Monitoring Transboundary Palestinian-Israeli Streams:

Implications for Cooperative Management Strategies

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I. Introduction

For some time, environmental managers have attempted to address the practical implications of the truism that water does not recognize political borders. It is estimated that the world contains 260 transboundary river basins. (Gleick, 2004) Since 1814, some 600 bi-and multi-lateral international agreements deal with non-navigational aspects of water management (Kiss, 2000). The complex, historic religious and territorial rivalries and tensions of the Middle East are exacerbated by the scarcity of water and the large number of surface and groundwater borders that traverse geopolitical boundaries. (Shuval & Dweik, 2007) Moreover, the contrast between the Israel's post-industrial economy and the developing dynamics that characterize its Arab neighbors makes implementation of a common restoration strategy even more difficult.

This article considers the major findings to emerge from a three year study of environmental conditions in two transboundary watersheds that cross the Palestinian Authority (PA) into Israel: the Hebron / Besor and the Zomar / Alexander. (Figure 1 and Figure 2). These stream systems are representative of over ten streams that originate in land under the jurisdiction of the PA in the West Bank and that flow into Israel. (Kaplan, 2004) The current of course goes both ways. . In a few watersheds, such as the Kidron stream which begins with sewage from East Jerusalem and reaches the Dead Sea in the east, the roles are reversed, with the downstream Palestinians receiving Israeli discharges. (Shapira and Mazor 2004, Israel Ministry of Environmental Protection, 2007)

Regardless of their pathway, most transboundary streams in the region are contaminated and characterized by widespread pollution from Palestinian sources (typically raw sewage), as well as a variety of point and nonpoint sources from within Israel. (Avnimelech & Ayalon, 1999; Morel, 2006) The unabated pollution harms instream ecosystems, contaminates ground water and constitutes a general aesthetic and health hazard. (Adler, 1995; Hassan & Egozi, 2001) Managing these natural resources is particularly challenging given the tense security situation and the difficulty of cooperation the governments of two vastly different national entities. (Feitelson & Haddad, 2001; Goodale, 2003) Coordinated management is required, so as the sides muddle towards ultimate reconciliation, meaningful environmental cooperation will require unusual determination and resourcefulness.

Historically, many of the region's streams were fed by high quality spring water. Due to decades of diversions, for agriculture and drinking water, streams have become dry. Beyond direct diversions, flow often is reduced due to a drop in ground water levels from the aquifers that feed the streams. (Juanico and Friedler, 1999) Alternatively, wadis that for generations were ephemeral streams with no flow except for occasional storm incidents have emerged as perennial streams, channeling raw or partially treated industrial or municipal wastes. (Ramat-Hovav Local Industrial Council, 2004; Tal, 2002)

Over the past twenty years, many actions have been taken and resources invested in stream restoration. (Shapira and Mazor 2004) Rehabilitating transboundary streams is an important environmental objective that can improve quality of life, environmental quality and provide a concrete example of the benefits of bi-national cooperation. (Brooks, 1996; Shuval,1986) Yet, cooperation between the PA and Israel remains minimal as a result of the security situation and politics of suspicion which characterizes the international dynamics. As a result, monolithic Israeli efforts to restore transboundary streams have been largely unsuccessful. (Tal, 2006)

There have been isolated exceptions that prove the rule. Among these is modest cooperation existing between Israeli's Hefer Valley and the Palestinian town of TulKarem in treating sewage that is discharged into the Alexander Stream. (Brandeis, 2003) But for the most part, a lack of coordination combined with national policies that do not prioritize environmental initiatives, rehabilitation of the region's streams has been only minimally successful.

Between 2004 and 2007, research was conducted by Palestinian and Israeli researchers to characterize the pollution loadings in the Hebron / Besor and Nablus / Alexander Streams and to consider rehabilitation strategies. Water sampled throughout the watershed with point and nonpoint discharges characterized. A hydrological model was developed, economic analyses of public's willingness to pay for stream restoration and a variety of options assessed. The results confirm the necessity of cooperation in watershed management and establishes several principles that should be at the heart of future cooperative strategies if the region is to successfully pursue the long process of environmental restoration.

