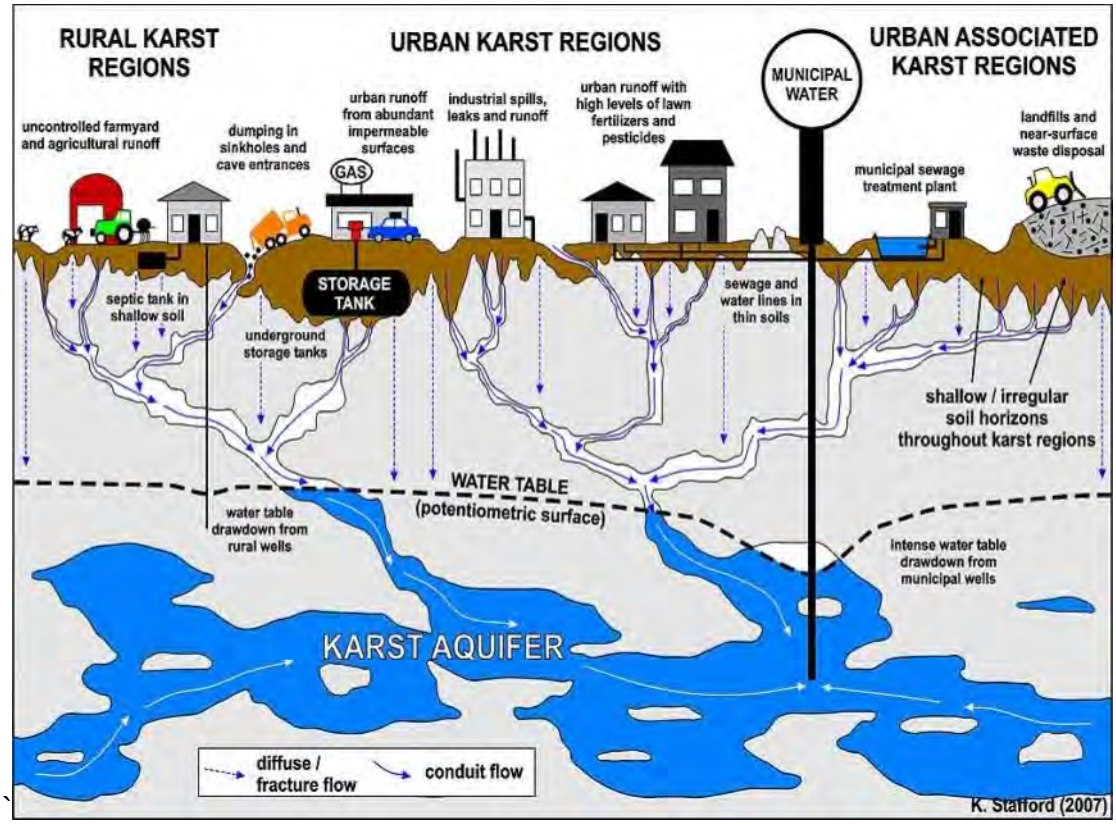


Figure 18: Pollution pathways in Karst areas

(STAFFORD, 2007)

In karst systems groundwater protection is very difficult due to:

- diffuse infiltration through fractures (matrix)
- concentrated infiltration through karst network (sinkholes, dolines, conduits)
- non-uniform groundwater flow.

The tracer tests conducted by the BGR project showed that flow velocities in the groundwater system are relatively high (70-200 m/h); in large conduits, such as Jeita Grotto they can even reach 2,000 m/h. Therefore pollution is spreading fast in the groundwater (MARGANE, 2012f). The high flow velocity causes relatively short residence times of groundwater within the aquifers. The short residence time is not sufficient to attenuate contaminants.

Spring discharge varies throughout the season, with quick responses to rainfall events (rain in the Jeita catchment arrives at Jeita often after less than 12 h). Spring discharges decrease significantly between July and November and many small springs dry out in the summer. Since all regional streams are fed by springs, all of them are periodic.

Areas with high or very high GW vulnerability cover 80.4 % of the catchment. Due to the high relevance of Jeita spring for drinking water supply in the Greater Beirut Area, protection of this vital resource must be a national priority. The BGR project has recommended to apply protection zones where a number of landuse restrictions are to be integrated in landuse planning of the catchment area (Figure 19).

4 Groundwater Protection Zones

Only through groundwater protection zones a meaningful reduction in the water pollution risk can be achieved. Current landuse licensing regulations and practices are inadequate. A zoning system must be introduced and applied to all major springs used for drinking water supply in Lebanon. Such zoning systems should be based on international experiences (MARGANE, 2003a).

Groundwater protection is not an isolated action but a long-term and multidimensional program. It comprises research, mapping, monitoring, modeling and analysis of the changes and processes that take place in a groundwater system. The delineation of groundwater protection zones follows natural criteria, mainly the groundwater travel time to springs and wells used for drinking water supply.

Groundwater protection zones for the groundwater catchment of Jeita spring were delineated by the BGR project based on groundwater vulnerability and travel time in groundwater (MARGANE & SCHULER, 2013). The protection scheme comprises three zones with different level of protection needs (landuse restrictions). Landuse restrictions in protection zone 2 must be more comprehensive than in protection zone 3.

Protection zone 1 is the most sensitive area where water of Jeita spring, used for drinking water supply, is directly accessible or where there is a direct connection to the water source, e.g. Jeita grotto, the canal from Jeita to Dbayeh and the potential cave collapse area (MARGANE & SCHULER, 2013). These need highest protection and no access to the public should be allowed (except for Jeita spring, where rigorous control of environmental protection by MAPAS must be enforced). A fence must be established and access to the public must be banned (except at the tourist site of Jeita grotto).

Protection zone 2 is the area of high groundwater vulnerability, where travel times are less than 10 days (die-off of most bacteria in GW). Here no activities (application of pesticides use of hazardous substances, etc.) which may have a potentially negative impact on GW quality should be allowed.

Protection zone 3 is the entire rest of the groundwater catchment. Here landuse practices must ensure that long or hardly degradable hazardous substances cannot reach Jeita spring.

Landuse licensing regulations must be changed to ensure adequate protection of water resources, e.g. for gas stations, quarries, etc. The proposal of landuse restrictions was made by the BGR project based on what would be principally necessary so that the final goal could be met. However, many of the proposed landuse restrictions will meet considerable resistance from land owners. A committee is needed to agree on the general procedure, the necessary landuse restrictions and the implementation and control mechanisms.

Success of this measure depends on the implementation and enforcement capacity of the governmental institutions responsible for this task. Penalties must be imposed for violation and a special police task force must be charged with control of the landuse restrictions (environmental police). A capacity building of the agencies responsible for water resources protection is urgently required.

The technical cooperation project based its groundwater vulnerability mapping on the COP method which seems being the most appropriate in such karstic environment.

Groundwater vulnerability map in the Jeita spring catchment is illustrated in Figure 19. While BGR proposed Jeita groundwater protection areas are illustrated in Figure 20.

The approach used concerning the delineation of groundwater protection areas (MARGANE & SCHULER, 2013) is applicable in all of Lebanon.

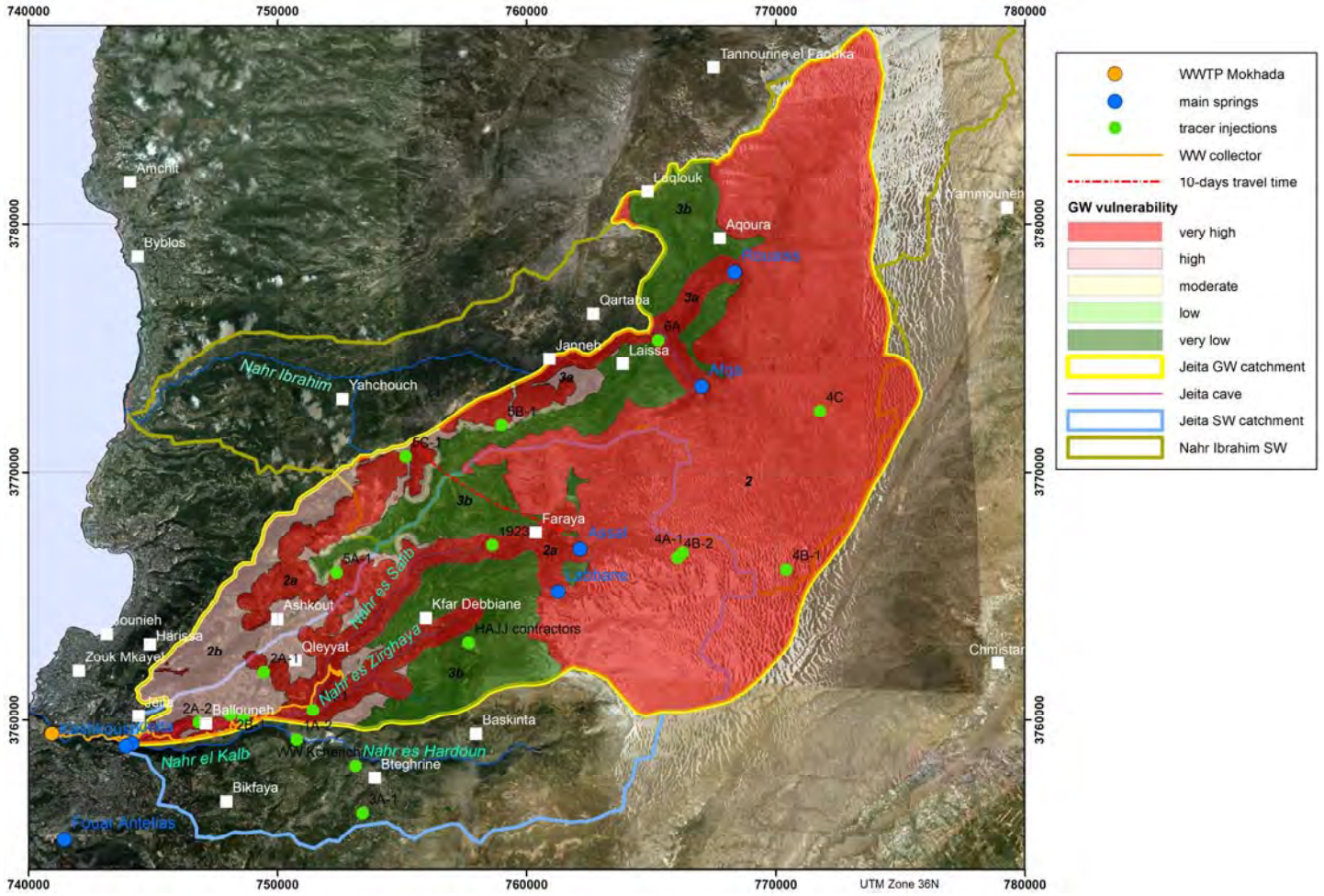


Figure 19: Jeita spring groundwater vulnerability map (MARGANE & SCHULER, 2013)

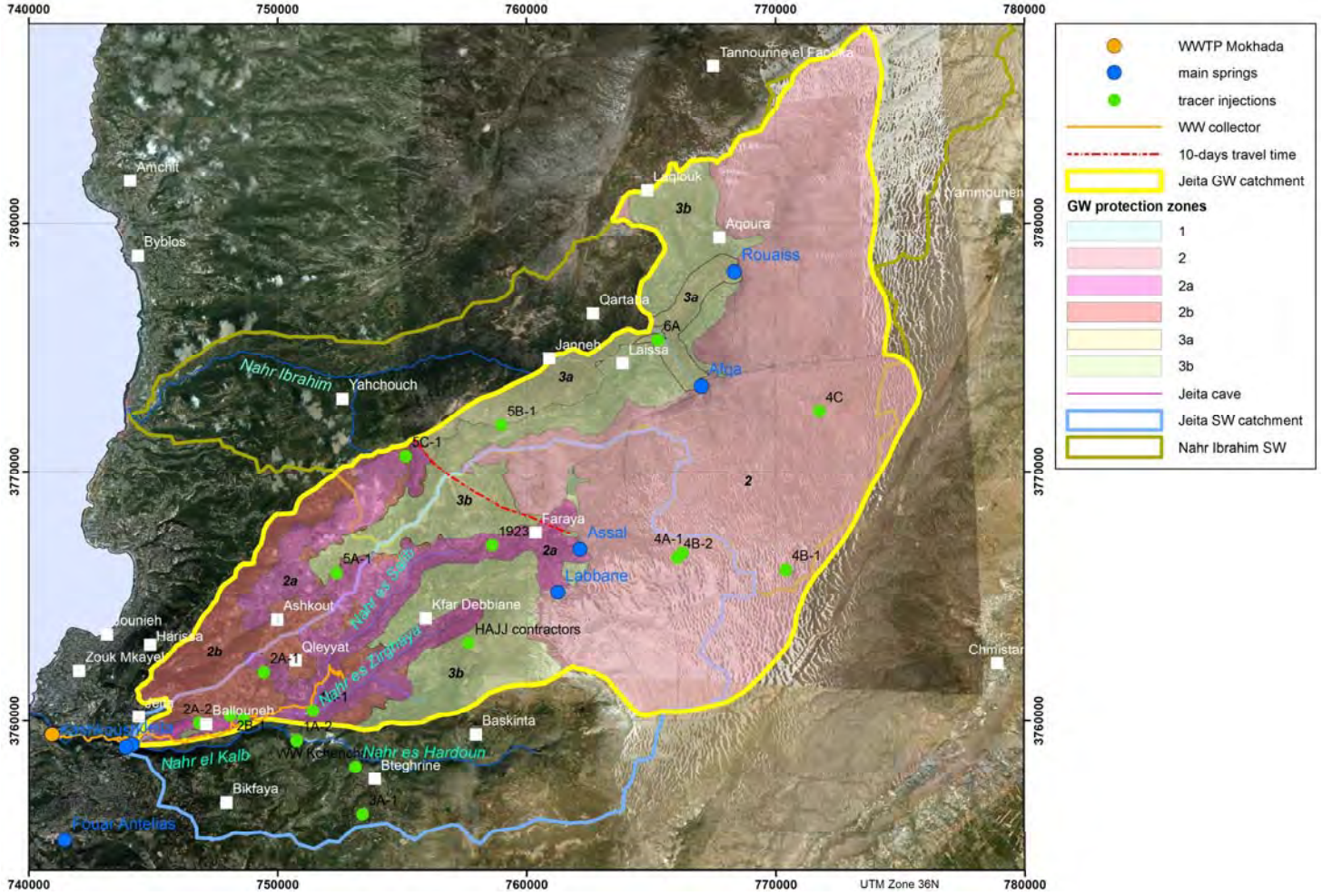


Figure 20: Proposed groundwater protection zones (MARGANE & SCHULER, 2013)

4.1 Legal Framework and Permitting System

The existing legislation related to groundwater protection in Lebanon is exhibited in Table 5. Unfortunately the existing legislation (Decree No. 639 of 26.03.1942 dedicated to the Protection of Nabaa al Assal, Faraya) is not just outdated but also not applied.

Despite that the permitting of any human activity in Lebanon prevail by law the respect of the environment and of the water resources (surface and groundwater) in particular, this fact is not respected mainly due to the lack of awareness at the related decision makers level in groundwater protection requirements. In addition to the lack of serious information related to groundwater vulnerability.

The BGR project Protection of Jeita Spring was a pioneer in delineating Jeita spring's GW catchment and in preparing its related vulnerability map and protection zones. GW vulnerability maps (MARGANE, 2003b) have never been a basis for urban planning in Lebanon as they were lacking so far. While they should be considered with great care if one wants to seriously follow the actuated laws and decrees.

Groundwater protection was mentioned in the last National Physical Master Plan produced by CDR and approved by the Council of Ministers in 2009, however, it lacked important details due to a related absence of information.

The application of the concept of groundwater protection requires major efforts at the level of related governmental institutions, in addition to major political and social hindrances.

Legislation needs to specify

- size and delineation method of protection zones
- landuse restrictions
- measures for compliance
- enforcement of compliance
- penalties for non-compliance
- governmental agency responsible for enforcement
- education and awareness raising of population and technical capacity building of the staff of the enforcement agency.

Table 5: Actuated Lebanese legislation related to groundwater protection zones

Reference	Content	Implementation status
(General Health Rules) Legislative decree No. 16/L of 1932	Emphasizes on the development of a protection zone around a well or a spring used for drinking water supply, and the prevention of any activity of potential risk within the protection zone.	Not seriously implemented since it is outdated and not revised.
(Drinking water abstraction projects) Legislative decree No. 227 of 1942 (articles 2 &4)	Emphasizes the authorization of the usage of water resources for drinking purposes and the identification of protection zones	Not implemented
Water Sources	Emphasizes on the identification of protection	Implemented but the

Protection Zone delineation) Decree No. 10276 of 1962 amended by decree 7007 of 1967	zones for water resources, based on the results of geological studies	council responsible of determining the protection zone does not have the required resources

Source: http//environ.chemeng.ntua.gr/ineco/Default.aspx ?t=195

5 Hazards to Groundwater

Contaminants are dissolved and transported together with infiltrating rainwater into the unsaturated soil and rock above the water table. In the saturated zone contaminants begin to migrate with groundwater flow. Pollutants may be attenuated in the unsaturated zone if related mechanisms are available (e.g. adsorption). Dilution in the saturated zone may lead to a considerable reduction in concentration of the contaminant in water. This dilution is seasonally very different. Some contaminants may be difficult to detect as their appearance may vary over time. Once groundwater becomes polluted, it is extremely difficult and expensive to clean up, even partially. This pertains especially to hydrocarbons.

Point and non-point source pollution represent a perfect example of a complex multidisciplinary problem that exists over multiple scales with tremendous spatial and temporal variability. A point source of pollution discharges to the environment from an identifiable location, whereas a non-point source of pollution enters the environment from a widespread area. The ability to accurately assess present and future point and non-point source pollution impacts on ecosystems ranging from local to global scales provides a powerful tool for environmental stewardship and guiding future human activities.

This part will detail the detected non-point sources and point sources of groundwater contamination.

Because of the variety and density of occurrence, the locations and impacts of the potential and actual polluters of groundwater in the study area are detailed separately.

Major pollution sources found in the Jeita catchment are displayed in Table 6.

Table 6: Wastes generated by major detected potential Hazards to Groundwater in the Jeita catchment

Hazard source	Generated pollutants
Sewerage systems: (open pits, etc)	Wastewater= organic and inorganic constituents: viruses, microorganisms (e.g. E.coli, Legionella pneumophila, Clostridium, Pseudomonas aeruginosa, Enterococcus faecalis, Giardia lamblia, Cryptosporidium parvum), nitrogen, heavy metals, organic matter content as well as trace organics like endocrine disrupting compounds and pharmaceutically active compounds. E coli and total coliform are used as an indicator for a contamination by wastewater.
Gas stations:	• Fuel (gasoline, diesel, petrol, kerosene etc.) • Lubricants • Used and or waste oils • Oily sludge from oil tank cleaning & oil/water separator • Solvents used to clean equipment • Antifreeze • Contaminated spill cleanup materials • Equipment from replacement & decommissioning of tanks & pipe work
Generators	used oil spills, oil containers disposal, Diesel reservoirs leakages
Cars reparation workshops	Petroleum products (oils, lubricants, etc. + tires & other vehicles spare parts, paints, etc.
Residential heating systems	Petroleum contamination (mainly diesel)
Dry cleans	Dense non-aqueous phase liquids (DNAPLs)
Industries (Injection wells, various chemicals & solid wastes disposal)	Liquid and solid Industrial wastes = Industrial contamination: Heavy metals, and other hazardous chemicals
Agriculture (protected and open field crops production)	Pesticides (e.g. Endosulfan, arsenic, dicamba, atrazine and prometon etc. & even solvents such as carbon tetrachloride) fertilizers (nitrates), herbicides (Paraquat, glyphosate, etc.) , hormones.), and solid wastes: (Pesticides containers, packaging and wrapping materials, used Poly Ethylene irrigation pipes & fittings, etc.
Feedlots and Slaughterhouses:	Infectious wastes : Manure, animal carcasses, used litters, etc. slaughtering wastes (Specific Risk materials, organs, bones, blood, carcasses, etc.), pharmaceuticals, disinfectants,
Illegal dumpsites	Household wastes; Construction wastes: mainly PVC, dioxins, heavy metals, arsenic, lead, chromium and polychlorinated biphenyls; Industrial solid wastes: Sludge, various solid wastes; Slaughtering wastes; Pharmaceuticals
Municipal solid waste collection facilities	When badly managed they produce hazards similar to dumpsites
Quarries:	Backfills; drill and blast operations: explosives, nitrate, etc.; rocks processing : bitumen, calcareous sludge, etc.; fuel storage and oils disposal
Hospitals & Healthcare clinics	Infectious waste, chemicals, heavy metals (e.g. Hg), detergents, Radioactive wastes, wastewater, household waste
Hotels, restaurants, & residences	Wastewater, household hazardous waste including batteries, solvents, used culinary oils, etc., in addition to diesel storage and wastes oils disposal
Improperly drilled and operated wells	Ease all nearby contamination
Military training, maneuvers, &exercises	Explosives, heavy metals, tires, etc.

Source: Field assessment

5.1 Non-point Sources

Non-point source pollutants are difficult or impossible to trace to a single source, they enter the environment over an extensive area and sporadic timeframe, are related (at least in part) to certain uncontrollable meteorological events and existing geographic/geomorphologic conditions. They may result in long-term, chronic effects on human health and soil-aquatic degradation.

Non-point sources of pollution are the consequence of agricultural activities (e.g. irrigation and drainage, applications of pesticides and fertilizers, runoff and erosion); urban and industrial stormwater runoff, erosion associated with construction; mining (quarries), road runoff; atmospheric deposition; livestock waste; hydrologic modification (e.g. dams, diversions, channelization, over pumping of groundwater, siltation). In the Jeita catchment the main non-point source hazard is wastewater.

5.1.1 Wastewater

Despite that in general wastewater is considered a point source of pollution, the current disposal systems existing in the Jeita catchment lead to consider it as a major non-point pollution source.

Lebanon is generating large and growing quantities of domestic and industrial wastewater which needs treatment. At present, Lebanon produces about 310 million cubic meters of wastewater annually, of which 250 million cubic meters is municipal/domestic wastewater, and about 60 million cubic meters industrial wastewater MoEW (National Water and Wastewater Strategy, 2010). No adequate treatment systems are currently available.

Wastewater is affecting the quality of groundwater resources almost everywhere in Lebanon (WORLD BANK, 2011).

5.1.1.1 Available Septic Disposal Systems

To date, the study area suffers from the complete absence of a proper sewage collection and treatment. When a sewage collection network exists in a village (Hrajel, Mayrouba and Ballouneh), it was mainly constructed due to individual initiatives and efforts. However these are implemented without proper design or planning (MARGANE, 2012d, 2012g; MARGANE & MAKKI, 2011, 2012)). The collected sewage is discharged in the nearby environment without any prior treatment, leading to major contamination hazards. Also, due to the often poor construction, major wastewater leakages from this partly existing network are frequent. Principally the currently existing network therefore has to be considered a major pollution risk and should be removed when a new network will finally be installed through professional projects.

Figure 21: Flooding wastewater from septic municipal network in Ballouneh

Despite existing actuated guidelines and laws, bottomless cesspits are the most common type and leaking wastewater thus directly infiltrates into the groundwater (Figure 21).

If closed septic tanks are installed, they are commonly illegally emptied during heavy rains into the environment or pumped into specific tankers which discharge

the collected wastewater into water courses (Figure 22), water canals or at any remote place in the nature (wood, forest) (Figures 14 & 15). These practices render wastewater a diffuse source of groundwater contamination.

Several touristic resorts of the catchment are not provided with piped sewerage systems. Instead, their buildings are provided with percolation pits (such as Satellity and Mzaar Intercontinental Hotel) or wastewater injection wells.

While all these illegal, unsound practices are widespread, we noticed the existence of private initiatives where entities have installed sewage collectors and a wastewater treatment plant such as at Faqra Club (Figures 22 & 23) where the wastewater of the residences is collected, then treated and reused for lawn irrigation. However, knowing the high GW vulnerability of this area, there is a necessity to apply a severe control and monitoring on the quality of the reused water. If the wastewater is improperly treated, the reused irrigation water would contaminate Jeita spring groundwater.

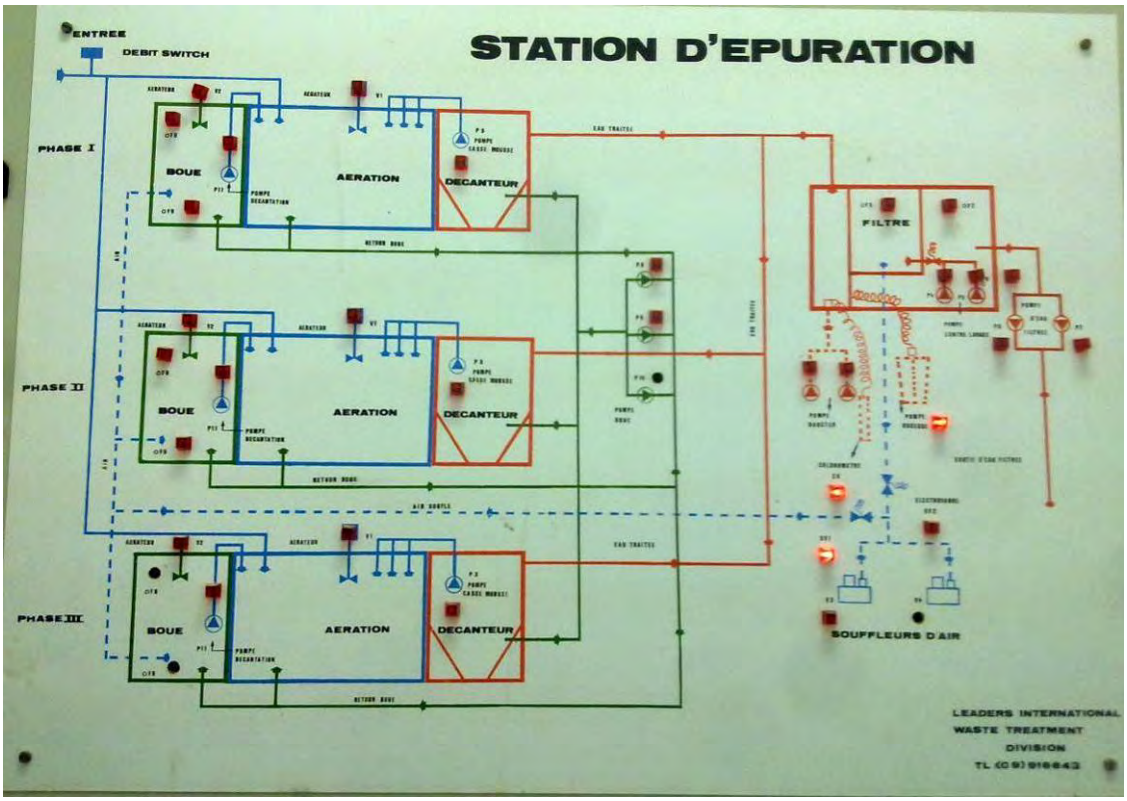


Figure 22: Adopted wastewater treatment system at Faqra Club

Also Notre Dame de Loueizeh University has a wastewater treatment plant; however, it appears to be undersized compared to the number of students. Quality of treated wastewater is to be monitored before discharging it in the environment. However, this problem will be resolved once this site is connected to the planned sewage network of the CDR/KfW Jeita Spring Protection Project (JSPP).

Lately, landuse planning imposed the establishment of septic tanks or small scale household wastewater treatment plants for the new constructions following guidelines issued by the Ministry of Environment in 2005 (Ministerial Decision 3/1 of August 6, 2005).

Figure 23: Wastewater Treatment Plant of Faqra Club

5.1.1.2 Existing sewage collection networks materials

Most established networks in the catchment are made of cement, asbestos cement (AC) and, for the newer ones, glass reinforced plastics (GRP). This variability of materials at household level renders their direct connection to a wastewater collection and treatment scheme quite difficult. When households are to be connected to a new wastewater scheme, the entire network in all houses has to be changed. Mostly household connections are not included in the planned wastewater (WW) schemes. Due to the fact that the current collection points are at a relatively low position, pumping is inevitable. This involves high costs not only for the connection but also for operation and maintenance. Many house owners may therefore not consider connecting to planned WW schemes.

5.1.1.3 Maintenance

Although the wastewater system is under the responsibility of the regional water establishments, the latter do not yet have the necessary personnel or operating department to carry out this function. Therefore, the operation and maintenance of the system still remains with the municipalities on whose territory the sewers are located. Many faulty connections between the haphazard wastewater network and the irrigation network are observed.

Private contractors assume the role of emptying sewage from cesspits. In absence of control, these empty the sewage in nearby streams or valleys (Figure 25).

KfW is financing the establishment of a secondary wastewater treatment plant by a soft loan, allocated to the Lebanese government through CDR and WEBML, The location of the Mokhada WWTP was chosen in coordination with the BGR project following hydrogeological investigations and communications with relevant stakeholders and civil society. This will include a main sewage collector from Mokhada (Zouk Mosbeh) to Kfar Debbiane, in addition to secondary lines in each of the following villages: (part of) Zouk Mosbeh, Jeita, Ballouneh, Aajaltoun, and Daraya. The studies related to the establishment of the WWTP are in progress. The related EIA, based on the EIA guideline proposed by the BGR project (MARGANE & ABI RIZK, 2011) was submitted in 2013 (MARGANE et al., 2013). Its implementation is expected to start in mid 2014.

Figure 24: Excavated cesspit in highly karstified limestone

Figure 25: Tanker dumping wastewater in Nahr el Salib near Deir Chamra

Figure 26: Waterway carrying sewage discharges

Figure 27: Wastewater discharge into Nahr el Kalb at Jeita

Figure 28: Discharge of untreated wastewater from Murr slaughterhouse in Aajaltoun

In the Jeita catchment wastewater collectors are either missing or heavily leaking, many of the being designed to carry wastewater only to the nearest river course (Figure 29). Approximately 2.9 MCM wastewater return into the underground each year, as much as the annual water demand of 56,000 persons.

Figure 29: Sewage canal discharging into Nahr el Salib at Hrajel

Some example of the bad wastewater management in the catchment can be summarized as follows:

The residential buildings upstream of and close to Assal and Labbane springs pose an imminent pollution risk. Most of these houses evacuate their sewage in bottomless cesspits, facilitating rapid infiltration of untreated wastewater. The establishment of a wastewater collection network is therefore of highest priority in this area, belonging to groundwater protection zone 2.

The municipality of Hrajel has built a very badly functioning WW collection system. Apart from the fact that WW is flowing most of the time not inside but outside of the 'network', the only purpose is to channel WW to Nahr el Salib, into which it is

discharged. At the same time the location where wastewater is discharged into the river course constitutes an area with very high riverbed infiltration.

Restaurants located near Afqa and Rouaiss springs evacuate their wastewater in bottomless cesspits. Wastewater from these restaurants must be collected in a septic tank, which must be regularly emptied and wastewater be brought to a designated location.

In the skiing area, at Wardeh and La Cabane the pollution risk by infiltrating wastewater is very high. A wastewater collection system must be installed using properly sealed septic tanks. These must be regularly emptied and discharged at a designated treatment facility.

The Satellity resort (Faitroun) is evacuating its wastewater into bottomless cesspits in a highly vulnerable karst, leading to a high risk of GW contamination.

There is a dilapidated restaurant near outlet 2 of the Roueiss spring. Wastewater from this restaurant presents a significant contamination risk.

5.1.1.4 Generated contamination

Wastewater contains a range of inorganic and organic constituents that must be reduced before discharge into the environment, otherwise constituting a health risk. Attention should be paid to nutrients, salinity levels, heavy metals, organic matter content as well as organics trace elements like endocrine disrupting compounds (EDCs) and pharmaceuticals.

Main bacteria found in wastewater are: Escherichia, Klebsiella, Enterobacter, Citrobacter, Yersinia, Serratia, Hafnia, Pantoea, Kluyvera, Cedecea, Ewingella, Moellerella, Leclercia, Rahnella and Yokenella. Such bacteria may cause short term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, and people with severely compromised immune systems (US EPA Primary Drinking Water Regulations). Main enteroviruses found in wastewater are detailed hereafter in Table 7.

The US EPA Primary Drinking Water Regulations indicate that drinking water should contain an absence of total coliform organisms or no more than one coliform-positive sample result when 5 to 39 samples are analyzed in a month and no more than 5% coliform-positive sample results when 40 or more samples are analyzed each month (http://water.epa.gov/drink/contaminants/index.cfm). To answer the “Total Coliform Rule requirements”: which is a routine sample that tests positive for fecal coliform or E. coli triggers repeat samples. If any repeat sample tests positive for total coliform, the system has an acute maximum contaminant level (MCL) violation, and then cannot be considered as being a safe source for drinking water supply.

This is unfortunately the case in the raw water from Jeita spring following the results of water analysis carried out by Beirut and Mount Lebanon Water Establishment Laboratories at Dbayeh (Figures 30 and 31).

In addition, a significant contamination with Salmonella typhimurium (mainly in Jeita/Kashkoush raw water) is frequently noted during WEBML monitoring of this vital resource.

