**Project title: Eco-Hydrological Assessment of River Restoration Projects - Nachal Tzipori as a study case**

**Final Report**

Funded by Nekudat Hen

Principle Investigators:

Dr. Orah Moshe, Prof. Marcelo Sternberg, Dr. Roey Egozi, Ms. Tal Ratner

Date: July 26, 2018

**Part 1: Geomorphological Stream Assessment**



**Part 2: Discussion: Eco Hydrological Analyses and Land Management**



**List of Figures**:

**List of Tables:**

**Appendices**

**Abstract**

We conducted a hydro-geomorphic assessment on a perennial stream in the Nahal Tzipori watershed, Israel. Field studies were conducted for one year from June 2017 to June 2018 on. The assessment followed the protocol according to the modified Italian based morphological quality indicator (MQI). This is the first geomorphic stream assessment conducted on perennial coastal streams in Israel. Due to the semi – arid Mediterranean climate in Israel the protocol was customized for application to the perennial coastal stream conditions found in the northern half of Israel. We propose this methodology as a consistent, cost-effective, robust approach to evaluate and compare the eco hydro geomorphic condition of coastal streams throughout Israel. Stream segmentation analysis resulted in 17 segments, 13 of them perennially flowing, sustained by springs and a perennial tributary. The uppermost four segments of the Tzipori stream are ephemeral, limited to winter storm-driven flow. Segments were analyzed according to the 23 metrics defined in the MQI, with assigned values based on specific criteria ranging from 0 to 6, generally, with extreme conditions scored as high as 12. Each segment is evaluated according to defined criteria, enabling comparison of different segments along the entire stream, to assess its related condition and state of degradation. Three categories were targeted which include functionality, artificiality, and morphology. Results show a range of condition, with the most upstream and downstream segments in not good condition, much of the stream in good condition, and the segment downstream from the confluence of Yiftachel receiving a rating of very good. Overall, we found reduced functionality, especially in terms of longitudinal connectivity of sediment and streamflow, with some areas of strong artificiality in both the most upstream and downstream segments. The riparian vegetation was highly degraded along the entire stream, providing little functional benefit. Species diversity was low and few dominant species typical from highly disturbed habitats characterized the vegetation. The water quality has a high concentration of suspended sediments during winter storms, likely carrying substantial agricultural chemicals in particular bound and dissolved forms. Results from the bed substrate analyses indicates a lack of typical downstream fining, suggesting interference in sediment flux and the loss of typical stream processes. Previous flood management efforts have resulted in a changed channel morphology and regulating efforts in the downstream segments have greatly reduced natural depositional processes. We conclude that the stream has been strongly altered and degraded, yet with high potential for restoration and improved ecological benefits. Recommendations to improve geomorphic conditions, protect water quality and restore stream functionality include improving the longitudinal connectivity of sediment flux and streamflow, increasing the functional width of native riparian vegetation, and implementing grazing management plans.

# Part 1: Geomorphological Stream Assessment

## A. Introduction

This document provides the final report for the project titled Eco-Hydrological Assessment of Mediterranean Rivers: Nahal Tzipori case study. This project seeks to contribute to river assessment knowledge gaps, particularly on geomorphology, hydrology, riparian vegetation and ecosystem services, but also in terms of nonpoint effects and sedimentation from agricultural land use, which are often neglected in assessments; Review existing methodologies around the world; adopt a rational, cost effective, process-oriented river assessment system for the classification and 1) characterization of Israeli rivers reaches. Apply assessment method according to recent fluvial hydrogeomorphological methods and ecological indices, taking into account anthropogenic parameters (e.g. land use and land covers) to different reaches of Nahal Tzipori and examine if modifications are required. Results from this study will help to inform policy makers and improve the scientific basis of restoration planning and policies. There is a lack of studies focused on the hydromorphological state of rivers in arid and semi-arid regions (Kijowska-Strugała et al, 2017). We reviewed existing stream assessment methodologies in order to develop a consistent, cost effective, process-oriented river assessment methodology for the delineation, classification, and characterization of Israeli rivers, according to recent fluvial geomorphological methods and ecological indices. We reviewed primary literature and comprehensive reviews of existing assessment methodologies. The results of our review are presented in Appendix A. Ultimately, we follow the stream assessment protocol Morphologic Quality Index (MQI) developed in Italy by Rinaldi et al (2011) and revised to integrate global efforts, (Rinaldi et al, 2016).

The primary goals of this effort include: characterizing the survey stream site from an eco-hydro-geomorphic basis, segmenting the stream based on specific geomorphic criteria, and evaluating the present conditions along different reaches of the stream, based on a defined scoring matrix. Factors in the matrix include a combination of attributes assessing stream functionality, morphology and artificiality. Data obtained and generated from this study resulted in creation of a GIS database, which can now be used to provide technical data to support and develop planning-related field restoration and intervention management projects in this basin. In addition, we evaluate these data through a comprehensive watershed-level framework to define risk and threats within the watershed. We conducted a land use analysis and evaluated anthropogenic stressors as part of a watershed-based ecological stream assessment established on a geomorphic foundation.

We applied this stream assessment protocol to Nachal Tzipori, as a detailed case study, where we characterize this stream in accordance with geomorphological principles following the MQI protocol. Benefits from this project include: obtaining detailed baseline data of current stream geomorphic conditions, identifying problem areas that contain hydraulic constraints, features that restrict the flow of sediments or streamflow, areas where the stream has lost functionality, and identifying other primary stressors in each segment. These baseline data can be used to evaluate trends in channel morphology and enables future comparison between existing conditions and future conditions resulting from implemented management actions, based on planned intervention or restoration projects. Detailed cross-section data collected during this study will allow us to evaluate streambank erosion and better understand the long-term sustainability of the stream channel, as well as potential effects of any intervention action. Direct benefits from this project also include identifying major environmental problems, defining data gaps and facilitating targeted research to contribute to restoration planning.

Long term potential outcomes from this stream assessment, if the implementation phase is successful, include: reduced soil erosion and reduced contaminated surface runoff, increased water quality protection, reduced annual maintenance costs, decreased future restoration costs (design, implementation and management), and improved ability to connect management actions to river condition. In addition, we have an opportunity to evaluate our successes, failures, and best management practice strategies, both in the long and short term.

In this final report, we present the results of all investigations, GIS analyses, field data collection efforts, existing project area knowledge, and integrated system analyses that enable prioritization of problem areas. All project tasks defined in the proposal were completed for this project. A total of 20 site visits were conducted over the year, which included field data collection both during rain storm events and during the driest times of the year. We reviewed existing studies conducted on the Tzipori stream and conducted interviews with relevant agencies and land managers. Existing project knowledge is integrated in relevant sections, throughout the report. Data was obtained from Israel Hydrologic Service, Survey of Israel (MAPI), Israel Meterologic Service, Israeli hydrological survey (IHS), Israel Nature and Park Authority (RATAG), Kishon Drainage Basin Authority (KRN), Kishon River Authority (KRA), and The Hebrew University of Jerusalem. We thank them for their cooperation and support of this project.

## B. Study Area

1. *Geographic Setting*

The Tzipori watershed basin covers an area of 293 square kilometers in the central and western parts of the Lower Galilee. Drainage areas include part of the Nazareth Mountains, the hills of the Lower Galilee in the Shfar'am region and much of the Beit Netofa Valley and Mount Tur'an. Nachal Tzipori is a major tributary of the Kishon river, flowing westward approximately 32 kilometers until it meets the Kishon River in the Zevulun Valley, approximately 5 kilometers before the Kishon discharges into the Mediterranean Sea (Fig. 1).

2. *Main Source Springs*

The upper section of the stream, from Maayanot Raina to Einot Tzipori, is characterized by ephemeral and flows only during winter rains. This upper section of the stream is highly altered. From Maayanot Raina, streamflow is channelized behind homes in a semi urban environment with bank protections and bed revetments until the stream is buried underground due to urban development, and streamflow is transferred through a tunnel culvert, where it eventually discharges into a fairly natural landscape. This upper section of the stream is ephemeral and contains storm driven flow. The stream channel flows westward through villages and open land until reaching Einot Tzipori, where a cluster of perennial springs exist. We refer to this as the spring source area (S13a).

Some flow from these springs is piped into an ancient stone pool structure, which is then channelized into a concrete trench (Fig. 2), into a culvert where it crosses the road, ultimately connecting to the mainstream of the channel. This discharge provides the flow to the perennial section of the stream, maintaining baseflow in most of the stream year round. Several other springs in this area are encased in concrete houses, with the water piped underground to the area Sephoria, (Segments (S) 11 and 12) where traditional, small, family-owned, farms currently use this water source for agricultural irrigation purposes without any control or regulation. New opportunities exist to provide alternative sources and reallocate these spring waters back to the stream (See Section K)

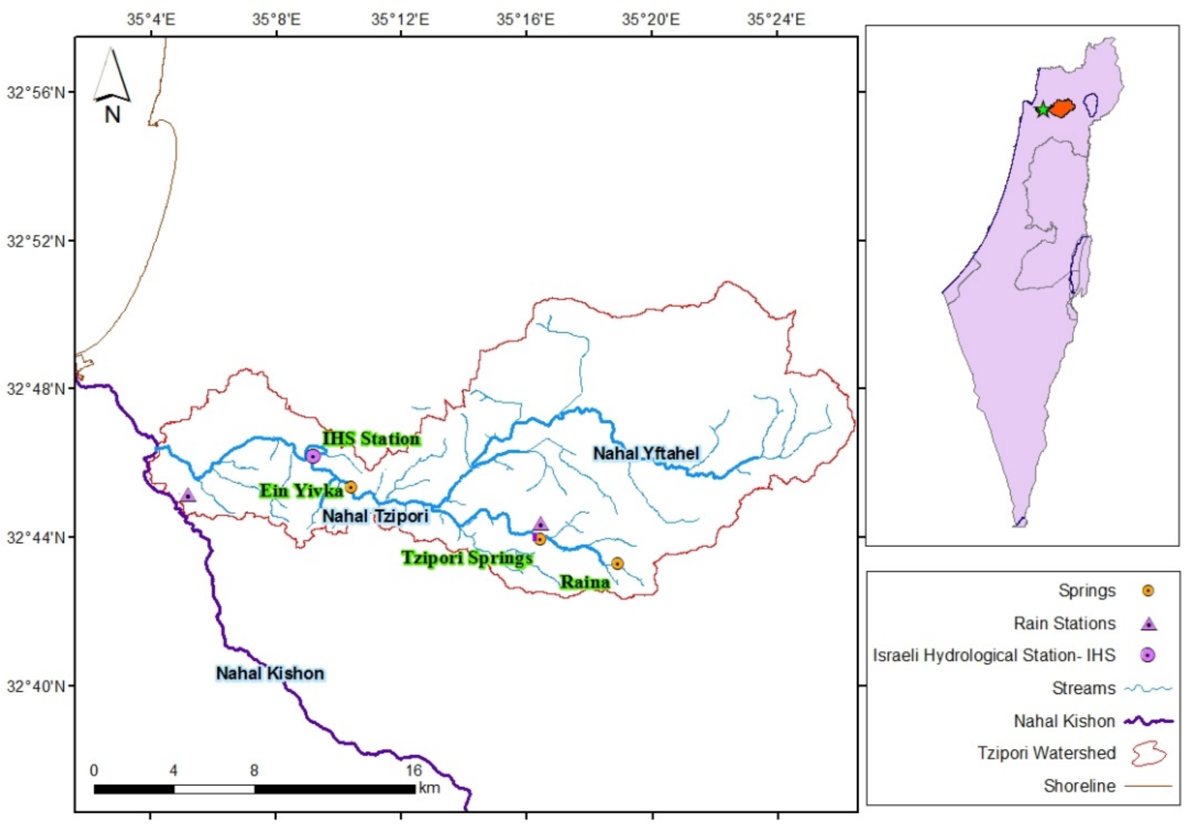



Fig. 1: a map of the watershed boundaries of Nachal Tzipori, showing its major water sources (tributaries and springs). The hydrologic (IHS) and rain station locations are also shown.

A preliminary subsurface investigation in the area of Einot Zippori was conducted during spring of 2018 by Ori Moran (Moran Consulting and Development, pers. comm). There he identified a group of springs near the access road to Moshav Zippori, with the main source springs called Ein Kastel and Ein Shuka. Although there has been significant development in that region, there does not appear to be significant changes in the flow rates since the 1960s (Moran, personal communication). However, the origin of the source springs remains unclear. The subsurface investigation revealed an underground water network related to a historic agricultural industrial system, likely created during the Roman era. Most of the water that flows from these springs are pumped into agriculture, as the water quality is high. Based on monitoring reports of the Nature and Parks Authority spring flow from these springs averages about 50 $m^3$/h in the spring and about 10 $m^3$/h in the fall. The water is free of contaminants and there is no significant change in their quality compared to previous years (Glazman 2017).

Fig. 2: Einot Tzipori Source Pool Concrete trench from source pool Concrete house for spring

The primary tributary contributing streamflow to the Tzipori stream is Nachal Yiftachel, which increases the stream discharge by an order of magnitude. The source of Yiftachel is a spring located in the Netofa valley and surrounding area. Their annual yield is 1.5-2 million $m^3$/yr (Glazman 2009) and in the past these water flows were used for agricultural purposes by Kibbutz Hasolelim. Yiftachel plays an important role in this stream, specifically in terms of sediment flux and streamflow.

Another significant source spring to Nachal Tzipori is Ein Yifka, west of the town of Kaabiya. This spring has been expanded into a large pool and holds a high recreational value, with high visitation for picnicking. Residents are often seen washing animals (ie. horses). It produces approximately one million cubic meters. In addition to these springs, there are a number of small springs that have a seasonal effect, among them: Ein Mahil, Ein Avinoam, Ein Rani, Ein Emet Abel, Ein Renanim, Ein Gat Hefer, Ein Lapidot, Ayin Tur'an and small springs on the banks of the stream west of the historic monks mill (Sever, 2011).

Fig. 3: (left) confluence-Tzipori Yiftachel; (bottom) Ein Yifka Source Pool; (top) Ein Yivka channel

Stream flow and discharge are largely affected by annual rainfall, where in average rainy years, the water flow in the summer is usually continuous throughout the stream channel. In drier years, the hydrologic conductivity may be interrupted due to both natural conditions and stream water extraction, which occurs both legally and illegally (see discussion in Section B, A3). During the winter, stormflows can contribute to the base flow on average 6 mcm. Flooding intensity is usually limited to immediately surrounding agricultural lands, except for extreme events where stream flow can reach several tens of cubic meters per second (Glazman 2016).

### 3. *Regional climate*

This case study was conducted on Nachal Tzipori, partially because it is representative of other streams in this region and also because it has a fairly natural condition with a potential for high ecological and recreational value The temperature of the watershed area ranges between 40 $^{0}$C in summer and 4 $^{0}$C in winter (Israel Meterological Service (IMS), 1995-2005). Coastal streams in Israel are characterized by a typical Mediterranean hydrologic regime, having high flow variability and low-water level during the summer. Regional average rainfall in the drainage basin is about 565 mm per year based on a data set ranging from 1980-2010. Accumulated rainfall for the hydrologic year 2017 to 2018 totaled 510-560 mm (Fig. 4), with this year falling within the range of an average rainfall year.

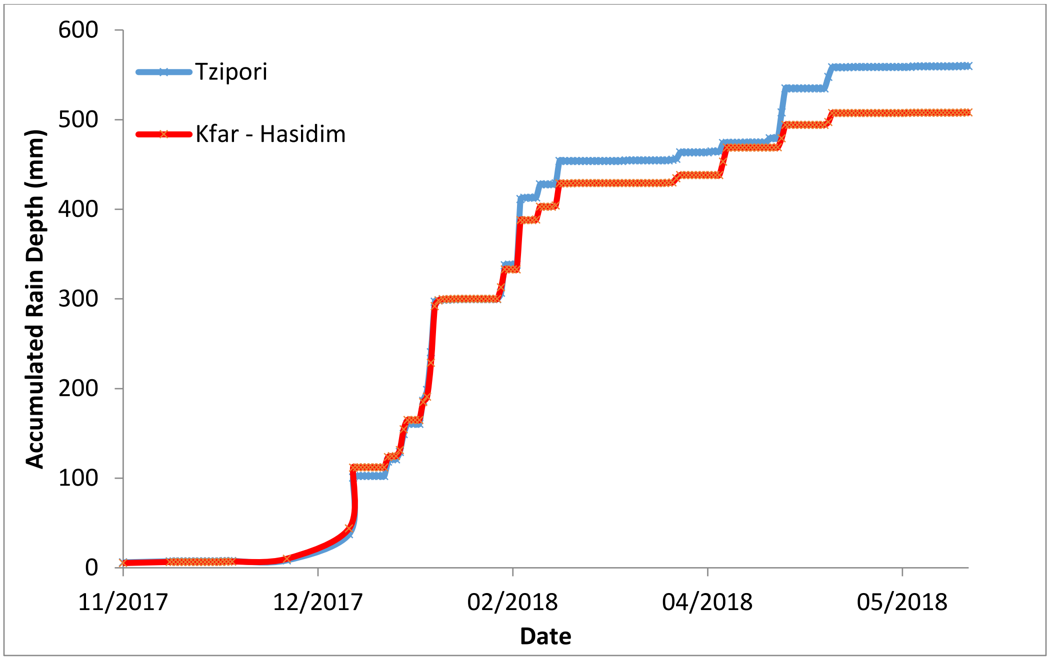


Fig. 4: Accumulated rainfall 2017-2018 (Note differences between gauges during winter vs. spring.)

We installed two rain monitoring stations in the watershed prior to the beginning of the rainy season, one in the upper watershed in Tzipori National Park and the second in the lower part of the watershed in Kfar Hassidim (Fig. 1). The accumulated rainfall (Fig. 4) is quite similar. The frequency and intensity of rainfall differed between the two stations (Fig. 5), highlighting the importance of the localized effects and spatial variability of seasonal rainfall. There was no consistent trend with one area receiving more rain than the other, rather it varied from storm to storm.

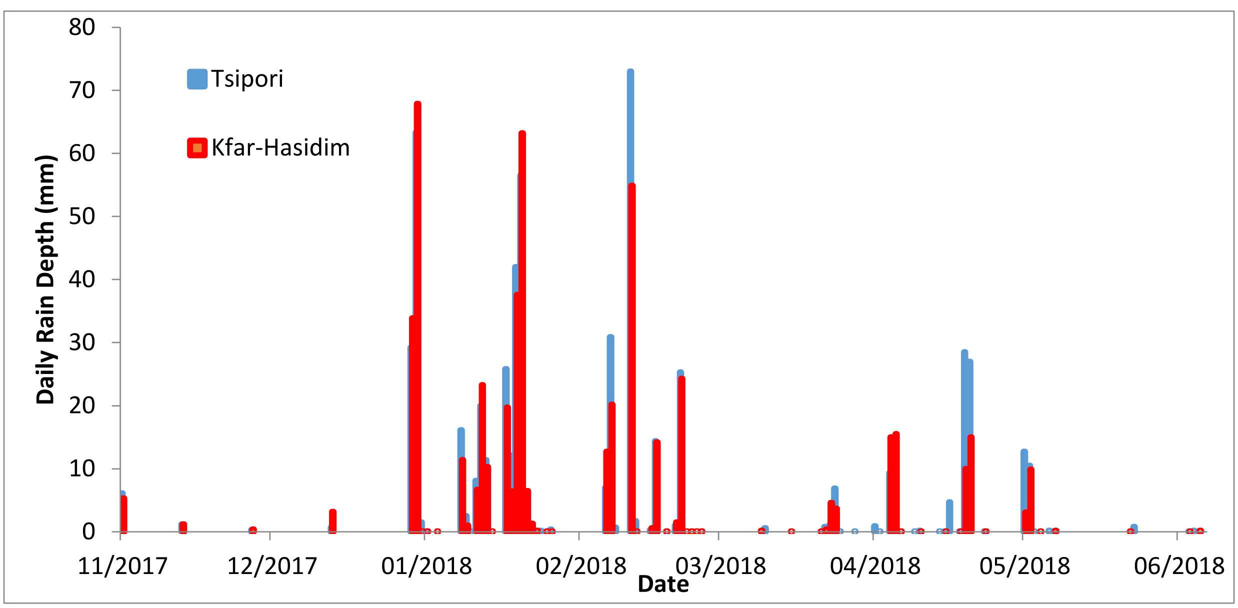


Fig. 5: Storm event rainfall 2017-2018 at upstream and downstream rain stations

4. *Geographic setting*

Nahal Tzipori geographic features include unique landscapes that distinguish it from the other Western Galilee streams, as described by Sever (2011): The stream begins in the Nazareth Mountains which is composed of soft chalk from the Senonian and Eocene period and flows in a fairly wide alluvial valley, with an average width of about 150 meters and in some places reaching about 400 meters. From Kaabiye in the east and until the river flows to the alluvial plain of the Zevulun Valley in the west, the stream flows between the Alonim - Shfar'am hills whose anticlines consist of Eocene chalks covered with a nari crust, a landscape similar to that of Ramat Menashe to the south. The hills, 200 to 300 meters above sea level, rise steeply to a height of 45 to 100 meters above the stream's valley to form a sharp topographic relief of a mountainous, winding river whose peak is the Ras Ali meander. There are various theories regarding the formation of the Ras Ali meander, for example formation by landslides that blocked the flow of the stream to the west. To the southeast of the hill, a small lake was created and gradually emptied as a result of the opening of a new channel toward the north, which expanded over the years, creating an impressive meander around Alil hill (Tzipori Stream 2000 administration). Fig. 6 and 7 present the lithology and soil units in the Tzipori watershed.

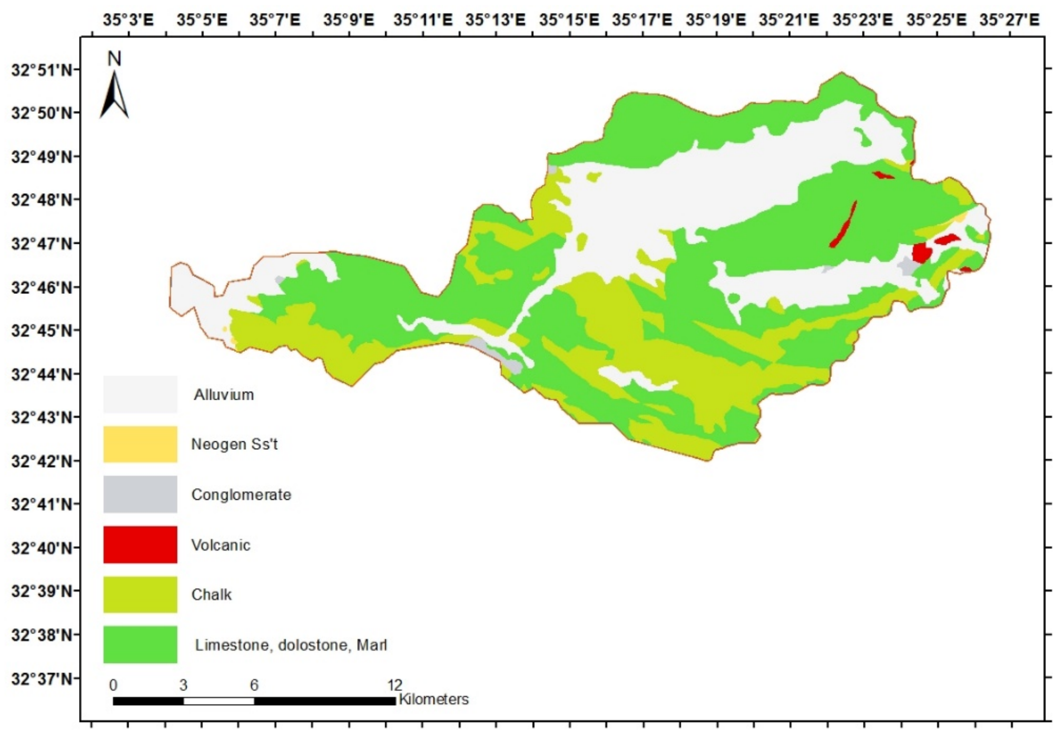



Fig. 6: Lithology map

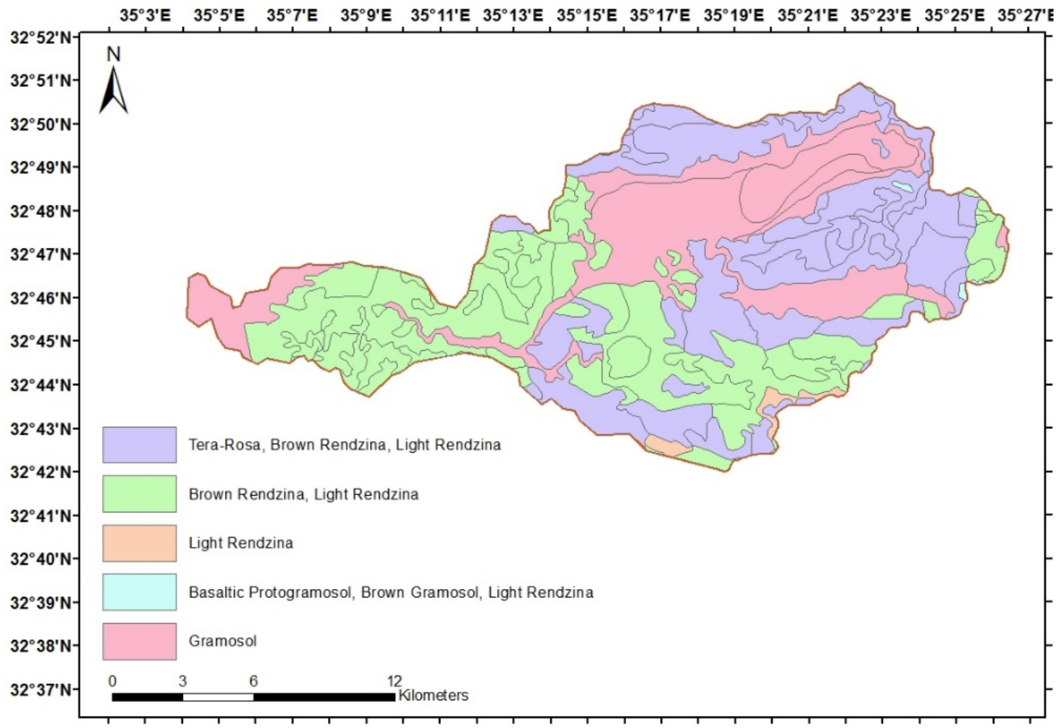



Fig. 7: Soil groups map

### C. Project Objectives

We seek to define and understand the processes that influence the pattern and character of the stream ecosystem, as well as identify primary stressors. There is an assortment of interrelated variables that determines the dimension, pattern, and profile of the present-day stream, shaping its physical form (Rosgen, 1994) and its role in the ecosystem. There is a large body of literature investigating these variables and developing methodology to better understand the fluvial morphological processes and interrelated metrics. Streams in a Mediterranean climate have unique sets of driving factors, with seasonal rainfall dynamics controlling channel morphology. The hydro-morphological state of a river is dependent on the features of the natural environment of the drainage basin, and particularly on the lithology and geomorphology, climatic conditions, hydrological regime, the type and density of the vegetation cover, as well as the anthropopressure (Kijowska-Strugała et al, 2017). In this study, we investigated these variables as well as identifying sources of anthropogenic pressures on the stream. Both the variability in annual rainfall and ongoing management interventions have greatly impacted the shape of the channel. The morphology of the stream results from adjustment of its boundaries to adapt to the current streamflow and sediment regime (Rosgen, 1994). Using a watershed approach, we obtained and integrated relevant data pertaining to soils, geology, water quality, river management, and field observations to create detailed GIS layers with spatially explicit data. We used spatial analysis based on the stream segments to compare the existing condition, ecological value and potential restoration opportunities. Stream segments will be referred to as S1, S2, etc.Appendi

## 1. *Stream assessment methodology*

Different reaches along a stream often demonstrate high morphologic and functional variability, resulting in significant ecological differences. We find similar habitats under diverse settings, and diverse habitats under similar settings, posing a real challenge for characterizing streams and assigning representative and meaningful values. Rinaldi et al (2011) developed a stream assessment methodology in an effort to comply with the European water framework directive (WFD, 2000) and later the flood directive (FD, 2007), based on a solid geomorphological foundation, with a stronger consideration of physical processes at appropriate spatial and temporal scales. The resulting Morphological Quality Index (MQI, Rinaldi et al., 2011, 2013a), was designed to comply with the European Committee for Standardization (CEN, 2002), specifically, for hydro-geomorphological assessments, applied to the WFD and FD. Rinaldi conducted a comprehensive literature review of assessment methodologies from around the world (REFORM, Rinaldi et al., 2013b) enabling consistent comparisons of methodology and application of hydromorphological modification between waters within a country and between different countries in Europe, which 'departure from naturalness' as a result of human pressures on hydromorphology. The resulting protocol suggests suitable sources of information that may contribute to describing the existing conditions and modification of hydromorphological features. As a result of this detailed review, the MQI has undergone several modifications to strengthen the methodology and include a wide suite of parameters from international assessments, in an effort to develop a comprehensive, consistent, easy to use method. Though the MQI does not provide an explicit "target vision" for possible river restoration, the evaluation structure provides a rational framework that is potentially useful for supporting analyses of interventions and impacts and for identifying and prioritizing management strategies, adequate restoration schemes, and monitoring programs (Rinaldi, et al. 2016). We have selected the modified MQI as the protocol for our hydromorphological assessment. We investigated these metrics and applied this protocol to our case study of Nahal Tzipori (Section C and D).

Studies investigating these processes and implementing geomorphic stream assessment methods have become more prevalent, however, to date, few, if any, comprehensive geomorphic stream assessments have been conducted in coastal perennial streams in Israel.

A recent study investigated the hydromorphological state and assessment of the habitat quality of selected streams of the Negev Desert, following the protocol defined in the River habitat survey (RHS) method (Kijowska-Strugała et al, 2017). Climatic differences between streams in southern Israel (i.e., Negev Desert, storm flow only) and central /northern Israel (perennial streams) are not comparable. Although Israel is a small country, contained within it are substantially different climatic regimes, resulting in three categories of river systems. The northern part of Israel has small rivers and streams that maintain perennial base flow, while the central part has streams that are more ephemeral. The southern part of Israel has a desert climate where the riverbeds are dry most of the year but suffer flash floods during storm events in the winter. Due to the specificity of the natural environment, these southern areas are characterized by a small degree of vegetation cover and limited infiltration, which promotes surface runoff (Laronne et al. 1992).

Further, due to the Mediterranean climate, stream systems in Israel differ overall from European streams, resulting in the need to modify assessment methodology. Environmental conditions in ephemeral or low-flowing streams tend to be particularly poor. To begin with, the endemic ecosystems are naturally under stress due to the short rainy season and the high-annual losses due to evapotranspiration during the dry summer months (Gasith and Hershkovitz 2010). Kijowska-Strugała et al, (2017) similarly concluded that the classification of the hydromorphological states of streams, commonly applied in Europe, requires readjustment of the ranges for assigning values for specific metrics in desert and semi-desert conditions, where the presence or absence of some hydromorphological elements may be natural and does not indicate a degraded hydromorphological state, ie. riparian vegetation is naturally absent in desert streams. This study seeks to evaluate metrics based on the MQI model, and assess where modification is needed to customize the analysis Israeli streams.

### *2. MQI Protocol*

The combination of field data collection and remote-sensing based GIS spatially explicit data analysis were applied to the calculation of the morphological quality (MQI) as defined by Rinaldi et al (2016). Stream segmentation was conducted based on detailed geomorphic based criteria, enabling a comparison of different reaches along the stream. A total of 27 parameters are defined, consisting of specific criteria for assigning values (Appendix B). The overall value determination results from the sum of each individual parameter, enabling a comprehensive assessment of the hydrological properties of the stream, translated into a numeric score, per segment. For the MQI morphological assessment, consistent with CEN (2002) standards and WFD requirements, metrics evaluate functionality, morphology, and artificiality. For example, both lateral and longitudinal continuity in sediment and wood flux, functional vegetation in riparian zone, floodplain conductivity, streambank erosion, morphologic issues pertaining to channel pattern and cross-section, channel bed structure and substrate, bed slope and artificiality indicators pertaining to alterations of flow and sediment upstream and within the reach. Specific categories considered in this protocol include: Geomorphological functionality, based on the observation of forms and processes in the present conditions, and their comparison with forms and processes normally associated with that river typology; Artificiality presence, frequency and continuity of artificial structures and interventions; and Channel adjustments, focused on recent morphological variations over a temporal frame of about 100 years. Each metric is assigned a score, enabling comprehensive qualification of the entire stream system. In general low scores reflect the most natural conditions and higher scores represent artificial elements and modification of the river channel.

## D. Methods and Background Analysis for Application of the MQI

### *1. Identification of landscape (or physiographic) units*

GIS analysis was performed using aerial photographs from 2016 (Ministry of Agriculture), DEM data (2014) and Lidar data (2011). Geological and geomorphological characteristics were identified. Overlaying the topographic contour lines, the physiographic units were delineated into hills and lowland areas (Fig. 8), in accordance with the MQI guidelines.

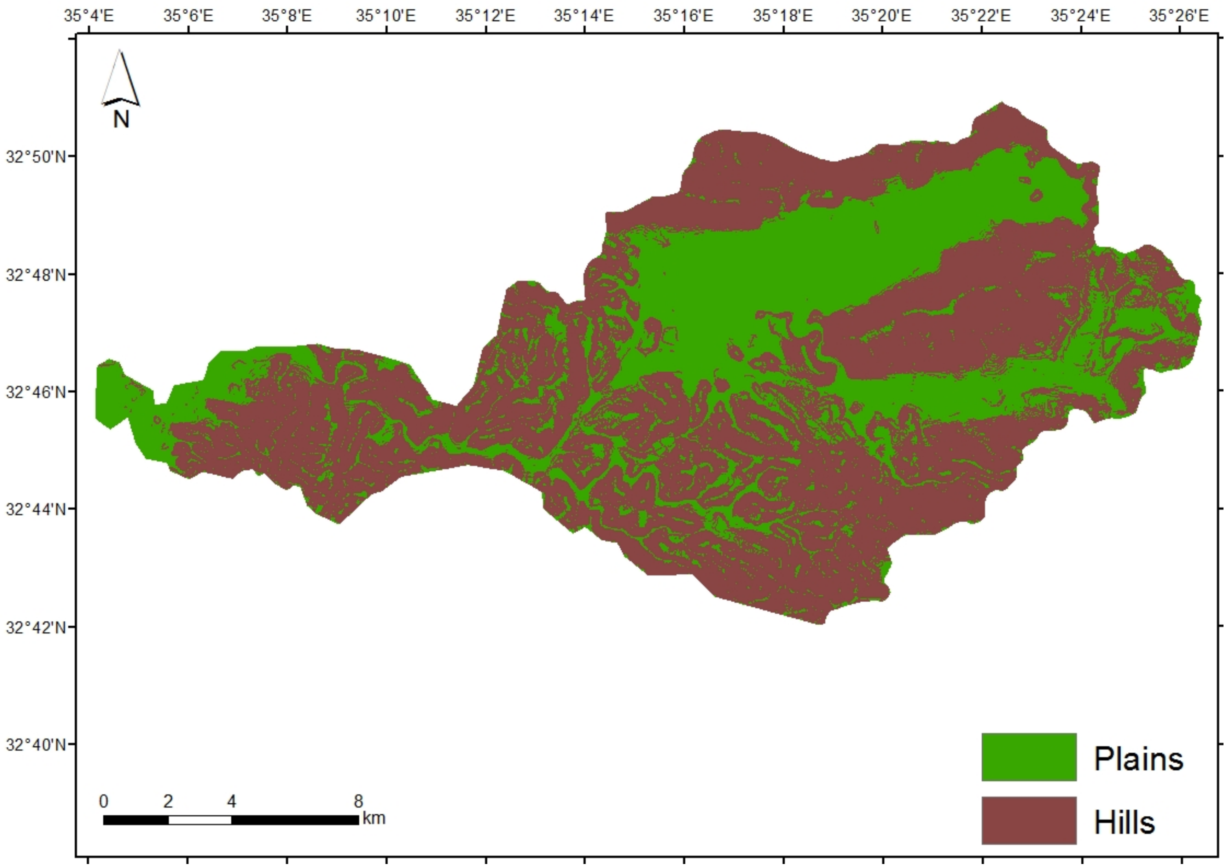



Fig. 8: Physiographic units

Data was collected using two methods. Real time kinematic (RTK) survey equipment (accuracy +mm) was used to measure stream cross sections and obtain a bed profile in 176 locations along the entire stream corridor. Sites were selected based on geomorphic features and transitions along the channel, areas with extensive bank erosion, recently created anabranching channels, representative landscape attributes, artificial features, and locations with ecological value. Places where stream banks were failing or in poor condition were also measured in detail to enable detailed comparison and evaluation of bank erosion in future surveys. We used the application Collector (ArcGIS, ESRI) to collect data on relevant field parameters. Appendix 3 presents the field data collection sheet from the June survey. We walked the length of the stream corridor over a six day period between June 4 and June 12, 2017 and collected detailed geomorphic data at a total of 273 data collection points. During the course of the one year study, we collected data from a total number of 463 data collection point locations within the stream to further delineate the precise location of the stream channel, and collect data on geomorphologic and hydrologic parameters. Over the course of the year, we returned to representative monitoring stations in each segment along the stream to measure water quality and evaluate flooding during and after storm events, conduct vegetation sampling and detailed bed sediment analysis and measure changes in baseflow and hydrologic conductivity.

Fig. 9 presents both the RTK cross-section measurement location and data collection locations. These data were used to establish a detailed baseline and will be used to monitor long term trends in bank stability and channel adjustments.

Results from this survey were used to create individual GIS layers. RTK data defining the lowest point in each profile were used to define the exact location of the stream bed. In addition, data collection involved entering the stream and obtaining the precise GPS location from inside the channel. Collectively, these points were connected to establish an accurate channel delineation. Lidar data were analyzed to confirm channel locations in areas where gaps existed between data collection locations. The resulting channel delineation provides an accurate channel that can be used to evaluate long term morphologic adjustments and trends along the stream. Representative locations where our channel delineation differs from the MAPI channel delineation are highlighted in Fig. 10, with the channel corridor derived from the June survey (blue line) in comparison to the MAPI channel (purple line). While sometimes these differences are subtle, they may be important in terms of our ability to quantify changes over time.