II. Study Sites

The Hebron / Besor Watershed

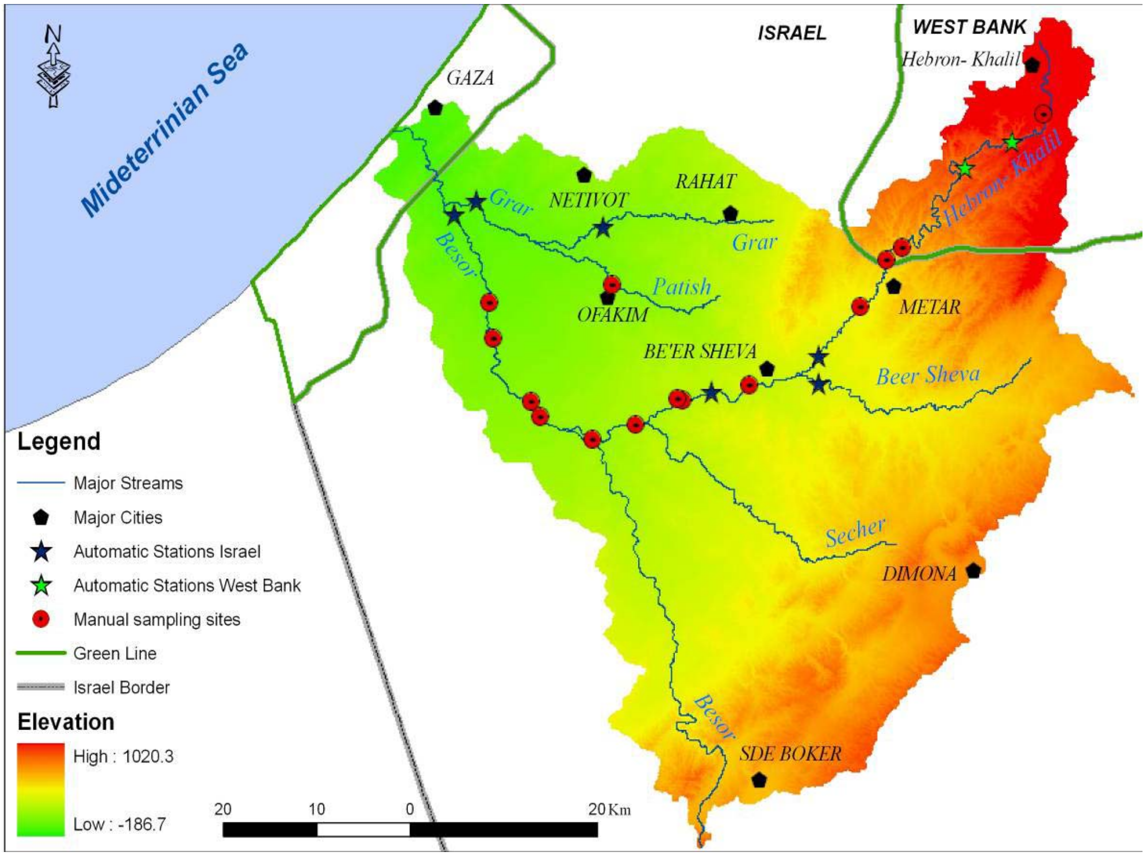
The Hebron / Besor drainage basin covers 3,500 square kilometers, extending from the Hebron Hills in the Palestinian Authority, crossing the border and flowing into the Israeli city of Beer Sheva where it joins water from tributaries in Israel's northern Negev, and ends in the Gaza Strip on the Mediterranean coast. (Figure 1) The basin is the largest of the area's coastal streams, and is characterized by many land uses: urban, rural, industrial, agricultural (both crop and livestock) grazing, firing ranges, and open spaces.

Located in a semi-arid and arid region, the streams in the Hebron/Besor naturally are ephemeral. During a rainy year, water may flow in the watershed six to seven times a year. (Kahana et al., 2002) During the course of the study, rainfall was far below past averages, with only one major rainfall event taking place, raising questions about the long term potential of climate change to affect precipitation patterns in the watershed. (Knowles & Cayan, 2002) This serves to accentuate the predominant role of wastewater in creating a permanent base flow that has changed the nature of the stream.

Since the 1990s the Hebron/ Be'er Sheva stream drains the untreated wastewater of the city of Hebron and the Jewish settlement of Qiryat Arba (Hassan and Egozi, 2001), home to approximately 200,000 residents. In addition to the domestic sewage of the city the stream also drains the wastewater of almost 100 industrial facilities (Morris et al,, 1998).

Recently, a plan has been drafted for the transformation of the Beer Sheva stream into a major recreational venue for the city. (JNF Blueprint Negev, 2006), Like the role of San Antonio River in reinvigorating development in San Antonio Texas, new residential and commercial developments are to be built in order to take advantage of the anticipated free-flowing, meandering green strip through the desert city, with its anticipated parks, sports facilities and artificial lakes. (Christensen, 2001, Eckhardt, 2005) To realize this urban renewal initiative, water quality in the stream must improve dramatically. Consequently, Israel has elected to construct a sewage treatment facility inside its border at the Shoqet Junction, which essentially is to provide secondary treatment for the raw Palestinian sewage that flows through the city. While such monolithic efforts by Israel may ameliorate the problem, study results suggest that a more comprehensive solution is required.

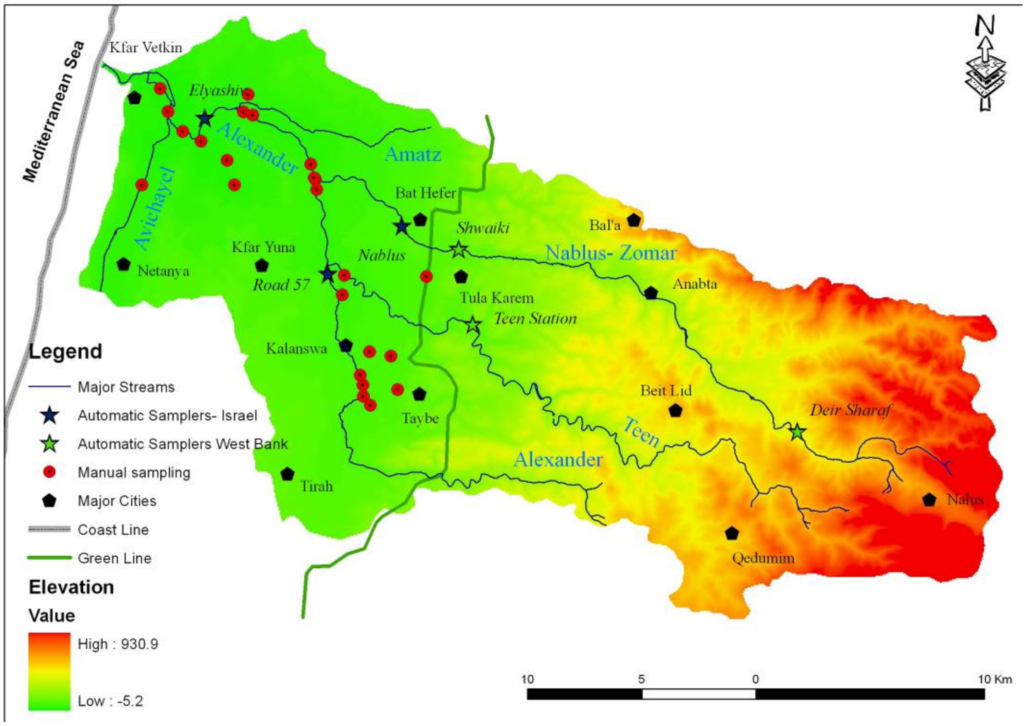
Fig. 1: Hebron / Besor basin and water quality monitoring network



The Zomar / Alexander Watershed

The second watershed assessed in this research drains into the Zomar/Alexander stream. The watershed is far smaller than the Hebron/Besor, covering 600 square kilometers, from the Samaria Mountains in the east, through Israel's rural Hefer Valley, up to its mouth in the western Mediterranean. (Figure 2) The main channel – the "Zomar" – in Arabic or "Alexander" as it is known in Israel has a total length of 44 km, 17 of which are naturally perennial. The western segment of the stream reaches the Mediterranean Sea and is relatively wide, holding water year-round. This estuarial section supports the region's only population of soft-back turtles, for which the stream has become famous.