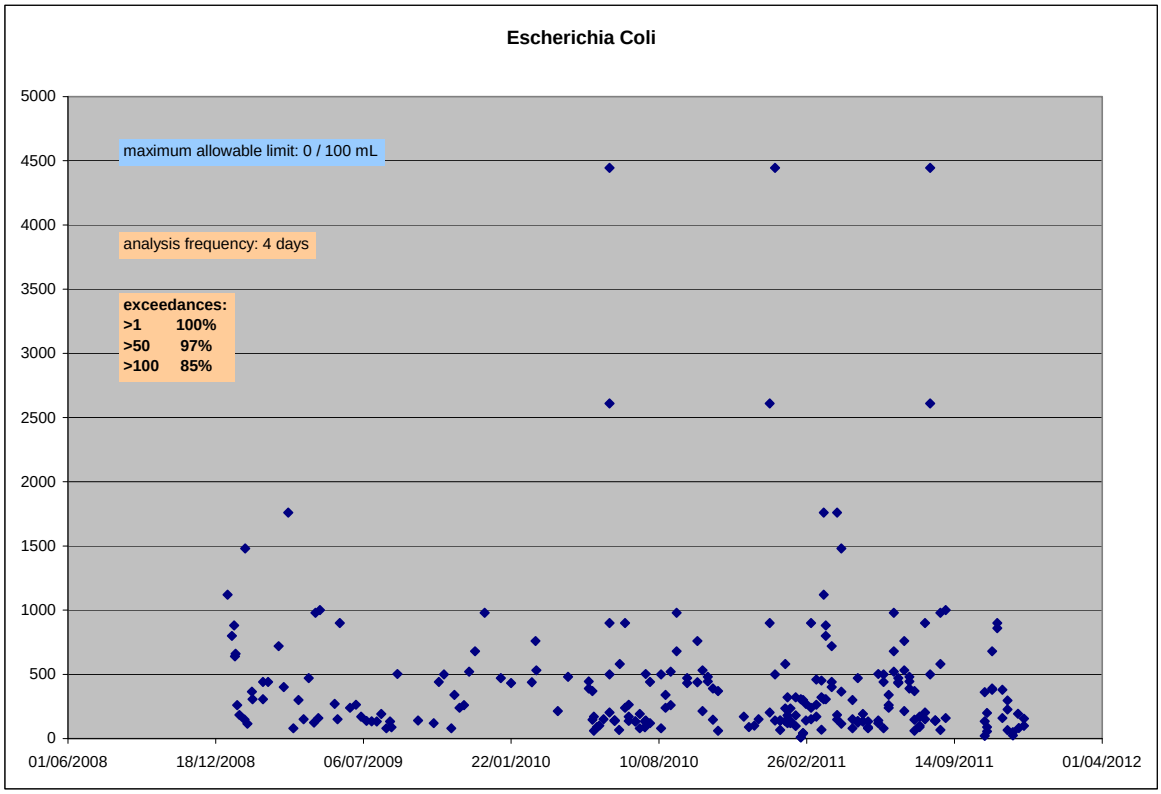


Figure 30: Echerichia coli detected in Jeita spring waters as analyzed by Beirut and Mount Lebanon Water Establishment laboratory

Chlorination is the main applied disinfection treatment of Jeita spring waters used for drinking water supply. Due to wastewater contamination the applied chlorination dose is quite high. As hydrocarbons are not eliminated through the treatment process at the Dbayeh drinking water treatment plant, chlorination may result in the formation of chlorinated hydrocarbons. These, however, cannot be analyzed by the Dbayeh laboratory due to lack of equipment.

A long exposure to high residual chlorine concentrations (Maximum Residual Disinfectant Level Goal= MRDLG=4) might lead to eye/nose irritation; and stomach discomfort. While a concentration higher than MRDLG=0.8 of chlorine dioxide (CLO_2) or of chlorite can lead to anemia at infants and young children, while fetuses of pregnant women might suffer of effects on their nervous system.

We note that chlorination and physical water treatments adopted by the water establishment Beirut and Mount Lebanon are unable to efficiently treat these viruses. The latter are becoming a real threat to public health in the areas fed by Jeita spring waters.

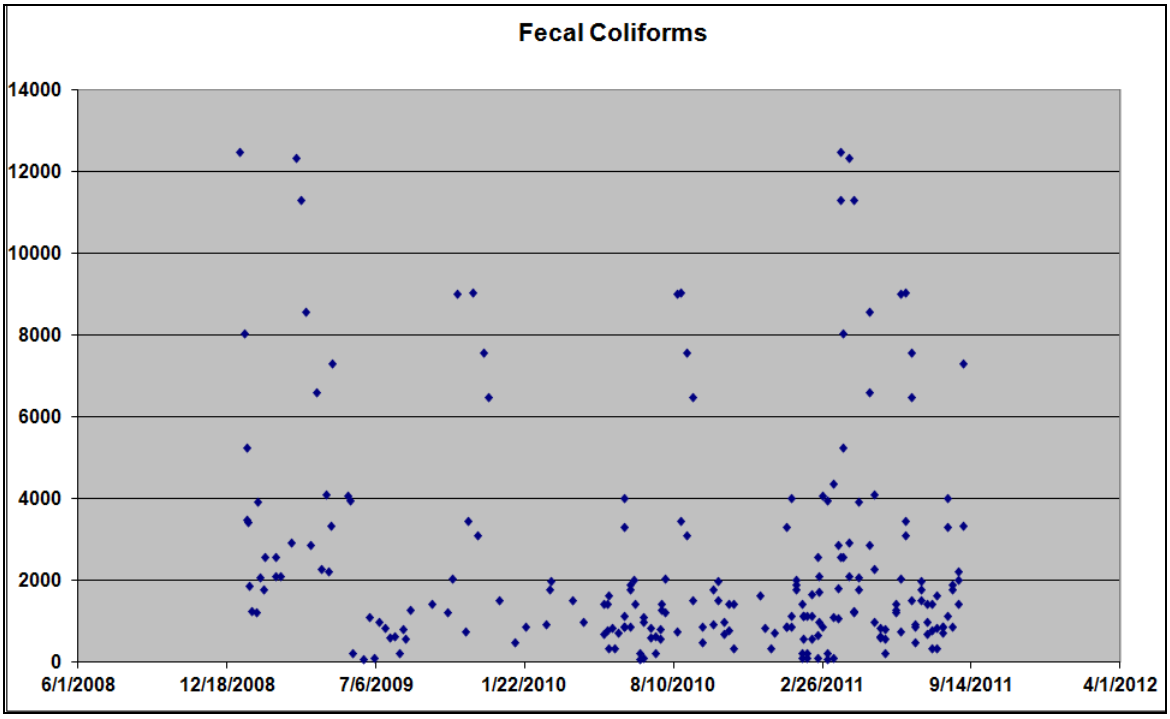


Figure 31: Content in Fecal coliforms of Jeita spring waters as analyzed at the laboratory of water establishment Beirut and Mount Lebanon

Table 7: Human enteric viruses that may be waterborne transmitted

Genus	Popular name	Disease caused
Enterovirus	Poliovirus Coxsackievirus, A, B	Paralysis, meningitis, fever Herpangina, meningitis, fever, respiratory disease, hand-foot-and-mouth disease, myocarditis, heart anomalies, rush, pleurodynia, diabetes?
	Echovirus	Meningitis, fever, respiratory disease, rush, gastroenteritis
Hepatovirus	Hepatitis A	Hepatitis
Reovirus	Human reovirus	Unknown
Rotavirus	Human rotavirus	Gastroenteritis
Mastadenovirus	Human adenovirus	Gastroenteritis, respiratory disease, conjunctivitis
Calicivirus	Human calicivirus	Gastroenteritis
	Norwalk virus	Gastroenteritis, fever
	SRSV	Gastroenteritis
	Hepatitis E	Hepatitis

Astrovirus	Human astrovirus	Gastroenteritis
Parvovirus	Human parvovirus	Gastroenteritis
Coronavirus	Human coronavirus	Gastroenteritis, respiratory disease
Torovirus	Human torovirus	Gastroenteritis

Source: BOSH (1998)

Such viruses have been subject to analysis in several Keserwan and Metn schools in 2013 (http://www.aljoumhouria.com/epaper/view/64496/666). The media noted a significant microbiological contamination of the supplied drinking water.

5.1.1.5 Stakeholders

To date, institutional management of the wastewater sector in Lebanon is ineffective. The roles and responsibilities are dispersed between ministries and many other authorities making it difficult to discern clear responsibilities for the monitoring and enforcement system.

Stakeholders of wastewater sector in the Jeita catchment are:

- Ministry of Energy and Water (MoEW) for issuing related sector strategies. In this respect, this ministry issued in 2012 a wastewater sector strategy and, in collaboration with FAO, issued guidelines for treated wastewater reuse in irrigation. In parallel, the BGR project Protection of Jeita Spring has elaborated and recommended wastewater reuse standards in consideration of hydrogeological criteria and groundwater vulnerability in Lebanon, which were not considered in the FAO document.
- Council for Development and Reconstruction (CDR): Responsible of the establishment of wastewater infrastructure.
- Water Establishment Beirut and Mount Lebanon (WEBML): Responsible for wastewater collection, treatment and reuse of treated wastewater.
- Municipalities: By law, municipalities in Lebanon are responsible for building and maintaining local infrastructure (sanitation, local roads, sidewalks, etc.) and providing basic services (solid waste management, wastewater treatment and construction permission). Unfortunately, most municipalities still lack the human and financial resources, environmental awareness, management capabilities, and/or political commitment necessary to carry out those tasks in an environmentally sound manner.
- Ministry of Environment (MoE): responsible of issuing guidelines for wastewater discharge and sewage infrastructure.
- Ministry of Health (MoH): responsible for protecting public health.
- Landuse Planning Directorate (under Ministry of Public Works): This must consider the wastewater management plan requirements in its future planning and decisions.
- Academic research institutions: Must provide a qualified technical staff able to operate and maintain the established wastewater treatment plant following the best criteria. Furthermore, academic training institutions are considered stakeholders, as there is a pressing need to build the capacity of everyone

involved in the wastewater sector on the operation and maintenance of wastewater systems.
- NGOs: Collaborate with donors and government to improve wastewater management status in Jeita spring catchment and the whole country.
- Donors and international organizations: who contribute to the development of Lebanon's capacities in wastewater management such as by financing the establishment of wastewater treatment plants.
- Private sector: that will collaborate in the construction and establishment of sewage networks and treatment plants. It is called to invest in the field of operating such networks.
- Public society: must get connected to the existing or to be established sewage collectors and respect the wastewater guidelines as far as pretreatment and sewage management procedures.

5.1.1.6 Legal framework

Existing legislation for the protection of water resources in Lebanon dates back to 1925. However, these laws were neither updated nor complemented with enforcement laws and decrees. The main regulations related to wastewater are listed below:

- **Order N° 144, 1925**: Protection of Surface Water and Groundwater Resources
- **Decree No. 2761 of 1933 (articles 5&6)** related to the Protection and Use of Public Water Properties) Emphasizes on the prohibition of the direct or indirect wastewater discharge and wastewater disposal into the sea and water streams. However, it is not implemented due to lack of enforcement mechanism.
- **Article 748 of the penal code** punishes up to 2 years imprisonment any disposal of products that can be dangerous for public health or general security in public waters. This law prohibits in its article 3 to dispose septic tanks loads and any contaminated effluent in the waterways, on the coast or in the vicinity of waters. Such violation is subject to two months imprisonment. It also prohibits digging bottomless cesspits and compels to block up the existing ones within a delay of one month. Related violation is subject to two months imprisonment. Article 4 compels the industrial establishments to purify their liquid effluents before its disposal.
- **The Penal code Legislative decrees N° 340 of 1943, paragraphs 745-749**: define sanctions such as: Imprisonment of those who executed any offensive activity, such as unauthorized drilling, pollution of water sources… This also involves paying of penalties. The penal code decrees are partially implemented nevertheless their application is hindered by political influence.
- **Decree N°14438, 1970**: establishing restrictions on the depth of unlicensed boreholes.

- **Decree N° 8735 promulgated in 1974**: Tackles pollution from solid and liquid wastes
- **Law N° 64/88 promulgated in 1988** states that the crime of polluting is sentenced by jail and can be even subject to a death sentence. This pollution was described as including: alteration of the environment by hazardous wastes causing damages to man, to the flora, the fauna, or to the air and water. The said polluting materials were detailed in an annex decree which can be put up to date at any time.
- **Decree 14438 of May 7th, 1970,** related to groundwater protection.
- **Ministerial decision 52/1 of 29th July 1996**: determines the standards of protection against pollution and lists standards for water quality and wastewater discharge. However, the application of the standards proved difficult; therefore, they were revised and amended under decision N°8/1, of January 2001.
- **Law 444 of 2002, article 57**: Identifies the set of administrative penalties set by the MoE, which are; a) payment for the restoration of damaged sites, b) license repeal, c) setting mitigating measures for projects to reduce their impacts, d) charging of penalties. However, this law is not implemented due to the absence of enforcement mechanisms.
- **Decision 3/1 of 2005**: sets environmental guidelines for the establishment and/or operation of small WWTP such as for households.

To date, Lebanon does not have a wastewater fee related to the generated amount of WW. Wastewater collection and treatment is charged separately from water supply by a municipality tax.

However, a national strategy for the wastewater sector was elaborated in 2010 and approved by the Lebanese government in 2012.

It stipulates the application of the polluter-pays-principle in addition to a new sewage tariff policy. Following this policy, each individual would pay a wastewater tariff varying in consideration of his connection to a sewage network. These tariffs would be used for the maintenance and operation of sewage collection networks and treatment plants that are previewed in the mentioned National Water Sector Strategy (NWSS).

5.1.1.7 Recommendations

Further infrastructure is required to reach a proper sewage management in the catchment. The establishment of sewage networks covering the whole catchment area and connecting them to wastewater treatment plants is crucial for the protection of the Jeita spring drinking water source. From the perspective of groundwater resources protection a centralized approach with WWTPs at the coast is recommended under current conditions (high deficits in electricity coverage, lacking control and enforcement, lacking institutional capacity). Decentralized small wastewater treatment plants may be established in small

villages, in relevant touristic resorts and in army barracks, however, these must consider the potential negative impact on downstream groundwater resources of the treated effluent.

Treated wastewater reuse is under current conditions not recommended in the Mount Lebanon mountain range. This area is predominantly karstic and release of insufficiently or not treated WW (e.g. in case of by-pass during peak flow) may lead to GW contamination. As proposed in a related report, the BGR project recommends using groundwater vulnerability maps to decide when treated WW reuse might be allowed.

A field survey assessing and locating the existing wells and bottomless boreholes used for WW discharge must be carried out. Active measures to close them and replace them by septic tanks in line with environmental regulations and groundwater protection requirements are needed.

Public awareness related to the contamination generated by unsound wastewater disposal in the nature and leakage to GW must be urgently raised. The issue of the health risks generated by disposing hazardous liquids in the wastewater network is to be explained to the public (i.e., petroleum oils, pesticides, etc.) and collection systems for such substances should be provided by the municipalities.

A harmonization of the legal framework and establishment of an enforcement agency (environmental police) are urgently required.

5.1.2 Agriculture

Non-point sources (NPS) represent the dominant source of surface water and groundwater contamination. Modern agriculture is at the root of the NPS groundwater contamination problem, since modern large-scale agriculture depends on the use of agrochemicals.

In Lebanon, agriculture accounts for approximately three quarters of the total water consumption. Its sources of irrigation water are springs and/or wells. Important uncontrolled groundwater withdrawals are related to agricultural activities. Farmers use either drip or surface irrigation with little concern to water conservation practices.

In Jeita catchment around 32 ha (7.8%) are used for agricultural land cultivation. Annually 4.3 MCM, or 28% of annual discharge of Labbane Spring is used for agricultural activity. Water use is mainly based on water rights stated in the land deed for a local spring or irrigation network. These rights define a time over which the water source may be used for irrigation not a water volume. This fact, coupled with poor farmers knowledge of crops water requirements lead to excessive use of water during the allocation days and intensive groundwater pumping during dry days.

When farmers do not have access to groundwater extraction, they usually build irrigation ponds where they store water to be used during dry period (Figure 32).

Produced crops are mainly fruit trees (apples, peaches) in addition to tomatoes, cucumber, beans and lettuces.

Figure 32: Photo of an irrigation pond near Lassa

In Jeita catchment , agricultural activity concentrates mainly on the aquitard (of low GW vulnerability). But it is also spread above the J4 aquifer. While it is replaced by housing in lower altitudes, agriculture is expanding in middle and higher mountainous regions.

Following MARGANE & SCHULER (2013), 28.0% of agricultural activity takes place on very high vulnerable GW (mainly within the 500 meter buffer zone of streams above the aquitard), while 60.7 % of agricultural areas are located on very low vulnerable GW. However, the noted anarchic practices (crop management) in this sector and its relevant contamination risk mainly due to the presence of irrigation wells within agricultural lands added to illegal disposal of agricultural wastes increase the related GW contamination risk.

Wells drilled within agricultural lands present a risk of facilitating direct groundwater contamination by the applied pesticides and fertilizers through irrigation return flow.

Moreover, in the Jeita catchment, main cultivated lands are on steep mountain slopes where terracing are built to retain soils. As conducted on shallow soils and fractured limestone, agricultural practices might easily contaminate groundwater

with different kinds of toxic contaminants (pesticides, nitrates, etc.) and many kinds of hazardous wastes.

Crops production location in the catchment is illustrated on Figure 33.

In 1999, the AUB Water Resources Center conducted a preliminary assessment of groundwater quality in Lebanon. The results showed that nitrate concentrations were moderately high in the sampled wells, Phosphate levels were within acceptable ranges. Pesticide residues were detected in trace concentrations: aldrin (30 percent of the sampled wells), dieldrin (12 percent), heptachlor (12 percent) and heptachlor epoxide (9 percent). In general, however, levels were lower than the health advisory limits set by the US EPA. Samples taken by the BGR project from major springs in Jeita catchment confirmed this finding (DOUMMAR et al., 2012).

However, considering the great danger on public health generated by water contamination by pesticides and fertilizers, the hazards of these elements and risks related to agriculture are considered in detail in this section. Especially that WEBML is unable to monitor or treat such contamination. Related monitoring is vital, considering analysis related to the components of the main used pesticides and fertilizers in the study area

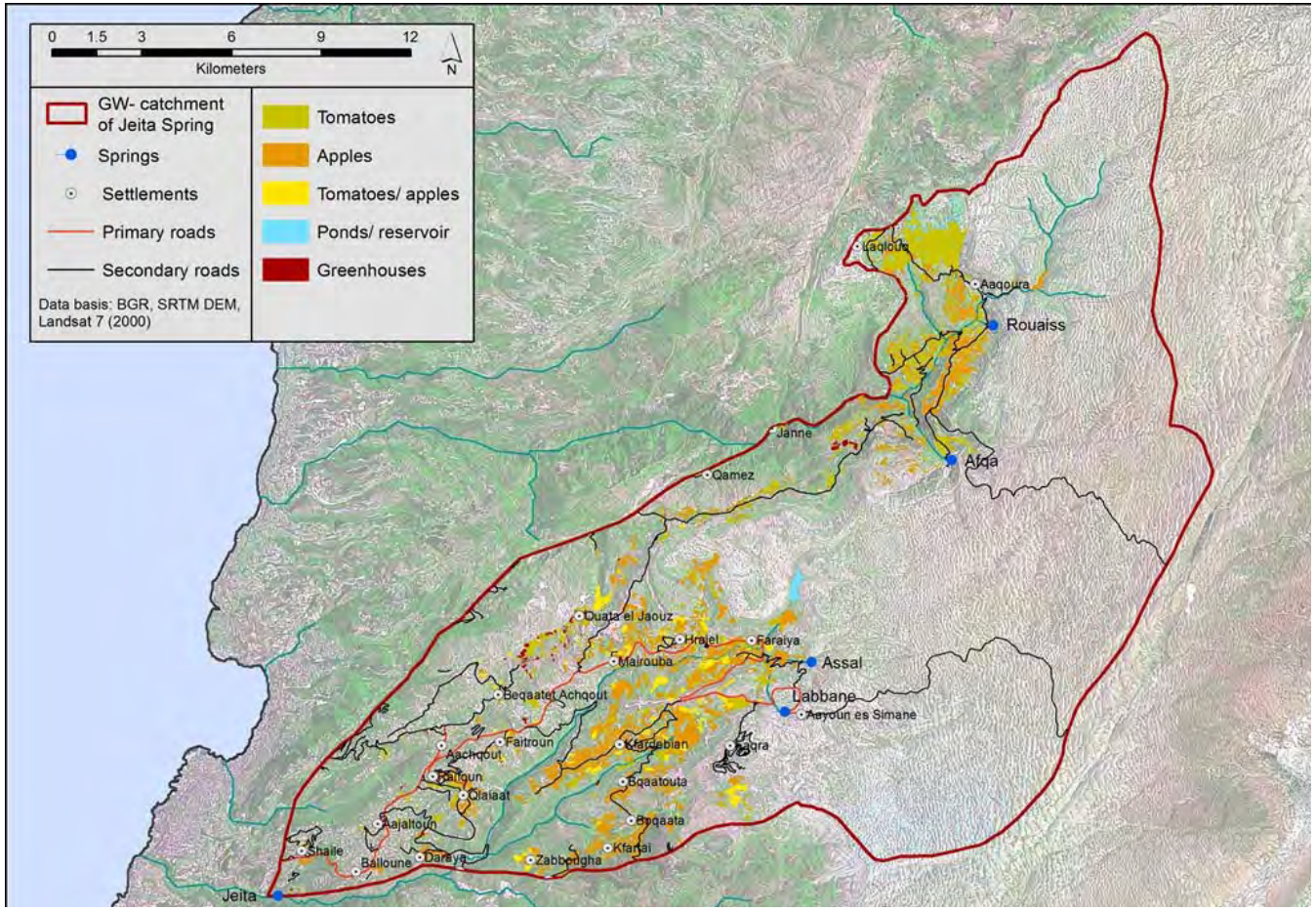


Figure 33: Distribution of the main agricultural areas in Jeita catchment (adopted from SCHULER & MARGANE 2012)

5.1.2.1 Pesticides

Pesticides are chemicals that are used to kill or control pests which usually include bacteria, fungi, and other organisms, in addition to insect, mite and rodents. Pesticides are inherently toxic.

While monitoring pesticides contamination in drinking water in Lebanon is practically absent and national drinking water standards have yet to be set for most pesticides, the danger of GW contamination by pesticides is quite high. This is due to the actual pest management practices spread in the country, the available pesticides in the Lebanese market and the disposal of pesticides containers in the nature (Figure 34) in complete absence of control and of facilities able to treat pesticides leftovers and containers.

Pesticides can contaminate surface water and groundwater from both point sources and non-point sources. Point sources are from specific locations such as storages at pesticide vendors or large-scale users, spill sites, disposal sites, and pesticide drift during application.

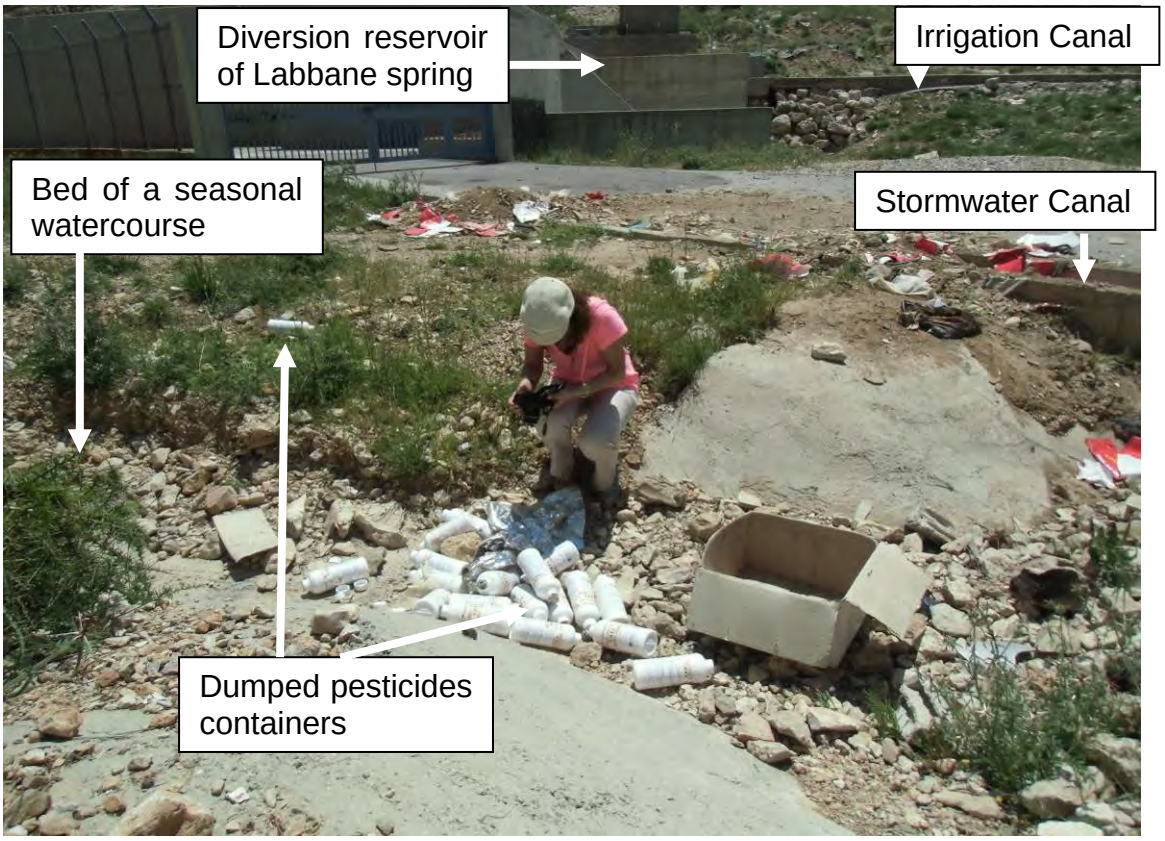


Figure 34: Pesticides containers dumped in a seasonal water course a few meters from the diversion reservoir of Labbane spring

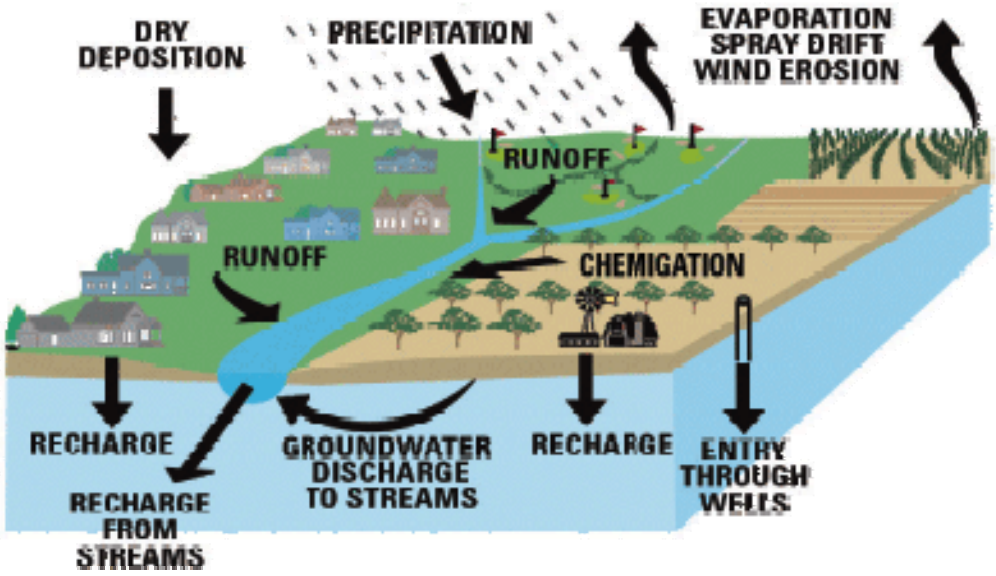


Figure 35: Schematic diagram illustrating routes of pesticide transport into surface and groundwater

(adopted from THODAL et al., 2008)

Pesticides typically enter groundwater when rainfall or irrigation exceeds the infiltration capacity (water holding capacity) of the soil. During heavy rainfall events pesticides may be transported with **surface water runoff** then to streams, rivers, and other surface-water bodies. Contamination of groundwater may result directly from **spills** near poorly sealed well heads and from **pesticide applications** through improperly designed or malfunctioning irrigation systems that also are used to apply pesticides. In this case, groundwater contamination occurs indirectly by the **percolation** of irrigation water **through soil layers and into groundwater** and **from pesticide residue in surface water**, such as drainage ditches, and streams (Figure 35; THODAL et al., 2008).

Potential herbicides and pesticides loads in groundwater are determined by soil, chemical, management, and climatic factors.

The agrochemical sector is uncontrolled in Lebanon. Many pesticides prohibited worldwide and by national laws, are still available on the Lebanese market, mostly imported from China or India under a different name. Also very common is refilling of imported products in Lebanon with false labeling. Low quality pesticides and fertilizers are devastating the market with obvious falsification of labels.

In 1988, following its ratification of the Rotterdam Convention, Lebanon announced a total ban on the import of many pesticides and adopted Act No. 64/88 of 12 August 1988 to that end. The list of banned pesticides is displayed in Annexes IV and V.

Also, many persistent organic pollutants (POPs) are currently used as pesticides in Lebanon despite its ratification of the Stockholm Convention which aims to eliminate or restrict the production and use of (POPs). Many related ministerial decision were issued by the Lebanese Ministry of Agriculture (MoA) to ban their import and use.

However, in absence of an efficient governmental agricultural extension service, farmers are at the mercy of agricultural companies who orientate their advices towards increasing their own profit and sales. Despite the issuance of a new decree law requiring the signature of an agriculture engineer on pesticides and fertilizers prescriptions, in practice these remain formalities and merchants arrange prescribing and selling their products in absence of any control. Hence, the farmer is subject to bad guidance leading to excessive application of fertilizers and pesticides at the expense of a higher production cost, a reduced production and bad environmental impact.

The field assessment revealed that at the cost of higher negative environmental impact, higher production costs, in addition to lower production quantity and quality, farmers are forced to reduce the pesticides application intervals (higher number of pulverization) and increase pesticides dosages due to low efficiency of available products.

In general, the pesticide danger is estimated based on the contamination risk generated by its active ingredient. Nevertheless, the active ingredient of the pesticide is not the only water contaminant agent. Inert ingredients include hazardous chemicals-solvents, detergents, and/or other chemicals that act as carriers and can make the product become more effective. As example, in a recent research published in ”Toxicology” (MESNAGE et al., 2013), it was shown that the most toxic compound is not glyphosate (active ingredient of round-up herbicide), which was the most assessed substance by regulatory authorities, but a compound called POE-15, which is not always listed on the herbicide label. Adjuvants of the POE-15 family (polyethoxylated tallow amine) have been revealed as actively toxic to human cells.

Furthermore, many pesticides contain arsenic which might induce skin damage or problems with circulatory, systems, and increase the risk of getting cancer. Arsenic was not analyzed by BGR or WEBML laboratory.

Some commonly used pesticides in Jeita catchment and their possible effect on human health are exhibited in Table 8.

Table 8: Active ingredients of the some commonly used pesticides in Jeita catchment and their impact on human health

Active ingredient	Potential health effects from long-term exposure
Aldicarb (unbanned PoP)	Soluble in water, Aldicarb & its by-products, aldicarb sulphoxide and aldicarb sulphone, inhibit acetyl-cholinesterase in the nervous system. Symptoms of poisoning include: dizziness, weakness, diarrhoea, nausea, vomiting, abdominal pain, excessive perspiration, blurred vision, headache, temporary paralysis & convulsions.
Atrazine	It was banned in the European Union (EU) in 2004 because of its persistent groundwater contamination. It is a harmful endocrine disruptor that causes reproductive defects & cardiovascular problems.
Azoxystrobin	Neurotoxic, carcinogen, cause general toxicity (Von Stackelberg K., 2012)
Carbofuran	Problems with blood, nervous system, or reproductive system
Diazinon	Locally prohibited but still available
Dinozeb	Reproductive difficulties
Dinoseb	Reproductive difficulties Reproductive difficulties; increased risk of cancer
Endrin	Causes liver problems Banned in Lebanon by Decree No 94/1 dated 20/05/1998, (still available on the market)..
Glyphosate	Glyphosate contamination generates kidney problems and liver difficulties. However, its adjuvants polyethoxylated tallowamine have been revealed as actively toxic to human cells
Iprodione	Risk of cancers however it has low persistence and is unlikely to contaminate groundwater (EPA 1998)
Malathion	Locally prohibited but still widely used
Mancozeb	Effect on nervous system, thyroid and carcinogenic effects
Kresoxim-methyl	Carcinogen, class not defined yet.
Methoxychlor	Reproductive difficulties
Micronized copper	Short term exposure: Gastrointestinal distress, Long term exposure: Liver or kidney damage, People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level
Oxamyl	Slight nervous system effects
Paraquat	Banned but still used in Lebanon
2,4-D Acid1,2	Kidney, liver, or adrenal gland problems
1,2 Dibromo-3-chloropropan(DBCP)	Reproductive difficulties; increased risk of cancer
Halo acetic acids (HAA5) Heptachlor epoxide	Increased risk of cancer Liver damage; increased risk of cancer Liver damage; increased risk of cancer- Banned in Lebanon by Decree # 94/1 dated 20/05/1998- Still used

Source: US EPA National drinking water regulations

In complete absence of adequate facilities able to receive, recycle and/or dispose empty pesticides containers and unused or expired pesticides, farmers are disposing them in the environment near or at their properties, in sinkholes or near water courses. This generates a high risk on groundwater quality.