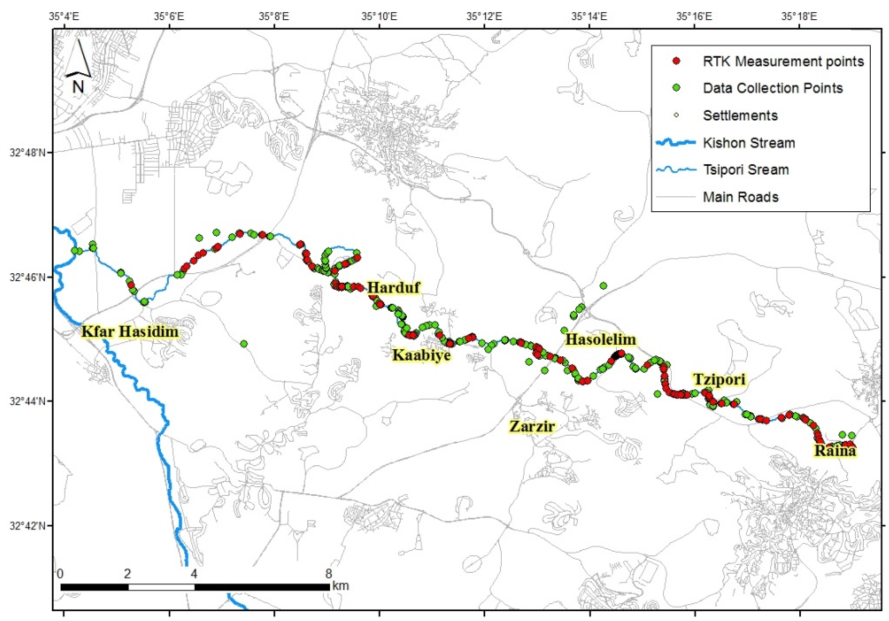



Fig. 9: Data collection location

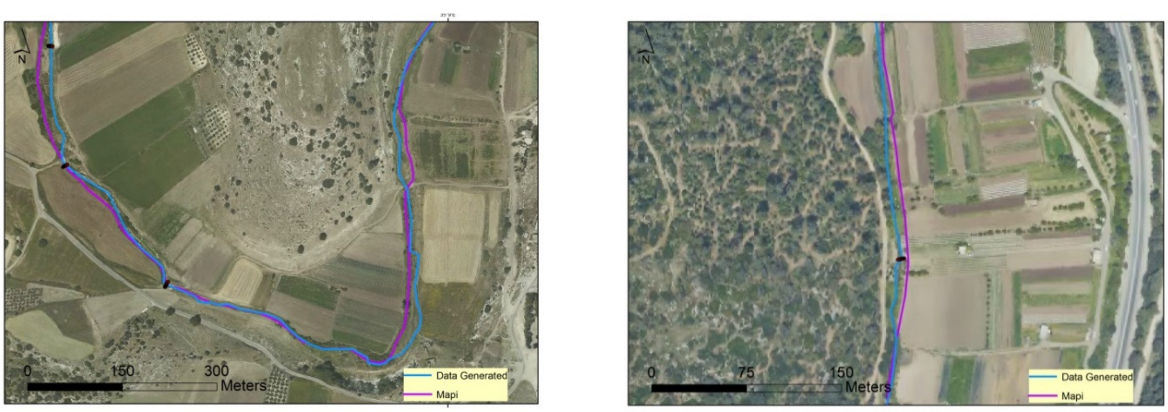



Fig. 10: Delineated stream comparing survey data to MAPI

*2. Designation of River Segments*

Based on the defined segmentation criteria, segmentation occurs at transitions due to physiographic units, changes in the width of alluvial flood plain, channel width variability, confluences, artificiality, and longitudinal profile. The stream was divided into relatively homogeneous reaches, defined as stream segments (i.e., a section of river along which present boundary conditions are sufficiently uniform, commonly a few kilometers in length). Our reach analysis was conducted using aerial photo interpretation, GIS analysis, RTK data collection and field reconnaissance. Following the protocol, significant elements that result in the alteration of flow occurring upstream of the reach, or which alter the continuity of water and sediment within the reach are considered as breaking points for the segmentation into reaches. Additional aspects considered as criteria for the division into channel reaches include discontinuities in bed slope, natural or artificial hydrological discontinuities (such as dams, check dams or diversion structures), and other primary sources of water entering the main stem of the stream that result in significant changes in discharge or sediment transport. Meaningful changes in channel width or channel bed sediment size can also be considered a criterion of separation in different reaches. In general, assessment guidelines specify that within each reach, no significant changes in valley setting, channel slope, imposed flow and sediment load occur (Brierley and Fryirs, 2005; Gurnell et al., 2009). For example the diversion dam located between segment two and three, and the confluence with Nachal Yiftachel, located between segment eight and nine, are examples of significant flow alterations resulting in segmentation divisions. The final designation of stream segments (Fig. 11) are the elementary units for the morphological assessment. A total of 17 reaches were defined.

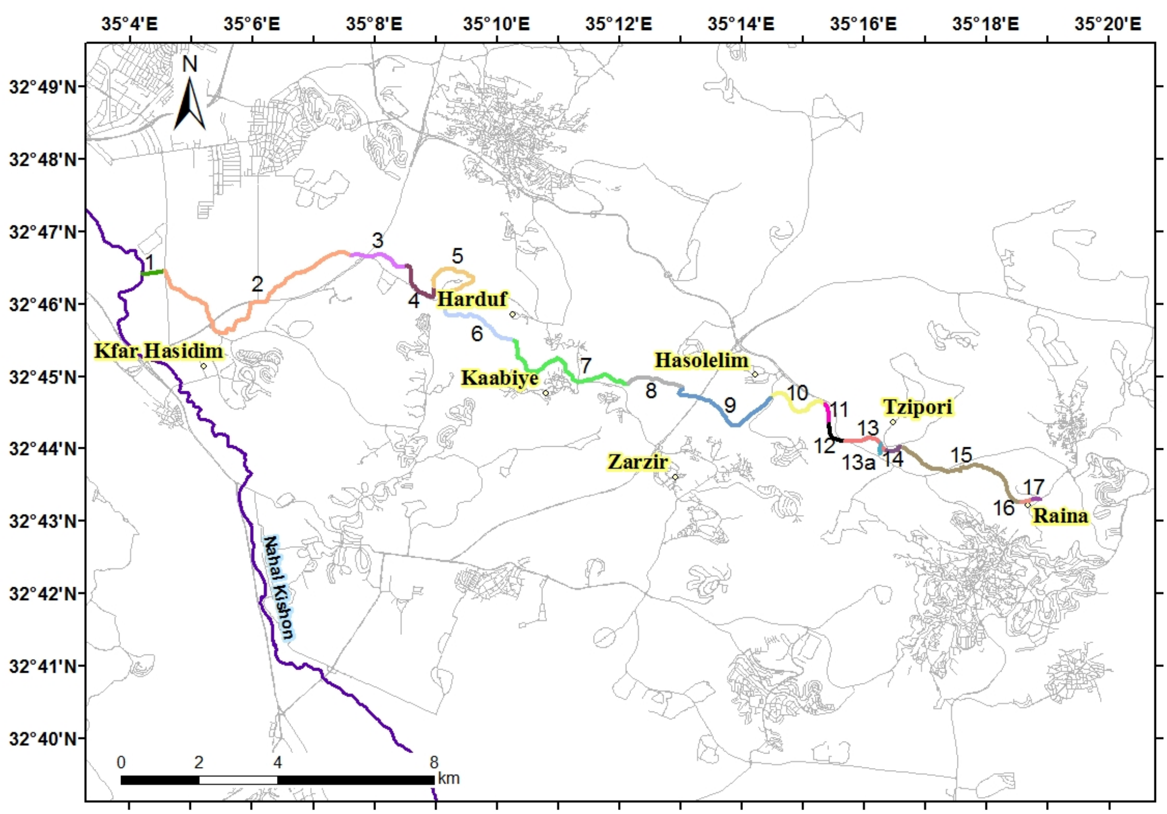



Fig. 11: Stream segmentation

Table 1 provides detailed data on each of the stream segments. Location coordinates) our presented at the upstream division point. Contributing drainage area was calculated based on DEM, DTM, and GIS analysis.  The contributing area was calculated for each segment, determined as the sum of each area, due to the hydrologic cumulative effect of runoff as you go downstream.

Table 1: Segments Details

| Segment | Upstream coordinates (latitude, longitude) | Downstream coordinates (latitude, longitude) | Reach_Length (m) | Upstream (distance from Kishon)(m) | Longitudinal Slope (Promil) | Accumulative Contributing_ Area (sq.km) |
|---|---|---|---|---|---|---|
| 1 | 35.075715<br>32.773814 | 35.069491<br>32.773807 | 607.84 | 607.84 | - | 293.589 |
| 2 | 35.126561<br>32.777959 | 35.075715<br>32.773814 | 6741.42 | 7349.25 | 2.5 | 281.596 |
| 3 | 35.141439<br>32.775660 | 35.126561<br>32.777959 | 1533.97 | 8883.22 | 5 | 260.453 |
| 4 | 35.143184<br>32.770790 | 35.141439<br>32.775660 | 1475.47 | 10358.69 | 6.6 | 256.747 |
| 5 | 35.152069<br>32.768483 | 35.143184<br>32.770790 | 2348.98 | 12707.68 | 6.6 | 250.490 |
| 6 | 35.171032<br>32.758248 | 35.152069<br>32.768483 | 2496.06 | 15203.74 | 11.5 | 246.272 |
| 7 | 35.202316<br>32.748375 | 35.171032<br>32.758248 | 4183.50 | 19387.24 | 7.4 | 237.923 |
| 8 | 35.217332<br>32.747078 | 35.202316<br>32.748375 | 1594.55 | 20981.79 | 6.6 | 222.841 |
| 9 | 35.241156<br>32.745022 | 35.217332<br>32.747078 | 3158.85 | 24140.64 | 10.2 | 220.138 |
| 10 | 35.256026<br>32.743734 | 35.241156<br>32.745022 | 1814.52 | 25955.16 | 12.8 | 22.049 |
| 11 | 35.257085<br>32.79 | 35.256026<br>32.743734 | 551.19 | 26506.35 | 15.8 | 20.294 |
| 12 | 35.261074<br>32.735161 | 35.257085<br>32.79 | 699.50 | 27205.85 | 14 | 19.358 |
| 13 | 32.271193<br>32.734878 | 35.261074<br>32.735161 | 1241.33 | 28447.18 | 15.9 | 18.736 |
| 13a | 35.270887<br>32.731929 | 32.271193<br>32.734878 | 281.58 | - | - | 0.063 |
| 14 | 35.277130<br>32.733652 | 32.272617<br>32.732968 | 494.09 | 28941.28 | 15.6 | 16.566 |
| 15 | 35.305526<br>32.723968 | 35.277130<br>32.733652 | 3352.54 | 32293.82 | 17.3 | 16.059 |
| 16 | 35.312496<br>32.721625 | 35.309289<br>32.721013 | 328.19 | 32857.57 | 30.3 | 5.718 |
| 17 | 35.315194<br>32.721836 | 35.312496<br>32.721625 | 218.47 | 33385.39 | 36.3 | 3.399 |

Based on field investigation and specifically, the RTK cross-section measurements, the stream profile was calculated throughout the length of the channel. Table 2 presents the channel morphology data, calculated based on RTK measurements. These include the elevation of both left and right streambanks, the slope of each streambank, the width of the channel and the width of the floodplain, and both confinement and sinuosity indices, presented as minimum, maximum, and average values per segment. Cross section profiles provide an excellent baseline for this stream. Stream geomorphic features were identified both in the field and using remote sensing analyses.

Table 2: Channel morphology details

| Segment | Longitudinal Slope (‰) | Left Bank Height (m) | Right Bank Height (m) | Left Bank Side Slope | Right Bank Side Slope | Channel Width (m) |
|---|---|---|---|---|---|---|
| 1 | - | - | - | - | - | - |
| 2 | 2.9 | 2.04 | 1.85 | 0.383 | 0.418 | 9.86 |
| 3 | 4.8 | 1.22 | 1.19 | 0.652 | 0.942 | 6.49 |
| 4 | 7.2 | 0.78 | 0.58 | 0.713 | 1.249 | 3.65 |
| 5 | 6.5 | 0.84 | 0.53 | 0.356 | 1.800 | 10.68 |
| 6 | 10.3 | 1.26 | 1.03 | 1.499 | 7.982 | 8.13 |
| 7 | 6.4 | 1.20 | 0.86 | 0.437 | 0.616 | 5.51 |
| 8 | 5.4 | 1.41 | 1.01 | 0.584 | 0.692 | 4.63 |
| 9 | 11.1 | 1.32 | 1.57 | 0.390 | 0.431 | 7.91 |
| 10 | -13.3 | 1.81 | 1.73 | 0.904 | 0.481 | 11.74 |
| 11 | 23.1 | 1.29 | 1.42 | 0.782 | 1.550 | 4.53 |
| 12 | 14.4 | 1.27 | 1.22 | 0.772 | 0.513 | 4.78 |
| 13 | 21.2 | 2.51 | 1.99 | 0.546 | 0.451 | 9.29 |
| 14 | 14.0 | 2.34 | 2.18 | 0.760 | 0.386 | 8.98 |
| 15 | 17.6 | 0.92 | 1.24 | 1.400 | 1.090 | 4.21 |
| 16 | 30.7 | 2.04 | 2.60 | 0.805 | 0.575 | 7.15 |
| 17 | 42.4 | 1.34 | 1.42 | 0.640 | 0.516 | 4.51 |

The longitudinal bed slope elevation of the stream channel was determined using RTK data by calculating from the downstream point in one segment, upstream to the downstream point of the above segment, enabling creation of a trend-line, and subsequently generating the $R^2$ value, which was greater than 0.96 in all cases. Bed slope ranged from 2.5 % at the downstream end to 36% in the uppermost section of the stream channel.

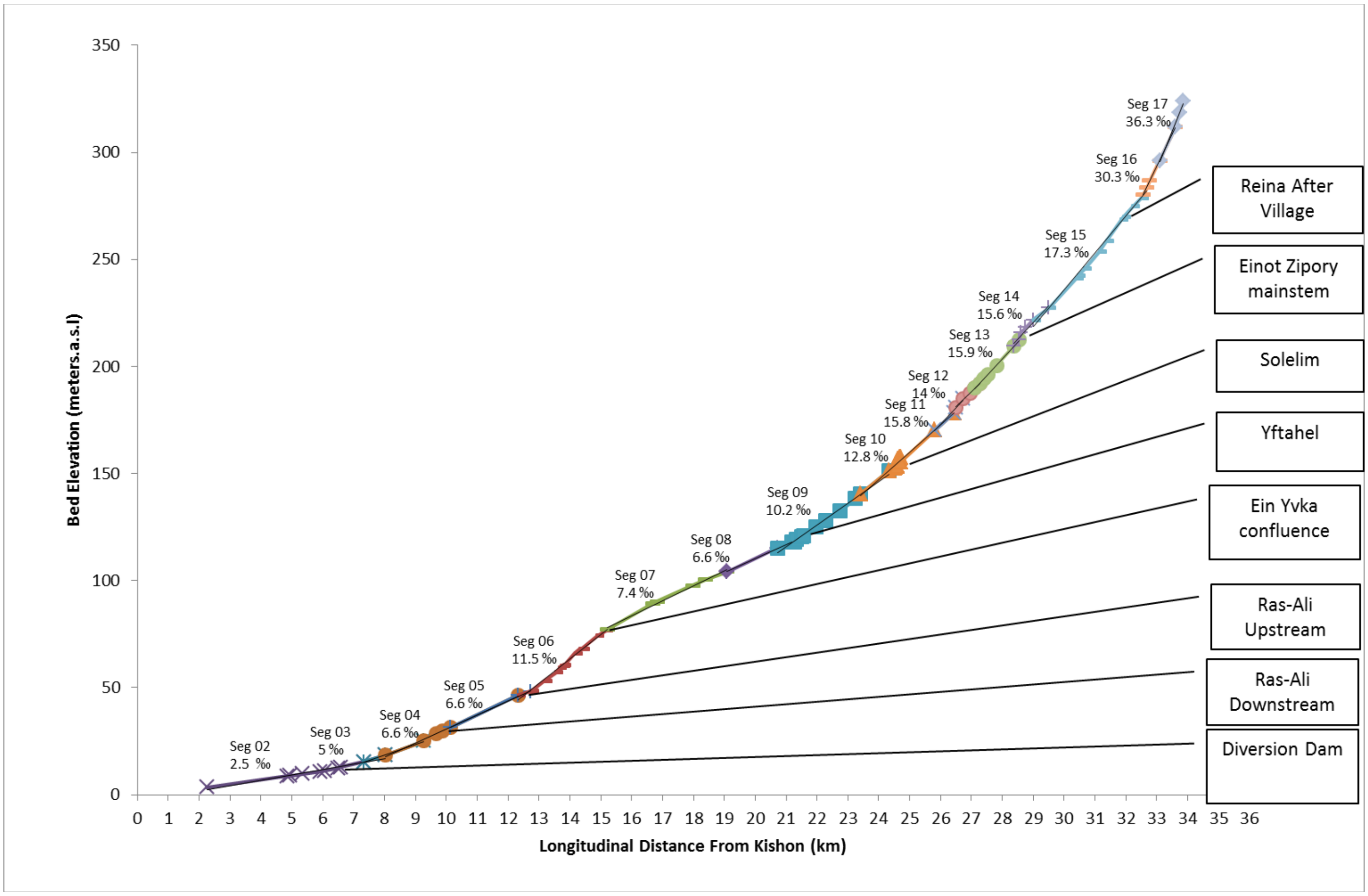


Fig. 2: Longitudinal bed slope

Fig. 12 presents the stream bed slope elevation relative to longitudinal distance from the confluence of the Kishon River. An inflection analysis (Fig. 12) was used to identify changes in slope elevation, correlated to specific stream locations to support the stream segmentation analysis.

### *4. Definition and analysis of confinement*

Confinement was used to evaluate channel processes and assist in the stream segmentation. Using remote sensing, digital elevation data and GIS analysis, we calculated the floodplain width based on contour lines. RTK data was used to define the channel width. Changes in width of the alluvial floodplain are considered as additional criterion for segmentation. Confinement index was calculated as the ratio between the floodplain width (including the channel) and the channel width. Consequently, the index is inversely proportional to the confinement: a minimum value of 1 indicates that the floodplain and channel coincide (i.e. there is no floodplain) (Rinaldi et al, 2016). The confinement degree for Tzipori is less than 10% in all locations, and based on the confinement index, the Tzipori falls into the class of low confinement (Table 3).

In general, unconfined channels have an alluvial floodplain that is nearly continuous and the river has no lateral constraints to its mobility. Tzipori stream is partly confined in S5, S6, and S11, due to the proximity of the hill bordering one side of the stream. The upstream segment of S13 is deeply incised, partly confining the channel.

Sinuosity Index is defined as the ratio between the distance measured along the (main) channel and the distance measured following the direction of the overall planimetric course (or ‘meander belt axis’ for single thread rivers) (Rinaldi et al, 2016). The stream encircles the hillside Ras Ali, forming a large meander (S5), resulting in a high sinuosity index value (Segment 5 is only partly confined by the hillside, because the other streambank is connected to a wide floodplain. We evaluated changes in sinuosity in the stream, (see Section D. CA1). The sinuosity index for the existing stream length was calculated for each segment (Table 3), as well as for the whole stream. Results show that the sinuosity index decreased from 1.5 in 1945 to 1.4 in 2017.


Fig. 13: S5 at Ras Ali showing partly confined stream meandering around hillside

Table 3: Sinuosity & Confinement (unitless dimension)

| Segment | Sinuosity Index | Confinement Index |
|---|---|---|
| 1 | 1 | - |
| 2 | 1.4 | 103.3 |
| 3 | 1.1 | 80.8 |
| 4 | 1.7 | 212.6 |
| 5 | 6.4 | 109.1 |
| 6 | 1.2 | 48 |
| 7 | 1.3 | 76.3 |
| 8 | 1.1 | 102.2 |
| 9 | 1.4 | 58.9 |
| 10 | 1.3 | 27.2 |
| 11 | 1 | 46.3 |
| 12 | 1.2 | 46.2 |
| 13 | 1.1 | 51.1 |
| 14 | 1.2 | 105.7 |
| 15 | 1.2 | 53.7 |
| 16 | 1.1 | 39.7 |
| 17 | 1 | 29.3 |

Based on the topographic map (Fig. 14), the surrounding hills has a maximum elevation of approximately 550-600 m. The highest value for single-thread channels reflects the fact that a sufficiently wide plain is needed for these channels to develop completely free meanders, equal to about 4.5 times the channel width (Leopold and Waldman, 1957).

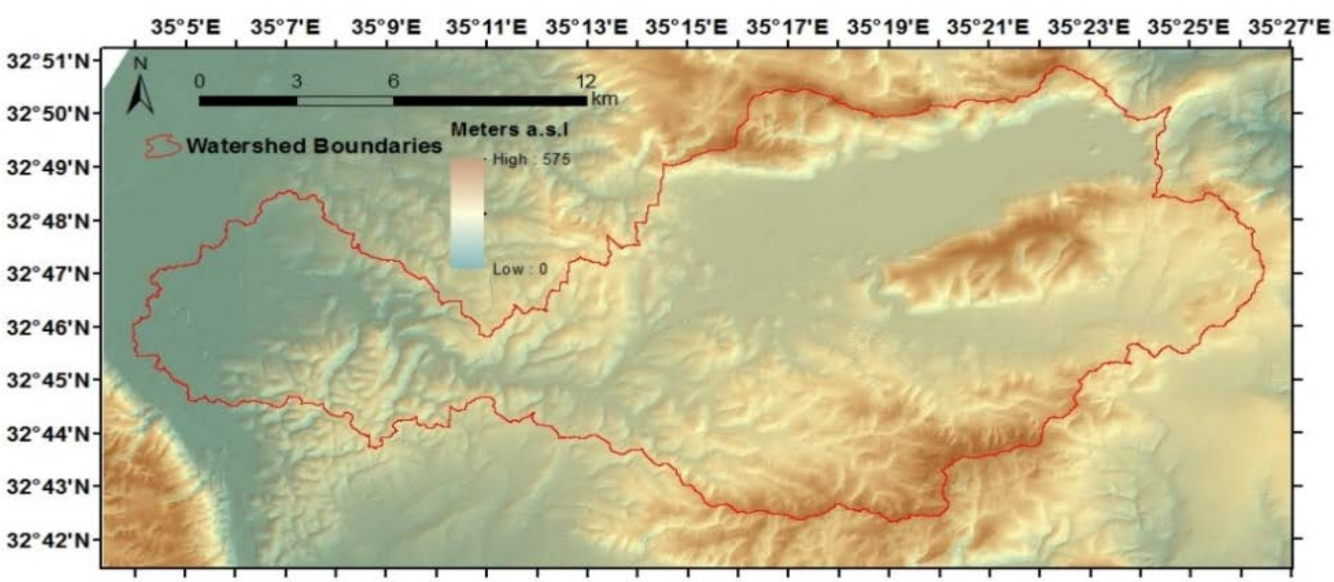



Fig. 3: Topographic map

## E. RESULTS: MQI METRIC ANALYSIS

Following are the variables that comprise the MQI, with short descriptions of each metric taken directly from the protocol (Rinaldi, et al., 2016). The analysis of each indicator is presented per segment. The scoring analysis and results is presented at the end of this section.

**F1: Longitudinal continuity in sediment and wood flux**

This indicator evaluates whether the longitudinal continuity of sediment and wood material is altered by human structures that intercept or create obstacles to their flow. The number of alterations is not critical, only their relevance: just one structure can cause a complete alteration of the flux, whereas many structures may have no significant effects (the number of structures is accounted for in the indicators of Artificiality). The main artificial structures are dams, check dams, and weirs. Other alterations can be due to crossing structures (bridges, fords). Structures located at the upstream reach limit are assigned to the upstream reach but are not evaluated for that reach, as the effects on the longitudinal continuity are considered for the downstream reach. This approach is taken for each metric.

Results from the bed substrate investigation do not show evidence of clear bed material distribution, which occurs as typical sorting under natural stream conditions as you go downstream (F10), suggesting that there is inference in the longitudinal continuity of sediment flux. However, for this assessment, we limit the scoring per the MQI to the presence of specific structures that result in interfering with sediment flows, as defined.

In the upper section of the stream, strong alteration of the storm driven channel has resulted in discontinuity of sediment and wood flux. Portions of Segment S17 consists of stone or concrete channelization and full bed revetment as the stream is confined between the backs of houses. At the beginning of S16, where the stream is buried in a tunnel culvert, restricting wood flux downstream. Although it discharges into a natural landscape at the beginning of S15, there is a 50 m section within S15 that is channelized into a concrete trench, preventing continuity in sediment and wood flux. At the downstream point of S14, a dropbox culvert transports stream flow under the main entrance road of Moshav Tzipori. Although this does not result in complete interception, it causes discontinuity, as well as resulting in stream incision. A series of culverts along the stream, especially in S12, creates a slight alteration in the continuity in sediment and wood flux along the stream channel, creating obstacles to the flux without complete interception. Although crossing structures are evaluated in A5, wood obstruction was observed in culverts located in S7 (photo below), resulting in slight alteration of continuity. During winter storms, the IHS weir does not obstruct flow. However during low summer flows, this feature interferes with sediment transport, as indicated by the channel bed substrate investigation results (see F.10) Infrastructure development in S3 have been occurring throughout this project, constructing a series of culverts under the Highway crossing of road 70. These intensive culverts will likely interfere with wood flux. In addition, at the downstream end of S3, a diversion dam creates a strong alteration, creating discontinuity and complete interception of sediment and wood. Similarly at the most downstream S2, a transversal structure creates an obstacle to the flux.


Fig. 4: (a) Culvert (S7) partially blocking wood flux (b) Structure downstream S2 strongly altering flux (c) IHS Station at ras ali (S5)

**F2: Presence of a modern floodplain**

A river in dynamic equilibrium builds a modern floodplain that is generally inundated for discharges just exceeding channel-forming flows (return interval of 1-3 years). The presence of a modern, frequently inundated floodplain promotes several important morphological, hydrological and ecological functions (attenuation of flood peak discharges, energy dissipation, fine sediment deposition, groundwater recharge, flood pulse, turnover of riparian habitats, etc.). Bed incision or artificial structures (levees) can alter this characteristic form and disconnect the floodplain from channel processes. Lateral extension and longitudinal continuity of a modern floodplain is considered here as an indicator of existing lateral continuity of water and sediment fluxes. Agricultural activities fills the majority of the floodplain today.

The floodplain connectivity analysis was based on two methods. First remote-sensing analysis of the 2016 aerial photograph, based on the physiographic unit classification, resulted in floodplain delineation using contour intervals. The width of the entire floodplain was calculated, and analyzed according to the final segmentation. Based on these data, we calculated the ratio channel width to floodplain width (Table 4).

Second, using field survey, RTK cross-sections were used to define the elevation of the streambanks, bank slopes and the elevation of the stream (Table 2).

Data obtained from the IHS provides long-term flow discharge data collected at the hydrologic station located in Ras Ali (S5) (Fig. 16). This is the only station on the stream, and has been collecting discharge, hydrograph's, and stream volume data since 1965. Peak flow data were analyzed based on historical records, enabling an assessment of this year's rain hydrologic year to be classified according to one of the following categories: drought conditions, lower than average, average, higher than average, flood conditions. Based on these criteria the hydrologic year 2017 to 2018 is categorized as an average hydrologic year.

Stream flow discharge (measured as event-dependent with data collection triggered by streamflow elevation thresholds) was analyzed for each hydrologic year on record, based on historical measurements from years 1965 to the present.

Table 4: channel width/ Floodplain width/ ratio

| Segment | Channel Width (m) | Floodplain Width (m) | Floodplain/ channel ratio |
|---|---|---|---|
| 1 | - | - | - |
| 2 | 10 | 1815 | 103 |
| 3 | 6 | 1007 | 81 |
| 4 | 4 | 779 | 213 |
| 5 | 11 | 1066 | 109 |
| 6 | 8 | 339 | 48 |
| 7 | 6 | 406 | 76 |
| 8 | 5 | 473 | 102 |
| 9 | 8 | 426 | 59 |
| 10 | 12 | 285 | 27 |
| 11 | 5 | 201 | 46 |
| 12 | 5 | 225 | 46 |
| 13 | 9 | 413 | 51 |
| 14 | 9 | 728 | 106 |
| 15 | 4 | 303 | 54 |
| 16 | 7 | 214 | 40 |
| 17 | 5 | 87 | 29 |

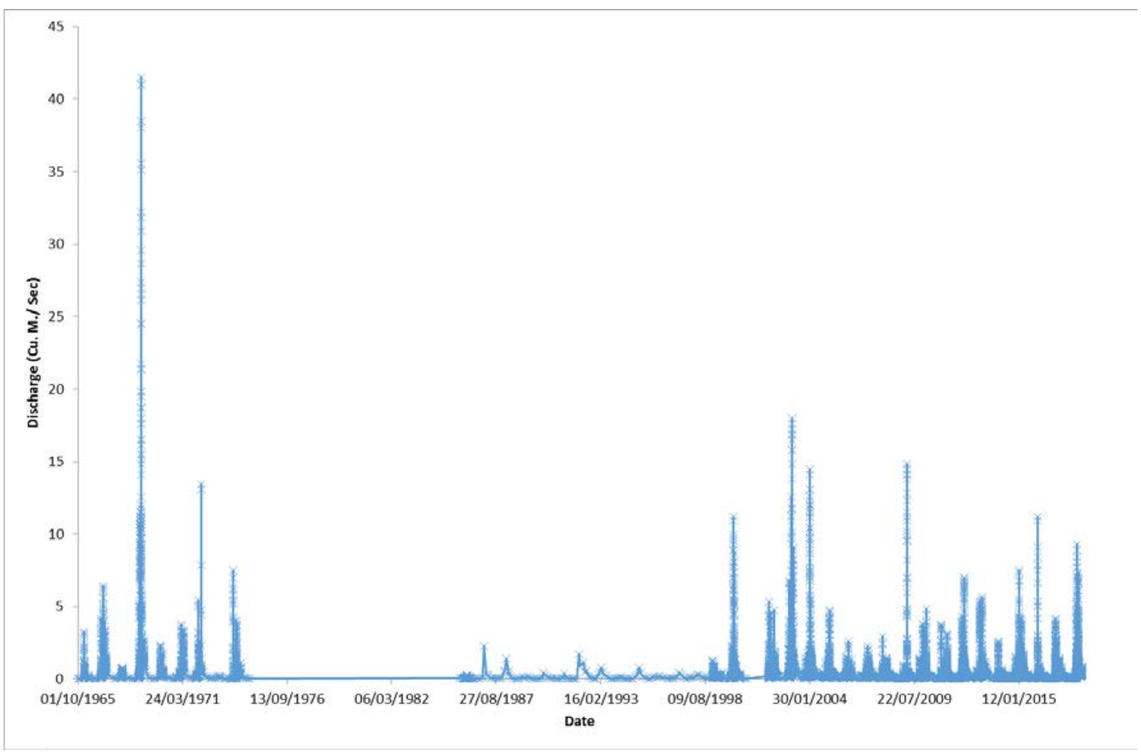



Fig. 5: Historical Discharge data

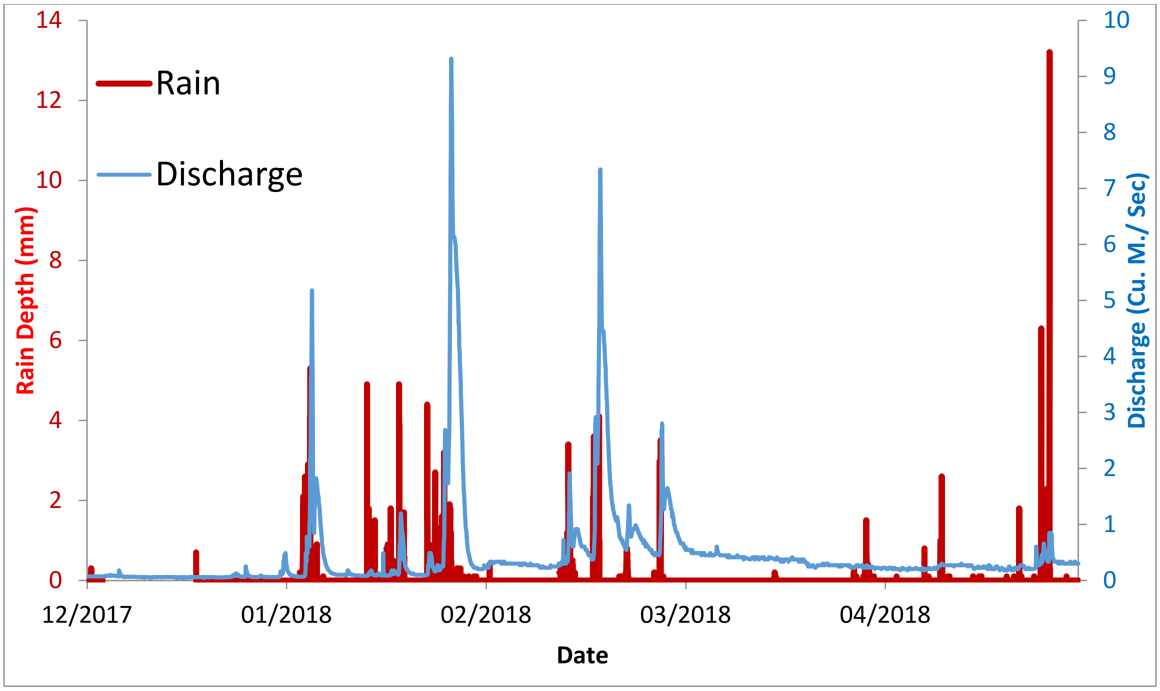



Fig. 6: 2017-2018 peak discharge flows and daily rainfall

The identification and delineation of the modern floodplain is based on the assessment of the modern floodplain continuity, defined as the percentage of reach length with presence of modern floodplain, even if only on one side of the channel, the lateral extent, i.e. its overall width (sum of both sides). Class *A* category is associated with floodplains having a lateral extent at least equal to *nW*, where *W* is the channel width, and *n* = 2 for single-thread streams, such as Tzipori. Cross-sectional data from each segment was analyzed (number of cross-sections varied, Table 2). Representative cross-sections (Fig. X) per segment was used to analyze floodplain connectivity, and assess levels of incision to estimate the hydrologic connection of the floodplain and stream area. According to the protocol, in the case of partly-confined channels, where the modern floodplain occupies all of the available valley floor, the reach is in class A even if the lateral extent is lower than *nW*. However, the nW value is in all cases smaller than the entire floodplain, partly due to the narrow channel widths.

Hillslope material suffering from erosion can temporarily be stored along small portions of modern floodplains or terraces before being involved in sediment transport. This metric can be evaluated using a strip conventionally 50 m wide for each side of the river corridor (i.e., channel and floodplain), starting from the base of the hillslopes. Paved roads or agricultural terraces are considered elements of disconnection as they reduce the potential supply of sediment (Rinaldi et al, 2016). Roads along the Tzipori stream are not paved, consisting of compacted dirt, and do not constitute elements of disconnection. The common crossing element along the streams are called Irish Bridges (or Fords- see discussion in A5) and do not result in floodplain disconnection, although they contribute to stream erosion.

The variable for floodplain connectivity potentially interacts with other variables.  As defined in the protocol, F2 interacts with (1) Vegetation in the fluvial corridor (F12 and F13), whereby in some cases, the vegetated fluvial corridor adjacent to the river channel corresponds to or includes the modern floodplain. Due to the expansion of agricultural lands, the stream channel was narrowed, resulting in the formation of modern vegetated terraces in some isolated locations, at a lower level compared to agricultural lands. In other cases these vegetated areas correspond to existing agricultural terraces. For these reasons, the identification of the modern floodplain and its distinction from the vegetated fluvial corridor was investigated in the field. Agricultural lands generally occupy terraces, except in the case where there is no bed incision.  Along S11 and S12, the stream channel has been pushed towards the hillside to expand the agricultural fields. This has been maintained by the presence of artificial levees (*A7*), which automatically prevents the surfaces external to the levees from being modern floodplains.

Vertical adjustments (*CA3*) includes incision, which causes the hydrological disconnection between the stream channel and its floodplain. However, a new floodplain surface may develop after bed incision, and so vegetated surfaces adjacent to the stream could be a modern floodplain. In areas along the stream where no incision has occurred and no artificial levees exist, the modern floodplain corresponds to the entire floodplain (even if it is completely occupied by agriculture, as is the case on Tzipori). Sections with deep incision results in a disconnection from the floodplain. For the purposes of this assessment we assume incision greater than 3 m results in floodplain disconnection, with this occuring primarily in S13.

**F3:  Hillslope – river corridor connectivity: Not applicable to unconfined streams**.

**F4: Processes of bank retreat**

Bank erosion is a key process contributing to sediment supply as well as to the development of the floodplain and the turnover of riparian vegetation and habitats. Therefore we evaluate whether bank erosion processes occur as expected for this specific river type (e.g. erosion along the outer meander bend in meandering channel sections), or if there is a significant difference, such as absence of erosion due to widespread bank control, or excessive bank failures due to instability of the system (e.g. due to channel incision).

The Drainage Authority has artificially constructed streambanks by re-grading the channel in some areas, both for flood management and restoration.  Several reservoirs were created along the stream (for example at the confluence of Yiftachel).  Detailed intervention data on stream regrading is not available.  Therefore, we assessed the stream in its current form for bank retreat processes. Streambank erosion processes appeared to be occurring along most of Nachal Tzipori, with accelerated erosion occurring in some areas as a result of intensive agriculture and overgrazing impacts (Section H).  Even in more incised areas, we did not observe excessive bank failures in any specific segment due to instability of the system. In perennial coastal streams, it can be extremely difficult to define the minimum level of bank erosion that is expected in unaltered conditions.  Controlling factors such as extensive bank protections, and other interventions that may induce a significant reduction in bed slope and therefore in stream energy (e.g., upstream of dams, weirs, check dams, etc.) are absent from this stream. In the majority of the stream, we observed frequent retreating banks. Upstream (S17 and S16) urban development has resulted in a more artificial channel, where minimal bank erosion can occur.  Similarly small areas with artificial banks protections and artificial levees are located in S11 and 12, reducing the occurrence of bank erosion along concentrated areas of the reach.

**F5: Presence of a potentially erodible corridor**

The presence of a potentially erodible corridor is widely recognized as a positive attribute of rivers. This indicator evaluates the potential for the river to move laterally over the next decades (as opposed to the indicator *F4* which evaluates the current processes of bank erosion). The presence of artificial elements that protect against possible erosion may alter expected natural lateral mobility, such as bank protection structures, embankments, artificial levees, as well as all other anthropic elements (e.g. houses, main roads) that restricts the stream from lateral channel dynamics. The majority of the stream banks on Nachal Tzipori are in a natural condition, with the exception of S17, and S16, which are channelized and buried as discussed, and S11 and S12, which has both artificial levees and artificial protection structures, due to the fact that the stream was moved closer to the mountainside to extend the agricultural fields. In the majority of the stream, there are continuous and sufficiently wide erodible corridors.

**F6: Bed configuration-valley slope: Not applicable (**confined channels)

**F7: Planform pattern**

This indicator evaluates whether the features characterizing the planform pattern of alluvial channels, including the longitudinal variability in channel width, are those expected for the channel pattern in their presence and spatial distribution or if they result from human alterations. The presence of instream geomorphic units, as well as channel width variability, have important implications in terms of ecological conditions, as they determine the availability and variability of physical habitats.

Planimetric characteristics for Nahal Tzipori are consistent with morphological typologies generally found in unconfined and partly confined streams, but limited to straight or sinuous channel form in a ripple pool setting. The large meander around Ras Ali (discussed above).  Based on our historical aerial photo analysis (F8), wandering, braided, or anabranching morphologies have not been present on the stream historically, however geomorphic units, such as sandbars, and gravel bars can be found.  Recent restoration efforts have resulted in some addition of anabranching areas, to increase habitat diversity. Being that they were created within five years, they are not considered in this analysis.