Fig. 2: Nablus / Alexander Basin and Monitoring Network



The basin shows the effects of fifty years of continuous contamination, associated with the accelerated development and increase in the sewage discharges from the Palestinian cities of Nablus (population, 135,000) and Tulkarem (54,200) as well as several Israeli municipalities, most notably the city of Netanya (population 173,000 and Taibeh, 33,000) the quantity of the effluents discharged into the stream is estimated to be roughly 3 MCM/year (The Ministry of Environmental Protection, 2000). All told, some seventy point sources of pollution continue to flow into the stream. Of particular concern is the seasonal discharge from twenty-six olive oil mills during the October/November harvesting period. The residues, contain extremely heavy organic loadings that do not respond to conventional municipal treatment, posing an enormous burden on the ecological systems of the stream.

The ongoing discharge from production processes in Palestinian stone mills, and a mix of pollutants in the streams caused by leaching from solid waste sites, garage oil, etc. cause addition contamination. Runoff from Israeli agricultural operations also contributes nonpoint pollution sources which the study revealed to be of considerable cumulative impact.

The poor conditions in the stream triggered the establishment of a comprehensive restoration plan in the 1990s that has gained both nationwide and international recognition. The plan was jointly adopted and implemented by Palestinian and Israeli local governments. Sewage treatment for the Netanya municipal sewage was upgraded and the treated wastewater transported to farmers ASIinside the watershed and used for irrigation. Several additional initiatives included scenic rehabilitation, bank stabilization, cleanup campaigns, reduction of several point sources through pre-treatment, parks and recreation areas in which stretches are set aside as a "showpieces" – along with myriad public campaigns to raise awareness about stream rehabilitation efforts.

In 2002, as part of this rehabilitation endeavor, an emergency waste purification facility was built adjacent to Kibbutz Yad Hanah on the edge of the Israeli border that intercepts the sewage discharges coming from the Nablus and Tulkarem regions. Through assistance from the German government, the city of Tulkarem installed a primary treatment facility for its municipal wastes. In 2007, three pilot projects were established on the Yad Hanah site to provide advanced treatment through a variety of biology techniques as preparation for the ultimate upgrading of the facility. Unlike the Shoqet plant, the waste water facility at Yad Hanah was not built unilaterally, but was the outgrowth of ostensibly successful cooperation between the Hefer Valley Regional Council and the city of Tulkarem. Stream conditions improved as a result. While the effluents released into the stream are monitored closely, no study prior to this one has considered the overall pollution loadings into the stream and the long-term prospects for restoration of aquatic ecosystems and recreation. The study, therefore, seeks to assess the lessons learned from restoration efforts thus far in these two watersheds given their new character as "perennial streams" as well as the broader implications for stream restoration to in facilitating environmental cooperation in semi-arid regions.

III. Methodology

A network of automatic hydrometric monitoring stations was set up for taking samples of storm events in the two basins. Four stations were set up in the PA territory, and ten in Israel, (Figure 1 and Figure 2). Monitoring the base flow was an important preliminary step for quantifying the dominant waste water "point source" inputs in both streams. Measurements of the quantity of base flow water discharge (Q) was undertaken at several stations along the Wadis of Hebron/Besor and in the Alexander stream during winter and spring 2006 using the velocity-area method. Discharge was calculated using the equation: $Q = Au$

where A is the cross section area of the stream [m^2] and u is the mean stream flow velocity [m/sec].

The measurements in the Besor stream were performed in seven sites along the stream from upstream to downstream during summer 2005, winter 2006 and spring 2006 (Table 2 and Figure 3), and in the Alexander stream in additional eight sites during summer, 2006. At each chosen location cross-sectional topography was measured to determine A; the average water velocity of 0.20 m-increment water columns was measured at 0.6 of the depth using an electromagnetic current meter (Marsh-McBirney Inc.'s, Flow-mate model 2002). The total discharge is a summation of the partial discharges of all water increments in the cross section. The mean velocity of a water column was measured at 60% of the depth (from the water level). The total discharge is a summation of all the partial discharges from the individual intervals in the cross section. This method assumed that the velocity at each vertical represents the mean velocity in the segment.

The characteristics of base flow during winter, spring and summer 2006 as well as the flood events during the 2005/6, 2006/2007 winter season were characterized based on 289 water samples in the Hebron/Besor streams and 488 samples in the Alexander/Zomar basin. The samples were taken from various locations at different time intervals in the two watersheds, either collected manually from various sampling points along the stream, or by automatic samplers at the permanent stations. The samplers in the stations were programmed to take samples every 15 minutes during the first hour of a rain event and every two hours at later stages, to allow for better characterization of the “first flush effect” where higher concentrations of pollutants are typically found. (Thornton & Saul, 1986; Skipworth et al., 2000; Lee et al., 2002).

All water samples were collected manually or automatically in 1-liter bottles. The bottles were cleaned by first soaking in phosphate-free detergent and then in nitric acid and finally rinsed with deionized water several times. In the field, the bottles were washed again with water from the stream before sampling. The samples were stored in thermally isolated cases filled with ice until they reached the laboratory for analysis and were stored in the lab in refrigerators at 4ºC. *In situ* measurements of water temperature, pH, dissolved oxygen, and electrical conductivity (EC) were taken using portable field multi-parameter kit (MultiCal®) at every site.

