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LITANI RIVER BASIN MANAGEMENT SUPPORT PROGRAM

LITANI RIVER FLOOD FIELD SURVEY REPORT

AUGUST 2010
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EXECUTIVE SUMMARY

Most of the Litani River Basin occupies Central and South Bekaa Valley. The valley is sandwiched between Mount Lebanon to the west and the Anti-Lebanon mountain range to the east. Winter precipitations fall heavily on both ranges and engender heavy flows which then spread across the valley whose bottom is almost flat and with a low north-south slope (on average 2.5 m/km). Floods are thus common occurrences in the valley but with the development of human activities (farming and urbanization), their impacts are increasing. A field survey has been conducted to:

- Assess the type of floods that occur in the Litani River Basin;
- Identify a reference flood that can be used to calibrate a flood model;
- Collect data and accounts from witnesses to define this reference flood;
- Assess the magnitude of flood damages; and
- Define the topographic survey necessary to build the model.

The main findings are that the Litani River Basin suffers from two types of flooding:

- Flooding from the Litani River and Major tributaries (Ghzayel, Berdawni, Qabb Elias); this is due to natural floodplain characteristics, compounded by lack of riverbed maintenance, existence of obstructions such as insufficient road bridges and irrigation weirs or other illegal constructions in the riverbed, dumping of all type of solid and hazardous waste, etc.
- Seasonal flooding from minor channels (Howayzek, Oqeyber, Faregh) mostly due to lack of agricultural drainage; this is due to the impermeability of soils (mostly clayey), and poor maintenance and disappearance of many drainage ditches in farm lands.

The flood model will assist in the definition of mitigation measures and structures to address river flooding as a public issue to be addressed by the GoL (since river is public property). Insufficient agricultural drainage is a different and private issue which could be handled by local authorities (municipalities) but is not governmental responsibility.

The largest flood of the Litani River in recent memory occurred in February 2003 and will be used as reference event to calibrate the flood model. No other large flood was identified and it is reasonable to consider that the 2003 flood has a period of return of 20 to 50 years. While some information was collected from accounts of witnesses regarding this flood, limited hydrologic data exists (only daily discharge values with unknown accuracy).

The damages generated by this flood were estimated at several million US$. (only considering direct impacts such as building damage, crop losses, etc. and not indirect ones such as bankruptcies, trade, business and job losses, etc.).

The works carried out after the 2003 flood and by the previous IRWA project were also reviewed. Most of the IRWA recalibration works were justified but not sufficient nor sustainable. Moreover many new (and often too small) bridges were built after the 2006 bombings by Israel.

Finally the needs for topographic survey were defined, and different flood models were considered for the modeling of the Litani River floods. One dimensional models are deemed sufficient here, so HEC-RAS is recommended as it is widely used, freely available on Internet, and maintained and regularly updated by the Hydrologic Engineering Center of the US Army Corps of Engineers.

ملخص تنفيذي

يغطي حوض نهر الليطاني بمعظمه سهل البقاع الجنوبي والاوسط، حيث يتوسط سلسلتي جبال لبنان الشرقية والغربية. تتساقط الامطار بشكل كبير على الجبال المحيطة وتتدفق إلى الوسط بحسب الانحدار الطبيعي وتنساب جنوبًا مع السهل بسبب الانحدار المقدر بـــ 2.5متر / كلم. لذلك فإن الفيضانات هي امر شائع الحدوث في البقاع، ولكن مع ازدياد النشاط البشري (الزراعي والسكاني) فإن حدة هذه الفيضانات وآثارها اخذت بالإزدياد.

لذلك تم اجراء مسح ميداني للوقوف على الامور التالية:

- تقييم انواع الفياضانات التي تحدث في حوض نهر الليطاني
- تحديد فياضانات مرجعية ليتم استخدامها لاحقًا في معايرة نموذج الفياضان موضوع البحث
- جمع البيانات واحتسابها من الشهود لتحديد هذه الفياضانات المرجعية
- تقييم حجم الأضرار من الفياضانات
- تحديد المسح الطبوغرافي الازم للمساعدة في بناء النموذج المذكور

ادت هذه الخطوات إلى نتائج رئيسية وواضحة لجهة معرفة ان حوض نهر الليطاني يعاني من نوعين من الفياضانات:

- الفياضانات من نهر الليطاني وروافده (الغزيل، البردوني، قب الياس)، الذي يرجع إلى خصائص السهول الفيضية الطبيعية، وما ضاعفه غياب الصيانة على مجرى النهر، وجود العوائق وعدم سماح العبارات تحت السدود بتصريف الكميات المتدفقة، اضف إلى ذلك السدود الصغيرة والعشوائية التي يقيمها المزارعون بغية الري في الصيف ولا يتم تفكيكها لاحقًا، وهناك ايضًا المنشآت الغير قانونية في حرم النهر وما زاد الطين بلة رمي النفايات الصلبة والخطرة عشوائيًا، الخ
- الفياضانات الموسمية من القنوات الصغيرة (حويزق، عقيبر والفارغ) يرجع ذلك في معضمه إلى غياب الصرف للري الزراعي، ونوعية التربة الكاتمة (معظمها طينية)، كذلك ضعف الصيانة وغياب العديد من خنادق التصريف في الاراضي الزراعية.

سوف يساعد نموذج الفياضانات العتيد في تعريف التدابير التي ستخفف من آثار الفياضانات باعتبارها قضية على الحكومة ان تعالجها (لأن النهر هو ممتلكات عامة) ولكن تبقى قضية الصرف الزراعي فهذه تقع على عاتق السلطات المحلية (البلديات) ولا علاقة للحكومة بشكل دقيق بها.

وقع اكبر فياضان في الفترة القريبة الماضية في العام ٢٠٠٣، حيث تم استخدام معطيات هذا الفياضان لمعايرة النموذج المقترح. إن اعتماد فيضان ال٢٠٠٣ كمرجع لفترات العودة ل٢٠ و٥٠ عامًا. بينما تم جمع بعض المعلومات من شهود عيان والمعلومات الهيدرولوجية المتوفرة (بيانات التصريف اليومي بنسبة دقة غير معروفة).

قدرت الاضرار الناتجة عن هذه الفياضانات بعدة ملايين من الدولارات. (تقسم الاضرار إلى مباشرة وغير مباشرة، المباشرة مثل الآثار الواضحة في تلف المباني، خسائر في المحاصيل الزراعية وغيرها، وغير المباشرة مثل حالات الإفلاس، والخسائر في العمليات التجارية، الخ).

تمت مراجعة الاعمال التي قامت بها IRWA بعد فيضان الـــ٢٠٠٣، حيث كانت بمعظمها اعمال لإعادة تقويم الضفاف، وهذا امرًا مبررًا لكنه غير كاف لجهة الاستدامة. علاوة على ذلك وبعد حرب العام ٢٠٠٦ فقد تم بناء العديد من الجسور المنخفضة والتي لا تسمح بصرف الكميات المتوقعة.

اخيرًا تم تحديد الاحتياجات اللازمة للمسح الطبوغرافي، بعد اعتبار نماذج مختلفة لفياضانات نهر الليطاني، بعد مقارنة كل هذه النماذج، اتخذ القرار باستخدام برنامج الـــ HEC-RAS الذي يلبي كافة متطلبات النموذج المنشود، كما وان هذا البرنامج هو متاح ويمكن تنزيله من الانترنت والاهم انه يتم تحديثه بانتظام وبصورة مستمرة من قبل مركز الهندسة الهيدرولوجية التابع لفريق مهندسي الجيش الامريكي.

1. INTRODUCTION

1.1 GENERAL DESCRIPTION OF THE PROJECT

The purpose of the LRBMS project is to set the ground for improved, more efficient and sustainable basin management at the Litani river basin through provision of technical support to the Litani River Authority and implementation of limited small scale infrastructure activities.

The project is composed of the following four components:

- 1: Building Capacity of the Litani River Authority (LRA) towards Integrated River Basin Management
- 2: Long Term Water Monitoring of the Upper Litani River
- 3: Integrated Irrigation Management
  - 3a: Participatory Agriculture Extension Program (PAEP)
  - 3b: Machghara Plain Irrigation Plan
- 4: Improving Litani River and Qaroun Dam Monitoring Systems:
  - 4a: Qaraoun Dam Monitoring System
  - 4b: Litani River Flood Management Model

1.2 PRESENT STUDY: LITANI RIVER FLOOD MANAGEMENT MODEL

Component 4b aims at strengthening LRA capabilities to be able to simulate and manage the Litani River against potential floods. This activity shall entail technical assistance, possible procurement of equipment and capacity-building.

The below is an illustrative list of the activities to be carried out under this component:

- Perform a field assessment of the upper Litani River Basin
- Carry out a topographic survey for selected segments of the upper Litani River and tributaries
- Define hydrologic and hydrologic software models to be used to model the floods of the Litani River
- Procure, install, and build the chosen models
- Train designated LRA personnel on the operation and monitoring of these systems.
- Delimitate the potential flooded area for several return periods in order to inform farmers and to guide the municipalities in urban planning and construction permits.
- Operate the model to identify and test different damage mitigation measures.

1.3 REPORT OBJECTIVES

The objective of the actual report is to perform a field survey of the Litani River and its tributaries upstream the Qaraoun Dam in order to collect information enabling the establishment of the topographical survey and the construction and calibration of the river model to be developed. The following subjects will be covered in this report:

- Assessment of the present situation of the River and major tributaries.
- Data collection on annual floods and on the flood of February 2003.
- Assessment of the magnitude of damages due to floods
- Data collection on the works and modifications conducted on the Litani River bed and tributaries since 2003.
- Definition of the Topographical survey

1.4 PROJECT AREA

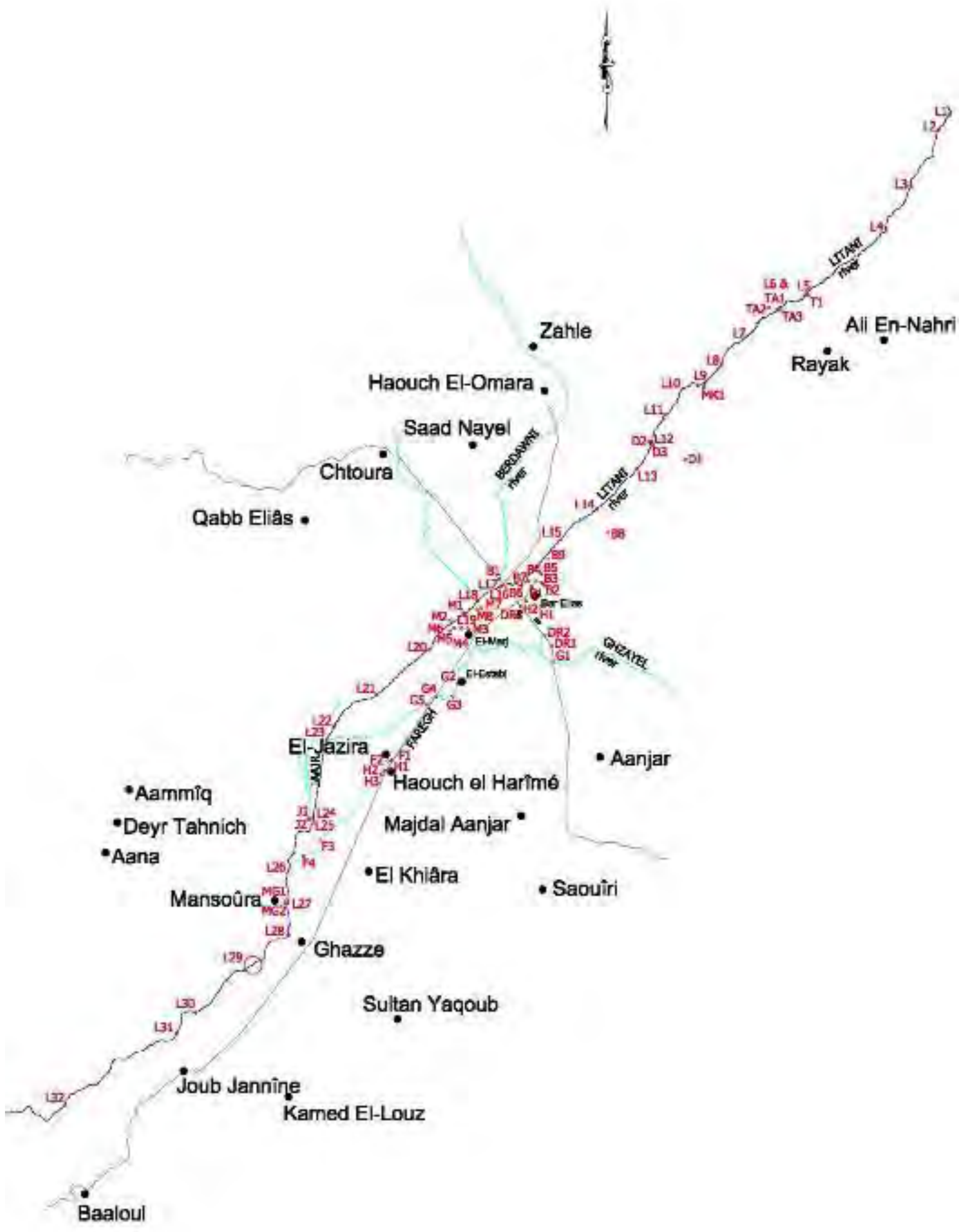
The area concerned by this study is situated in the upper and mid catchments of the Litani River.

The upper sub-catchment covers approximately half of the basin (50%), having a considerable width (up to30 km), and hosting the major springs yielding in the basin. The middle sub-catchment covers 20% of the basin and imbeds the Quaroun Lake. Slope gradient shows a moderate increase from upper sub-catchment to middle sub-catchment.

Its total area is provided in figure 1.1 and includes the following villages and towns:

Haouch er Rafqa, Temnine el Tahta, Rayak, Haouch Hala, Tell Amara, Dalhamieh, Bar Elias, El Marj, El Establ, Haouch el Harime, Ghazze, Mansoura, Tell Znoub, Joub Jannine…

Figure 1.1: Illustration of the assessed area



2. ASSESSMENT OF THE LITANI RIVER AND MAJOR TRIBUTARIES

2.1 ASSESSMENT

The assessment and findings related to the Litani River and major tributaries present situation and flooding areas are based on several meetings and site visits undertaken by Robert Bounahed (Dar al Handasah Nazih Taleb & Partners, Lebanon):

- An initial one week assessment during the week of November 29th, 2009 with Geert Prinsen (Deltares, Netherlands). During this week available reports were studied and several meetings were held with people from the Litani River Authority and from the Ministry of Energy and Water. A one-day field trip accompanied by DAHNT site Engineer Mohammad Dalla to the upper Litani basin was also undertaken.
- One site visit accompanied by Eric Viala (IRG, USA) on December 21st, 2009 during which the starting location of the assessment was set and visited in addition to 5 other sites on the Litani River water course. Mr Viala explained the methodology that has to be implemented in such kind of field survey and pointed on the objectives of the mission.
- A meeting with Eng Mahmoud Sraj on December 26st, 2009 at the Ministry of Energy and Water from whom a multitude of files and press articles concerning the flood of 2003, the maintenance work on the Litani River and the demolition of illegal building in the vicinity of the Litani River were retrieved.
- Several site visits between December 22nd and January 15th accompanied by Mohammad Dalla DAHNT site Engineer in the West Bekaa region. During those visits more than 40 locations on the Litani, Ghzayel, Berdawni, Jaair, Faregh and Houwayzek water courses were visited. In addition to several interviews with local people and Flood Water Levels locations that were undertaken in order to fix points which coordinates will be surveyed in the topographic works. Several meetings with municipalities' responsible were also held.
- One site visit on January 22 accompanied by Eric Viala and Mohammad Dalla which purpose was to evaluate the work done and to assess the situation after a seasonal flood.