Nachal Tzipori occupies lowland areas and coastal plains with low valley gradients.  Therefore it is possible that this single-thread, straight plane typology with some sinuosity, showing relative width homogeneity, and occasional or no bars, is the natural planform.  In general the stream banks are not artificially fixed. However, agricultural activities have been occurring in this watershed for many generations, and therefore there remains some question as to whether it is or is not natural. It is with caution that we assign this channel as a typical morphology, although this morphology is consistent with other coastal streams in the area.

Altered situations can be related to the presence of artificial elements, including interventions/actions which modify the normal pattern of geomorphic units (e.g. transversal structures). As discussed, S17 and S16, upstream has strong artificial elements resulting in consistent morphological pattern alterations for a significant portion of the reach. Two primary artificial elements are found in the downstream section of Tzipori. The presence of the diversion dam located at the downstream end of S3, which results in the formation of an altered geomorphic regime and development of a secondary channel throughout the entire length of S2. The transversal structure located at the downstream end of S2 unifies the two channels at the upstream end of S1. The mean channel width averages 7 m and ranges from 2 m to 24 m (Fig. 18, Table 4).

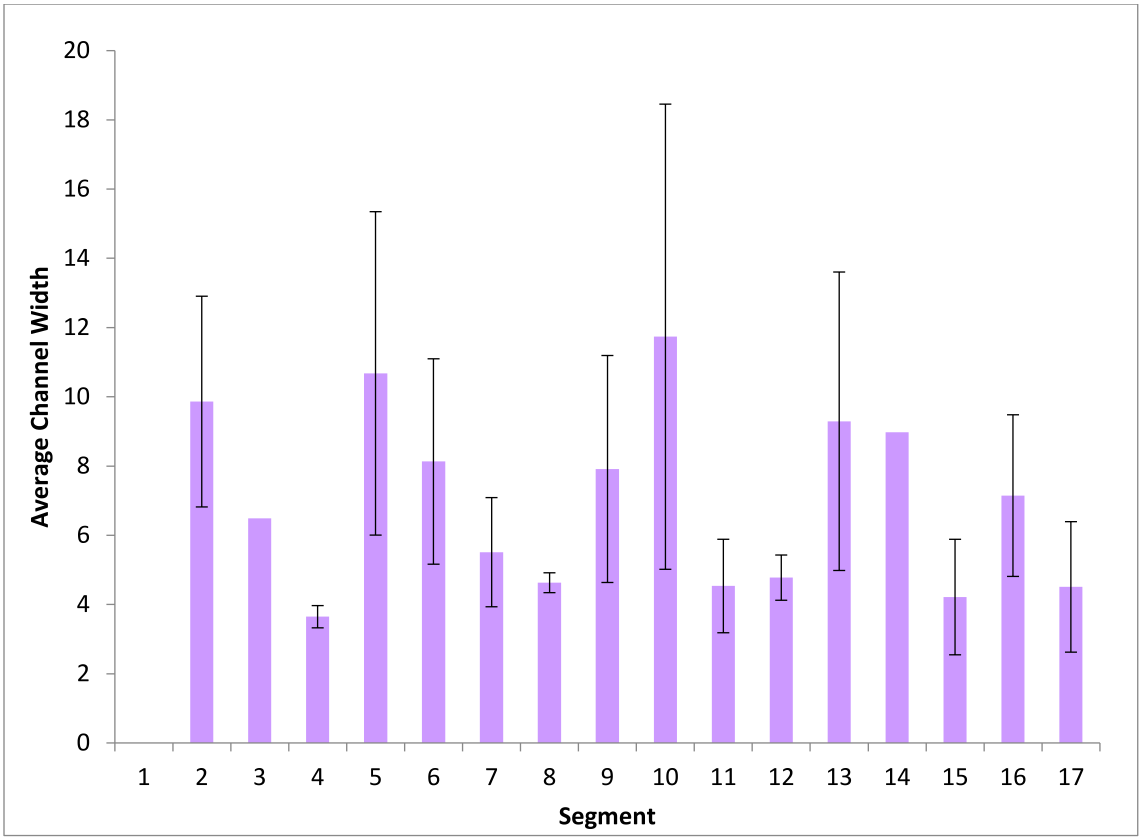


Fig. 7: Average channel width per segment (standard deviation)

As shown on Table 4, there is no significant change in longitudinal variability in channel width along the stream corridor, nor are there any significant changes in mean bed slope along the channel. Recent restoration activities conducted by the Kishon Drainage Authority (KRN) at the downstream end of S10 and locations along S5 and S6 attempted to increase geomorphic variability by widening the stream channel, constructing step pools and building vegetated islands, with the intention of increasing ecological habitat diversity. However, as these restoration activities occurred within the last few years, the effects on geomorphology are not included since the river needs sufficient time to adapt to the newly imposed (restored) conditions (Rinaldi et al, 2016). At this point, management interventions conducted on the stream are not considered on a holistic basis, targeting overall stream functionality. Instead, they are approached on a localized point along the stream, without full consideration of upstream and downstream impacts.

**F8: Presence of typical fluvial forms in the floodplain**

This indicator accounts for the presence or absence of typical fluvial forms (such as oxbow lakes, secondary channels, ridges and swales more or less hydrologically connected to the channel, etc.) that are normally expected to exist in the floodplain. Floodplains of most unconfined (or partly confined) alluvial rivers in natural conditions are typically characterized by some degree of morphological and topographic heterogeneity related to the presence of these geomorphic units. These fluvial forms have an important geomorphological and hydraulic role, as well as ecological relevance in determining floodplain habitats. The absence of these fluvial forms is generally related to artificial modifications and land use changes within the floodplain (e.g., urbanization, agriculture, infrastructures, flood defense schemes) and indicates a certain degree of alteration of the morphological functionality of the river. However it is possible that in this Mediterranean climate, semi-arid landscape, the absence of these lands forms is a natural condition and did not result from artificial modification or land use changes in the floodplain.

Some degree of lateral mobility in the past is expected, generating some fluvial landforms (e.g., minor/subdued ridge-swale topography or occasional floodplain depressions) in the floodplain, although the current energy and rate of bank erosion may be extremely low. The indicator does not evaluate the frequency or the areal extent of fluvial forms, but only their presence/absence in the floodplain. The indicator is mainly assessed using historical sources, but historical information is needed to firm whether morphological changes were due to human interventions. An existing fluvial feature identified and delineated during the June 2017 survey is a wetland, located near the stream channel in S2, which may have historically been more hydrologically connected to the stream (Fig. 19).

We conducted a historical analysis based on a set of aerial photos from 1945. A total number of 13 aerial photographs were obtained from MAPI and geo-rectified in order to conduct the historical analysis. During this assessment, careful investigation of indicators regarding these fluvial landforms was conducted Fig. 20 presents the delineated channel. Based on the historic assessment, S2 shows the most substantial channel modification, including the historic presence of a large meander or possibly a small oxbow lake. The absence of fluvial features in the Mediterranean landscape in general and in the analyzed historic aerial photos leads us to cautiously assign the absence of indicators of these features as the natural stream system. We therefore assign a value of zero where no indication of change has occurred.

Fig. 19: Wetland located near S2 stream channel (June 2017)

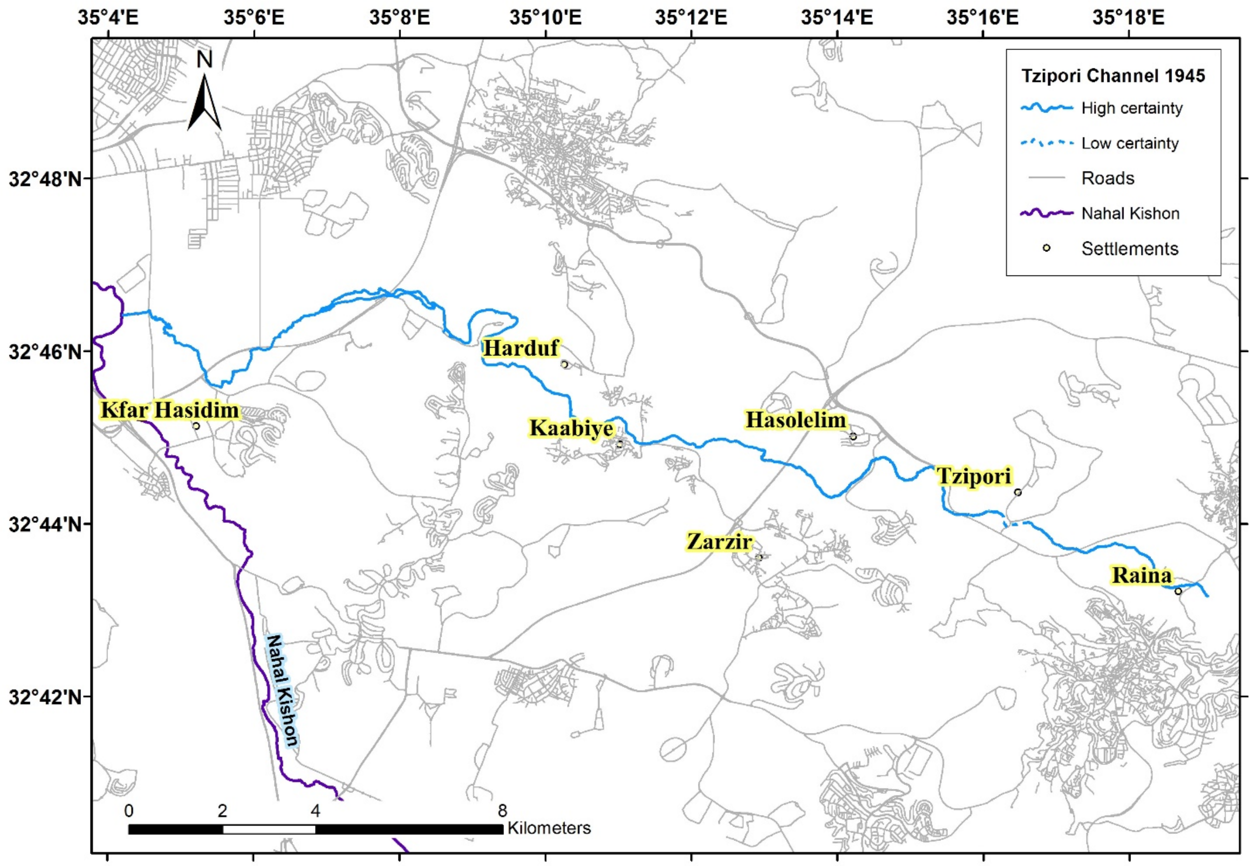



Fig. 20: Historic stream channel

**F9: Cross-section variability**

This indicator evaluates variability in the channel cross-section (in terms of channel depth), that is expected for the channel morphology of the reach as a consequence of the presence and heterogeneity of geomorphic units. The morphological heterogeneity of cross-sections is highly relevant for physical habitat diversity in many river systems. Homogenous cross-sections are usually associated with altered conditions. Alterations can be related to the presence of artificial elements (e.g. bank protections), channel maintenance interventions, or to human related channel adjustments (e.g. incision due to sediment starvation).

Israel has a regulatory-driven practice of maintaining the channel cross section at the bankful configuration targeting the 10 year flood recurrence (TAMA 34b3). This trapezoidal alteration for flood control optimization results in a level of artificiality affecting all cross sections of the stream, although detailed site specific data does not exist. Therefore, we assign a score of 3 to all segments, with specific areas with consistent alterations for a significant portion of the reach receiving a 5, as compared to historical aerial photo analysis.

The KRN is developing plans to widen the stream corridor in S13 and reduce the streambank slopes in this highly incised section. The artificial channel bed in S17, and artificial burying of the stream in S16 completely destroyed the natural cross-section. The main entrance road to Moshav Tzipori that separates the perennial stream from both the upstream storm-driven segment and the source area springs, resulted in the presence of strong alterations for a significant portion of S13.

Traditional farming in S12 has also strongly altered the channel configuration, both through farm expansion and extensive culverts, including one tunnel culvert. The downstream alterations in S2 have also resulted in extensive modification of the cross-section, creating the secondary channel. While cross-section variability can be found along the stream, the presence of significant alteration is limited to these segments. The segments defined above were scored with a five, while all others segments were assigned a score of three.

Channel bed profiles enable accurate definition of stream geomorphology, providing estimates of bankful elevation, degree of incision, floodplain connectivity and streambank elevation and slope. Extensive field data collection resulted in 173 detailed cross-sections collected along the entire stream corridor. This will provide a detailed baseline to enable long-term evaluation of streambank erosion and geomorphic changes that may result from intervention activities. Representative cross section bed profiles are presented in Fig. 21.

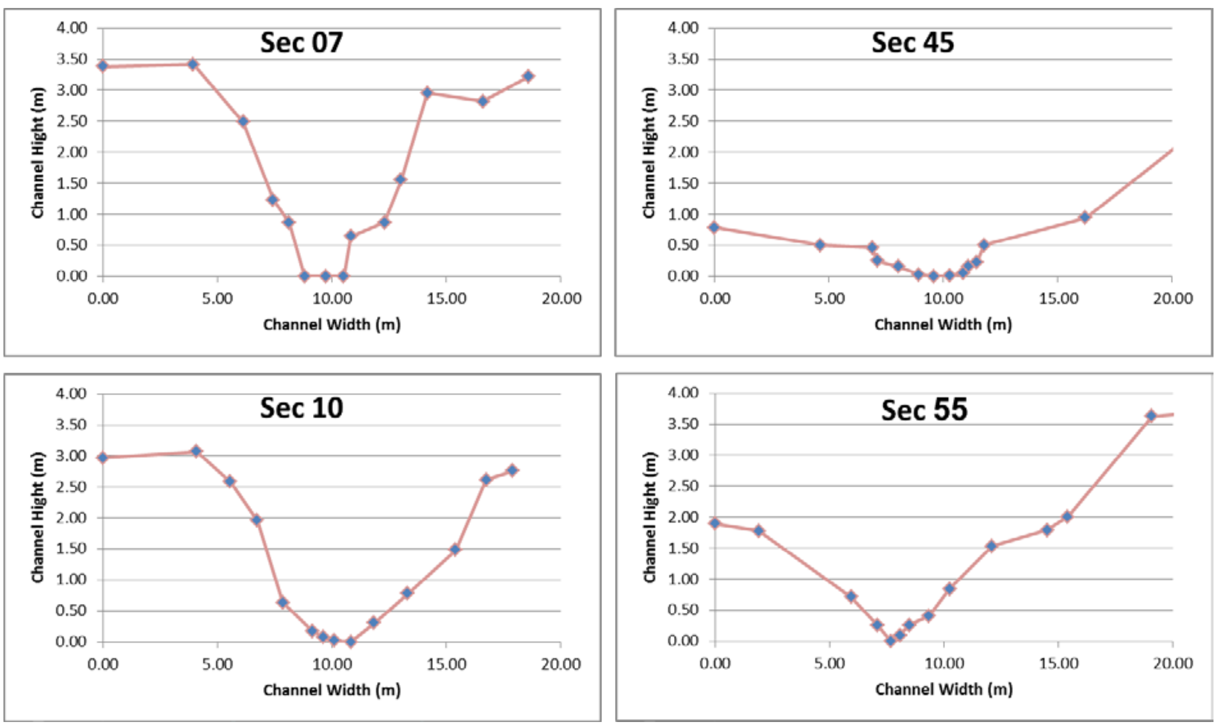


Fig. 21: Representative cross section bed profiles

**F10: Structure of the channel bed**

A stream in natural condition exhibits heterogeneity of both bed and bar sediment size, structure and texture, except in some specific cases (i.e. confined bedrock channels or streams with fine bed sediment). The structure and heterogeneity of the channel bed sediment have several implications for the functionality of bedload processes and flow resistance, and are important for aquatic physical habitats. Bed material is sampled for a range of purposes, including measurement of substrate suitability for spawning fish and other aquatic organisms, as input for equations to calculate bed mobilization, bed load transport rates, and likelihood of scour, and as a measure of grain roughness in the channel (Kondolf et al, 2003).

This indicator takes into account possible alterations of the bed sediment, such as armoring, clogging, substrate outcrops, burial of river bed and bed revetments, related to morphological adjustments (e.g. bed incision or excessive aggradation due to anthropic interventions) or directly to human interventions (e.g. revetments). Armoring refers to the presence of a surface layer in which bed material size is significantly coarser than the sublayer.

Clogging refers to an excess of fine sediments (potentially linked to excessive soil erosion because of land use changes, or to alterations of hydrological regime) causing interstitial filling of the coarse sediment matrix and potentially smothering the channel bed. Similarly to clogging, burial is generally associated with an excessive input of fine sediments to the stream channel caused by extensive bank erosion or soil erosion related to agricultural activity, land use changes (e.g. deforestation) or release of fine sediments from dams. In general there is no evidence of armoring, clogging or burial on the Tzipori.

A more detailed and quantitative bed sediment analysis was conducted on May 13 and June 7, 2018. We used a gravelometer to conduct a detailed bed sediment size analysis, defining substrate into categories ranging from <2 mm to greater than 180 mm. Sampling occurred in 10 segments(Fig. 27), along the stream where we selected representative stream sections 100 m in length. We collected a total of 200 bed sediment samples in each 100 m section, collected by two samplers working simultaneously.

The range of sizes present in natural sediment is typically presented in cumulative size distribution curves. Grain diameters corresponding to specific percentile values can be read directly from the curves plotted on semilogarithmic paper or by liner interpolation. $D_{16}$ is the size (in mm), at which 16% of the sample is finer, $D_{25}$ the size at which 25% is finer, etc. Probably, the most widely used percentile values is $D_{50}$, the median diameter (Kondolf et al, 2003). The pebble count (Wolman, 1954) is a sampling of approximately 100 grains (stones) on the river bed (or gravel bar) on a grid or line. The pebble count can be conducted on an exposed gravel bar, by wading in shallow water, or, in grater water depths. The stone measured at each sample point is selected randomly as the fingers falls to the bed. The intermediate axes of the stones are measured either with a ruler or passed through template in which squares have been cut in the sizes of the grain size classes. Analogues to sieve size opening, and recorded within predetermined size classes (Kondolf et al, 2003).

Results from this effort are presented below.

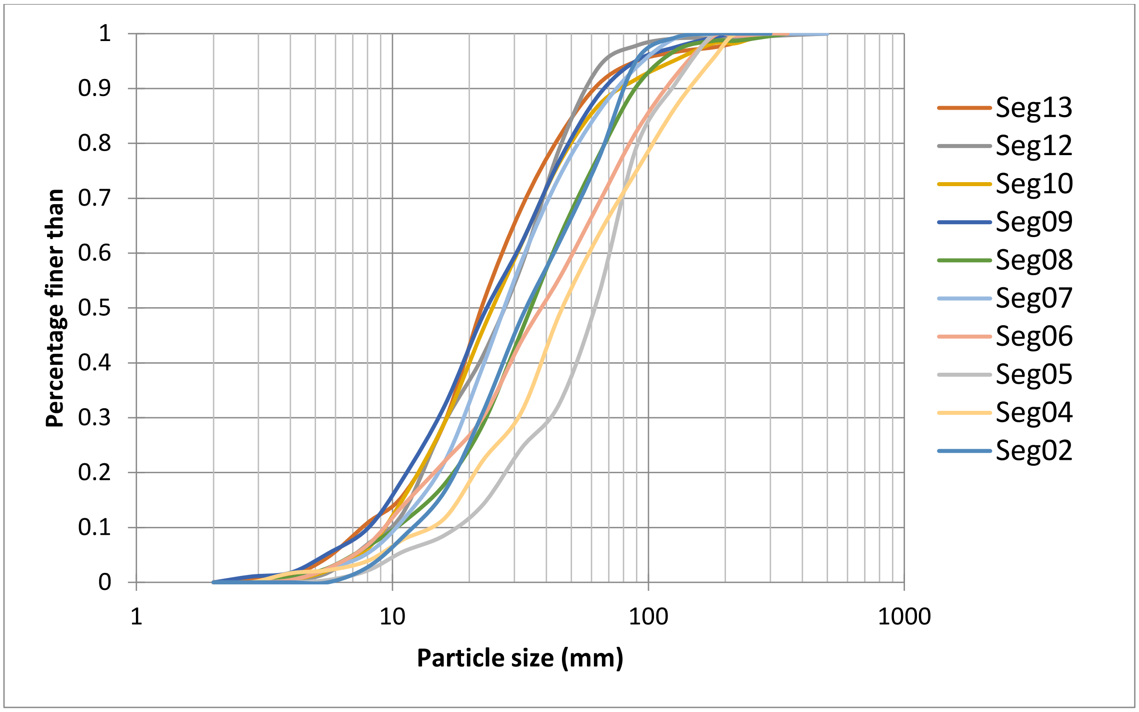



Fig. 22: Cumulative particle size distribution curves for the Tzipori stream at different segments.

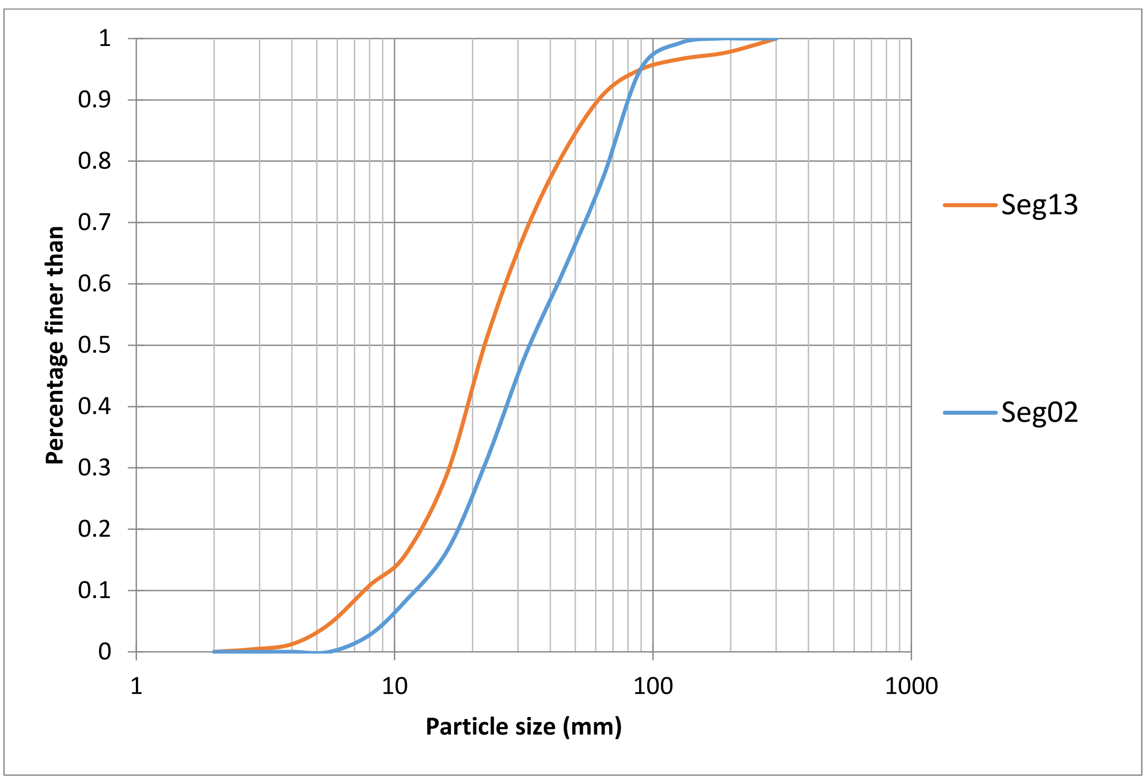



Fig. 23: Cumulative size distribution curves for Tzipori stream comparing upstream (S13) and downstream (S2)

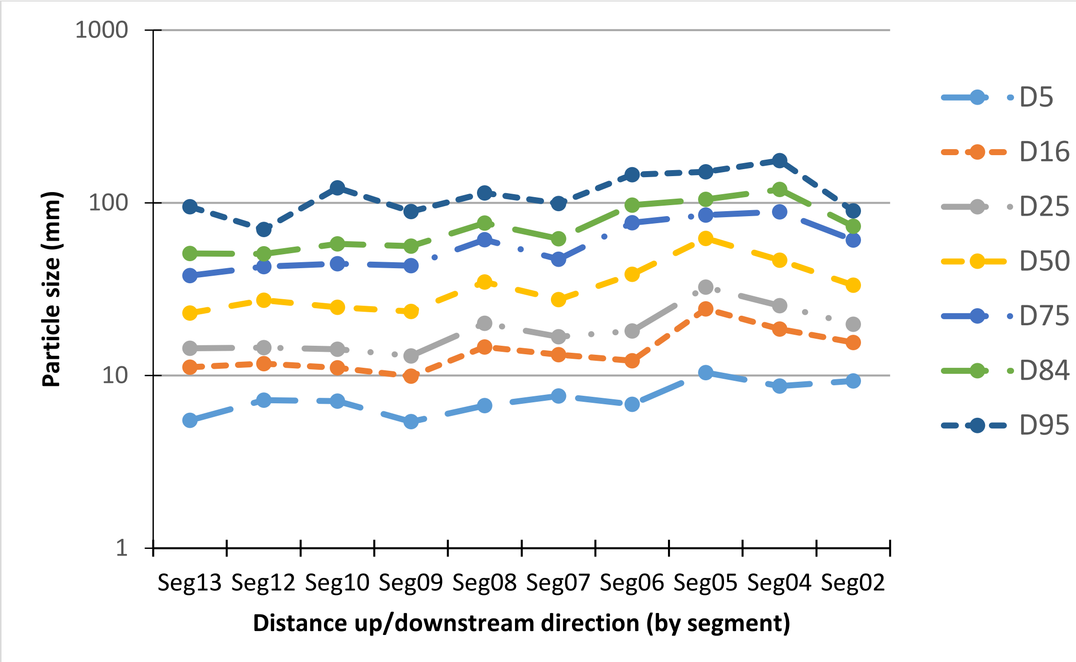



Fig. 24:  s

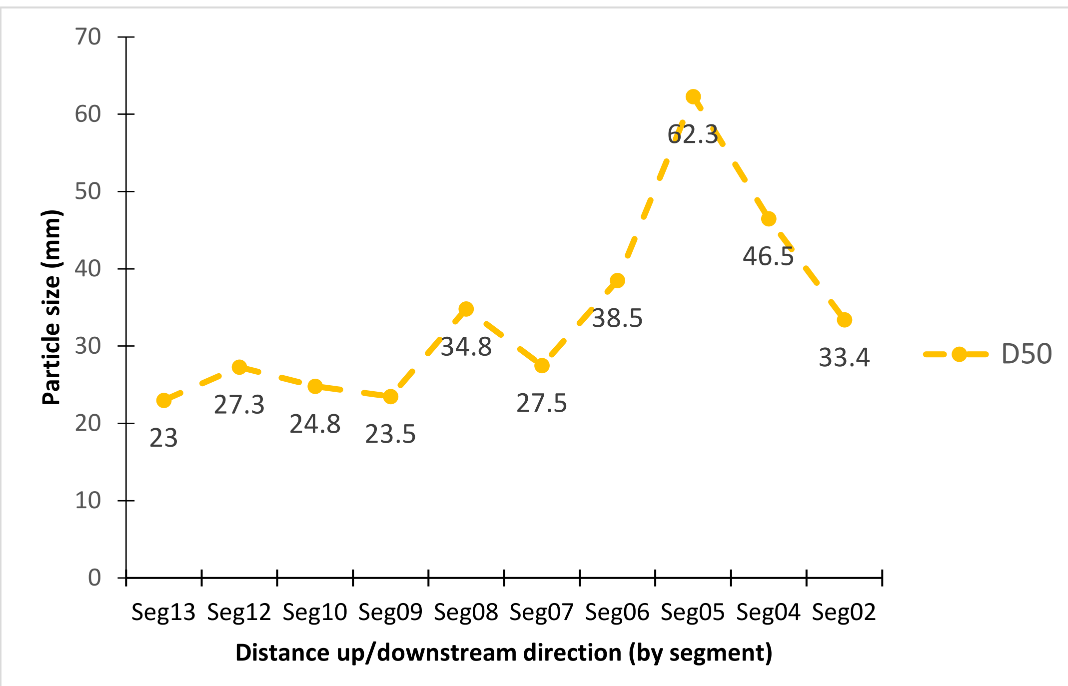



Fig. 25: Median particle size for each segment

Fig. 22 illustrates the cumulative size distribution curves for the Zipori stream at different segments. S13 is at upper stream location where as S2 is at the downstream location. The results indicate that in general Tzipori is a gravel bed river, but lack clear bed material sorting towards the downstream direction which is a typical trend found in many gravel bed streams (except for ephemeral desert streams governed by intensive flash flood flow regime). You would expect to get the segments' particle size distribution curves ordered from the finest distribution at the downstream to the courser one at the upstream segments, and although D50 ranges between 20 and 60 mm its not by segment. This is most pronounced in Fig. 23 where only S13 and S2 are shown. Surprisingly, S2 PSD is courser than S13 PSD but to $D_{95}$. Further investigation of the main percentiles of the segments' PSD shows $D_{95}$ in most segments is two orders of magnitude larger than D5 indicating bed material ranging from sand to cobbles dominated by gravels over a range of sizes from fine to very coarse gravel. Secondly, the same trend identified in Fig. 22 is clearly seen here as well. It may be the result of anthropogenic impacts of different types in in the different segments which control PSD. At two locations seg8 and seg5 we see coarser PSD compare to upstream and downstream segments. We explain these by contribution of the Yiftahel tributary to S8 and by the HIS weir at S5 (Fig. 24). These effects are clearly seen in Fig.25 when plotting D50 only as the median size representing PSD. There are two significant increases in size at seg8 and seg 5 as mentioned above.

Fig. 8: Gravelometer sampling

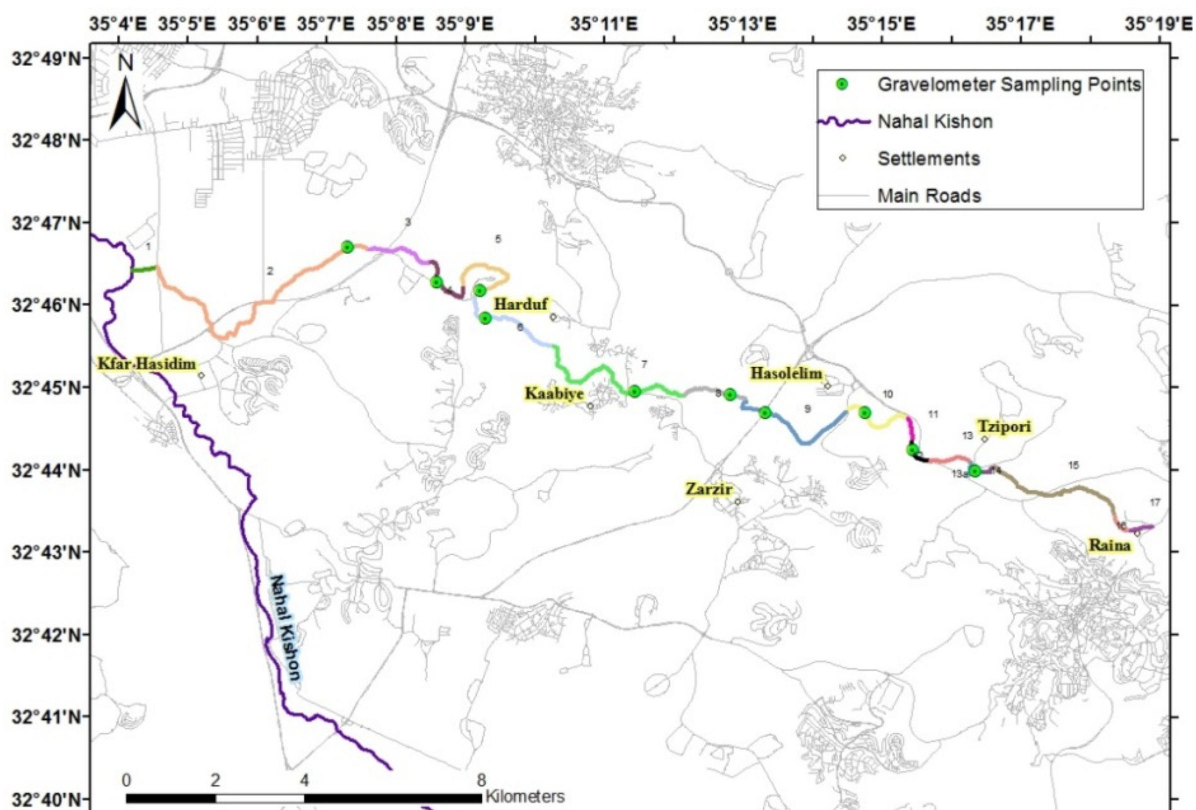



Fig. 9: Gravelometer sampling locations

**F11: Presence of in-channel large wood**

Agricultural activities have been ongoing for many generations in this watershed and there is insufficient evidence to predict accurate historical conditions. There are only isolated clusters of woody vegetation visible in the earliest aerial photographs, 1945. While some stretches of the stream include clusters of woody riparian vegetation today, dominated by figs and willows, in general the vegetation along this stream corridor is non-native and herbaceous. We therefore cautiously assign this stream as class A, having a natural absence of tree vegetation. We identified a very limited presence of large wood along the reach, including trees, trunks, branches, root wads having a length > 1 m and diameter > 10 cm. This material has several effects on geomorphic-hydraulic processes, and has various implications for ecological processes (habitat diversity, input of organic matter, etc.). Small quantities of wood branches were found trapped in the entrance to culverts during the rainy season, for example at the bridge by Kaabiye (S7, a see photo X). While these are not large wood, it may contribute to additional flood hazard. A reach, or a portion of it, is evaluated as altered when the presence of wood is extremely limited or completely absent (approximately < 5 elements every 100 m of channel length). Purposes of this assessment we assume the absence of wood as a natural condition and scored all segments with zero.

**F12 and F13: Vegetation in the fluvial corridor**

Naturally functioning riparian vegetation, i.e. the expected woody and shrub vegetation typically with a patchy, mixed-age structure, and freely interacting with fluvial processes (erosion, sedimentation, flooding). The vegetation assessed by the indicator *F12* is not limited to the riparian zone immediately adjacent to the riverbanks, but is extended to the overall river corridor. The latter includes the area extending from the channel to the hillslopes (or the old terraces), theoretically including the entire floodplain, and that is functional to the normal geomorphic processes (flow resistance, bank stabilization, wood recruitment, sediment trapping, etc.). Only the geomorphic functioning of the vegetation is considered, so species identification is not required. The width of functional vegetation in the fluvial corridor and linear extension along the banks are the main aspects taken in consideration since these factors are the primary determinants of their level of interaction with the morphological processes of erosion, sedimentation and flooding.

**F12: Width of functional vegetation**

This indicator assesses the average width (or areal extension) of functional riparian vegetation in the fluvial corridor directly connected with the channel. The vast majority of the vegetation in the riparian corridor is limited to a narrow strip adjacent to the stream, generally consisting of ruderal opportunistic species and/or nutrient loving herbaceous species. Some sections have a mixed willow habitat with a higher ecological value.

In the case of partly confined and unconfined channels, the width of functional vegetation is evaluated as a function of channel width. For partly confined - unconfined channels, connected functional vegetation with a total width (sum of the two sides) of at least nW, where W is the channel width, n = 2 for single-thread channels. The functional width includes either woody or shrub species, with a significant presence of the former (> 33% of the width occupied by woody vegetation). *Class A*: the vegetation corridor is sufficiently wide, having a width > *nW* (*W*: mean channel width); *Class B*: the vegetation corridor has a medium width, being included between 0.5*W* and *nW*; *Class C*: the vegetation corridor is extremely narrow, having a width ≤ *0.5W*.

Fig. 10: Vegetation sampling

During the June, 2017 survey, observations were recorded regarding the functional vegetation width. Riparian vegetation is dominated in most areas by non-native herbaceous ruderal species, present in very limited strips less than 10 m between agricultural fields and the stream. On May 13, 2018 a detailed vegetation sampling efforts was conducted in six representative reaches along the stream.

The riparian vegetation was sampled and analyzed by considering represented sampling sites in each segment along the stream. Vegetation was sampled in mid-May at the peak of flowering of the riparian plant species. These sites correspond to similar sample sites where water quality and soil sediments were investigated.

At each sample site, the river bank was divided into right and left side of the stream. Within each side three vegetation belts were recognized based on proximity to the water and position of the vegetation roots on flooded or dry soil. Three perpendicular transects crossed the stream at each site. The length of each transect was determined by the width of the water stream and that of the vegetation belts (Fig 28).

The three typical vegetation belts along each transect were determined as follows: 1) Water vegetation *Obligate Wetland* – plants (aquatic) grow in water and are either emergent, submergent, or floating (standing on the stream flow); 2) Hydrophytic vegetation (*Facultative Wetland* ) – plants which have adapted to growing in the low-oxygen (anaerobic) conditions associated with prolonged soil water saturation or temporal flooding conditions; and 3) Hygrophytic vegetation, plants adapted to the conditions of abundant soil moisture but with roots on unflooded soil and above ground on air.

Seven different representative sites were sampled along the Zippori stream characterizing all range of riparian vegetation along the Zippori stream. At each site, three transects perpendicular to stream crossed each vegetation belt.

Vegetation cover at the species and plant functional groups level was monitored along each transect. Species composition and species diversity at each transect was considered. The vegetation was classified into five plant functional groups according to life cycle and taxonomy as follow: annual grasses, annual legumes, annual forbs (includes crucifers, composites, umbelifers and other annual species), perennial grasses, perennial forbs and phanaerophytes (shrubs and trees).

The "species linkage to water" used as an indicator for disturbance was categorized as following: *Obligate wetland* (almost always occurs in wetlands, > 99%) under natural conditions; *Facultative wetland* (usually occurs in wetlands 67% – 99%, but occasionally found in non-wetlands; *Facultative upland* (usually occur in non-wetlands 67% – 99%, but occasionally found in wetlands); *Obligate upland* (Occur almost always > 99%, in non-wetlands under natural conditions).

A synanthropic (human associated species) index was considered as a measurement of disturbance. It was categorized as follow: 1) Obligate natural; 2) Mostly natural; 3) Equal natural/synanthropic; 4) Mostly synanthropic; 5) Obligate synanthropic.

Statistical analyses were done to estimate difference among sites using different vegetation indexes. Similarly, statistical analyses were carried to study species diversity indexes among sites. Contingency analysis was carried out to compare the relationship between plant species “water affinity” index and their respective synanthropic index.

**Vegetation Sampling Results:**

Along the whole stream sampled, a quite narrow vegetation cover was noted. Riparian vegetation cover ranged from 9.2 m at the widest site (S13) to 2.6 m at its narrowest site (S10). Mean vegetation length along the whole stream was 6.2 m.

River water length along the stream was similar as no significant differences between sites was noted. Mean water length along the river was 3.9 m, with a widest length of 6.2 m and a narrowest of 2.7 m.

The hydophytic belt was quite variable along the stream ranging from 5.7 m to 35 cm length. Significant differences between sites were noted as site 6 had the widest hydrophytic belt (5.7 m). This site was significantly different from S 8, 9, 10, 13 & 13a, respectively. Site 13 showed significant differences with site S5 & S6 with the narrowest belt of all sites (only 35 cm). No significant differences between left or right side of the stream.