The analysis of major ions was carried out at the analytical laboratories of the Zuckerberg Institute for Water Research at Ben-Gurion University of the Negev. Following the determination of bicarbonate (by acid-base titration, ± 5 mg/L), all samples were filtered through a 0.45-µm filter. Calcium, magnesium, sodium and potassium were measured using atomic adsorption (Perkin Elmer, ±1%). Chloride, sulfate, nitrate and bromide were measured using ion chromatography (Dionex, ±1%). Ammonia was measured pectrophotometrically (Hitachi-U2000, ±0.05 mg/L with a detection limit of 0.03 mg/L).

The analysis of trace elements was carried out at the Interdepartmental Laboratory of the Faculty of Agricultural, Food and Environmental Quality Sciences of The Hebrew University of Jerusalem in Rehovoth. Analyses for trace elements were carried out using inductively coupled plasma-atomic emission spectrometry (ICP-AES) according to EPA method 6010B. An acid base digestion (HNO_3) was carried out for Total Recoverable Metals according to standard method 3030 E. Effluent parameters including Biological Oxygen Demand (BOD), Total Organic Carbon (TOC) and Dissolved Organic Carbon (DOC), microbial analyses (General count of cells, coliform bacteria, and fecal coliform bacteria), and nutrients (Organic nitrogen and organic phosphorus) were analyzed according to standard methods procedures.

"Biological health" assessment:

Integrality of the macroinvertebrate community was used as a proxy for stream health. This requires comparing the community structure of the studied stream/site with that of an undisturbed situation (reference stream/site). For the Hebron/Besor stream in the semi-arid and arid regions no reference situation was available. Therefore, an alternative approach was applied which assesses stream health according to the relative value of sensitivity of the assemblage to pollution (taxa sensitivity index = ASI, modified after Chessman, 1995). ASI aggregates the multiplication of the proportion of each taxon in the assemblage by its relative sensitivity score (from lowest = 1 to highest= 10). The ASI of an assemblage varies on a scale of 1 (lowest) to 10 (highest). Stream health is expressed as follows: >7 = "very good"; 5.1-7 = "good"; 4.1-5 = "fair"; 3.1-4 = "fairly poor"; 3-2.1 = "poor"; ≤2 = "very poor".

For the Zomar/Alexander coastal stream a multi-metric procedure was used for calculating the Benthic-Index of Biological Integrity (B-IBI, modified after Barbour 1996). A relatively undisturbed section of a comparable coastal stream (the nearby Yarkon Stream) was used as a reference. This information formed the basis for a community structure analysis. Only those community variables that were significantly correlated with pollution variables (degradable organic matter – BOD, ammonia) were used in the analysis and are referred to as metrics. These included the proportion of non-biting midges (family Chironomidae), mayflies (order Ephemeroptera) and of dragon and damsel flies (order Odonata); taxa richness, and indices of evenness and of sensitivity of the taxa to pollution (ASI, after Chessman 1995, 2004). The value of the metrics was scored on a scale 1, 3 and 5. For metrics whose values decrease with increasing disturbance, the score of 5 was given when the value was equal or higher than the median value of this metric in the reference situation. The score of "1" was given when the value of metrics was equal or lower than the minimum value of this metric in the reference situation. The score of "3" was given to intermediate values. For non-biting midges whose proportion in the assemblage increases with organic pollution, the scoring was reversed. The sum of scores of all metrics was divided by the maximum possible value ("30") and expressed as percent biological integrity. Stream health was expressed on a relative scale as follows: ≥87% = "very good"; 75-86% = "good"; 61-74% = "fair"; 47-60% = "fairly poor"; 35-46% = "poor"; < 35% = "very poor".

Macroinvertebrates were collected using semi-quantitative sampling that involves net jabbing (hand net 0.42mm pore size) along a constant distance (10m) usually in vegetated habitats. Samples were preserved in a 70% ethanol solution and transported to the laboratory where the organisms were sorted, identified and counted.

IV. Findings

The following presents the most significant findings from the study, summarized according to watershed. After characterization of discharge and stream flow, water quality is described, with an emphasis on the key indicators of municipal sewage. Self-purification processes are identified and evalauated. The biological health of each watershed is then assessed.

Hebron/Besor Watershed

Flow and Infiltration to Groundwater: In the Hebron/Besor watershed, the predominant initial source of pollution in the watershed is the effluents and raw sewage leaving the urban Hebron and Qiryat Arba areas. Measurements suggest that 15,000 cubic meters of sewage per day, mostly untreated, flow over 120 kilometers downstream until reaching Israel's Besor Reserve near the Negev village of Tze'elim. This steady baseflow fundamentally alters the character of the stream, transforming it from a seasonal stream where high quality storm water flows for only a few days a year throughout a largely semi-arid watershed, to one with a constant flow of sewage throughout the year.

Table 1: Losses from Hebron to Shoqet According to Seasonal Measurements

Seasons	Total loss (%)	Evaporation (%)	Infiltration (%)	Infiltration (m^3)
Summer 2005	60	7	53	8,000
Winter 2006	76	4	72	11,000
Spring 2006	43	6	37	6,000
Summer 2006	82	6	76	11,000

Table 2: Self Purification - COD, BOD, TOC and Nutrient values in Hebron/Besor Stream

Hebron/Besor (Palestinian)	Hebron/Besor (Palestinian)		Hebron/Besor (Israel)	
	Range	Average	Range	Average
EC [mS/cm]	1.254 – 3.49	1.874	0.72-3.05	1.80
TSS [mg/l]	42 - 3506	713	33-11234	3774
Total COD [mg/l]	240 - 1190	654	12.5-771	388
Total BOD [mg/l]	81.6 - 1050	498	13.8-272	137
TOC [mg/l]	97.2 - 386	220	86-223	141