2.2 DESCRIPTION OF THE ASSESSED AREA

The area situated between Haouch er Rafqa and the Qaraoun Lake in the Bekaa region was assessed. The Data Sheets for the key or representative locations on the water courses are provided in Appendix A.

The assessed area can be divided into four sub areas on the Litani River according to the river slope, flooding susceptibility and proximity of populated areas:

- The first sub area is situated between Haouch er Rafqa and Dalhamieh.
- The second sub area is situated between Dalhamieh and Bar Elias upstream Damascus road.

- The third sub area is situated between the village of Bar Elias downstream Damascus road and the village of Ghazze.
- The fourth sub area is situated between Ghazze and the upstream edge of the Qaraoun Lake.

2.3 FIRST SUB AREA (HAOUCH ER RAFQA – DALHAMIEH)

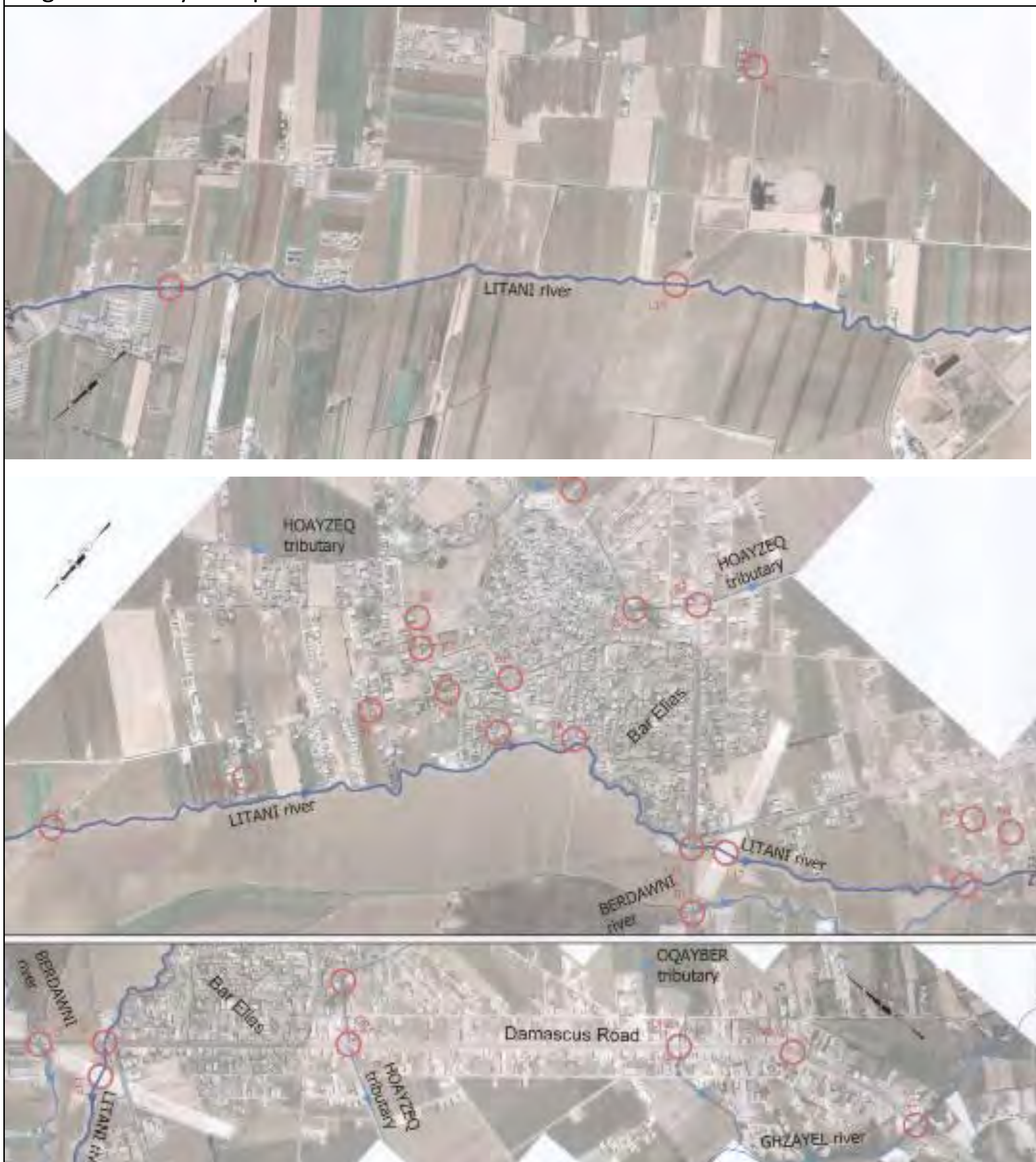
- The length of the Litani River inside this area is around 20 km, the width ranges between 6m and 11m and the water course slope is around 3.3 m/km.
- The key or representative locations on the Litani River water course in this area are:
  - L1, L2: Haouch er Rafqa
  - L3: Chamieh
  - L4: Jisr En Nahriyé
  - L5: Temnin El Tahta
  - L6, L7: Tell Amara
  - L8: EL Ghabé
  - L9: Mkhat El Laouz
  - L10, L11: El Ferzol
  - L12: Dalhamieh
- The locations of water levels to be surveyed in this area are:
  - TA1, TA2, TA3: Tell Amara
  - T1: Temnin el Tahta
  - MK1: Mkhat el Laouz
  - D1, D2, D3: Dalhamieh
- The River Main Channel in this sub area is mainly covered with weeds and stones in addition to solid waste in some particular locations.
- The flood of February 2003 mainly affected the areas surrounding bridges.
- It should be noted that the majority of the bridges in this area were destroyed and that not all the new bridges sections are of sufficient capacity.
- The lands surrounding the Litani River in this area are mainly used for agricultural purposes.

Figure 2.1: Key or representative locations and Flood Water Levels within the First Sub Area

2.4 SECOND SUB AREA (DALHAMIEH – BAR ELIAS)

- The length of the Litani River inside this area is around 8 km, the width is around 12m and the slope is around 2 m/km.
- The key or representative locations on the Litani River water course in this area are:
  - L13: Dalhamieh
  - L14: Ain Ez Ziyyan
  - L15, L16: Bar Elias
- The key or representative locations on the Howayzek tributary are:
  - H1, H2: Bar Elias
- The locations of water levels to be surveyed in this area are:
  - B1, B2, B3, B4, B5, B6, B7, B8, B9: Bar Elias
  - DR1, DR2, DR3: Damascus Road
- The River Main Channel is mainly covered with weeds and stones.
- The flood of February 2003 mainly affected the areas surrounding bridges near the village of Dalhamieh.
- At the Litani left bank downstream the village of Dalhamieh, the area situated between the Litani water course and the Houwayzek tributary was totally flooded in 2003.
- Oqeyber tributary situated on the left of Howayzek also flooded in 2003 mainly in the area upstream and on Damascus road.
- The Berdawni River also situated in this area has also flooded in 2003 in the zone situated around the bridge on Damascus road.
- The lands surrounding the Litani River in this area are mainly used for agricultural purposes except for the village of Bar Elias which is highly populated.

Figure 2.2: Key or representative locations and Flood Water Levels within the Second Sub Area



2.5 THIRD SUB AREA (BAR ELIAS - GHAZZE)

- The length of the Litani River inside this area is around 16 km, the width ranges between 12m and 20m and the slope is around 0.4 m/km.
- This area is where the intersections of Litani River with its main three tributaries (Ghzayel, Berdawni and Qabb Elias (also named Jaair)) are located.
- The key or representative locations on the Litani River water course in this area are:
  - L17: Bar Elias
  - L18, L19, L20, L21: El Marj
  - L22, L23, L24, L25, L26: Houach el Harime
  - L27: Mansoura
- The Ghzayel River which is the Major tributary of Litani River originates from Chamsine spring. The length of this River within the present sub-area is about 11km and its width about 20m. The key or representative locations on the Ghzayel River water course are:
  - G1: Deir Zenoun
  - G2, G3, G4, G5: El Establ
- The Berdawni River which is one of the Major tributaries of Litani River originates from Berdawni spring. The length of this River in addition to the Chtaura tributary within the present sub-area is about 10km and its width about 15m. The key or representative locations on the Berdawni River water course are:
  - B1: Bar Elias
- The Qabb Elias River which is one of the Major tributaries of Litani River originates from Qabb Elias spring. The length of this River in addition to the Hafir tributary within the present sub-area is about 10km and its width about 10m. The key or representative locations on the Jaiir - Qabb Elias River water course are:
  - J1, J2: Haouch el Harime
- The Faregh which is an artificial tributaries of Ghzayel River originates from Litani River. The length of this tributary is about 7.5km and its width about 5m. The key or representative locations on the Faregh Tributary are:
  - F1, F2, F3, F4: Haouch el Harime
- The locations of water levels to be surveyed in this area are:
  - M1, M 2, M3, M4, M5, M6, M7, M8, M9: El Marj
  - H1, H2, H3: Haouch el Harime
  - MG1, MG2: Mansoura Ghazze
- The Litani, Ghzayel, Berdawni and Jaair Main Channels are mainly covered with weeds despite being cleaned on two different occasions since the flood of 2003.
- Many rehabilitation and recalibration works were conducted on the Litani, and Ghzayel near the bridges and on critical points as part of the IRWA Project.
- The flood of February 2003 affected the villages of El Marj, Haouch el Harime and Mansoura.
- The village of El Marj was flooded from Chtaura tributary at the area situated at the right bank of Litani and from the Litani at the area situated at the left bank of Litani and from Ghzayel at the area situated at the right bank of Ghzayel.
- The village of Haouch El Harime was flooded from the Faregh tributary.
- The area flooded in the village of Mansoura during the flood of 2003 is situated around the bridge.
- The lands surrounding the Litani River in this area are mainly populated areas.

Figure 2.3 : Key or representative locations and Flood Water Levels within the Third Sub Area

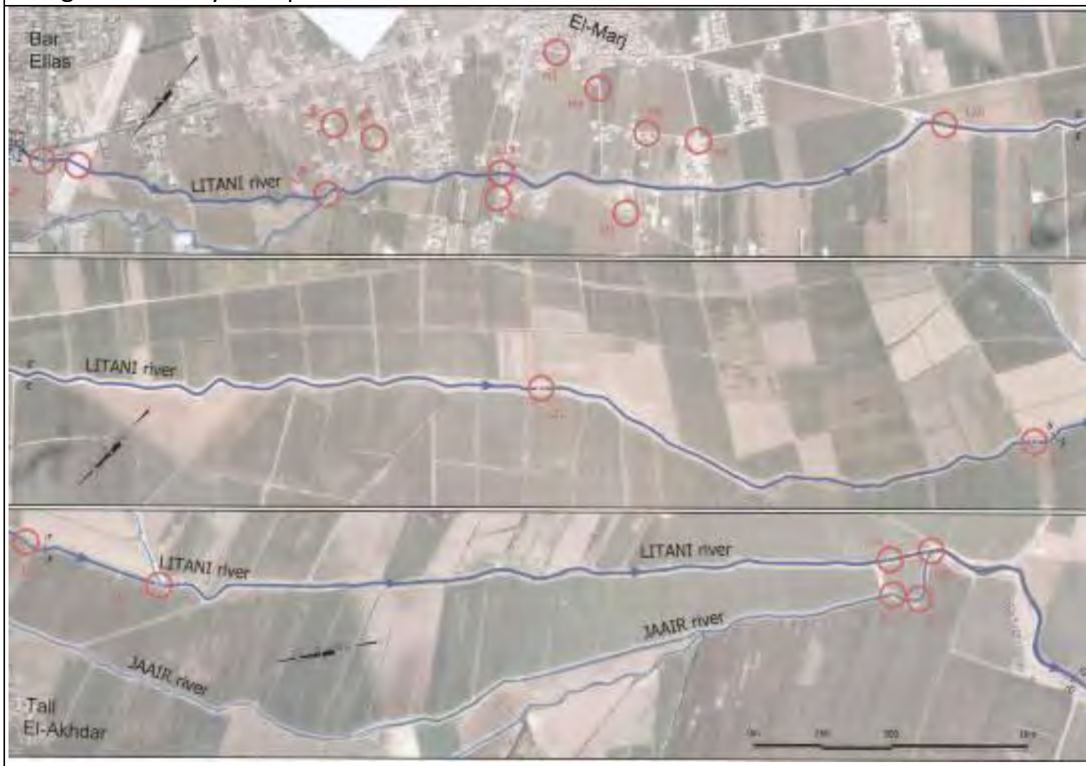
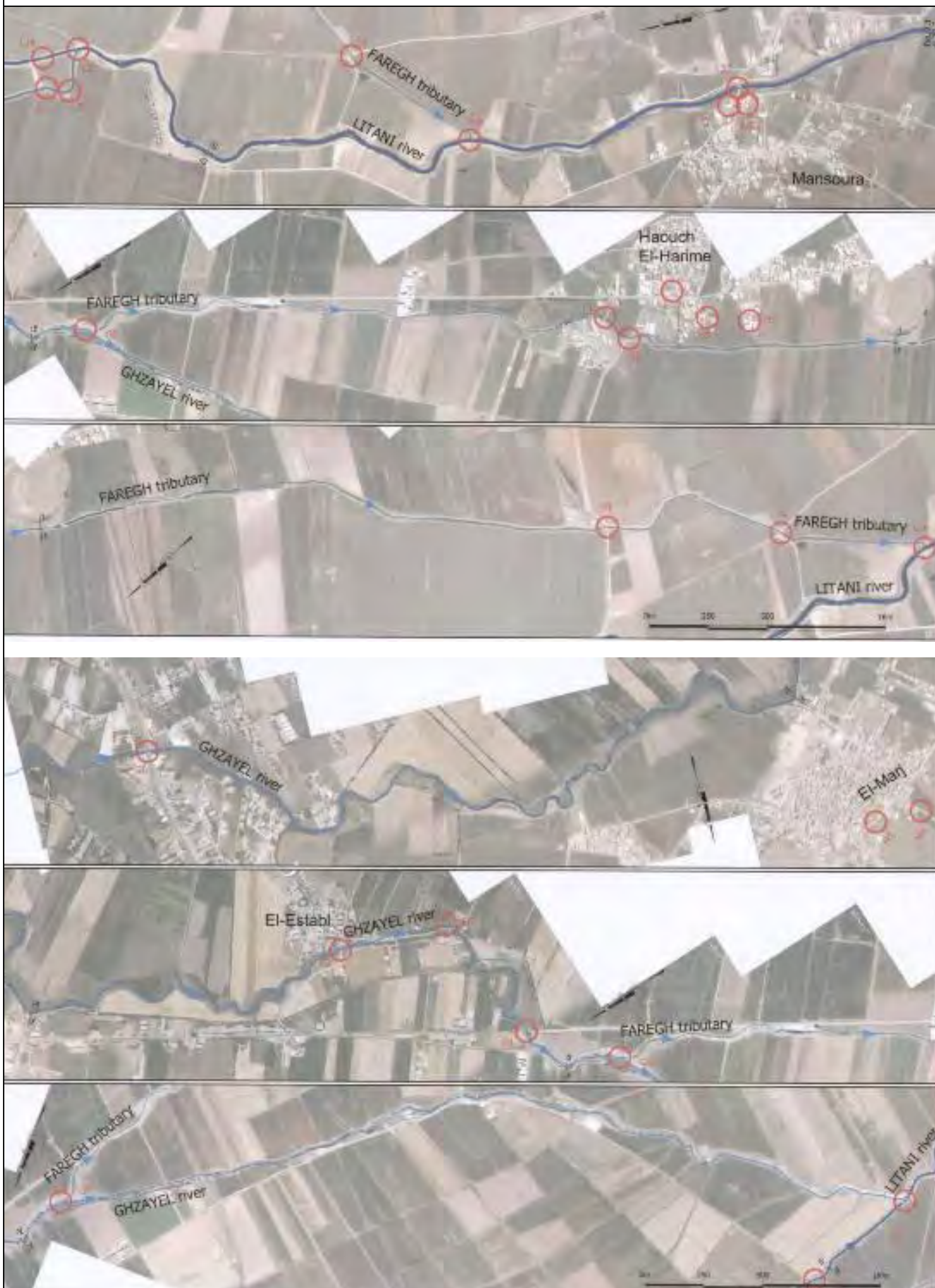


Figure 2.3 (continued): Key or representative locations and Flood Water Levels

within the Third Sub Area



2.6 FOURTH SUB AREA (GHAZZE – QARAOUN LAKE)

- The length of the Litani River inside this area is around 17 km and the width can reach 25m to 30m.
- The slope of the first part of this area (about 8 km) is about 0.4 m/km and the second part around 3.3 m/km.
- The key or representative locations on the Litani River water course in this area are:
    - L28, L29: Ghazze
    - L30, L31, L32: Joub Jannine
- The River Main Channel is mainly covered with weeds and stones in the first part.
- Many locations in the first part were cleaned and recalibrated. According to several testimonies, the flood of February 2003 mainly affected the areas surrounding bridges.
- The lands surrounding the Litani River in this area are mainly used for agricultural purposes.