In the hygrophytic belt most of the vegetation was established along the stream. This belt was also quite variable ranging its length from 6 m to none. Also here significant differences among belts were noted. Site 13a with its widest hygrophytic belt (6 m) was significantly different from sites 5, 6 & 10 with their narrower belts respectively.

Sites 5 and 6 show very narrow belts of all classes indicating a strong degradation of the stream bank.

| SITE (Segment) | 5 | 6 | 8 | 9 | 10 | 13 | 13a |
|---|---|---|---|---|---|---|---|
| **Veg. Width (cm)** | 506.7 | 678.3 | 538.3 | 523.3 | 201.7 | 420.0 | 796.7 |
| **Number of Species** | 3.0 | 4.5 | 3.2 | 3.5 | 2.7 | 2.0 | 5.2 |
| **Shannon Diversity Index** | 0.6 | 1.2 | 0.7 | 0.8 | 0.6 | 0.3 | 1.1 |
| **Evenness** | 0.6 | 0.8 | 0.8 | 0.7 | 0.8 | 0.7 | 0.6 |

Table 5: Vegetation belt with and species diversity indexes along the different study sites

Among all plant functional groups considered no significant differences between sites was observed. Plant functional groups were represented by annual grasses (9%), annual legumes (9%), annual forbs (includes crucifers, composites, umbelifers and other annual species - 27%), perennial grasses (9%), perennial forbs (37%) and phanaerophytes (shrubs and trees – 9%).

Additionally, equal representation was noted between two sides of the stream bank. Phanaerophytes was the dominant plant functional group, being represented by *Rubus sanctus* shrubs and *Salix acmophylla* trees with 32% and 6% mean plant cover, respectively, along the stream. Perennial grasses composed the second most common plant functional group with the presence of *Cyanodon dactylon* with almost 22% along the whole stream. From the remaining 55 species identified their relative plant cover was quite small ranging from 3% to single individual presence.

Within the 58 identified species in all transects, only 3 are alien (introduced) species (*Datura ferox*, *Ricinus communis*, *Xanthium italicum*). Additional alien species were recognized along the Tzipori stream out of the transects (e.g. *Erigeron* spp., *Melia azedarach*, *Xanthium strumarium*, *Paspalum distichum*).
Distribution due to the "linkage to water" groups showed a 48% of the high linkage group (Obligate wetland - 19 spp., Facultative wetland – 9 spp.), 21% of Facultative upland and 31% of Obligate upland, The remaining group, which totally doesn't occur in wetlands under natural conditions, was found here probably as a result of disturbance.

The results showed relative narrow vegetation belts, with very low number of species richness and species diversity. Significant differences in species diversity were noted between site 13 (lowest value, Table 5) versus sites 6 and 13a (highest species diversity indexes). The high evenness values shown indicated high dominance of few species with no significant differences among sites (Table 5).

The synanthropic classification of all species showed that 24% of the vegetation along the stream belong to the obligate natural category, 24% were mostly natural; 19% were equal natural/synanthropic; 21% were mostly synanthropic and 12% were obligate synanthropic. It was noted that 76% of the vegetation had a linked to human disturbed habitats.

The contingency analysis showed a positive significant correlation (Pearson analysis 64.47; *P Value* <0.0001) between disturbance and synanthropic species. Species from dry habitats were also present at wet sites. All species of the obligate synanthropic category are also nitrophylic species (species dominant in highly fertilized soils) and mostly found at S 5 and S6 (lower stream part).

A rare and endangered species, *Vicia galeata*, was found at site S10. This species is a narrow world distribution range and its conservation should be considered.

**Discussion:**

The results of the vegetation sampling showed that the whole Tzipori stream is highly degraded. The vegetation along the stream is highly impacted by human activities that become evident by the lack of clear typical river bank vegetation belts and very narrow banks. The width of the vegetation belts is very narrow with no functional capabilities of regulating water flow along the stream. The lack of significant differences between plant functional groups between sites is a clear reflection of the degraded status of the stream. The dominance of *Rubus sanctus* shrubs along important parts of the stream, makes the river bank quite inaccessible to other species to get established with the consequence creation of a monotypic landscape with very low species diversity. Additionally, the relative low number of species found along the stream (58 species), also indicate a high dominance of few species that prevent the establishment of a richer flora. This also evident by the relative high evenness values found along the stream and the lack of any significant difference among them.

The high synanthropic vegetation values obtained are a clear indication of human intervention along the stream with the nutrient additions as pollutants to the water. Results from a survey of exotic species (Dufour-Dror (2017) support these findings.

**F13: Linear extension of functional vegetation**

This indicator evaluates the longitudinal continuity of functional riparian vegetation along the banks, expressed as a percentage of the length covered by riparian vegetation against the total length of the reach (both banks), and for any areal extension. The Tzipori stream it is believed to historically have a natural absence of woody riparian vegetation, in general averaging less than 10% of the stream corridor. This is also true today. There is a lack of longitudinal connectivity of functional vegetation, with many areas having no functional riparian vegetation.

## *Artificiality*

The most upstream segments (S16 and S17) have been strongly altered, with a high degree of artificiality, including full stream bed revetment and stream burial. At the most downstream segments (S2), a diversion dam was constructed to enable stream water diversion and extraction for agricultural irrigation. In addition, we collected the locations of other structures within the stream corridor, for example culverts, bridges, artificial levies, bank armoring and bank stabilization structures. Fig. 29 presents a map of the summary of the artificial elements. Each of these is discussed in the relevant sections below.

The first four indicators of artificiality consider the alteration of the driving variables for channel morphology, which are water discharges and sediment transport, separating the alterations of the same variables occurring upstream from those occurring within the reach. A distinction is made to evaluate impacts upstream, which affect downstream reaches, versus those that affect the reach itself. Indicators *A1* and *A2* are the only two concerned with the conditions existing upstream (catchment scale) of the analyzed reach, while the next two indicators *A3* and *A4* concern the alterations of the same characteristics, but within the reach. In evaluating a structure (e.g. a dam) located at the boundary between two reaches (e.g. between an upstream reach *n1* and a downstream reach *n2*), conventionally the structure is assigned to the upstream reach, however the effects of the structure are considered as alterations both in the reach (indicators *A3* and *A4*) and as upstream alterations (indicators *A1* and *A2*) for the downstream reach.

**A1: Upstream alteration of flows**

This indicator evaluates the overall alterations of flows occurring upstream of the reach.

The indicator is split into two sub-indicators as follows: A1M and AIH.

A1M: Upstream alteration of flows with potentially relevant effects on channel

Morphology (i.e. may cause changes of the bankfull channel size because of morphological adjustments). This indicator evaluates possible alterations of flow conditions that may have a significant effect on morphological processes, emphasizing the reduction or increase of channel-forming discharges, affected by interventions at the catchment scale, such as dams, impoundment (i.e. water retention by weirs), discharge diversions or water abstractions, spillways, retention basins, etc.

Three broad classes of discharge are considered in this parameter: (1) channel forming discharges (return interval from 1.5 to 10 years); (2) discharges with a return interval > 10 years; (3) flows below channel-forming discharges. Discharges with return interval (*RI*) >10 years have relevant morphological and hydraulic effects, although their effect on channel morphology is lower than the channel-forming discharge, because of their lower frequency. Flows below channel-forming discharge (return interval *RI* < 1.5 years) includes the range of discharge which varies from low-flow conditions to small or moderate flow events below channel-forming flows. Low flows below threshold conditions of erosion and sediment transport are considered to have negligible effects on channel morphology. There is only one IHS station monitoring stream discharge, therefore data needed for estimating the discharges with given return intervals, and information to evaluate the effects of interventions on such discharges, is limited.

In general the perennial stream is in its natural state with minimal management, until the downstream crossing of Road 70 (near the end of segment 3). Extensive construction activities at the road 70 interchange has been ongoing throughout the course of this project, likely contributing sediment due to exposed soil stockpiles adjacent to the stream used for the construction effort. A series of eight culverts have been installed during this year. Within a kilometer downstream of the road 70 crossing, the stream channel becomes highly modified by anthropogenic activities, due to the construction of a diversion dam at the downstream end of S3. This is the only structural intervention on the Tzipori stream channel, altering longitudinal continuity of both water and sediment water discharge. This structure has a significant effect (induced changes ≤ 10%) on channel-forming discharges (return interval RI from 1.5 to 10 years) and also on discharges with RI > 10 years. There are no locations on the stream where streamflow is released back into the stream to increase low flows during the dry season.

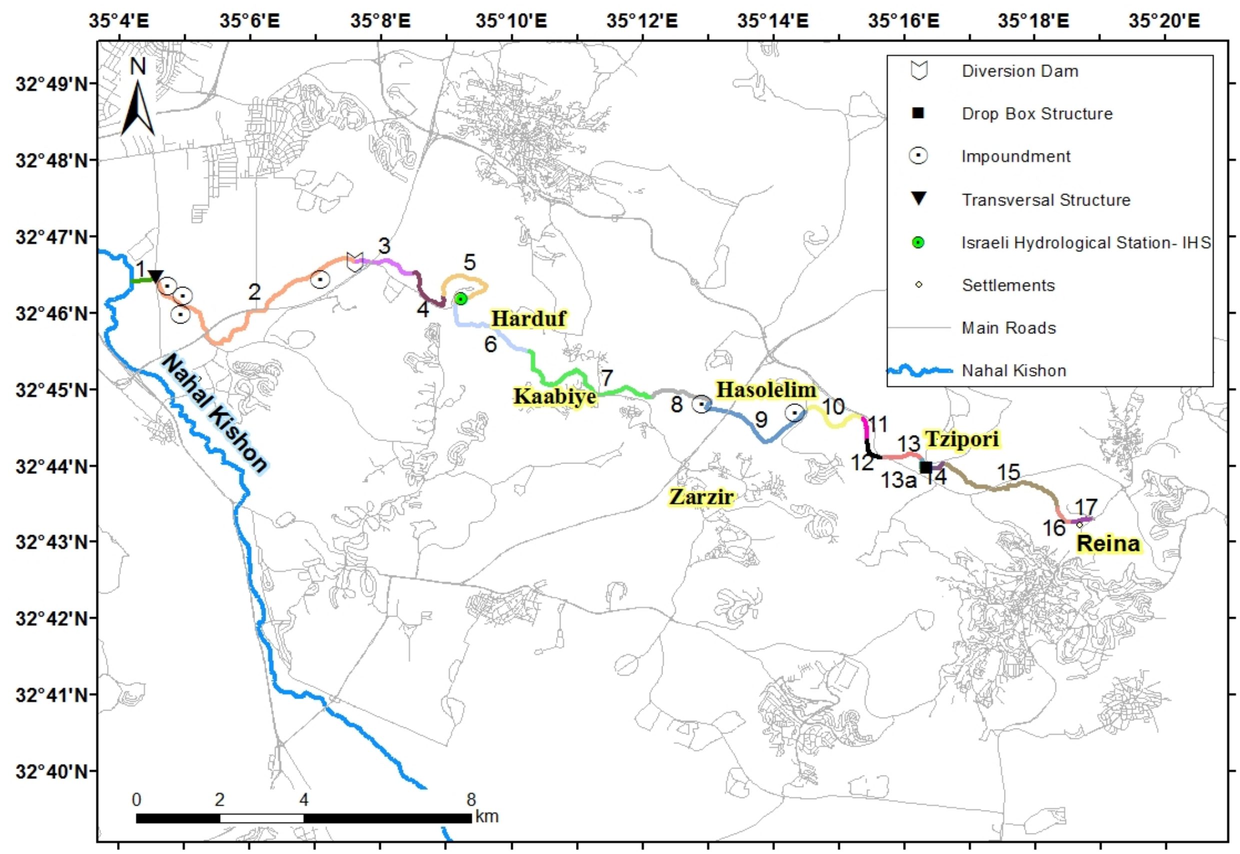



Fig. 11: Alteration of flows

The diversion dam operates based on an elevation threshold, designed to enable base flow to pass uninterrupted, but allow stream water extraction to occur during the rainy season, once the stream water elevation reaches a threshold level. The dam was constructed to divert floodwaters to water reservoirs for the purpose of agricultural irrigation. The diversion dam structure is assigned to the upstream reach (S3), but the effect of the structure on longitudinal continuity is evaluated in the downstream reach.

A series of reservoirs were constructed as a cooperative project managed by three Kibbutzim in Zebulun Valley. These water reservoirs (S2) are operated by the Kibbutzim for water storage and irrigation ponds. , There are three large pools, with capacities at 500,000 $m^3$, 750,000 $m^3$, and

860,000 $m^3$ (Assaf Koshet, Kibbutz Maccabi, pers. comm). The largest reservoir was constructed most recently, in 2009, at a depth of 9 m. Waters from this pool are specifically used to irrigate new avocado fields. Two additional small reservoirs have a combined capacity of 550,000 $m^3$. Further downstream, 70 dunams of previously operated as fishponds were expanded to function as a retention pond that directly extracts base flow into a holding pond, where natural settling occurs, after which water is pumped directly to irrigate fields. This water supports the production of corn, cotton, watermelon, and new avocado fields.

An agreement was made with the water authority to allow these kibbutzes to withdraw water for agricultural irrigation. Officially, extraction of stream water was intended to be limited to winter floodwaters, as reflected in the design of the diversion dam. However as the floodwaters have high suspended sediments concentrations, these waters are therefore less desirable to the Kibbutzim as agricultural irrigation. Their practice is to extract their full allocated amount in the first storms, since the amount of rainfall each year is uncertain (Assaf Koshet, Kibbutz Maccabi, pers. comm) Rather than flushing through the stream, this water is diverted and retained. In addition, as explained above through the process of the holding pond, base flow is extracted all year. Water allocation rights are not tied to annual rainfall or storm discharge. An estimated extraction volume of approximately 2.5 million $m^3$ per year is currently removed from the stream. Technically, the agreement between RATAG, the Water Authority and the kibbutzim requires that the operators leave 100 $m^3$/h base flow during the summer, although it is not clear if this limitation is occurring. There are no meters installed on the stream or by the diversion dam and no monitoring is occurring. Based on observations, it appears that the kibbutzim are extracting base flow, both in the winter and in the summer (Ratner, KRN). Further downstream, Kvar Hassidim and Yagur also have stream water extraction rights, which defines in their water extraction agreement that they are required to leave 30 $m^3$/h in the stream. No supervision or monitoring of water extraction volumes occurs and there are no fees collected for the utilization of these water resources.

The adverse impact on streamflow has led to the development of a new water plan. This plan was developed with cooperating agencies, including The Water Authority, the Nature and Parks Authority, the Ministry of Environmental Protection, the Kishon Drainage Authority and the Ministry of Agriculture, where it was decided to allocate additional water to the stream and release all the spring water to support the stream ecosystem. However, the process of obtaining water quotas from outside sources to irrigate the agricultural plots along the river, has not yet been completed and no alternative sources have been defined. As no alternative source has been identified to support the agriculture, this plan has not yet been implemented.

There are several small reservoirs, impoundments, and sediment retention basins that were constructed further upstream, primarily to capture floodwaters for agricultural irrigation. Kibbutz Solelim constructed one reservoir by the confluence of Yiftachel in the 1970s, but it was abandoned and is not currently managed (Photo X). It functions today to early contain flood waters. This feature is now included in long-term restoration plans as a perennial pond (T. Ratner, personal communication). A second small reservoir located by Solelim (Photo X) is also used for storing water for agricultural irrigation.

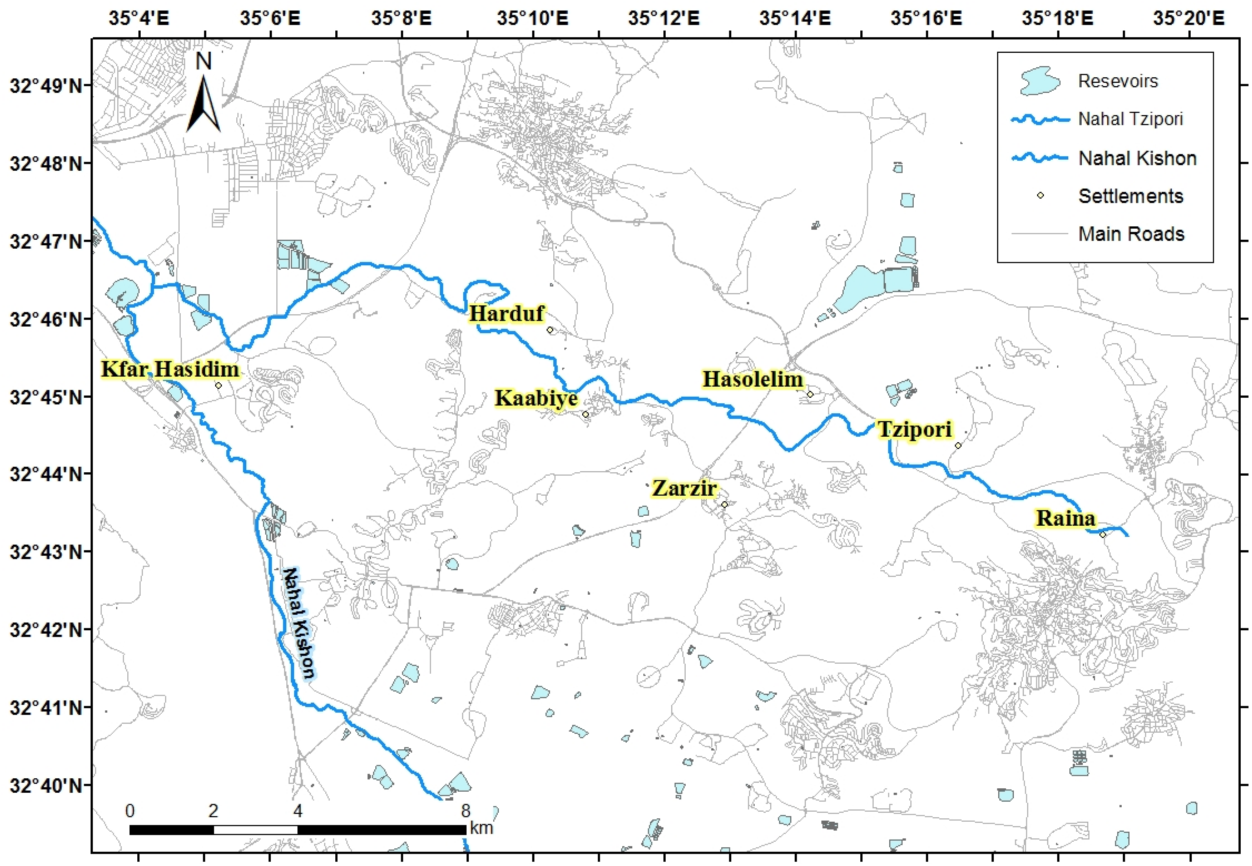



Fig. 30: Reservoirs

Fig. 31: Reservoir by Solelim

Fig. 32: Abandoned reservoir at confluence with Yiftachel

The longitudinal discontinuity of water flow between the source springs at Einot Tzipori and the stream channel due to the road to the entrance of Moshav Tzipori. This road also bisects the upstream storm-driven section to the perennial stream, which has resulted in strong incision beginning at the upstream end of segment 13.

The parameter A1H concerns evident flow alterations, which, although impairing some biological processes, may have small effects on channel morphology, i.e. may cause changes of some of the geomorphic units, but not having significant effects on the bankful channel size. Nachal Tzipori does not have existing structures controlling the abstractions for irrigation, beyond the dam diversion discussed above, and no hydropower stations exist in the watershed.

**A2: Upstream alteration of sediment discharges**

An indirect evaluation of the alterations in sediment transport is obtained based on the existence in the catchment of blocking structures that intercept bedload (dams, check dams, weirs), accounting for their drainage area in relation to the reach drainage area. The indicator does not consider hillslope interventions (e.g. reforestation, landslide stabilisation, etc.). Major blocking structures, such as dams, are evaluated here only for their effect on sediment trapping (impacts on flow regime are considered in *A1*). Interception of the bedload and river fragmentation may have significant effects on the reach's morphological dynamics. This may cause a reduction of depositional features (e.g. bars), inducing erosion processes and eventually promoting unstable conditions.

There is an absence of structures for the interception of sediment fluxes on the stream, with the exception of the diversion dam discussed above at the downstream end of S3. This structure intercepts sediment fluxes during storm events. At the downstream end of S17, the stream is buried through a tunnel underground. This alteration results in the interception of sediment fluxes, although the underground section discharges into its natural stream channel. Since there is total bedload interception at this location, and it is unclear how much sediment is discharged at the end of the segment, the scoring reflects a B-1 rating. A dropbox culvert structure is located at the downstream end of section 14 likely causes a slight alteration of sediment discharge, but is less than 5% of the reach, so is considered as a negligible impact on downstream sediment flux.

**A3: Alteration of flows in the reach**

This is evaluated in the same way as *A1*, but in this case it refers to interventions along the reach. Interventions include spillways, flow diversions or water abstractions, and retention basins. Dams are excluded because they are necessarily identified with the limit of reach, therefore their effects in terms of alteration of discharge are necessarily evaluated in the reach downstream.

The diversion dam discussed at the downstream end of S3 has a downstream impact of water flow within the reach. Further, as discussed above, the Kibbutzim extract base flow from S2 directly. In addition to the diversion dam, water withdrawal resulting from management practices inside the reach, not considered relevant for altering channel forming discharges, is accounted for by this indicator. Stream abstractions, defined here as the act of removing water from the stream, is an important issue in the system. While the existing extractions may not significantly alter channel forming discharges, they do significantly affect flow in the reach, especially during the dry season. The volume of flow in the stream Tzipori is largely affected by the utilization of water for irrigating agricultural plots, where water extraction occurs both legally and illegally.

In addition to the series of reservoirs discussed above in S2, small private farmers are illegally extracting water for their own, private agricultural activities. Illegal stream water extraction is occurring commonly through pumps connected to extraction hoses and occasionally by filling watering trucks. We recorded locations where stream water extraction was visible during the June 2017 survey (see photo). Pumping from the stream via hoses was observed in 22 locations along the stream during the June survey, as shown in Fig 34. The highest concentration of these illegal extraction hoses was observed in the section of the stream northeast of Ka'abiya (S6) and Ras Ali (S5).

Fig. 33: Illegal water extraction from stream

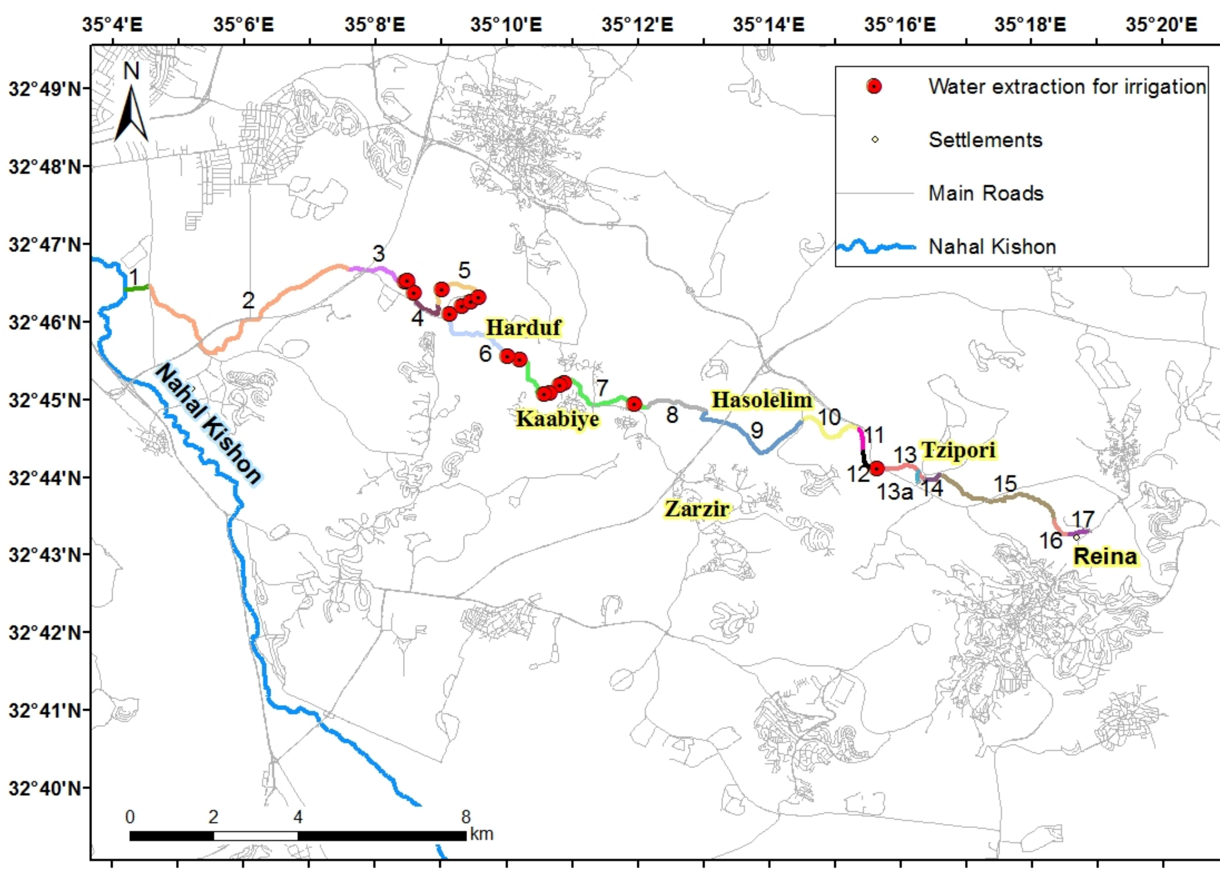



Fig. 34: Illegal Stream Water Extraction locations

The only existing hydrologic monitoring location where stream discharge is measured is at the IHS station at Ras Ali. There are no measurements downstream to estimate the impacts of streamflow extraction by either private farmers or via the diversion dam which supports the impoundment ponds. Therefore, sufficient data to apply specific indices of hydrological regime alteration are not available. However, as the stream water extraction management practices have obvious and relevant effects on flow conditions, we adopt the simplified procedure**,** based on a criterion of presence/absence of specific types of pressure causing obvious, relevant low flow alterations.

To evaluate the hydrologic longitudinal continuity, the presence and depth of baseflow was measured during the June 2017 survey. Baseflow was observed in the entire channel at that time, from Einot Tzipori until the confluence of the Kishon River, maintaining hydrologic connectivity throughout the channel. The depth of standing water in the stream channel ranged from 8 to 50 cm, with an average depth of 19 cm. The location where 50 cm water depth was measured was in an artificial pool, created for the purpose of stream water extraction for private land irrigation. The construction of pools by placing small boulders and rocks in the stream channel was observed frequently along the stream channel.

A second baseflow survey was conducted September 26, 2017. At that time, a section of 2.2 km was measured within the stream where hydrologic connectivity was discontinuous, and the streambed was dry (Fig 35). No isolated pools were found in this section.

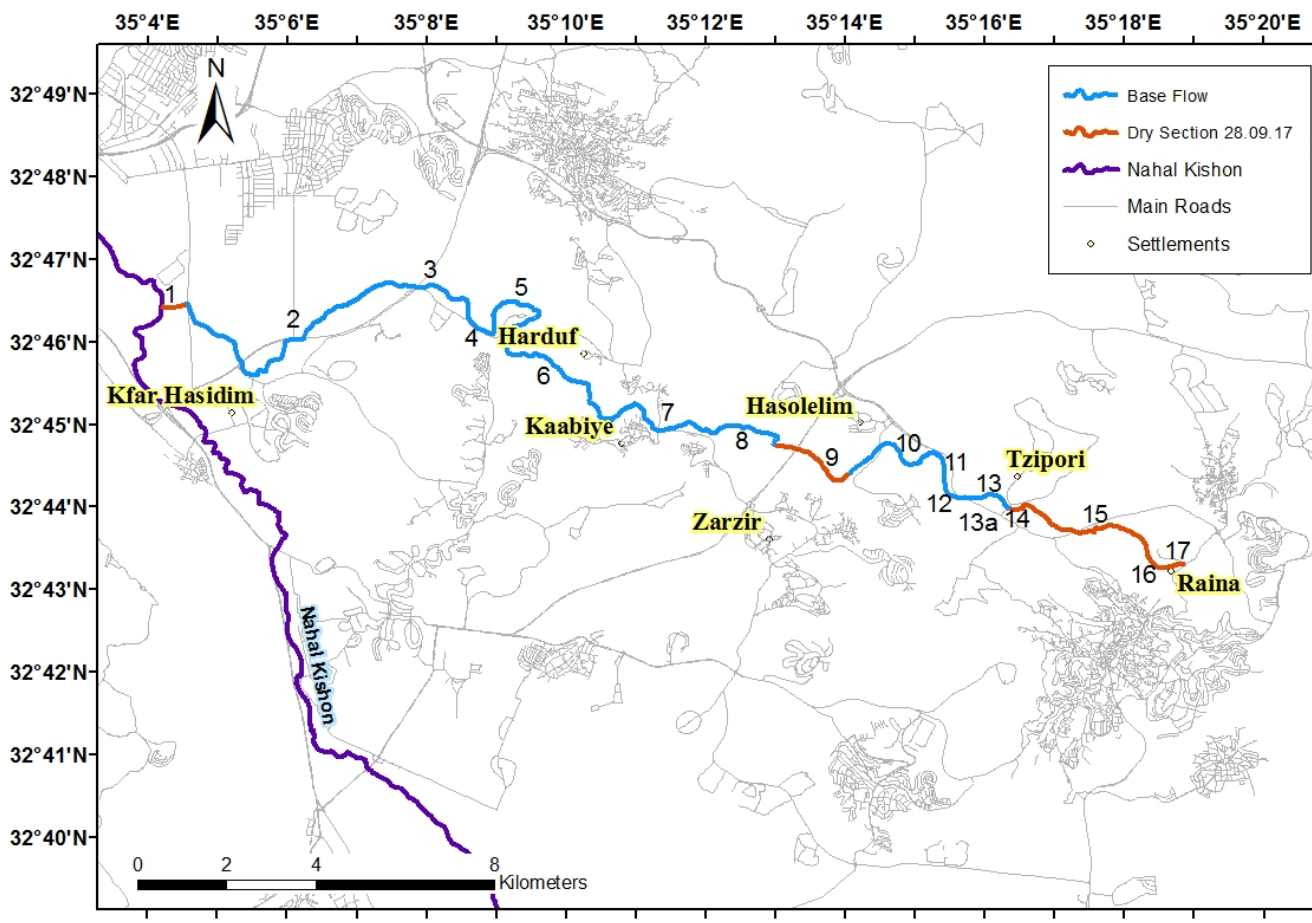



Fig. 12: Hydraulic connectivity (dry segment 26/09/17)

Fig. 14: Winter flows

Fig. 13: Summer flows

**A4: Alteration of sediment discharge in the reach**

This indicator is based on the typology and frequency of blocking structures intercepting bedload along the reach (check dams, weirs, diversion structures, etc.) or other structures causing its alteration (e.g. retention basins, dam downstream, bed consolidation) by producing a partial sediment trapping or bedload reduction induced by a decrease in bed slope. There is an absence of structures for the interception of sediment fluxes, with the exception of the diversion dam discussed above. There are no significance changes in bed slope steepness along the stream channel resulting from intervention structures.

**A5: Crossing structures**

This accounts for the presence and frequency of crossing structures, including bridges, fords, and culverts, which may reduce or intercept sediment and wood transport. Only bridges which interfere with the fluvial corridor are considered, i.e. those bridges with some artificial element (piers or abutments) in the channel or adjacent plain, or which potentially interfere with water fluxes although only during exceptional flood events. The protocol describes fords, known in Israel as Irish bridges, as being counted only when it is composed of fixed crossing structures (i.e. dirt roads are not considered), because of their partial influence on bedload (coarse sediment). Cases where streams cross urban areas underground are considered as culverts. These tunnel culverts have effects on channel cross-sections and lateral continuity similar to a crossing structure, while the additional alterations associated to a culvert (fixed banks, bed revetments) are evaluated separately through the indicators *A6* and *A9*.

A total of 57 crossings and culverts were identified during the June survey. Remote-sensing analysis of aerial photographs was also conducted to confirm the final assessment. .Fig. 38 shows the locations of identified features, which enabled assessment of the scoring criteria of # crossings/ 1000 m. Table 7 presents all the scoring results.  At the downstream end of S17 the stream travels underground for 450 m until the downstream end of S16, where it daylights into a natural landscape (tunnel culvert). As the entire segment is the tunnel culvert, S17 was assigned the highest score for crossing features.  The crossing by the concrete trench in S15 also alters flows and continuity. This road separates the sheep and goat pen from the cow pen, both in sheds on the stream.  The dropbox culvert downstream end of S14, discussed earlier alters sediment bedload continuity. There is a historic Turkish bridge located in S13 (Photo), which functions as a hydraulic constraint during winter storms. This can be used as a positive future if it is included in the restoration plans currently being prepared in partial mitigation for the infrastructure development in this segment of the stream (see recommendation section at the end of this report). There are several culverts in S 12 that interfere with winter flows. The set of culverts at the bridge in Kaabiye (photo) alters both wood flux and storm water flows. We calculated the number of crossings per 1000m for each segment, in accordance with scoring criteria.

While the presence of an Irish bridge does not alter flow continuity or intercept sediment or wood transport, it does provide opportunities for vehicles to enter and cross the stream. The bed of an Irish bridge is sometimes paved with concrete, sometimes with stone, and sometimes consists of natural stream bed sediment or dirt road, which may have influence on bedload (coarse sediment). There are many locations where Irish bridges cross the stream. The analysis of the culverts was the basis of the scoring for this indicator. Water quality is not evaluated as a metric in this analysis, but it is important to note that the risk of introducing potential contaminants from vehicles, in addition to mobilizing bed sediment and causing erosion of these materials, likely has an influential role in the system. Irish bridges are a common feature in Israeli streams used both by recreational vehicles and by farmers. Representative photos of culverts and crossings shown below (Fig.39, 40).

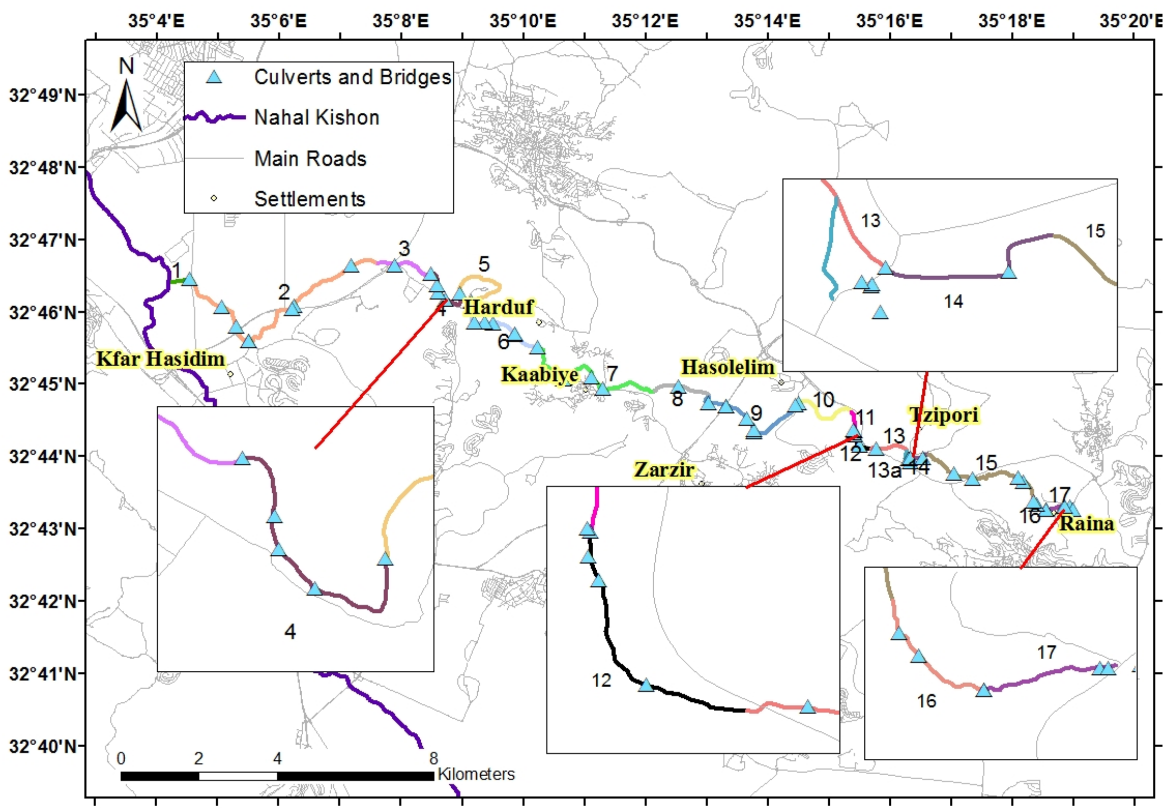



Fig. 38: Crossing structures locations

Fig. 15: Culvert in Sephoria, Segment 12

Fig. 40: Turkish Bridge, Segment 13

**A6: Bank protections**

Bank protections are measures that artificially restrict the streambank and alter the supply of sediment and wood from lateral channel mobility, including both hard bank reinforcement (walls, rip-raps gabions, groynes), and soft reinforcement (bioengineering). In general, Tzipori stream banks are in a natural condition. Specific localized areas, such as in S16, the entire segment is a tunnel culvert, therefore scored as having the presence of artificial bank protection for the total length of the segment. There are a few locations where the stream is channelized in concrete trenches. In S15 there is an 80 m section where the stream is channelized in a concrete trench that goes between animal pens, however as this trench comprises less than 33% of the of the segment, it still receives the lowest score, limited to a localized presence. The rest of this segment is more or less a natural stream channel. There are a series of artificial bank protective measures on the stream in S12 (photo). There are no other significant segments with artificial bank protections. The elements of artificiality in each segment are presented on Fig. 43.