An expressive example to such practices, noted during the field assessment is the presence of tens of disposed empty methyl bromide containers outside greenhouses at Wata el Jaouz (Figure 36). Although this pesticide is internationally and nationally banned, Lebanese farmers find their way to keep on using it, despite buying it at very high prices from monopole sellers.

During the field survey it was frequently observed that at residential gardens, remaining and expired pesticides are disposed within the residential wastewater, or spilled in the nearby storm water canal, or at the municipal wastes bins.

Considering the danger of such practices, a related capacity building is urgently required, not only for the farmers but also of the vendors and at the whole public society level. A control mechanism for import and sale of banned pesticides is urgently needed.

Figure 36: Empty container of D-Fume (Methyl bromide; banned pesticide) disposed of in the nature

Moreover, the extensive use of herbicides (e.g. glyphosate, 2,4 D and paraquat; use restricted by the Ministry of Agriculture) in crop protection and in private residential gardens (mainly on lawns) generates a significant risk of groundwater contamination in Jeita catchment .

5.1.2.2 Fertilizers

Knowing the unsound fertilization practices common in the Jeita catchment, the contamination risk by fertilizers is not to be neglected. Fertilizer is any organic or inorganic material of natural or synthetic origin (other than liming materials) that is added to a soil to supply one or more plant nutrients essential to plant growth.

Organic fertilizers

Organic fertilizers include naturally occurring organic materials, (e.g. chicken litter, manure, worm castings, compost, seaweed, guano, bone meal) or naturally occurring mineral deposits (e.g. saltpeter, KNO_3). Poultry litter and cattle manure often create environmental and disposal problems, making their use as fertilizer beneficial. Bones can be processed into phosphate-rich bone meal; however, most are simply buried in landfills.

Organic fertilizers have been known to improve biodiversity (soil life) and long-term productivity of soil, and may prove a large depository for excess carbon dioxide. However, when untreated and unfermented, its use can generate a high risk of GW contamination by microbiological constituents in addition to nitrates and dioxins. The field assessment revealed that many farmers use untreated, unfermented manure which most probably generates a water contamination.

Under aerobic conditions, such as in the Jeita groundwater catchment (O2 concentration in Jeita varies commonly between 9.5 and 10.5 mg/l), the natural nitrate concentration in groundwater is a few milligrams per liter and depends strongly on soil type and on the geological situation. The monitored NO_3 contents in Jeita spring raw water vary between 8 and 15 mg/l, those of NH_4 range between 0.1 and 0.3 mg/l. In all samples the detection limit of 0.025 mg/l NH_4 was exceeded (Figure 37).

In karstic environment and shallow soil cover conditions such as in Jeita catchment , the use of nitrate must be considered with great care due to the groundwater vulnerability.

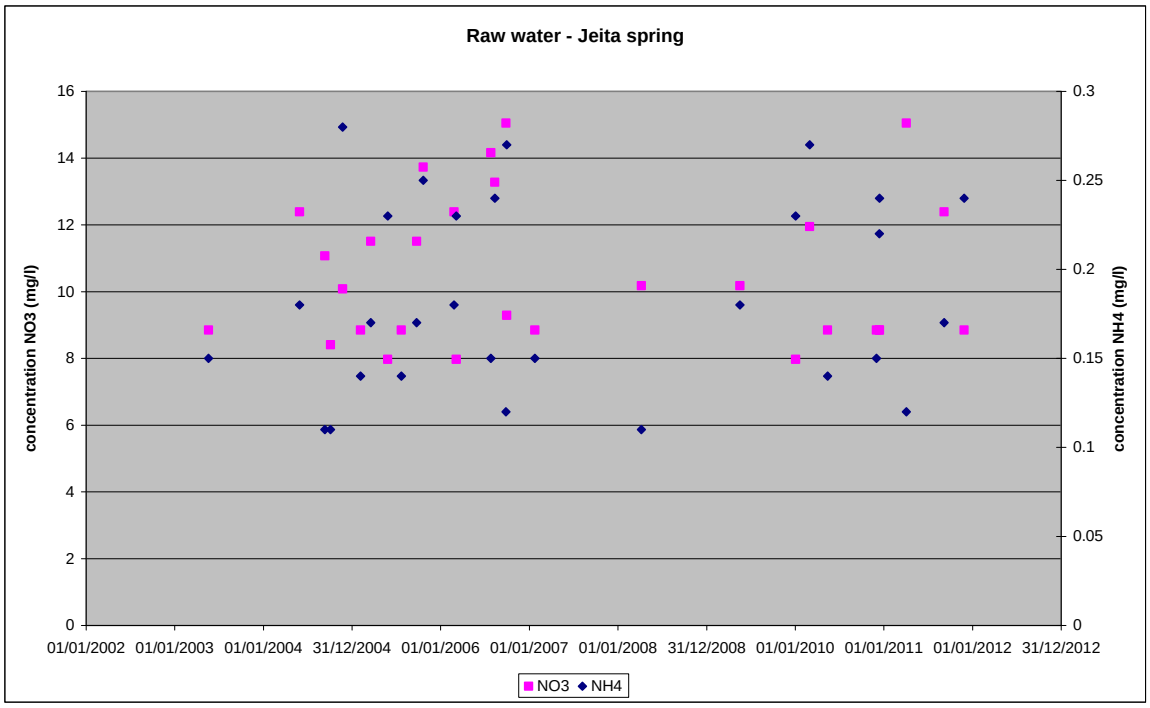


Figure 37: Ammonium and nitrate concentration in raw water of Jeita spring

Inorganic (chemical) fertilizers

In addition to organic fertilizers (bovine and caprine manure, poultry manure and composts), the most commonly used chemical fertilizers in the Jeita catchment are: ammonium nitrate (NH_4NO_3), ammonium sulfate $(NH_4)_2SO_4$ (21 %), potassium sulfate (K_2SO_4) (46 %), phosphoric acid (H_3PO_4) (60 % P_2O_5), NPK (a combination of 20/20/20 or 17/17/17 or 15/15/15, etc.), superphosphate P_2O_2 12%, iron chelates (i.e. chelated iron, a soluble complex of iron, sodium and a chelating agent (e.g. ethylenediaminetetraacetate (EDTA)) or iron chelates EDDHA with 6% Fe, trace elements in fertilizers are: (B, Mg, Mn, Mo, etc.), sulfur and Chile nitrate (which is also used as explosive in quarries).

Inorganic fertilizers typically provide, in varying proportions:

- six macronutrients: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S);
- eight micronutrients: boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), zinc (Zn) and nickel (Ni).

High application rates of chemical fertilizers aiming at maximizing crop yields combined with the high solubility of these fertilizers lead to increased concentrations of organic fertilizers in runoff into surface water as well as leachate into groundwater.

Incorrect labeling of the fertilizers, very common in the Lebanese market, contributes to bad fertilizer management. In absence of serious control of the fertilizers market and an efficient agricultural extension service, farmers tend to apply high amounts of chemical fertilizers, fearing nutrient deficiency. This leads to excessive soil salinity and to major nutrients infiltration towards groundwater.

The widespread use of ammonium nitrate is particularly damaging, as plants absorb ammonium ions preferentially over nitrate ions, while excess nitrate ions which are not absorbed, dissolve (by rain or irrigation) in water and reach runoff or groundwater.

Nitrate levels above 10 mg/L (10 ppm) in groundwater can cause 'blue baby syndrome' (methemoglobinemia), leading to hypoxia (which can lead to coma and death if not treated).

According to WHO (2011) high concentration of nitrate (levels above 50 mg/L in groundwater) in drinking water may cause methemoglobinemia. Groups especially susceptible to methemoglobin formation are young infants, children and pregnant women.

Main fertilizers components related to hazardous contaminants and their effects on human health are listed in Table 9.

Table 9: Effect on human health of hazardous components existing in commonly used fertilizers as macro, micro or trace elements

Hazardous element	**Effect of related GW contamination on human health**
Nitrate	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome
Nitrite	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.
Barium	Increase in blood pressure
Beryllium	Intestinal lesions
Cadmium	Kidney damage
Chromium (total)	Allergic dermatitis
Copper	Short term exposure: Gastrointestinal distress Long term exposure: Liver or kidney damage People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level
Cyanide	Nerve damage or thyroid problems
Fluoride	Bone disease (pain and tenderness of the bones); Children may get mottled teeth
Lead	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities. Adults: Kidney problems; high blood pressure
Mercury	Kidney damage

Source: US EPA (http://water.epa.gov/drink/contaminants/index.cfm#Inorganic)

Fluoride and arsenic are among the most serious inorganic contaminants in drinking water worldwide. Both are not analyzed by WEBML. A potential fluoride source may be the basalt intrusions.

The use of slow – release fertilizers is recommended as a means to reduce the high nitrate infiltration from fertilizers. The proper timing of fertilizer application is relevant too.

GW contamination of phosphorus has not been as widespread, or as severe, as for nitrogen compounds. The maximum phosphate concentration encountered in Jeita spring measured by WEBML is 0.25 mg/L P.

Radioactive elements **Uranium** (at levels from 7 to 100 pCi/g) and **Polonium-210** are contained in phosphate fertilizers and are absorbed by the roots of plants and stored in plant tissue. The leaching of access irrigation water to GW containing such fertilizers may lead to recognizable uranium and polonium concentration in groundwater. Both were never measured by WEBML.

For these reasons, it is recommended that fertilizers management, through careful observation of soil characteristics and crops requirement, take place to mitigate the effects of excess fertilizer application and leaching to GW.

Lebanon is a producer of superphosphates, with an export of 309,458 tones (MoE 2005).

5.1.2.3 Solid wastes from agricultural activities

Contaminated pre-harvest crops are often disposed of by plowing the crop into the soil, thereby creating the potential for aflatoxin contamination of groundwater due to the potential leaching and adsorption of aflatoxin in soils.

The results of related studies demonstrate that groundwater contamination by aflatoxin B1 or its derivatives, aflatoxin B2 and G2 would be expected to occur where the soils are extremely sandy or shallow (http://www.epa.gov/ogwdw/consumer/pdf/mcl.pdf).

We note that shallow soils are widespread in Jeita catchment , and that sandy soils are particularly found near the outcrops of the C1geological unit, e.g. in Qehmez, Ain el Tannour and Hayata.

In addition, agricultural activities produce the following hazardous solid wastes, commonly disposed of near the farms in the nature:

- **Ash & sludge** from burned wastes & used oils resulting from agricultural machinery (tractor, sprayer etc).
- **Plastic wraps & containers** from farm chemicals, such as pesticides, herbicides, fertilizers, etc. (Figure 23)
- **Farm-business hazardous waste**, including solvents, pesticides & other hazardous chemicals that are generated from general use of farm equipment or farming procedures.

- **Wrapping wastes: plastics, painted cartoon or polystyrene boxes, etc.** (Figures 38, 39 & 40).
- **Irrigation systems:** old pipes & irrigation fittings (Figure 41)

Figure 38: Dumped polystyrene boxes used for agricultural products packaging

Figure 39: Empty plastic containers dumped near an agricultural property

A new approach to pesticides and fertilizers (organic and chemical) use and disposal practices is necessary to ensure a proper protection of Jeita Spring GW. During the field assessment, fertilizers bags and pesticides containers (sometimes half full) were frequently found dumped in the nature, sometimes inside or on the borders of water courses or inside sinkholes. Such practices are illustrated in Figures (40 and 41).

Figure 40: Chemical fertilizer bag dumped on a riverside in Kfar Debbiane

Figure 41: Solid Wastes commonly generated by fertigation, irrigation and pest management practices

Agricultural wastes incineration

Agricultural wastes incineration, common practice among rural society, presents a high risk to groundwater quality. No specific design standards exist to adequately protect the environment from air pollution or GW contamination resulting from burning and ash disposal of wet trash, plastic product containers, waste oil and other hazardous products used on farms.

Farmers traditionally dispose of their wastes on-site. Common disposal methods have included open air, barrel or domestic incineration of garbage and trash or simply piling or burying trash in a ditch. Open air incineration practices of on-farm burning may lead to significant amounts of toxic substances, such as lead, cadmium, chromium, dioxin and furan compounds in soils and subsequent flushing to GW. Repeated burning on the same location under similar weather conditions may cause the toxic substances in smoke and ashes (especially heavy metals such as lead, mercury & arsenic) to accumulate in a concentrated area.

Dioxin (2,3,7,8-TCDD) leads to reproductive difficulties and increased risk of cancer. It results from emissions from waste incineration and other combustion at temperatures < 1,200°C.

Figure 42: Photo of resulting ash following agricultural wastes incineration in agricultural terraced land

The following legal framework exists concerning such practices:

Law No. 64 dated 12/08/1988 related to the protection of the environment against pollution from hazardous wastes and materials, which makes preserving the environment from pollution the responsibility of each physical or juridical person.

Decision No. 52/1 dated 29/08/1996 which determines the maximum allowable limits of specified contaminants in the air, water and soil , including the specifications of domestic potable water and sanitation liquid or solid waste burial techniques.

Recommendations

It is important to reach an effective and tangible commitment by the authorities to environmentally sound practices in agriculture. The following actions are to be undertaken to reach a proper protection of GW resources:

- Prohibition of agricultural activities in protection zones 1 and 2 (MARGANE & SCHULER (2013). Existing agricultural landuses in zone 1 should be

phased out and compensated, those in protection zone 2 may have to be granted a stay under the condition that only treated organic fertilizers are used.

- Limit agricultural production to protection zone 3, and restrict the use of all kinds of chemicals (pesticides and fertilizers). Only the application of treated organic fertilizers should be allowed in GW protection zone 3.

This would require a related awareness raising and technical assistance to promote the use of organic fertilizers instead of using chemical fertilizers in agriculture, to shift the existing cultivation into organic agriculture, and introduce natural and bio agents for pest management.

It is crucial to design and put into practice a national long-term plan that includes the necessary control and management mechanisms for water resources.

Farmers must:

- Buy and use only essential products, recycle or reuse them when possible and dispose of remaining products in a way that will not pose a risk to drinking water.
- Pay particular attention to pesticides classified as "restricted use", and abide pesticides banning laws and decisions.
- Use hazardous products away from existing wells (> 100 m), even when all the spills and drips are contained.
- Stop disposing of trash on the farm, with the exception of organic waste that can be composted (such as, leaves and straw).Separate waste and save it for an agricultural waste collection program (a related program should be created and implemented by the union of municipalities, Resulting wastes should not be incinerated in open air but rather used in a composting process able to generate income. Such activity is urgently needed in the whole country. Some municipalities (outside the catchment area, such as Beirut) are successfully collecting and composting gardens maintenance green wastes,
- never incinerate farm wastes in protection zone 2 in open air.
- Return excess products to the intended activity. For example, before disposal of pesticide-container, rinse them with water and spread on fields at the proper application rate for the pesticide.
- Collect any unusable wastes for appropriate disposal.
- Adopt drip irrigation instead of surface irrigation.

The introduction, implementation and enforcement of relevant legislation are needed. Law enforcement must insure that environmentally protective conditions are met before some disposal practices are permitted.
Also, drinking water standards for pesticides are yet to be set. Responsible agencies (WEBML) must monitor this potential type of contamination in vulnerable areas.

To achieve the above listed recommendations the following requirements are to be fulfilled:

- Improve governmental agricultural extension capacities and service for farmers.
- Have an efficient enforcement agency (e.g. environmental police) able to apply control on the pesticides and fertilizers use: as far as application dates, quantity and mostly quality (composition) of the used products.
- Provide a composting facility for collecting all organic waste from animal farms, agricultural farms and slaughterhouses that can be used to produce treated organic fertilizer (site should be near demand and production sites and on GW protection zone 3, e.g. in Wata el Jaouz).
- Provide a collection and temporary storage facility for solid and liquid hazardous waste at a central location in GW protection zone 3 (e.g. Wata el Jaouz, on J5 geological unit). The site must be well protected against leakage to groundwater. From there hazardous waste will be transported to a designated site for permanent storage, once officially declared.

5.1.3 Urban runoff (stormwater)

Stormwater runoff is the most common way in which nonpoint source pollution (NPS) reaches local rivers, creeks and lakes. That part of rainwater which is not absorbed by soil and vegetation, is flushed together with chemicals, nutrients, sediments and other forms of NPS into local streams (either directly with surface water runoff or through storm sewers).

A major goal of stormwater management is to increase absorption of rainwater by soil and vegetation, usually by reducing the speed of flow or by retaining stormwater in basins. This will reduce the amount of pollutants being carried off into storm sewers and streams, as well as reduce flooding. Increasing absorption by soil has the added benefit of helping to maintain groundwater supplies which are seriously depleted in many areas.

In Jeita catchment infiltration of strongly contaminated stormwater by sewages, roads runoff, agriculture, etc. presents a threat to groundwater as much of the stormwater and with all its constituents, such as viruses, bacteria, salmonella, and many toxicants (hydrocarbons, pesticides, heavy metals) will ultimately end up in groundwater.

Measures must be taken to mitigate its contamination and to reduce the infiltration of contaminants from stormwater into groundwater.

Effective control of urban runoff involves reducing the velocity and flow of storm water, as well as reducing pollutant discharges. In developed countries, local governments use a variety of stormwater management techniques to reduce the effects of urban runoff. Stormwater BMPs, such as in place in the several states of the US, may focus on water quantity control, while others focus on improving water quality, and some perform both functions.

Pollution prevention practices include: ("http://en.wikipedia.org/wiki/Low-impact_development" \o "Low-impact development") installation of green roofs and improved chemical handling (e.g. management of motor fuels and oil, fertilizers and pesticides). Runoff mitigation systems include bio retention systems, constructed wetlands, retention basins and similar devices to reduce water turbidity (http://en.wikipedia.org/wiki/Infiltration_basin").

The existing stormwater drainage system at the roads must be improved, ensuring that no stormwater can enter the water supply or wastewater collection system. No surface water drainage shall enter either Labbane spring, the conveyor to the reservoir or the reservoir. The surface runoff channel passing close to Labbane spring must be deviated to pass to the north of the reservoir. This drainage system must be built in such a way that no underflow or overflow could occur. A large part of surface water running off in this channel is draining stormwater from the Faraiya – Aayoun es Simane road. The stormwater drainage along this road must be upgraded so that no stormwater runs off from the road towards Labbane spring. All stormwater must be drained along the road (MARGANE & SCHULER, 2013).

To prevent having wastewater disposal in stormwater channels by private wastewater trucks, it is recommended that the government operate wastewater evacuation from private septic tanks in the areas that are not covered by the wastewater conveyor to a treatment plant) and empty them at designated WWTPs. Otherwise private enterprises doing so would need to install a GPS tracking system.

The establishment of a stormwater retention basin is recommended at the location where stormwater is currently discharged in the nature, upstream of Jeita. The stormwater network should be continued to beyond Jeita catchment in order to reduce the contamination load generated on Jeita spring by contaminants carried by the stormwater.

Figure 43: Rainwater flooding and damaging the road at Bquaatouta during a rainy day

Figure 44: Gypsum Sludge resulting from quarries and cutting blocks disposed in the storm water canal on a road side

Figure 45: Stormwater carrying stones and soil damaging the road in Bquaatouta during a rainy day

5.2 Point Sources

Point source pollutants, in contrast to nonpoint source pollutants, are associated with specific locations as origin of pollution.
Table 10 displays the point hazards sources assessed in the Jeita catchment

Table 10: Point source groundwater hazards assessed in the Jeita catchment and their associated location in relation to the proposed protection zones

Hazards sources	Assessed hazard sources inside JC	Protection zone				
		1	2a	2b	3a	3b
Dumpsites	74		47	26		
Hospital	1			1		
Gas stations	59		22	23	1	13
Industries	33		12	13		8
Quarries	25		9	2		14
Slaughterhouses	2			2		
Feedlots & Poultry housing	33		7	9	1	16
Touristic resorts & restaurants	18		13	4		1

Source: BGR field assessment

5.2.1 Feedlots (Livestock and Poultry Production).

Feedlots have been defined by the Minnesota Pollution Control Agency (MPCA) "A lot or building or combination of lots and buildings intended for the confined feeding, breeding, raising, or holding of animals and specifically designed as a confinement area in which manure may accumulate, or where the concentration of animals is such that a vegetative cover cannot be maintained within the enclosure. Open lots used for the feeding and rearing of poultry (poultry ranges) shall be considered to be animal feedlots. Pastures shall not be considered animal feedlots." (MPCA, 1997). Because of the high density of animals and lack of vegetation common to feedlots, these areas can contaminate water resources with animal dung and other waste related to the raising of animals (dead animals, medicaments (especially antibiotics), contaminated fodder). Poultry feed may contain arsenic to promote growth. Poultry and other animal farms transfer a number of bacteria and viruses, such as Escherichia coli, Salmonella typhimurium, Campylobacter jejuni, Staphylococcus aureus, etc., which may therefore be found not only in the waste of animal farms but also in groundwater.

Indicators for pollution from animal farming, such as Cryposporidium, and other frequently occurring bacteria and viruses such as Clostridium perfringens, Giardia lamblia (intestinalis), Pseudomonas aeruginosa, Enterococci are not included in the WEBML regular water analysis (MARGANE et al, 2013).

Because there was no database, the BGR project compiled one for the existing water analysis results at WEBML, covering the past 10 years. The compiled data shows that raw water permanently exceeded the limits of the Lebanese drinking water standard for Escherichia Coli, and other faecal coliforms, and that Salmonella is frequently found in the Jeita/Kashkoush raw water. The high levels of contamination by Salmonella are most likely related to the huge amount of feedlots and slaughtering wastes dumped in the environment.

Limited data was available on feedlots and other sources of animal waste in the Jeita spring groundwater catchment, except for an incomplete list of farms that the ministry of agriculture could provide. However the list included only the feedlot owner name and phone number with the name of the village only (without georeferences or number of raised animals).

Figure 46 shows the locations in the catchment of assessed feedlots, while Table 11 presents the number of animals existing at the assessment time. Table 12 provides a figure of the average amount of manure produced per animal per day and per year. This display aims at highlighting the significant amount of manure generated especially that the whole generated quantity is evacuated in the environment without prior treatment (Figure 47).

Grazing in the highlands is undertaken between June and November but only a few Bedouin shepherds live within the Afqa catchment. In the highland area,

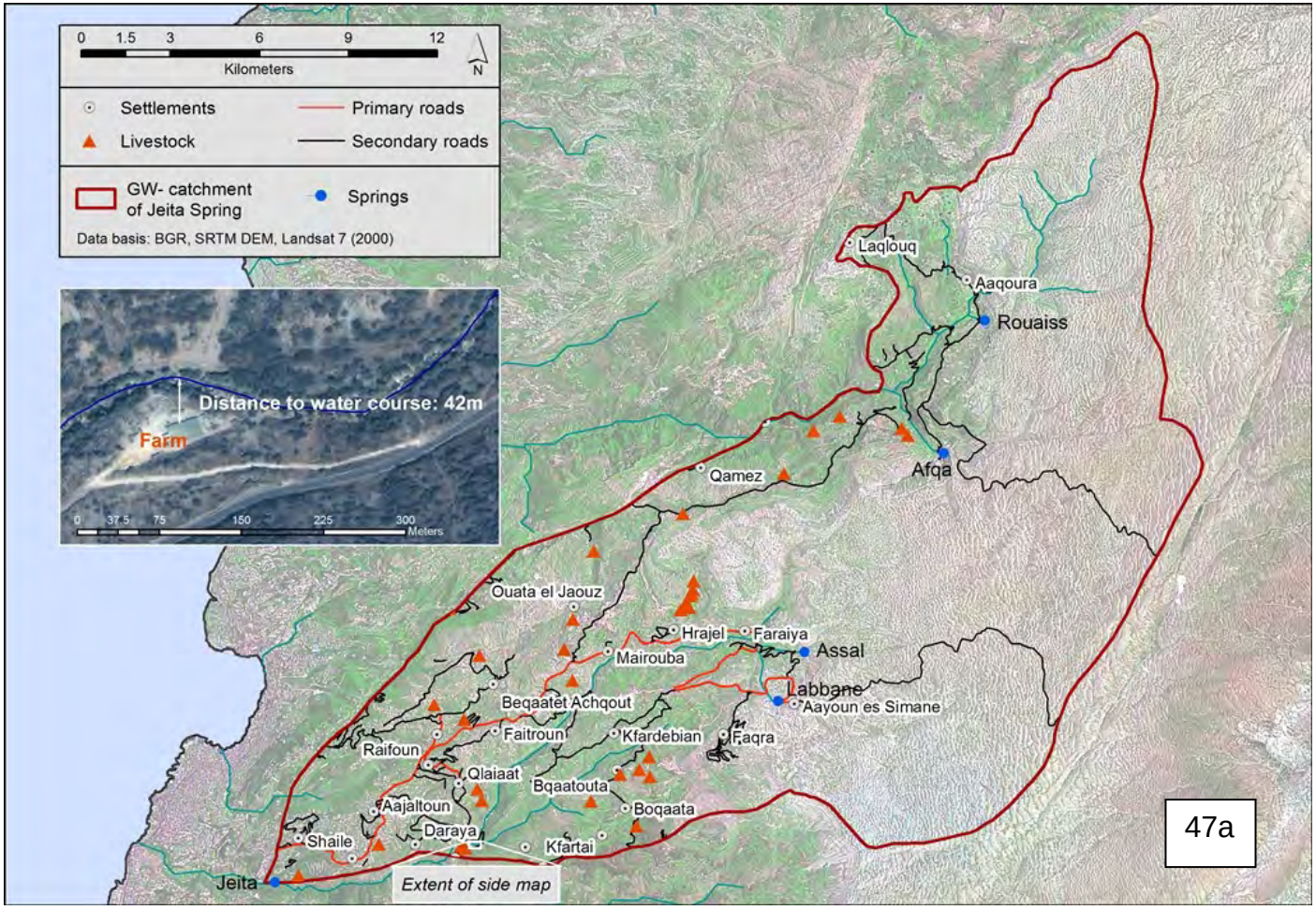
proposed by MARGANE & SCHULER (2013) as groundwater protection zone 2, the overall number of cattle should remain low.

Figure 46: Grazing in Kfar Debbiane (on C4 Cretaceous plateau)

Currently, 31 animal farms are operated within the catchment of which 18 farms are located on low or very low vulnerable GW resources, for example in the area of Bqaatouta and north of Hrajel. However, 13 animal farms are located on high or very high vulnerable GW, on the Lower Aquifer. GW is not only threatened directly by infiltration of pollutants from farms but also indirectly through infiltration via surface water courses. Figure 47 displays the location of a farm that is in close proximity to Nahr es Salib.

An alarming incompliance with urban planning decisions related to the protection of Nahr El Kalb and Nahr Ibrahim rivers (and tributaries)

The animal farms located in Beit Chebab and Mar Boutros, close to Nahr el Kalb (Figure 48), from which animal waste is directly discharged into Nahr el Kalb do not have an effect on Jeita spring as water from this part of Nahr el Kalb does not flow to Jeita spring. It is, however, assumed that Kashkoush spring receives water from infiltration in this part of Nahr el Kalb as investigations by the BGR team in 2012 related to sludge releases from quarries have shown (MARGANE, 2012c). (Kashkoush spring waters are mixed with Jeita waters and used for drinking water supply of Greater Beirut area.


0 1.5 3 6 9 12
Kilometers
N
Settlements
Livestock
Primary roads
Secondary roads
GW- catchment of Jeita Spring
Springs
Data basis: BGR, SRTM DEM, Landsat 7 (2000)
Distance to water course: 42m
Farm
0 37.5 75 150 225 300
Meters
Laqlouq
Aaqoura
Rouaiss
Afqa
Qamez
Ouata el Jaouz
Hrajel
Faraiya
Assal
Mairouba
Labbane
Aayoun es Simane
Beqaatet Achqout
Faitroun
Kfardebian
Faqra
Raifoun
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Aajaltoun
Boqaata
Daraya
Shaile
Kfartai
Jeita
Extent of side map
47a

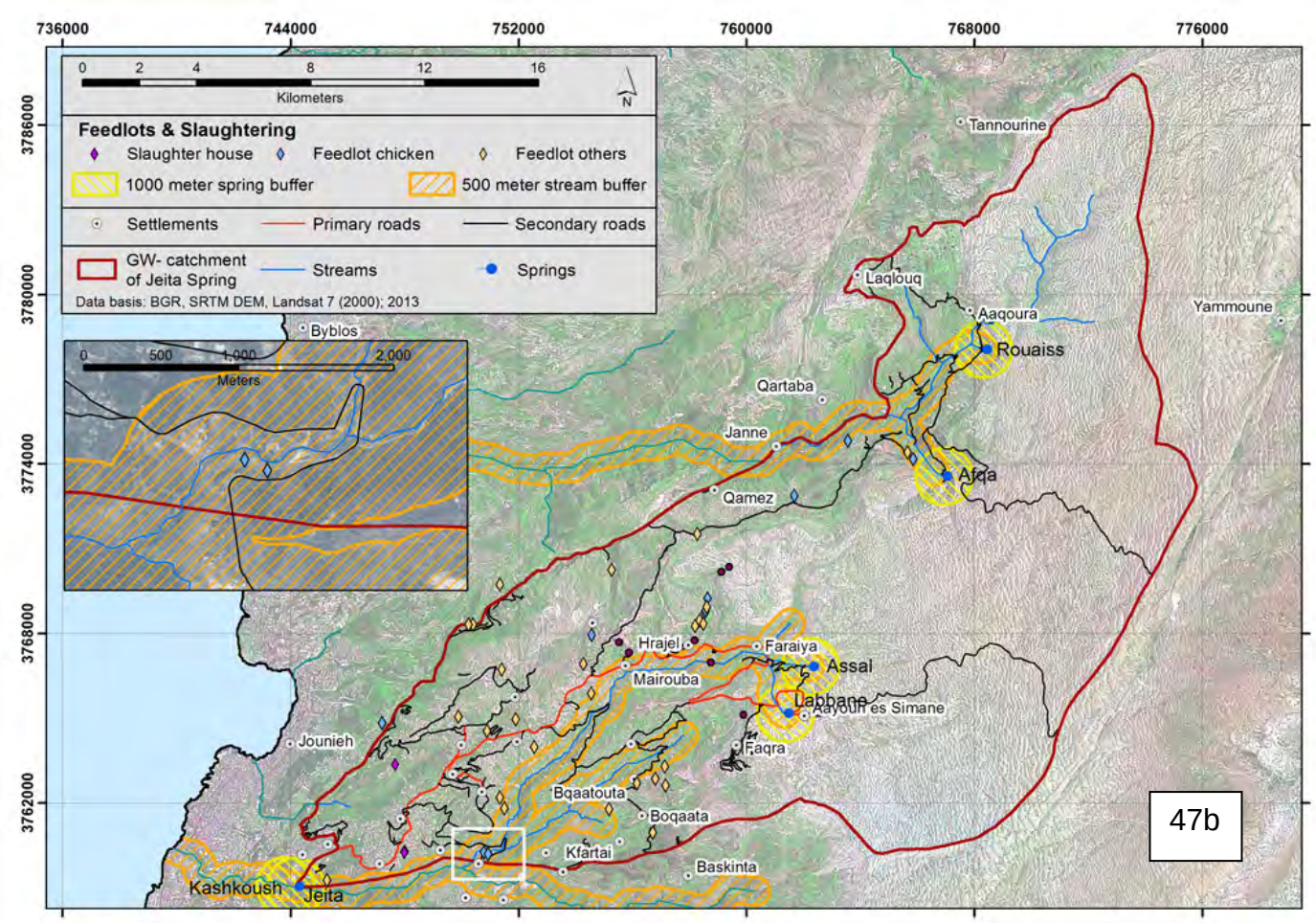

Figure 47: Location of the assessed livestock farms (a) and feedlots (b) in Jeita catchment , with highlight to a farm closer than 42m to Nahr es Salib watercourse

Figure 48: Animal waste dumped from farm directly into Nahr el Kalb

Table 11: Distribution of the assessed farms in Jeita catchment villages (bovine, ovine, caprine and poultry production)

Village	Number of farms				No. of Ovines + Caprine	No. of bovines	Poultry
	Ovines Caprine	Bovines	Swine	Poultry			
Aajaltoun	3	1		1	320	500	
Achkout		1				9	
Afqa		3				16	
Bekaatet achkout		1					
Bekaatet kanaan		1				25	
Bkaatouta	4	1			639	2	
Bzemmar	1				250		
Daraya				1			10000
Feytroun	1				60		
Ghosta				2			5000
		2			200	348	
Hayata		1				30	
	1	1			60	25	
Hrajel	7	4		2	3700	82	20500
Jeita	1				100		
Qehmez	2	2		1	521	11	16000
Kfardebian	4	3			335	40	
Kleyaat		3	1			8	
Lassa		4				37	9000
Mayrouba							
Mghairet							
Nahr el dahab		2				40	
Raachin	4				1021		
Rayfoun							
Seraaita		1		1		8	40000
Sheileh							
Wadi el karem		1				2	
Wata el jaouz		1		1		8	37000
Zabougha							
Total at Jeita catchment	**28**	**31**	**1**	**10**	**6706**	**392**	

Source: Field assessment

Table 12: Average amount of manure produced per animal per day and per year (excluding bedding)

Animal	**Quantity: of manure in lbs. /day**	**Quantity of manure per animal in tons / year**
Beef Cow (1000 lbs)	63	11.5
Pig – grow/finish (220 lbs.)	14	2.5
Sheep – lamb (125 lbs.)	5.0	1.825
Layer Hen (4 lbs.)	0.25	41.5 x (10^{-3})
Growing Broiler at 6 weeks of age *	30-35	10.95 – 12.775

Source: Information derived from the USDA Soil Conservation Service Agricultural Waste Management Field Handbook
http://www.uri.edu/ce/healthylandscapes/livestock/how_manure_overall.htm
*** http://ohioline.osu.edu/b804/804_3.html**

Table 12 is meant to underline the important quantity of manure generated by meat animals production in Jeita catchment while table 13 displays the major negative impact of this activity on groundwater

Table 13: Negative impact of animal production and slaughtering on water resources

Activity	**Negative environmental impact**
Rearing in poultry housing	▪ Emission of ammonia, odors and dust to atmosphere and subsequent deposition on land
Cleaning hard standing around housing	▪ Contaminated runoff entering watercourses
Incineration of carcasses	▪ Contaminating ash build up in soil around incinerator
Untreated litter utilization	▪ Surface run-off to watercourses; nitrate leaching from soil, increase in soil mineral & metal content. Aflatoxins contamination of soil and water
Storage of fuel	▪ Potential soil & water contamination
Disposal of pharmaceutics	▪ Potential for soil & water contamination
Disposal of disinfectants	▪ Potential for soil & water contamination
Disposal of slaughtering wastes	▪ Potential for soil & water contamination

Figure 49: Truck load of unfermented manure just disposed of in the nature

Main used hazardous pharmaceuticals in animal production within Jeita catchment are: Thiophanate (fungicide), Oxytetracycline, Enrofloxacin, Penicillin, Spyramicine, Phenyl bithadon and Dichlophenate, Oxytocin, Atropine.