Figure 2.4 : Key or representative locations and Flood Water Levels within the Fourth Sub Area

3. DATA COLLECTION ON THE FLOODS

3.1 METHODOLOGY

Preventing and/or mitigating flood damage to human, lives, constructions and activities due to flooding is commonly done through:

- An assessment of past flood events, based on an extensive field survey;
- A topographic survey (defined during the field survey) that provides essential hydraulic data such as river cross-sections, opening and sections of bridges crests of riverbanks, weirs and embankments, etc.
- The use of a flood model.

Information of past floods relies usually on three sources of information:

- Hydrologic data (discharges and water levels), as recorded by gauging stations;
- Field survey: so as to get a hydraulic feel for how water flows along the river and through the various structures (bridges, weirs, culverts, etc. it is here critical for proper calibration to understand that some of these structures may have modified, built or rebuilt after the reference flood, with consequences for the flow conditions); and
- Witnesses: residents who witnessed recent floods and can describe its extent, duration, impacts, etc; maximum water levels are usually easy to identify from witnesses and pictures are sometimes available; It is especially interesting to identify senior residents who have been living in the same location for a long time as they can put recent floods in perspective and compare them to older events.

It is important to note why witnesses are essential. First because hydrologic data is not always available or reliable or covering long periods of time. Second because gauging stations at best provide water levels in a few locations and are thus insufficient to define past floods and also properly calibrate a flood model that would cover a long stretch of river.
The validity (or truthfulness) of a flood model heavily depends on its calibration, that is on the process of constructing and adjusting the model so that it can properly represent past known events. It is then legitimate to extrapolate the model to represent events of higher magnitude and expect the results to be reasonably valid.

3.2 HYDROLOGIC DATA

Hydrologic data in the form of daily flows for several gauging stations on the Litani and its tributaries were delivered by the Litani River Authority. The Table 3.1 provides the list of these stations with the years of available data. These daily discharges are of limited interest since:

- They are daily averages and the detailed hydrograms are unknown;

- Their accuracy is unknown; and
- Corresponding water levels are unknown.

Older discharge data is also available for the 30s, 40s and 50s at several locations (Joub Jenine notably) from the Point 4 publications that led to the establishment of the LRA and the construction of Qaraoun Dam. Hydrologic data in the form of daily and hourly rainfall were also retrieved for several rainfall station located in the project area. The table 3.2 provides the list of these stations with the years of available data.

Table 3.1: Available data received for LRA		
Station No	**Station**	**Years available**
351	CHAMSINE SPRING - After Spring	67-68 and 02-03 to 07-08
352	GHZAYEL - Anjar 1	61-62, 67-68, 91-92, 97-98 and 02-03 to 07-08
353	GHZAYEL - Anjar 2	61-62, 67-68, 91-92, 97-98 and 02-03 to 07-08
354	GHZAYEL - Damascus Road	61-62, 67-68, 91-92, 97-98 and 02-03 to 07-08
356	BERDAOUNI - Damascus Road	61-62, 67-68, 91-92, 97-98 and 02-03 to 07-08
359	CHTAURA VALLEY - Damascus Road	67-68 and 05-06 to 07-08
360	edDELM VALLY - Qabb Elias	67-68 and 02-03 to 07-08
363	LITANI - Joub Jannine	02-03 to 07-08
366	Kfarzabad	67-68, 03-04 to 05-06 and 07-08
367	YAHFOUFA - Ain El Sikeh	02-03 to 07-08
368	LITANI - Qillya	61-62, 67-68 and 03-04 to 07-08
489	LITANI - Khardale	61-62, 67-68 and 02-03 to 07-08
490	After Ghandourieh Valley	67-68 and 02-03 to 07-08
492	LITANI - After CanalInlet	67-68, 91-92 and 02-03 to 07-08
493	LITANI - Sea Mouth	67-68, 91-92, 97-98 and 02-03 to 07-08

Table 3.2: Available rainfall data		
STATION	**Years available**	**Parameter**
Rayack_Tell Amara	1998 to 2009	Daily Rainfall
Zahle	2000 to 2009	Daily Rainfall
Marjeyoun	march 2009 to february 2010	Daily Rainfall
Qaraoun*	2001 to 2009	Daily Rainfall
Lebaa**	2000 to 2009	Daily Rainfall
Saghbine	1998 to 2000	Daily Rainfall
Kherbet Kanafar (LRA station)	June 2006 to April 2010	Hourly Rainfall
years (2001, 2002, 2007 & 2008) are incomplete** * many years incomplete**		

3.3 TYPES OF FLOODS

The Litani River Basin suffers from two types of flooding:

- Flooding from the Litani River and Major tributaries (Ghzayel, Berdawni, Qabb Elias); this is due to natural floodplain characteristics, compounded by lack of riverbed maintenance, existence of obstructions such as insufficient road bridges and irrigation weirs or other illegal constructions in the riverbed, dumping of all type of solid and hazardous waste, etc.
- Seasonal flooding from minor channels (Howayzek, Oqeyber, Faregh) due mostly to lack of agricultural drainage; this is due to the impermeability of soils (mostly clayey), and poor maintenance and disappearance of many drainage ditches in farm lands.

3.4 HISTORICAL FLOODS

Most of the Litani River Basin occupies Central and South Bekaa Valley. The valley is sandwiched between Mount Lebanon to the west and the Anti-Lebanon mountain to the east. Winter precipitations fall heavily on both ranges and engender heavy flows which then spread across the valley whose bottom is almost flat and with a low north-south slope (on average 2.5 m/km). Floods are thus common occurrences but with the growth of human activities (farming and urban areas), their impacts are increasing.

According to witnesses' accounts and to information collected during the field survey, it was deducted that from 1962 to present, the flood of February 2003 is one of the two highest floods in addition to possibly 1962. In other years like 1992 people talk about smaller floods. The fact that limited recollection exists regarding other large historic floods can be understood from a combination of factors:

- Past floods had less impacts as people were more informed about floods and floodable areas and were either avoiding such areas (in terms of constructions and farming) or else coping with the events; urban growth has, as often, pushed people to occupy "riskier" areas and thus increased the related impacts;
- Lebanon has had its share of traumatic events in the past 35 years and floods are not necessarily the most dramatic ones, thus preventing good recollection; population changes and moves make it also difficult to find long-term senior residents with a good memory of past floods;
- Clayey soils make also for regular flooding of the valley along the Litani river and it is thus

difficult to distinguish between lack of proper agricultural drainage and actual river flooding (as discussed before).

The flood of 2003 was selected to represent high flow conditions and to calibrate the model in accordance to its data since it is a recent flood and hence data collection is easier and since flow records for the Litani and its tributaries are available for this flood.

About 40 high water levels were identified through the field survey, either from photographs or from witnesses' accounts. These Water Levels Locations Sheets are provided in Appendix B.

Based on the qualitative information collected on the field, it is also reasonable to assume that 2003 was a relatively rare event, with a period of return between 20 and 50 years.

3.5 SEASONAL FLOODS

During the carrying out of the field survey, two seasonal floods were examined. The first one appeared in December 2009 and the second one in January 2010. The most affected regions by the floods are:

- The region situated upstream the village of Bar Elias along Howayzec tributary.
- The region situated upstream the Bridge on Berdawni River on Damascus Road.
- The region around the Mansoura Bridge on the Litani River.
- The region of the village of Haouch El Harime situated along the Faregh tributary.

In addition to those four major regions several other cultivated terrains were partially flooded because of lack or improper agricultural drainage.

3.6 GENERAL INFORMATION ABOUT THE FLOOD OF 2003

The heavy rains in February 2003 pounded the Lebanese territory and caused great losses. The February 2003 flood is one of the biggest historical floods ever encountered in the Litani.

The big flood of 2003 occurred after approximately 10 consecutive days of heavy rainfall in combination with snowmelt. 36 mm of rainfall were recorded during one day at the station of Haoush el Omara (Zahle) in the Bekaa Valley (in reference to Assafir newspaper 22/2/2003).

The area in the valley affected by flooding is reported to be more than 400 km2, extending from north of Damascus road near the village of El Delhamieh to Job Jannine. The circulation was partially or completely stopped in more than three locations on Damascus road.

In the Bekaa valley, the meteorological station of Haoush el Omara has recorded 772.4 mm of rainfall since winter has started whereas it was only 451.1 mm in the same period of previous year. It must be noted that the average calculated over 30 years is 447 mm and that the recorded rainfall is the maximum since 1969 (Meteorological department, International Airport of Beirut).

The Qaraoun Dam has a maximum capacity of 220 MCM and regulates the downstream discharge. Flooding during the first part of February 2003 caused the Litany River Authority LRA to open the security outlets starting from February 16th (in reference to Al-Mustaqbal newspaper 15/2/2003) causing damages in the region located downstream the dam.

The flood caused big damages, 80% of the cultivated area in the Beqaa valley have been totally inundated (in reference to L'Orient le Jour newspaper 20/2/2003). The losses are huge and the most affected regions are: Haouch el Harime, El Khiara, Ghazze, El Mansoura and El Nasriyeh (in reference to Assafir newspaper 2/2003). The West Bekaa was transformed to a series of isolated islands only accessed by the mean of boats or heavy trucks (in reference to Al Anwar newspaper 22/2/2003).

3.7 CHRONOLOGICAL INFORMATION ABOUT THE FLOOD OF 2003

According to the news reported in several local newspapers (Assafir, Al Anwar, Al Mustaqbal, The daily Star, l'Orient le Jour…) the following chronological order of the storm was deducted:

- 12/2/03 to 13/2/03:
    - Beginning of the first heavy rain spell
- 14/2/03:
    - Nasser Nasrallah General Director of LRA:
        - Average Litani Flow to the Qaraoun Dam = 7 Mm^3/d = 80 m^3/s.
- 15/2/03:
    - 3rd Day of the first heavy rain spell
- 16/2/03:
    - Nasser Nasrallah General Director of LRA:
        - Opening of the Bottom Outlets,
        - Average Litani Flow to the Qaraoun Dam = 9 Mm^3/d = 110 m^3/s,
        - Limited infiltration.
- 17/2/03:
    - El Khardali flooded
    - Bar Elias and El Marj flooded
    - End of First heavy rain spell
- 19/2/03:
    - Beginning of the second heavy rain spell
- 20/2/03:
    - Bar Elias and El Marj flooded
    - El Qasmieh flooded (Restaurants flooded)
- 21/2/03:
    - Bar Elias: Flooded land situated between Litani River and Houaizec Tributary (Al Anwar 22/02/03)
    - El Marj flooded: use of little boats for transportation
    - Aerial picture showing the entire Bekaa Valley flooded
    - Nasser Nasrallah General Director of LRA:
        - Highest levels in Litani since 1954
        - Rainfall: 36 mm from 6 am 20/2/2003 to 6 am 21/2/2003 (Haouch El Oumara)

    - Average Litani Flow to the Qaraoun Dam = 15 Mm^3/d = 174 m^3/s
- 22/2/03:
    - End of second heavy rain spell
- 23/2/03:
    - Beginning of third heavy rain spell (snowfalls)
- 26/2/03:
    - End of third heavy rain spell

3.8 CONCLUSION ON THE FLOOD EVENTS

The Flood of 2003 was the result of heavy rains during several short periods of time in addition to rainfall on snow producing snowmelt which produced a large water runoff.

The floods in the Litani River basin area can be divided into two categories:

- Flooding from the Litani River and Major tributaries (Ghzayel, Berdawni, Qabb Elias)
- Flooding from minor tributaries (Howayzek, Oqeyber, Faregh, Chtaura) and from lack of drainage Channels

The main causes of the flooding from Litani River and major tributaries are:

- Natural floodplain characteristics due to high runoff generated by heavy rainfalls on both mountain ranges and very low slope of the Bekaa valley leading to limited riverbed capacity;
- Natural weather regime with long dry season where flow is minimal thus generating sedimentation, island formation and instability of river banks.
- Growing of vegetation in the river bed (weeds, trees, marshes, bamboos…) which is caused by the presence of nutrients in the river coming from waste water and fertilizers.
- Dumping along the river of all type of solid and hazardous waste (wheels, dead animals, furniture, plastic bottles, chemicals…).
- Construction of embankment weirs for irrigation by pumping creating obstacles inside the river bed or lowering river sides to install pumps or to connect with irrigation channels.
- Existence of illegal buildings inside the River bed.
- Existence of numerous road bridges with insufficient hydraulic openings.

The main causes of the (seasonal) flooding from minor tributaries and from insufficient drainage:

- Poor maintenance and disappearance of many drainage ditches from farm lands, for example by ploughing all the way to the plot border (modern farmers tend to worldwide disregard old traditions and want to maximize short-term benefits).
- Very low slopes of the Bekaa valley and Litani riverbed leading to slow water flow and to high water levels.
- Growing of vegetation in the river bed (weeds, trees, marshes, bamboos…).
- Impermeability of soil in the Bekaa region (clay and hydromorphic texture) which causes low infiltration of running water.
- Dumping along the tributaries of all type of solid and hazardous waste (wheels, dead animals, furniture, plastic bottles, chemicals…).
- Heightening river sides by the creation of levees which blocks the water coming from small tributaries (Case of Chtaura tributary which floods into other tributaries which are blocked at their intersection with the Litani downstream El Marj Bridge) toward the Litani and other major tributaries which causes the flooding of the plain.

- Existence of bridges or culverts with limited section.

It must be made clear here that there is a difference between:

- River flooding which has significant impacts and is a public issue (river bed is public property) to be addressed by Central Government and/or local authorities(municipalities);
- Lack of proper agricultural drainage which at plot level is a private problem (farmer managing own private land) and thus not governmental responsibility; at the level of larger areas, the lack of proper agricultural drainage could be handled by local authorities but one needs to keep in mind that this should be done in collaboration with farmers and possibly with their contribution (why would some farmers benefit privately from public help as opposed to other water users somewhere else who have similar or different water issues?)

4. FLOOD DAMAGE ASSESSMENT

4.1. INTRODUCTION

Floods are natural events that occur regularly in river plains. With population and economic growth, more and more infrastructures and human activities settle or take place in floodplains and thus get impacted by floods. Damages due to floods impact different types of structures or activities (stakes) and can be direct (physical damage due to submersion and water flows) or indirect (disruption of human and notably economic activities).

The table below is commonly used in France to categorize flood damages per stake and type of impacts.