Fig. 41: Culvert to channel (S12) with artificial bank

Fig. 42: S15 concrete walls by animal pens

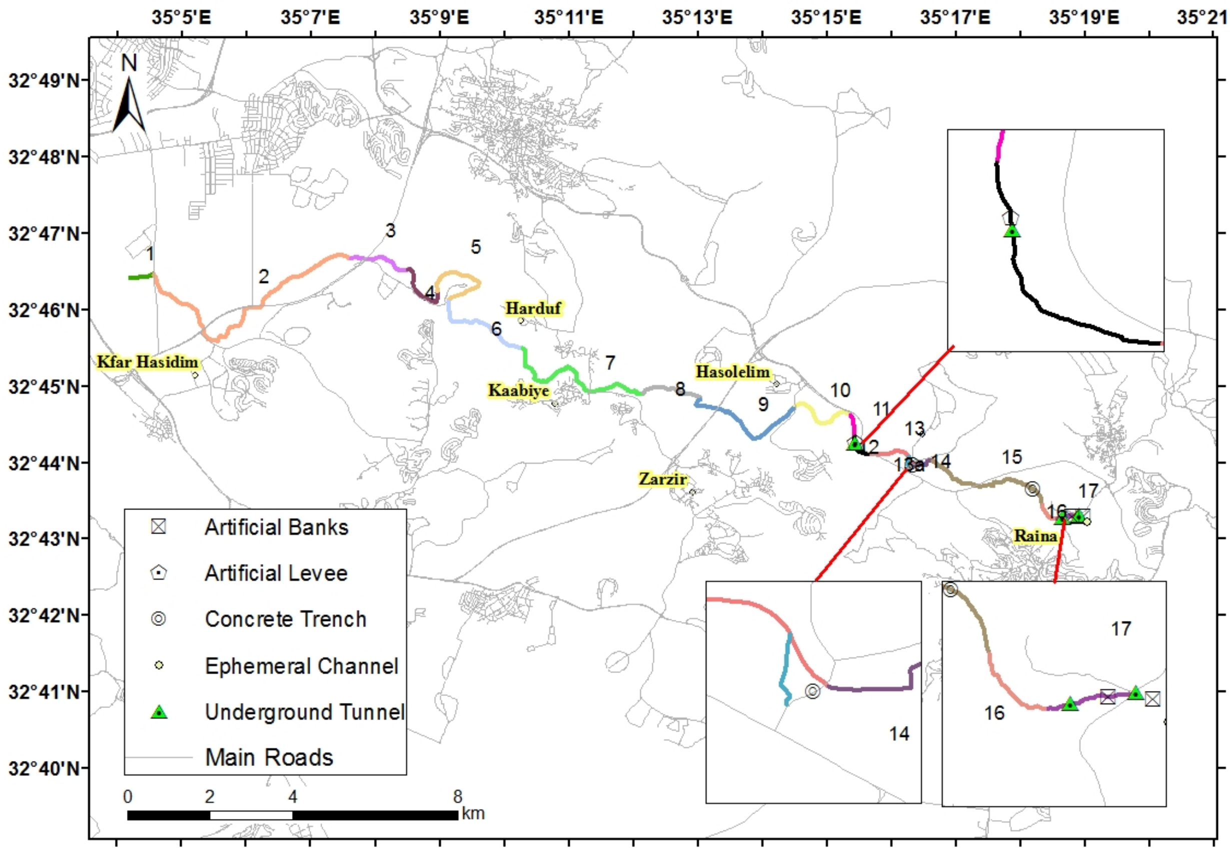



Fig. 43: Map of Artificial Elements

**A7: Artificial levees**

This indicator accounts for the presence and position of artificial levees (or embankments). They have an effect on the lateral hydrological continuity impeding the natural flooding of areas adjacent to the river. Scoring for the assessment is based on their longitudinal continuity and distance from the channel. Bank protections (evaluated in *A6*) with a height greater than the floodplain level are also evaluated by this indicator, as well as all those artificial infrastructures (e.g. roads) which also functions as a levee. Traditional agriculture has been occurring in segments 11 and 12 for generations. The desire to expand agricultural fields in this area resulted in altering the location of the stream bed (see A8). Presently stream is located directly adjacent to the hillside, as possible, maintained by artificial levees consisting of soil berms.

**A8: Artificial changes of the river course**

This indicator accounts for artificial past changes in the river course (recent or in historical periods). Only certain and relevant artificial changes were considered that have altered the natural channel morphology and modified natural geomorphological and hydraulic processes, with resulting loss of physical habitats.

Changes in the stream channel location were determined by overlaying the channel delineation produced during this project with the 1945 Geo rectified channel delineation (see discussion F8 on fluvial landforms). Results of comparative analysis are shown in Table 6. Both due to resolution limitations and the small width of Mediterranean streams, it was not possible to accurately estimate channel width or compare this metric. However, we overlaid the GIS layer of the delineated 1945 stream corridor, and compared it to the existing stream channel, measured both in the field and with RTK measurements, producing a precise delineation. We then use GIS analysis to measure differences in the stream channel. The limit of accurate detection is estimated at 15 m, which is therefore used as a threshold, where all measurements are presented subtracting this assumed error.  Due to the size of the stream in this climate we assigned scoring of parents changes of river course not limited to meander cutoffs In order to quantify the extent of modifications to the stream channel (Fig. 44), based on the stream segmentation map. The analysis of the change in stream channel location showed the most significant changes occurred in S2 (Table 6).

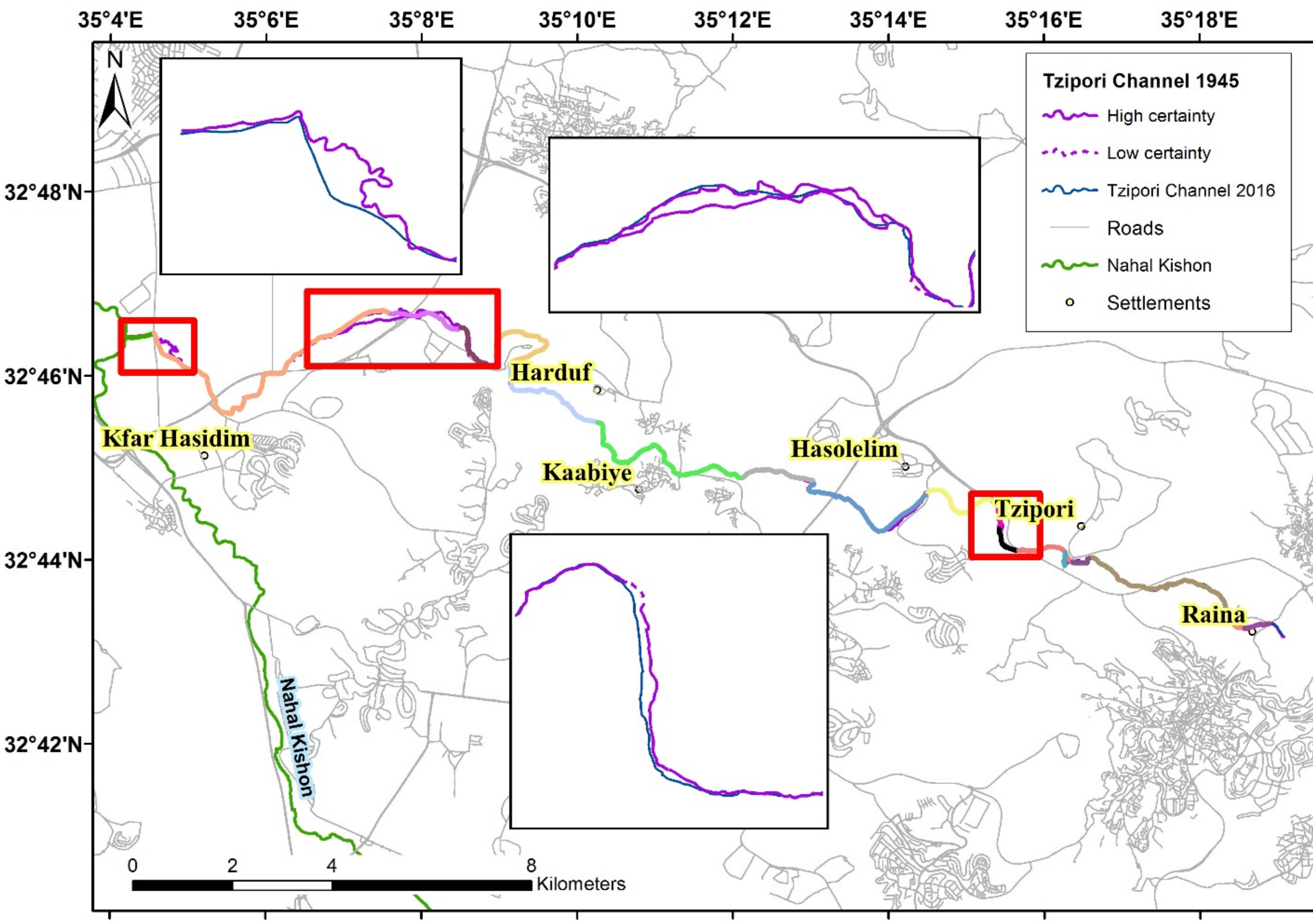



Fig. 44: Comparative analysis of historic stream channel location (1945) and (2017)

Table 6: Comparative analysis of Historical aerial photos 1945 and 2016

| Section | Maximal visible Shift (m) | Straighten meanders | Overall change | Remarks |
|---|---|---|---|---|
| 1 | 10 | No | 1 | |
| 2 | 300 | Yes | 3 | Extensive straightening; Possible braiding |
| 3 | 100 | Yes | 3 | |
| 4 | 30 | No | 1 | Possible anabranching Island |
| 5 | 10 | No | 1 | |
| 6 | 10 | No | 1 | |
| 7 | 20 | No | 1 | |
| 8 | 40 | No | 1 | |
| 9 | 70 | Yes | 1 | |
| 10 | 20 | No | 2 | Channel shift, pushed along the hillside |
| 11 | 50 | No | 2 | Channel shift, pushed along the hillside |
| 12 | 50 | No | 1 | Channel shift |
| 13 | ? | ? | 1 | Tzipori springs, channel uncertain |
| 14 | ? | Yes | 2 | Tzipori springs, channel uncertain |
| 15 | 20 | No | 1 | |
| 16 | 30 | Yes | 1 | |
| 17 | - | No | 3 | |

Notes: Classification

0 - No change

1 - Slight change

2 - Moderate change

3 - Major change

Detecable shift threshold is 15m, (assumed error) all changes are measured as reported plus 15m

**A9: Other bed stabilization structures**

This indicator accounts for other crossing structures which, in general, cause increases in the rigidity of the bed, paving or reinforcement, but without significantly altering the sediment transport. These include bed sills and ramps built to reduce bed incision, often in association with bridges, and revetments of the channel bed, both impermeable and permeable. Widespread presence of Irish bridges, both paved and unpaved, may constitute bed revetments, as they cause alteration in channel morphology in terms of the disappearance of bed sediment and related bed forms (loss of habitats) as well as in terms of an alteration of vertical continuity with groundwater (hyporheic zone). The uppermost segment of the stream has portions consisting of total bed vetment with impermeable systems (segment 16 and 17). Although Irish bridges may be considered permeable revetments, proportionally they do not comprise > 33% of the reach.

Fig. 17: S17 artificial bed revetment

Fig. 16:  S15 artificial bed revetment by animal pens

In segment 15 there is an 80 m segment where the stream is channelized in a concrete trench that goes between animal pens, however as this trench comprises less than 33% of the of the segment, Insert photos of concrete trenches

***A10: Sediment removal***

This indicator evaluates the relative intensity of sediment removal activities, which may induce negative effects on morphological processes and evolution (bed incision) and on the river ecosystem (Rinaldi et al., 2005).  Sediment removal includes either mining activity (excavation of gravel or sand pits for sediment exploitation) and interventions aimed at channel dredging and re-sectioning to reduce flood risk (e.g., channel lowering and widening). The indicator does not account for local sediment removal, such as in the case of maintenance upstream from retention basin/check dams (these effects are already accounted for by indicator *A4*). The KRN is responsible for reducing flood risk. In general there is minimal sediment management of the stream corridor. There is no program targeting sediment removal activities, including dredging, on an annual basis. No known sand mine extraction activities have been conducted on the stream, although in the upper part of the stream.  According to the KRN, dredging or maintenance activities may occur occasionally in limited areas (in the channelized area of Solelim (segment 9) and in Kvar Maccabi avocado plantation (segment 4), to reduce sediment accumulation resulting from soil erosion and for mosquito abatement. However little information is available and there are no records of dredging activities, volumes of sediment removed, or specific locations where dredging has occurred. In general, dredging occurs only if the channel is blocked, which is rare. Dredging does not generally occur along the mainstem of the main channel, until after the interchange at Road 70.  As discussed in the indicator A4, stream water extracted after the diversion dam frequently contains a high concentration of suspended sediments, however due to limited access in the impoundment area, there is no program for removal of accumulated sediments (personal communication, Assaf Koshet). Although this has resulted in reduced reservoir capacity, no active sediment removal is planned. There are no records of sediment removal from any of these basins, either by the KRN or Kibbutzim.

**A11: Wood removal**

Nachal Tzipori does not have a naturally wooded riparian corridor. The stream has supported agricultural activities for many generations. It is not clear if historically the stream had woody species, although Willow is found in isolated segments, and was likely the dominant woody species in the past. Analysis of the historic aerial photos from 1945 showed greater woody riparian vegetation than is seen today however it is unclear how much woody riparian vegetation is natural for this watershed and climate. Intense grazing by sheep, goats, and cows has resulted in denuded vegetation in many sections of the stream. However, there is no active or historic wood removal program on the stream. According to the protocol, this variable is not evaluated above the tree-line and in streams with natural absence of riparian vegetation. As there is no data to confirm whether the absence of woody riparian vegetation is natural, we assume for the purposes of this assessment that if willows dominated the stream, their population was significantly reduced longer than 70 years ago. Therefore for scoring purposes, we assume the absence of removal of woody material at least during the last 20 years in all segments.

A wooded riparian corridor provides many ecological benefits, including lowering the stream water temperature, providing shade and organic inputs into the stream, and creating habitat for aquatic species. Given the importance of this factor, a new project was recently established, in collaboration with Dr. Yaron Hershkivitz, to compare the species composition and macro invertebrate community in areas shaded by woody vegetation (willow stands) versus open areas lacking riparian vegetation or with rural herbaceous species, providing no shading. Results from this study are expected to be published by the end of 2019. Furthermore, due to the expected ecological benefits of wood in the stream, we propose a Willow restoration effort to investigate the potential success of planting Willow posts along the stream (see recommendation section).

**A12: Vegetation management**

Riparian woody vegetation in the fluvial corridor (banks, floodplain, recent terraces) and in the channel (mature and pioneer islands) generally performs several morphological functions, in particular providing wood material (from natural tree death, bank erosion, occasional toppling and breakage, or from hillslope processes in confined channels). Moreover, woody vegetation traps sediment and wood material during floods, contributing to the diversity of the river habitat mosaic. Aquatic vegetation (either submerged or emerged) may also have a significant impact on river hydraulics, and consequently on sediment accumulation and erosion (e.g. Gurnell et al., 2006, Gurnell and Grabowski, 2016). Periodic interventions of vegetation cutting may have various impacts on the morphological and biological natural processes related to riparian vegetation. Vegetation cutting of riparian areas not directly in contact with the channel (but included in the fluvial corridor) has lower morphological and ecological impacts compared to intervention on channel banks. Aquatic vegetation is also frequently removed or partly removed by cutting and/or dredging for safety reasons.

The KRN is responsible for maintaining the stream channel and they do not conduct vegetation removal or herbicide spraying as a general rule. There has been no historic or current vegetation removal or invasive species management program conducted as a maintenance strategy. Agricultural activities have been ongoing for many generations. Land clearing to expand farmland has contributed to extensive degradation of the riparian vegetation. In many areas, agriculture extends to within 10 m of the stream, leaving no native riparian vegetation as a buffer along the stream channel.

Fig. 18: Lack of riparian vegetation due to over grazing and intensive agriculture (S10 left) and (S9 right)

Grazing activity is considered to be part of vegetation cutting, as it prevents vegetation growth, as defined in the protocol. Combined with the effects of agricultural land expansion discussed above, heavy grazing pressure in certain segments has resulted in the overall absence of native riparian vegetation. Grazing pressure is so severe that little vegetation remains anywhere near the channel by the end of the summer. Restoration efforts conducted by KRN to restore native vegetation in isolated areas required installing fenced enclosure to protect the plantings. Although these areas were locked, when the end of the summer arrives with little remaining vegetation for grazing, farmers have been observed cutting locks on these enclosures and allowing their herds to graze inside these protected areas. Even in the spring grazing pressure is very high as shown in the photos below. Occasionally stands of high quality riparian vegetation can be found, particularly isolated sections where willow trees are the dominant species in the riparian corridor. Scoring for this indicator is based on observations with severe denuded riparian vegetation, in combination with the results from the detailed vegetation sampling effort in conducted in eight segments. While there are no specific cutting interventions on riparian vegetation in the last 20 years or aquatic vegetation in the last five years, and there is no specific clearcutting in any reach, the partial or total removal of riparian vegetation by agricultural activities (S10) or intense grazing (S5, S6) is captured in this indicator. It was clear that the riparian vegetation was highly degraded by over grazing (Figure 47).

## Channel Adjustments

This set of indicators aims to assess channel adjustments (planimetric and vertical changes) which have occurred in previous decades. Only channel adjustments related to human impacts are quantified, therefore it is crucial to identify the controlling factors of such adjustments.

Since these indicators are based on a comparison with a historical condition, only adjustments in channel form are considered. We conducted a historic analysis based on aerial photos from 1945, resulting in a delineation of the historic channel.  The 2017 June field sampling effort resulted in an accurate delineation of the existing stream channel. GIS analysis overlaying comparing these two layers enabled estimating calculation changes.


Fig. 19: Channel delineation challenges using 1945 aerial photos

The following three indicators are assessed below to complete the protocol. These were evaluated based on the comparison between the geo rectified 1945 historic photos and 2016 aerial photos, as well as field validation.

### *CA1: Adjustments in channel pattern*

This indicator evaluates the occurrence and intensity of adjustments in channel morphological configuration, i.e. the change in channel pattern (sinuous, meandering, braided, etc.). A change in channel pattern during past decades is generally a symptom of an alteration of some of the processes controlling channel morphology (in particular of the driving variables, i.e. flow regime and sediment transport). Significant changes in channel pattern cause an alteration of river physical habitats related to the different channel morphologies. The protocol specifies that a qualitative observation of the channel pattern in the two aerial photos is sufficient to evaluate whether a significant channel pattern adjustment has occurred.  In addition, since the channel delineation used for the analysis was very precise, as well as geo-rectification of the historic photos, therefore enabling a GIS-based quantification of the channel changes.

Results of this analysis are presented in A8: Artificial changes of the river course. The most upstream (segment 16 and 17) and most downstream (segment 1, 2 and 3) have undergone extensive alteration resulting in significant changes to the channel morphology. Importantly, the downstream end of S2 has undergone extensive straightening in a section that naturally had high meandering and sinuosity. Based on GIS analysis, the distance along stream has decreased from 7695 m in 1945, with a calculated Sinuosity Index of 1.6, as compared to a distance of 6741 m today, as measured in the 2017 aerial photo, with a Sinuosity Index of 1.4. The actual distance from the downstream end of S3 to the upstream end of as one, in a straight line, is 4760 m. This point is near the location where the Tzipori merges with the Kishon River. The functional importance of S2 in the watershed may have been critical to the sediment deposition processes. The resulting straightening may have a contributing role in the high sediment deposition into the Kishon River, and ultimately into Haifa Port. Based on the historical aerial photograph analysis, S3 may have historically been braided (Fig. 44), whereas today there is no natural braiding on the stream.

**CA2: Adjustments in channel width**
This indicator evaluates the occurrence and amount of changes in channel width from a period included in the interval 1930s - 1960s to present day. The width of the stream today is on average several meters and based on the 1945 aerial photos, look similar. However this resolution it is impossible to accurately assess this indicator. Given that it is likely that there has been some artificial narrowing of the stream channel, due to agricultural land expansion.

**CA3: Bed-level adjustments**
This indicator accounts for the occurrence and amount of bed-level adjustments (incision or aggradation), considered among the most relevant physical alterations affecting a number of processes (e.g. lateral connection with the floodplain, alteration of in-channel physical habitats, etc.). There are no dams, sediment extraction activities, or other direct and obvious cause of the bed level change. The longitudinal bed slope analysis (Fig. 23) did not reveal a significant slope break along the length of the channel.

## F. Conclusions

Each metric was evaluated per segment and assigned a value in accordance with the defined criteria presented in Rinaldi, et al (2016). The three components (geomorphological functionality, artificiality, and channel adjustments) do not have the same weight within the final score of the MQI: artificiality has the highest weight on the overall scoring, followed by functionality and channel adjustments. Although past conditions are important and may affect the morphological quality, the artificial constraints and the functioning of processes in the present condition are considered the two main components of the evaluation.

The following classes of morphological quality were defined: (i) very good or high, $0.85 \leq MQI \leq 1$; (ii) good, $0.7 \leq MQI < 0.85$; (iii) moderate, $0.5 \leq MQI < 0.7$; (iv) poor, $0.3 \leq MQI < 0.5$; (v) very poor or bad, $0 \leq MQI < 0.3$.

Table 7: Scoring Results for MQI

| Metric | Segment | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| **Continuity** | | | | | | | | | | | | | | | | | |
| F1- longitudinal continuity in sediment and wood flux | 0 | 5 | 5 | 0 | 5 | 0 | 3 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 5 | 5 | 3 |
| F2 - presence of modern floodplain | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 3 | 0 | 0 | 5 | 5 |
| F3: Hillslope – river corridor connectivity | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| F4- presence of bank retreat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 3 | 3 |
| F5- presence of potentially erodible corridor | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 0 | 3 | 3 |
| F6: Bed configuration-valley slope | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Morphology** | | | | | | | | | | | | | | | | | |
| F7- planform pattern | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 3 | 3 | 3 | 5 | 5 |
| F8- presence of typical fluvial landforms in the floodplain | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Cross-section configuration** | | | | | | | | | | | | | | | | | |
| F9- variability of cross-section | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 5 | 5 | 5 | 3 | 5 | 5 | 5 |
| F10- structure of the channel bed | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 5 |
| F11-presence of in-channel large wood | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **vegetation in the fluvial corridor** | | | | | | | | | | | | | | | | | |
| F12- width of functional vegetation | 3 | 3 | 2 | 2 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 3 | 3 | 3 | 3 |
| F13- linear extension of functional vegetation | 5 | 5 | 5 | 3 | 5 | 5 | 3 | 3 | 5 | 5 | 5 | 5 | 3 | 3 | 3 | 5 | 5 |
| **artificiality** | | | | | | | | | | | | | | | | | |
| A1- upstream alteration of flows with potentially relevant effects on channel morphology | 0 | 3 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6 |
| A1h- upstream alteration of flows without potentially relevant effects on channel morphology | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A2- upstream alteration of sediment discharges | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| **alteration of longitudinal continuity in the reach** | | | | | | | | | | | | | | | | | |
| A3- alteration of flows in the reach | 0 | 6 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 |
| A4- alteration of sediment discharge in the reach | | 2 | | | | | | | | | | | | | | | |
| A5- crossing structure | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 3 | 3 | 2 | 3 | 2 | 3 | 3 |
| **alteration of lateral continuity** | | | | | | | | | | | | | | | | | |
| A6- bank protections | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 12 | 6 |
| A7- artificial levees | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 0 |
| **alteration of channel morphology and/or substrate** | | | | | | | | | | | | | | | | | |
| A8- artificial changes of river course | 2 | 3 | 3 | 2 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 2 | 0 | 2 | 0 | 12 | 6 |
| A9- other bed stabilization structures | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 12 | 8 |
| **intervention of maintenance and removal** | | | | | | | | | | | | | | | | | |
| A10- sediment removal | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A11- wood removal | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| A12- vegetation management | 0 | 1 | 0 | 0 | 3 | 3 | 2 | 0 | 5 | 5 | 5 | 5 | 0 | 1 | 0 | 0 | 0 |
| **channel adjustments** | | | | | | | | | | | | | | | | | |
| CA1- adjustments in channel pattern | 0 | 6 | 6 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 0 | 3 | 0 | 6 | 6 |
| CA2- adjustments in channel width | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| CA3- bed-level adjustments | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| **Segment** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** |
| **Final Cumulative Score** | **23** | **52** | **38** | **19** | **28** | **23** | **19** | **14** | **23** | **21** | **40** | **46** | **24** | **24** | **24** | **85** | **75** |
| Morphological Alteration Index (MAI): MAI = Stot/Smax | 0.19 | 0.42 | 0.31 | 0.15 | 0.23 | 0.19 | 0.15 | 0.11 | 0.19 | 0.17 | 0.32 | 0.37 | 0.19 | 0.19 | 0.19 | 0.69 | 0.60 |
| **Morphological Quality Index: MQI = 1 - MAI = 1 – Stot/Smax** | **0.81** | **0.58** | **0.69** | **0.85** | **0.77** | **0.81** | **0.85** | **0.89** | **0.81** | **0.83** | **0.68** | **0.63** | **0.81** | **0.81** | **0.81** | **0.31** | **0.40** |
| **Rating** | **good** | **mod** | **mod** | **good** | **good** | **good** | **good** | **v good** | **good** | **good** | **mod** | **mod** | **good** | **good** | **good** | **poor** | **poor** |

ND = Not Detectable due to small streams
NA= Not Applicable to unconfined or partly confined streams
stot = sum of scores
smax = maximum possible based on category C= 124
Rating Criteria:
0 <MQI<0.3: very poor; 0.3 <MQI<0.5: poor; 0.5 <MQI<0.7: moderate; 0.7 <MQI<0.85: good
0.85 <MQI<1.0: very good

The resulting score per segment is presented in Fig 49.  Lower scores reflect a more natural state and a higher geomorphic rating.

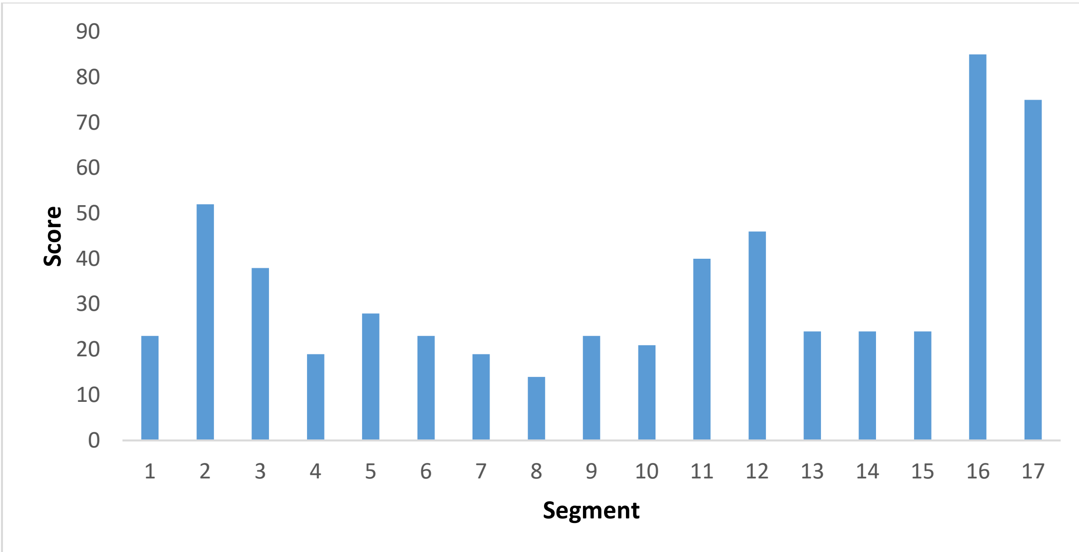



Fig. 20: Scoring results of MQI by segment

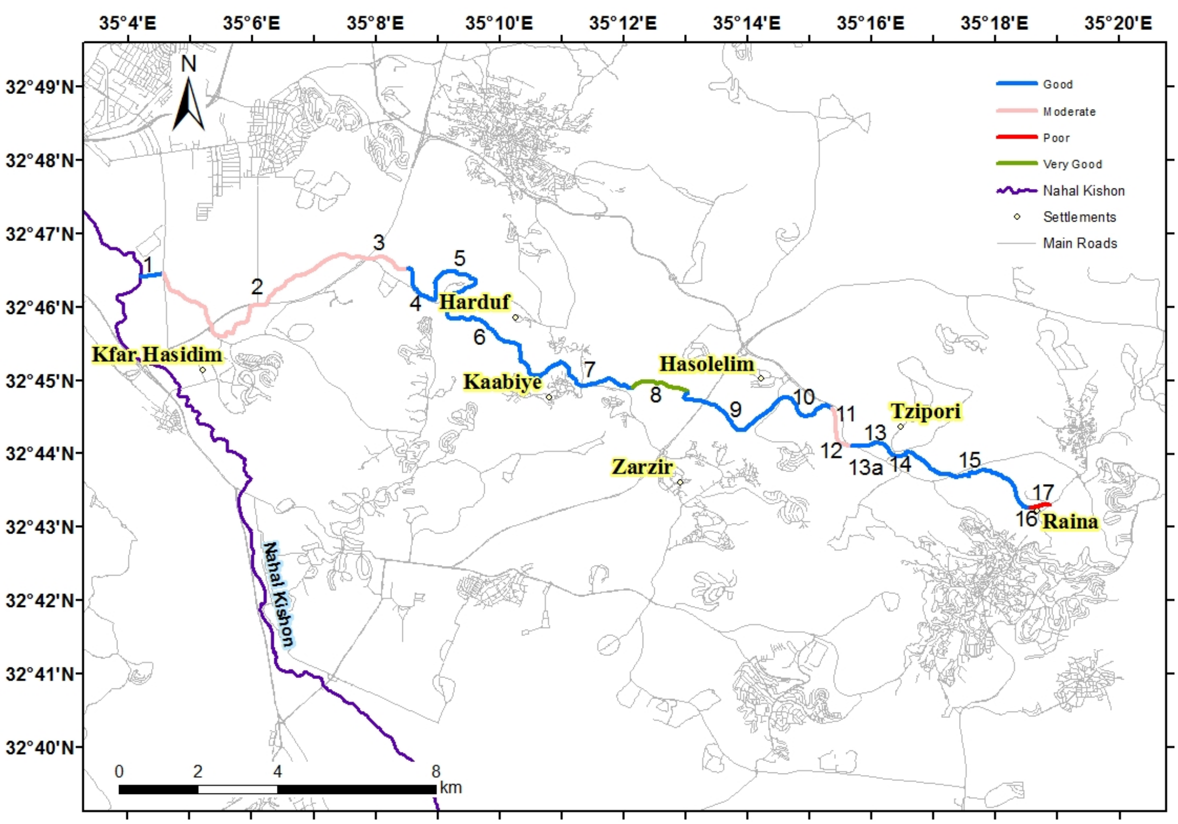



Fig. 50: MQI rating results based on score and standard deviation

Summary of MQI results

The river assessment process revealed many interesting insights into Tzipori stream. The only segment receiving a "very good" rating is S8. Most of the segments received a rating of "good", suggesting that the stream condition retains ecological and functional value, even with the intensive agriculture, over gazing, urban development, regulation of the stream for flood management and extensive stream water extraction practices. Several segments are incised and disconnected from the floodplains while other areas have had extensive alterations, affecting the stream flow and sediment processes. However, the stream retains natural channel bed for the majority of the perennial stream, with only small sections consisting of bank protections. There are several culverts and crossing structures that interfere with hydrologic connectivity. Overall, the stream suffers from anthropogenic effects, in particular heavy agricultural activity, resulting in a lack of natural riparian vegetation and the direct input of nonpoint source (nps) pollutants, both chemical pollutants and sediment erosion / deposition. There is a high concentration of cows and goats in the watershed that enter the stream frequently throughout the watershed, resulting in severe bank erosion and occasional bank failure, as well as nps pollutant resulting from frequent deposition of animal waste. In addition to the nps pollution, the ongoing discharge of blood into the stream constitutes an important source of pollution, which we hope to end permanently. Currently proposed restoration activities will address the incision in S13. In addition recent new measures to fund existing water plans will results in an increased allocation of stream water and reduced stream water extraction, specifically from the spring source area in S13a. Recommendations to improve the ecological habitat and reduce overgrazing and agricultural impacts are presented in the sections below.

A common feature along the stream was that the herbaceous vegetation was highly grazed by sheep, goats and cattle. The animals grazed along the stream with any evident type of control of this activity, adding additional elements of degradation to this type of ecosystem. The combined activities of plant cover removal, trampling along the stream banks and deposition of excrements in the water stream all add to the continue state of degradation of the stream. Urgent intervention by the responsible authorities is needed in order to restore the stream conditions.

*Recommended Modifications to MQI for Israeli Streams*

The first challenge we encountered in applying the European methodology was that the MQI analysis relies heavily on remote-sensing and generally bases analysis of many metrics of stream geomorphic conditions on aerial photo interpretation and subsequent GIS analysis (i.e. evaluating the length of eroding banks along the reach). This is followed by limited field reconnaissance conducted to field check preliminary assessments, for example channel width. Application of the MQI on Nachal Tzipori revealed that the level of detailed information needed for the analysis was not possible to assess using existing aerial photographs. Although the aerial photo resolution was high (25 cm), most Israeli streams consist of a narrow channel and limited stream flow most of the year, making it difficult to define the exact stream corridor and morphologic details as it moves through the mosaic of agricultural areas through the valley. In addition to the scale and streamflow limitations, this land has been inhabited for thousands of years, making it difficult to assess "natural conditions." There are no reference streams available for comparison (Tal & Katz, 2012). Therefore, this analysis required an extensive field data collection effort to support the remote-sensing analysis.

The following metrics were found not to be directly relevant to coastal perennial streams in Israel:
**F3: Hillslope –** river corridor connectivity: Not applicable to unconfined streams.
**F6: Bed configuration-valley slope:** Not applicable to unconfined streams
**F13: Linear extension of functional vegetation:** Not applicable to streams with natural absence of woody riparian vegetation, Israeli streams may be naturally unforested.
**A11: Wood removal:** Natural absence of woody vegetation along stream
**CA2: Adjustments in channel width:** Insufficient resolution to evaluate
**CA3: Bed-level adjustment:** Insufficient data and resolution to evaluate

## Part 2: Discussion: Related Eco Hydrological Analysis and Management

### G. Land use analysis

To examine the anthropogenic pressures on the stream, we conducted a detailed land use analysis. Fig. 51 provides the results of the GIS land use and land cover evaluation. The Nahal Tzipori watershed area was categorized initially into the following land uses: agricultural lands, built areas (impermeable lands), forested areas, and undeveloped, vegetated land.

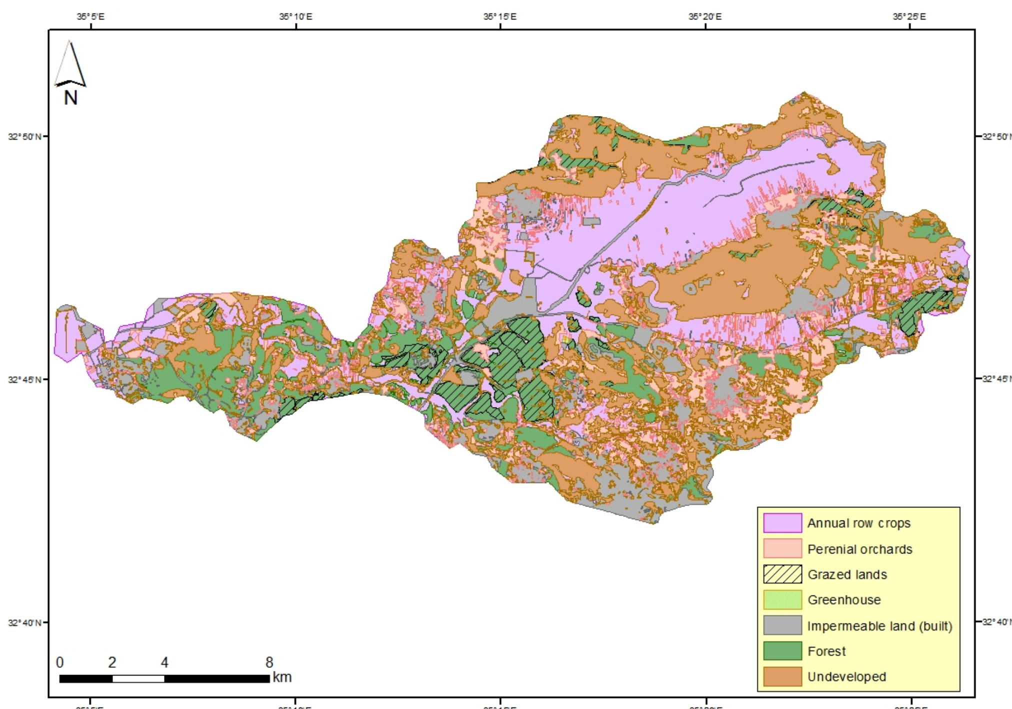


Fig. 51: Land Use in the Tzipori Watershed

A total of 47% of the watershed is categorized as agricultural. Agricultural lands were then subdivided into types of agriculture, categorized as annual crops, perennial orchards, greenhouses and grazed lands. Table 8 presents the land use categories, area and percent of lands within the watershed per category. Table 9 classifies the agricultural lands based on these categories and their distance from Nachal Tzipori. This analysis was then completed by segment, calculating the percent lands in each category.

Table 8: Land use in watershed

| **Land use** | **Area (sq.km)** | **% Lands** |
|---|---|---|
| Annual row crops | 73 | 23.7% |
| Forest | 47 | 15.2% |
| Grazed lands* | 36 | 11.5% |
| Greenhouse | 0.3 | 0.1% |
| Impermeable land (built) | 45 | 14.4% |
| Perenial orchards | 35 | 11.2% |
| Undeveloped | 74 | 23.9% |

* Grazed lands overlaps other areas

Table 9: Land use by distance from stream

| **Category** | **Total Area (Sq m)** | **0-10m (Sq m)** | **10-25m (Sq m)** | **100-500m (Sq m)** | **Over 500 m (Sq m)** |
|---|---|---|---|---|---|
| Annual field crop | 66,189,635 | 115,006 | 396,334 | 5,153,557 | 58,345,287 |
| Annual row crop | 1,623,722 | 1,566 | 14,662 | 421,613 | 1,080,487 |
| Greenhouse | 301,292 | 0 | 354 | 50,591 | 247,658 |
| Perennial orchard | 35,027,842 | 24,368 | 124,495 | 1,508,921 | 32,726,430 |
| Grazed Lands | 35,648,621 | 0 | 8,289 | 3,377,166 | 32,046,230 |

*Data source: Ministry of Agriculture (2016)*

A detailed analysis of agricultural types of activity was then calculated within each segment, analyzed within distance categories (Fig. 52). See Appendix 4 for complete data table. In many areas along the stream, agriculture lands exist within 10 m from the stream, creating the highest level of anthropogenic pressure resulting from land use. Total agricultural lands (%) within each segment located within 10 m from the stream.