Legal framework of the animal production in Lebanon

Table 14: Main decisions related to animal production in Lebanon

Reference	Focus	Details	Implementation status
Ministerial decision N° 16/1 dated March 21st 2001		Provides environmental guidelines related the waste management inside the farm	Implementation hindered by the lack of required staff at MoE able to cover the whole Lebanese territory
Decision N°. 320 of 1926		Emphasizes on the prohibition of the direct or indirect disposal of animal manure and the formulation of wastes depots within the haram (protection zone) of water springs used for public use.	Not implemented in absence of an enforcement agency
Ministerial decision N° 9/1 dated December 2nd 2004	Distance from Residences	Determines the minimum distance that must separate all kinds of farms intended to be created & or operated in unclassified (by urban planning) populated areas	Not respected in many cases
Decision No 3 dated January 24, 1996 of the Supreme Council for	Landuse restrictions on feedlots and farms	Determines the conditions (distances to water courses, residences, etc) upon which the urban planning approves the permit	Not respected in many cases

Reference	Focus	Details	Implementation status
Urban Planning			
Ministerial decision No 16/1 dated March 3rd 2001	Environmental guidelines for feedlots & poultry farms	Environmental requirements for allocating construction and / or operation permits for cattle farms &/or poultry &/or pets (Such as rabbits, pigs, etc.).	Partially (limited) implemented many exceptions have been noted

Main stakeholders for feedlots are: Ministry of Agriculture, Ministry of Health, Ministry of Environment, and the Directorate of Urban Planning, in addition to the Governor. Many municipalities expressed their inability to close some existing feedlots operating within their areas despite deploying serious related efforts.

5.2.2 Slaughterhouses

Two major slaughterhouses are located in Jeita catchment, one in Ghosta the other in Aajaltoun. The first mainly slaughter bovine, ovine and caprine, while the latter frequently slaughters also swine. Poultry slaughtering is in general conducted in specific slaughterhouses, located outside Jeita catchment, except for few farms such as the ones located in Lassa.

The two slaughterhouses which act also as feedlots as being important animals importers to Lebanon, dispose their liquid effluents directly in the nature, without any prior treatment (Figures 28, and 50), in addition to a huge quantity of generated manure, and other solid wastes (Figure 50).

In Lebanon, slaughterhouses come under the supervision of the animal husbandry division of Ministry of Agriculture who is mainly responsible for day-to-day operation/maintenance of the slaughterhouses. The MoE is responsible for environmental issues, while Ministry of Industry and Urban Planning Directorate have a major decisive role for issuing the establishment permit; the MoH must monitor public health related issues (hygiene, etc.). The municipality is responsible for monitoring the compliance to guidelines (e.g. waste and wastewater management). The Ministry of Industry provides them the operation permit. Slaughtering sector is far from being controlled, mainly due to overlapping responsibilities between relevant governmental institutions and the lack of an environmental laws enforcement agency, added to a lack of necessary accessible infrastructure (waste recycling facilities or incinerators) and selfishness and inexistent environmental awareness at the level of the slaughterhouses operators .

The two assessed slaughterhouses in Jeita catchment are service-oriented and, as such, perform only the killing and raising of animals without onsite rendering operations. They are without adequate basic amenities concerning proper pretreatment of effluent and cleaning. These slaughterhouses suffer from very low hygiene standard posing a major public health and environmental risk due to illegal disposal practices of waste and highly polluted effluent (Figures 32, 33).

Furthermore the authorization (decision of the Minister of Agriculture issued in 2012) of slaughtering by butchers has also increased slaughtering related groundwater contamination risks (Figure 33) due to a very spread unsound slaughtering wastes disposal.

Common practice is the use of unfermented manure as fertilizer otherwise manure is directly dumped in the nature (Figure 49). Tens of manure trucks are being disposed of in the nature every week from the two slaughterhouses/feedlots.

Figure 50: Liquid and solid slaughtering wastes disposed directly in the valley from the slaughterhouse at Ghosta

Solid wastes are neither recycled nor discharged safely. They are either illegally dumped in the nature or incinerated generating aflatoxins and other soil and GW contaminants. Also slaughterhouses untreated liquid effluents are commonly discharged in the environment (Figures 28, 29 and 50) generating a high risk of GW contamination.

Systematic negligence of landuse regulations (min. distance to roads, residential land and surface waters) is obvious (Aajaltoun slaughterhouse is located on the road, very close to residential buildings, and discharges its liquid effluents (rich in blood, pesticides, antibiotics, etc.) on the road side in a very vulnerable groundwater context (Figures 28).

In both slaughterhouses, blood collection is not done upon slaughtering. The blood goes down the drains, straight to the environment causing severe pollution of GW. Due to inadequate facilities at the slaughterhouses and scattered illegal slaughtering of animals, blood, which can be collected for making use in pharmaceutical or agro industries, is lost to become a contamination source.

Furthermore, evisceration generates maximum amount of waste. The butchers as well as the two slaughterhouses generally discharge visceral material in municipal waste bins and wash the small intestines at their facilities then dispose the effluents in the nature and thus create high risk of GW pollution (Figure 34).

Figure 51: Open air slaughtering at a butcher lacking of minimum hygienic conditions

Figure 52: Animal carcasses (bones) discharged at a dumpsite covering an area exceeding 500 m^2 in Kfar Debbiane

Figure 53: Untreated effluent discharged by Chbeir slaughterhouse (located in Ghosta) in the environment.

Figure 54: Drainage of liquid effluents generated by cleaning towards a bottomless open cesspit at the Ghosta slaughterhouse

Figure 55: Basin filled with insecticide, once fully used the rest will be discharged without treatment in the above mentioned cesspit at Ghosta slaughterhouse

Figure 56: Big quantity of manure illegally disposed of in the nature

Figure 57: Viscerae dumped at a huge illegal dumpsite near Lassa

Figure 58: Aajaltoun slaughterhouse located on a road side and discharge of effluents into nature

Recommendations

Considering the huge amount of contamination generated by the feedlots and the slaughterhouses in the Jeita catchment, and the absence of a facility able to valorize their wastes and reduce their environmental impact, the establishment of such facility is highly needed and recommended.

Furthermore, slaughterhouses, medium and big scale farms must be forced to treat their liquid effluents before discharging it in the wastewater system or in the environment.

Any discharge of such untreated effluent can create significant risk of Jeita spring groundwater contamination mainly in protection zone 2. it would also affect the operation of the planned CDR/KfW wastewater treatment plant once connected to it.

5.2.3 Quarries

The problem of quarries has emerged in Lebanon with large-scale reconstruction projects during the 1990's. With limited authority control, demand for materials has been significant.

Lebanon did not succeed in adequately managing this issue. Many quarries (the majority of them) are unlicensed, and most of them, even the authorized ones, have not respected legal requirements in terms of material extraction and site rehabilitation.

The attitude of the authorities has been divided between the recognition of economic and social importance of quarries, the need to put an end to illegal activities or on the contrary tolerating them, or total and firm prohibition on the entire territory. The authorities did not take a definitive decision whether extraction sites should be concentrated in few zones, or on the contrary, distributed on small and medium-sized quarries all over the country (CDR, 2005).

28 operating quarries were identified and assessed (following a questionnaire detailed in Annex 2) in the study area (Figure 63), plus one quarry at Abou Mizane (on the outside limit of the catchment), which discharges its wastes at Jeita catchment, mainly in Kalb river.

In addition to their effect on the landscape and soil stability (Figure 59), quarries represent a real threat to surface and groundwater as well. Sediments and toxic materials (i.e. explosives and hydrocarbons generated by fuel storage and oils disposal) are flushed through water bodies after mining.

Figure 59: Quarry putting in danger land stability in Hrajel area

Considering the existing hydrogeological context, the location of the existing operating quarries and the practices assessed in the catchment, we note the following generated threats to Jeita spring groundwater:

- The storage and handling of fuels and lubricants for operation of machines are likely to cause GW contamination.
- Mismanagement of water resources: surface water diversion or GW pumping (conducted to cover water requirements, to allow quarrying operations or washing out of fine materials) is a potential qualitative (intrusion of hazards) and quantitative (over-abstraction, lowering of GW table) threat to GW.
- Change in flow direction of surface waterways and groundwater.
- Exposure of groundwater to direct and indirect contamination (via surface water pollution which infiltrates towards groundwater) (MARGANE, 2012b)
- Decrease or removal of protective cover leading to an increased access by pollutants to groundwater.
- High erosion potential causes mobilization of fine material and washout towards streams. Tailings and sludge, reaching surface waters, increase their turbidity. Turbid surface water infiltrates into GW. Turbid GW is difficult to treat (chlorination becomes ineffective).
- Generated waste is illegally dumped in the environment. As example to such practices, we mention that the BGR project monitored recurring high turbidity peaks showing up at Dbayeh during 2010-2012. Following field

investigations the project proved that they were resulting from injections of sludge from ponds of the HAJJ sandstone quarries in Bqaatouta. Travel time to Jeita spring was around 24 h (April-June 2012). (MARGANE, 2012d).

- Non-compliance with law to rehabilitate quarries after extraction. Abandoned quarries are often used as landfills.
- Blasting operations increase cracks and fissures in the karst network, leading to potential of collapse of karst caves and dolinas. The adopted explosives (Chili nitrates) and dynamite (prohibited by actuated Lebanese laws) present a real threat to GW quality.
- The lack of hydrogeological information and knowledge prevents environmental sound management of quarries. Despite the requirement of an EIA before establishing new quarries (recent requirement, which is not applied on any quarrying activity in the catchment as EIA decree was actuated in August 2012).
- Governmental negligence of municipalities' and public society's complaints about extraction practices.
- Lack of environmental awareness at the level of the quarries operators and managers.
- Predominance of personal interests on the community's basic rights, due to absence of laws enforcement and dominating political hindrances.

The location of three quarries east of Bqaatouta close to Zirghaya river course recalls a possible generated surface water contamination that would quickly infiltrate towards groundwater (Figure 63). Vulnerability mapping of the area showed that the entire J4 outcrop area in Nahr es Salib and Nahr es Zirghaya must be included in protection zone 2 where quarrying activities must be completely forbidden.

Zgheib quarry of Wata El Jaouz went more than 300 m deep counting from the original mountain level, with a perimeter of 1500 m^2 significantly changing the landscape and generating environmental impact despite being located on the aquitard. The high amount of used explosives and vertical blasting endangers the whole geological structure of the area (risk of collapses, landslides, etc.), added to the huge amount of dust generated.

The quarries located at Mayrouba present a lower risk, being located on the aquitard, far from surface water courses.

Figure 60: Dust generated by quarrying operations

Figure 61: Dust covering the area close to Zgheib quarry located Near Wata el Jaouz

Figure 62: Dust generated during aggregates processing at Mehanna quarry, Wata el Jaouz

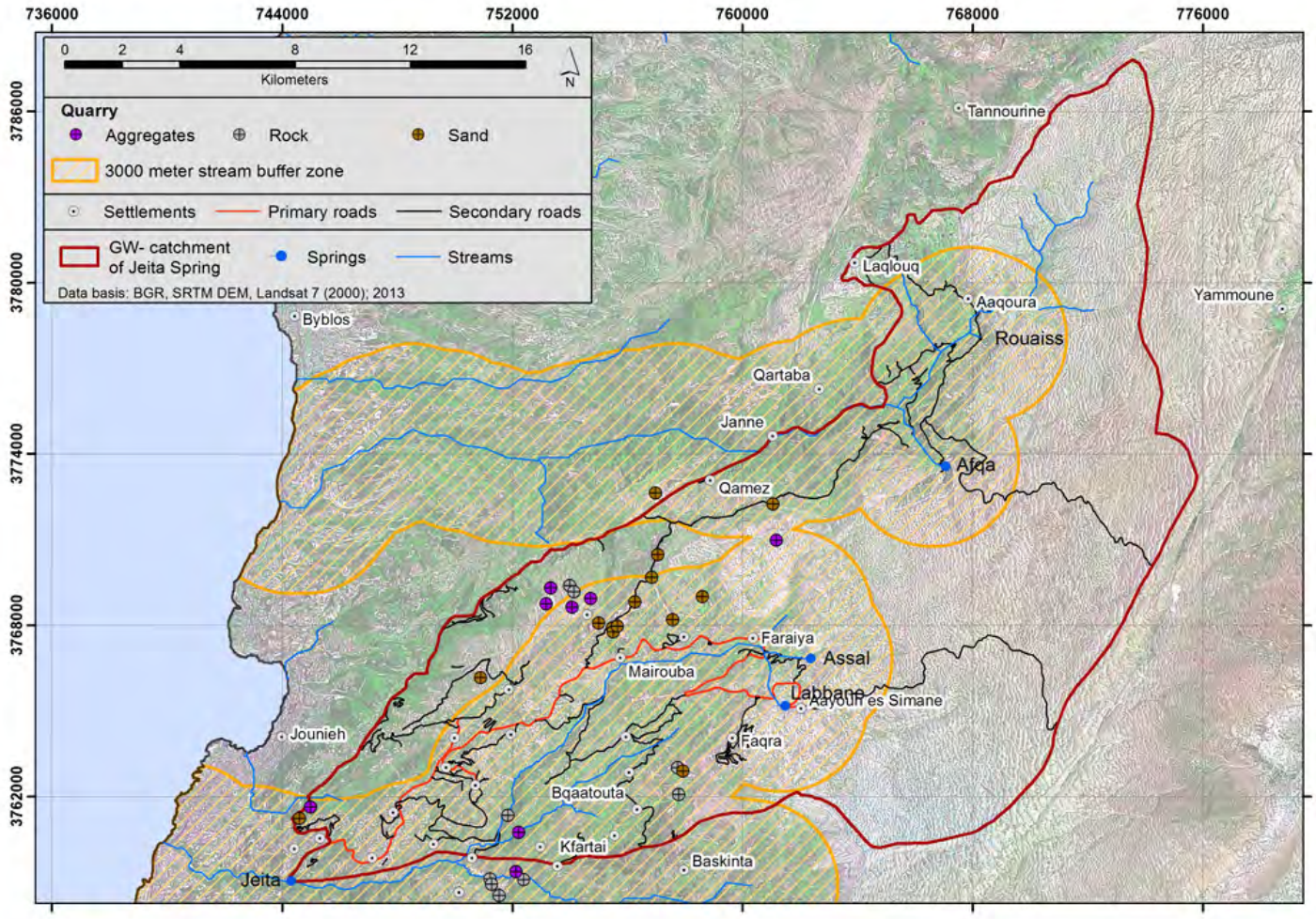

Figure 63: Location of the quarries currently operating in the Jeita catchment and ruling rivers buffer areas

Stakeholders and legal framework

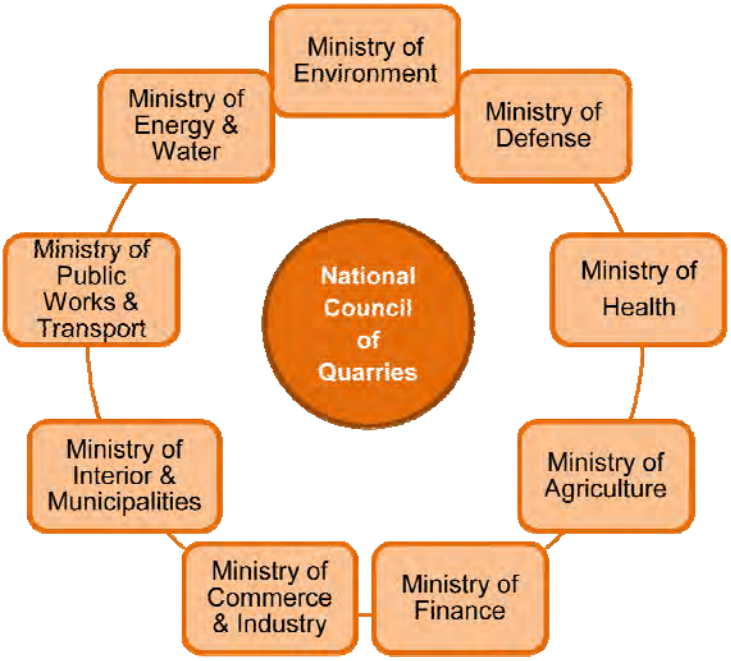

Figure 64: Ministries involved in the National Council of Quarries

Legal framework of quarries in Lebanon

Decision 325 of November 8, 1935: which outlined the legal framework for quarrying activities. The quarrying sector was first organized by decree 880/2002 which was amended by decree 16456/2006, then by decree 1735/2009.

Decree 1735/2009 states that this sector would be ruled by the National Council of Quarries which include general directors of 9 main ministries. This council has provided a general strategic plan defining quarrying areas. However this definition was not based on rigorous criteria or considerations and was not respected.

Despite the National Plan emitted by the National Council of Quarries, prohibiting any quarrying activity in all the present quarried area of the Jeita catchment , more than 8 quarries are still active despite municipalities and public society's complaints.

This is justified by relevant authorities by the fact that regional or national interests must override the local interests and by the need of the extracted limestone and sand for answering the demand of the developing construction sector.

All quarries currently operating in the Jeita catchment are working upon a yearly renewal of old operation permits allowed following law 1735/2009. Responsible staff of the Lebanese Ministry of Environment assured during meetings that the MoE requested the Council of Ministers to cancel these permits by the end of 2012, however, they were not cancelled.

Thus, in addition to the municipalities, the National Council of Quarries (Figure 64) is by law the main stakeholder of the quarry sector. However, this council, where too many stakeholders are represented, has been so far unable to control the quarrying sector.

Decision 2, 77th session of the Council of Ministers, made the following amendments:

- localization of quarries in the eastern mountain chain.

- mandatory rehabilitation of quarried sites at the expenses of the owners by terracing and replanting (Ministry of Agriculture, 2003).

The State Consultative Council proceeded to protect the environment by dismissing the appeal to abrogate the quarries and crushers regulating decree, on the ground of its impacts on public safety, public health, the environment, geological balances and groundwater (Decision No. 381 of 13/11/2002).

In other matters, the State Consultative Council decided to compensate the citizens affected by the activities of public works contractors as a result of the collapse of soil during the works, and to prohibit the use of explosives in the quarry to prevent causing damages to neighboring estates.

Several Environment Ministerial decisions have tried to set criteria for the use of sand and rock quarries: Decision No. 182/1, 183/1, 184/1, 185/1, 186/1 of 1997, (ELARD ENVIRONMENTAL CONSULTANTS AND ALEM & ASSOCIATES (2007),

Moreover, by Decision No. 25 of 13/10/1999: the Council sought to ensure the implementation of this decree and considered as illegal the sand and gravel quarries and crushers operating without license. The hope to limit quarrying activities relies now on the EIA decree, promulgated in August 2012. This decree force to conduct EIA studies for proposed quarrying sites (to protect the water resources). However, if this decree acts on new quarries a solution must be found to mitigate the impact of the operating ones that impose high risks to Jeita spring groundwater.

5.2.3 Dumpsites and Waste Management

Population growth and urbanization in absence of waste separation and related recycling facilities, added to a severe lack of environmental awareness are worsening the problem of waste management in Lebanon.

A study conducted by the WORLD BANK (2004) on the state of environmental degradation in Lebanon, quantified the cost of degradation caused by pollution from illegal dumping and waste burning to be around $10 Million per year, and rising. A comprehensive analysis of the waste sector is given in the report 'State and Trends of the Lebanese Environment' published by the Ministry of

Environment (MoE, 2010). Approx. 30% of municipal solid waste (SWEEP-NET, 2011) is still dumped in the nature due to lacking official waste disposal facilities for all types of waste.

Political indecision has so far prevented the implementation of a National Municipal Solid Waste Management Plan in Lebanon, as proposed in 2006 jointly by MoE and CDR. Waste management in the Beirut Mount Lebanon governorate is still managed under the Emergency Plan, in place since 1997. Municipal solid waste is collected in most villages by the company SUKLEEN (Beirut/Quarantina) and transported to the Naameh landfill, under the operation by the company SUKOMI. (also operates the Amrousieh and Quarantina solid waste treatment plants and the Coral composting plant; CDR, 2011). The municipalities have to cover the costs for waste collection, transport and dumping. This cost is deducted from their annual allocation directly by the ministry of finance without passing by the municipality records. Head of municipalities and board cannot discuss or access the figure of the deducted sum from their municipality annual allocations. Most villages in Jeita catchment are serviced by SUKLEEN, except: Bquaatouta, Boqaatet, Ashkout, Zabougha, Nahr El Dehab, Wadi El Karem, Quehmez, Ain El Delbe, Boqaatet Kanaan, Saraaita, Kfartay, Laqlouk, Aakoura, Afqa (Huge dumpsite), Mghayra Lassa, Janne, Korkraya, Deir Chomra, Yanouh, Ain El Ghoeybeh and Ghabat,

These are mainly served by private persons living in the local area.

We note that municipalities included in the Union of Jbeil municipalities dispose of their wastes mainly at Hbaline waste facility, while others dump them randomly in the nature or at assigned dumpsites.

In kesserwan area, some municipalities, have their own dumpsites (Which are currently banned by actuated laws) where they frequently incinerate green wastes and different other kinds of wastes that are not collected by Sukleen, such as the wastes generated by factories or slaughterhouses located in their area (Aajaltoun, BAllouneh, etc.).

Open dumping impacts surface and ground water quality. Unlike controlled landfills which are equipped with basal lining systems to intercept leachate, open dumps release leachate directly into the environment. Leachate will seep into groundwater or runoff into nearby watercourse.

The BGR project has assessed **74 major illegal dumpsites** within the Jeita spring GW catchment (Figure 66, Annex 6) and has located other 13 dumpsites through studying raster images of the catchment area

- 47 dumpsites were found within areas where Jeita spring is highly vulnerable to contamination.
- 26 dumpsites are located in vulnerable areas,
- 1 dumpsite is located on aquitard far from streams, despite its wide size, this one can be considered as presenting a lower risk to Jeta spring .

These dumpsites include mainly: Construction wastes, Household wastes including: dumping batteries, pharmaceutics, plastics, chemicals, plastics, cartoon, organics, etc., and Hazardous wastes: pesticides containers, pharmaceuticals, slaughtering wastes, animal carcasses, etc.

More than 40 dumpsites out of the 74 (more than half) are made of construction wastes. If adequately valorized, these wastes would reduce the pressure on quarrying, can help in the land reclamations, and mostly would reduce the important contamination load imposed on Jeita spring.

15 of the assessed dumpsites include tires. Once burned, these produce highly contaminating concentrated ashes, while the tires can actually be recycled, and many tires recycling companies are operating in Lebanon.

Of these dumpsites, we mention those which generate a critical imminent danger on Jeita spring quality due to its location, size and or its content of hazardous materials

- A dumpsite located in Qleyaat cadastral area, despite being owned by Bkerke, this land is used by an individual who arranged getting a land rehabilitation permit. Through this permit, it is receiving huge amount of wastes from Metn and Keserwan areas, at the rate of truck per 5 minutes. All kinds of wastes are being dumped there. These include mainly industrial slaughtering and construction wastes. People living in the neighborhood complained about the situation and raised the action at the media. Following the project intervention, a claim was submitted by Daraya and Qleyaat municipalities to the Ministry of Environment asking to take action. Several open air waste incinerations were observed at this site including the incineration of the wastes collected from recently blasted plastic factory and cartoon factory. The dumpsite is located straight above the underground river of Jeita spring. A tracer test carried out by the project in April 2010 not far from this site showed that any contamination can reach Jeita within 62 hours.
- Boqaatet Achqout dumpsite, huge dumpsite as far as area covered and quantity and kind of dumped wastes. The municipality is directly involved in the issue, by charging a local private person to collect the residential wastes and dump them in the nature. Wastes encountered at this site are mainly resulting from the activities held in the village, i.e. restaurants, residences, etc. (Figure 65).
- Lassa dumpsite: This dumpsite is located in GW protection zone 3a. Which indicates a high GW vulnerability. Furthermore, in addition to household wastes, this dumpsite includes feedlots and slaughtering wastes, comprising viscerae and many other highly contaminating wastes, batteries, etc. The bad odors and the nature of the wastes dumped at this site urge for a quick action to clean the site. The municipality is directly involved in the issue too.

- 2 dumpsites located in Kfartey present a direct risk. One of them is located on the riverbank, while the other falls at less than 100m distance from the river. These dumpsites include tires, construction wastes and household wastes as well (including batteries, etc).
- Aajaltoun municipality dumpsite: located in a highly GW vulnerable area and at few tens of meters of the river, this dumpsite helds industrial wastes resulting mainly from the factories located within the municipality area. A common practice in this dumpsite is open air waste incineration which present a high risk of GW contamination.
- Dumpsites located at the boundary between Faytroun and Kfardebiane. The river bed separating the two villages also separates two important dumpsites presenting a significant risk of GW and surface water contamination. These dumpsites include all kind of wastes: empty fertilizers bags, pesticides containers, tires, petroleum oil containers, household wastes, construction wastes, etc. The adopted treatment measures at these locations are mainly open air incineration and covering the wastes with soil. without any treatment. Fact that does not prevent wastes leachates from contaminating the river waters and the GW as well.

Dumping of construction waste is common everywhere in the catchment. There is one large construction waste dump near the Mar Roukoz College in Qleyyat. Here waste seems to be partly sorted according to size but also other waste is dumped here.

A large problem is the burning of plastic waste (e.g. Raifoun; Figure 71) and of used tires (e.g. at a dumpsite in Ballouneh; Figure 72), and various wastes in Aajaltoun dumpsite. This process leads to the formation of carcinogenic, mutagenic and teratogenic polycyclic aromatic hydrocarbons (PAH).

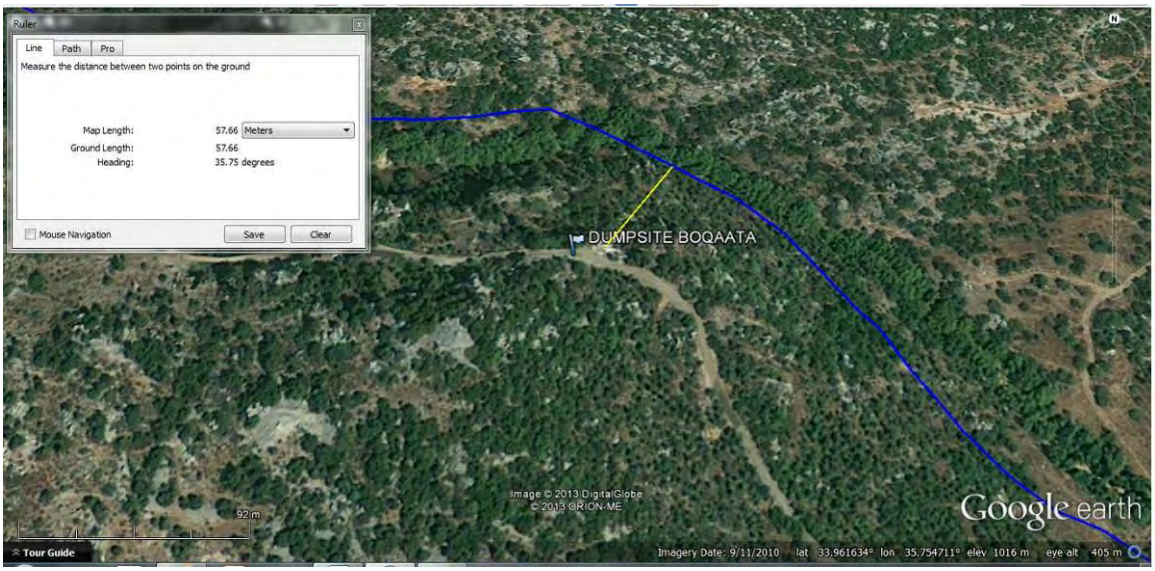

Figure 65: Huge municipal dumpsite located at less than 60m of El Msann river course

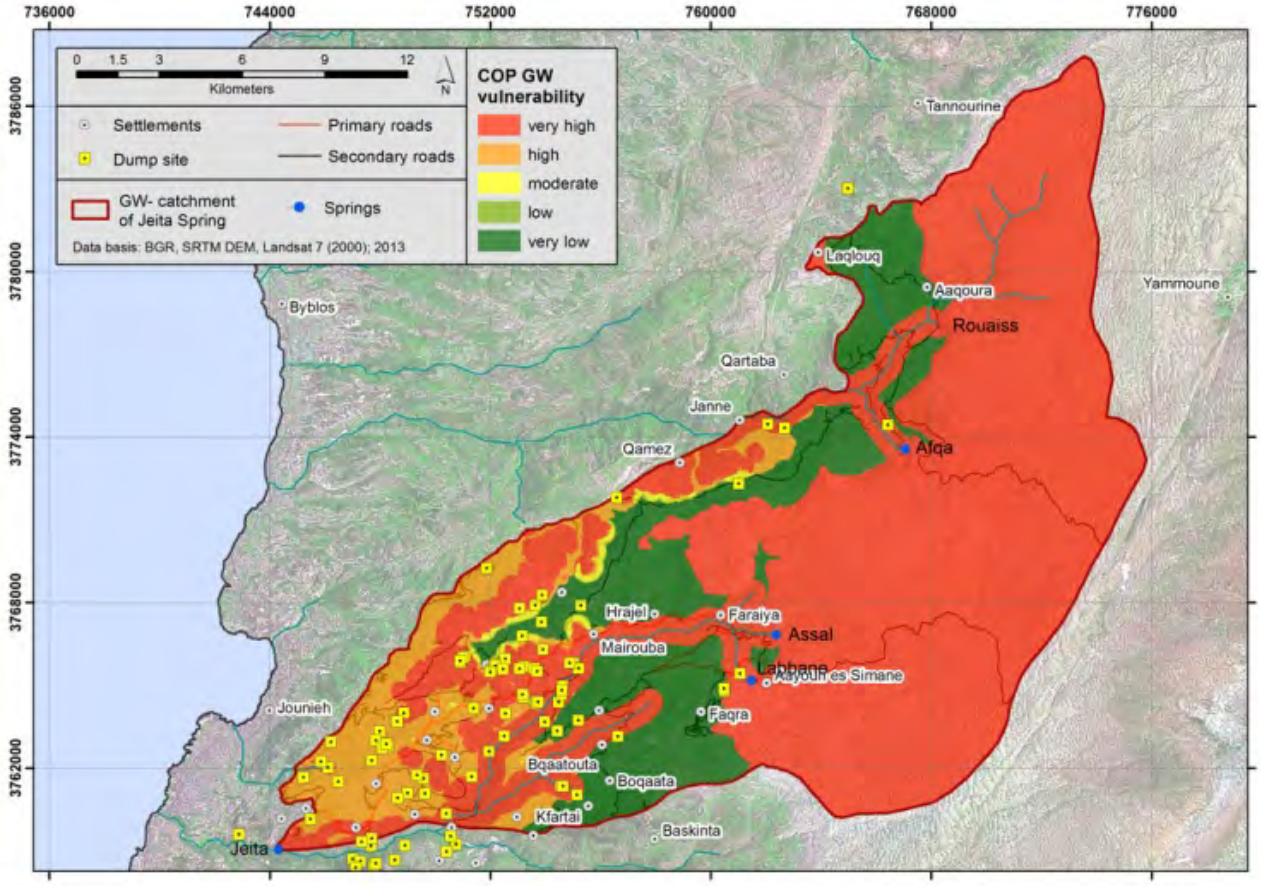

Figure 66: Location of the assessed illegal dumpsites in the Jeita spring GW catchment with emphasis to GW vulnerability and the existing rivers and springs

Table 15: Legal framework related to wastes in Lebanon, and its assessed implementation status in the Jeita catchment

Reference	Focus	Details	Implementation status
Decree-Law No. 8735 (dated 23 August 1974)	Maintenance of public cleanliness	Municipalities are responsible for the collection & disposal of household wastes, & the location of waste disposal sites should be approved by the health council of the Mohafaza.	Partially implemented as some municipalities of JEITA CATCHMENT are dumping their wastes in the environment at illegal dumpsites mainly through local private wastes collectors
Municipal Act of 1977 (legislative decree No. 118, Article 49)	Build solid wastes facilities	Authorizes municipal councils to build solid waste disposal facilities. Municipalities report to the local governor & the MOIM, which manages the allocation & distribution of funds from the IMF, under the control of the MOF. Outside the GBA, municipalities use IMF resources to pay for SWM services including street sweeping, waste collection, & disposal.	Waste collection fees payment & incentives for municipalities to host wastes treatment facilities are subject to hot discussions nowadays, due to municipal complaints related to the imposed wastes collection fees..
MOIM Decree No. 9093 (dated 15 November 2002)	Incentives for municipalities to build solid wastes facilities	Provides financial incentives to municipalities for hosting SWM facilities or landfills. In particular, municipalities who agree to host a sanitary landfill or a SWM facility would according to the decree receive five-folds their annual allocation from the IMF & 10-folds this allocation in case the facility serves 10 municipalities or more.	Luckily, no legal solid wastes disposal facilities are located in JEITA CATCHMENT However, in other areas, municipalities are complaining from the lack of payment of promised incentives. Actually, to date, the decree has never been implemented.
The **law N° 973** enforced by the **law project N° 8735/1974**	**Pollution by Solid Wastes**	Prohibits in its article 1 to dispose in the public property the rubble, the spoil earth, the refuse, the agricultural or industrial wastes, the car carcasses. It states that such act is subject to a fine payment in addition to two months imprisonment.	Not properly implemented due to lack of enforcement agency.(Figures: 64,
Decision 52/1 (1996) issued by the Ministry of Environment	**Pollution of air, water & soil from oils & wastes incineration**	Pertaining to specifications & rates relative to reducing pollution of air, water & soil. Four Annexes were included with relevant interest to the protection of the atmosphere (Article 1), these are: - Annex 11: Maximum value allowed for the emissions of air pollutants resulting for used burned oils; - Annex 12: Maximum value allowed for the emissions of air pollutants resulting from domestic waste incineration;	Implemented at the level of some establishments only while individuals keep on violating this law under daylight without any limitation (Figure 66).