Table 3: Major ions concentrations in the Hebron Stream

Major ion [mg/l]	Hebron/Besor (Palestinian)		Hebron/Besor (Israel)	
	Range	Average	Range	Average
Cl	83.6 - 740	240	84-654	295.9
SO_4	27.9 – 44.1	33	25.1-80.4	44.4
Br	0	0	0	0
HCO_3	478 - 730	625	216-804	597
Na	74.6 - 520	190	53-366	199.5
K	15.9 – 25.8	21	10.7-45.6	29.5
Ca	48.3 – 67.1	56	38.1-97.5	62.2
Mg	16.9 – 37.8	27	8.42-53.5	27.5
Total N	64.2 – 88.8	74.6	9-91	50.317
Total P	1.86 – 14.4	8.47	1.36-0.59	0.975
NO_3	8.98 – 14.0	11	0-2.18	0.66
PO_4	9.02 – 19.99	15	0-30.67	8.33
NH_4	54.9 - 105	75	17-85.2	66.0

It is important to note that a significant portion of the water in the Hebron/Besor, however, does not reach the Israeli border. Measurements of flow taken from the different monitoring stations along the length of the stream in various seasons indicate that along the stream's first 60 km can reach between 40% and 90% of the wastewater discharged (8,000 - 11,000 cubic meters) percolates into ground water before it reaches the green line and the Beer Sheva stream. (Table 2) This represents transmission losses in the channel during the flow and infiltration into the ground water, far beyond the potential water lost by evaporation and transpiration by plants and vegetation cover from the streambed. The rate of percolation appears to be seasonal as reflected in Table 1. The quality of the water which infiltrates the surrounding aquifer in the upper stretch is extremely poor – and is in fact raw sewage.

Water Quality: Water quality in the stream varies dramatically along its flow as a process of biological purification clearly emerges from sampling results. Table 3 shows a dramatic contrast between average parameters measured in the upper reaches of the watershed near Hebron and those in the lower Israeli stretches. In particular, the drop in nutrient concentrations for Total phosphorus and NO_3 is on average, an order of magnitude reflecting the general reduction in the concentration of organic material flowing in the stream. The declining gradient in the level of pollution along the sampling route between the top and the bottom segments of the stream is further reflectd in the drop of 91.7% in biological oxygen consumption (BOD), 87.7% in chemical oxygen consumption (COD), 73.9% in overall nitrate levels, and 72.8% in overall ammonia levels (yearly average).

The results suggest that water quality improvement is not as predictable and linear as anticipated. Figures 3 and 4 show unanticipated increases in BOD and COD levels in the lower stretches of the stream. The possibility of additional, local contamination by small point source discharges in Israel cannot be ruled out. For example, local "contributions" of pollutants to the base flow were observed from a few points along the Besor basin. These appear to be primarily derived from inadequate treatment levels in the sewage systems of the Israeli communities of Beer Sheva, Ofakim, Rahat, and Meitar. In addition, raw sewage was observed flowing into Beer Sheva Stream from Beer Sheva's southern discharge station during light rainfalls. Yet, these additions, are insufficient to explain the sudden increase in organic loadings and BOD/COD levels. Rather it is likely, that the sewage that penetrated into the subsurface during the initial flow of the stream, returns to the surface and joins the stream flow in downstream reaches.

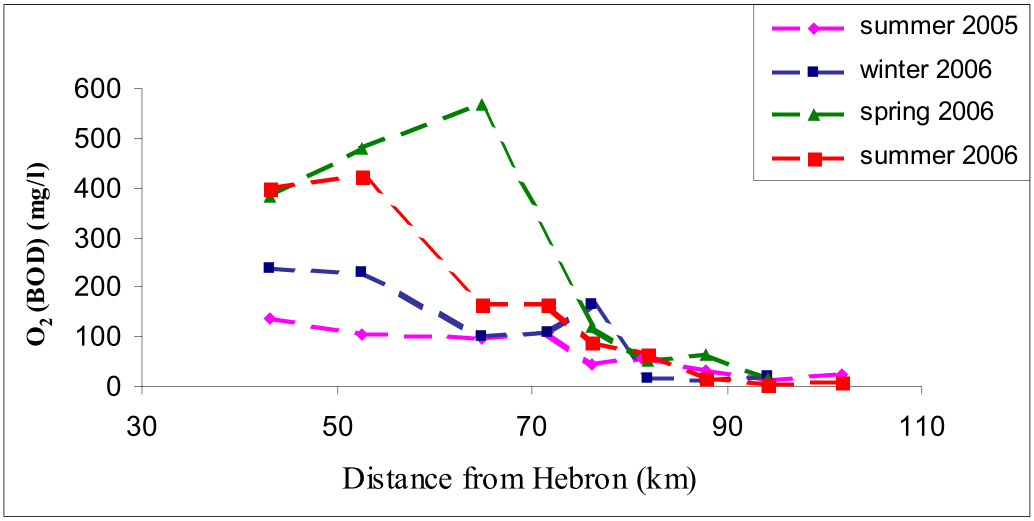


Figure 3: BOD variation along the main Hebron-Beer Sheva stream.