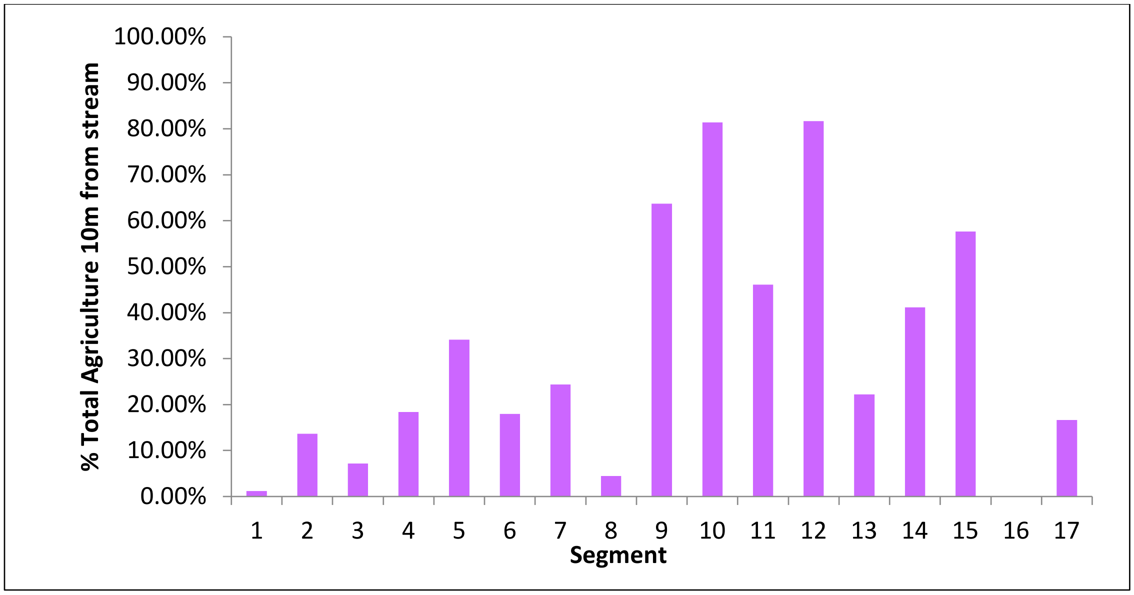



Fig. 52: Total agricultural lands (%) within each segment located within 10 m from the stream

The type of agriculture resulting in the highest risk to the stream is annual row-cropped agricultural lands, due to the annual turning of the soil and the high chemical inputs. We compared percentage of annual row-cropped agricultural lands for each segment. From the midpoint of the stream, distance categories calculated row cropped agricultural lands based on their distance from the stream from 10 m, 25 m, 50m, 100m, and 500m (Fig. 53).

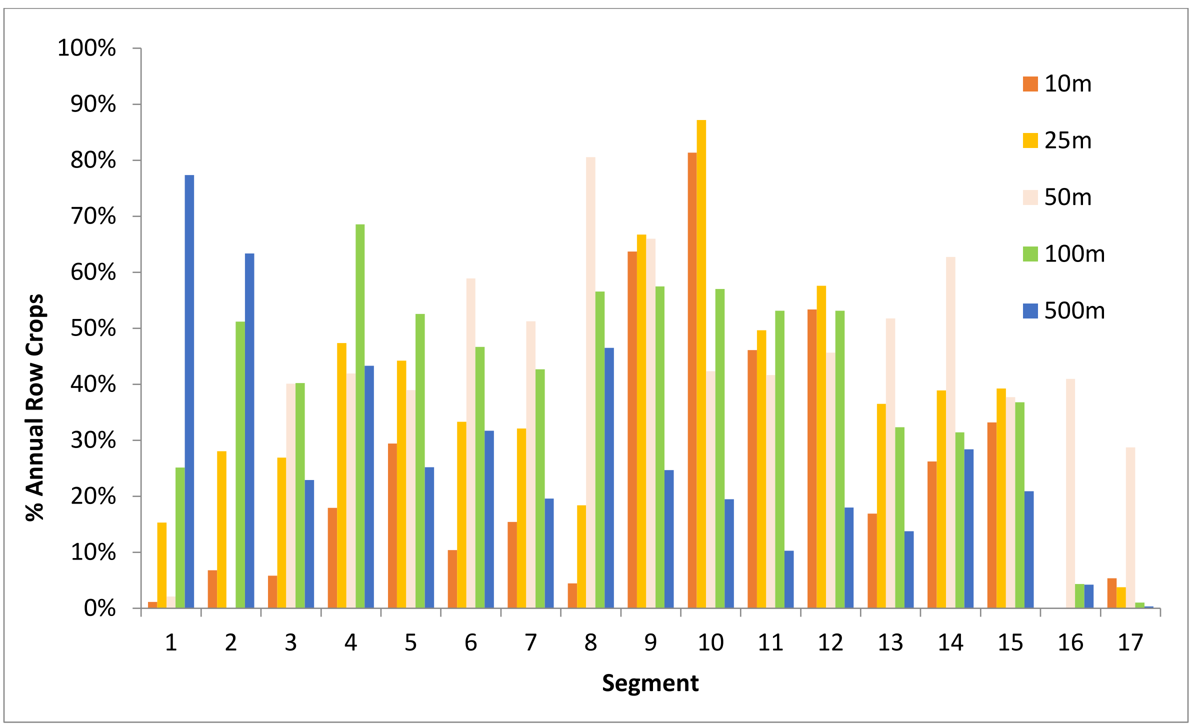



Fig. 53: Annual row cropped land (%) per segment, with distance from rivers categorized into within 10 m, 25m, 50m, 100m, 500m.

We compared the percent of land in annual row-crops from the midpoint of the stream, assigned into distance categories ranging from 10 m or less for each segment.  Segment S9-S10 having the highest intensity of lands within 10m from the stream in row cropped agriculture, followed by S11-S12.  The lowest percent of annual row-cropped land within 10 m was found in S8.  Segments S1-S3 also has a low percent lands, but are in a highly altered setting, due to the diversion dam and impoundment ponds.  In the upper section of the stream, S 16-S17 have low percent of lands due to urbanization encroaching the stream.

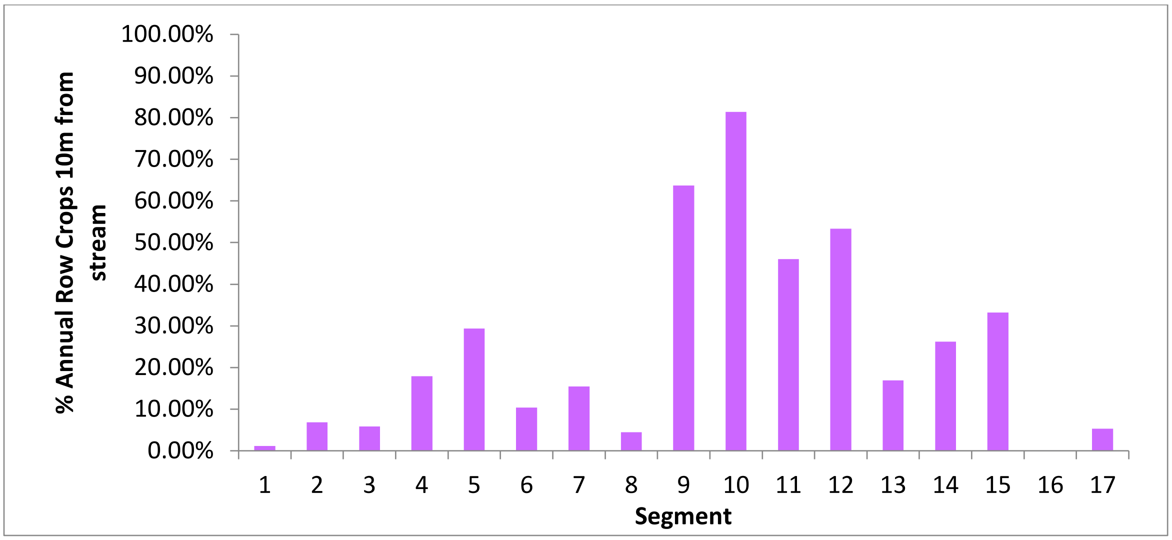


Fig. 54: Total annual row cropped lands (%) within each segment located within 10 m from the stream

## H. Identification of Stressors

*Agricultural Pressures*

Israeli streams have suffered from generations of agricultural expansion, stream water exploitation, channel regulation and artificial modifications to enable infrastructure development and agricultural development and expansion. Agricultural watersheds are inundated with nutrients from both fields and overgrazing, as well as other agricultural chemicals. High rates of erosion are common from fields as well as streambank erosion from animal trampling. This combination of overgrazing and agricultural expansion has resulted in the severe degradation of riparian vegetation along the entire stream. The few studies investigating stream pollution suggests that nonpoint sources from agriculture and urban runoff are the single greatest source of nutrients and other pollutants to the streams (Tal et al. 2010a).

Government policies regarding water use have resulted in depleting streamflow downstream to support agriculture. Streams have been denuded, waters polluted, channels straightened, floodplains and wetlands lost and banks eroded. Predictably, the environmental impacts of the country’s aggressive water management policies have been substantial adding degradation to the critical conditions currently found in the Tzipori stream.

*Development Pressures*

There are several issues affecting the quality of habitat in the upper stream. To simplify road planning, streams have been rerouted to reduce flood risk, dramatically altering the natural stream bed morphology and water quality, resulting in significant environmental impacts. The ongoing development around the town of Reyna has resulted in recent impacts to the stream bank, adding additional elements of artificiality with highly degrading effects. In addition to the fact that in S 17 the stream is squeezed between houses with artificial bank protections, the neglect of the system is readily apparent in the high volume of garbage filling the stream channel (photo). The tunnel culvert comprising S 16 was recently constructed, as this area was developed during 2017 and paved. The stream is discharged from the tunnel culvert (photo) into a fairly natural landscape (photo).

There are apparently no restrictions in terms of setbacks for building next to streambanks. A new house being constructed in S 15 is only a few meters from the streambank (photo).

Fig. 55 : Blocked stream S16; Culvert discharge S16; Discharge into S15; New House construction

New road development is currently occurring in the upstream segment S13, near the source area. This is discussed in detail below.

*Overgrazing*

Grazing intensity results in streambank degradation, high nutrient inputs and fecal coliform degrading water quality, and high vegetation degradation. As part of the land use analysis we analyzed grazed lands, which are designated for this purpose under the Ministry of Agriculture. We analyzed designated grazing lands within each segment relative to distance from the stream. From the midpoint of the stream, distance categories ranged from 10 m or less, 25 m, 50m, 100m, and 500m (Fig. 56). Results show that only in S2-S3 are lands within 25m, with no segments having grazing within 10 m or less from the stream. However, direct observation in the field reveals that many shepherds lead their herds in the areas surrounding the stream channel, and often inside the stream channel, especially in S5-S6, where little vegetation exists

due to the over grazing.  This can be seen in the results from the vegetation sampling (see Section D. F12).
is important to note that this grazed lands analysis is only the official land designation along no. Whereas

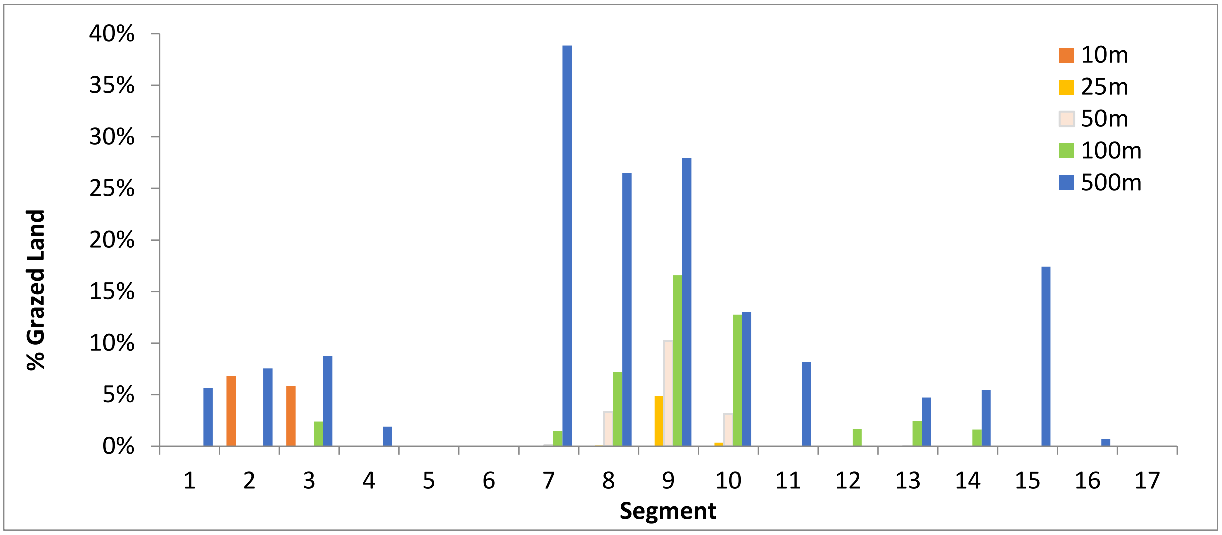


Fig. 56: Grazed land (%) per segment, with distance from rivers: 10 m, 25m, 50m, 100m, 500m
(data does not reflect field observations in the 10m or less category and within 25m)

Overgrazing is an importance negative issue on Israeli streams.  This stream is being misused by large herds of cows, goats, and sheep. As discussed in section A 12, The effects of overgrazing on vegetation is so extensive that it constitutes vegetation removal, leaving the entire stream corridor door in a severely degraded condition.  Results from the vegetation survey support this conclusion. Recommendations to address this problem are presented in the next section. Nutrient waste from these animals contribute to water quality degradation resulting from these nonpoint source inputs into the stream.  Lastly the detrimental effect on streambank stability and erosion is obvious and locations with high overgrazing frequency.  We used the metric of fecal coliform as an indicator for grazing by segment. Traditionally coliform bacteria is used as an indicator of fecal contamination (e.g. Escherichia).  Results showed significantly higher fecal coliform levels in S12, although this may have resulted from a localized of a horse pen located directly on the stream, slightly upstream from our sampling location. Therefore, it is not necessarily indicative of overgrazing, although it does represent stream impacts in that area that are ongoing.

Fig. 57: Degraded streambanks from over grazing

Fig. 58: Goat over grazing on hillside

## I. Water Quality and Resource Management

*Stream water extraction*

Stream water extraction has been occurring for decades to support agricultural activities. Previously, agricultural production was the sole priority. In the year 2000, the cabinet's 'Governmental Decision 18/7/2000' for the first time, specifically approved allocation of 50 mcm of fresh water to nature – essentially an allocation for the restoration of Israel's streams (Tal & Katz, 2012). In recent weeks (July 2018), funding allocations have enabled the implementation of existing and approved water plans for many streams, including Tzipori.

In fact laws pertaining to allowable uses of water only recently included the stream in the natural environment surrounding the stream as an acceptable use of water alone. In addition to the legal stream water extraction via the impoundments in S2, operated by the Kibbutzim, discussed in section A3, illegal stream water extraction is occurring throughout the stream (Fig. 51). Areas where large stones were added into the stream bed to create pooling, enabling installation of a hose and a pump to extract water and directly applied to the farm fields is a common problem. A master plan for water use has already theoretically allocated additional water resources to the stream (date of report). The water that is transported by pipe from the spring source shown as 13 a on Fig 50 is scheduled to be replaced by alternative water sources. However, those sources have not yet been identified and therefore the reallocation of additional stream water to the stream has not yet occurred.

*Water Quality*

In the summer and fall the downstream segment is affected by the tidal regime in the Kishon. Spike and water quality along the river are sampled annually in the spring and autumn by the Nature and Parks Authority and the Ministry of Environmental Protection, Kishon River Authority.

We measured basic water quality metrics during the June 2017 survey, with approximately 50 measurements obtained using an Oakton hand held multiparameter meter. Temperature, pH and salinity were measured along the entire stream channel. Temperature ranged from 21 to 31 degrees Celsius, with an average of 25. Temperature fluctuates seasonally and throughout the day, relative to the degree of shading by riparian vegetation.  The pH ranged from 7.1 to 8.3, with an average measurement of 7.9.  EC ranged from 478 to 587, with an average reading of 518.  In general, these data demonstrate hydrologic connectivity and a small range of variability in these parameters.

Based on the final segmentation, we established water quality monitoring stations that we visited during and/ or immediately after rain storm events.  In addition, we collected measurements throughout the year to assess the variability of these measures.  Results from these water quality sampling events focus on turbidity and suspended sediment concentrations.  These data are presented in Appendix 6.

*Suspended sediment concentrations during winter storm flows*

We collected water samples from along the stream during the winter to assess the suspended sediment concentration and compare between segments turbidity, as an indicator of Upland soil erosion, streambank erosion, and potential inputs of agricultural chemicals. A baseline turbidity survey was conducted on November 30, 2017 (Fig. 59). Results show a cumulative increase sediment concentration from upstream to downstream as you would expect from cumulative she flow runoff.

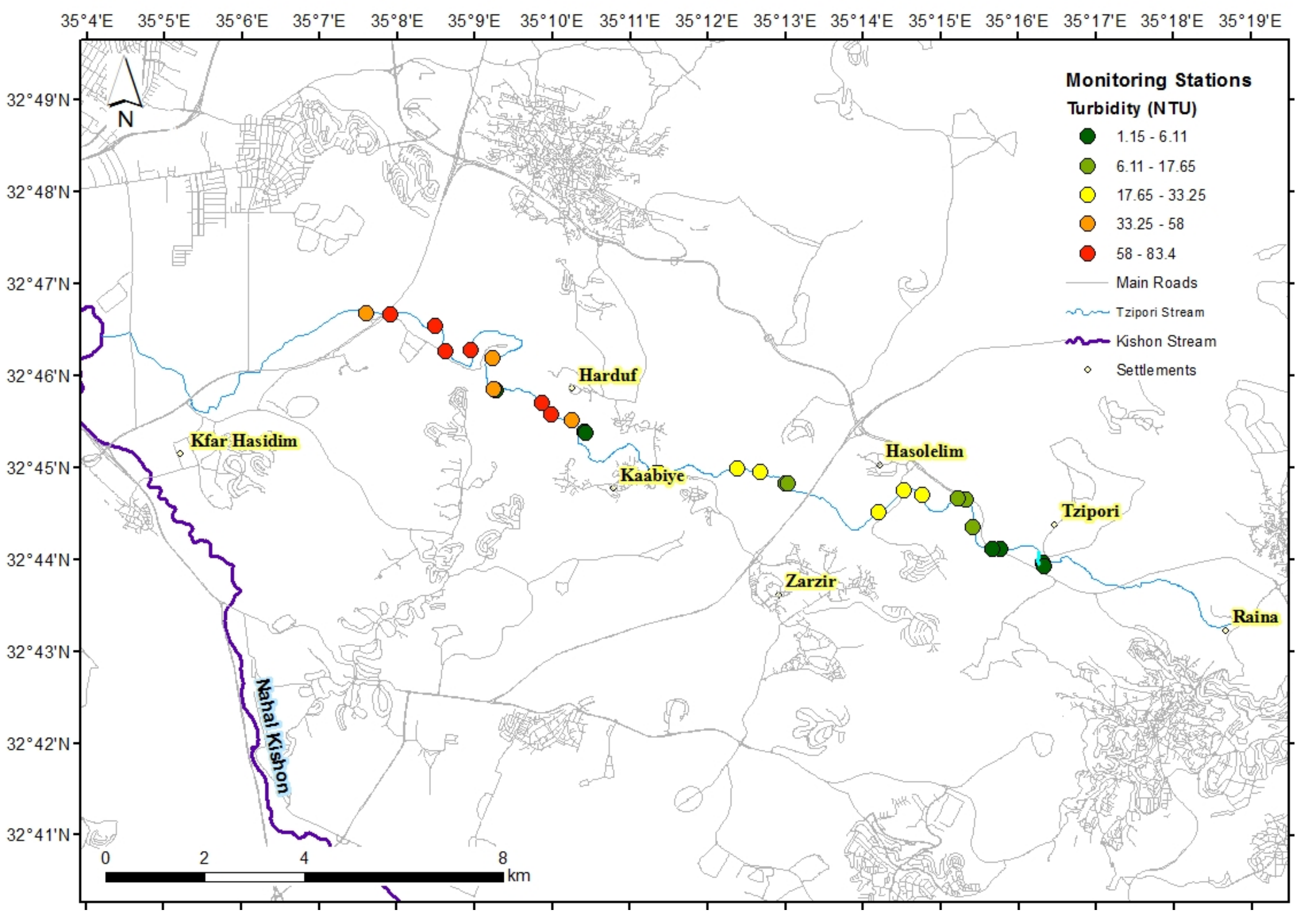



Fig. 59: Turbidity monitoring stations

We returned to these monitoring stations for water sample collection during and immediately following rain storm events on January 4, January 29, and February 18, 2018. An EPA certified turbidity meter (LaMotte 2020we) was used to analyze water samples in the field. In addition we collected 500 ml samples, which were placed in a drying oven (105 C) in a laboratory, to obtain the dry weight of the suspended sediments (mg/l).  The highest concentration of suspended sediments were found during the first large winter storm event (Fig. 60).

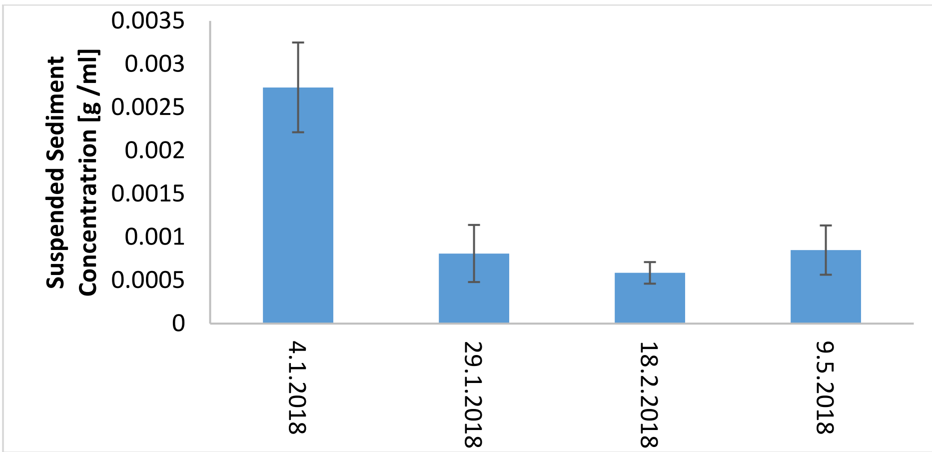



Fig. 60: Average suspended sediments concentration during four sampling events

We conducted a two way analysis of variance (ANOVA) test to evaluate the roles of sampling date and stream location as explanatory variable factors for the suspended sediment concentration results. In order to complete the two way ANOVA test, we eliminated segments that did not have data for all three sampling dates from the test. In segments where a few water samples were analyzed in one segment, averaged results were used.  The resulting P value of $4.6e^{-8}$ represent very high significance for variation by date as opposed to variation by segment which yield a P value of 0.82. This indicates that sampling date is the primary categorical variable explaining the data.

Future efforts will target simultaneous sampling using both methods in order to compare the measurement methods.

***Non-Point Source Pollution*:**

The stream channel flows through a mosaic of agricultural lands, some small traditional farms and some large scale, commercial, intensive farms.  The presence of riparian vegetation is critical for filtering surface runoff and reducing the deposition of both sediments and chemical pollutants into the stream channel.  The presence of vegetation acting as a buffer is included in the focus of this project.  The June 2017 survey included data collection as to the presence, absence and size of existing buffer areas, with detailed assessment of existing vegetation composition and structure occurring as part of the vegetation sampling effort (F12).  There are many locations along the stream where agricultural activities occur on both sides of the stream channel and extend up to the channel banks with no buffer at all (Fig. 61).

Fig. 61: Stream flows through intensive agricultural area without any riparian vegetation

Funding allocated as part of this project for water sampling enabled analysis of eight water samples collected on June 7, 2018 from eight segments along the stream corridor (Fig. 62). Water sampling locations and results. The samples were immediately placed on ice and transferred to a laboratory representative on the same day as collection for sample analyses. Results from these samples are presented below (Table 10). A pesticide screen showed non-detectable levels in all samples.

Table 10: Analytic results from June 9, 2018

| Sample ID | fecal coliform (MPN/G) | Total N | NO2 (mg/L) | NO3 (mg/L) | org N (mg/L) | P (mg/L) | Pesticides (LC/MS) |
|---|---|---|---|---|---|---|---|
| 1-13-turk | 3,000 | 17.16 | 0.02 | 15.5 | 1.64 | 0.15 | ND |
| 2-12-seph | 12,000 | 15.56 | 0.165 | 14.1 | 1.29 | 0.21 | ND |
| 3-10-sol | 3,000 | 14.82 | 0.039 | 13.7 | 1.08 | 0.21 | ND |
| 4-8-yitf | 5,000 | 11.38 | 0.035 | 9.7 | 1.64 | 0.2 | ND |
| 5-7-kaab | 9,000 | 12.45 | 0.03 | 10.3 | 2.12 | 0.18 | ND |
| 6-6-monk | 900 | 12.31 | 0.01 | 10.8 | 1.5 | 0.24 | ND |
| 7-5-ras | 2,400 | 11.68 | 0.023 | 10.3 | 1.36 | 0.11 | ND |
| 8-2-div | 500 | 11.09 | 0.025 | 9.7 | 1.36 | 0.18 | ND |

There is a large database of water quality data collected by RATAG and the Ministry of the Environment, as well as hydrological data from the hydrometric station. Some of these data were integrated into this report.

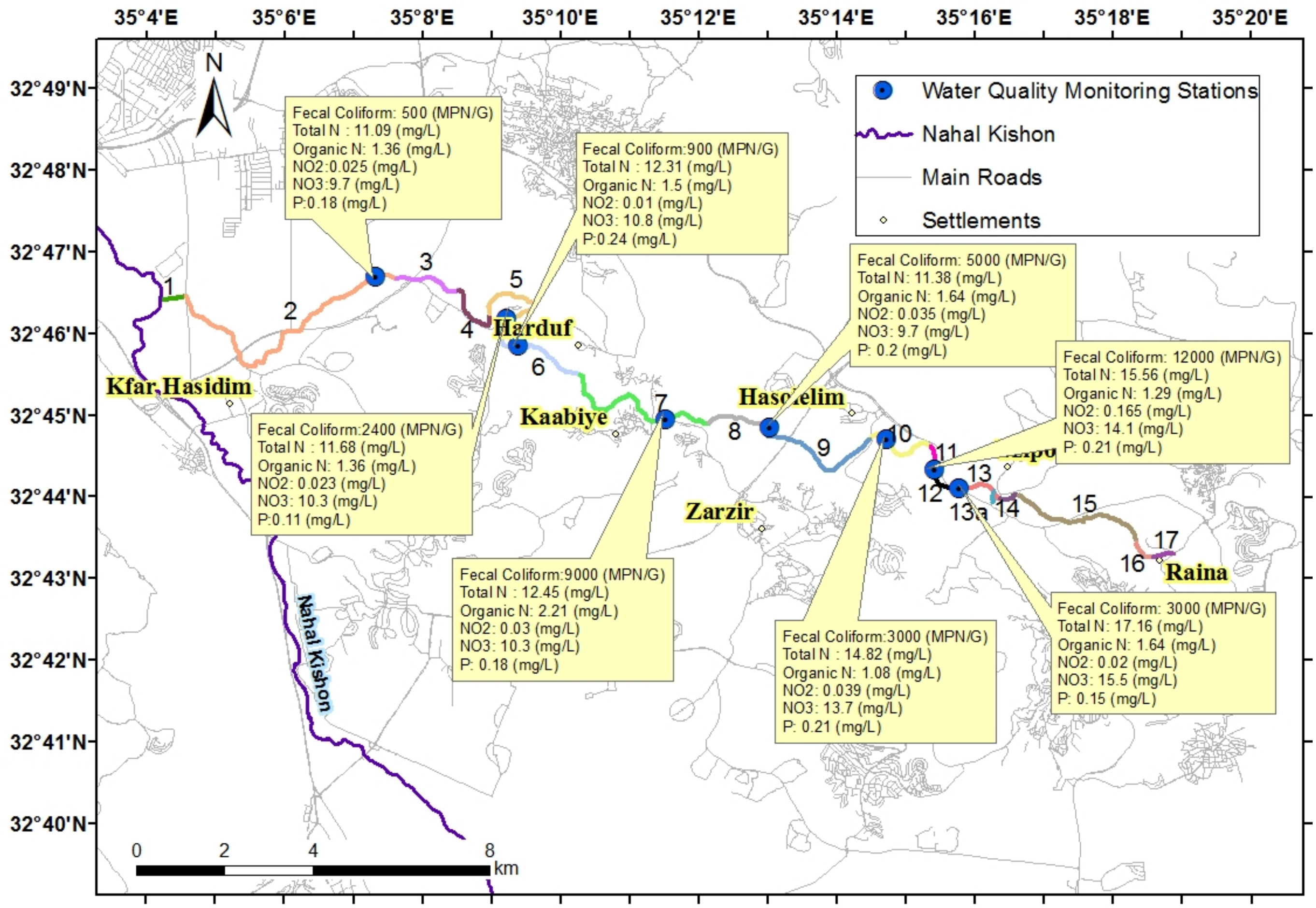



Fig. 62: Water sampling locations

## ***Point Source Pollution*:**

*Raw sewage ad treated wastewater inputs*

Another unfortunate issue common to Israeli streams is the discharge of raw or partially treated wastewater into the stream. Wastewater treatment plants are undersized in many locations with the capacity difference increasing due to population growth. While wastewater treatment systems may overflow during large storm events, in other cases it is known that ongoing discharges occur throughout the winter. Known locations where wastewater enters the stream are shown in Fig. 65. In the upper part of the watershed, waste from the city of Nazareth is transported through a pipe to a wastewater treatment facility. During the month of April, 2018, a contractor hit and damaged a pipe, causing raw sewage to enter the stream channel several hundred meters above Einot Tzipori. Upon further investigation, it was determined that several areas along this piping network included illegal connections thus contributing to the insufficient size of the pipe, leading to overflows of this wastewater. Efforts were made by the drainage Authority to contain this pollution however substantial amounts of waste enter the stream. Kfar Manda had temporary authorization to discharge wastes into the stream until a waste treatment facility could be constructed. However no action was taken to construct this facility. The town requested permission to continue this discharge however The Water Authority says there is insufficient evidence that they are trying to reduce the pollution and refused to give permission. Unfortunately Kfar Manda continued to discharge this way all winter, having no other alternative to treat their waste. The Ministry of Environmental Protection can press charges on Tahigid because they discharged without authorization. Regrettably, this has not occurred to the best of our knowledge.

Fig. 63: Kfar Manda waste discharge pipe Downstream from Nazareth, sewage line break

We found a pipe discharging blood into Nachal Tzipori, originating in a chicken slaughter house, in an area along the stream where traditional farming has been occurring for generations (Fig. 64). Blood was observed entering the stream during each of five site visits. Representatives of KRN visited this location on September 26, 2017 and observed the discharge. A formal alert was filed with the Ministry of Environmental Protection Hotline and an enforcement agent has investigated.

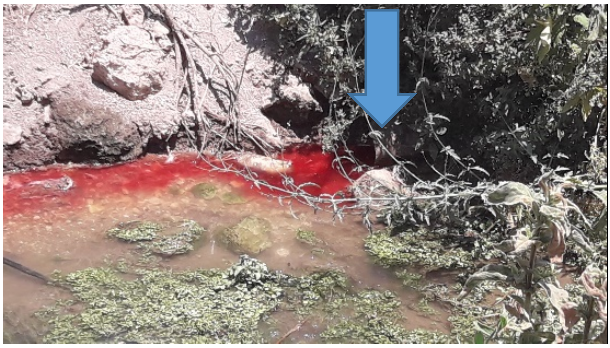


Fig. 64: Blood discharging into stream from a pipe Blood flowing downstream, behind artificial levees

The Nazareth situation was caused by both a line break and due to an undersized pipe that was overwhelmed with illegal connections. Legally, restrictions exist when the sewage pipe is adjacent to a water pipe, requiring protections. When a sewage line is running right along the stream, no protections are required because the damage is assumed to be negligible. The existing paradigm is that sewage discharges overflow into the stream not considered an unusual or serious problem. Third location where waste was entering the stream was in Zarzir, where sewage pump stations were not functioning. While this source is not daily it has been frequent over the last two years. All known source areas are presented on Fig. 65.

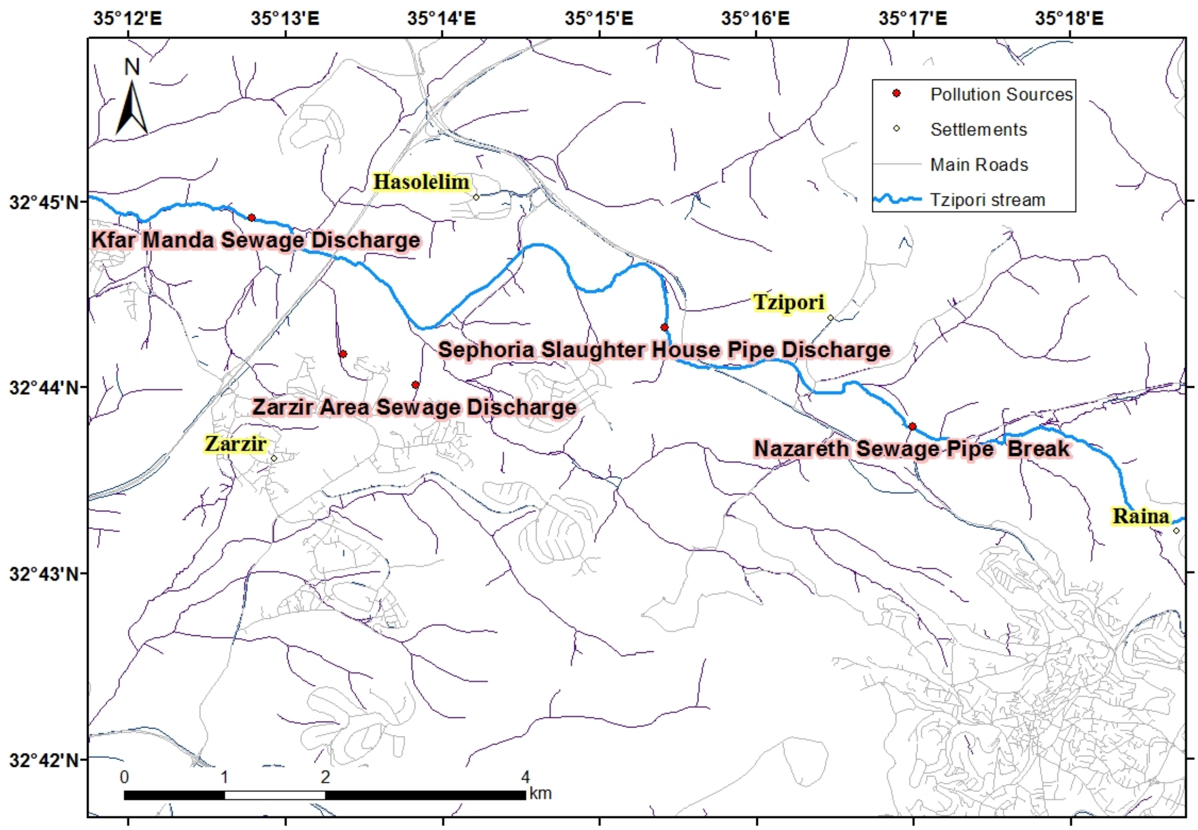



Fig. 65: Pollution sources map

## I. Past Restoration activities and related projects

Several issues pertaining to the stream channel have gained importance due to recent or pending projects. We discuss these issues in our study in order to strengthen the scientific basis of the planning and decision making efforts.

1) The KRN conducted river restoration activities in the area near the historic Monk Mill and Ras Ali (S6 and S5) between 2016 and 2017. This involved the construction of a trail along the stream to increase recreational benefits and acts as a barrier to expanding agriculture, adding protective stones around the source spring areas, and modifying the stream channel to introduce an anabranching morphology to increase habitat diversity. We have collected detailed cross-section profiles in these areas to enable evaluation of the long-term sustainability of the channel modifications. One goal of this project was to connect local

people to the stream by increasing access and offering opportunities to improve stewardship.

Fig. 67: New trail crosses over stream in one section

2) KRN conducted geomorphic restoration activities in the area near Solelim. During the summer 2017, the contracted Lygam to regrade the streambank, widen the stream channel, reduce the incised condition of the stream and try to reconnect the floodplain. They added boulders to prevent off road vehicle access and added small step pools to the channel bed. A handful of trees were planted on the newly established slopes in September 2017. The Jewish National Fund (JNF) funded the effort, using tree material collected from within the watershed, obtained from a nursery in Harduf. Vegetation planting of herbaceous native species did not occur and the slopes remained bare at the onset of the rainy season. The bank suffered severe erosion in some locations. We measured the initial streambank cross-section using precise RTK collection, as well as the restored streambank cross sections after the winter rains. We will analyze these data to estimate how much sediment was lost from that one area. We will monitor it again at the end of the next rainy season, in order to assess the sustainability of the new profile and evaluate the channel features over time. This small section provides an opportunity to evaluate our restoration actions, measure our success, and learn lessons to improve our efforts. Long term monitoring will enable us to assess the process of the stream in finding a new equilibrium. Results from this monitoring will enable assessment of this type of geomorphic intervention and improve future restoration efforts.

3) Infrastructure improvements around Einot Tzipori includes the construction of a new interchange, the widening of the road, and the development of a new entrance road into Moshav Tzipori. The road will cross the meadow across from the Einot Tzipori spring and cross over the stream via construction of a new bridge. A small channel originating from the springs of the Einot Tzipori springs currently flows through this meadow (see Fig. 1) prior to merging with the main stream of the Tzipori.

The construction of the new interchange began in June 2018. Heavy earth moving equipment began to remove the riparian vegetation at the end of segment 13. Streambank erosion was highly visible. Using a turbidity meter, we collected stream water samples upstream and downstream of the riparian vegetation destruction. Turbidity increased from 3 to 76 NTU, and sediment was visibly transferred from the stream banks into the stream channel. No stream protective measures had been implemented. Trees designated for conservation were nearly lost, due to inadequate supervision of inspectors. Upon notifying the KRN, protective fencing was implemented to reduce the direct transport of streambank and upland sediments into the channel.

Mitigation funds are available to the KRN resulting from these impacts and a restoration plans are being developed, providing an opportunity to widen the stream in this area (S13) and reduce the severe incision. The small channel that currently passes through this meadow will be merged with the primary stream channel just across from the Einot Tzipori spring to maintain hydrologic connectivity. Opportunities exist to restore the wet meadow and potentially increase the habitat value and recreational opportunities in the whole area surrounding the springs (see recommendations at the end of this document).

Fig. 66: Plan for new entrance road to Moshav Tzipori and new interchange

## K. Recommendations

There is increased interest in improving ecosystem services and agricultural watersheds. Opportunities exist to collaborate between authorities and tackle some of these challenges that are degrading valuable natural resources. We provide a list defining a series of new opportunities to restore degraded streambanks and unique habitats surrounding the stream source. We provide a list of protective measures and policy guidelines that would improve the conservation of soil and water resources and benefit the valuable stream ecosystem.

Due to present infrastructure development in S13, an opportunity exists to restore the source springs area as a wet meadow and remove some elements of artificiality. A new entrance road to

Moshav Tzipori and a new interchange are being constructed in the area surrounding Einot Tzipori (segment 13). Based on the historical analysis of 1945 aerial photos and interviews pertaining to the hydrology in the source area Einot Tzipori, we suggest the following issues for consideration in designing the restoration project resulting from mitigation funding obtained for the infrastructure development activities in the area of Moshav Tzipori.

***Restoration opportunities***

Proposed Stream Restoration:
A. Einot Tzipori Spring Source Pools

1) Remove concrete housing containing springs in the source area of Einot Tzipori
2) Re-allocate the spring flow currently piped to Sephoria to stream and remove piping
3) Removing paved road and construct bridge
4) Re grade if needed to restore wet meadow ecosystem
5) Develop educational signs to explain the unique habitat
6) Create a beautiful boardwalk through the wet meadow to increase recreational opportunities, educate the public and protect the sensitive wetland habitat
7) Remove elements of artificiality, such as concrete trenches
8) Restore the hydrologic connection between the spring source area to the stream
9) Utilize the Turkish bridge located in S 13, currently functioning as an hydraulic constraint, interfering with longitudinal continuity during winter storm flows. This can be used as a positive feature if it is included as a boundary for a nature reserve. Area could function as a wet meadow, a unique ecological habitat in Israel.
10) Explore using natural, low impact design (LID) approaches for boardwalks, trails, and other recreational features. T
11) Install educational signage to increase recreational benefits and improve stewardship
12) Seek to identify restoration opportunities that increase connectivity of longitudinal and lateral fluxes and ecological habitats. Consider indirect impacts on the entire stream system for each intervention activity, connecting the morphological adjustments per project with the goal of improving overall longitudinal connectivity and improved stream functionality.