Reference	Focus	Details	Implementation status
Decision 103/1 of the minister of environment issued on 4/7/1997	Environmental supervision of the dumpsites /landfills	Landfills are under the supervision & control of the MOE. Local responsible institutions (i.e. municipalities) must report any dumping & replace the dumps at approved landfills	Partly implemented as sometimes the municipality which must report illegal dumping is actually behind this illegal action (i.e. Boquaatet Ashquout municipality, Ajaltoun municipality, Afqa mayor, etc.)
Integrated Solid Waste Management (ISWM) law approved by COM in December 2011	Integrated Solid Waste Management: waste "prevention & reduction" ;"material reuse, recovery & power generation" In addition to private sector participation:	Includes pertinent provisions related to : • ISWM including waste treatment & disposal • Allocation of SWM responsibilities & overall institutional setting • Information management, including data storage & record keeping • Management of non-hazardous waste, including collection, storage, sorting, treatment, reuse, composting, power generation, & final disposal • Management of hazardous waste, including updating classification of hazardous waste, management of healthcare waste, & prohibition of trans-boundary waste movement • Financing, cost recovery, & incentives, including potential sources of financing, & cost recovery via tax exemptions & others • Penalties &sanctions, & application of the "polluter pays principle".	Its implementation faces many hindrances: Absence of enforcement agency able to apply the previewed sanctions Lack of staff & means at MoE to monitor wastes generating establishments Lack of awareness at the public sector level Lack of information related to the hydrogeological contexts in Lebanon, which makes the reliability of the prepared EIAs questionable. Lack of environmental awareness at the municipal police level. Interference of political influences

Also, the municipality is by law responsible for damages caused by illegally dumped waste, such as by municipality vehicles and private vehicles that might catch fire (MOUBAYED et al., 2012).

Figure 67: Huge illegal municipal dumpsite in Boqaata Ashqout

Figure 68: Truck dumping municipal waste at a roadside
(this action is a clear violation to law)

Figure 69: Trucks discharging construction wastes in the nature

Figure 70: Extensive construction waste dumping at Mar Roukoz College

The encountered wastes in these dumpsites are mainly:
- Construction wastes
- Household wastes
- Manure
- Slaughtering wastes, i.e. remains of dead animals, blood, bones
- Agricultural wastes: pesticides containers, fertilizers empty bags
- Industrial wastes generated mainly at Daraya, and Aajaltoun
- Tires

Buried hazardous wastes

On June 5, 1988, around 15,800 barrels and 20 containers of Italian waste were discovered on the Keserwan shore, East Beirut and Ghazir (http://www.thefreelibrary.com/Transboundary+movement+of+hazardous+wastes+into+Lebanon%3A+Part+1.+The...-a0134620004). A Lebanese scientist was hospitalized after he fell ill while inspecting some of the barrels of waste. According to GREENPEACE (1996;) (http://www.fouadhamdan.org/cms/upload/pdf/ItalianToxicWasteInLebanon_FouadHamdan_GreenpeaceReport_ENGLISH_May1996.pdf), "Lebanese and Italian scientists established that the toxic waste consisted of: the explosive substance nitrocellulose; outdated adhesives, organophosphate pesticides, solvents as well as outdated medication; oil residues and highly toxic heavy metals like lead, mercury and cadmium; arsenic; chlorinated substances; PCBs, and other substances. Hundreds of barrels contained extremely high concentrations of the lethal substance dioxin." A part of the hazardous wastes was removed and sent back, however, people of the Hrajel, Faraya and Kfardebiane area affirm still having hundreds of barrels buried at different places in their region, probably on the Upper Aquifer of the Jebel Qana or Wardeh area. They state that those who came in contact with these barrels have quickly died after contact under mysterious circumstances and they relate the significant increase in cancer within their society to these buried hazardous wastes. The GREENPEACE report states that goats in the Aayoun es Simane area and in the highland further to the east died in 1994. Barrels were found at different places in or near the Jeita catchment (e.g. 1988 in Bteghrine and in 1994 in Yahshoush).

Due to the fact that the Upper Aquifer has very high groundwater vulnerability, its protection is a national priority. As it is unknown whether hazardous wastes remained in the catchment, the responsible institutions should pursue the issue and remove the hazardous waste (if any).

Figure 71: Wastes incineration, common practice in Lebanon

Figure 72: Tires and other various waste incinerated at Daraya dumpsite

Pollution by Liquid Wastes

Contamination may be generated by healthcare laboratories, mainly the one related to Aajaltoun hospital,, by dentists and by industries (e.g. at Daraya (polyethylene factory, hunting rifle cartridge factory, textile factory), at Shaile (printing press) and several cutting stone factories all over the catchment: Deir Chamra/Abu Mizaine, Boqaata Ashkout), the slaughterhouses (one in Daraya, the other in Ghosta), the feedlots, the illegal dumping and discharge of wastewater, etc.

Stakeholders of Waste Management in Lebanon:

- **Ministry of Interior:**

Following to Decree-Law No. 8735 (dated 23 August 1974) related to the maintenance of public cleanliness, municipalities are responsible for the collection and disposal of household wastes. Location of waste disposal sites should be approved by the health council of the Mouhafaza. The Municipal Law of 1977 (legislative decree No. 118, Article 49) authorizes municipal councils to build solid waste disposal facilities. Municipalities report to the local governor and the MoIM, which manages the allocation and distribution of funds from the IMF, under the control of the Ministry of Finance.

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- **Ministry of Environment:**

According to MOE's new organizational structure (Decree No. 2275, dated 15 June 2009), solid waste issues fall under the Service of Urban Environment (Department of Urban Environmental Pollution Control).
Council for Development and Reconstruction (CDR): CDR has the responsibility to prepare national sector plans in coordination with the different line ministries. CDR is empowered to seek international funding for these plans and then manage their execution. As different projects are completed, the ownership of facilities and assets built are in principle handed over to the respective line ministries or establishments for management and operation.

- **Ministry of Public Health:**

As previously stated in this report, based on Decree 8377 dated 13/12/1961 and Law 546 dated 20/10/2003, this ministry is responsible for licensing health institutions including hospitals and clinics. MoH is therefore indirectly responsible for healthcare waste. The ministry, through regional Health Councils, is indirectly involved in the permitting of small-scale solid waste treatment facilities. Additionally, the **Syndicate of Private Hospitals pl**ays a major role in the evaluation, classification and accreditation of hospitals, which must submit a waste management plan for licensing.

- **Ministry of State for Administrative Reform**

The Office of the Minister of State for Administrative Reform (OMSAR) is a governmental organization that seeks to develop the institutional and technical

capacities of ministries, other government and public agencies, and municipalities. Under the EU funded program *Assistance to the Rehabilitation of the Lebanese Administration* (ARLA), OMSAR launched a municipal SWM program to improve the provision of solid waste services in rural areas However; this project did not cover the Keserwan area which is the main part of Jeita catchment. It covers the Jbeil district, where it installed a waste disposal landfill at Hbaline. This facility is being currently renovated for waste treatment. It is expected to become operational in 2014.

A part of the dispensaries spread over the catchment (List in Annex 3) are under the direct umbrella of the Ministry of State for Administrative Reform. These are the health clinics including some social assistance activities (i.e Ballouneh center, …).

5.2.4 Industries and Factories

Three categories of industrial pollution were identified in the Jeita catchment.

- The first is the surface and subsurface disposal of liquid effluents loaded with organic chemicals and heavy metals, which reach groundwater through the karstic bedrock.

- The second and more widespread source of industrial pollution is from leaky underground gasoline storage tanks and the uncontrolled surface dumping of waste oils and petroleum by-products and residues.

- The third is the dumping of solid wastes resulted from industrial activities.

This section will present an overview of the industries and factories existing in the Jeita catchment highlighting their environmentally unsound practices and related groundwater contamination risks. This, with emphasis to the related actuated Lebanese national legal framework and environmental guidelines.

In addition to the building stones factories and the cement stones factories, which generate frequent turbidity problems, this part will tackle the threat generated by:

- Five factories set in the called" Daraya's industrial area,
- A Steel processing factory located in Ballouneh
- Three factories located at Aajaltoun industrial area:
- An Intravenous and dialysis solutions and medical devices manufacturing company: ALFA located in Sheileh named ALFA LABS
- Solvent using industries: dry cleans and printing factories
- Bakeries

5.2.4.1 Rock cutting and cement stones factories

Mainly dedicated to cut the large limestone blocks extracted in the local quarries, Rock saws factories process also imported blocks of rocks, e.g. marble from Italy

(e.g. at Deir Chamra). The large blocks of rocks are processed for either exterior facades or interior use of decoration stone (tiles, window sills, etc.).

Following the decision No 60/1 dated 10/9/2001, rock saws are classified as industries of class 2, which means that they are believed to present a high risk on the environment. Therefore, they can only be established in locations classified as “industrial areas” by the Landuse Planning Department.

During the field assessment, we noted that the guidelines set in decision 6/1 are not fully applied mainly concerning liquid and solid waste management as these are disposed of in the environment while collection and sale of the fine white limestone sludge as filler could generate an income able to cover all related management costs.

Dried sludge and collected filler can be sold as filler in many activities such as tiling, etc. However, it is widely illegally discharged in the environment leading to a high turbidity in surface and groundwater.

Such turbidity will hinder the adequate microbiological treatment of the water dedicated for drinking water supply. Chlorination efficiency would be largely reduced.

Figure 73: Rock saw at Raachine cutting decoration stone

Figure 74: The rocks are cut using water with the blade to avoid dust spread in the air and related disturbances to workers

Figure 75: Wastes generated by a decoration stone factory at Boqaata Achkout

Figure 76: Cleaning of rock cutting equipment needs large amounts of water leaving fine white sludge everywhere

Figure 77: Limestone sludge from rocks cutting factories dumped in the nature

Figure 78: White sludge and waste dumped from rock cutting factory into river course, Deir Chamra

Figure 79: White sludge and waste dumped from rock cutting factory into river course, Deir Chamra

Figure 80: Construction wastes generated by building stone factory in Raachine, dumped in the nature.

5.2.4.2 Cement stone factories

The hazards assessment located 16 factories for prefabricated bricks (Annex 8) in the Jeita catchment. One of them is found approx. 20 m from Nahr es Salib. All remains are dumped into the river course (Figure 81).
7 of the 16 assessed cement stones factories are located in relatively low vulnerable areas (protection zone 3b) while the other nine are at very highly vulnerable locations and therefore present a high risk on Jeita spring.

Figure 81: Prefabricated brick factory at Deir Chamra dumping waste into Nahr es Salib

5.2.4.3 Factories at the Daraya industrial zone

Following the GW vulnerability mapping, the Daraya 'industrial zone' is located in protection zone 2a, where transit time towards Jeita spring is less than 10 days and therefore must be well protected against any contamination source.

At this location, four factories are present:

- Two industrial refrigeration factories shares the same building with a polyethylene pipes fabrication unit.
- A floorcloth (floor cleaning cloth) factory
- A hunting rifle cartridges factory

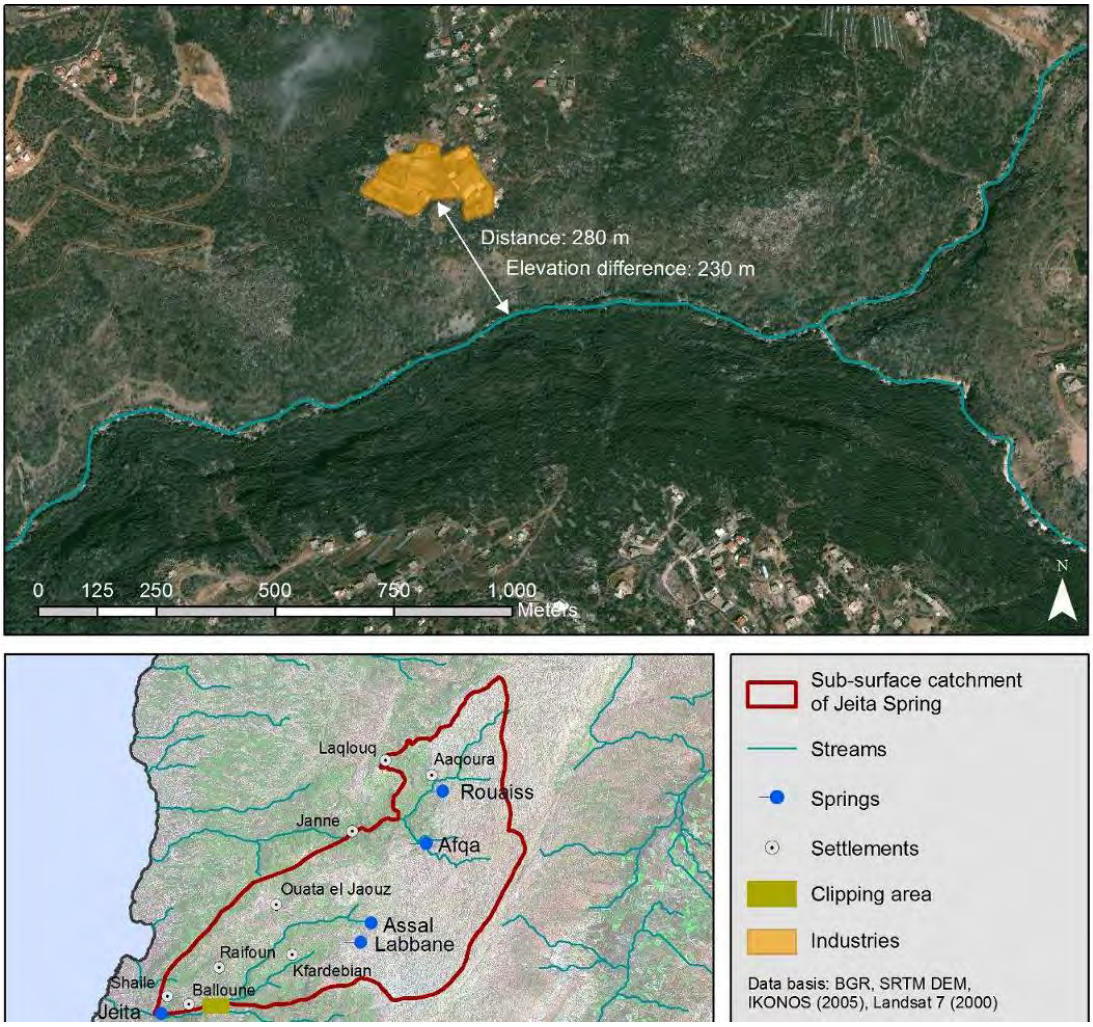

Figure 82: Google Earth snapshot and map showing the so called “industrial zone” at Daraya.

Polyethylene pipe factory and industrial refrigeration factories

The solid wastes of these three factories are spread allover the surrounding area. Environmentally unsound practices have been noted at these factories, which are set within the same building. They dispose of their liquid effluents without any prior treatment, directly in the nature, few meters from Nahr el Kalb river course.

Their wastewater is discharged in a bottomless cesspit just overlooking Nahr El Kalb valley.

These establishments were recently inspected and warned of closure by the Ministry of Environment which requested them to build a proper septic tank. However despite all, the situation did not improve. The following photos (Figure 83 and Figure 84) taken two months following the warnings reflect well the situation (nothing changed).

Figure 83: Entrance of the PE pipes factory; solid waste piled up everywhere

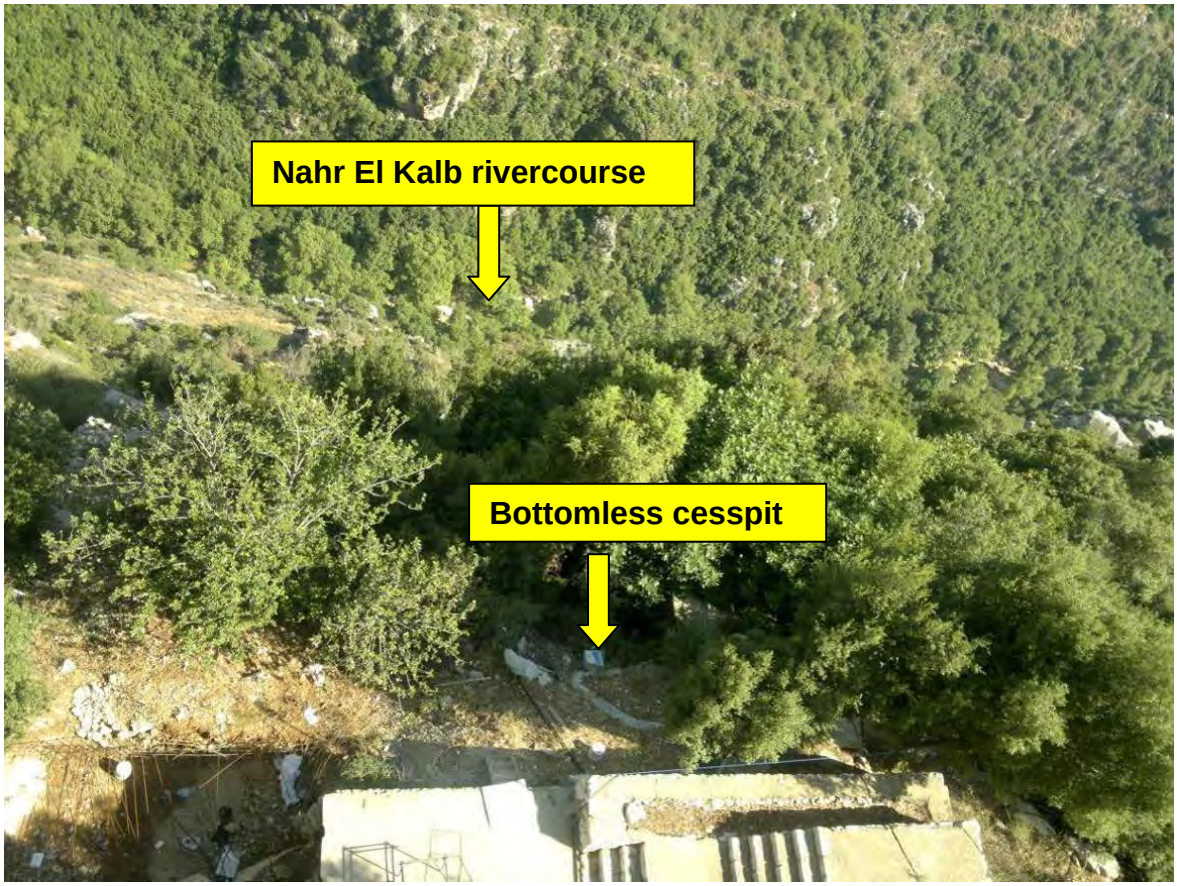

Figure 84: Cesspit where the industries (PE pipes & Industrial refrigeration) evacuate their wastewater

Figure 85: Piles of solid wastes generated by the refrigeration system factory

Figure 86: A view from inside the refrigeration systems factory

Figure 87: Empty chemicals and oils containers dumped in the nature at the Daraya “industrial” area

Figure 88: Industrial wastes dumped at municipal wastes collection bins at Daraya near the factories

National Ammunition: Hunting rifle cartridge factory

Distance to Jeita underground river= 516,13 m.

Distance to Nahr el Kalb river= 272.5 m

Despite the danger that one can assume being generated by such a factory, especially when run in a country lacking any kind of control, this establishment seems to follow sound environmental management practices concerning solid waste recycling, water management (recycling system: water collected and reused; Figure 89), and cleaning (mainly based on dry vacuum cleaning). They are also adopting in part green energy sources (wind turbines and photovoltaic systems) hoping to fully replace their actually used diesel generators by renewable energy sources.

Figure 89: Water reservoir collecting the used water for further reuse

However, most shotgun shells produced are loaded with lead balls. Thus monitoring of liquid effluent generated by this factory especially in respect of heavy metal content is necessary.

The main stakeholders for this factory are:

- The municipality of Daraya,
- The Ministry of Interior as being the entity who issued the operation permit and who can abolish it if required.
- The Ministry of Environment

The site inspection of this factory revealed the following:

Plastic and metal wastes are collected, separated and properly stored in designated bins and regularly sent to recycling facilities outside the catchment (Figure 90).

Figure 90: Solid waste collected in separate bins

Carton is used several times, until fully damaged. It is then disposed of with municipal waste as the generated quantity does not justify the cost of sending it to recycling. Used oils are used as energy source for boilers at the factory premises.

However, a major weak point was noted concerning the management of the reservoir collecting process water before recycling. Water from this reservoir was observed to flow over straight to Nahr el Kalb valley without treatment. Process water may contain heavy metals and other chemicals.

Furthermore, wastewater is collected in a three compartment septic tank (separator). Following the statement of the factory's manager, this septic tank was never emptied as it was never filled yet. *This fact suggests that it is a bottomless cesspit, infiltrating into GW rather than a septic tank*.

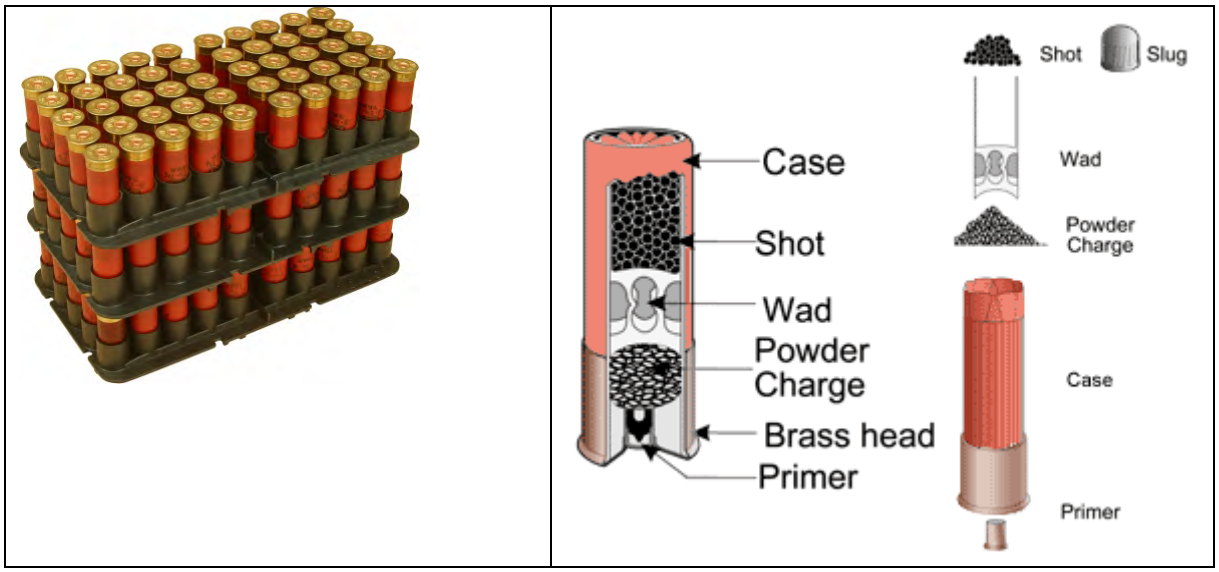

Figure 91: Hunting shotgun shell

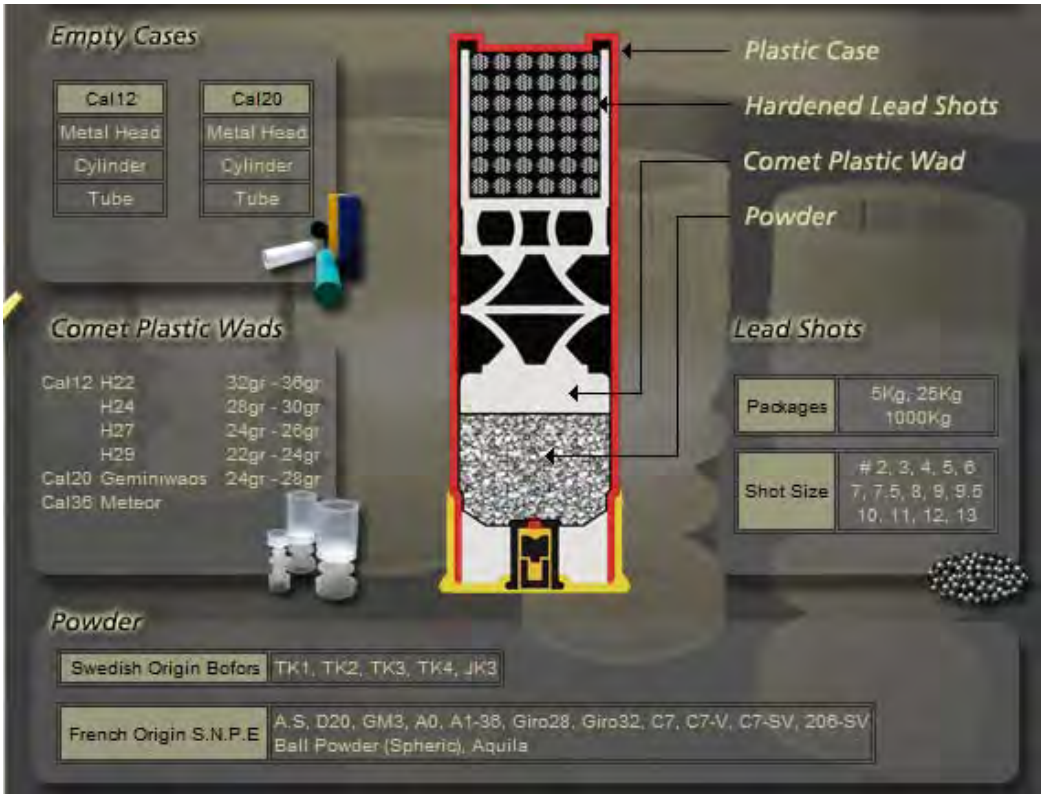

Figure 92: Components of the hunting shotgun shells produced in Daraya
Source: http://www.nationalammunition.com/Components.asp

Figure 93: Plastic wastes collected in bags and stored in a dedicated storage room ready to be sent to the recycling facility

To a question about the first materials used, the manager mentioned:
- Brass plated steel
- HDPE (high-density polyethylene)
- Gun powder (no further details of composition was provided)
- LDPE (light-density polyethylene)

Trichloroethylene (TCE) is used for cleaning of machines. Process water, leaking (mainly from the water recycling reservoir and from the cesspit) to Nahr el Kalb, may therefore contain TCE.

We note that In 2005 TCE was formally characterized by the USEPA (the United States Environmental Protection Agency) as a human carcinogen and a non-carcinogenic health hazard. A 2011 toxicological review performed by the EPA continues to list trichloroethylene as a known carcinogen EPA, 2011).

Lead used for loading the shots, may accumulate on in the surrounding soil or flushed during cleaning and may then be included in the process water as well.

5.2.4.4 Steel Processing Factory in Ballouneh - Carosserie Assad Saliba

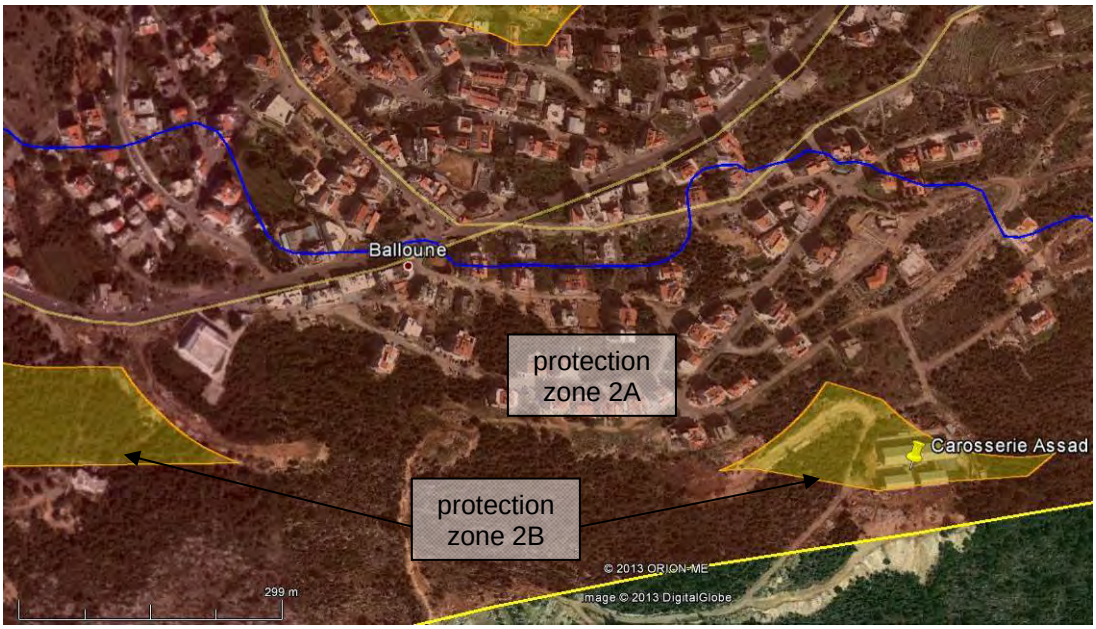

Figure 94: Location of the Carosserie Assad Saliba relatively to Jeita spring groundwater river

Established in 1979, at Ballouneh, Carosserie Assad Saliba is located in a very GW vulnerable area, assumed as protection zone 2a where similar activities must be completely banned.

The facility is a steel processing industry. It undertakes conversion of trucks and automobiles on a13,800 square meter lot with about 4,000 square meters of hangars.

It mainly manufactures fixed and tipping bodies, flatbeds, cargo boxes, water and fuel tanks, mounted on small pick-up trucks or large trucks as well as semi-trailers, in addition to manufacturing of special purpose vehicles and fire fighting vehicles.

The number of manufactured units per year: depends widely on the situation inside the country, few years ago this number exceeded 100 unit per year, while in the last two years, it was reduced to almost 20 units/ year.

Waste management is an issue to monitor and control at this establishment.

Field visit revealed that solid wastes are disposed of at a bin then incinerated at the property. Such incineration causes important GW contamination.

Main generated wastes are:

- Metals : supposed being recycled, part of them is incinerated onsite (Figure 95)
- Cartoons: used until exhausted then incinerated with other wastes

- Plastic containers and metallic (contaminated) containers of oils, paints, rust proofers, various solvents: disposed of in the neighboring environment (Figure 96)
- Waste oils: reused at the facility.
- Sand contaminated with oil spills (Figure 97): disposed in neighboring nature
- Household wastes generated by the operators at the facility are dumped in the nature at the facility neighborhood, or regularly incinerated. (Figure 98) at the open air.

Figure 95: Metallic wastes laying on a previously incinerated layer of metallic remaining, waiting for open air incineration, at the property

Figure 96: Empty containers dumped in the open air within the property

Figure 97: Sand used to contain an important oil spill

Figure 98: Household wastes dumpsite found at the facility's property

Wastewater is discharged in an open cesspit that was never emptied since 1979. Considering the position of the site upon the Jeita spring underground river, this cesspit is believed to be leaking straight to Jeita spring GW, generating an important contamination.

Liquid effluents are disposed of without pretreatment in the cesspit or in the facility's drainage system that discharges straight to the neighboring environment.