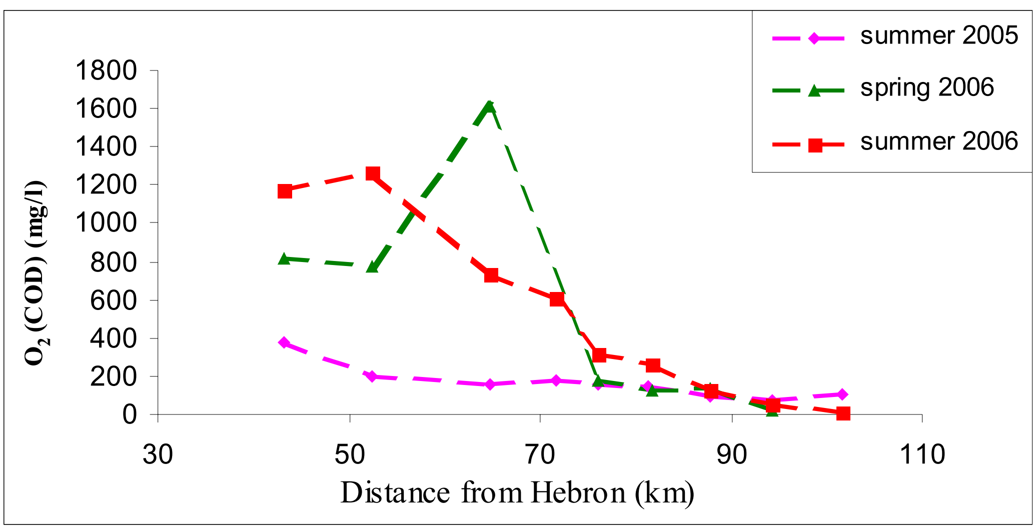


Figure 4: COD variation along the Main Hebron-Beer Sheva Stream.

Specifically, in the summer of 2005, an increase in flow was observed in the vicinity of the city of Beer-Sheva (about 60-70 km from the Hebron Outlet) and downstream of the Hipushit site, 94 km from Hebron. During the winter of 2006, additional flow was measured in Israel, close to Tel Sheva until Sh'hunot and an even greater addition of flow was observed as well at the Quarry Site, peaking at the Secher Site at 7,590 m3/day In comparison to other seasons, during the spring of 2006 higher discharges were measured at most of the sites (12,110 m^3/day at the Metar Forest Site. A considerable increase in discharge began at the Hazerim Site and reached a peak (10,900 m^3/day) at the Secher Site. In the summer of 2006 the downstream Hebron reached a lower discharge of 2,770 m^3/day) Mass balance calculations and geo-chemical profiling of the stream's water and underlying groundwater also show that in certain stretches of the stream (downstream towards Beer Sheva) there was an increment of growing nitrate and sodium levels that can be associated with the entry of contaminated groundwater flow.

Sewage, of course, is not the sole source of contamination. Heavy metal levels of chrome, copper, titanium, barium, and zinc were measured in the upstream segments, but generally decline in the down-stream segments of the stream. Two cases of high Mercury (Hg) levels (0.071 mg/l and 0.081 relative to the proposed local standard of 0.0005 mg/l) were measured in lower segments. Cr concentrations of 0.126 mg/l were also detected. For the adsorbed phase trace elements, high concentrations of Cr and Cd were found in all sites (34-27,500 and 0-630 mg/kg respectively) and Cu was also measured at most of the sites (34-3,200 mg/kg). This suggests that industrial waste discharged from Hebron's leather and tanning industry reaches the stream year-round.

Overall, the water quality in the lower reaches of the stream remains low, and the levels of pollutants exceed recently proposed Israeli standards (Lawhon, 2005) which require tertiary treatment before the release of effluents into streams. Self-purification processes do occur, and the warm climate expedites this oxidation process. Yet, the likely reappearance of sewage, as it follows the stream in a subsurface flow, contributes to the generally poor quality of water in the lower reaches.

Biological Health: The prevalence of sewage in the Hebron/Besor watershed is not only apparant from the chemical parameters measured (e.g., BOD levels close to 500 mg/l when present standards are set at 10 mg/l) but also in the makeup of the macroinvertebrate community of the streams. The relatively poor macroinvertebrates biodiversity (overall 28 taxa), and the dominance of a single or a few taxa (Evenness

<0.64, Table 4), along with the overall poor streams health confirm the environmental impacts of these discharges on the entire basin.

Table 4: Range values of macroinvertebrate taxa richness, evenness and assemblage sensitivity index and respective stream health of the Besor watershed streams over the study period (n = number of samples in each site).

Stream	Hebron	Be'er Sheva			Grar		Besor		
Site	Sh-Brd	T-S	Hip-Dn	Qu*	P-HaSh	Re-Brd	E-B*	E-S*	Hav-Brd
samples (n)	1	1	1	1	2	1	2	2	1
Taxa richness	5	3	10	3	6	2	9-11	7-10	10
Evenness	0.46	0.21	0.56	0.1	0.21	0.1	0.26-0.65	0.08-0.46	0.64
ASI	1	1.9	2.1	2	1.9-2.1	2	2.8-4.4	2-3	3.1
Stream Health	very poor	very poor	poor	very poor	very poor - poor	very poor	poor - fairly poor	very poor - poor	fairly poor

* Springs located outside the main channel.

The state of macroinvertebrate community in the upper tributary (Hebron stream) was even worst than of those on the lower parts of the basin. Only four taxa were found at the two sampling sites ("Rihiya" and "Thahariya"), all of which midge larva (order Diptera). Two families- hover-flies (Syrphidae) and moth-flies (Psychodidae), were the most dominant (>99%), representing macroinvertebrate with highest tolerance to organic pollution (sensitivity = 1). The extremely low biodiversity and the nature of the macroinvertebrates found are in agreement with the very poor water quality at these sites. This is also reflected by the strong dissimilarity of the upper tributaries macroinvertebrate community from that of the down stream communities (Figure 5).