B. Stream Channel
These restoration efforts include removal of artificial constraints and morphological reconstruction, as well as efforts to conserve soil and water resources.

1) Remove hydraulic and geomorphic constraints, as possible
2) Reduce stream incision by re-grading streambanks and targeting source of the problem
3) Reconnect the floodplain to the stream channel
4) Restore native riparian vegetation along the stream channel
5) Increase the functional width of the riparian vegetation
6) Conduct scientific study to assess the feasibility and potential success of restoring woody riparian vegetation by planting willow posts
7) Investigate the potential of using native Gome plants to stabilize the streambanks within and immediately adjacent to the stream channel
8) Reduce streambank erosion by ensuring that slopes do not remain bare and unvegetated during the rainy season.

9) Defined protective measures to require that soil stockpiles situated near the stream channel must be covered during the rainy season, (i.e. plastic tarps)
10) Define restrictions for easements to prevent building and house construction within 10 meters of the streambank, to reduce flooding risk.
11) Develop educational campaign to improve stewardship and reduce garbage disposal in the stream channel

Grazing Management

1) Create upland habitat by adding water troughs and shade features
2) If efforts from #1 are unsuccessful, fencing options for excluding access to the stream channel should be considered. Price estimates range from 136 nis/ m or 300,000 nis/km (Orit Ginzberg, MOAG, pers. comm). While this is an expensive, the degradation to the stream channel requires intervention.
3) Limit access to the stream to designated crossings
4) Allocate additional resources to provide management and inspection and ensure grazing inside the stream is limited. Grazing control is crucial to prevent continued degradation

Vegetation buffer restoration

1) Based on the results from this analysis, and related data from GIS, land use ownership, and other important criteria, target degraded areas on the stream for restoration of the vegetation buffer.
2) Considered experimental trials to compare the functional efficiency and potential ecological benefits of different species, including native Willow (*Salix* spp.), *Vitex agnus-castus* and *Nerium oleander*. This effort should include plants ecologists, erosion specialists and river restoration scientists.

Agency Supervision and Record Keeping

1) Little data exists regarding previous or ongoing management activities, for example dredging or channel restoration actions. We recommend detailed documentation and record keeping to enable an evaluation of interventions and stream functioning in future intervention and restoration studies.
2) The continuous presence of the national authorities as regulatory entities is crucial to maintain the functionality along the Tzipori stream. The current lack of regulation and enforcement leads to the ongoing mismanagement of this unique ecosystem and its degradation.

Develop and Implement Construction Policy Guidelines

1) Construction of the trail along the stream involved soil grading activities. During a site visit on June 7, 2017, we observed soil stockpiles that had been placed on the down gradient side of the new trail, on the top of the hillside. These materials were directly up-gradient of the stream, within 30m. Policy guidelines should define best management practices for handling and placement of these materials to minimize soil loss and protect streams.
2) The construction of the cement trail along the stream has succeeded in increasing recreational benefits. We recommend investigating LID building materials for future bridges, trails, and other restoration projects. Guidelines that define acceptable and optimal materials for use in natural stream settings would facilitate implementation.

3) We recommend alternatives be considered to placing cement directly into the stream channel. Bridge designs that minimize interference with streamflow and do not create a hydrologic constraint should be encouraged.
4) Soil stockpiles were observed in S3 by the construction of the new culverts under road 70. During and after rain events the soil stockpiles were exposed to rain splash impacts. We recommend policy guidelines define best management practices for handling and placement of construction materials to minimize erosion and soil loss. Infrastructure development is ongoing. Protective measures are needed to provide guidelines, for example minimum distances for placement of soil stockpiles to optimize stream protection.
5) As part of the construction of the interchange and new entrance road to Moshav Tzipori, riparian vegetation was removed by heavy equipment. We observed the detachments of soil along the streambank and measured high increases in turbidity concentrations (NTU) in the stream. We recommend policy guidelines to define protective measures to reduce streambank erosion and soil loss when in-channel construction is occurring.

**L: References**


Agences de L´Eau (1998): SEQ Physique. A system for the Evaluation of the Physical Quality of watercourses. Version 0. Angers, November 1998. In: Mc Ginnity P.M., Mills P., Roche W. and Muller M. (2005): A desk study to determine a methodology for the monitoring of the 'morphological conditions' of Irish Rivers. Final Report. Environmental RTDI Programme 2000-2006. Central Fisheries Board - Compass Informatics - EPA. 237 p.

Arthington A.H. (1998): Comparative Evaluation of Environmental Flow Assessment Techniques: Review of Holistic Methodologies. LWRRDC Occasional Paper 26/98. ISBN 0 642 26745 6.

Bailey R.C., Norris R.H., Reynoldson T.B. (2004): Bioassessment of freshwater ecosystems: using the reference condition approach. Springer, New York, 170 pp.

Bertoldi W., Gurnell A.M. Drake N.A. (2011): The topographic signature of vegetation development along a braided river: Results of a combined analysis of airborne lidar, color air photographs, and ground measurements. Water Resource Research 47:W06525.

Buffagni A., Erba S., Ciampitiello M. (2005): Il rilevamento idromorfologici e degli habitat fluviali nel contesto della direttiva europea sulle acque (WFD): principi e schede di applicazione del metodo Caravaggio - Notiziario dei metodi analitici, 2, Istituto di Ricerca sulle Acque, CNR IRSA:32-34.

Brierley GJ. and Fryirs K.A. (2005): Geomorphology and river management: applications of the river style framework. Blackwell, Oxford, UK, 398 p.

Clarke, S. J., Bruce-Burgess, L. and Wharton, G. (2003), Linking form and function: towards an eco-hydromorphic approach to sustainable river restoration. Aquatic Conserv: Mar. Freshw. Ecosyst., 13: 439–450. doi:10.1002/aqc.591

Dufour S., Piegay H. (2009): From the myth of a lost paradise to targeted river restoration: forget natural references and focus on human benefits. River Research and Applications 25:568-581.

Environment Agency (a) (1998): River Geomorphology: a pratical guide. Environment Agency, Guidance Note 18, National Centre for Risk Analysis and Options Appraisal, London, 56 pp. In: Sear D. A., Hill C.T. and Downes R. H. E. (2008): Geomorphological assessment of riverine SSSIs for the strategic planning of physical restoration. Report NERR013. Natural England Research, 82 p.

Environment Agency (b) (2003): A refined geomorphological and floodplain component. River Habitat Survey FD 1921, GeoRHS fieldwork survey form and guidance manual. Warrington, DEFRA/EA Joint R&D – Project 11793, prepared by University of Newcastle.

Environmental Agency (c) (EA): Technical Assessment Method, Hydromorphology Project. Water Framework Directive Programme. Unpublished report, 26 p.
Fernandez D., Barquin J. and Raven P.J. (2011): A review of river habitat characterisation methods: indices vs. characterisation protocols. Limnetica 30(2):217-234.

European Commission (2000) - Directive 2000/60 EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the fi eld of water policy. Of cial Journal L 327, 22/12/2000, 73 pp.

Gonzalez Del Tanago M. and Garcia De Jalon D. (2006): Attributes for assessing the environmental quality of riparian zones. Limnetica, 25(1-2):389-402.

Gurnell, A., Surian, N. & Zanoni, L. (2009): Multi-thread river channels: A perspective on changing European alpine river systems. Aquatic Sciences. 71: 253.

Jungwirth M., Muhar S., Schmutz S. (2002): Re-establihing and assessing ecological integrity in riverine landscapes. Freshwater Biology 47:867-887.

Kail, Jochem, Daniel Hering. 2009. The influence of adjacent stream reaches on the local ecological status of Central European mountain streams. River Research and ApplicationsVolume 25, Issue 5.

King J.M., Tharme R.E. and de Villiers M.S. (eds) (2008): Environmental flow assessments for rivers: manual for the Building Block Methodology. WRC Report No TT 354/08. Updated Edition. Water Research Commission, Pretoria, South Africa.

Kijowska-Strugała, Małgorzata, Łukasz Wiejaczka, Judith Lekach, Anna Bucała-Hrabia. Diversification of the hydromorphological state and the habitat quality of streams in the Negev Desert (Israel). Environ Earth Sci (2017) 76:99.

Kleynhans C.J., Louw M.D. and Graham M. (2008): Module G: EcoClassification and EcoStatus determination. In: Kleynhans C.J., Louw M.D., Thirion C., Rossouw N. J. and Rowntree K. M. (2005): River EcoClassification: Index of Habitat Integrity (Section 1, Technical manual), Joint Water Research Commission and Department of Water Affairs and Forestry report (South Africa), 96 p.

Ladson A.R., White L.J., Doolan J.A., Finlayson B.L., Hart B.T., Lake P.S. and Tilleard J.W. (1999): Development and testing of an Index of Stream Condition for waterway management in Australia. Freshwater Biology 41:453-468.

Mc Ginnity P.M., Mills P., Roche W. and Muller M. (2005): A desk study to determine a methodology for the monitoring of the 'morphological conditions' of

Irish Rivers. Final Report. Environmental RTDI Programme 2000-2006. Central Fisheries Board - Compass Informatics - EPA. 237 p.

Muhar, S,. K. Januschke . J. Kail . M. Poppe . S. Schmutz . D. Hering . A. D. Buijs. 2016. Evaluating good-practice cases for river restoration across Europe: context, methodological framework, selected results and recommendations. Hydrobiologia (2016) 769:3–19

Munne A. and Prat N. (1998): QBR: Un indice rapido para la evaluacion de la calidad de los ecosistemas de ribera. Tecnologia del Agua 175:20–37.

Nardini, Andrea, Giuseppe Sansoni, Ileana Schipani, Giulio Conte, Andrea Goltara, Bruno Boz, Simone Bizzi, Anna Polazzo, Marco Monaci. 2008. The Water Framework Directive: A Soap Bubble? An Integrative Proposal: FLEA (Fluvial Ecosystem Assessment). CIRF – Centro Italiano per la Riqualificazione Fluviale . www.cirf.org

Palmer M.A., Bernhardt E.S., Allan J.D., Lake P.S., Alexander G., Brooks S., Carr Poff N.L., Allan J.D., Palmer M.A., Hart D.D., Richter B.D., Arthington A.H., Rogers K.H., Meyer J.L. and Stanford J.A. (2003): River flows and water wars: emerging science for environmental decision making. Frontiers in Ecology and the Environment 1:298–306.

J., Clayton S., Dahm C.N., Follstad S.J., Galat D.L., Loss S.G., Goodwin P., Hart D.D., Hassett B., Jenkinson R., Kondolf G.M., Lave R., Meyer J.L., O’Donnell T.K., Pagano L. and Sudduth E. (2005): Standards for ecologically successful river restoration. Journal of Applied Ecology 42:208-217.

Parsons M., Thoms M.C and Norris R.H. (2004): Development of a standardised approach to river habitat assessment in Australia. Environmental Monitoring and Assessment 98:109-130. In: Mc Ginnity P.M., Mills P., Roche W. and Muller M. (2005): A desk study to determine a methodology for the monitoring of the 'morphological conditions’ of Irish Rivers. Final Report. Environmental RTDI Programme 2000-2006. Central Fisheries Board - Compass Informatics – EPA, 237 p.

Raven P.J., Fox P., Everard M., Holmes N.T.H. and Dawson F.H. (1997): River habitat survey: A new system for classifying rivers according to their habitat quality. Freshwater Quality: Defining the Indefinable?. 215-234. In: Raven P.J., Holmes N.T.H., Charrier P., Dawson F.H., Naura M. and Boon P.J. (2002): Towards a harmonized approach for hydromorphological assessment of rivers in Europe: a qualitative comparison of three survey methods. Aquatic Conservation: Marine and Freshwater Ecosystems 12(4):405-424.

Raven P.J., Holmes N.T.H., Charrier P., Dawson F.H., Naura M. and Boon P.J. (2002): Towards a harmonized approach for hydromorphological assessment of rivers in Europe: a qualitative comparison of three survey methods. Aquatic Conservation: Marine and Freshwater Ecosystems 12(4):405-424.

Rinaldi, Massimo, Nicola Surian, Francesco Comiti, Martina Bussettini. (2011). IDRAIM – stream hydromorphological evaluation, analysis and monitoring system: Guidebook for the evaluation of stream morphological conditions by the Morphological Quality Index (IQM) Version 1. Rome, March 2011

Rinaldi, Massimo, Nicola Surian, Francesco Comiti, Martina Bussettini. (2011). The Morphological Quality Index (MQI) for stream evaluation and hydromorphological classification. Italian Journal of Engineering Geology and Environment 1 (2011).

Rinaldi M., Surian N., Comiti F. and Bussettini M. (2013): A method for the assessment and analysis of the hydromorphological condition of Italian streams: The Morphological Quality Index (MQI). Geomorphology 180-181:96-108, doi: 10.1016/j.geomorph.2012.09.009.

Rinaldi, Massimo, Barbara Belletti, Wouter Van de Bund, Walter Bertoldi, Angela Gurnell, Tom Buijse, Erik Mosselman. 2013. REstoring rivers FOR effective catchment Management. Review on eco-hydromorphological methods. Deliverable for Project funded by the European Commission within the 7th Framework Programme (2007 – 2013).

Rinaldi, Massimo, Nicola Surian, Francesco Comiti, Martina Bussettini. (2015). A methodological framework for hydromorphological assessment, analysis and monitoring (IDRAIM) aimed at promoting integrated river management. Geomorphology 251:122-136

Rinaldi, Massimo, Barbara Belletti, Martina Bussettini, Nicola Surian. (2017). New tools for the hydromorphological assessment and monitoring of European streams**.** Journal of Environmental Management 202(2017) 363-378.

Rosgen D.L. (1994): A classification of natural rivers. Catena 22: 169-199

Rosgen D.L. (1996): Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO, 390 p. In: Rosgen D. (2006): The Natural Channel Design Method for River Restoration (+ 1996_StreamNotesReview). Wildland Hydrology, 12 p.

Rosgen D.L. (2006): A Watershed Assessment for River Stability and Sediment Supply (WARSSS). Wildland Hydrology Books, Fort Collins, CO. http://www.epa.gov/warsss/

Sear D. A., Hill C.T. and Downes R. H. E. (2008): Geomorphological assessment of riverine SSSIs for the strategic planning of physical restoration. Report NERR013. Natural England Research, 82 p.

Siligardi M., Bernabei S., Cappeletti C., Chierici E., Ciutti F., Egaddi F., Franceschini A., Maiolini B., Mancini L., Minciardi M.R., Monauni C., Rossi G.L., Sansoni G., Spaggiari R. and Zanetti M. (2002): I.F.F. Indice di funzionalità fluviale. Manuale ANPA/2000.

Surian, Nicola & Rinaldi, Massimo & Pellegrini, Luisa. (2011). Channel adjustments and implications for river management and restoration. Geografia Fisica e Dinamica Quaternaria. 34: 145-152.

Tal, Alon and David Katz. 2012. Rehabilitating Israel's streams and rivers. Intl. J. River Basin Management iFirst, 1 –14.

Weiss A., Matouskova M. and Matschullat J. (2008): Hydromorphological assessment within the EU-Water Framework Directive - trans-boundary cooperation and application to different water basins. Hydrobiologia 603:53-72.

Wyżga B., Zawiejska J., Radecki-Pawlik A. and Amirowicz A. (2010): A method for the assessment of hydromorphological river quality and its application to the Czarny Dunajec River, Polish Carpathians. In Radecki-Pawlik A. and Hernik J. (eds.): Cultural Landscapes of River Valleys. Publishing House of the University of Agriculture in Krakow, 145-164.

**Appendix 1: Summary of Literature Review- Stream Assessment Methodology**

*1. Background and summary of approach*

In recent years, stream geomorphic processes and their dynamic equilibrium conditions have gained attention. We now understand that they are essential for promoting and maintaining healthy functioning of aquatic and riparian ecosystems and supporting habitat diversity (e.g. Clarke et al., 2003; Palmer et al., 2005, Rinaldi, 2016). In recognition of the importance of these geomorphic processes, The Water Framework Directive (WFD) (European Commission, 2000), requires inclusion of morphological aspects, in addition to water quality and biological aspects, in order to obtain an evaluation of stream ecological state. They define parameters to consider, including: flow regime modifications, sediment transport, river morphology, and lateral channel mobility. As a result, many countries developed methodological approaches to stream morphological assessment and classification, based on a census of physical habitats and diversity of fluvial forms, also known as physical habitat assessment or river habitat survey procedures (Rinaldi et al, 2011, Gunell et al., 2009). Examples of stream habitat surveys adopted in Europe include: the River Habitat Survey (RHS) (Raven et al., 1997), the National Physical Habitat Index (National Environmental Research Institute) in Denmark, the Physical S.E.Q. (AGENCES DE L'EAU, 1998) in France, and the Caravaggio (Buffagni et al., 2005).

During the last 20 years, many ecological and hydromorphological assessment methods have been developed in different countries, each targeting different aspects or applying different approaches in terms of goals, scales, and parameters. As a result, individual stream assessment studies vary widely in the specific parameters and classifications. Several stream assessment review studies have been conducted, resulting in recent efforts to integrate different approaches, fill in data gaps and target indicators and parameters that provide the most benefit for use within this context (Raven et al., 2002; McGinnity et al., 2005; Weiss et al., 2008, Fernandez et al. 2011). Most recently, Rinaldi et al. (2013) conducted a comprehensive review funded by the European Commission Restoring rivers FOR effective catchment Management (REFORM) project, which included evaluating 139 published papers, in addition to technical guides, conference proceedings, book chapters, and unpublished academic works (PhD /Masters thesis). The goal was to develop an integrated eco hydromorphological assessment framework that enables consistent characterization and analysis, with clearly defined parameters that reflect recent scientific advances and standards developed, and also complies with the WMD. The subsequent revised morphological quality index (MQI, Rindaldi et al, 2013) is the result of this recent efforts and provides a solid basis for the design of our Tzipori stream assessment study.

The term "hydromorphology" can be defined as "the discipline that, by integrating hydrology and fluvial geomorphology, aims to study fluvial form and processes, their interactions with human impact, and the consequent implications on ecological processes (Rinaldi et al, 2013)". Improved understanding of the geomorphological processes responsible for river functioning contributes to better stream assessment and classification and importantly, for supporting analyses of interventions and impacts, as well as the design of mitigation measures (Rinaldi et al, 2011). Since the term was introduced by the WFD in 2000, (EUROPEAN COMMISSION), investigators often evaluate: (a) the extent of modification to the flow regime; (b) the extent to which water flow, sediment transport and the migration of biota are impacted by artificial barriers; and (c) the extent to which the morphology of the river channel has been modified, including constraints to the free movement of a river across its floodplain (SEAR et al., 2008).

Rinaldi et al. (2013) divided the hydromorphological assessment method into 5 categories: (1) physical habitat assessment; (2) riparian habitat assessment; (3) morphological assessment; (4) hydrological regime assessment; (5) fish longitudinal continuity. This categorization enables a detailed comparison of methods based on analysis of specific parameters in both time and space, for example at comparable spatial scales (i.e. site, reach, catchment) and contexts (e.g. river channel, riparian areas, floodplain). The specific basis for each parameter of the assessment is discussed in the next section.

2. *Detailed stream assessment parametric evaluation*

The most common approach is physical habitat assessment, which aims to identify, survey and characterize physical habitats and/or the overall condition of rivers and streams. Generally, they are applied at a local/reach scale, consider all the spatial components of a river corridor (channel, riparian area and floodplain), and assess the hydromorphological condition at the present time.

Field surveys are conducted in almost all physical habitat assessment methods with less than half of them using a rapid assessment protocol. Commonly, field analysis is combined with data from maps and/or remote sensing to: compare the present and the historical conditions, characterize the survey site, support the selection of the assessed reaches, create a large scale database inventory and eventually support/plan further field analysis, carry out a large scale assessment or support the identification/definition of reference status. Models are not commonly used in assessment methods.

Methods vary in terms of the longitudinal spatial scale of application, where data can be collected from fixed or variable reach lengths, generally based on a selection of homogenous reaches or, in some cases, on the entire river length (e.g. MHR in Poland). Several methods select the assessment reach by scaling the length in proportion to the channel width. A few use equally spaced transects or selected point features (e.g. ICE). Most methods uses a qualitative assessment (index and/or score) of river conditions into 5 or 7 quality classes.

Concerning the lateral spatial scale of application, all physical habitat methods perform an analysis on the channel, while a slightly smaller proportion focus also on river banks and riparian areas. It is less common to consider the surrounding floodplain. As the in-channel physical habitats are the main focus of the evaluation, physical habitat assessment methods are often used to support biological sampling (mainly macroinvertebrates).

All methods focus on the assessment of the present river status in terms of temporal scale. In some cases, historical conditions are used as reference conditions, although this approach can be problematic. Reference conditions are explicitly taken into account in more than half of methods. This is discussed in the next section. Most methods classify physical quality status, based on a quantitative evaluation, using a scoring system, collecting an inventory of features and assessing the river physical condition by calculating a final index. This category also includes methods aiming to evaluate the overall functioning of the stream (e.g. IFF in Italy, SEQ in France). Methods may also include some qualitative evaluation of ecological indicators (ie. vegetation in riparian areas, macroinvertebrates, etc.) to provide an overall evaluation of stream conditions. Color-based maps are the most common study result, which can inform future projects when entered in a spatially explicit GIS format.

Temporal changes in the hydrological regime are rarely considered (e.g. MHR) in stream assessments. This is one area that the stream assessment methodology needs to be modified for Israeli streams, as the temporal changes in the hydrological regime during the annual cycle are significant. Many Israeli streams are ephemeral, flowing only during storm events, while only a small number of streams maintain hydrologic connectivity all year.

The main gap identified by Rinaldi et al, (2013) in existing hydromorphological analysis methods is the insufficient consideration of physical processes, frequently limited to physical habitat, which is only one component of an overall hydromorphological evaluation and does not reveal the ongoing adaptation process essential to river function, based on pressure-responses (i.e. causes-effects). Understanding the geomorphic processes is an essential component for designing and implementing rehabilitation actions. The River Styles Framework (Brierley and Fryirs, 2005), is an example of a morphological assessment procedure that is based on a geomorphological approach.

Approximately half of the methods analyzed collect information on large scale catchment/valley characteristics. The analysis of detailed hydrological information is limited, with most assessment methods characterizing the hydrologic condition only at the time of the survey (e.g. estimation of discharge). In Australia, for example, the hydrological assessment is more detailed and meaningful, considering several properties of the river regime (e.g. Ladson et al., 1999; Parson et al., 2004). In addition, the IHI from South Africa, in its assessment of river perturbations (channel and riparian area) provides specific metrics for the assessment of hydrological alterations (Kleynhans et al., 2008). Some methods are limited to recommending that the assessment should be conducted under specific hydrological conditions such as during the early summer and during low flows.

All methods include a field component as part of the assessment to contribute towards several objectives, including to survey the presence/absence of selected river features, to measure specific river characteristics, and to qualitatively evaluate some component of the assessment. Specific channel features evaluated in most assessment methods include: channel pattern, channel forms, channel dimensions, flow-types, bed substrate, in-channel vegetation, presence of woody debris, and artificial features. Many of these methods evaluate banks/riparian zones feature, such as bank profile, occasionally bank material, artificial features and land use.

Most methods record channel dimensions, although usually this is limited to a visual estimation of channel width. In contrast, few methods measure the extent of bed features (i.e. bars, islands, etc.), (ie.Australian AusRivAs). Methods rarely incorporate measurements of bank or floodplain widths. In terms of substrate characterization, most methods provide some information on sediment size and composition, while very few methods assess sediment substrate alterations such as channel armouring and clogging (or embeddedness) (e.g. the French CarHyCE, the Australian AusRivAs). This can be explained by the difficulties of assessing substrate alteration. Most methods include in their assessment the evaluation of in-channel artificial features (i.e. dams, weirs, culverts, deflectors, etc.), which can potentially alter the presence and quality of physical habitats.

Both the banks and riparian zone strongly influence the channel, therefore, many methods evaluate the presence of artificial features (e.g. bank protection, dykes, channelization, etc.) and land use. The extent of bank erosion assessment varies substantially. However, many methods collect features related to bank profile and shape, indicators of the presence of potential habitats for biota (refugia), rather than information on bank stability. However the assessment of longitudinal, lateral and erosion processes can be obtained in part indirectly from the assessment and inventorying of natural and artificial features. On the other hand, a very small proportion of methods take account of processes related to channel adjustments (widening/narrowing, aggradation/degradation).

Only a small proportion of assessment methods collect specific information on fluvial forms in the floodplain (e.g. presence of oxbow lakes and wetlands), while land use coverage is often assessed. Information on the presence of fluvial forms in the floodplain is useful for the assessment of the state of lateral hydraulic connectivity.

*3. Riparian habitat assessment, hydrologic regime and fish barriers*

Riparian habitat assessment methods aim to identify, survey and assess riparian habitat conditions of rivers and streams in their present condition (at the time of the survey). Some riparian zone measurements focus on the degree of naturalness of riparian vegetation on a reach scale (e.g. structure, continuity, coverage). Riparian systems have been considered to be an integral component of riverine systems for several decades (González Del Tánago & García De Jalón, 2006), but the development of specific methods devoted to assessing riparian ecosystem conditions are a relatively recent practice, at least in Europe (Munné & Prat, 1998).

The assessment of riparian conditions general follow field assessment protocols, some using rapid field assessment protocols (using index/quality classes). Remote sensing techniques remain limited, while no methods make use of data derived from modelling techniques. Some methods make an inventory of features, which often correspond with the sampling of vegetation community composition. These methods are similar in scale to physical habitat assessments, with riparian habitat assessments focused on the reach scale, within areas of homogenous vegetation characteristics (variable reach lengths). Several methods define, a priori, the size of the river reach to be assessed (e.g. 100m x 100m in the Italian BSI&WSI). The Spanish RFV is the only example in which reach length is scaled to channel width; this method is more geomorphologically-based in comparison with others.

Vegetation features frequently measured include: vegetation structure (i.e. herbs, shrubs, trees), vegetation longitudinal continuity, vegetation width, specie composition and coverage; occasionally vegetation regeneration and riparian soil. Riparian structure and longitudinal continuity are assessed by about 70% of methods, whereas the riparian vegetation width is assessed by only 50%. Emphasis is placed on the presence of exotic species and their abundance in comparison with endemic ones. The width of the riparian vegetation buffer along a river is also considered, given that it may support the quality of lateral riparian habitat continuity, and connectivity with its floodplain (floodplain land use). Concerning the floodplain, methods collect data mainly on land use and fluvial forms (providing information on lateral connectivity).

Morphological assessment. Only a small proportion of methods attempt to relate the assessment to river processes, using methods to conduct a geomorphological evaluation rather than a physical habitat assessment, incorporating morphological characteristics and/or human pressures on hydromorphology. These methods differ from physical habitat assessment methods as they have a broader geomorphological perspective, and give a greater consideration to physical processes (e.g. hydrological and sediment continuity, sediment transport, erosion, channel adjustments) and alterations derived from human pressures. They are generally applied at the reach and catchment scales and generally evaluate the river hydromorphological conditions at a greater temporal scale. Longitudinal connectivity for both water flow and sediment flux are generally determined indirectly, based on presence of transversal structures. Less than 40% of methods evaluate channel adjustments.

Assessment of hydrological regime alteration

Physical habitat assessment methods generally use hydrological information only to characterize the hydrologic condition at the time of the survey (e.g. estimation of discharge). Methods for the assessment of hydrological regime alteration analyze specific hydrological indicators of rivers and streams to assess the impact of human pressures on the hydrological regime. They often focus on alterations which affect the longitudinal continuity of water flow (e.g. intakes, impoundment, diversions) and mainly focus on the reach scale. Parameters most commonly analyzed for possible alterations include the five main components of the hydrological regime: magnitude, frequency, timing, duration, rate of change of discharges. These data can be applied using some or all the Indicators of Hydrologic Alteration (IHA, Poff et al., 2003). Additional parameters evaluated occasionally include minimum and maximum flow, annual and inter-annual variability, intermittent flow and a range of pressures such as flood diversions, groundwater interactions, hydro-peaking, impoundment, channel changes and large scale pressures. The source of information can be existing hydrological data series, field data collection, modelling or map/remote sensing. Generally, obtaining existing hydrological data and data on river/land management prevails, although hydrologic data were not analyzed commonly.

One goal for this component of analysis is to assess flow requirements of the many interacting components of aquatic systems (Arthington, 1998; King et al., 2008) and the output is a description of a flow regime needed to achieve and maintain a specified river condition. Assessing flow regime alterations may result in an index evaluating the degree of deviation from unaltered conditions. Relatively few methods exist for the identification and quantification of hydrological regime alteration, even though the scientific community agree on the basic components of the hydrological regime to be assessed (Bussettini et al., 2011).

Indirectly, the HCA Watershed assessment takes into account hydro-peaking as a consequence of morphological alteration. Hydrological assessment methods do not consider physical and spatial relationships between the river and its floodplain (lateral continuity = as consequence of incision) and only a few methods assess the consequences of river degradation.

Typology limitations are specific for each method and country: for e.g. Spanish methods apply mostly to Mediterranean rivers; northern Europe methods are often limited to low energy systems (e.g. DHQI); only the Spanish IHF apparently is applicable to temporary streams. These will be most relevant to this study.

Some assessment methods include an evaluation for fish longitudinal continuity, focused on understanding the impact that cross sectional structures (i.e. barriers) have on the movement and migration of fish communities, often using data from maps and remote sensing analysis. Some collect specific barrier attributes, such as height, slope and material. While early methods simply aim to obtain a database inventory of the location of barriers, more recent methods also attempt to assess the passability of barriers (mainly at the single barrier scale) both in terms of their structural characteristics and of the biological capacities of fish communities to pass them (e.g. swimming/jumping abilities, life history). The most common aim of this category of methods is to support barrier management (prioritize actions, e.g. remove barrier and/or build fish pass). This stream is not significant fish habitat and therefore, this component of stream assessment will not be a focus for this study.

In terms of river processes, large scale sediment connectivity has been poorly assessed in most methods. More than 75% of methods assess bank erosion and stability, mostly indirectly and qualitatively (e.g. evidence of bank erosion, bank protection structures). Given that most of the methods focus on physical habitat, river processes related to channel adjustments are generally poorly assessed. Even more infrequent is the assessment of vertical changes (signs of river incision), although the MQI includes guidelines on this assessment.

*4. Reference Sites*

One objective of the geomorphic stream classification methodologies, according to the WFD requirements, is evaluating the deviation of present conditions from a given reference state and potentially using this as a basis to define goals for river restoration. Almost 50% of reviewed methods relate riparian quality to reference conditions. Reference condition comparisons may be based on (i) empirical data obtained from reference sites; (ii) historic information (e.g. old maps); (iii) modelled reference conditions (including conceptual models); (iv) theoretical conditions taken in absence of any relevant alteration; (v) expert judgement selecting representative reaches within the existing stream; (vi) on the historic range of variability and/or evolutionary sequence and ergodic reasoning (Brierley and Fryirs, 2005). One idea is to use the Leitbild concept (e.g. Lawa), corresponding to the equilibrium state that would develop under the present natural setting without further human intrusions. Some methods define “reference conditions” in terms of forms (presence and number of given features) making use of “reference reaches” in present conditions (although these may be partially altered). Although the reference conditions approach is a well-established methodology for the assessment of freshwater ecosystems (e.g. Bailey et al., 2004), the definition of a reference state for hydromorphology is problematic (Jungwirth et al., 2002; Palmer et al., 2005**).** The scientific community recently agreed to renounce using the past or a “pristine” completely undisturbed state as reference condition (Rinaldi, et al, 2013). This is because, besides being extremely difficult to define, it would be associated with watershed conditions completely different from the present.

While there is ongoing debate of reference conditions (Brierley & Fryirs, 2005; Dufour & Piégay, 2009), new concepts and approaches have been introduced that are becoming widely accepted (ie. guiding image, Palmer et al., 2005; evolutionary trajectory, Brierley & Fryirs, 2005). Other options include defining a “dynamic equilibrium” (Clarke et al., 2003; Palmer et al., 2005), or the consideration of “reference processes” or “reference process-form interactions” (Bertoldi et al., 2011) rather than “reference forms”. The concept of evolving fluvial system trends or “trajectory” (Brierley & Fryirs, 2005; Dufour & Piégay, 2009) is important because it focuses not on the recovery to a past condition but ensuring that future actions will be compatible with the existing trends of channel adjustment. It is important to state clearly whether reference conditions are used to assess deviation from a natural condition and/or to define goals for river restoration (Jungwirth et al., 2002).

## *5 Application to WFD*

The evolving science of ecohydromorphology seeks to analyze interventions and impacts aimed at the design of restoration actions, as required by the WFD. The spatial scale of investigation needs to be sufficient to represent the river ecosystem, as limiting the analysis to an individual reach is inadequate for a real diagnosis and comprehension of morphological problems, as the physical degradation of a site is generally the consequence of processes and causes on a wider scale. Streams may suffer from adjustments to land use changes by incising, for example (Surian et al., 2017). While methods that assess present forms (i.e. bars, riffles, pools) may indicate positive features (e.g. a reach changing from a braided to a single thread morphology, but still maintaining a diversity of forms), they often neglect the alterations of processes related to the channel adjustments (e.g. disconnection with floodplain, loss of aquatic and riparian habitats). Some assessment methods (Caravaggio: Siligardi et al., 2002) evaluate the overall ecological functionality of a river reach, although hydromorphological aspects and/or reference conditions may not be used. Recently, a methodological framework of integrated assessment of the ecological status was proposed (FLEA: Fluvial Ecosystem Assessment) (Nardini et al., 2008), which is specific for the requirements of the WFD and also includes the elements of hydromorphological quality. The overall direction of assessment methodology in recent years in including a stronger geomorphological component, with an increasing consideration of physical processes and longer temporal scales.

## *6 Ecological Assessments*

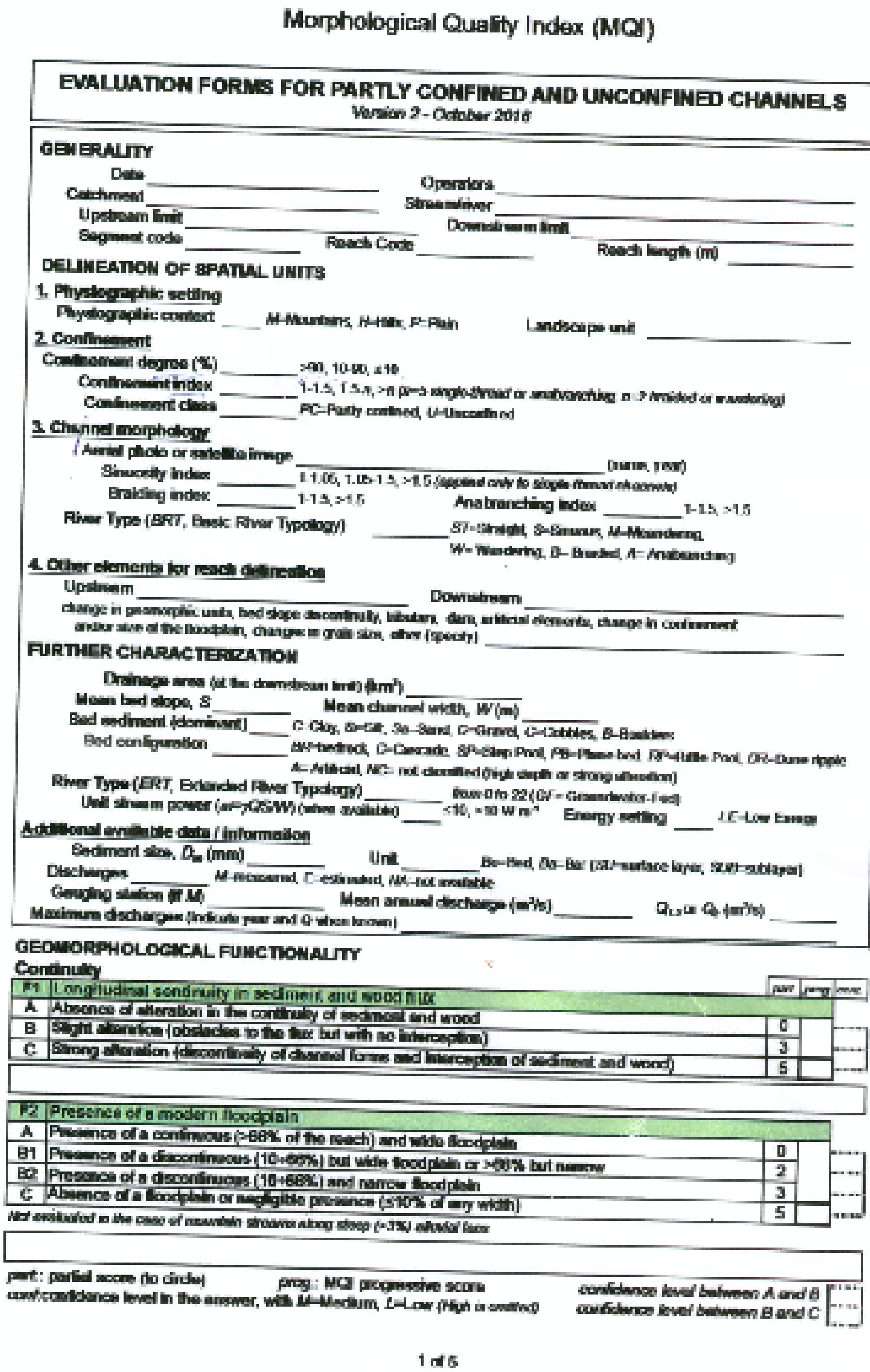
Other methods not directly aimed at WFD compliance target stream evaluation and geomorphological analysis, specifically for management and restoration purposes (ie. Fluvial Audit, 1998; River Styles Framework, Brierley & Fryirs, 2005). Almost half of methods may be able to identify causes of ecological impacts (at least for fish longitudinal continuity). Some methods are specifically used to identify causes of the failure in achievement of the good/high ecological status (i.e. MImAS, RHAT, HEM).

Ecological status assessment methods are generally based on a characterization of different organism groups, comparing current conditions with type-specific reference conditions. Methods are applied in general at the reach scale. Rinaldi et al (2013) reviewed 91 methods covering fish fauna, macrophytes, benthic diatoms, and benthic invertebrates from 27 European countries.  To comply with the WFD, separate assessment methods are required for four ‘biological quality elements’ – fish fauna, macrophytes, benthic diatoms, and benthic invertebrates. For each water body, these assessments are combined using the ‘one out – all out’ rule where the biological quality element with the lowest status determines the final status (Caroni et al, in press).