Considering the elements found onsite, this effluent probably contains **Heavy metals**, degreasers, petroleum solvents, alcohols, glycolether, volatile organic compounds, engine & radiator flushes chlorinated hydrocarbons, toluene, phenols, Hydraulic (brake) fluid dichloroperchloroethylene, Motor oil, grease, fluorocarbons, diesel, , rust proofers , transmission fluids, waste oils, paints components, silicone, etc.

Figure 59: Drainage system discharging liquid effluents into the neighboring environment

5.2.4.5 Factories Located at Ajaltoun Industrial Area.

- **Ste George Matta Aajaltoun: Furniture factory**
- United Plastic Manufacturing
- Aluminum Workshop: Generating insignificant wastes quantity due to its small size
- Silicone filling workshop: in course of relocation

Ste George Matta Aajaltoun

E: 35.690994°, N: 33.961907°, 775 alt: m asl
Groundwater protection zone: 2B
Type of facility: Furniture factory
Municipality: Aajaltoun
Owner: George Matta
Year established: Early 60s
Type of production: Wooden and steel furniture
Disposal of waste:
Solid wastes are collected by Sukleen, the uncollected part is dumped at Aajaltoun municipal dumpsite. Where wastes (Nylons, plastics, waste oils, empty containers of first materials and oils, are regularly incinerated in the open air. This illegal operation generates a higher contamination.
Treatment/disposal of wastewater:
Wastewater is disposed of in a dedicated septic system made of 3 compartments. These were never emptied, which means that they are bottomless, leaking to the GW. No industrial effluent treatment before disposal of liquid effluents in the WW system.

Main First materials used in this factory are:

- Thinner
- Hardener,
- Fillers,
- Paints,
- Glue,
- Wood,
- Steel,
- Empty containers
- Diesel and oils required for operating the private generator and heating system.

Recommendations:
Laboratory analysis of the wastewater generated at this site is recommended. This to get a figure of the contaminants generated at this location.
Once done, a proper liquid effluent pretreatment can be applied as per actuated laws.

If not pretreated, the wastewater produced will keep on contaminating the environment. If connected to a wastewater treatment plant, some untreated components might cause problems in the functioning and sustainability of the WWTP.

United Plastic Manufacturing Ajaltoun

E 35.690721 N: 33.960842
Related liquid effluents are being discharged without treatment in open cesspits, infiltrating directly to Jeita groundwater. Also, part of this factory's solid wastes were found dumped in the nature at few tens of meters above the factory, generating a significant contamination risk especially that this factory and the related dumpsite are located on a highly vulnerable GW. Contamination generated at his site would reach the drinking water supply in less than 10 days of time.

These solid wastes include tiny plastic materials

ALFA LABS: Intravenous and dialysis solutions and medical devices manufacturing in Sheileh

The field assessment revealed that this establishment includes a private gas station and two diesel generators to cover its demand of petroleum products and electricity.

Fuel and diesel related to the gas station are stored in USTs installed by United Company following a supply contract with ALFA LABS. The volume is regularly checked in these USTs and compared with the supplied and used quantities.

The wastewater of the facility is evacuated in three cesspits of which one is regularly emptied twice a year while the other two were never emptied as never filled. The only logical explanation would be that these are bottomless cesspits and therefore constitute sources of groundwater contamination by wastewater.

We note that this location falls inside recommended groundwater protection zone 2b, where GW is highly vulnerable, travel times from this location to Jeita spring is much less than 10 days.

5.2.4.4 Legal Framework

Decree 8018/2002 defined permitting procedures for all industrial establishments. Class I, II and III establishments follow a two-tier permitting process (establishment permit then operation permit) whereas Class IV and V establishments require only one permit (establishment and operation).
Between February and March 2012, the Ministry of Industry enacted several regulations in the form of decisions related to industrial permitting and based on previous industrial Laws and Decrees including Decree 8018/2002.
The industrial permitting procedure can be summarized by the following chart:

Nevertheless, it is important to note that the Minister of Industry can approve or reject a permit application regardless of the recommendation of the inter-ministerial Permitting Committee. (ECODIT 2012)

Table 16: Regulatory framework related to water resources and industries

Reference	Focus	Details	Implementation status
Decree No 642/ of June 2 1997	Creation of the MOI	Determines the role & responsibilities of MOI, mainly as responsible of the industrial sector as far as permitting, activation & development, in addition to the creation of a permitting committee at MOI.	Implemented
Decree No 5243			
Decree No. 8018 of 2002, article 20	Guidelines and Criteria for Permitting the Construction & the use of Industries)	Indicates the required distances of the industrial zones from the surface & groundwater bodies.	Non adequate legislation
Decision No. 3/1of 2000, (article 3, paragraphs 1&3), Decision No. 5/1 of 2000, (article 3, paragraph 1&3). Decision No. 16/1 of 2001, (article 3, paragraphs 1&3), Decision No. 29/1 of 2001, (article 3, paragraphs 1&3) Decision No. 61/1 of 2001, (article 3, paragraph 1&3),	Environmental Criteria to permit the construction and the use farms, dairy processing plants, plastic industries, and fruit processing plants)	Indicates water conservation methods to limit water consumption in production and cleaning in industrial settings. Examples are: dry cleaning, high pressure nozzles, & the" BATCH" method used for cleaning fruits & vegetables.	Not implemented due to the lack of enforcement mechanisms.
(General Industrial Health Criteria) Decision No. 6/1 T of 1936, appendix 2		Emphasizes the prevention of the use of wells or cisterns/tankers as sources for water supply. Instead, water should only be supplied from the public piped water network, or springs	Not implemented since the government cannot secure enough water.

Stakeholders

Main stakeholders of the industrial sector are:
- Ministry of Industry which, following decree 642/97, is responsible of issuing the permits related to the establishment of industrial activities.
- Landuse Planning Department
- Municipality and union of municipalities
- Ministry of Health
- Ministry of Environment
- Ministry of Agriculture (for food factories)
- Chamber of Industries
- Public society

5.2.4.5 Solvent using industries: dry cleans and printing factories

Solvent using industries (SUI), among others, are expanding in Jeita catchment without adequate waste management.

Currently, used solvents are sometimes disposed of improperly and thereby polluting the environment, degrading quality of related water bodies. Thereto, industries of printing & packaging, smaller printing presses, car paint shops, and dry cleans have been identified as potential pollution sources in Jeita catchment.

Two major dry cleans are located in the study area: one in Aajaltoun, the other in Ghosta. Other dry cleans are rather shops as they do not really clean the laundry at their location but just collect them and send them to the two mentioned ones or to dry cleans outside the catchment area.

Also, car paint shops were found having very limited activity in the study area and present therefore a negligible risk of hazard to JS groundwater.

Main Generated Contaminants (Chlorinated Solvents) and effects on human health

Chlorinated solvents are volatile organic (carbon-based) compounds (VOCs) that contain chlorine. In general, they have low water solubility and high volatilities and densities relative to other VOCs. They are used in dry cleaning, manufacture of foam, paint removal/stripping, metal cleaning and degreasing.

We note that these solvents also can be found in a variety of household consumer products including drain, oven, and pipe cleaners, shoe polish, household degreasers, typewriter correction fluid, deodorizers, leather dyes, photographic supplies, tar remover, waxes, and pesticides.

In this respect, to detect such contamination, major elements to be checked in groundwater are methylene chloride (dichloromethane), PCE [perchloroethylene], TCE [trichloroethylene], and TCA [1,1,1-trichloroethane].

PCE is still the solvent of choice for dry cleaners.

These solvents have been associated with both acute and chronic human-health problems. Some are suspected to be carcinogenic. They have a high water solubility that is high relative to their MCLs. This means that even small spills can result in substantial groundwater contamination problems with respect to human health (MORAN, 2005).

To protect groundwater from hazardous solvents, generated by dry cleans and little factories using solvents, such as printed textile production at Daraya which is located at a highly vulnerable location, two printing factories at Shaile, in addition to 12 trouser press at Daraoun, solvent recycling must be introduced within the concept of “Cleaner Production”. The technology transfer of solvent poses a win-win situation for industries and environment (BATSCH, 2011).

Restrictions of use of such solvents need to be imposed in the proposed GW protection zones 2 for Jeita spring.

5.2.4.6 Bakeries

One bakery is operating in Jeita spring catchment, located in Aajaltoun. Based on interviews with the bakery operators, potential related pollution risks and environmental problems during operation are displayed in Table 17.

Table 17: General hazards and environmental problems associated with the operation of bakeries

Activity	Aspects	Impacts
All activities from storage of raw materials, mixing, fermentation, baking, packaging, to sale of bread and pastries	- Use of diesel generators - Improper handling and storage of fuel - Improper disposal of used oils - Generation of liquid wastes - Generation of solid wastes	- Risks of fuel and used oils spillage - Waste dumping - Land and water pollution
Washing of floor, equipment and utensils	- Generation of liquid effluent -	- Risks of pollution of water courses by insecticides / pesticides/ rodenticides

The field assessment showed that this bakery sells the unsold and spoilt bread to swine and poultry farms of the area. Other generated wastes: e. g. plastics, jute / gunny bags and carton boxes are disposed of with the municipal wastes. The operators of the bakery insisted that insecticide,

pesticide and rodenticide treatments are undertaken by private companies who dispose of their used empty containers on their own. No wastewater reuse or treatment prior to disposal.

This is not in line with the promulgated ministerial decision No 103/1 of 2010. The latter defines the wastes generated by the bakeries and imposes guidelines for best waste management practices and water use rationalization.

To reduce their risk on groundwater, bakeries should:

- Rationalize the water use
- Minimize the generation of effluents through process and recycle wastewaters, aiming for total recycling.
- Minimize unplanned or irregular discharges of wastewater caused by equipment failures, human errors, and faulty maintenance procedures.
- Perform sound housekeeping and maintain high hygienic standards leading to significant reduction of the need for pests treatment.
- Store diesel in safe well sealed reservoirs including a leakage alarm device.
- Collect and sell used oils and avoid spills.
- Replace diesel electricity generators by renewable energy (i.e. wind and photovoltaic energy).

Considering their generated pollution risks, bakeries should not be allowed in groundwater protection zones 2. In Lebanon, bakeries should follow environmental guidelines provided in decision 103/1.

Stakeholders of this sector are:

- Ministry of Industry (Entity allocating the permit)
- Ministry of Environment
- Landuse Planning Department
- Municipality
- Ministry of Health
- Ministry of Economy and Trade
- Union of bakery owners
- Public society

Stakeholders

Main stakeholders of the industrial sector are:
- **Ministry of Industry** which, following decree 642/97, is responsible of issuing the permits related to the establishment of industrial activities.
- **Industrial Research Institute:** established in 1955, the Industrial Research Institute (IRI) is a Lebanese not-for-profit institution dedicated to industrial research and scientific testing and analysis. In 1997 linked to the Ministry of Industry, this institute provides technical assistance and advice to private industries on cleaner production methods. It includes a quite sophisticated laboratory which has to date earned accreditation for more than 300 testing methods used in a dozen lab units. In terms of staffing, IRI has about 127 people, 50 percent of which work in the lab.

- **Chamber of Industries**
- Landuse Planning Department
- Municipality and Union of Municipalities
- Ministry of Health
- Ministry of Environment
- Ministry of Agriculture (for food factories)
- Public society

5.2.5 Contamination by Petroleum Products and By-products

The most widespread source of industrial pollution is from leaky underground gasoline storage tanks and the uncontrolled surface dumping of waste oils and petroleum by-products and residues (EL-FADEL, 2002).

The latter are generated by gas stations (detailed in Technical Report No. 7, RAAD & MARGANE, 2012) residential heating systems (infrastructure and diesel storage) and by diesel and fuel generators used to produce private electricity to compensate for insufficient electricity coverage in Lebanon.

While generators intended to produce electricity to be sold to the public are subject to permits issued by the Ministry of Environment, private residential generators and residential heating systems do not follow any specific permitting requirements.

The field assessment showed that an anarchic disposal of used oils in the wastewater or in the environment is common practice in the study area, added to bad maintenance of diesel storage facilities.

5.2.5.1 Residential Heating Systems and Storage Facilities

Residential heating oil storage tanks have been installed and widely used in Lebanon especially in the last 15 years in the mountainous areas. There are

two types: aboveground tanks (typically found in basements or outside of a home) and underground tanks (buried).

Underground storage tanks are a major concern because they are a potential source of contamination of soil and groundwater as leakages are often not noticed. They also pose a fire and explosion hazard under certain conditions.

Also, leaking pipes are commonly detected, and sometimes not repaired in such heating systems. This in disregards of the danger they generate. The high number of oil storage tanks and the general negligence with regards to leakages poses a severe risk to the groundwater resources. The danger of groundwater contamination in this case is increased by the presence of wells and boreholes in residences, easing the direct transfer of the contaminants to groundwater.

Figure 100: Observed diesel leakage from diesel reservoirs related to residential heating system at Raifoun

Figure 101: Leaking residential diesel heating system

5.2.5.2 Generators

Diesel generators are a major source of pollution in Lebanon and they are growing in capacity and number every year especially in the absence of a continuous provision of electricity by the Lebanese government. Now would be an ideal time for regulators and industry to pursue strategies to advance the generation of clean renewable energy, such as from wind, water and sun.

Following an assessment of the operational practices of generators in the Jeita spring catchment, we can state that in the villages where there are no large generators selling electricity to individuals, residences are furnished with smaller private ones in a way to ensure a continuous energy supply.

Operating generators of important size require a permit following environmental guidelines set by the Ministry of Environment (Circular 10/1 dated on 21/4/2011 related to the operation of electricity generators). However, these guidelines attributed little consideration to monitor the related diesel storage and to impose penalties on operators who discharge or spill their used oils in the nature.

The main considered issue is the noise and air pollution, while groundwater resources protection is lacking in control measures and guidelines as well. Generators operation is mainly under the authority of the municipality and the Ministry of Environment. MoE provided some (lacking) environmental guidelines and opened the way to the public to present claims in case of disturbances related to excessive noises or gas emissions.

The field survey showed that when generators are being operated directly by their owners (not by workers), they are well maintained, and fewer spills are observed in their surroundings. Nevertheless, we noticed a severe lack of environmental awareness at the level of all operators. They usually discharge the used oil directly in the nearby soil or in the wastewater of their residence or in stormwater drainage of their building, leading to groundwater contamination.

The assessed generators are illustrated in Table 18. In this table, empty cells correspond to villages where each residence or building possesses its own generator, in absence of generators selling electricity to the public. In this case the generated contamination is more diffuse and widespread and also more difficult to assess and to control.

We also note that even in the villages where there are generators selling electricity to the public, many residences operate private generators as well.

Table 18: Distribution of diesel generators dedicated to private electricity vendors in Jeita catchment

Municipality	Number of Generators	Number of Inhabitants	Number of Residences
Achqout	5	7500	2500
Afqa		2000	100
Ain ed Delbe		600	130
Ain el Ghoueiby		250	30
Aajaltoun	7	2500	1000
Akoura	2		
Boqaata Achkout	2		
Bokaatet Kanaan		650	150
Bqaatouta		1800	200
Bzoummar	1	3000	1000
Chahtoul		2000	600
Daraya	1	1600	200
Der Chamra			
Dlebta	2	3000	400
Eghbe			
Faraya	4	5000	2500
Faitroun	2	7000 winter /12000 summer	3500
Ghebet		700	72
Ghosta	3	4000	1200
Harissa-Daraoun	6	5000	2000
Hayata		850	150
Hrajel	4	11000	13000
Janneh		438	35
Jeita	13	5000	1200
Kfar Debbiane	9	12000	5000
Kfartay		350	50
Qorqraya		50	25
Laqlouq		3000	1300
Lassa		3000	250
Marj Baskinta			
Mayrouba	2	2500	1000
Mghayra			
Nahr El Dahab		1000	150
Qehmez		1500	240
Qleyaat	4	5000	2700
Raashine			
Raifoun	2	1000 winter / 5000 summer	

Municipality	Number of Generators	Number of Inhabitants	Number of Residences
Saraita		660	60
Shaile	10	5000	1200
Wadi el Qarm		550	50
Yanouh		2000	250
Zabougha		600	130

Source= Field assessment

Figure 102: Well maintained private generator

Figure 103: Surrounding of a generator used to sell electricity the public: oil spills, leakages and contaminated solid wastes

Figure 104: Improper storage of used oils at a generator dedicated to sell electricity to the public

Figure 105: Diesel leakage from a generator

Figure 106: Oil and diesel spills surrounding a diesel generator in Aajaltoun

5.2.5.3 Touristic and recreational resorts

In these resorts we find in general diesel reservoirs of significant size, they always include a gas station with USTs, or vehicles repair workshops, adding to this high risk of groundwater contamination by petroleum product, the pollution generated by their unsound sewage management, in absence of a wastewater collection and treatment system.

The field assessment and the groundwater vulnerability study in the catchment (MARGANE & SCHULER (2013) noted the following major risks to: Presence of a number of hotels and resorts within protection zone 2 mainly of Labbane and Assal springs. Inducing infiltration risks of wastewater and heating oil from storage tanks and spills.

There are two main ski lift stations in the Assal catchment: Wardeh (also called Domaine Wardeh) and Aayoun es Simane (also called Domaine Jonction). At the Aayoun es Simane ski station there is a gas station and repair workshop for the machinery required for skiing and lifts operations. The Aayoun es Simane ski lift station is located on the boundary between the Labbane and Assal GW catchments, both in protection zones 2, while the

Wardeh lift station is located in protection zone 2 of Assal spring. Both present infiltration risks of: wastewater (from toilets and restaurants), fuel from storage tanks and oil from the repair workshops.

Figure 107: Residential area overlooking Assal spring

There are several skidoo and quad bike rentals in Aayoun es Simane and along the road to the Wardeh parking. Another skidoo rental is located on the road passing close to Labbane spring. Most of them have their own repair workshop on site. There is a high risk of infiltration of fuel from storage tanks and oil from the repair workshops. Rentals must be informed about the risk and regular inspections are necessary to avoid contaminations.

According to our knowledge there is no fuel storage at the Wardeh ski lift station, but there is oil storage for heating. Also, there is a repair workshop at Aayoun es Simane for all machinery used for ski lift operations, as well as several skidoo and quad bike rentals, partly with workshops and probably with unlicensed fuel storage. There is a gas station located at the Aayoun es Simane ski lift station, storing an unknown amount of fuel. Infiltration of fuel and oil into groundwater from these points is therefore considered a high pollution risk.

A restaurant is located very close to Assal spring and water distribution system. The restaurant must be inspected to ensure that no pollution risk emanates from it.

It must be ensured that no surface water can drain from the area upstream towards the spring, especially from the buildings and the road south of it (distance only 140 m; Figure 107).

According to the groundwater vulnerability map, the entire catchment of Labbane spring is classified as very highly vulnerable. Therefore, the entire groundwater catchment of Labbane spring must be declared as groundwater protection zone 2 (MARGANE & SCHULER, 2013).

The following pollution risks must be addressed:

Wastewater: The collection of wastewater at Aayoun es Simane must have highest priority. The nearest buildings are located only around 300 m distant from Labbane spring. Therefore the pollution risk by infiltrating wastewater is very high.(Figure 108)

Hotels: It is highly recommended not to allow building of new or extensions of existing hotels with more than 20 rooms in zone 2. They should be built only downstream of the GW catchments of Assal and Labbane, i.e. in protection zone 3 of Jeita spring.

Restaurants: new restaurants should not be allowed unless they are connected to the new wastewater collection system. A wastewater collection system must be installed for all existing restaurants using closed septic tanks. These septic tanks must have a sufficiently large holding capacity to accommodate all wastewater occurring during winter and be regularly emptied after the winter season. The untreated wastewater must be brought to a designated location by an authorized company.

Ski lift stations: It is also recommended not to allow building new or extensions of exiting ski lift stations unless environmental impact assessments (EIAs) have been prepared proving that negative impacts on water resources (groundwater and surface water) cannot occur. An EIA should be undertaken for the existing ski lift stations; these stations should be upgraded implementing constructional changes so that negative impacts on water resources (groundwater and surface water) cannot occur.

Skidoo and quad bike rentals: No new or extensions of existing skidoo and quad bike rentals should be allowed. The existing skidoo and quad bike rentals should not be allowed to store fuel or undertake repairs on their premises. Repairs should be done outside protection zones 2 of Afqa, Assal, Labbane and Rouaiss spring catchments.

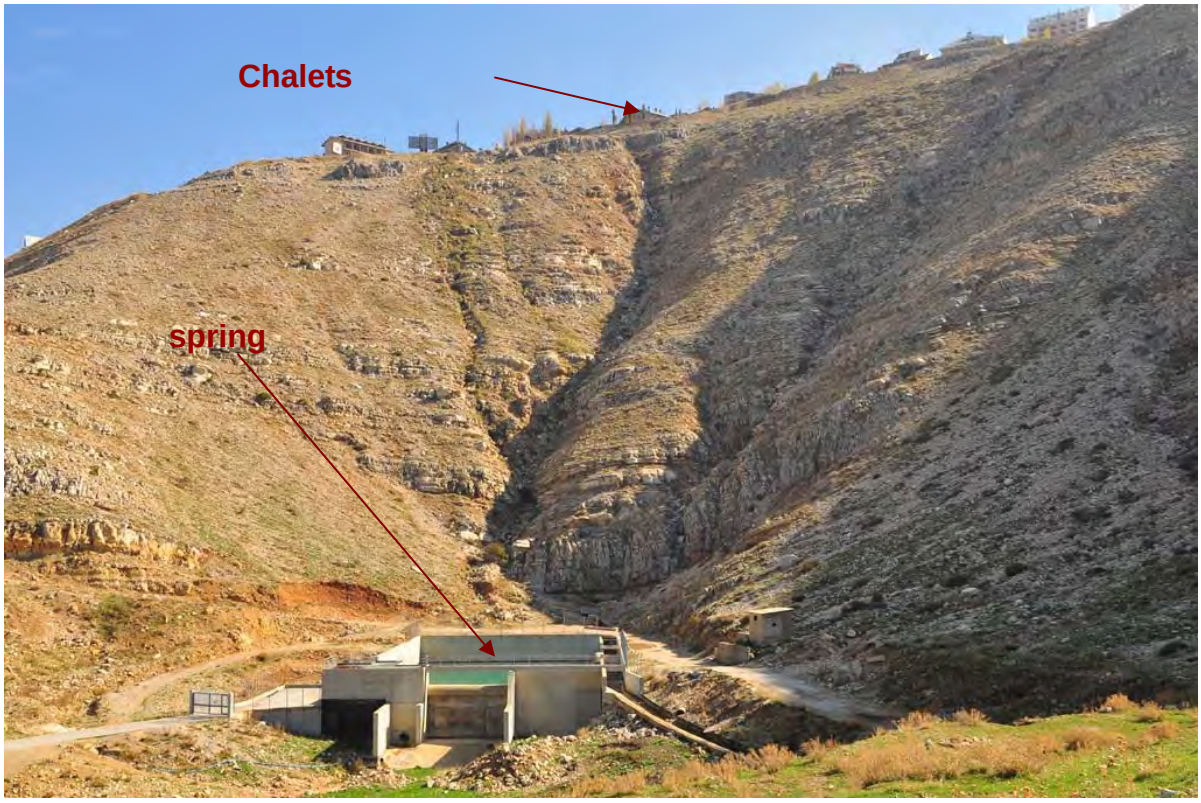

Figure 108: Chalets upstream of Labbane spring

5.2.5.4 Vehicles reparation workshops

Often operating without permits, these workshops present a risk of groundwater contamination mainly due to spills of used oil, solvents, acids, grease, anarchic disposal of solid wastes (empty containers, spare parts, etc.).

We gladly note that used batteries are not disposed of in the environment but rather kept and sold for recycling.

Figure 109: Car repair workshop showing major oil spills outside and big amount of solid wastes outside

Vehicle repairs should be done outside protection zones 1 and 2 of Jeita, Afqa, Assal, Labbane and Rouaiss spring catchments, and in the remaining part of Jeita catchment, they must be forced to adopt best management practices preventing anarchic disposal of liquid and solid wastes and insuring proper storage of used oils and old batteries that are to be sent to certified entities for recycling. Used spare parts should be brought to a collection point to be specified by the municipality. From there they should be transferred to a specialized scrap yard.

5.2.6 Wells

Currently no inventory of wells exists in Lebanon. The UNDP project *Lebanese Center for Water Management and Conservation (LCWMC)* is in the process to establish a database of all wells in Lebanon, however, it will take years to compile such a consolidated archive containing all relevant borehole information. The connections established by a borehole between land surface and groundwater can be a potential pathway for contaminants and thus lead to groundwater contamination. Normally at the land surface well heads are protected against infiltration by a raised concrete platform. Casing and backfill also provide a protection against infiltration. Drinking water supply wells are normally protected by a perimeter of at least 10 m to all sides surrounded by a fence. Abandoned wells are normally filled and plugged by concrete. All the above mentioned measures to avoid contamination are not

practiced in Lebanon, not even for drinking water wells. At the level of the Water Establishments there is a serious lack of understanding for such required protective measures.

More wells are being continuously drilled to meet the increasing demand for water, which makes it difficult to estimate their number. Besides the production wells constructed and operated by official agencies or public sector organizations, there are numerous private sector wells. These are generally shallow, mostly less than 100 m in depth with a yield of about 50-80 m³/day. Well construction by the private sector has increased considerably since 1975 due to the breakdown of public services for the delivery of water during the period of civil war in Lebanon.

In Jeita catchment as in the whole country, wells are commonly illegally drilled, without any kind of environmental consideration. For example, we mention having assessed at Marj Baskinta the presence of a drilled well for groundwater abstraction at 50m distance from a gas station. Thus, this well is located at insignificant distance of the USTs where hydrocarbons are stored and leakage may occur, generating a high risk of groundwater contamination by hydrocarbons.

More than 50 unlicensed wells were reported in Boqaata and Wata el Jaouz.

A well dedicated to sell water to the public is operated at KARAM gas station, in Ballouneh,

Furthermore, a quick look to the village of Ain ed Delbe emphasis that in this village of only 130 residences one can find at least 15 wells. Knowing that these residences evacuate their wastewater into cesspits, one can easily assume having a high risk of wastewater contamination in such conditions.

Improperly abandoned wells can act as a conduit through which contaminants can reach groundwater if the well casing has been removed, as is often done, or if the casing is corroded. In addition, some people use abandoned wells to dispose of wastes such as wastewater and used motor oil. These wells are a potential direct pathway for contaminants.

Poorly constructed irrigation wells can allow contaminants to enter groundwater too. Often pesticides and fertilizers are applied in the immediate vicinity of wells on agricultural land so that irrigation return flows will reach the wells.

Figure 110 shows the negligence towards wellhead protection from contamination. In Mokhada a water supply well is located less than 1 m from a highly frequented public road with no protection whatsoever against infiltration of stormwater from the road or even intentional pollution.

In July 2012 we observed the drilling of a private well in Ballouneh, directly over the underground river of Jeita, maybe even penetrating the cave. The well was intended for water supply to subsequently built greenhouses (Figure 111).

Figure 110: Drinking water well at Mokhada: without protection against contamination

Figure 111: Private well drilled in July 2012 in Ballouneh for water supply to greenhouses directly over the underground river of Jeita

5.2.6.1 Legal framework related to wells

The Lebanese government must enforce the licensing of wells by imposing heavy penalties for violations in order to reduce construction of new illegal wells.

While decree No. 14438 of 2 May 1970, articles 2, 11, 16 limited the permit of groundwater abstraction to 4 years, and included the purpose of use (domestic, agricultural, or industrial), it was not severely enforced due to the inability of the government to secure water supply.

Old well permits, relying on decree No. 14438 mention the maximum allowable daily extraction volume and impose the installation of abstraction metering devices at the well head. However, due to lack of staff and capacities at the Ministry of Energy and Water is not enforcing this decree and neither controlling nor monitoring the extracted quantities. The government lacks an effective mechanism to enforce existing regulations and permits for drilling wells and maintaining the appropriate distances between wells and springs.

Legislation related to well construction and operation is presented in Table 19.

Table 19: Legal framework concerning well construction and operation in Lebanon

Reference	Focus	Details	Implementation status
(Management of Water Abstraction and its Use) Decree No. 14438 of 1970, articles 2, 11, 16	Water allocation (water abstraction)	Emphasizes the necessity of obtaining a 4-year permit for groundwater abstraction and:drilling boreholes exceeding 150 m of depth. The permit should also include the purpose of use (domestic, agricultural, or industrial). It also regulates the granting or the exemption of the prospecting permit.	Not totally enforced due to the inadequacy of the law given that the government cannot provide secure water resources.
(Management of Water Abstraction and Its Use) Decree No. 14438 of 1970, article 9	Water tariffs	Indicates the annual fees for water abstraction in public (1,000,000 LL/yr) or private (500,000 LL/yr) properties. This also includes the cost of property damage and the cost of utilizing the property.	
(Management of Water Abstraction and Its Use) Decree No. 14438 of 1970, article 15	Water tariffs (agriculture and industry)	Indicates the annual rates per 1 m^3 of the total amount of water licensed for irrigation (100 LL/m^3), and industrial activities (600 LL/m^3). This may also include the cost of damage of the property.	

Reference	Focus	Details	Implementation status
(The Law of Penalties) Legislative decrees No. 340 of 1943, paragraphs 745-749	Sanctions	Imprisonment of those who executed any offensive activity, such as unauthorized drilling, pollution of water sources, etc., penalties.	Partly implemented
Art. 6 of Decree 320/26	Limit the use of groundwater	defines specific legislation concerning the use of groundwater	Partly implemented

No code is useful without enforcement provisions. Foremost is the enforcement of payment of charges, tariffs and penalties by the users. Enforcement of issues related to groundwater, such as well-logging (providing a lithological log after well completion, including geophysical log as evidence) and issuance of licenses for well drilling, must be stressed.

5.2.7 Healthcare Sector: Hospitals and Healthcare Clinics

Lebanon is still considered as one of the countries that lack adequate and well-operated infrastructure for management and disposal of healthcare wastes. As a result, unresolved environmental problems has been accumulating for years now, which lead to major issues such as : 1) Increased air pollution due to indiscriminate burning of the medical waste; and 2) water and soil pollution due to inappropriate disposal of health care effluents and wastes (SWEEP-NET, 2010).

In addition to healthcare wastes, the environmental impacts of healthcare establishments are associated with energy use (generation of electricity and heating for buildings, vehicles, fuel storage), water use, procurement and household waste generation (non-clinical waste). This section will focus on the disposal of clinical waste as this constitutes a significant risk to Jeita spring groundwater, since other kinds of wastes are fully detailed in other sections of this report.

Major sources of healthcare waste in Jeita catchment are: hospitals, clinics, laboratories, and mortuaries; While minor sources are physician's office, dental clinics, pharmacies, elderly nursing homes, etc.

Healthcare waste (HCW) is defined as the total waste stream from a healthcare facility (HCF). 75-90% of it is similar to domestic waste. This fraction, referred to as healthcare general waste (HCGW), constitutes of paper, plastic packaging, food preparation, etc. that haven't been in contact with patients (WHO 1999). 10-25% is infectious/ hazardous waste that requires special treatment. This fraction is referred to as healthcare risk waste (HCRW). If these two basic categories of waste aren't separated properly, the entire volume of HCW must be considered as being infectious according to

the precautionary principle, hence the importance of setting up a safe and integrated waste management system!

Following the risks they can generate, hazardous Healthcare wastes WHO classifies them in 10 categories.

5.2.7.1 Categories of HCRW

The hazardous fraction of HCW (10-25%) is usually classified into the following waste groups (WHO 1999):

1-Infectious waste

All wastes that are susceptible to contain pathogens (or their toxins) in sufficient concentration to cause diseases to a potential host are considered as infectious waste, e.g. discarded materials or equipment, used for the diagnosis, treatment and prevention of disease that has been in contact with body fluids (dressings, swabs, nappies, blood bags…). This category also includes liquid waste such as faeces, urine, blood or other body secretions (such as sputum or lung secretions).

2-Pathological and anatomical waste

Pathological waste consists of organs, tissues, body parts or fluids such as blood. Even if pathological waste may contain healthy body parts, it has to be considered as infectious waste for precautionary reasons.

Anatomical waste is a sub-group of pathological waste and consists of recognizable human body parts, whether they may be infected or not. Following the precautionary principal, anatomical waste is always considered as potential infectious waste.

3-Hazardous pharmaceutical waste

Pharmaceutical waste includes expired, unused, spilt and contaminated pharmaceutical products, drugs and vaccines. In this category are also included discarded items used in the handling of pharmaceuticals like bottles, vials, connecting tubing. Since the Ministry of Health has taken specific measures to reduce the wastage of drugs, HCFs should deal only with small quantities of pharmaceutical waste.

This category also includes all drugs and equipment used for mixing and administration of cytotoxic drugs. Cytotoxic drugs or genotoxic drugs are drugs that have the ability to reduce/stop the growth of certain living cells and are used in chemotherapy for cancer. Cytotoxic waste is dealt with under a separate heading.

4-Hazardous chemical waste

Chemical waste consists of discarded chemicals (solid, liquid or gaseous) that are generated during disinfecting procedures or cleaning processes. They may be hazardous (toxic, corrosive, flammable…) and must be used and disposed of according to the specification formulated on each container. Nevertheless non-explosive residues or small quantities of outdated products may be treated together with infectious waste.

5-Waste with a high content of heavy metals

Waste with high contents of heavy metals and derivatives are potentially highly toxic (e.g. cadmium or mercury from thermometers or manometers). They are considered as a sub-group of chemical waste but require specific treatment.