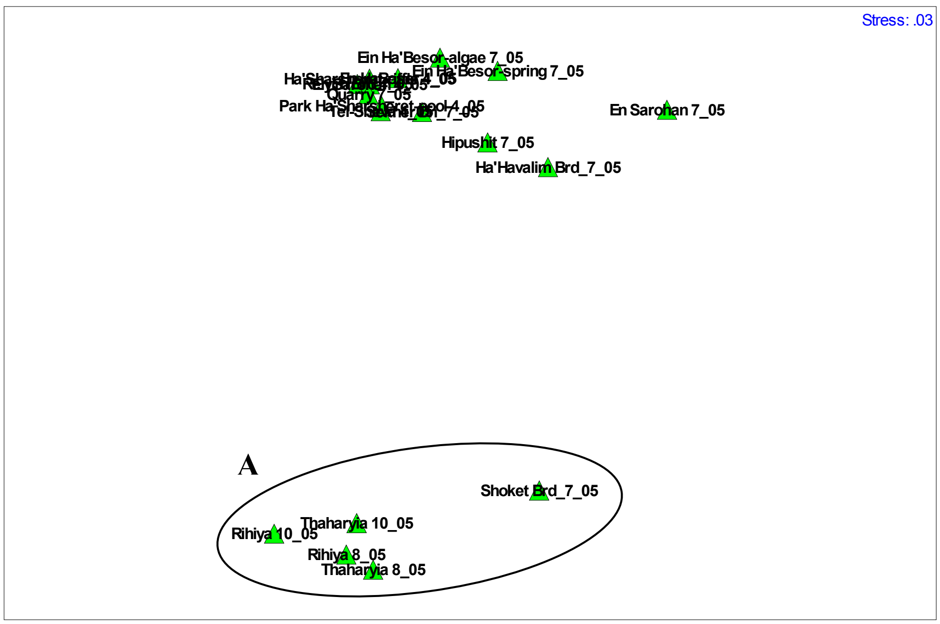


Figure 5. Multidimensional scaling of similarity analysis (Bray-Curtis) of macroinvertebrate assemblages sampled along the Hebron / Besor watershed. Circled group indicates sites located in Hebron stream.

Zomar/ Alexander Watershed

Flow and Infiltration to Groundwater: Similar to the situation in the Hebron/Besor watershed, discharge measurements revealed that in all of the Palestinian and Israeli sections of the Zomar/Alexander watershed, the predominant source of water and pollution in base-flow were sewage effluents. The Nablus tributary, contributes the majority of the water flowing in the stream, first comprised of raw sewage and industrial effluents, which are partially treated upon entry into Israel. Several additional point sources discharge into the stream, but they are largely intermittent depending on seasonal factors. For example, the Tnuvot waste treatment plant, typically diverts all its effluents for reuse by agriculture. On rare occasions, when there is no demand by farmers, treated effluents will be discharged into the stream. Fish ponds, occasionally will release waters; etc.

Water Quality: Average base flow data for the stream are listed in Table 5 revealing the broad range of conditions along the stream with as much as a twenty-fold differential for some parameters (e.g., NH4). This reflects the presence of sewage treatment, dilution levels, natural in-stream purification processes and the estuarial conditions that begin to emerge

	Kalanswa landfill st (3)	**Alexander Stream road-57 (4)**	**Up stream Zomar Stream (3)**	**Down stream Zomar Stream (4)**	**park G. Hayim (2)**	**Maabarot- fish pond (2)**	**Elyashiv (5)**	**Maabarot (5)**	**Nablus/Zomar Stream Station (9)**
H4	20.2 13.4-24.9	20.1 1.479-30.4	1.1 0.518-2.276	18.7 7.3-32.4	9.7 2.478-16.9	17.5 17.01-18	13.8 2.27-35.8	7.6 4.352-11.43	43.2 22.3-72.4
O2	2.0 0.1-5.1	1.8 0.64-4.56	0.5 0.14-0.8	8.6 0.76-20	1.0 0.77-1.18	5.1 1.08-9.058	5.6 0.71-11.8	4.9 1.14-6.942	4.7 0.2-14.364
SS	20.8 20-21.4	30.5 12-46	60.7 52-70	79.8 42-142	58.0 50-66	94.0 58-130	63.8 36-106	106.5 80-134	62.7 20-150
OD	75.5 65-89.3	48.2 15.68-79.8	38.1 6.7-77.8	72.9 61.8-98.2	48.6 46.08-51.2	48.0 35.2-60.8	63.2 49.6-75.4	58.7 51.8-64.96	97.5 50.21-172
OD	16.1 10.5-25.1	13.5 4.4-23.2	9.5 1.7-21	28.8 19.4-36.7	29.3 22.3-36.2	28.4 22-34.7	22.7 4.83-36.7	20.7 6-43.1	28.3 10.6-58.9
N	19.3 14.8-23.4	5.9 4.191-8.513	6.0 5.3-6.7	24.3 12.9-40.3	15.3 8.298-22.3	24.6 24.08-25.1	16.5 8.24-23.838	18.0 13.8-22.606	43.2 30.4-65.06
P	5.1 3.03-6.87	7.7 3.5-15.9	3.4 2.1-6	5.4 1.66-7.65	6.2 4.14-8.18	7.6 5.6-9.6	4.6 2.01-5.8	6.6 4.9-10.4	7.2 3.68-12.9

Table 5: Range and average of Base flow concentrations (mg\L) in the Alexander catchment (con)

as the stream reaches the sea. Total P concentrations, however, deviated little during the course of the stream's flow (from 3.5 to 15.9 mg/l). In all cases, concentrations were far above new recommended Israeli levels for in-stream phosphorus concentrations of 1 mg/l. This can be explained by the sewage treatment technologies in use in the discharging Israeli facilities. Present secondary (biological) treatment reduces organic loadings with moderate efficacy, but its treatment does not remove phosphorus as effectively.

Sampling was also carried out during several storm events. Results indicate that salinity and major ions concentrations are much lower for in-stream concentrations during floods events than in the base flow. Lower levels of BOD,COD, NH_4 , and total N were also recorded during storm events. Dilution, however, is more pronounced down stream, with somewhat higher in-stream concentrations in the Zomar stream appearing storms relative to the Alexander stream.