Types of damage	Direct		Indirect	
Stakes	**Examples**	**Cost evaluation**	**Examples**	**Cost evaluation**
Residential houses	Destruction or degradation	Reconstruction, repair or cleaning costs	Alternative housing during reconstruction/repair Decrease in house value	Cost of alternative housing
Factories and private sector facilities	Destruction or degradation	Reconstruction, repair or cleaning costs	Interruption of production, loss of clients, loss of jobs, bankrupcy	Production decrease and economic losses, impacts from long-term job losses?
Farms	Destruction or degradation of crops	Areas impacted and estimated yield decreases	Decrease in land value Bankrupcy, loss of jobs	Production decrease and economic losses, impacts from long-term job losses?
Public infrastructure (hospitals, schools, administrative buildings, etc.)	Destruction or degradation	Reconstruction, repair or cleaning costs	Service interruption	Cost of delays or of alternative service sources
Road infrastructure	Destruction or degradation of roads and structures (e.g. bridges)	Reconstruction, repair costs	Road or bridge restriction or closure, increased travel times for users	Increased costs for transport companies Economic losses for factories, farms, etc.
Other transport infrastructure (ports, airports, railways, canals, etc.)	Destruction or degradation	Reconstruction, repair costs	Transport restriction or closure, increased travel times for users	Increased costs for transport companies Economic losses for factories, farms, etc.
Public services (water, electricity)	Destruction or degradation of infrastructure (networks, plants, etc.)	Reconstruction, repair costs	Service interruption	Production losses and economic losses for factories, farms, etc.
Tourist infrastructure (hotels, restaurants, campings, etc.) & historic locations/buildings	Destruction or degradation	Reconstruction, repair costs	Decrease in tourism	Economic losses
Natural environment (rivers, wetlands, forests)	Destruction or degradation	Reconstruction, repair costs	Pollution	Pollution impacts Depollution costs

Floods (notably flash floods) can also claim lives of human beings. These are direct impacts that are not considered here because:

- such occurrences have not been reported so far regarding floods of the Litani River; and
- Financially estimating the cost of life is always a difficult and controversial topic.

Assigning costs to direct impacts is not always easy as it may be more than just physical repairs (for example crop losses are difficult to "repair"). It is however becoming feasible as formulas and mechanisms are being developed in Europe and in the US. These formulas or standard values are mostly established by insurance companies since they cover floods as they do for other types of risks.

Numerous surveys have also been carried out to assess the costs of flood damages and references exist. These references have been adapted here to Lebanon where such formulas or standard values do not exist yet.

Assigning costs to indirect impacts (which can go as far as including psychological impacts on populations) is much more difficult. Most of the associated economic losses are caused by the temporary or permanent unavailability of structures or equipment. Such losses can even lead to job losses and bankruptcies.

The objective of this damage estimation study is simply to give an idea of the magnitude of the economic cost of a Litani flood, so only direct impacts will be calculated. Indirect impacts will be for now considered to be, at most, of an equivalent magnitude.

4.2. DAMAGE ASSESSMENT FOR THE FLOOD OF 2003: METHODOLOGY AND RESULTS

The study area includes the region situated between Bar Elias and Mansoura which was the most affected by the flood of February 2003.

Combined with existing information on land use and flood depth, maps of the flooded areas provide information that can be used for flood damage assessment, urban and rural planning and validating flood simulation models.

The concept of damage function is used when calculating flood damage.

In order to assess flood damage correctly, the impact parameters need to be incorporated in a method (Water depth, Duration of flooding, Flow velocity, Sediment concentration, Sediment size, Wave or wind action, Pollution load of flood water, Rate of water rise during flood onset). However, due to the lack of information and the difficulty in integrating such variables, damage is generally related to only water depth.

In the case of built-up areas, the land use class is expressed per unit area. The economic value of the land use class is estimated in order to calculate the damage. This value is based on the principle of replacement value: how much money it would cost to obtain the 'identical' object. The damage function has values included between 0 and 1, with the value 0 if there is no damage and the value 1 if there is maximum damage.

This analysis has the purpose to give an assessment of the damage of flood by using the damage functions which are available in the literature. The assumptions listed below had to be made to do the flood damage assessment:

- The damage function is a function only of inundation depth, although flood damage is determined by more factors, as explained before.
- The damage functions must be increasing functions, which means that as the inundation depth grows, also damage rises.

- During a flood event, some damage can be avoided by appropriate action from the people who live in the floodplain. Therefore cars are not taken into account of the damage assessment.
- An important question in damage calculation is which assumption has to be made with respect to the behavior of the people. This is caused by the fact that damage is a function of many physical and behavioral factors, like for example the content of the house and the preparation time. Hence, uncertainties in the damage functions are not dealt with in this analysis.
- The maximum damage values are here only indicative and are based on the average price per m2 for a house or an apartment. This information is deducted from the local market prices.

The damage function used in this study depends on several components: different land used classes, flood depth factors, economical value per square meter.

The study area corresponds to the region situated between Bar Elias and Mansoura in the West Bekaa close to the Litani River, which was severely flooded on February 2003.

The flooded area was individuated and considered according to the map of the flooded area provided by the Litani River authority from the IRWA project and based on the Field Survey conducted by Robert Bou Nahed from DAHNT.

The flood damage depends on the land use type: in urban areas floods produce as a consequence much more damage than floods in a rural area. The land use classes, which are used to calculate the flood damage, correspond to:

- Agricultural areas
- Built-up area (Residential, Industrial and Commercial areas)
- Infrastructure

A satellite view showing the estimated delimitation of the February 2003 flood and an estimation of land use based on the information collected during the field survey is provided in figure 4.1.

Figure 4.1: Land use of the flooded area in February 2003 (1/4)

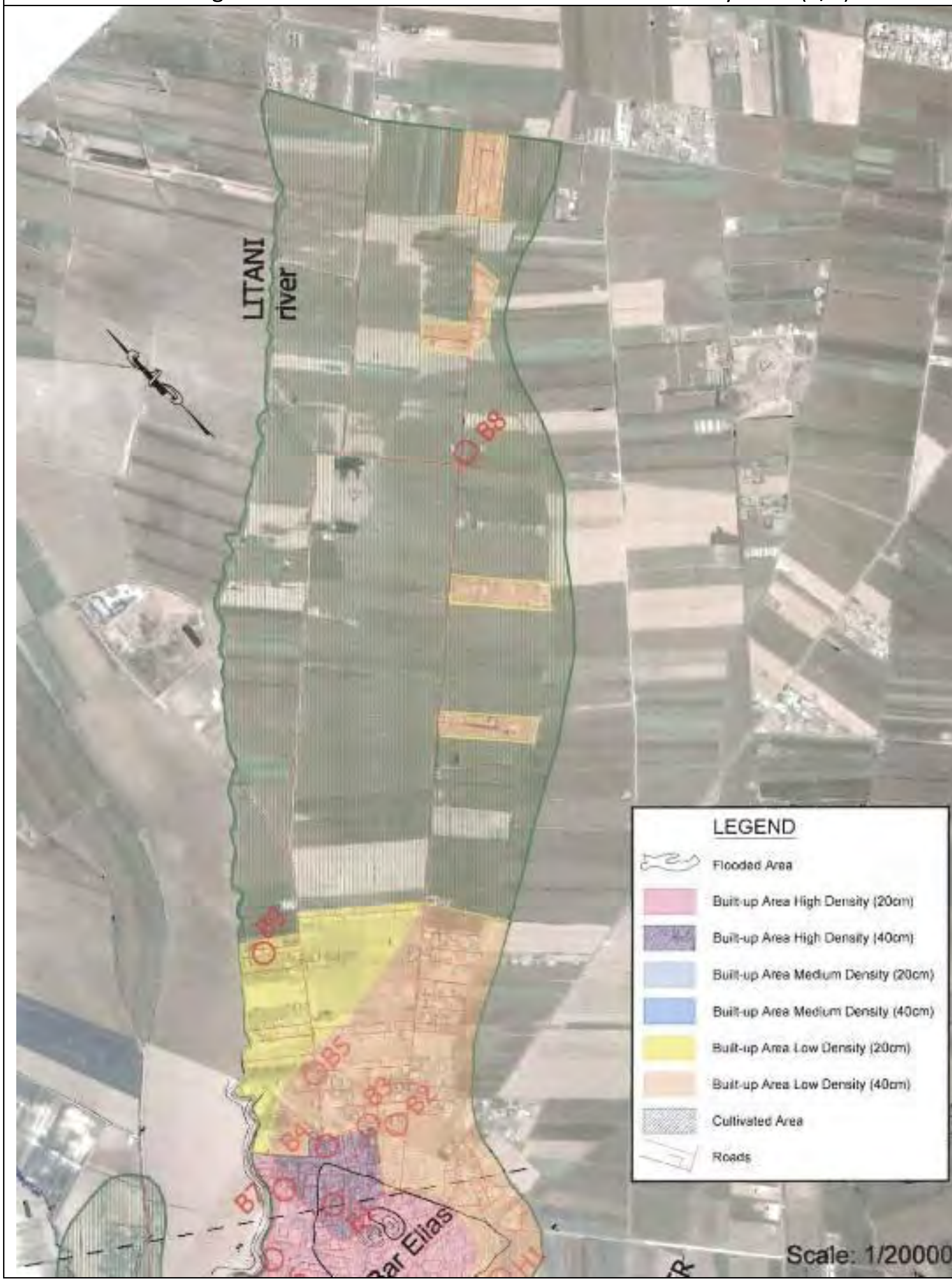


Figure 4.1: Land use of the flooded area in February 2003 (2/4)

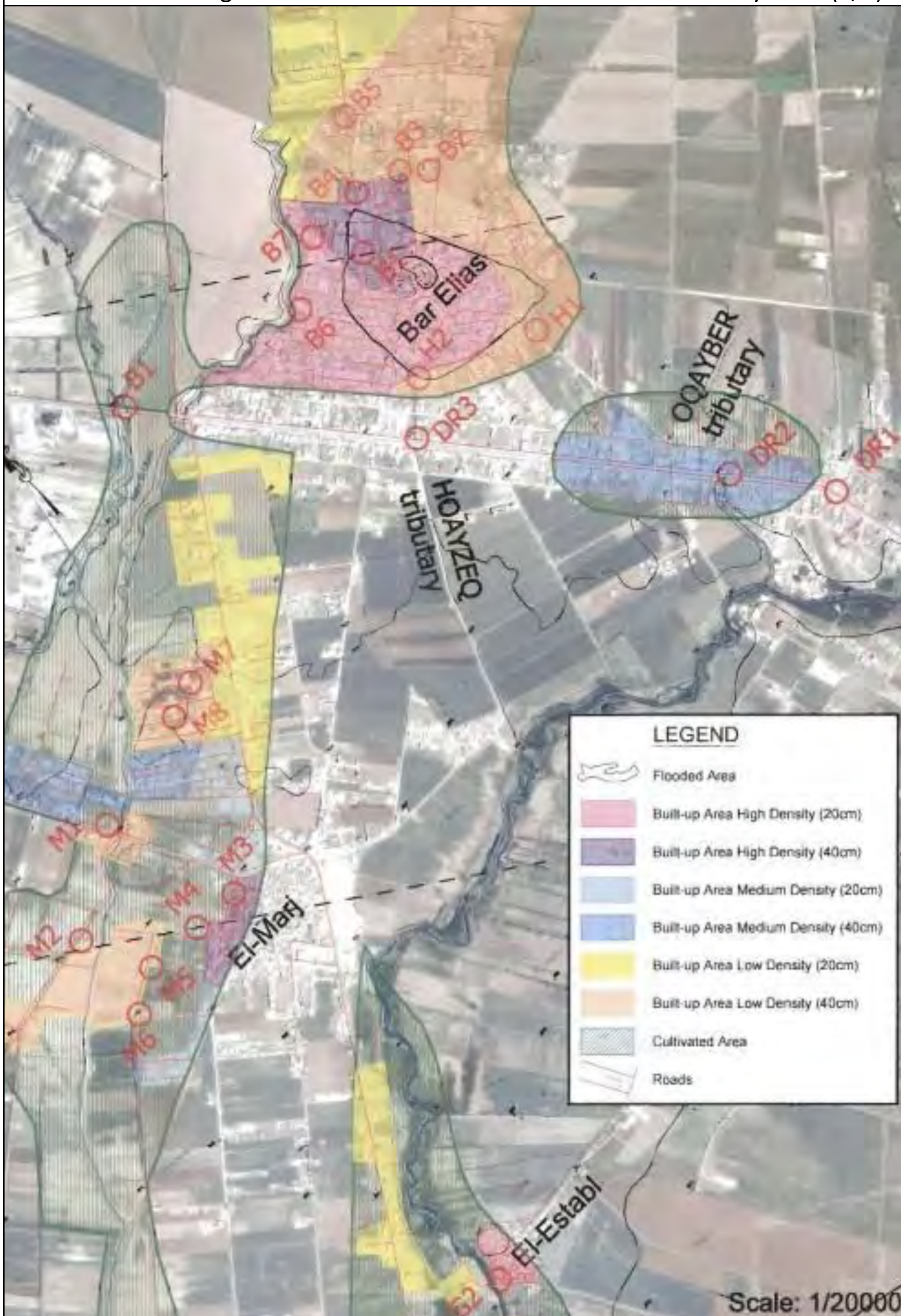


Figure 4.1: Land use of the flooded area in February 2003 (3/4)

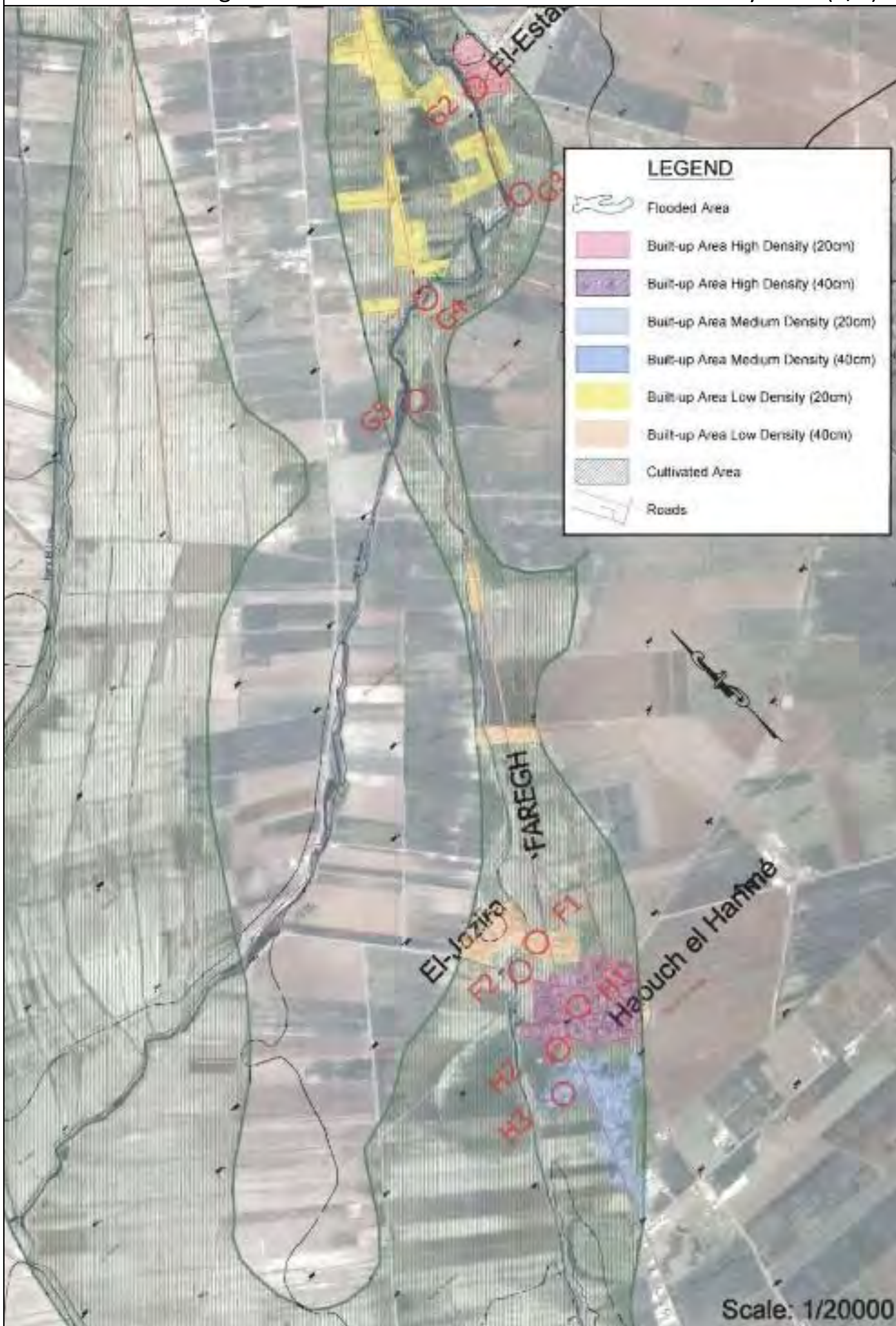


Figure 4.1: Land use of the flooded area in February 2003 (4/4)

4.2.1. AGRICULTURAL AREAS

The damage in agricultural and vegetated areas does not depend on the inundation depth.