6-Pressurized containers

Pressurized containers consist of full or emptied containers or aerosol cans with pressurized liquids, gas or powdered materials.

The last four categories (7-10) are considered as highly hazardous and therefore require special attention:

7-Sharps

Sharps are items that can cause cuts or puncture wounds (e.g. needle stick injuries). Whether they are infected or not, sharps are considered as highly dangerous and potentially infectious waste. They must be segregated, packed and handled specifically within the HCFs to ensure the safety of the medical and ancillary staff.

8-Highly infectious waste

Highly infectious waste consists in microbial cultures and stocks of highly infectious agents from medical analysis laboratories. They also include body fluids of patients with highly infectious diseases.

9-Genotoxic / cytotoxic waste

Genotoxic waste derives from drugs generally used in oncology or radiotherapy units that have a high hazardous mutagenic or cytotoxic effect. Faeces, vomit or urine from patients treated with cytotoxic drugs or chemicals should also be considered as genotoxic, their proper treatment or disposal raises serious safety problems.

10-Radioactive waste

Radioactive waste includes liquids, gas and solids contaminated with radionuclides whose ionizing radiations have genotoxic effects. The ionizing radiations of interest in medicine include X- and γ-rays as well as α and β

particles. An important difference between these types of radiations is that X-rays are emitted from X-ray tubes only when generating equipment is switched on whereas γ-rays, α and β particles emit radiations continuously.

The type of radioactive material used in HCF results in low level radioactive waste. It concerns mainly therapeutic and imaging investigation activities where cobalt ^{60}Co, technetium ^{99m}Tc, iodine ^{131}I and iridium ^{192}Ir are most commonly used.

With the noticeable exception of Cobalt ^{60}Co, their half-life is reasonably short (6 hours for ^{99m}Tc, 8 days for ^{131}I and 74 days for ^{192}Ir) and the concentrations used remain low. A proper storage with an appropriate retention time is sufficient to prevent spillage of radioactivity to the environment.

5.2.7.2 Sources of Healthcare Wastes in Jeita catchment

Within Jeita catchment the field assessment revealed the existence of one operating hospital (Saint Georges Hospital) located in Aajaltoun, one nursing home for the elderly located at Shaile, and 19 dispensaries:

Saint George Aajaltoun Hospital

Located in proposed protection zone 2b (where hospitals should not be allowed), any contaminant generated by this hospital will reach Jeita waters within less than 10 days of travel time. Therefore it is currently generating a high contamination risk to the major source of the drinking water supply for the Greater Beirut Area.

Fortunately, following the Ministry of Environment's efforts and by the assistance of a European grant, Potentially Infectious Medical Waste (PIMW) is collected from Aajaltoun hospital (as from many others in the country) and safely treated by Arc En Ciel. But the problem of disposal of untreated laboratory and other liquid wastes (listed hereafter), in addition to the problem of radioactive wastes remain to be addressed at this location. Wastes that are treated in the autoclave by Arc En Ciel are:

- Needles, catheters,
- Single use fields
- Compresses, spittoons,
- Disposable gloves, disposable material,
- Laboratory equipment (petri dishes, cultures, swabs, slides, culture media, pipettes, etc.)
- Dialysis membranes, bandages
- Anatomical parts, irrigation and drainage pockets, blood, urine, biological samples,
- Syringes, various sensors, tubes,
- Infusion sets, glasses that contained blood or secretions

Are also considered medical waste in the absence of infection risk wastes that fall into one of three categories:

- quills materials, cutting edges to be discarded,,
- blood products not fully used or expired,
- human or animal anatomic wastes

We note that when non-infectious waste is mixed with medical waste they themselves become infectious wastes. However, waste separation is more or less carried out with care at the hospital, especially that Arc en Ciel charges for this waste based on the weight (per Kg) of PIMW treated.

The Potentially Infectious Medical Waste (PIMW) collection and treatment is carried out by Arc en Ciel (Figure 112) taken at a healthcare wastes treatment unit at Sin el Fil.

Figure 112: Potentially infectious medical waste collected at the hospital in special yellow bags and filled in dedicated carts, which are transported in closed trucks carrying alarm signs

The following PIMWs are not treated by Arc en Ciel:

- Chemicals and laboratory solutions (mercury, formaldehyde ...)
- Mercury thermometers
- Cytotoxic and expired medicines
- Radioactive waste
- Recognizable organs
- Batteries, accumulators
- Oils, fats and of course all the assimilated waste to household waste

The project has tried to assess the waste management practices at Aajaltoun hospital in order to check how the PIMWs that are not treated by ARC en Ciel are disposed of, however, the responsible of this hospital refused to collaborate or to provide any related information.

Informal field investigation showed that this hospital:

Discharges its liquid effluents (Chemicals and laboratory solutions, cytotoxic and radioactive effluents) etc., without any prior treatment into its sewage system. The latter relies on a septic tank, which is regularly (?) emptied by private tankers who dispose of the content in the neighboring environment due to the absence of a nearby treatment plant designated to receive it.

Mercury thermometers are, in addition to empty oil containers, disposed of with municipal waste, generating a significant potential danger to the public health.

Recognizable organs that are not collected by Arc en Ciel are of insignificant quantity and are incinerated inside the hospital.

Disposal and storage of radioactive solid waste is still unclear, due to contradictory information, stating from a side that these are stored at closed areas, while others assure that these wastes are buried in the environment.

When chemical and pharmaceutical waste is disposed of in unlined dumpsites or in unlined pits, they may contaminate ground and surface water, particularly when large quantities are disposed of.

Major threats from improper waste handling at Saint Georges Aajaltoun hospital are believed to be chemical and toxic threats through chemical and pharmaceutical exposure.

This can threaten citizens in the Greater Beirut Area who use the water for drinking, bathing and cooking; in addition to damaging plants and animals in the local ecosystem.

In addition to illegal dumping, burning or incinerating of healthcare waste, may create additional problems, as it produces toxic air pollutants, dioxins and heavy metals, distributed over a wide area. Dioxins are believed to be potent carcinogenic agents. They do not biodegrade, and accumulate in progressively higher concentrations as they move up the food chain.

Heavy metals such as mercury and cadmium are toxic and/or cause birth defects in small quantities and can also concentrate in the food chain. Finally, disposable pressurized containers pose another hazard for incineration, as they can explode if burned.

In short, current adopted wastes incineration and disposal of large quantities of untreated hazardous chemicals and pharmaceuticals is a serious problem, especially considering the high groundwater vulnerability in the area of the Aajaltoun hospital and the importance of this vital GW resource.

Serious Environmental Mitigation and Monitoring of waste management are urgently needed at Saint Georges - Aajaltoun hospital.

Public dispensaries

As secondary sources of healthcare wastes, the field assessment in Jeita catchment identified 19 operating public dispensaries (listed in Annex 5), army healthcare unit located in each barrack, in addition to dental clinics and pharmacies.

Most public dispensaries dispose of their waste without any treatment, with the municipal wastes. Luckily, their activities are in most cases limited to medical consultations while major interventions are in general carried out at the hospitals. At this level, the main generated contamination would be due to expired pharmaceuticals disposed of with municipal waste, or illegally dumped in the nature.

There is an alarming lack of awareness at the level of the dispensaries and pharmacies that, unless clinical waste is properly segregated, handled, transported and disposed of, it can present a severe risk to the public health and to the environment.

Major attention must be allocated to the wastes management practices at dispensaries including γ-rays, dental clinics and conducting operations (even minor ones).

An alarming presence of “Benzoylecgonine” in surface water and Jeita groundwater was observed in 2010 and 2011. According to DOUMMAR et al. (2012) benzoylecgonine (metabolic is introduced in surface water (Nahr El Salib) at the level of Hrajel village. In addition, Iodinated X- ray contrast media (widely used in practical surgery) and one of the typical associated products, iopamidol, was found in wastewater Hrajel, Nahr El Salib river and Jeita spring, indicating discharge of contrast media with wastewater from healthcare establishments.

We note that Hrajel and Kfar Debbiane have both dispensaries conducting laboratory analysis of urine and blood, in addition to a dentist, minor operations and x-rays,

Solid infectious wastes are sent by Hrajel dispensary to Arc en Ciel for treatment, while laboratory effluents are disposed in the wastewater network (which is actually discharging in the nature without any treatment). X-rays wastes are kept in plastic bags in a separate room.

5.2.7.3 Legal framework

Lebanon has ratified two international conventions dealing with hazardous wastes: the Stockholm convention on persistent organic pollutants and the

Basel Convention on the control of transboundary movements of hazardous wastes and their disposal.

In the past years, the Ministry of Environment tried to reduce the discharge of contaminating healthcare wastes in the environment.

The decree law setting guidelines related to the healthcare public clinics dates back to 1955. It does not include any guideline related to waste management in the clinics. In this respect, MoE has issued a ministerial circular (No 4/1 dated October 9, 2003) addressed to all healthcare institutions urging them to respect law 444 related to the protection of the environment and decree law No. 64/88 (Preservation of the environment from pollution generated by hazardous wastes and dangerous materials) and amended the decree 8006, dated June 11, 2002, which forces healthcare establishments to sterilize the Potentially Infectious Medical Waste they generate, and issued decree law 13389, dated September 30, 2004. The latter specifies healthcare waste categories and sets guidelines for health care waste management. However, these institutions did not abide to mentioned laws and guidelines. Thus, in September 2008, the minister of environment issued a new circular urging these institutions again to follow the required rules and guidelines.

Decree No. 8006 (issued in 2002), on hospital waste requires in Article 1 that an EIA should be undertaken for collection and disposal of medical waste before any construction. The enforcement of this article is highly recommended to protect Jeita spring from pollution by related waste.

Actually, if it was applied, none of the existing healthcare facilities located in protection zone 2 would be allowed. And those located in protection zone 3 would be subject to severe monitoring of practices mainly related to their waste (liquid and solid) management (storage and disposal). However, currently this sector is still far from being controlled.

5.2.7.4 Recommendations

A detailed assessment of the Environmental impact of healthcare facilities is urgently required in Jeita catchment All healthcare facilities must be forced to cooperate with MoE and provide a waste and wastewater management plan. A supervision and control of its implementation is needed, if not possible by MoE then by an environmental NGO. An active mitigation of environmental impact related to existing healthcare institutions is vital for avoidance of Jeita spring contamination. Permitting for new hospitals, dentists clinics, pharmacies, medical clinics and elderly nursing houses must be limited to proposed GW protection zone 3 of Jeita spring.

5.2.8 Cemeteries

Cemeteries constitute an indispensable use for urban settlements. If located in highly vulnerable sites, depending on the form of burial and the subsequent practices, the cemeteries burial areas can threaten the environment, polluting groundwater.

The mostly used systems to burry corpses in the Jeita catchment can be divided in two categories:

- In Christian villages: The dead body is contained in a wooden coffin then placed in a niche, at specific constructed superposed niches. Then several years later, after the body's decomposition, the remaining of the bones is emptied in the related cemetery's crypt.
- In Islamic villages (Afqa and Lassa) the dead body is buried directly in the ground without a casket. In such cases, the decomposition of the corpses create potentially polluting substances (USLU et al, 2009).

  Table 20 points out the annual potential releases from the burial of a single corpse progressively throughout the first 10 years following burial.

Table 20: Example annual potential releases from a single human burial (FOGLI, 2004)

Year	Potential Mass Releases (g)					
	C	NH4	P	SO4	Cd	Ni
1	6000	870	250	210	0.01875	0.00375
2	3000	435	125	105	0.009	0.002
3	1500	217.5	62.5	52.5	0.005	0.001
4	750	108	31.3	26.3	0.002	0
5	375	54.4	15.6	13.1	0.001	0
6	187.5	27.2	7.8	6.6	0	0
7	93.8	13.6	3.9	3.3	0	0
8	46.9	6.8	2	1.6	0	0
9	23.4	3.4	0.98	0.82	0	0
10	11.7	1.7	0.49	0.41	0	0

According to FOGLI (2004), the cemetery utilizing inhumation is comparable to the effects on the environment to a dump of organic matter in the soil and in the surrounding strata". Adding to this, the potential contamination by corpses submitted to embalming processes using preservatives containing carcinogenic formaldehyde.

In terms of groundwater protection, the best would be to have a superficial soil that is melted and porous and beneath, a stratum of cllay which would prohibit the infiltration of the cadaverous liquid towards the groundwater.

The best way to avoid GW contamination is to locate the cemetery at a large enough distance from water courses (at least 100 meters), from wells (at least 200-250 meters according to the regulations in different developed countries) from drainages of cultivated fields (at least 10 meters). Cemeteries should principally not be located in GW protection zones 1 and 2. However, this will not be possible to implement in the groundwater catchment of Jeita. It is recommended to prepare EIAs for all cemeteries in Jeita catchment .

Majors, planners, cemetery managers and citizens are called to act with more responsibility towards their environment. Ecological cemeteries which accommodate more sensitive approaches to the environment with respect to burial locations and practices must be put on their agenda.

Despite existing national regulations urging to consider water resources protection in the establishment of cemeteries (e.g., strategic plan for Nahr El Kalb valley), they are far from being applied due to:

- Lack of environmental awareness at both, decision makers who allocate the permits and public society.
- Lack of information related to soil and groundwater
- Lack of environment rules enforcement mechanisms and authorities.
- Dominance of personal over public interests.

5.2.9 Army Posts and Explosives

Army barracks and facilities present as any other human activity many risks of contamination to the groundwater. Of these we mention:

- Petroleum contamination generated by diesel and fuel storage, environmentally unsound operations using petroleum products, electricity generators, etc.,
- Wastewater
- Healthcare waste
- Equipment and vehicle maintenance waste and spills including Cyanide (classified by US EPA as extremely toxic to humans (http://www.epa.gov/ttnatw01/hlthef/cyanide.html)
- Ammunitions: Mainly destruction of expired or damaged ammunition, currently frequently conducted in highly vulnerable areas of Kfar Debbiane (dolines in C4 geological unit)

The wastewater infrastructure must be considered with care at army barracks. Army maneuvers including explosives must take place where there is a geological barrier of at least 5 m thickness so that generated PAHs cannot directly infiltrate into groundwater.

When destroying expired or damaged ammunition, the operation must be conducted at an area where groundwater is of low or very low vulnerability to contamination.

The project had contacts with the army headquarters on how to reduce contamination risks from army operations and due to the very positive response is optimistic that the Lebanese army will address related issues shortly. The army showed full collaboration and is ready to act upon proper practical related recommendations. High ranking officers showed being open to any possible collaboration with international entities able to provide assistance in improving environmental status at barracks, other facilities and routine operations related to waste separation and recycling, wastewater infrastructure, improving fuel storage infrastructure, etc.

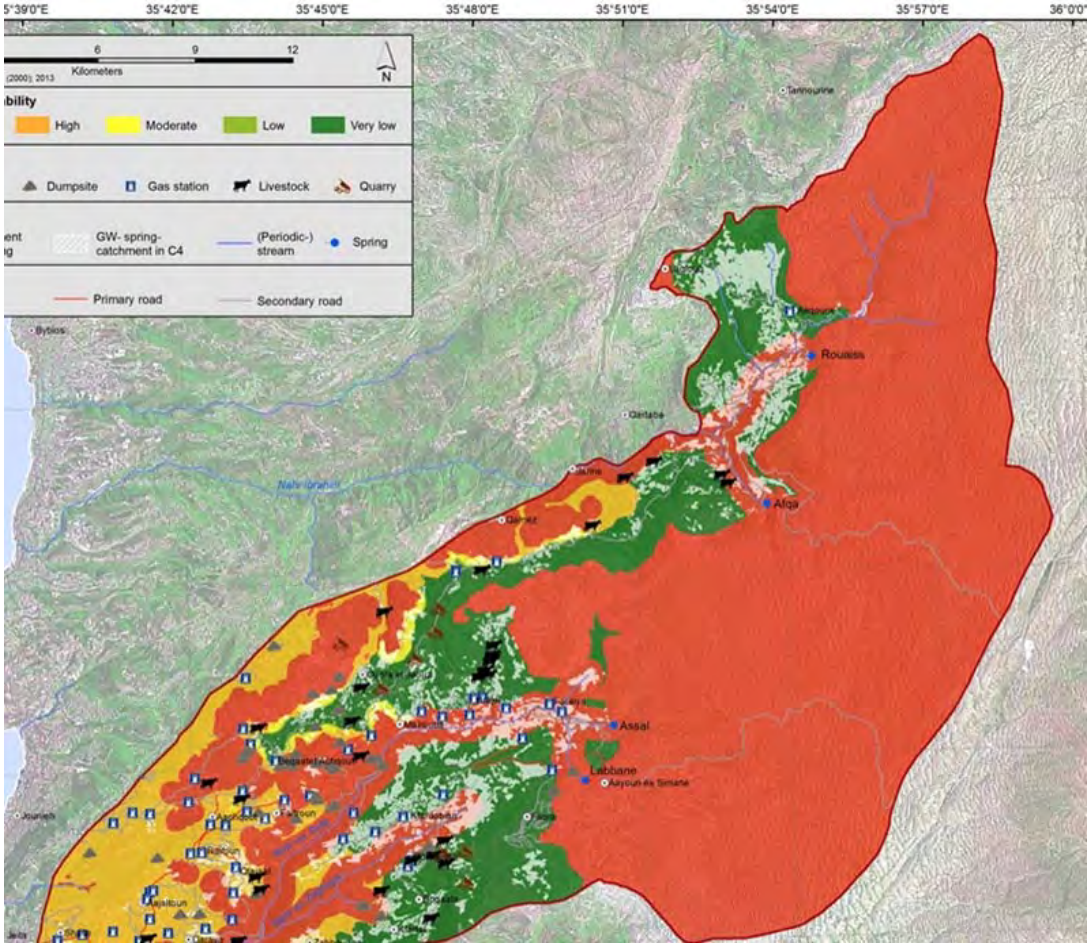

Figure 113: Hazards in groundwater catchment of Jeita spring and GW vulnerability

6 Stakeholders

- Ministry of Energy and Water
- Beirut and Mount Lebanon Water Establishment
- Litani River Authority
- Ministry of Environment
- Ministry of Agriculture
- Ministry of Health
- Ministry of Interior and Municipalities
- Governorate
- Directorate General of Administrative and Local Councils (Decree 4082/2000): which has a supervisory and monitoring role over municipalities.
- Municipality
- Ministry of Public Works: Directorate General of Urban Planning (DGUP)
- Ministry of Industry
- Ministry of Defense
- Ministry of Tourism
- Ministry of Higher Education
- Public Society

7 Conclusion

Jeita spring catchment is characterized by a high level of karstification and topographic gradient, leading to very high groundwater flow velocities. This renders groundwater protection a difficult task.

The natural protection of groundwater (shallow or absence of soil cover) is insufficient in this catchment while numerous pollution sources are spread all over the .

Uncontrolled urban development and environmentally unsound practices in land uses within a highly karstified geological context lead to a high risk of groundwater contamination of Jeita spring, the main drinking water source for the Greater Beirut area.

80% of the catchment area (405.6 km^2) was classified following hydrogeological assessments as being highly or very highly vulnerable to

contamination (protection zone 2). However, this area includes a significant number of severe pollution sources:

- 59 operating gas stations where the USTs are single layered, badly manufactured, excessively old (more than 20 years, thus probably leaking) installed without any leakage detection or prevention means. 45 of these gas stations are located in highly vulnerable areas (travel time < 10 days), in complete absence of monitoring or treatment of hydrocarbons contamination by WEBML, while in presence of such contamination, the practiced chlorination treatment would lead to carcinogenic compounds.
- In addition, to gas stations, potential hydrocarbons contamination generated by widely spread generators and unmaintained and unmonitored residential heating systems, 24 car reparation workshops is to be considered being almost of the same magnitude.
- 25 assessed quarries of which 11 are located at less than 10 days travel time from Jeita spring are frequently causing high turbidity in Jeita spring and Kashkoush river, in addition to a huge destabilization of soil and deforestation, and to a high risk of groundwater contamination by the (illegally) used explosives and the anarchic storage of fuel and oils.
- Fortunately large sized factories and industries are still not common in the Jeita spring catchment. However, 33 factories of various types were found applying unsound environmental practices in complete contradiction with actuated laws and guidelines. In particular 25 of these, located in protection zone 2 must be closely monitored as presenting a high risk of water resources contamination.
- Medium and small sized feedlots, small, medium and big scale poultry housing are very spread in the catchment area. 33 of these animal farms were assessed, 16 of them are located in protection zone 2 (where such activities must be prohibited. Wastes management is catastrophic in these farms and many of them are even located at locations restricted by current actuated landuse decisions.
- Two slaughterhouses (located in protection zone 2b) are spreading their wastes in the vulnerable environment without any prior pretreatment, can lead to a serious public health issue due to a high risk of microbiological groundwater contamination.
- A major hospital located in Ajaltoun (highly vulnerable location), in addition to spread healthcare centers, dentist's clinics and dispensaries are discharging their liquid wastes in the environment without any prior treatment. While some of their solid wastes are collected and treated by Arc en Ciel, radioactive wastes and various others are unsoundly discharged in the environment leading to a serious concern of related contamination. An alarming presence of "Benzoylecgonine" (cocaine metabolite) in surface water, Jeita groundwater and tap water was observed, and iopamidol (iodinated X-ray contrast media), was found in

wastewater Hrajel, Nahr El Salib river and Jeita spring, indicating discharge of contrast media with wastewater from healthcare establishments.

- The field assessment revealed the presence of 18 touristic resorts and restaurants in addition to 18 schools within the Jeita spring catchment. Unfortunately these are not properly equipped by proper wastewater systems and they frequently dispose their wastes in the environment. Several assessed dumpsites were found being related to these establishments.
- 74 dumpsites of various origin were assessed in the catchment area. 73 of these are located at less than 10 days travel time from Jeita spring. In absence of recycling facilities, these dumpsites include wastes generated by all the activities conducted in the catchment area: industrial, healthcare, animal production and slaughtering, residential, construction wastes, pesticides, fertilizers, tires, etc. Solid wastes management is an urgent issue to resolve in the Jeita catchment considering its imminent generated risk on water resources. Many dumpsites are at river borders, others are directly above the Jeita underground river or near the main springs in the area. The nature of the existing wastes and its generated risk call to an immediate action in this respect to recollect the wastes, clean the sites and create an efficient wastes collection, sorting and recycling system. Wastes open air incineration is widely practiced despite being prohibited by actuated laws, in complete absence of enforcement and environmental awareness.
- Unsound agricultural practices, use of unfermented manure, unsound fertilizers and pest management, use of furrow irrigation in some locations, absence of pesticides containers collection and treatment facilities are leading to a serious environmental contamination by intensive agriculture.
- Anarchic drilling and lack of maintenance of groundwater wells were revealed during the field assessment. Some of these were drilled within gas stations or at roads borders or even in the middle of the road, or agricultural properties becoming a direct source of groundwater contamination by all kinds of nearby contaminants. Some wells were drilled directly over the underground river of Jeita.
- Wastes generated at the Army barracks and explosives destruction might cause a risk to groundwater if not well managed. However the Lebanese Army's headquarter is quite aware of the matter and was very cooperative in respect to the project recommendations related to waste management.
- Absence of stormwater management in the catchment area might lead to serious contamination by all kinds of contaminants especially that wastes generated by all human activities are spread in the environment, and therefore related contaminants are carried by

stormwater which infiltrates to groundwater or reach surface water resources.

- Last but not least, wastewater can be considered as the main issue in the Jeita catchment. Leaking open bottom cesspits are spread all over the area and unsound disposal of wastewater extracted from closed cesspits is the ruling practice. When a wastewater collection network exists in a village, it is badly designed, very poorly maintained and the untreated wastewater is being discharged in the environment, mainly in the river courses. Facts that increase the contamination risk generated by wastewater. However, a wastewater collection and treatment project funded as a soft loan by the German government through the Ministry of Economic Development and Cooperation (BMZ) through KfW Development Bank in partnership with CDR is in its final stages (related EIA awaiting approval) following an extensive related technical assistance provided by the BGR project protection of Jeita spring. BGR issued guidelines for treated wastewater reuse in respect to groundwater vulnerability criteria, in addition to guidelines related to the criteria to be considered in the choice of the wastewater treatment plant (WWTP) location in reference to georisks and other criteria. Also a detailed EIA guideline to be followed in karstic environments like everywhere in the Lebanon and Antilebanon mountain ranges was issued by the project. An important part of the catchment area is supposed to be covered by a wastewater collection and treatment network planned to be funded by AFD and EIB, while another smaller part is prospected to be covered by another project funded by the Italian cooperation for development.

Considering the large variety of contamination sources (diffuse and point sources), protection of Jeita spring cannot be reached without the commitment by all stakeholders and mainly the public society.

While the actuated laws and decisions reveal an awareness of the problems, their enforcement and monitoring is still unfortunately quite far from this stage.

Lebanon suffers from a **weak enforcement and monitoring regime:** It has a poor record for implementing and enforcing environmental laws. With limited exceptions, violations of environment-related laws are going either undetected or were not pursued and requirements are often unendorsed especially with the public and private sector not acting in the interest of the environment but mainly in their own interest.

For example, article 43 of Law 444 requires the MoE “to take all the necessary measures to protect the environment when the operation of a classified establishment causes damage to the environment, and to get rid of the source of danger on the polluter’s expense” … it also sets “the criteria to apply on each category of establishments as well as the conditions of stopping, closing temporarily or permanently any establishment whenever it

constitutes a danger to the environment." However, related required enforcement was not foreseen in this Law. In absence of environmental police and within the current lack of means (financial, technical and staff…) the Ministry of Environment still has a long way to go before being able to apply environmental laws and guidelines which in some cases require an update (such as imposing double layered underground storage tanks in gas stations and installation of leakage detection devices).

Although self-monitoring and auto control are being required by article 42, these are not being applied with the exception of monitoring air emissions from cement industries and the treatment of infectious medical waste.

Article 53 requires the provision of an insurance policy against all risks threatening the environment by "every person exploiting a classified institution or using chemical products, harmful and/or dangerous is not being applied or monitored". Penalties of infringement in accordance to the law (article s59-62) include imprisonment of between one month and one year and a fine ranging between LBP 2.0 million (US$ 1,400) to LPB 10 million (US$ 7,000) are not being applied and are in the meantime not adequate to be truly considered by polluters.

The landuse permitting practices must change otherwise groundwater resources protection will not be reached. The permitting system must seriously consider the preservation of water resources as an objective, and therefore be based on the groundwater vulnerability evaluation. Groundwater protection zones must be applied to reduce the risk of pollution.

The BGR project prepared the required Jeita spring vulnerability maps and proposed the adoption of specified groundwater protection zones in the entire groundwater catchment. Related stakeholders (Ministry of Energy and Water, Landuse Planning Department (Department of Urbanism), Ministry of Environment (through the EIA decree), CDR, Governors and municipalities were approached and requested to adopt the proposed delineation at the soonest in the permitting process and restrict the permitting of contaminating activities.

Protection of Jeita spring cannot be reached other than by the cooperation between all stakeholders. A related awareness rising is needed not only at the level of the public society but also at the level of decision makers as little is known in Lebanon about groundwater. This was partly done by the BGR project but much more public awareness is needed.

The overlapping responsibilities and powers between governmental institutions are leading to an anarchical uncontrollable situation especially under a lack of political will to interfere in the subject of water quality issues.

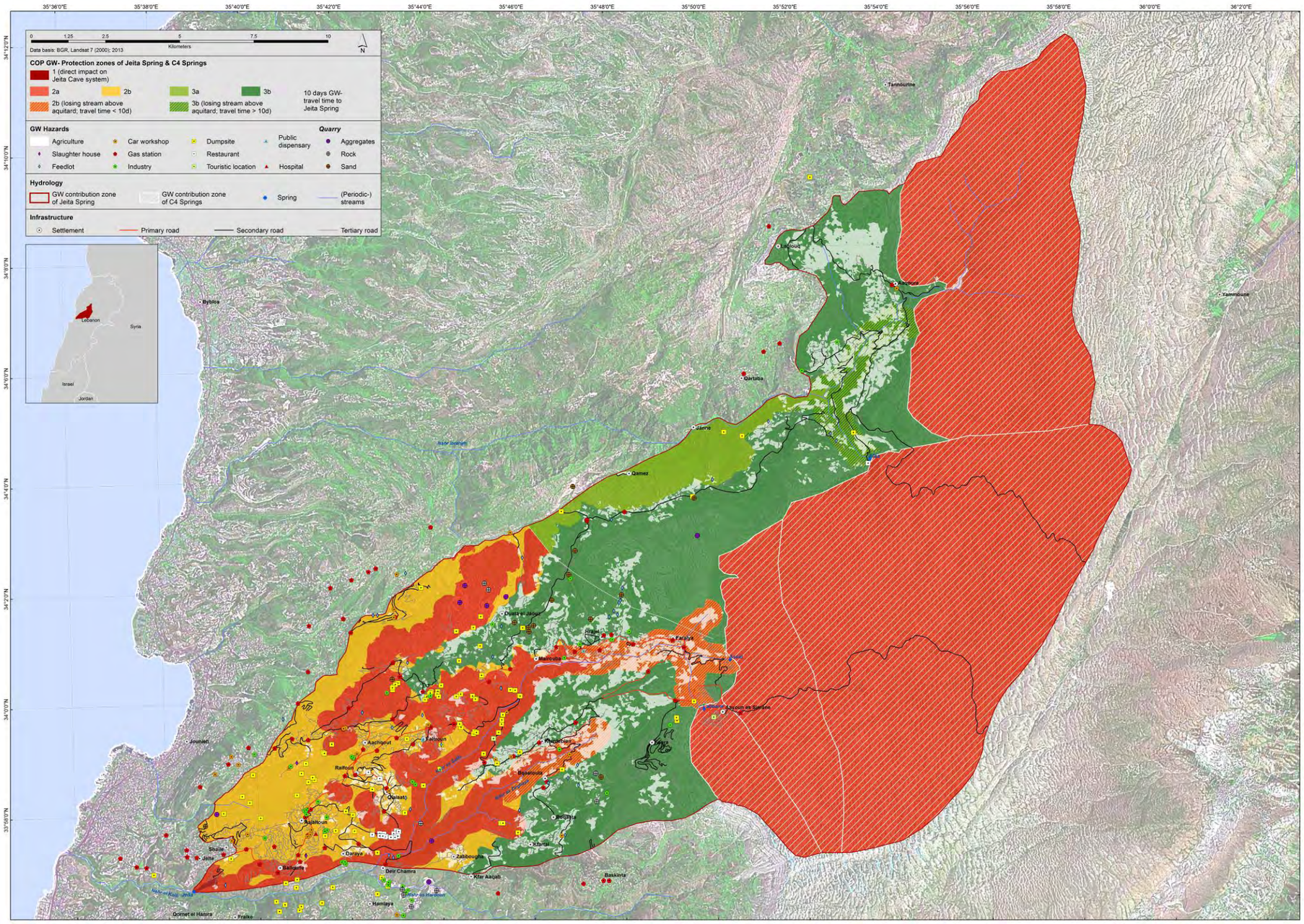

Figure 114: Inventory of Hazards to Jeita spring

8 Recommendations

The groundwater protection concept proposed by the BGR project (MARGANE & SCHULER, 2013) must be adopted in the Jeita catchment to ensure a safe drinking water supply for the Greater Beirut Area. This requires that landuse restrictions will be imposed and enforced in the delineated most vulnerable areas.

Implementing landuse restrictions for water resources protection has social and economic benefits for the entire society and also for the local population. Tourism is more likely to develop in an ecologically sound landscape.

Sustainable economic development, including the quality of life, is intimately linked to environmental sustainability. As such, the preservation of vital groundwater resources is an integral part of human rights. The significant environmental degradation in almost all sectors in Lebanon underlines the critical need for the authorities to enforce relevant existing laws and regulations, and to establish an effective environmental control and management system.

Landuse licensing regulations must be changed to ensure adequate protection of water resources, e.g. for industrial and commercial activities, gas stations, quarries, healthcare facilities, drilling and use of wells, agriculture, etc. An applied strategic landuse planning for the Jeita catchment considering groundwater protection criteria would enhance the quality of life in the area and its natural resources, leading to a more sustainable economic development.

Lebanon has already paid a high cost of environmental degradation which is tragically increasing as no adequate action is taken to avert it. Following the World bank report published in 2004, It was evaluated as being: 655 Million USD in 2000 and equivalent to 3.9 % of GDP and 969 Million USD in 2008 (published in 2011).

An adequate protection of the groundwater resources of Jeita spring is critical for sustainable drinking water supply of the Greater Beirut Area and for the local population in the Jeita spring catchment. Water resources protection concerns both governmental and nongovernmental stakeholders. As groundwater protection is a national priority involving a multitude of stakeholders, such a major change in landuse practices can only be brought about bringing together all relevant stakeholders at the highest level and agreeing on the general procedure, the necessary landuse restrictions and the implementation and control mechanisms. This High Committee on Water Resources Protection should also work on amending all national laws and regulations required to help improve drinking water quality, such as thjose mentioned below.

Success of this measure depends on the implementation capacity of the governmental institutions responsible for this task.

A penal code to prevent, restrict, and punish all acts of illegal exploitation or contamination of Jeita spring groundwater resources is an imminent requirement. An important component of the code is the control of well drilling and illegal GW abstraction. Application of the “polluter-pays-principle” must be enforced and fines for damaging the environment must be adjusted to a level that such acts will not be regarded as a trivial offense anymore but become financially noticeable.