Other efforts in the US to target the natural features of the stream channel (ie. bed substrate) in designing restoration projects (Rosgen, 1996) has been adopted by the Unites States Army Corp of Engineers (USACE).  These efforts resulted in a methodology to conduct a watershed assessment based on sediment flux and geomorphic processes that targets optimal river stability as a restoration goal (Rosgen, 2006).  Aspects from this work will be incorporated into our study.

The CMA from Oregon (OWEB, 2000) supports a final Watershed Condition Evaluation, when combined with other protocols. Similarly, the recent River Styles Geomorphic Condition (RSGC), developed on the basis of the RSF by Brierley and Fryirs (2005), has been incorporated in the River Condition Index assessment protocol (Healey et al., 2012) to specifically assess the physical component (forms) of the overall assessment of river condition.  Several efforts have recently been devoted to correlating geomorphologic analyses to the ecological state of a stream (ie: Kail & Hering, 2009; Wyżga et al., 2010).  Austria Guidelines for assessing the hydromorphological status of running waters have adopted Mühlmann (2010) as the official method for the assessment of hydromorphological conditions to support the ecological status assessment. Recent efforts to evaluate excellent examples of river restoration across Europe will also advance methodological framework, selected results and recommendations (Muhar, et al. 2016).

## Appendix 2: MQI Protocol and Scoring Criteria



Morphological Quality Index (MQI)

**EVALUATION FORMS FOR PARTLY CONFINED AND UNCONFINED CHANNELS**
*Version 2 - October 2016*

**GENERALITY**

Date ____ Operators ____
Catchment ____ Stream/river ____
Upstream limit ____ Downstream limit ____
Segment code ____ Reach Code ____ Reach length (m) ____

**DELINEATION OF SPATIAL UNITS**

**1. Physiographic setting**
Physiographic context ____ *M*=Mountains, *H*=Hills, *P*=Plain    Landscape unit ____

**2. Confinement**
Confinement degree (%) ____ >90, 10-90, ≤10
Confinement index ____ 1-1.5, 1.5-n, >n (n=5 single-thread or anabranching, n=2 braided or wandering)
Confinement class ____ *PC*=Partly confined, *U*=Unconfined

**3. Channel morphology**
Aerial photo or satellite image ____ (name, year)
Sinuosity index ____ 1-1.05, 1.05-1.5, >1.5 (applied only to single-thread channels)
Braiding index ____ 1-1.5, >1.5    Anabranching index ____ 1-1.5, >1.5
River Type (*BRT*, Basic River Typology) ____ *ST*=Straight, *S*=Sinuous, *M*=Meandering, *W*=Wandering, *B*=Braided, *A*=Anabranching

**4. Other elements for reach delineation**
Upstream ____ Downstream ____
change in geomorphic units, bed slope discontinuity, tributary, dam, artificial elements, change in confinement and/or size of the floodplain, changes in grain size, other (specify) ____

**FURTHER CHARACTERIZATION**

Drainage area (at the downstream limit) ($km^2$) ____
Mean bed slope, *S* ____ Mean channel width, *W* (m) ____
Bed sediment (dominant) ____ *C*=Clay, *Si*=Silt, *Sa*=Sand, *G*=Gravel, *Co*=Cobbles, *B*=Boulders
Bed configuration ____ *BR*=bedrock, *C*=Cascade, *SP*=Step Pool, *PB*=Plane bed, *RP*=Riffle Pool, *DR*=Dune ripple, *A*=Artificial, *NC*=not classified (high depth or strong alteration)
River Type (*ERT*, Extended River Typology) ____ from 0 to 22 (*GW*=Groundwater-Fed)
Unit stream power ($\omega=\gamma QS/W$) (when available) ____ <10, >10 W $m^{-2}$    Energy setting ____ *LE*=Low Energy

**Additional available data / information**
Sediment size, $D_{50}$ (mm) ____ Unit ____ *Be*=Bed, *Ba*=Bar (*SU*=surface layer, *SUB*=sublayer)
Discharges ____ *M*=measured, *E*=estimated, *NA*=not available
Gauging station (if *M*) ____ Mean annual discharge ($m^3/s$) ____ $Q_{1.5}$ or $Q_b$ ($m^3/s$) ____
Maximum discharges (indicate year and Q when known) ____

**GEOMORPHOLOGICAL FUNCTIONALITY**

**Continuity**

| F1 | Longitudinal continuity in sediment and wood flux | part | prog | conf |
|---|---|---|---|---|
| A | Absence of alteration in the continuity of sediment and wood | 0 | | |
| B | Slight alteration (obstacles to the flux but with no interception) | 3 | | |
| C | Strong alteration (discontinuity of channel forms and interception of sediment and wood) | 5 | | |

| F2 | Presence of a modern floodplain | part | prog | conf |
|---|---|---|---|---|
| A | Presence of a continuous (>66% of the reach) and wide floodplain | 0 | | |
| B1 | Presence of a discontinuous (10÷66%) but wide floodplain or >66% but narrow | 2 | | |
| B2 | Presence of a discontinuous (10÷66%) and narrow floodplain | 3 | | |
| C | Absence of a floodplain or negligible presence (≤10% of any width) | 5 | | |

*Not evaluated in the case of mountain streams along steep (>3%) alluvial fans*

part: partial score (to circle)    prog.: MQI progressive score
conf: confidence level in the answer, with *M*=Medium, *L*=Low (*High is omitted*)
*confidence level between A and B*
*confidence level between B and C*

1 of 5

Fig. 68: MQI Protocol and Scoring criteria

**Appendix 3: Tzipori Field Data Collection Sheet (June 2017 survey)**
**Data collection method using application Collector by ESRI**

Date

| | | |
|---|---|---|
| | sample location | inside channel |
| | | channel bank |
| | | within 5 m channel |
| | | within 10 m channel |
| code | Metric | description |
| 1 | channel width | |
| 2 | physiographic unit | hills |
| | | lowlands |
| 3 | Confinement | partly confined |
| | | unconfined |
| 4 | morphology | straight |
| | | wandering |
| | | meandering |
| | | sinuous |
| 5 | Bed Sediment | bedrock |
| | | boulders |
| | | cobbles |
| | | gravel |
| | | sand |
| | | silt |
| | | clay |
| | | concrete |
| 6 | configuration | cascade |
| | | step pool |
| | | plane bed |
| | | riffle pool |
| | | dune ripple |
| | | artificial |
| | | spring pool |
| | | sand bars |
| 7 | stream power | fast moving |
| | | slow moving |
| | | stagnant |
| 8 | longitudinal connectivity | absence of alteration |
| | | slight alteration |
| | | strong alteration |

| | | |
|---|---|---|
| 9 | floodplain | continuous and wide |
| | | discontinuous |
| | | no floodplain |
| 10 | Bank condition | >10 % eroded |
| | | <10% but significant |
| | | not significant |
| 11 | Erodible corridor | >66% |
| | | 33-66% |
| | | <33 % |
| 12 | Sediment transport | deposition fans |
| | | gullies |
| | | no signs of sediment loss |
| 13 | morphological pattern | natural |
| | | <33 % altered |
| | | >33% altered |
| 14 | channel pattern | tributary entering |
| | | oxbow lakes |
| | | secondary channel |
| | | historic remnant |
| | | braiding |
| | | anabranching |
| | | none |
| 15 | cross section | collected RTK |
| | | homogenous |
| | | heterogenous |
| 16 | Bed structure | natural |
| | | amoring or clogging <50% |
| | | amoring or clogging >50% |
| | | substantial burial |
| 17 | wood | large wood whole reach |
| | | some wood <50% |
| | | minimal wood |
| 18 | vegetation width | |
| | | ag adjacent |
| | | dirt farm road no veg |
| | | aquatic vegetation |
| | | trees inside channel |
| | | vegetation sprayed |
| 19 | vegetation length | continous |

| | | |
|---|---|---|
| | | 33-90% |
| | | <33% |
| 20 | features | trees |
| | | boulders in river |
| | | boulders on banks |
| | | |
| | | |
| | | tracks from ORV |
| | | cow manure |
| | | wetlands present |
| | | impoundment |
| | | sediment removal site |
| | | fencing |
| | | pipes |
| | | visible habitat use |
| 21 | flow continuity | no significant alteration |
| | | Some alteration |
| | | Significant alteration |
| | | artificial river channel |
| 22 | Flow Modification | diversion |
| | | dam |
| | | withdrawals |
| | | weirs |
| | | none |
| 23 | Flow connectivity | presence of baseflow |
| | | isolated pools |
| | | dry bed |
| 24 | crossing structures | none |
| | | bridge |
| | | culvert |
| | | concrete trench |
| | | road |
| | | irish bridge |
| 25 | Bank Protection | natural bank |
| | | armoring |
| | | levees |
| | | bed stabilization |
| 26 | Water Quality | ph |
| | | EC |

**Appendix 4: Complete Land Use Analysis**

**( by segment and by distance categories from the stream)**

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | Area (sqm) | 1,331,988 | 25 | 85,110 | 0 | 29,205 | 0 | 1,446,328 |
| | | % Lands | 92% | 0% | 6% | 0% | 2% | 0% | 100% |
| | 10m | Area (sqm) | 131 | 0 | 1,876 | 0 | 9,296 | 0 | 11,303 |
| | | % Lands | 1% | 0% | 17% | 0% | 82% | 0% | 100% |
| | 25m | Area (sqm) | 4,329 | 0 | 8,626 | 0 | 15,362 | 0 | 28,317 |
| | | % Lands | 15% | 0% | 30% | 0% | 54% | 0% | 100% |
| | 50m | Area (sqm) | 15,590 | 0 | 20,267 | 0 | 18,411 | 0 | 54,268 |
| | | % Lands | 29% | 0% | 37% | 0% | 34% | 0% | 100% |
| | 100 m | Area (sqm) | 18,653 | 0 | 33,771 | 0 | 21,754 | 0 | 74,178 |
| | | % Lands | 25% | 0% | 46% | 0% | 29% | 0% | 100% |
| | 500 m | Area (sqm) | 356,337 | 0 | 83,385 | 0 | 20,945 | 0 | 460,666 |
| | | % Lands | 77% | 0% | 18% | 0% | 5% | 0% | 100% |
| 2 | | Area (sqm) | 14,043,656 | 4,054,896 | 7,211,859 | 2,547,662 | 3,831,720 | 1,389,289 | 33,079,081 |
| | | % Lands | 42% | 12% | 22% | 8% | 12% | 4% | 100% |
| | 10m | Area (sqm) | 9,471 | 6,695 | 92,834 | 9,469 | 20,518 | 0 | 138,987 |
| | | % Lands | 7% | 5% | 67% | 7% | 15% | 0% | 100% |
| | 25m | Area (sqm) | 97,446 | 15,393 | 155,967 | 30,331 | 48,295 | 0 | 347,433 |
| | | % Lands | 28% | 4% | 45% | 9% | 14% | 0% | 100% |
| | 50m | Area (sqm) | 284,690 | 28,040 | 244,940 | 65,012 | 72,504 | 0 | 695,187 |
| | | % Lands | 41% | 4% | 35% | 9% | 10% | 0% | 100% |
| | 100 m | Area (sqm) | 711,176 | 41,547 | 413,513 | 118,952 | 104,727 | 0 | 1,389,915 |
| | | % Lands | 51% | 3% | 30% | 9% | 8% | 0% | 100% |

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| | 500 m | Area (sqm) | 4,343,431 | 120,997 | 1,509,005 | 431,297 | 406,028 | 47,816 | 6,858,575 |
| | | % Lands | 63% | 2% | 22% | 6% | 6% | 1% | 100% |
| 3 | | Area (sqm) | 601,095 | 629,889 | 157,234 | 547,755 | 1,769,706 | 967,347 | 4,673,027 |
| | | % Lands | 13% | 13% | 3% | 12% | 38% | 21% | 100% |
| | 10m | Area (sqm) | 1,570 | 0 | 2,809 | 367 | 22,159 | 0 | 26,906 |
| | | % Lands | 6% | 0% | 10% | 1% | 82% | 0% | 100% |
| | 25m | Area (sqm) | 18,032 | 0 | 5,763 | 12,599 | 30,601 | 0 | 66,994 |
| | | % Lands | 27% | 0% | 9% | 19% | 46% | 0% | 100% |
| | 50m | Area (sqm) | 50,420 | 2,258 | 10,108 | 36,980 | 34,044 | 0 | 133,811 |
| | | % Lands | 38% | 2% | 8% | 28% | 25% | 0% | 100% |
| | 100 m | Area (sqm) | 109,075 | 12,585 | 15,388 | 86,951 | 40,690 | 6,514 | 271,204 |
| | | % Lands | 40% | 5% | 6% | 32% | 15% | 2% | 100% |
| | 500 m | Area (sqm) | 331,085 | 152,937 | 53,266 | 398,087 | 257,368 | 251,248 | 1,443,991 |
| | | % Lands | 23% | 11% | 4% | 28% | 18% | 17% | 100% |
| 4 | | Area (sqm) | 771,137 | 3,215,899 | 1,051,278 | 260,890 | 1,007,280 | 63,311 | 6,369,795 |
| | | % Lands | 12% | 50% | 17% | 4% | 16% | 1% | 100% |
| | 10m | Area (sqm) | 5,425 | 0 | 4 | 125 | 24,688 | 0 | 30,242 |
| | | % Lands | 18% | 0% | 0% | 0% | 82% | 0% | 100% |
| | 25m | Area (sqm) | 35,922 | 0 | 4 | 843 | 39,083 | 0 | 75,852 |
| | | % Lands | 47% | 0% | 0% | 1% | 52% | 0% | 100% |
| | 50m | Area (sqm) | 95,156 | 0 | 56 | 2,036 | 54,448 | 0 | 151,695 |
| | | % Lands | 63% | 0% | 0% | 1% | 36% | 0% | 100% |
| | 100 m | Area (sqm) | 212,078 | 1,923 | 6,476 | 6,237 | 82,688 | 0 | 309,401 |
| | | % Lands | 69% | 1% | 2% | 2% | 27% | 0% | 100% |
| | 500 m | Area (sqm) | 506,843 | 164,846 | 42,132 | 44,593 | 348,353 | 63,589 | 1,170,355 |

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | % Lands | 43% | 14% | 4% | 4% | 30% | 5% | 100% |
| 5 | | Area (sqm) | 818,049 | 1,937,124 | 307,832 | 290,730 | 862,230 | 93,947 | 4,309,912 |
| | | % Lands | 19% | 45% | 7% | 7% | 20% | 2% | 100% |
| | 10m | Area (sqm) | 14,725 | 0 | 13,305 | 2,361 | 19,713 | 0 | 50,104 |
| | | % Lands | 29% | 0% | 27% | 5% | 39% | 0% | 100% |
| | 25m | Area (sqm) | 55,615 | 0 | 17,404 | 13,971 | 38,854 | 0 | 125,844 |
| | | % Lands | 44% | 0% | 14% | 11% | 31% | 0% | 100% |
| | 50m | Area (sqm) | 130,728 | 0 | 18,591 | 34,660 | 68,573 | 0 | 252,552 |
| | | % Lands | 52% | 0% | 7% | 14% | 27% | 0% | 100% |
| | 100 m | Area (sqm) | 260,218 | 6,783 | 24,823 | 72,439 | 130,851 | 0 | 495,115 |
| | | % Lands | 53% | 1% | 5% | 15% | 26% | 0% | 100% |
| | 500 m | Area (sqm) | 499,669 | 663,943 | 123,358 | 158,161 | 445,205 | 93,947 | 1,984,283 |
| | | % Lands | 25% | 33% | 6% | 8% | 22% | 5% | 100% |
| 6 | | Area (sqm) | 1,388,275 | 3,588,297 | 1,249,369 | 705,622 | 1,413,485 | 1,045,566 | 9,390,615 |
| | | % Lands | 15% | 38% | 13% | 8% | 15% | 11% | 100% |
| | 10m | Area (sqm) | 4,859 | 5 | 6,325 | 3,566 | 32,047 | 0 | 46,803 |
| | | % Lands | 10% | 0% | 14% | 8% | 68% | 0% | 100% |
| | 25m | Area (sqm) | 38,568 | 1,670 | 7,933 | 20,525 | 47,204 | 0 | 115,900 |
| | | % Lands | 33% | 1% | 7% | 18% | 41% | 0% | 100% |
| | 50m | Area (sqm) | 104,857 | 10,106 | 8,289 | 50,893 | 55,548 | 0 | 229,693 |
| | | % Lands | 46% | 4% | 4% | 22% | 24% | 0% | 100% |
| | 100 m | Area (sqm) | 214,437 | 53,273 | 9,799 | 110,193 | 71,950 | 0 | 459,652 |
| | | % Lands | 47% | 12% | 2% | 24% | 16% | 0% | 100% |
| | 500 m | Area (sqm) | 709,983 | 670,175 | 121,349 | 253,424 | 484,455 | 0 | 2,239,385 |
| | | % Lands | 32% | 30% | 5% | 11% | 22% | 0% | 100% |

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| 7 | | Area (sqm) | 3,274,102 | 4,949,164 | 2,609,473 | 2,225,565 | 2,018,273 | 1,358,873 | 16,435,450 |
| | | % Lands | 20% | 30% | 16% | 14% | 12% | 8% | 100% |
| | 10m | Area (sqm) | 12,974 | 0 | 8,529 | 7,523 | 55,015 | 0 | 84,041 |
| | | % Lands | 15% | 0% | 10% | 9% | 65% | 0% | 100% |
| | 25m | Area (sqm) | 67,320 | 1,850 | 10,460 | 47,110 | 83,109 | 0 | 209,849 |
| | | % Lands | 32% | 1% | 5% | 22% | 40% | 0% | 100% |
| | 50m | Area (sqm) | 174,635 | 12,508 | 14,034 | 119,337 | 98,620 | 465 | 419,600 |
| | | % Lands | 42% | 3% | 3% | 28% | 24% | 0% | 100% |
| | 100 m | Area (sqm) | 359,370 | 63,053 | 36,640 | 228,399 | 142,802 | 12,287 | 842,551 |
| | | % Lands | 43% | 7% | 4% | 27% | 17% | 1% | 100% |
| | 500 m | Area (sqm) | 813,077 | 904,623 | 676,347 | 644,815 | 773,873 | 338,652 | 4,151,386 |
| | | % Lands | 20% | 22% | 16% | 16% | 19% | 8% | 100% |
| 8 | | Area (sqm) | 1,188,464 | 823,275 | 252,341 | 31,116 | 407,837 | 439,394 | 3,142,427 |
| | | % Lands | 38% | 26% | 8% | 1% | 13% | 14% | 100% |
| | 10m | Area (sqm) | 1,375 | 0 | 904 | 7 | 28,630 | 0 | 30,916 |
| | | % Lands | 4% | 0% | 3% | 0% | 93% | 0% | 100% |
| | 25m | Area (sqm) | 14,351 | 0 | 2,535 | 7 | 61,007 | 55 | 77,956 |
| | | % Lands | 18% | 0% | 3% | 0% | 78% | 0% | 100% |
| | 50m | Area (sqm) | 68,169 | 41 | 6,739 | 7 | 80,722 | 5,337 | 161,015 |
| | | % Lands | 42% | 0% | 4% | 0% | 50% | 3% | 100% |
| | 100 m | Area (sqm) | 187,205 | 14,401 | 7,353 | 1,950 | 96,147 | 23,866 | 330,922 |
| | | % Lands | 57% | 4% | 2% | 1% | 29% | 7% | 100% |
| | 500 m | Area (sqm) | 757,179 | 239,739 | 67,752 | 6,344 | 345,428 | 211,659 | 1,628,100 |
| | | % Lands | 47% | 15% | 4% | 0% | 21% | 13% | 100% |
| 9 | | Area (sqm) | 57,826,543 | 27,060,142 | 28,215,072 | 26,145,253 | 58,808,082 | 34,887,068 | 232,942,161 |

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | % Lands | 25% | 12% | 12% | 11% | 25% | 15% | 100% |
| | 10m | Area (sqm) | 39,838 | 1,121 | 15,304 | 0 | 6,299 | 0 | 62,562 |
| | | % Lands | 64% | 2% | 24% | 0% | 10% | 0% | 100% |
| | 25m | Area (sqm) | 109,163 | 16,687 | 20,192 | 0 | 9,619 | 7,926 | 163,586 |
| | | % Lands | 67% | 10% | 12% | 0% | 6% | 5% | 100% |
| | 50m | Area (sqm) | 228,284 | 45,383 | 23,258 | 0 | 13,730 | 35,374 | 346,030 |
| | | % Lands | 66% | 13% | 7% | 0% | 4% | 10% | 100% |
| | 100 m | Area (sqm) | 424,649 | 139,346 | 27,901 | 0 | 24,561 | 122,425 | 738,882 |
| | | % Lands | 57% | 19% | 4% | 0% | 3% | 17% | 100% |
| | 500 m | Area (sqm) | 1,117,502 | 1,701,637 | 163,070 | 14,106 | 266,448 | 1,263,716 | 4,526,479 |
| | | % Lands | 25% | 38% | 4% | 0% | 6% | 28% | 100% |
| 10 | | Area (sqm) | 429,662 | 1,161,317 | 99,344 | 0 | 65,009 | 629,480 | 2,384,812 |
| | | % Lands | 18% | 49% | 4% | 0% | 3% | 26% | 100% |
| | 10m | Area (sqm) | 29,638 | 0 | 999 | 0 | 5,785 | 0 | 36,422 |
| | | % Lands | 81% | 0% | 3% | 0% | 16% | 0% | 100% |
| | 25m | Area (sqm) | 79,422 | 1,081 | 2,756 | 0 | 7,521 | 307 | 91,087 |
| | | % Lands | 87% | 1% | 3% | 0% | 8% | 0% | 100% |
| | 50m | Area (sqm) | 150,330 | 13,362 | 5,782 | 0 | 11,417 | 5,779 | 186,671 |
| | | % Lands | 81% | 7% | 3% | 0% | 6% | 3% | 100% |
| | 100 m | Area (sqm) | 235,822 | 99,112 | 6,960 | 0 | 18,855 | 52,721 | 413,469 |
| | | % Lands | 57% | 24% | 2% | 0% | 5% | 13% | 100% |
| | 500 m | Area (sqm) | 429,662 | 1,073,519 | 61,814 | 0 | 56,786 | 583,683 | 2,205,465 |
| | | % Lands | 19% | 49% | 3% | 0% | 3% | 26% | 100% |
| 11 | | Area (sqm) | 101,324 | 770,741 | 2,449 | 0 | 61,414 | 716,089 | 1,652,018 |
| | | % Lands | 6% | 47% | 0% | 0% | 4% | 43% | 100% |

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| | 10m | Area (sqm) | 5,436 | 2,048 | 0 | 0 | 4,315 | 0 | 11,798 |
| | | % Lands | 46% | 17% | 0% | 0% | 37% | 0% | 100% |
| | 25m | Area (sqm) | 14,575 | 9,197 | 0 | 0 | 5,603 | 0 | 29,375 |
| | | % Lands | 50% | 31% | 0% | 0% | 19% | 0% | 100% |
| | 50m | Area (sqm) | 30,113 | 22,437 | 0 | 0 | 6,208 | 0 | 58,758 |
| | | % Lands | 51% | 38% | 0% | 0% | 11% | 0% | 100% |
| | 100 m | Area (sqm) | 61,770 | 46,422 | 0 | 0 | 8,060 | 0 | 116,252 |
| | | % Lands | 53% | 40% | 0% | 0% | 7% | 0% | 100% |
| | 500 m | Area (sqm) | 101,324 | 470,636 | 2,449 | 0 | 28,391 | 382,961 | 985,761 |
| | | % Lands | 10% | 48% | 0% | 0% | 3% | 39% | 100% |
| 12 | | Area (sqm) | 114,167 | 299,433 | 22,476 | 78,807 | 106,562 | 34,479 | 655,924 |
| | | % Lands | 17% | 46% | 3% | 12% | 16% | 5% | 100% |
| | 10m | Area (sqm) | 7,093 | 0 | 0 | 3,761 | 2,439 | 0 | 13,293 |
| | | % Lands | 53% | 0% | 0% | 28% | 18% | 0% | 100% |
| | 25m | Area (sqm) | 19,250 | 197 | 0 | 9,183 | 4,786 | 0 | 33,416 |
| | | % Lands | 58% | 1% | 0% | 27% | 14% | 0% | 100% |
| | 50m | Area (sqm) | 39,337 | 1,476 | 0 | 18,568 | 7,412 | 0 | 66,792 |
| | | % Lands | 59% | 2% | 0% | 28% | 11% | 0% | 100% |
| | 100 m | Area (sqm) | 72,351 | 10,896 | 6,343 | 31,059 | 13,324 | 2,252 | 136,224 |
| | | % Lands | 53% | 8% | 5% | 23% | 10% | 2% | 100% |
| | 500 m | Area (sqm) | 109,931 | 295,648 | 15,858 | 58,315 | 96,921 | 34,479 | 611,153 |
| | | % Lands | 18% | 48% | 3% | 10% | 16% | 6% | 100% |
| 13 | | Area (sqm) | 2,518,667 | 1,717,403 | 5,652,412 | 3,467,201 | 5,314,260 | 565,997 | 19,235,939 |
| | | % Lands | 13% | 9% | 29% | 18% | 28% | 3% | 100% |
| | 10m | Area (sqm) | 4,227 | 0 | 0 | 1,335 | 19,480 | 0 | 25,041 |

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | % Lands | 17% | 0% | 0% | 5% | 78% | 0% | 100% |
| | 25m | Area (sqm) | 80,858 | 0 | 36,651 | 49,878 | 53,982 | 0 | 221,369 |
| | | % Lands | 37% | 0% | 17% | 23% | 24% | 0% | 100% |
| | 50m | Area (sqm) | 152,402 | 4,477 | 67,648 | 95,149 | 71,354 | 14 | 391,045 |
| | | % Lands | 39% | 1% | 17% | 24% | 18% | 0% | 100% |
| | 100 m | Area (sqm) | 259,447 | 46,041 | 163,196 | 175,318 | 139,198 | 19,647 | 802,847 |
| | | % Lands | 32% | 6% | 20% | 22% | 17% | 2% | 100% |
| | 500 m | Area (sqm) | 797,252 | 578,570 | 1,499,043 | 1,156,473 | 1,334,918 | 437,897 | 5,804,152 |
| | | % Lands | 14% | 10% | 26% | 20% | 23% | 8% | 100% |
| 13a | | Area (sqm) | 17,583 | 19,990 | 0 | 8,845 | 16,224 | 0 | 62,641 |
| | | % Lands | 28% | 32% | 0% | 14% | 26% | 0% | 100% |
| 14 | | Area (sqm) | 156,858 | 50,461 | 86,472 | 97,379 | 116,064 | 48,190 | 555,423 |
| | | % Lands | 28% | 9% | 16% | 18% | 21% | 9% | 100% |
| | 10m | Area (sqm) | 3,320 | 0 | 1,921 | 1,894 | 5,532 | 0 | 12,668 |
| | | % Lands | 26% | 0% | 15% | 15% | 44% | 0% | 100% |
| | 25m | Area (sqm) | 11,673 | 0 | 5,582 | 5,847 | 6,904 | 0 | 30,006 |
| | | % Lands | 39% | 0% | 19% | 19% | 23% | 0% | 100% |
| | 50m | Area (sqm) | 24,946 | 0 | 8,805 | 15,174 | 10,608 | 0 | 59,533 |
| | | % Lands | 42% | 0% | 15% | 25% | 18% | 0% | 100% |
| | 100 m | Area (sqm) | 38,097 | 0 | 19,892 | 32,004 | 29,269 | 1,946 | 121,207 |
| | | % Lands | 31% | 0% | 16% | 26% | 24% | 2% | 100% |
| | 500 m | Area (sqm) | 156,858 | 49,435 | 86,218 | 97,379 | 114,213 | 48,190 | 552,292 |
| | | % Lands | 28% | 9% | 16% | 18% | 21% | 9% | 100% |
| 15 | | Area (sqm) | 1,920,945 | 517,136 | 1,981,875 | 2,595,416 | 3,325,135 | 131,777 | 10,472,284 |
| | | % Lands | 18% | 5% | 19% | 25% | 32% | 1% | 100% |

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| | 10m | Area (sqm) | 21,114 | 0 | 13,678 | 15,548 | 13,226 | 0 | 63,566 |
| | | % Lands | 33% | 0% | 22% | 24% | 21% | 0% | 100% |
| | 25m | Area (sqm) | 62,360 | 0 | 24,838 | 45,268 | 26,344 | 0 | 158,810 |
| | | % Lands | 39% | 0% | 16% | 29% | 17% | 0% | 100% |
| | 50m | Area (sqm) | 126,568 | 0 | 41,707 | 101,364 | 45,837 | 0 | 315,476 |
| | | % Lands | 40% | 0% | 13% | 32% | 15% | 0% | 100% |
| | 100 m | Area (sqm) | 230,708 | 0 | 82,974 | 214,027 | 99,225 | 0 | 626,934 |
| | | % Lands | 37% | 0% | 13% | 34% | 16% | 0% | 100% |
| | 500 m | Area (sqm) | 680,370 | 0 | 512,829 | 1,025,349 | 976,444 | 61,475 | 3,256,467 |
| | | % Lands | 21% | 0% | 16% | 31% | 30% | 2% | 100% |
| 16 | | Area (sqm) | 45,819 | 85,893 | 1,308,682 | 253,862 | 623,434 | 0 | 2,317,691 |
| | | % Lands | 2% | 4% | 56% | 11% | 27% | 0% | 100% |
| | 10m | Area (sqm) | 0 | 0 | 592 | 5,028 | 5,820 | 0 | 11,440 |
| | | % Lands | 0% | 0% | 5% | 44% | 51% | 0% | 100% |
| | 25m | Area (sqm) | 0 | 0 | 3,199 | 12,906 | 13,026 | 0 | 29,132 |
| | | % Lands | 0% | 0% | 11% | 44% | 45% | 0% | 100% |
| | 50m | Area (sqm) | 9 | 0 | 11,376 | 26,598 | 21,285 | 0 | 59,269 |
| | | % Lands | 0% | 0% | 19% | 45% | 36% | 0% | 100% |
| | 100 m | Area (sqm) | 5,265 | 0 | 36,173 | 50,525 | 28,847 | 0 | 120,810 |
| | | % Lands | 4% | 0% | 30% | 42% | 24% | 0% | 100% |
| | 500 m | Area (sqm) | 23,710 | 0 | 302,055 | 163,153 | 69,336 | 0 | 558,253 |
| | | % Lands | 4% | 0% | 54% | 29% | 12% | 0% | 100% |
| 17 | | Area (sqm) | 26,144 | 373,416 | 1,873,919 | 316,428 | 807,227 | 0 | 3,397,134 |
| | | % Lands | 1% | 11% | 55% | 9% | 24% | 0% | 100% |
| | 10m | Area (sqm) | 970 | 0 | 11,793 | 2,056 | 3,339 | 0 | 18,158 |

| Segment | | | Annual Row Crops | Forest | Impermeable land (built) | Perenial orchards | Undeveloped | Grazed land* | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | % Lands | 5% | 0% | 65% | 11% | 18% | 0% | 100% |
| | 25m | Area (sqm) | 1,721 | 0 | 30,982 | 5,247 | 7,599 | 0 | 45,548 |
| | | % Lands | 4% | 0% | 68% | 12% | 17% | 0% | 100% |
| | 50m | Area (sqm) | 1,918 | 0 | 69,974 | 9,403 | 10,703 | 0 | 91,998 |
| | | % Lands | 2% | 0% | 76% | 10% | 12% | 0% | 100% |
| | 100 m | Area (sqm) | 1,919 | 0 | 155,387 | 13,029 | 18,124 | 0 | 188,459 |
| | | % Lands | 1% | 0% | 82% | 7% | 10% | 0% | 100% |
| | 500 m | Area (sqm) | 3,190 | 0 | 861,331 | 80,120 | 86,943 | 0 | 1,031,584 |
| | | % Lands | 0% | 0% | 83% | 8% | 8% | 0% | 100% |

* Grazed land overlaps other areas

**Appendix 5: Species List (Vegetation Sampling conducted May 9, 2018).**

| | |
|---|---|
| *Adiantum capillus-veneris* | שערות-שולמית מצויות |
| *Alopecurus myosuroides* | זנב-שועל ארוך |
| *Ammi majus* | אמיתה גדולה |
| *Apium nodiflorum* | כרפס הביצות |
| *Arundo donax* | עב-קנה שכיח |
| *Centaurea iberica* | דרדר מצוי |
| *Chenopodium vulvaria* | כף-אווז מבאישה |
| *Convolvulus arvensis* | חבלבל השדה |
| *Cuscuta Sp.* | SPכשות |
| *Cynanchum acutum* | חנק מחודד |
| *Cynodon dactylon* | יבלית מצויה |
| *Cyperus longus* | גומא ארוך |
| *Datura ferox* | דטורה אכזרית |
| *Dittrichia viscosa* | טיון דביק |
| *Ecballium elaterium* | ירוקת-החמור מצויה |
| *Epilobium hirsutum* | ערברבה שעירה |
| *Ficus carica* | פיקוס התאנה |
| *Galium aparine* | דבקה זיפנית |
| *Helminthotheca echioides* | תולענית דוקרנית |
| *Hordeum geniculatum* | שעורה נימית |
| *Juncus acutus* | סמר חד |
| *Lactuca serriola* | חסת המצפן |
| *Lythrum junceum* | שנית מתפתלת |
| *Lythrum salicaria* | שנית גדולה |
| *Malva parviflora* | חלמית קטנת-פרחים |
| *Medicago polymorpha* | אספסת מצויה |
| *Melissa officinalis* | מליסה רפואית |
| *Mentha longifolia* | נענע משובלת |
| *Mercurialis annua* | מרקולית מצויה |
| *Nasturtium officinale* | גרגר הנחלים |
| *Ononis spinosa* | שברק קוצני |
| *Parapholis incurva* | דק-זנב קשתני |
| *Parietaria judaica* | כתלית יהודה |
| *Persicaria lapathifolia* | ארכובית הכתמים |
| *Phalaris brachystachys* | חפורית מצויה |
| *Phragmites australis* | קנה מצוי |
| *Piptatherum miliaceum* | נשרן הדוחן |
| *Polygonum equisetiforme* | ארכובית שבטבטית |
| *Polypogon monspeliensis* | עבדקן מצוי |
| *Prosopis farcta* | ינבוט השדה |
| *Ricinus communis* | קקיון מצוי |
| *Rubus sanctus* | פטל קדוש |

| | |
|---|---|
| *Rumex pulcher* | חומעה יפה |
| *Saccharum ravennae* | קנה-סוכר גבוה |
| *Salix acmophylla* | ערבה מחודדת |
| *Schedonorus arundinaceus* | בן-אפר מצוי |
| *Silybum marianum* | גדילן מצוי |
| *Sinapis alba* | חרדל לבן |
| *Solanum nigrum* | סולנום שחור |
| *Sonchus oleraceous* | מרור הגינות |
| *Torilis arvensis* | גזיר מזיק |
| *Trifolium alexandrinum* | תלתן אלכסנדרוני |
| *Trifolium repens* | תלתן זוחל |
| *Urtica pilulifera* | סרפד הכדורים |
| *Verbena officinalis* | ורבנה רפואית |
| *Vicia galeata* | בקית הביצות |
| *Vicia villosa* | בקיה שעירה |
| *Xanthium italicum* | לכיד איטלקי |

**Appendix 6: Stream Water Turbidity and Suspended Sediment Concentrations**

| Sample ID | Date | Segment | SS (mg/l) | Turbidity (NTU) |
|---|---|---|---|---|
| 1 | 04/01/2018 | 13a | ND | 5.73 |
| 3 | 04/01/2018 | 13 | 0.002 | 712 |
| 4 | 04/01/2018 | 12 | 0.00375 | 1891 |
| 5 | 04/01/2018 | 10 | 0.0025 | 743 |
| 6 | 04/01/2018 | <Null> | 0.002692 | 29 |
| 7 | 04/01/2018 | 9 | 0.0028 | 1017 |
| 8 | 04/01/2018 | 8 | 0.0032 | 1203 |
| 9 | 04/01/2018 | 7 | 0.002857 | 84.7 |
| 10 | 04/01/2018 | 6 | 0.002917 | 63 |
| 11 | 04/01/2018 | 5 | 0.002143 | 79 |
| 12 | 29/01/2018 | 13a | 0.001 | ND |
| 13 | 29/01/2018 | 13a | 0.001111 | ND |
| 14 | 29/01/2018 | 13 | 0.0015 | ND |
| 15 | 29/01/2018 | 13 | 0.001 | ND |
| 16 | 29/01/2018 | 10 | 0.000444 | ND |
| 17 | 29/01/2018 | 10 | 0.001111 | ND |
| 18 | 29/01/2018 | 10 | 0.00075 | ND |
| 19 | 29/01/2018 | 12 | 0.001 | ND |
| 20 | 29/01/2018 | 10 | 0.0005 | ND |
| 21 | 29/01/2018 | 9 | 0.00075 | ND |
| 22 | 29/01/2018 | 9 | 0.0005 | ND |
| 24 | 29/01/2018 | 8 | 0.000667 | 26.7 |
| 25 | 29/01/2018 | Y | 0.000714 | 28.3 |
| 26 | 29/01/2018 | 9 | 0.000678 | 17.8 |
| 27 | 29/01/2018 | 7 | 0.00025 | ND |
| 28 | 29/01/2018 | 7a | 0.00075 | ND |
| 29 | 29/01/2018 | 7 | 0.00075 | ND |
| 30 | 29/01/2018 | 6 | 0.000227 | ND |
| 31 | 29/01/2018 | 4 | 0.000444 | ND |
| 32 | 29/01/2018 | 5 | 0.00125 | ND |
| 33 | 29/01/2018 | 6 | 0.001 | ND |
| 34 | 29/01/2018 | 3 | 0.001 | ND |
| 35 | 18/02/2018 | 17 | ND | 12.4 |
| 36 | 18/02/2018 | 15 | ND | 7.8 |
| 37 | 18/02/2018 | 15 | ND | 34.7 |
| 39 | 18/02/2018 | 15 | ND | 739 |
| 41 | 18/02/2018 | 13a | ND | 9.2 |
| 42 | 18/02/2018 | 14 | ND | 34.7 |

| Sample ID | Date | Segment | SS (mg/l) | Turbidity (NTU) |
|---|---|---|---|---|
| 43 | 18/02/2018 | 13 | 0.000476 | 59.3 |
| 44 | 18/02/2018 | 10 | 0.0005 | 82.5 |
| 45 | 18/02/2018 | 12 | 0.0005 | 49.4 |
| 46 | 18/02/2018 | 8 | 0.000476 | ND |
| 47 | 18/02/2018 | Y | 0.0005 | ND |
| 48 | 18/02/2018 | 9 | 0.0005 | 88 |
| 49 | 18/02/2018 | 7 | 0.000667 | ND |
| 50 | 18/02/2018 | 7 | 0.000444 | ND |
| 51 | 18/02/2018 | 6 | 0.000667 | ND |
| 52 | 18/02/2018 | 5 | 0.000667 | ND |
| 53 | 18/02/2018 | 3 | 0.000444 | ND |
| 54 | 18/02/2018 | 2 | 0.00075 | ND |
| 55 | 18/02/2018 | 1 | 0.00075 | ND |

SS= Suspended Sediments; ND= No Data