The conducted field survey and the information provided from LRA reveals that agriculture was interrupted during a cropping season because the water content of the inundated area was high during a period of 2 to 3 months.

An estimation of the agricultural revenues for a period of one year in the Bekaa based on previous studies conducted by DAHNT gives a value of 0.1 to 0.2 US$/m2 of cultivated land. Considering that a land is cultivated twice per year, a damage factor of 50% can be adopted.

The overall cultivated area included in the flooded area is estimated to 10,000 ha. 25% to 50% of this area was damaged directly from the Litani and tributaries flood.

The evaluation of the damage caused by the flood of February 2003 in agricultural areas is estimated to 0.5 to 1 Millions of US$.

4.2.2. RESIDENTIAL AREAS

Flood damage in residential areas is calculated per hectare. The applied flood damage function is based on damage data of the Commissie Watersnood Maas provided for assessing damage in the floodplain of the Meuse River. Damage to cars is not taken into account because there is usually enough time to move these cars onto the higher parts of the area.

A hazard map where the hazard levels correspond to different water depth was considered to obtain the hazard flood depth. It was obtained based on the results of the field survey (Refer to figure 4.1).

Linear interpolation is used to obtain the complete function of damage factor for the house and its content that is presented in figure 4.2.

The study area includes the following built-up Land Use classes, which are separated depending on their water level:

- High density built-up area (Average Water Level = 20 cm or 40 cm)
- Medium density built-up area (Average Water Level = 20 cm or 40 cm)
- Low density built-up area (Average Water Level = 20 cm or 40 cm)

According to known market prices, the average price per m2 for built up area in the West Bekaa region in 2003 is estimated to 250 US$. For the purpose of the damage evaluation method herein proposed, these figures should be considered like a reconstruction cost, namely the costs for rebuilding to a standard responding to local conditions.

All the necessary data are available to propose an assessment for the different residential categories of land use which is considered representing 90% of built-up area.

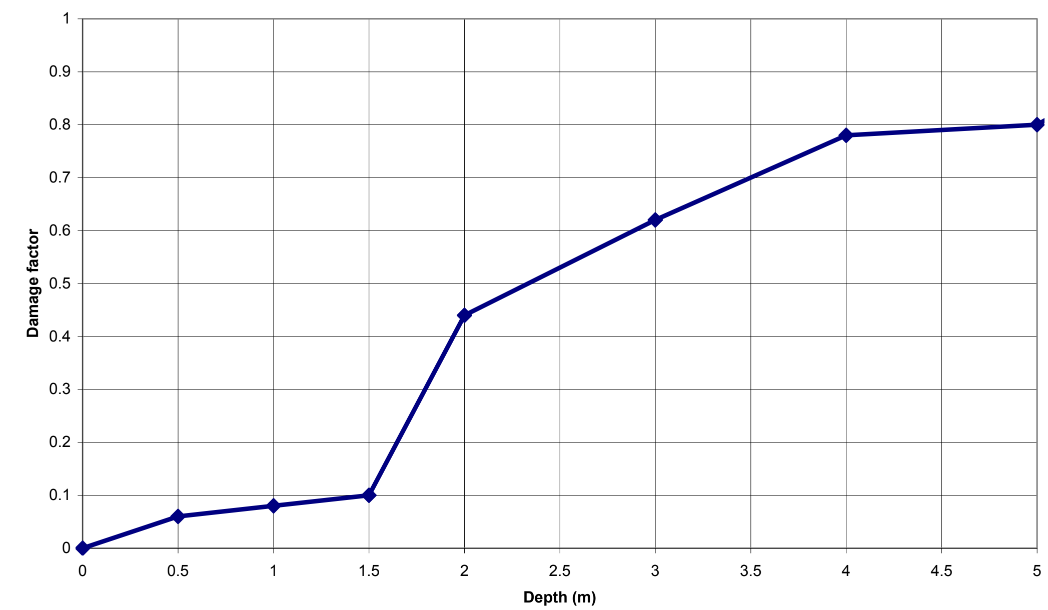


Figure 4.2: Proposed damage function for houses (property and content)

In order to take into consideration that the houses in the Bekaa are usually built higher than the natural ground level and according to the observations of the field survey, the water height was reduced by 10cm to 20cm when applying the generic formula below:

Damage Cost = p * A * H * V

- p= % of built-up density covered surface in a X land use
- A= area (m2) of the X land use
- H= water depth damage factor
- V= average price for m2 for an apartment.

The results are provided in table 4.1.

Table 4.1: Residential areas damage cost				
Area (m2)	**Land Use classes**	**Water depth**	**Density factor**	**Damage Cost (US$)**
500,000	Built-up high density	0 cm to 10 cm	70%	≈ 500,000
300,000	Built-up high density	10 cm to 20 cm	70%	≈ 900,000
150,000	Built-up medium density	0 cm to 10 cm	30%	≈ 100,000
525,000	Built-up medium density	10 cm to 20 cm	30%	≈ 600,000
900,000	Built-up low density	0 cm to 10 cm	10%	≈ 100,000
1,450,000	Built-up low density	10 cm to 20 cm	10%	≈ 600,000
Total				**≈ 2,800,000**

4.2.3. INDUSTRIAL AND COMMERCIAL AREAS

The most suitable method is to evaluate flood damage in industrial and commercial area according to water depth. The maximum damage cost of industry is assessed per m2. The damage function adopted in our study is provided in figure 4.3.

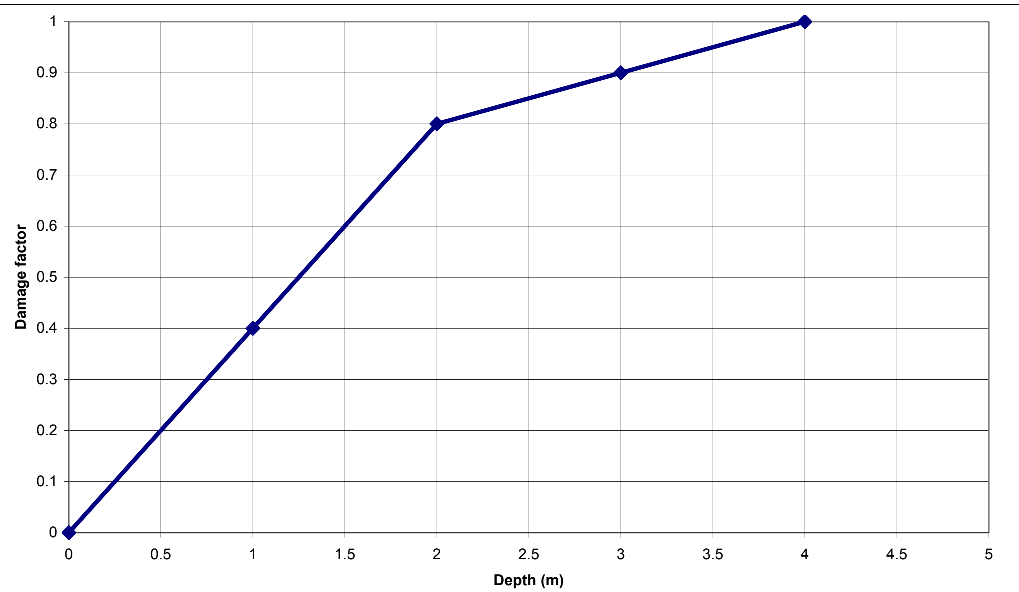


Figure 4.3: Proposed damage function for commercial and industrial areas

All the necessary data are available to propose an assessment for the different commercial and industrial categories of land use which is considered representing 10% of built-up area. The results are provided in table 5.2.

Table 4.1: Residential areas damage cost				
Area (m2)	**Land Use classes**	**Water depth**	**Density factor**	**Damage Cost (US$)**
500,000	Built-up high density	0 cm to 10 cm	70%	≈ 175,000
300,000	Built-up high density	10 cm to 20 cm	70%	≈ 325,000
150,000	Built-up medium density	0 cm to 10 cm	30%	≈ 25,000
525,000	Built-up medium density	10 cm to 20 cm	30%	≈ 225,000
900,000	Built-up low density	0 cm to 10 cm	10%	≈ 50,000
1,450,000	Built-up low density	10 cm to 20 cm	10%	≈ 250,000
Total				**≈ 1,000,000**

4.2.4. INFRASTRUCTURE

The damage is calculated per unit length rather than per unit area. The maximum damage values vary depending on the type of road. In the floodplain there are 90 km of mainly roads and rails. The used damage function is provided in figure 4.4.

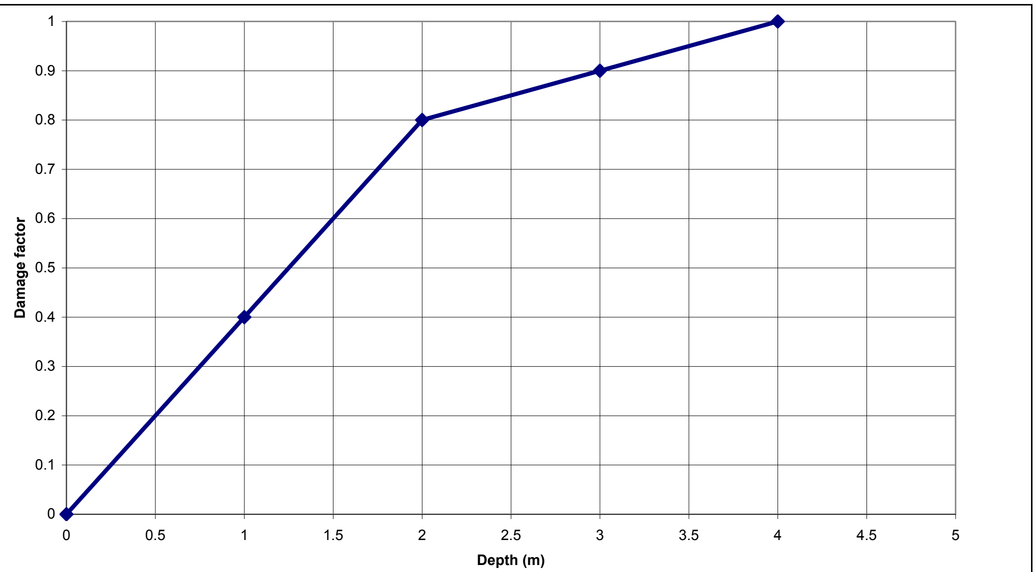


Figure 4.4: Proposed damage function for infrastructure

Considering an average water depth varying between 0cm and 20cm for all roads and an average price of 100 US$ for the construction of one linear meter of road, the damage cost of infrastructure is estimated between 0.1 and 0.2 Million US$.

4.3. CONCLUSION

The results listed above, provide an average estimate and should not be considered as a detailed cost assessment of the damage, since they are strongly depending on the quality of the damage functions and the availability of detailed datasets.

Additionally, for the area under examination, the actual damage might be lower, because the area is prone to flooding and the citizens have adapted to that.

The quality of the damage assessment also depends on the quality of the classification which was made considering satellite views, previous studies data and the field survey collected information after 7 years from the flood.

The total damage cost estimation based on the above functions and assumption is several millions US$ (possibly 3 to 5 Millions US$).

5. REHABILITATION AND RECALIBRATION WORKS AFTER 2003

Two main projects involving works inside the Litani river course influencing the flood events were conducted since the flood of 2003:

- The demolition of illegal buildings in the river course and the cleaning performed after the flood of 2003 by the Lebanese Army (LA), the Ministry of Energy and Water (MEW) and the Higher Relief Council (HRC) in collaboration with the Municipalities.
- The works done by the IRWA project on 11 selected critical points in the Litani and Ghzayel River course.

In addition to the two projects, the rebuilding of bridges after their destruction during Israeli war of 2006 has also its effects on flood events.

5.1. WORK DONE BY THE LA, MEW AND HRC

According to Al Mustaqbal newspaper dated 16/12/2003, 10 km of water courses mainly belonging to Litani and Ghzayel were cleaned, rehabilitated and recalibrated after the flood of 2003. Deposited materials, trees and weeds were removed and some enlargements of the river bed were conducted. The region that was mainly rehabilitated is situated between the Marj Bridge and Joub Jannine Bridge which is the most critical flooding zone. In this zone, the river width was enlarged to approximately 25 meters especially in the flooded regions of El Marj, Haouch el Harime, Ghazze and Mansoura.

5.2. WORK DONE BY THE IRWA PROJECT

As part of the IRWA Project, 11 critical points (refer to Appendix C for a visual comparison for the status of these locations before and after the IRWA works and their present status and to figure 5.1 for the locations of these points) were identified as being most critical points on the river, requiring an urgent intervention. The field visits showed that Litani River presents Instability on banks and Sedimentation.

The main criteria of that classification were: the banks morphology, the presence of any natural obstacle like trees, permanent weeds or artificial ones like bridges, over passes or buildings on the banks.

The 11 critical points where interventions were conducted on the Litani and Ghzayel Rivers and at the intersections with Berdawni and Faregh were as follows:

- L1 Litani- Haouche al Omara - Damascus road: Recalibration of the river section upstream and downstream the bridge and cleaning of the section under the bridge. Gabions mattresses and geocomposite were executed.

- LB2 Litani- Berdaouny- Marj: Enlargement of the river width, recalibration of the river banks for 3 km and execution of mattresses and gabions with geocomposite on every bank.
- L3 Litani - Marj Bridge: Execution of 160 m of gabions & geocomposite for every side of the river. Cleaning the bed and recalibrating of the banks for approximately 4 Km.
- L4 Litani – Marj: Recalibration the river section for a length of about 4 k m.
- LG8 Litani- Ghazael - Al Wakf: Execution of gabions for 20m for the protection of an existing pumping station and recalibration along Litani and Ghzayel river for a length of 4.3 km upstream and downstream the confluence.
- G1 Ghazael- Anjar - Damascus Road: Enlargement of the width of the river to 18 m, execution of 160m of gabions and geocomposite for every side of the river and cleaning the bed and recalibration of the banks for approximately 4 km.
- G6 G7 G9 Ghazael - Harimeh el Soughra: Re-arrangement of the river section and reinforcement of the banks with gabions and mattresses on every side of the river and cleaning the bed and recalibration of the banks upstream and downstream the Bridge.
- GF 10 Ghazael - Faregh - Harimeh el soughra: Recalibration of the river bed for about 2 km and local protection by the mean of gabions for a pumping station.
- L14 Litani - Kherbet Kanafar: Backfilling an area of erosion with rocks and recalibration of the Banks for 200 lm.