A special police task force (environmental police) should be established (as was done with great success in Jordan in 2006: Royal Department for Environment Protection, RDEP) and must be charged with control of the landuse restrictions. **In the absence of such a police force at the moment, it may to be relied on the Lebanese army to ensure groundwater protection enforcement and protection of all vital water resources.**

Facilities for municipal waste separation at source must be created to reduce solid waste to be sent to landfills, enhance solid waste recycling and reduce illegal dumping.

Specific collection sites for receiving dangerous solid and liquid waste such as empty pesticides containers, batteries, expired pharmaceuticals, paint, solvents, etc. are needed. However, such places would need to be specifically protected against groundwater pollution and storage of the hazardous material must only be temporary before being transferred to designated suitable hazardous waste disposal sites.

A composting factory able to treat manure and organic waste produced by agricultural farms and livestock and poultry production taking place at Jeita catchment is needed. At the same time it could provide organic fertilizer to farmers which may be used in GW protection zone 3.

A detailed risk assessment of the dumpsites spread over the Jeita spring catchment must be implemented because many may contain hazardous material. These dumpsites must be urgently cleaned up and rehabilitated. The existing dumped wastes must be separately sent to recycling factories, while construction wastes can e.g. be used for land reclamation in the existing quarries.

Construction waste sites, designed for this specific purpose, should be made available at designated suitable places so that these materials are no more dumped illegally everywhere in the nature.

Quarries must be subject to severe permitting restrictions in the Jeita catchment, especially in the recommended protection zones.

Gas stations spread allover the catchment area are far too numerous. They must be all subject to an environmental audit, considering the GW vulnerability at their location and any potential negative impact on water resources, their design and infrastructure, in addition to their operation practices and general risk to the public (distances to important places such as

schools, churches, etc.). An awareness campaign must be conducted at the gas station managers and operators level. Collaboration between MoE, MoEW, APIC and the municipalities would be highly recommended in this respect.

Furthermore, capacity building of the agencies responsible for water resources protection is urgently required. The proposed groundwater protection zones for all major springs in the groundwater catchment of Jeita spring (MARGANE & SCHULER, 2013) should be implemented as soon as possible. Signs at the boundaries of GW protection zones 1 and 2 should be erected to inform the population of the fact that they are entering a sensitive zone and that certain landuse restrictions apply within this zone. Also a service number should be mentioned where to call in case of violation (e.g. Environmental Police).

Monitoring of water quality in the catchment must be improved. This would require establishing a real water laboratory, able to process a large number of samples and analyze all potentially occurring contaminants. Unfortunately WEBML laboratory has a severe lack in related equipment and capacity and no action has been taken for years to upgrade it and improve its service.

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ANNEX 1: List of Main Municipalities of the Jeita Spring Groundwater Catchment Area

Village	Casa
Aaqoura	Jbeil
Aarasta	Jbeil
Afqa	Jbeil
Ghabat	Jbeil
Hdaine	Jbeil
Janneh	Jbeil
Laissa	Jbeil
Mchaa El Ftouh	Jbeil
Mejdel	Jbeil
Mzarib	Jbeil
Qamez	Jbeil
Qorqraya	Jbeil
Saraita	Jbeil
Ashkout	Kesrouane
Aaramoun K	Kesrouane
Ain Ed Delbe	Kesrouane
Ain Er Rihane	Kesrouane
Aajaltoun	Kesrouane
Ard El Ghabe	Kesrouane
Ballouneh	Kesrouane
Boqaata	Kesrouane
Boqaata Ashkout	Kesrouane
Bqaatouta	Kesrouane
Bzoummar	Kesrouane
Daraya	Kesrouane
Dlebta	Kesrouane
Eghbe	Kesrouane
Faitroun	Kesrouane
Faraya	Kesrouane
Ghosta	Kesrouane
Harissa	Kesrouane
Hiyata	Kesrouane
Hrajel	Kesrouane
Jabal Homsaya	Kesrouane
Jeita	Kesrouane
Jouret Mhade	Kesrouane
Kfartay Keserwan	Kesrouane
Maarab	Kesrouane
Mayrouba	Kesrouane
Mazraat Kfardebian	Kesrouane
Nahr Ed Dahab	Kesrouane
Ouata Ej Jawj	Kesrouane
Qleyyat	Kesrouane
Raashine	Kesrouane
Rayfoun	Kesrouane
Shahtoul	Kesrouane
Shaile	Kesrouane

Baskinta	Metn
Kfartay Metn	Metn
Ouadi El Karm	Metn
Zabbougha	Metn
Aaqoura	Jbeil
Aarasta	Jbeil
Afqa	Jbeil
Ghabat	Jbeil
Hdaine	Jbeil

ANNEX 2: Questionnaires used for the field assessment

Assessment of Crops production in Jeita catchment

Village: _____ **Municipality**:_____
Georeferences: N _____ E _____ **GPS Accuracy**:_sats
Owner's name: _____ **Owner's phone**: _____

Crop produced and related surface:

□ **Fruit trees** _____ m^2
□ **Open field vegetables (specify):** _____ m^2 _____
□ **Greenhouses**_____m^2

Production schedule

Crop	Jan	Feb	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept	Oct	Nov	Dec

Fertilization schedule

Crop description	Fert. nature	Fertilizer comm. name	Composi-tion	Applica-tion rate	Applied quantity	Applica-tion date	Remarks

Production enhancement schedule

Crop description	Hormone commercial name	Composi-tion	Application rate	Applied quantity	Application date	Remarks

Pest management

Crop description	Pesticide commercial name	Active ingredient	Application rate	Applied quantity	Application date	Related Pest

Weeds management

Crop description	herbicide commercial name	Active ingredient	Application rate	Applied quantity	Application date	Remarks

Soil sterilization

Surface (m2)	Sterilization mean	Active ingredient	Application rate	Applied quantity	Application date	Remarks

Irrigation system maintenance:

Frequency of application of acids:

_____

Kind of acids used and rates:

_____

Water Source: _____

Any problems related to water quality?

_____
_____

Estimated average quantity of water used per year:

_____

Wastes management

Enumerate the wastes generated (liquid and solid)

_____
_____

Disposal mean of each type of wastes:

Description	Specification	Disposal Location	Quantity	Remarks
Pesticides leftover				
Pesticides empty containers				
Wrapping materials				
Packing materials				
Old irrigation pipes & other Irrigation system fittings				
Old PE sheets				
Pest management instruments & fittings (lance, sprayer, etc.)				
Other (specify)				

Quarries

Location: **Village:** _____ **Municipality**: _____

Georeferences **N** _____ **E:** _____

Altitude: _____ **GPS** **Accuracy:** ___Satellites:

Owner Name: _____ **Owner's phone:** _____

Date of start: _____

Category of exploitation: _____

- □ Quarry related to a specific construction project, and within it.
- □ Quarry for commercial use.

Surface of the Quarry: _____

Removed material (m^2):

- □ Vegetation
- □ Arid Land
- □ Cultivable Soil (existing depth)

Presence of sinkholes in the quarried area

- □ Yes: (number: _____) ☐No

Category of Quarries (Kind of extracted materials):

- □ sand,
- □ Rocks (specify kind) _____
- □ Mosaic (decoration stones)

Did you reach the groundwater while excavating?

- □ Yes ☐No

Did you face the need to pump water while extracting?

- □ Yes ☐No

Did you face the need to modify a trajectory of a seasonal water flow?

- □ Yes ☐No

How deep go your excavation: _____m

Storage management

Description	Volume consumed /week	Storage facility	Capacity/ reservoir	Number of reservoir	Nature of reservoirs	Location

Water						
Fuel						
Diesel						
Oil						
Quarries extracts like stones, sand, et						
Other (specify)						

Rock blasting adopted technique:

_____

Explosives nature:

_____

Quantity of explosives used/week:

_____

Methods of explosion:

_____

Extraction method:

_____

Disposal of the extracted material:

_____

Waste management:

Enumeration of the generated wastes with quantities per week if possible:

_____

_____

_____

Liquid wastes:

- Storage

  Location_____
- Disposal Location

  _____
- Disposal Mean

  _____

Solid wastes:

- Storage

  Location_____
- Disposal Location

  _____

- Disposal Mean

_____

Measures taken to reduce water use

_____

_____

Source of Water _____

Generators

Owner's name: _____ **Owner's phone:** _____

Village : _____ **Municipality of:** _____

Georeferences: N _____**E** _____ **Altitude:** _____

GPS Accuracy: _____ satellites. **Distance to residences:** __

Number of generators: _____ **Energy source:** _____

Power of each generator in KVA: _____ _____ _____ _____

Source of diesel fuel: □ Company □ Gas station

Mean consumption per month: _____

Mean consumption per operation hour: _____

Mean number of operation hour per month: _____

Number of Diesel storage tanks:

Capacity of each: _____ _____ _____ _____ _____

Nature: □ Steel □ Other materials (Specify) _____

Coating Materials: _____

Anti leakage measures: _____

Leakage detection means: _____

Liquid Wastes management:

Liquid wastes generated:

Used oils: _____

Water: _____

Antifreeze _____

Storage Location: □ Underground □ Above ground

Storage facility: _____

Disposal mean: _____

Quantity disposed per week: _____

Solid Wastes management:

Kind of wastes:_____

Location of storage: _____ Location of disposal:_____

Storage facility:_____

Disposal mean: _____

Quantity disposed per week: _____

ANNEX 3: Persistent pesticides of high infiltration capacity

Source : MEF (1995) and (OFAG, 2004)

Aldicarb	Metribuzine	Ethofumesate
Difenamid	Atrazine	Methyl Oxydemeton-
Metobromuron	Disulfoton	Bromacil
Alloxydim	Monolinuron	Ferbame
Dimethoate	Bensulide	Piclorame
Metolachore	Diuron	Carbofuran
Anilazine	Napropamide	Furalaxyl
Dinoseb	Bentazone	Sethoxydime
Chloroprophame	Hexazinone	Tebuthiuron
Cletodime	Isoproturon	Terbacil
Cyanazine	Lindane	Triadimefone
Cycloate	Linuron	Trichlopyr (ester)
Dalapon	Trichlorfon	MCPA
Dazomet	Metalaxyl	Simazine
Dicamba	Methamidophos	2,4-D
Dichloro-1,3-propene	Methomyl	2,4-DB

ANNEX 4: List of the Pesticides Banned following ratification of Rotterdam convention in 1998:

http://www.pic.int/Countries/Statusofratifications/tabid/1072/language/en-US/Default.aspx

Chemical	**Decision nature**
2,4,5-T and its salts and esters	No consent to import
Alachlor	**No decision yet**
Aldicarb	**No decision yet**
Aldrin	No consent to import
Asbestos – Actinolite, Anthophyllite, Amosite, Crocidolite, and Tremolite	No consent to import
Benomyl (certain formulations)	No consent to import
Binapacryl	No consent to import
Captafol	No consent to import
Carbofuran (certain formulations)	No consent to import
Chlordane	No consent to import
Chlordimeform	No consent to import
Chlorobenzilate	No consent to import
DDT	No consent to import
Dieldrin	No consent to import
Dinitro-ortho-cresol (DNOC) and its salts	No consent to import
Dinoseb and its salts and esters	No consent to import
1,2-dibromoethane (EDB)	No consent to import
Endosulfan	**No decision yet**
Ethylene dichloride	No consent to import
Ethylene oxide	No consent to import
Fluoroacetamide	No consent to import
Hexachlorocyclohexane (mixed isomers)	No consent to import
Heptachlor	No consent to import
Hexachlorobenzene	No consent to import
Lindane	No consent to import
Mercury compounds including inorganic and organometallic mercury compounds	No consent to import
Methamidophos (certain formulations)	No consent to import
Methyl parathion (certain formulations)	No consent to import
Monocrotophos	No consent to import
Parathion	No consent to import
Pentachlorophenol and its salts and esters	No consent to import
Phosphamidon (certain formulations)	No consent to import
Polybrominated biphenyls (PBB)	**No decision yet**
Polychlorinated biphenyls (PCB)	**No decision yet**
Polychlorinated terphenyls (PCT)	**No decision yet**
Tetraethyl lead	**No decision yet**
Tetramethyl lead	**No decision yet**
Thiram (certain formulations)	No consent to import
Toxaphene	No consent to import
Tributyl tin compounds	**No decision yet**
Tris (2,3-dibromopropyl) phosphate (TRIS)	No consent to import

ANNEX 5 : Pesticides banned in Lebanon

(MOA DECISION 1/94, DATED 20/5/1998)

1. 1,2 dibromo-ethane
2. 1, 2 dichloro-ethane
3. 2,3,4,5- Bis (2-butylene) tetrahydro-2-furaldehide [*Repellent-11*]
4. 2,4,5-trichlorophenoxyacetic acid (2,4,5-T)
5. Acrolein
6. Acrylonitrile
7. Aldicarb
8. Adrin
9. All compounds containing arsenic salts.
10. Aminocarb
11. Aramite
12. Arsenious oxide
13. BHC Technical (not Gamma HCH-Lindane)
14. Binapacryl
15. Butocarboxium
16. Butoxycarboxium
17. Cadminate
18. Cadmium Calcium Copper Zinc Chromate Complex
19. Cadmium compounds
20. Calcium Arsenate
21. Calcium Arsenite
22. Calcium cyanide
23. Captafol
24. Carbon tetrachloride
25. Carbonphenothion
26. Chloranil
27. Chlordane
28. Chlordecone
29. Chlordimefon
30. Chlorinated camphene [*Toxaphene*]
31. Chlormephos
32. Chloromethoxyproylmercuric acetate (CMPA)
33. Chlorthiophos
34. Copper Acetoarsenite
35. Copper Arsenate
36. Copper Arsenite
37. Crimidine
38. Crotoxyphos
39. Cyanothoate
40. Cycloheximide
41. DBCP (Dibromo chloro propane)
42. DDT
43. *Decachlorooctahydro 1,3,4 methoxy 2H cyclobuta (cd) pentalen-2-one [Chlordecone].*
44. Dechlorane
45. Demephion-O
46. Demephion-S
47. Diamidafos

48. Dibromochloropropane
49. Dicrotophos
50. Dieldrin
51. Dimefox
52. Dimetilan
53. Dinoterb salts
54. Dinoseb salts
55. Dioxathion
56. Edifenphos
57. Endothion
58. Endrin
59. EPN (Ethyl (p-nitrophenyl) thio benzene phosphonate)
60. Erbon
61. Ethylan
62. Ethyl Parathion
63. Ethylene Dibromide
64. Ethylene oxide
65. Fensulfothion
66. Fluoroacetamide
67. Fosthietan
68. HCH containing less than 99.0% of gamma isomer
69. Heptachlore
70. IFSP = Aphidan
71. Isazophos
72. Isobenzane
73. Isodrin
74. Isothioate
75. Isoxathion
76. Kepon
77. Lead arsenate
78. Leptophos
79. Maleic hydrazine and its salts, other than salts of choline, potassium and sodium.
80. Medinoterb acetate
81. Mercuric chloride
82. Mercuric Compounds (Organic and Inorganic)
83. Mirex
84. Nitrofen
85. OMPA [*Schradan*]
86. Oxydeprofos
- *Parathion ethyl*
87. Phenazine
88. Phenylmercuric oleate (PMO)
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89. Phenylmercury acetate (PMA)
90. Phospholan
91. Potassium 2,3,5 trichlorophenate (2,4,5,-TCP)
92. Pyriminil [*Vacor*]
- *Repellent-11*
93. Safrole
94. Salithion

- *Schradan*
95. Silvex
96. Sodium arsenate
97. Sodium arsenite
98. Sodium Cyanide
99. Sodium fluoroacetate
100. Sodium pentachloro-phenoxide (Sodium pentachlorophenate)
- *Strobane*
101. TDE (1,1- Dichloro-2,2-bis (p-chlorophenyl) Ethane
102. TEPP (Tetra ethyl diphosphate or Tetra ethyl pyrophosphate or Ethyl pyrophosphate)
103. Terpene polychlorinates [*strobane*]
104. Thallium sulfate
105. Thionazin
- *Toxaphene*
106. Triamiphos
107. Trichloronate
108. Trysben
- *Vacor*
109. Vinyl chloride
110. Wipeout

Compounds listed in italics have been already cited under different names.

Source: Lebanon State of the Environment Report Ministry of Environment/LEDO
Appendix C.

ANNEX 6: List of the public dispensaries located in the Jeita catchment

Name	Location
Ajaltoun dispensary	Ajaltoun
Ashkout public center	Ashkout
Ballouneh Ashkout public healthcare center	Ballouneh
Hrajel Public Healthcare Center	Hrajel
Boqaata (closed)	
Boqaata Ashkout medical center	Boqaata Ashkout
Kfar Debbiane	Kfar Debbiane
Daraoun	Daraoun
Raashine public dispensary	Raashine
Saint Maroun dispensary	Jeita
	Jeita
Mayrouba Public dispensary	Mayrouba
Public dispensary	Hayata
(closed)	Chahtoul
Public dispensary	Faitroun
Public dispensary	Faraya
Public dispensary	Shaile
Public dispensary	Ghosta
Miserable's Relief Center	Kfar Debbiane
Caritas	Rayfoun

Annex 7: List of illegal dumpsites in the Jeita catchment

Hazard source	E	N
DUMPSITE	35.728455	33.999767
DUMPSITE	35.746776	34.021156
DUMPSITE 10 FAYTROUN	35.761400	34.001870
DUMPSITE 11 FAYTROUN	35.741574	34.001190
DUMPSITE 2	35.756709	33.994569
DUMPSITE 2	35.749593	34.024450
DUMPSITE 2 BOQAATA BIG	35.755710	33.961850
DUMPSITE 2 FAYTROUN	35.746320	33.989730
DUMPSITE 24	35.709650	33.953945
DUMPSITE 3	35.756304	33.993064
DUMPSITE 3 FAYTROUN	35.745810	33.989090
DUMPSITE 3 KFERTAY	35.754930	33.961880
DUMPSITE 3 RIVER KFARDEBIAN	35.826464	33.997071
DUMPSITE 4	35.756111	33.991799
DUMPSITE 5	35.754969	33.989274
DUMPSITE 6	35.749316	33.982992
DUMPSITE 6	35.740573	34.020211
DUMPSITE 6 FAYTROUN	35.747150	33.999690
DUMPSITE 7	35.733222	33.978726
DUMPSITE 7 FAYTROUN	35.745843	34.000527
DUMPSITE 8	35.727047	33.973856
DUMPSITE 8 FAYTROUN	35.746860	33.999550
DUMPSITE 9	35.694048	33.987032
DUMPSITE 9 FAYTROUN	35.759670	34.002050
DUMPSITE 9 FAYTROUN	35.759670	34.002050
DUMPSITE ANIMAL BONES	35.739920	34.000510
DUMPSITE BALLOUNEH MUNICIPALITY	35.680186	33.946408
DUMPSITE BEKAATET ASHKUT3	35.733519	34.000614
DUMPSITE BEQAATET ASHKUT	35.730458	34.001757
DUMPSITE BEQAATET ASHKUT1	35.734461	34.003914
DUMPSITE BEQAATET ASHKUT4	35.732967	34.001354
DUMPSITE BEQAATET ASHKUT5	35.730838	34.002120
DUMPSITE BEQAATET ASHKUT6	35.730086	34.001497
DUMPSITE BEQAATET ASHKUT7	35.729150	34.000636
DUMPSITE BEQAATET ASHQOUT2	35.733229	34.002195
DUMPSITE BQAATOUTA	35.777758	33.977578
DUMPSITE BRIDJE RIVER KFARDEBI	35.763160	34.000090
DUMPSITE FAYTROUN	35.746950	33.989490
DUMPSITE KFERTAY	35.761080	33.958890
DUMPSITE NABBOUT	35.733879	33.986081
DUMPSITE ON RIVER BANK	35.762956	34.000234
DUMPSITE RAACHINE	35.718589	34.004965
DUMPSITE RAACHINE1	35.718763	34.005028
DUMPSITE RAACHINE2	35.717020	34.003911
DUMPSITE RAACHINE3	35.716766	34.003026
DUMPSITE RAACHINE4	35.717826	34.004578
DUMPSITE TIRES	35.716679	34.003638

DUMPSITE	35.656334	33.953215
DUMPSITE 10	35.708382	33.973076
DUMPSITE 11	35.691314	33.984355
DUMPSITE 12	35.684461	33.981369
DUMPSITE 13	35.682749	33.978434
DUMPSITE 14	35.686791	33.977109
DUMPSITE 15	35.685190	33.975808
DUMPSITE 16	35.680937	33.971894
DUMPSITE 17	35.660960	33.971904
DUMPSITE 18	35.663661	33.969941
DUMPSITE 19	35.667487	33.965232
DUMPSITE 20	35.654032	33.966889
DUMPSITE 21	35.698565	33.966657
DUMPSITE 22	35.701108	33.965512
DUMPSITE 23	35.701560	33.960608
DUMPSITE 4 FAYTROUN	35.741330	33.991130
DUMPSITE 5 FAYTROUN	35.740850	33.992160
DUMPSITE 8 FAYTROUN	35.749318	34.006676
DUMPSITE ACHKOUT BIG	35.690870	33.984650
DUMPSITE AJALTOUN	35.694660	33.960880
DUMPSITE FEYTROUN 1	35.721480	33.988060
DUMPSITE FROM INDUSTRIES AJALTOUN	35.690794	33.959423
DUMPSITE HARISSA	35.665129	33.978338
DUMPSITE KLAYAAT	35.720050	33.965766
DUMPSITE SHAHTOUL LANDFILL	35.728079	34.033628
DUMPSITE WASTE AJALTOUN	35.687520	33.976390
DUMPSITE VERY WIDE	35.754087	33.979961

Source: BGR field assessment

Annex 8: Industries in the Jeita catchment

Hazard source	E	N
ALPHA LABS SHEYLE	35.66884	33.9593
ALUMINIUM WORKSHOP AJALTOUN	35.69105	33.96113
BAKERY OLEYAAT	35.72311	33.97512
CEMENT BLOCKS ACHKOUT	35.7012	33.98326
CEMENT BLOCKS	35.75383	34.02207
CEMENT BLOCKS DEIR CHAMRA	35.71733	33.95289
CEMENT BLOCKS KFARDEBIANE	35.777	33.98368
CEMENT BLOCKS MAYROUBA	35.77961	34.01138
CEMENT BLOCKS OLEYAAT	35.72416	33.97429
CEMENT BLOCKS 2 HRAJEL	35.79735	34.01643
CEMENT BLOCKS 3 HRAJEL	35.79701	34.01644
CEMENT BLOCKS 4 HRAJEL	35.80356	34.01873
CEMENT BLOCKS AJALTOUN	35.69152	33.96506
CEMENT BLOCKS AJALTOUN	35.68853	33.96988
CEMENT BLOCKS HRAJEL	35.78544	34.0153
CEMENT BLOCKS KFARDEBIAN	35.8176	33.99017
CEMENT BLOCKS MGHAIRA	35.8823	34.10443
CEMENT BLOCKS MGHAIRA 2	35.86917	34.09612
CEMENT BLOCKS MAYROUBA	35.78263	34.03524
CONSTRUCTION ROCKS GHOSTA	35.67898	33.98074
DARAYA NATIONAL AMMUNITION	35.69662	33.9514
DRY CLEAN 2 AJALTOUN	35.68347	33.96719
DRY CLEAN AJALTOUN	35.68411	33.96748
GEORGE MATTA FURNITURES	35.69156	33.96119
MINERAL BOTTLED WATER BKAATOUTA	35.79385	33.97011
MOULIN D'OR BAKERY AJALTOUN	35.68414	33.96612
ROCK SAW	35.71469	34.00221
ROCK SAW	35.73033	34.00082
ROCKS SAW	35.73053	34.00093
SILICONE FILLING AJALTOUN	35.69079	33.96102
STEEL ACHKOUT	35.70179	33.98294
TECHNOTEX DARAYA	35.69779	33.95147
UNITED PLASTIC MANUFACTURING AJALTOUN	35.69072	33.96084

Source: BGR field assessment

Annex 9: Cars repair workshops in the Jeita catchment

Hazard source	E	N
CAR SERVICE 2 KFARDEBIAN	35.78066000030	33.98212000000
CAR SERVICE 5 KFARDEBIAN	35.75815999990	33.99535000050
CAR SERVICE 7 ACHKOUT	35.69917999970	33.99193000000
CAR SERVICE 8 ACHKOUT	35.69851000030	33.99171000040
CAR SERVICE KFARDEBIAN	35.77684000010	33.98428999970
CAR WORKSHOP FAYTROUN	35.72941099970	33.99216500030
CAR REPARATION GHOSTA	35.67823600040	33.98023800020
CAR REPARATION SHEILY	35.66257399950	33.96054499990
CAR SERVICE 2 ACHKOUT	35.70195999990	33.98265000020
CAR SERVICE 3 ACHKOUT	35.70202999990	33.98272999970
CAR SERVICE 5 AJALTOUN	35.68473999970	33.96801000030
CAR SERVICE AJALTOUN 2	35.68589000020	33.96141000040
CAR SERVICE 6 ACHKOUT	35.70313999950	33.98395999970
CAR SERVICE ACHKOUT	35.70182999950	33.98266999960
CAR SERVICE AJALTOUN	35.68538999990	33.95994999960
CAR SERVICE KLAYAAT	35.71450000030	33.97255000040
CAR SERVICE WORKSHOP HAYATA	35.71792200000	34.02493899960
CAR SERVICES CHAHTOUL	35.71805099990	34.02737599990
CAR SERVICES TIRES SHOP 2 AJALTOUN	35.68426000020	33.95933999980
CAR SERVICES TIRES SHOP AJALTOUN	35.68536000020	33.96033000000
CAR SERVICE 3 KFARDEBIAN	35.75928000000	33.98182000030
CAR SERVICE 4 KFARDEBIAN	35.75365000020	33.98116000020
CAR SERVICE AKOURA	35.90459900010	34.12013499970
CAR SERVICES MAREJ BASKINTA	35.77701000000	33.95762999990

Source: BGR field assessment

Annex 10: Feedlots and slaughterhouses in the Jeita catchment

Hazard source	E	N
FEEDLOT AND SLAUGHTERHOUSE MURR AJALTOUN	35.68361160370	33.95368197240
FEEDLOT AND SLAUGHTERHOUSE CHBEIR GHOSTA	35.68117936200	33.98164301680
FEEDLOT 2	35.78357999970	33.97269000040
FEEDLOT AKIKI	35.72243099970	34.01107699960
FEEDLOT BOKAATA	35.76182000020	33.96561000000
FEEDLOT BOVINS AFKA	35.87894200050	34.07686300030
FEEDLOT BOVINS HAYATA	35.71200000050	34.02563999980
FEEDLOT BOVINS HRAJEL BOTROUS KHALIL	35.80095200030	34.02921699990
FEEDLOT BOVINS HRAJEL CHARBEL KHALIL	35.79817399960	34.02507200020
FEEDLOT BOVINS HRAJEL GHASSAN	35.79947699970	34.02391999980
FEEDLOT BOVINS KLAYAAT	35.72052000030	33.97024999960
FEEDLOT BOVINS MARJ BASKINTA	35.77821999990	33.95775999990
FEEDLOT BOVINS OVINS 2 ACHKOUT	35.70549000000	33.99638000030
FEEDLOT BOVINS OVINS ACHKOUT	35.71623999990	33.99162999960
FEEDLOT BOVINS OVINS HIYATA	35.71036899990	34.02567499960
FEEDLOT BQAATOUTA ABDO	35.77258999980	33.97368999970
FEEDLOT FAYTROUN	35.75628999990	34.00263000030
FEEDLOT OVINS	35.73399599970	33.98610300000
FEEDLOT OVINS BKAATOUTA	35.77978000020	33.97495000020
FEEDLOT OVINS HRAJEL JEAN AKIKI	35.79642000000	34.02333000020
FEEDLOT OVINS NAHR DEHAB	35.76529999960	34.04186999960
FEEDLOT OVINS QEHMEZ	35.79818999970	34.05262000040
FEEDLOT PIGS QLEYAAT	35.72209377450	33.96678812220
FEEDLOT POULTRY	35.75702999970	34.02135000020
FEEDLOT POULTRY AIN GHWAIBE	35.85640000030	34.08101000020
FEEDLOT POULTRY DER CHAMRA	35.71543999950	33.95229999970
FEEDLOT POULTRY DER CHAMRA 2	35.71389999960	33.95296000000
FEEDLOT POULTRY FARM	35.83541000010	34.06392000030
FEEDLOT POULTRY FARM GHABAT	35.88099999980	34.07459000020
FEEDLOT POULTRY HRAJEL CHARBEL GHOSN	35.80143100020	34.03196200000
FEEDLOT POULTRY HRAJEL CHARBEL SALLOUM	35.80058499970	34.02817400010
FEEDLOT POULTRY HRAJEL SARKIS CHAMOUN	35.80017900040	34.02750900010
FEEDLOT RIZK	35.72735600010	33.99512200010
FEEDLOTS BKAATOUTA HAJ	35.78340600030	33.97882399980
FEEDLOTS BOVINS WATA JAWZ	35.75356999990	34.01219000040
FEEDLOTS OVINS JEITA	35.65406406650	33.94533201130

Source: BGR field assessment

Annex 11: Gas stations in the Jeita catchment

Hazard source	E	N
Gas station	35.843325	33.993243
Gas station	35.67323900720	33.94879629160
Gas station	35.71252709900	33.95036727160
Gas station	35.66672970750	33.95142655940
Gas station	35.68144890010	33.95184756470
Gas station	35.68082361690	33.95389780640
Gas station	35.66197741580	33.95605715680
Gas station	35.69053557080	33.95582719040
Gas station	35.67221936630	33.95662513510
Gas station	35.70292794620	33.95674751740
Gas station	35.71189936800	33.95906513770
Gas station	35.68458007510	33.95984684340
Gas station	35.68378783650	33.96529118210
Gas station	35.71246502210	33.96638943870
Gas station	35.68467840020	33.96707669430
Gas station	35.68587125400	33.96756573070
Gas station	35.71361181520	33.97336011880
Gas station	35.77080297880	33.97229857840
Gas station	35.77207814190	33.97399834590
Gas station	35.69859272430	33.97742223020
Gas station	35.70237097030	33.97763573480
Gas station	35.74954234030	33.98035206550
Gas station	35.76019470480	33.98201748830
Gas station	35.71049210550	33.98486180090
Gas station	35.70548498180	33.98527414100
Gas station	35.67326622150	33.98632764430
Gas station	35.72371362490	33.98650274800
Gas station	35.76970942140	33.98592692600
Gas station	35.68554513480	33.98854502810
Gas station	35.75316793210	33.98736960270
Gas station	35.67971895800	33.98900578340
Gas station	35.71776973380	33.98846268010
Gas station	35.69843601270	33.99150529440
Gas station	35.73035138120	33.99141681910
Gas station	35.73880745500	33.99223121110
Gas station	35.78317743480	33.99167739600
Gas station	35.71647933150	33.99423400780
Gas station	35.70070259160	33.99789803980
Gas station	35.81961383810	33.99753931330
Gas station	35.72782093260	34.00222530070
Gas station	35.75195964040	34.00473921780
Gas station	35.71960703550	34.00693703960
Gas station	35.81009142000	34.00651945030
Gas station	35.75987510450	34.00838296970
Gas station	35.71722267350	34.01121301230
Gas station	35.78356225740	34.01308100160
Gas station	35.79262572460	34.01335937660

Gas station	35.82337075220	34.01350923220
Gas station	35.77680100500	34.01467886690
Gas station	35.80489543470	34.01487547980
Gas station	35.81934852200	34.01578856540
Gas station	35.79426765050	34.01779119500
Gas station	35.79708760420	34.01791673780
Gas station	35.70205194560	34.02064205700
Gas station	35.71847901280	34.02498309940
Gas station	35.78933754770	34.05255234420
Gas station	35.78917578350	34.05283618360
Gas station	35.80306475900	34.05495251480
Gas station	35.90290699970	34.12115900030

Source: BGR field assessment

Annex 12: Quarries in the Jeita catchment

Extracted materials	E	N
AGGREGATES	35.729512382	33.95705649
AGGREGATES	35.7519096981	34.0276712864
AGGREGATES	35.7420937934	34.028864844
AGGREGATES	35.7589730998	34.0302129146
AGGREGATES	35.7441030001	34.0339069996
DECORATION STONES	35.7257161326	33.9624436299
ROCKS & AGGREGATES	35.7526892514	34.0324539274
ROCKS & AGGREGATES	35.751208563	34.0344601571
SAND	35.7167241286	34.0061929378
AGGREGATES	35.6515143605	33.9667330361
SAND	35.6472589157	33.9632414362
AGGREGATES	35.8293694114	34.0470725224
AGGREGATES	35.7899900003	33.97616
SAND	35.791894738	33.9749802083
SAND	35.7896080003	34.0227799998
SAND	35.7687629997	34.0212370004
SAND	35.7756570928	34.0287813306
SAND	35.7821130005	34.0363420001
SAND	35.7846633361	34.0435372634
SAND	35.8010859997	34.0298540003
SAND	35.7670369999	34.0194770001
SAND	35.7617522694	34.0223577288
SAND	35.7668398971	34.0207170547
SAND	35.8285445035	34.0585086363
Sand	35.7900370005	33.9675970001

Source: Field assessment