These eleven critical points were identified as being bottlenecks for the flows and most of works carried out were riverbed cleanup and riverbed recalibration/widening.

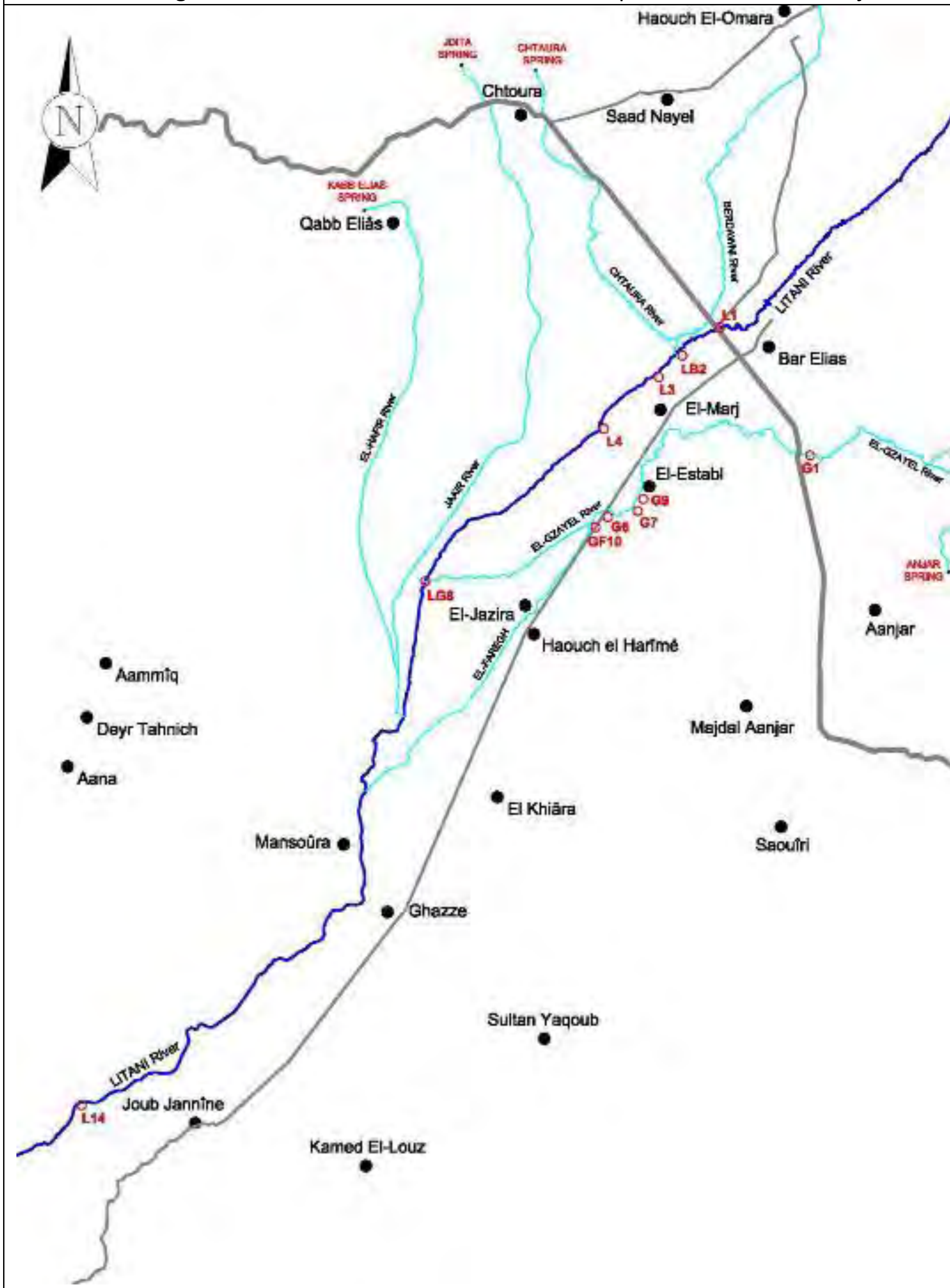
The flood analysis for each site was however succinct and relied on single-point hydraulic calculations (Manning-Strickler formula). Such calculations are only valid for uniform flows, that is long stretches of river/canal with constant sections, steady slopes and no structures such as bridges and other obstructions.

1-D hydraulic equations for (gradually varied) fluvial flows have to be used for meandering rivers changing cross-sections the presence of structures such as culverts and bridges. Such equations clearly state that water levels in a river are always controlled by downstream conditions, notably during floods by downstream structures such as bridges.

The works carried out under IRWA were thus of limited impact in the sense that:

- Since they were mostly cleanup works and not repeated since, they were obsolete within a few years as deposits and notably garbage re-accumulated.
- They only marginally lowered water levels since obstacles such as (too small) bridges command water levels upstream of them.

Figure 5.1: Locations of the 11 intervention points in the IRWA Project



5.3. WAR OF JULY 2006

During the war of July 2006, several bridges on the Litani Riverespecially in the region situated upstream the village of Dalhamieh were destroyed and rebuilt. The new bridges were built without any consideration for the flow capacity.

- Bridge in Haouch er Rafqa (Location L2): The new bridge and new culvert flow capacity is less than the old ones.
- Bridge in Chamieh (Location L3): The New road and bridge are constructed on a new location with a much better flow capacity.
- Jisr En Nahriye Bridge (Location L4): No information about the bridge which seems to be new.
- Bridge in Tell Amara (Location L6): The new bridge is 50cm lower than the old bridge.
- Bridge in El Ghabe (Location L8): The new culvert flow capacity is less than the old steel bridge.
- Bridge in Mkhat el Laouz (Location L9): The new Bridge Section is similar to the old bridge.
- Bridge in Ferzol (Location L10): No information about the bridge which seems to be new.
- Bridge in Ferzol (Location L11): The New road and bridge are constructed on a new location with a much better flow capacity.
- Bridge in Dalhamieh (Location L13): The new Bridge Section is similar to the old bridge.

In addition to the bridges rebuilt after the war of July 2006, a new bridge is under construction on the Litani River as part of the new international road. This bridge is situated just downstream the one on Damascus road. During two seasonal floods encountered at the end of the year 2009 and at the beginning of 2010, the water Level reached a height 60cm under the lowest level of the bridge.

5.4. EFFECTS ON THE MODEL

Since the calibration of the model will be based on the testimonies of water levels during the flood of 2003, all the recalibration, cleaning, protection of the banks and construction of new bridges should be taken into consideration:

- The flow conditions downstream the village of Dalhamieh except the new bridge on the new international road should be better than the ones existent during the flood of 2003.
- The flow conditions upstream the village of Dalhamieh may be better than the existent conditions during the flood of 2003 in some locations (Chamieh, Ferzol) and may be worst (Haouch er Rafqa, Tell Amara, El Ghabe).

6. TOPOGRAPHIC SURVEY

The necessity of the topographical survey in a particular area depends on the social and economical impact of the flood. The objective of the field work done is to identify the critical zones susceptible to flooding in order to locate the starting and ending points for the topographical survey of the Litani River and tributaries and to intensify the topography inside these zones.

The critical zones where the topographical survey should be intensified are the urbanized, commercial and industrial areas in addition to the public structures (roads, bridges, electrical and sanitary equipments) susceptible to be attained by the floods.

In rural zone where the information collected about historical floods is not sufficient and where the impact of such floods is minimal, the topographical survey should be done only for the determination of typical sections to be adopted along the region.

It is very important to establish specifications for such survey in order to guide the surveyors because they most often have little or no knowledge in hydraulic works.

The following information should be included in the specifications:

- Longitudinal profiles alignments
- Transversal sections locations and length
- Specific structures to be surveyed
- Location of the flood water levels to be surveyed

The proposed SOW for the topographic survey is provided in Appendix D.

7. FLOOD MODELS TO CALCULATE RIVER FLOW VELOCITIES AND LEVELS

7.1. PURPOSE OF A FLOOD MODEL

Preventing and/or mitigating flood damage to human, lives, constructions and activities due to flooding is commonly done through:

- An assessment of past flood events, based on an extensive field survey, which involves visual inspections of structures and unrepaired damage, identification of possible high water marks, riverbed erosions and other hydro-morphological signs. The interview of witnesses is also essential to inform the extent, duration, and impact of the floods, even if such accounts have to be cross-referenced. The field survey allows to identify properly all features impacting flows, both natural (meanders, riverbed changes, and artificial (bridges and other structures or obstructions, embankments, etc.) and their level of impact.
- A topographic survey (defined during the field survey) that provides essential hydraulic data such as river cross-sections, opening and sections of bridges, crests of riverbanks, weirs and embankments, etc.
- A hydrological study based on available data from gauging stations such as flood discharges and water levels.
- The use of a flood model, which allows to:
  - First properly describe past (known) flood events, so as to better understand these (through the mapping and floodable areas, the definition of high risk buildings and areas, the identification of bottlenecks such as bridges, etc.)
  - Then extrapolate to other types of floods, either larger or simply different, to assess their potential impact on structures, constructions and human activities at large;
  - Also simulate flood protection or mitigation measures (channel improvements, construction, modification or replacement of structures such as bridges and embankments, construction of reservoirs, etc.) and to assess their influence on flood impacts and potential damage.
  - Also simulate flood protection or mitigation measures (channel improvements, construction, modification or replacement of structures such as bridges and embankments, construction of reservoirs, etc.) and assess and compare their influence on flood impacts and potential damage;
  - Finally define integrated flood protection plans that involve and combine the most effective, sustainable and cost efficient measures in terms of structures as well as practices and activities (from more responsible urban planning to better agricultural practices).

The various types of flood models are reviewed hereafter.

7.2. SLOPE-AREA METHODS

The simplest "model" available for computing flow levels and velocities is the use of empirical formulas such as Chezy and Manning equations. These formulas (slope-area methods) use simple relationships between discharge, slope, and cross-section geometry and roughness. They are only suitable for computing water conditions for a single discharge value (steady flows) under uniform flow conditions (constant cross-section, roughness and slopes, such as irrigation or other man-made canals). They are often inappropriate for natural river flows.

7.3. ONE-DIMENSIONAL STEADY FLOW MODELS

Steady flow hydraulic models, as the name implies, are confined to applications in situations of steady or gradually varied flow. These types of model are often easy to use and are based on simple hydraulic calculations using the principle of conservation of energy to compute flood levels. The hydraulic equation includes only the terms for "convective" acceleration (due to momentum), potential energy, friction losses and singular losses.

Steady flow models are restricted to modeling river and floodplain systems under the following conditions:

- The flood hydrograph is generally of long duration with a slow rate of rise such that attenuation effects are minor and backwater effects have the most significant influence on flood levels;
- The slope of the river reach is less than 1 in 10 (so that the flow is fluvial and computation proceeds upwards long the channel based on a set downstream condition);
- There is no significantly large floodplain which could significantly attenuate the flood hydrograph. If storage attenuation effects are significant, it may be necessary to first compute the attenuated flow (by runoff routing perhaps) before proceeding with the hydraulic model.

The most common of the steady flow one-dimensional models is HECRAS (US-Army Corps of Engineers).

Steady flow models are normally one-dimensional, although models such as HECRAS have some quasi-two-dimensional capabilities with 'split-flow' option and can thus be used in a fairly creative manner to compute flood levels in reasonably complex river networks.

Field data requirements for this type of models are river cross-sections and dimensions of special structures (bridges, culverts, weirs, etc.) likely to cause backwater effects. The main model parameters are the roughness coefficients, and flow contraction/expansion coefficients (for friction and singular losses).

Applications of one-dimensional flow models are common and are generally quite appropriate for most river flood studies. Quite often, it is the significance of flood attenuation rather than limitations of one-dimensional flow assumptions that inhibits the wider application of steady one-dimensional flow models.

7.4. ONE-DIMENSIONAL UNSTEADY FLOW MODELS

Unsteady flow models are more rigorous, taking into consideration the significance of hydrograph and storage characteristics on flood attenuation. Briefly, the hydraulic equation includes the local acceleration term (time variation of velocity) along with the terms of the steady equation: convective acceleration (due to momentum), potential energy, friction losses and singular losses.

In most natural rivers under normal flood conditions, the local acceleration term is usually an order of magnitude lower than the convective acceleration term. This has led to many models discounting the local acceleration from the equation to improve model stability by relaxing the maximum space and time increment requirements. Models such as HEC-RAS (unsteady) or MIKE-11, fall into this group of unsteady flow models.

In a situation where the shape of the flood hydrograph is 'peaky', that is when flow conditions are rapidly varied (such as in a failure event of a dam or embankment), the additional local acceleration term becomes significant. Models such as DAMBRK and MIKE-11 are equipped to model such situations.

Field data requirements for this type of model are similar to those for steady models.

7.5. QUASI TWO-DIMENSIONAL FLOW MODELS

Even in gradually varied flow conditions, the occurrence of flood breakouts and floodplain storage in a channel/floodplain flow situation can have a significant influence on the attenuation/reduction of flow in the channel. This has led to the development of quasi two-dimensional models, aimed at a 'compromised' modeling structure of a fairly rigorous hydraulic computation in the primary flow direction (i.e. along the channel) and some accounting for lateral flow characteristics and floodplain storage. The lateral connection between cells/nodes are often by simple weir or channel flow formulas.

There is a further type of quasi two-dimensional model for water quality modeling in rivers. These models are 'two-dimensional' in the vertical axis to model such stratified flow phenomena as salt intrusion. Such models include MIKE-12, CARIMA, SOBEK and TIDEWAY-2DV.

Data requirements for this type of model are higher than one-D models: additional survey data will be needed on the ground profile at the lateral flow connections and dimensions of the side channels.

7.6. TWO- AND THREE-DIMENSIONAL FLOW MODELS

Full two and three-dimensional models solve the equation of motion in all directions of flow. They are by far the most rigorous but also require the most ground information to compute flow characteristics reliably. Owing to the rigorous nature of such models, computation can be time consuming and require high speed computers.

Two-dimensional models have been used to study localized hydraulic effects such as occur in the vicinity of bridge crossings or to study flows and tide effects in large floodplains or estuarie.

Three-dimensional models are not often applied to river and floodplain studies and are mainly used in ocean and estuary studies which involve water quality modeling investigations where variation of water pollutants is dependent on flow distribution (x and y directions) and density (z direction).

7.7. CONCLUSION

One dimensional models are deemed sufficient here, and considering both the extent and types of floods in the Litani river basin, as well as LRA's current modeling capacity.

HEC-RAS is strongly recommended as the model to be used. HEC-RAS is widely used world-wide and notably in the US where it is the model for 90% of flood studies.

HEC-RAS exist with both steady and unsteady versions, is freely available on Internet, and is maintained and regularly updated by the Hydrologic Engineering Center of the US Army Corps of Engineers.

APPENDIX A: KEY OR REPRESENTATIVE LOCATIONS DATA SHEETS

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L1
	Locality	Haouch Er Rafqa

2. PHOTOS

River Downstream the Bridge

Satellite View (Approximate Flooded Area in 2003)

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	■
	Trees	■

5. FLOOD PLAIN		
	Short Grass	■
	High Grass	
	Cultivated Area	■
	Trees	

6. GENERAL NOTES

Area Upstream the Bridge Flooded in 2003
Basement of House (Downstream Bridge / Left Bank) Flooded in 2003
Intersection of Litani with Wadi Sbat Effluent
Wadi Sbat Effluent in Concrete Channel along the road

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L2
	Locality	Haouch Er Rafqa

2. PHOTOS

Bridge on Main Road (2 Culverts - Width = 2m)

Culvert for the Access to the Farm (4 pipes D=1200)

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Area Near Bridge Flooded in 2003
Presence of Farm Downstream the first bridge Left Bank
Old bridges Destroyed in 2006 War
Farm Not Flooded in 2003

DATA SHEET - LITANI

1. IDENTIFICATION

	Label	L3
	Locality	Chamieh

2. PHOTOS

Bridge (Downstream) Wing Walls under construction

Satellite View (Old road and Bridge axis shown)

3. MORPHOLOGY

	Presence of Leeves	[illegible]	NO
	Presence of Bridge	[illegible]	NO
	Presence of Solid Waste	YES	[illegible]
	Presence of Dam	YES	[illegible]
	Presence of Pump	YES	[illegible]

4. MAIN CHANNEL

	Clean	
	Stones	[illegible]
	Weeds	[illegible]
	High Weeds	
	Trees	

5. FLOOD PLAIN

	Short Grass	
	High Grass	
	Cultivated Area	[illegible]
	Trees	

6. GENERAL NOTES

Area Near Bridge Flooded in 2003
Old bridge Destroyed in 2006 War
New Location for the New Bridge (Much Better Section)
Presence of free fall Downstream the bridge

DATA SHEET - LITANI

1. IDENTIFICATION	
Label	L4
Locality	Jisr En Nahriyé

2. PHOTOS

Bridge (Upstream)

Satellite View

3. MORPHOLOGY		
Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

No Information about the 2003 Flood
Bridge seems to be Newly constructed
Old Bridge should have been destroyed in 2006
Presence of solid waste dump area near

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L5
	Locality	Temnin El Tahta

2. PHOTOS

Bridge (Downstream)

Satellite View (Approximate Area Flooded in 2003)

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Contact Person: Moustafa Mourtada (Tel: 03810278)
Area Near Bridge Flooded in 2003
Marble Factory (Left Bank Upstream)
Dead Animals dumped in the River
Old Bridge destroyed in 1965 due to a flood
1978 Flood (Water Level Upstream the bridge = Bridge Level)
2003 Flood (Water Level Upstream the bridge = 10cm to 20cm Under Bridge Level)

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L6
	Locality	Tell Amara

2. PHOTOS

Bridge (Downstream)

Satellite View (Approximate Area Flooded in 2003)

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Contact Persons: Ali Mazloum (Tel: 03-645456) - Ali Al Razzal (Tel: 03-530977)
Area Near Bridge and road Flooded in 2003
Old Bridge destroyed in 2006 War
New Bridge is 50cm Lower than old bridge
Main Channel composed of Concrete and Stones Walls downstream

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L7
	Locality	Tell Amara

2. PHOTOS

Foot Path

Minor effluent to Litani

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	■
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	■
	High Grass	
	Cultivated Area	■
	Trees	

6. GENERAL NOTES

Location Near Tanmia Chicken

Area Flooded in 2003 100m from both sides of the foot path

Depth of Water in Flooded area (2003) = 40cm

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L8
	Locality	El Ghabé

2. PHOTOS

Culvert Upstream

River Main Channel

3. MORPHOLOGY			
	Presence of Leeves	[illegible]	NO
	Presence of Bridge	[illegible]	NO
	Presence of Solid Waste	YES	[illegible]
	Presence of Dam	YES	[illegible]
	Presence of Pump	[illegible]	NO

4. MAIN CHANNEL		
	Clean	
	Stones	■
	Weeds	■
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	■
	Trees	

6. GENERAL NOTES

Old Bridge (Steel) destroyed in 2006 War
New Bridge/Culvert composed of 4 pipes D=800mm
Width of River on the Bridge = 6.5m
Width of River Upstream and Downstream = 3 to 4m
Seasonal Flooding around the bridge

DATA SHEET - LITANI

1. IDENTIFICATION

	Label	L9
	Locality	Mkhat El Laouz

2. PHOTOS

Nahr Hala Effluent

Bridge Downstream

3. MORPHOLOGY

	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL

	Clean	
	Stones	■
	Weeds	■
	High Weeds	
	Trees	

5. FLOOD PLAIN

	Short Grass	
	High Grass	
	Cultivated Area	■
	Trees	

6. GENERAL NOTES

Old Bridge destroyed in 2006 War
New Bridge Section similar to old bridge
Water depth in the region around the bridge around 1m in 2003 flood

DATA SHEET - LITANI

1. IDENTIFICATION	
Label	L10
Locality	El Ferzol

2. PHOTOS

Bridge

River Bed Downstream

3. MORPHOLOGY		
Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

Old Bridge destroyed in 2006 War
New Bridge Width = 6.5m
Area Flooded in 2003

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L11
	Locality	Ferzol

2. PHOTOS

Bridge Upstream

River Upstream

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Area Upstream the Bridge Flooded in 2003 (Water Depth 20cm to 40cm)
Old Bridge (Culvert with low level) destroyed in 2006 War
New Bridge on a new road (Better Section)

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L12
	Locality	Dalhamieh

2. PHOTOS

Bridge Upstream

Construction inside river Bed

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Area Near Bridge Flooded in 2003 (Water Level – 40cm to 50cm)
Construction inside River Bed

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L13
	Locality	Dalhamieh

2. PHOTOS


Bridge (Upstream)


River (Downstream)

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

No Flood encountered in 2003
Old bridge Destroyed in 2006 War
Wastewater into the River
Dead Animals inside River Bed

DATA SHEET - LITANI

1. IDENTIFICATION

Label	L14
Locality	Aïn Ez Ziyyan

2. PHOTOS

Concrete Structure inside River Bed

River

3. MORPHOLOGY

Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL

Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN

Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

No Flooding in 2003

Old Culvert doesn't exist anymore

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L16
	Locality	Bar Elias

2. PHOTOS

River Downstream of the Bridge

Satellite View

3. MORPHOLOGY			
	Presence of Levees	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Bridge on Damascus Road

Upstream and Downstream Sections Rehabilitated as part of the IRWA Project

Illegal construction in the River Bed Demolished in 2003

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L17
	Locality	Bar Elias

2. PHOTOS

Bridge from Upstream

River Downstream the Bridge

3. MORPHOLOGY			
	Presence of Leeves	[illegible]	NO
	Presence of Bridge	[illegible]	NO
	Presence of Solid Waste	YES	[illegible]
	Presence of Dam	YES	[illegible]
	Presence of Pump	YES	[illegible]

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

New Bridge on the New International Road (Under Construction)
Bridge didn't exist in 2003
Water Level 60cm under the lowest level of the bridge in a 2009 Seasonal Flood

DATA SHEET - LITANI

1. IDENTIFICATION	
Label	L18
Locality	El Marj

2. PHOTOS

Litani Berdawni Intersection

Satellite View

3. MORPHOLOGY		
Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

Litani and Berdawni Intersection
Location Rehabilitated as part of the IRWA Project

DATA SHEET - LITANI

1. IDENTIFICATION

	Label	L19
	Locality	El Marj

2. PHOTOS

Pipe under bridge blocking Solid Waste

River Upstream

3. MORPHOLOGY

	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL

	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN

	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Pipe Crossing under bridge blocking Solid Waste and Flow
Location Rehabilitated as part of the IRWA Project

DATA SHEET - LITANI

1. IDENTIFICATION	
Label	L20
Locality	El Marj

2. PHOTOS

River Bed

Aerial View

3. MORPHOLOGY		
Presence of Leeves		NO
Presence of Bridge	YES	
Presence of Solid Waste	YES	
Presence of Dam	YES	
Presence of Pump	YES	

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L21
	Locality	El Marj

2. PHOTOS

River Bed

Drainage Canal blocked by Levees

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Winter water courses and drainage canals blocked by levees

DATA SHEET - LITANI

1. IDENTIFICATION	
Label	L22
Locality	Haouch El Harime

2. PHOTOS

Old Culvert Destroyed

River Bed

3. MORPHOLOGY		
Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

Old Culvert destroyed

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	123
	Locality	Haouch el Harime

2. PHOTOS

Litani - Ghzayel Intersection

Litani River Bed

3. MORPHOLOGY			
	Presence of Leeves		NO
	Presence of Bridge	YES	
	Presence of Solid Waste	YES	
	Presence of Dam	YES	
	Presence of Pump	YES	

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Rehabilitation Work as part of the IRWA Project

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L24
	Locality	Haouch el Harime

2. PHOTOS

Old Bridge from Downstream

Old Bridge from Upstream

3. MORPHOLOGY			
	Presence of Leeves		NO
	Presence of Bridge		NO
	Presence of Solid Waste	YES	
	Presence of Dam	YES	
	Presence of Pump	YES	

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

No information about the flood of 2003

Old bridge difficult access

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L25
	Locality	Haouch el Harime

2. PHOTOS

Litani - Jaiir Intersection

Satellite View

3. MORPHOLOGY			
	Presence of Leeves		NO
	Presence of Bridge	YES	
	Presence of Solid Waste	YES	
	Presence of Dam	YES	
	Presence of Pump	YES	

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

No information about the flood of 2003

DATA SHEET - LITANI

1. IDENTIFICATION

Label	L26
Locality	Haouch el Harime

2. PHOTOS

Faregh from Upstream the Culvert

Litani - Faregh Intersection

3. MORPHOLOGY

Presence of Leeves		NO
Presence of Bridge		NO
Presence of Solid Waste	YES	
Presence of Dam	YES	
Presence of Pump	YES	

4. MAIN CHANNEL

Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN

Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

Litani Bed Cleaned two years ago
Culvert under road serving for access to a firm
Culvert section very limited

DATA SHEET - LITANI

1. IDENTIFICATION

Label	L27
Locality	Mansoura

2. PHOTOS

Bridge from Upstream

Bridge from Upstream after a seasonal flood in 2010

3. MORPHOLOGY

Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL

Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN

Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

Area around bridge flooded in 2003
Area flooded during a seasonal flood in 2010
Water Levels about 20cm to 30cm

DATA SHEET - LITANI

1. IDENTIFICATION	
Label	L28
Locality	Ghazze

2. PHOTOS

Litani River Bed Main Channel

Litani Flood Plain

3. MORPHOLOGY		
Presence of Leeves	YES	[illegible]
Presence of Bridge	YES	[illegible]
Presence of Solid Waste	YES	[illegible]
Presence of Dam	YES	[illegible]
Presence of Pump	YES	[illegible]

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

DATA SHEET - LITANI

1. IDENTIFICATION	
Label	L29
Locality	Ghazze

2. PHOTOS

River Bed

River Bed

3. MORPHOLOGY		
Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

No information about the Flood

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L3D
	Locality	Joub Jannine

2. PHOTOS

River Bed

River Bed

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Near Chicken Farm

DATA SHEET - LITANI

1. IDENTIFICATION

Label	L31
Locality	Joub Jannine

2. PHOTOS

Bridge from Upstream

River Bed downstream the bridge

3. MORPHOLOGY

Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL

Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN

Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

Main Channel Height 2 to 3 meters

DATA SHEET - LITANI

1. IDENTIFICATION		
	Label	L32
	Locality	Joub Jannine

2. PHOTOS

River Bed

River Bed torrential flow

3. MORPHOLOGY			
	Presence of Leeves	YES	[illegible]
	Presence of Bridge	YES	[illegible]
	Presence of Solid Waste	YES	[illegible]
	Presence of Dam	YES	[illegible]
	Presence of Pump	YES	[illegible]

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	■
	Trees	■

5. FLOOD PLAIN		
	Short Grass	■
	High Grass	
	Cultivated Area	■
	Trees	■

6. GENERAL NOTES

Flood Plain with high transversal slopes

DATA SHEET - GHZAYEL

1. IDENTIFICATION		
	Label	G1
	Locality	Deir Zenoun

2. PHOTOS

River Downstream the Bridge

Satellite View

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Area Flooded but not from the Ghzayel

Rehabilitation Works as part of the IRWA Project

DATA SHEET - GHZAYEL

1. IDENTIFICATION		
	Label	G2
	Locality	El Establ

2. PHOTOS

River Downstream the Bridge

River Upstream the Bridge

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	■
	Trees	

5. FLOOD PLAIN		
	Short Grass	■
	High Grass	
	Cultivated Area	
	Trees	
	Road	■

6. GENERAL NOTES

Foot Path - Minor Bridge

Rehabilitation Works as part of the IRWA Project

DATA SHEET - GHZAYEL

1. IDENTIFICATION	
Label	G3
Locality	El Establ

2. PHOTOS

Bridge (Downstream)

Bridge (Upstream)

3. MORPHOLOGY		
Presence of Leeves	YES	NO
Presence of Bridge	YES	NO
Presence of Solid Waste	YES	NO
Presence of Dam	YES	NO
Presence of Pump	YES	NO

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	
Road	

6. GENERAL NOTES

Foot Path - Minor Bridge

Rehabilitation Works as part of the IRWA Project

DATA SHEET - GHZAYEL

1. IDENTIFICATION	
Label	G4
Locality	El Establ

2. PHOTOS

Bridge (Upstream)

Bridge (Downstream)

3. MORPHOLOGY		
Presence of Leeves		NO
Presence of Bridge		NO
Presence of Solid Waste		NO
Presence of Dam	YES	
Presence of Pump	YES	

4. MAIN CHANNEL	
Clean	
Stones	
Weeds	
High Weeds	
Trees	

5. FLOOD PLAIN	
Short Grass	
High Grass	
Cultivated Area	
Trees	

6. GENERAL NOTES

Area Flooded in 2003

Rehabilitation Works as part of the IRWA Project

DATA SHEET - GHZAYEL

1. IDENTIFICATION		
	Label	G5
	Locality	El establ

2. PHOTOS

Connection to Faregh River blocked during the Winter

Ghzayel River Upstream

3. MORPHOLOGY			
	Presence of Leeves	YES	
	Presence of Bridge	YES	
	Presence of Solid Waste	YES	
	Presence of Dam	YES	
	Presence of Pump	YES	

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Faregh River is used for Irrigation purposes during the summer season
A dam is constructed at its entry to block the water from Ghzayel

DATA SHEET - BERDAWNI

1. IDENTIFICATION		
	Label	B1
	Locality	Bar Elias

2. PHOTOS

Bridge Upstream during a Seasonal Flood

Bridge Downstream during a Seasonal Flood

3. MORPHOLOGY			
	Presence of Leeves	YES	
	Presence of Bridge		NO
	Presence of Solid Waste	YES	
	Presence of Dam	YES	
	Presence of Pump	YES	

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Area Seasonally Flooded because of diversion works for the execution of an international road
Area Flooded in 2003

DATA SHEET - JAAIR

1. IDENTIFICATION

	Label	J1
	Locality	Haouch el Harime

2. PHOTOS

Jaair River Bed

Jaair River Bed

3. MORPHOLOGY

	Presence of Leeves	YES	[illegible]
	Presence of Bridge	YES	[illegible]
	Presence of Solid Waste	YES	[illegible]
	Presence of Dam	YES	[illegible]
	Presence of Pump	YES	[illegible]

4. MAIN CHANNEL

	Clean	
	Stones	
	Weeds	■
	High Weeds	
	Trees	

5. FLOOD PLAIN

	Short Grass	■
	High Grass	
	Cultivated Area	■
	Trees	

6. GENERAL NOTES

DATA SHEET - JAAIR

1. IDENTIFICATION

	Label	J2
	Locality	Haouch el Harime

2. PHOTOS

Jaair River Bed

3. MORPHOLOGY

	Presence of Leeves	YES	
	Presence of Bridge	YES	
	Presence of Solid Waste	YES	
	Presence of Dam	YES	
	Presence of Pump	YES	

4. MAIN CHANNEL

	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN

	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Area Flooded in 2003

Area seasonally flooded

DATA SHEET - FAREGH

1. IDENTIFICATION		
	Label	F1
	Locality	Haouch el Harime

2. PHOTOS

Jazire Bridge

Satellite View

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	■
	Weeds	■
	High Weeds	■
	Trees	

5. FLOOD PLAIN		
	Short Grass	■
	High Grass	
	Cultivated Area	■
	Trees	

6. GENERAL NOTES

Area Flooded in 2003

DATA SHEET - FAREGH

1. IDENTIFICATION		
	Label	F2
	Locality	Haouch el Harime

2. PHOTOS

Bridge

Satellite View

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	■
	Weeds	■
	High Weeds	■
	Trees	

5. FLOOD PLAIN		
	Short Grass	■
	High Grass	
	Cultivated Area	■
	Trees	

6. GENERAL NOTES

Area Flooded in 2003

Area seasonally flooded

DATA SHEET - FAREGH

1. IDENTIFICATION		
	Label	F3
	Locality	Haouch el Harime

2. PHOTOS

Bridge (Downstream)

Bridge (Upstream)

3. MORPHOLOGY			
	Presence of Leeves	YES	[illegible]
	Presence of Bridge	[illegible]	NO
	Presence of Solid Waste	[illegible]	NO
	Presence of Dam	YES	[illegible]
	Presence of Pump	YES	[illegible]

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

DATA SHEET - FAREGH

1. IDENTIFICATION		
	Label	F4
	Locality	Haouch el Harime

2. PHOTOS

Bridge (Upstream)

Bridge (Downstream)

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

DATA SHEET - HOWAYZEK

1. IDENTIFICATION		
	Label	H1
	Locality	Bar Elias

2. PHOTOS

Solid Waste Upstream the Bridge

Satellite View

3. MORPHOLOGY			
	Presence of Leeves	YES	NO
	Presence of Bridge	YES	NO
	Presence of Solid Waste	YES	NO
	Presence of Dam	YES	NO
	Presence of Pump	YES	NO

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Area Flooded in 2003

Area seasonally flooded

DATA SHEET - HOWAYZEK

1. IDENTIFICATION		
	Label	H2
	Locality	Bar Elias

2. PHOTOS

Bridge

Satellite View

3. MORPHOLOGY			
	Presence of Leeves	YES	
	Presence of Bridge	YES	
	Presence of Solid Waste		NO
	Presence of Dam	YES	
	Presence of Pump	YES	

4. MAIN CHANNEL		
	Clean	
	Stones	
	Weeds	
	High Weeds	
	Trees	

5. FLOOD PLAIN		
	Short Grass	
	High Grass	
	Cultivated Area	
	Trees	

6. GENERAL NOTES

Area Flooded in 2003

Area seasonally flooded

APPENDIX B: FLOOD WATER LEVELS

WATER LEVELS - BAR ELIAS

Label
B1

Locality
Bar Elias

Contact Person
Mohammad Dalla

Water Level
Superior Limit of Island Bloc

Label
B2

Locality
Bar Elias

Contact Person
Mohammad Dalla

Water Level
Inferior Limit of red bloc on fence wall

Label
B3

Locality
Bar Elias

Contact Person
Houssam El Hajj

Water Level
Superior Limit of Bloc in house garden

WATER LEVELS - BAR ELIAS

Label
B4

Locality
Bar Elias

Contact Person
Mohammad Dalla

Water Level
Limit shown in picture
House Main Entrance

Label
B5

Locality
Bar Elias

Contact Person
Khalil Zein

Water Level
Limit shown in picture
House Main Entrance

NA

Label
B6

Locality
Bar Elias

Contact Person
Khalil Soueid

Water Level
Road Level

WATER LEVELS - BAR ELIAS

Label
B7

Locality
Bar Elias

Contact Person
Mohammad el Sabeh

Water Level
First Step level

Label
B8

Locality
Bar Elias

Contact Person
Shehade Kassem Arafat

Water Level
As shown in picture

Label
B9

Locality
Bar Elias

Contact Person
Said Amer Ellouais

Water Level
As shown in picture

WATER LEVELS - DAMASCUS ROAD

Label
DR1

Locality
Deir Zenoun

Contact Person
Firas El Meiss

Water Level
Superior limit of island block

Label
DR2

Locality
Deir Zenoun

Contact Person
Hussein Hazime

Water Level
One meter away from side walk
As shown in picture

Label
DR3

Locality
Bar Elias

Contact Person
Jamil El Sayyed

Water Level
Superior limit of island block

WATER LEVELS - EL MARJ

Label	M1
Locality	El Marj
Contact Person	Mohammad Dalla
Water Level	Villa Main Entry Street 9 #126 As shown in picture

Label	M2
Locality	El Marj
Contact Person	Shehadeh Saleh
Water Level	As shown in picture

Label	M3
Locality	El Marj
Contact Person	Abdo Zaarour
Water Level	As shown in picture Near Mini Market

WATER LEVELS - EL MARJ

Label
M4

Locality
El Marj

Contact Person
Mohammad Abdellah Hamdanieh

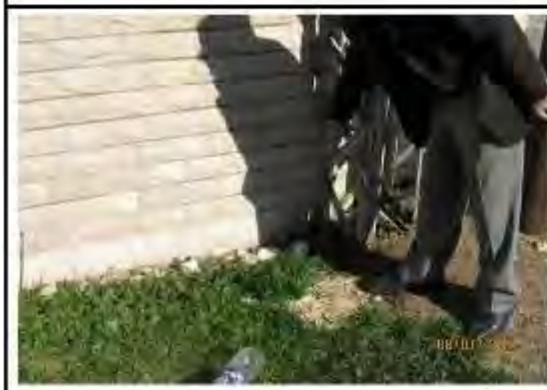
Water Level
Last Step

Label
M5

Locality
El Marj

Contact Person
Mohammad Zein Eddine

Water Level
As shown in picture



Label
M6

Locality
El Marj

Contact Person
Mohammad El Melhem

Water Level
As shown in picture

WATER LEVELS - EL MARJ

Label	M7
Locality	El Marj
Contact Person	NA
Water Level	10 cm above road level on this pile

Label	M8
Locality	El Marj
Contact Person	NA
Water Level	El Marj Street 2 #107 As shown in picture

Label	M9
Locality	El Marj
Contact Person	NA
Water Level	Near Bridge on Marj to Haouch el Harime Road As shown in picture

WATER LEVELS - HAOUCH EL HARIME

Label
H1

Locality
Haouch El Harime

Contact Person
Abdellah Handouss

Water Level
As shown in picture

Label
H2

Locality
Haouch El Harime

Contact Person
Omar Ahmed Ahmed

Water Level
As shown in picture

Label
H3

Locality
Haouch El Harime

Contact Person
Riad Ali Issa

Water Level
As shown in picture

WATER LEVELS - MANSOURA / GHAZZE

Label
MG1

Locality
Mansoura

Contact Person
Ali Ibrahim

Water Level
As shown in picture
Upstream of the Mansoura Bridge
Concrete Block

Label
MG2

Locality
Mansoura

Contact Person
Ali Ibrahim

Water Level
As shown in picture
Upstream of the Mansoura Bridge

WATER LEVELS - TELL AMARA

Label
TA1

Locality
Tell Amara

Contact Person
Ali Mazloum

Water Level
Electrical Pile
Upper Level of Concrete
Near Tell Amara Bridge

Label
TA2

Locality
Tell Amara

Contact Person
Ali Mazloum

Water Level
Tree on road
Limit of the flooded area
Near Tell Amara Bridge

Label
TA3

Locality
Tell Amara

Contact Person
Ali Mazloum

Water Level
Red Wall
Limit of flooded area
Near Tell Amara Bridge

WATER LEVELS - TEMNIN / MKHAT EL LAOUZ

NA	**Label** T1 **Locality** Temnin el Tahta **Contact Person** Moustafa Mourtada **Water Level** Edge of the Manufactury Building 20 cm of water Near Temnin el Tahta Bridge
	**Label** MK1 **Locality** Mkhat el Laouz **Contact Person** NA **Water Level** Upper Level of the concrete pile

WATER LEVELS - DALHAMIEH

Label
D1

Locality
Dalhamieh

Contact Person
Jamal Saad

Water Level
Near Mini Market Shop

Label
D2

Locality
Dalhamieh

Contact Person
NA

Water Level
As shown in picture

Label
D3

Locality
Dalhamieh

Contact Person
NA

Water Level
As shown in picture

APPENDIX C: IRWA WORKS

L1 Litani- Haouche al Omara - Damascus road

Before IRWA

After IRWA

Present Situation

LB2 Litani- Berdaouny- Marj	
	
Before IRWA	After IRWA
	
Present Situation	

<table>
<tr><th colspan="2">L3 Litani - Marj Bridge</th></tr>
<tr><td></td><td></td></tr>
<tr><td>Before IRWA</td><td>After IRWA</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">Present Situation</td></tr>
</table>

L4 Litani - Marj (L4)	
	
Before IRWA	After IRWA
	
Present Situation	

LG8 Litani- Ghazael - Al Wakf	
	
Before IRWA	After IRWA

Present Situation

G1 Ghazael- Anjar - Damascus Road	
	
Before IRWA	After IRWA

Present Situation

G6 Ghazael - Harimeh el Soughra

Before IRWA

After IRWA

Present Situation

G7 Ghazael - Harimeh el Soughra	
	
Before IRWA	During IRWA

Present Situation

G9 Ghazael - Harimeh el Soughra	
	
Before IRWA	During IRWA

Present Situation

GF10 Ghazael - Faregh - Harimeh el soughra

Before IRWA	During IRWA

Present Situation

L14 Litani - Kherbet Kanafar

Before IRWA

During IRWA

Present Situation

APPENDIX D: TOPOGRAPHIC SURVEY

The survey will include (providing both NGL elevations and distances):

- Regular Cross Sections
- Cross Sections on Bridges
- Flood Water Levels
- Longitudinal Profiles

Regular River Cross Sections: The cross sections survey shall be conducted at the locations specified by IRG to measure the river bed, including main channel and flood plain. The main channel survey shall include:

- Four points (Top and Bottom levels of the banks) for a main channel width inferior to 4 m.
- Five points (Top and Bottom levels of the banks and middle of the main channel) for a main channel width ranging between 5 and 15 meters.
- Six points (Top and Bottom levels of the banks and middle of the main channel + 2 points in the main channel) for a main channel width superior to 15 m.

The Flood Plain survey shall include a point every 10 meters (or if any significant slope change) to be measured from the upper level of the bank or the lower level of a levee (if existent). It shall be limited by:

- Either a distance of 50m from each bank;
- Either a distance where the natural ground elevation is at least 1 m higher than the bank.

Whichever of the two conditions is met first.

Cross Sections on Bridges: The bridge survey shall be conducted at the locations specified by IRG to measure bridge opening and river bed cross sections and include:

- Diameter and elevation of the invert if a pipe or culvert (and number if several pipes);
- Elevation and width of the invert of the bridge otherwise;
- Elevation and width of the ceiling of the bridge;
- Thickness of piles dividing the opening if any;
- Elevation of the road on top of the bridge; and
- Elevation each 10m on the road (or if any significant slope change) for a distance of 50m from each side of the bridge.

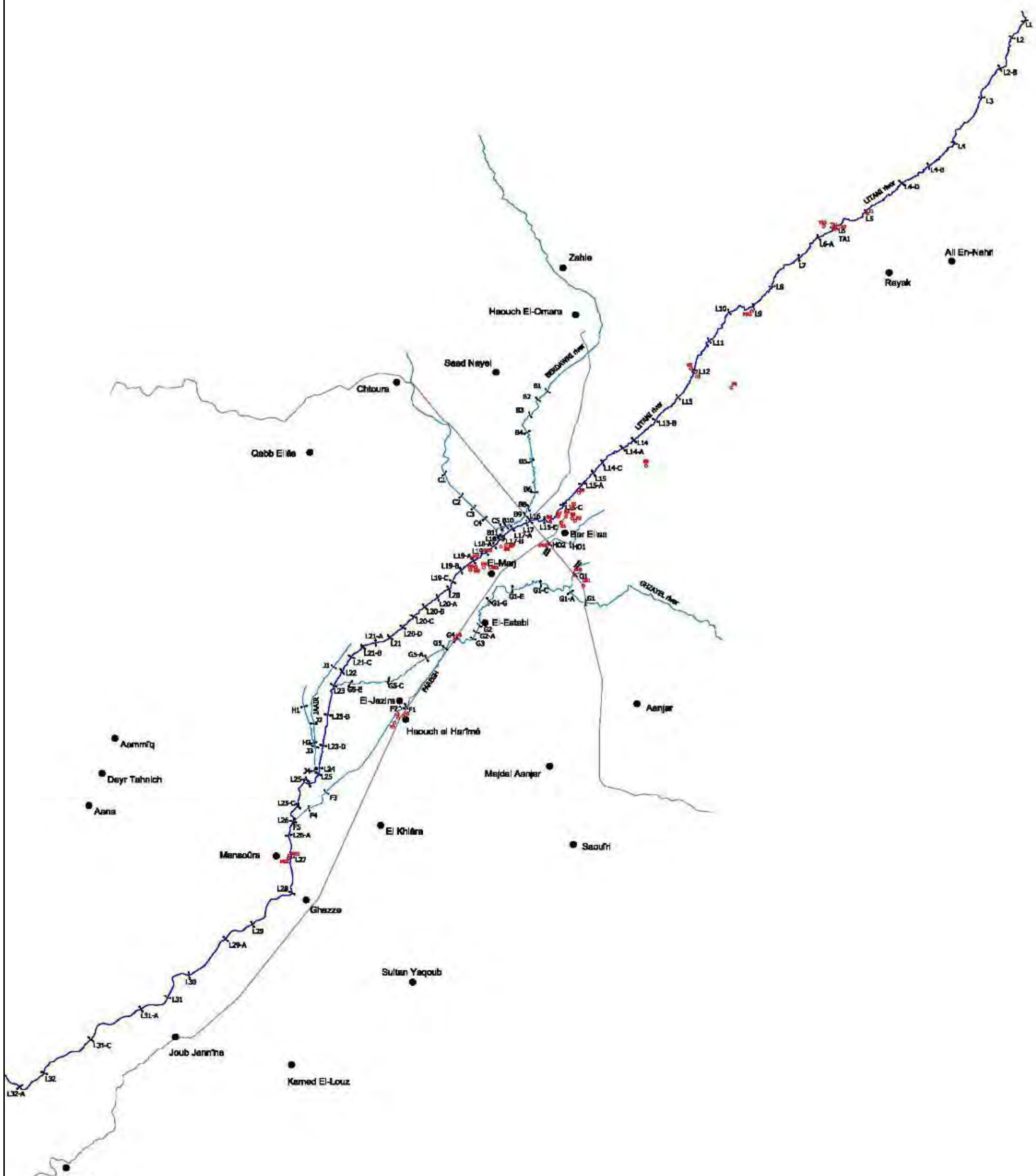
As well as two regular cross-sections as described above, upstream and downstream, at a minimum distance of 10 meters from the bridge or at a sufficient distance from the natural river bed .

Flood Water Levels measurement points: these are maximum water levels that were reached during the 2003 flood and identified through a field survey. The elevation of each of these points is to be measured by the surveyor. The location, description, contact persons and photos of the points to be surveyed will be provided by IRG.

Longitudinal profiles: The longitudinal profiles survey is to measure elevations of the water level all along the Litani River and the tributaries of Ghzayel, Berdawni and Jaair. The longitudinal profiles survey should be done after the end of the cross sections and flood water levels survey and should be undertaken during a period of two days maximum. The distance between points will be maximum 100m and match the already surveyed cross-sections.

The locations of Cross Sections and Flood Water Levels to be surveyed are provided in figure 7.1.

Figure 7.1: Locations of Cross Sections and Flood Water Levels



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