Pollution concentrations during rainfall events show dramatic temporal shifts, reflecting the so-called "first flush" effect in the stream. For example, COD and BOD levels dropped from 104 and 33 mg/L, to less then 27 and 4.3 respectively in the later stages of the storm events. The event of Feb. 9-10, 2006 was among the largest ever recorded in the catchment, with discharges exceeding 10 m^3/sec for more then 24 hours. Under such conditions, a strong "dilution effect" was anticipated which should have been reflected in measurements of major ions and other compounds. Results were somewhat surprising

Figure 6 shows maximum concentrations during one event during the initial peak discharges (19:00-23:00) as well during the last part of the event. This reflects the clear, addition of pollution from nonpoint sources. The over all mass of Nitrogen and Phosphorus was ~ 23,000 kg and 5,100 kg respectively, during the Feb.9-10 event (mean Total N), compared to 1700 kg and 1100 in the Dec, 16-17.2005 event (Table 6). In the base flow, the daily contribution appears to be less then 500 kg of Nitrogen and less then 100 kg of Phosphorus. Accordingly, the nutrient loadings during large events appear to be two orders of magnitudes higher, highlighting the contributions of Non Point Sources.

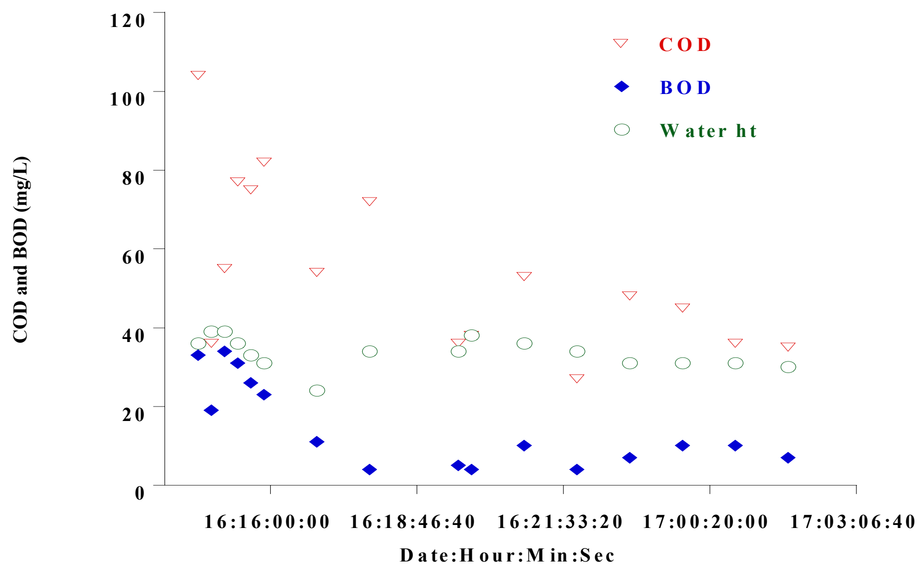


Figure 6: Storm event 16-17/12 automatic station on road 57.

Moreover, pollution loads during storm events, seem to be much higher in comparison with the pollution loads in base flow. Furthermore, the data show that the larger the discharge of the storm, the larger the pollution loads. Accordingly, the highest quantities of nutrients discharged into the stream correspond to the storm of December 24-27, 2005. This event had both the largest overall discharge and the highest peak discharge. These results can be explained by the fact that water flowing in the stream already contains nutrients. The levels of these nutrient levels differ in between the storm events. At the same time, results consistently indicate that the greater the amount of water flowing the stream, the higher the nutrient loads. This would support the existence of a "cumulative effect", meaning that even if concentration is lower, the overall load might be higher, since more water flows through the stream.

Measurements suggest that during storm events between 59-92% of the TN and 81-95% from the TP could be attributed to Non Point Sources. These values presents the upper limit of the possible contribution from non-point sources, and do not take into account additional possible sewage inputs. One should take into consideration that some of the loads could be attributed to re-suspended material and sediments accumulating in base flow. But the low concentration of sediments (25 and 34 mg/L of TSS respectively) measured in June 2006 from the outlet of the Yad-Hanna waste treatment plant suggest a relatively minor contribution from these alternative sources for sediments.

Table 6: Nutrient loads in the different storm events as calculated for Elyashiv station. (Percentages of the relative contributions of Nonpoint Sources in the various events are given in parenthesis.)

Storm event	Cumulative/average Discharge (m^3)	Peak discharge (m^3/sec)	Average concentration (mg/l)		Average load (Kg)		Differential load (Kg)		# of samples
			TN	TP	TN	TP	TN	TP	
16-19.12.05	426,308	6.25	5.3	3.1	2265 (82%)	1323 (92.8%)			7
24-26.12.05	1,104,303	15.03	6.22	2.72	6871 (94.2%)	3006 (96.8%)	7043	2863	18
14-16.1.06	389,090	6.6	3.71	1.91	1441 (72.2%)	741 (87.2%)	1433	610	7
25-29.1.05	581,857	6.875	4.1	3.46	2411 (83.4%)	2012 (95.3%)	2631	1798	13
8-11.2.06	3,252,166	61.4	5.4	1.7	17,562 (97.7%)	5529 (98%)			**
Baseflow	20,400*	0.34	19.6	4.65	400	95			5

*Average of baseflow of 27.8.05-27.8.06 from hydrological service data

** No samples were taken at this station at this event; average concentrations were extrapolated from concentrations in Nablus tributary and station 57.

As can be seen in Table 7, overall nutrient loads in storm events are much higher than those loads in base flow, at least by an order of magnitude. The results are similar to the trend appearing at the down stream “Elyashiv” monitoring station. During rainfall events, it is plausible to assume that almost all of the sources of nutrients originate from non-point sources (99.7-99.8%, Table 6).

Table 7: Nutrient loads as calculated for road 57 stations

Storm event	Cumulative/ average Discharge (m^3)	Peak discharge (m^3/sec)	Average (mg/l)		Average load (kg)		Number of samples
			TN	TP	TN	TP	
16-19.12.05	743,972	7.67	4.2	3.81	3122 (99.7%)	2822 (99.7%)	17
24-26.12.05	1,152,282	20.42	3.33	1.78	3841 (99.7%)	2045 (99.6%)	18
8-10.2.06	1,450,000	160	3.2	1.8	4630 (99.8%)	2660 (99.7%)	
Baseflow	1,000	0.01	11.4	8.3	11.4 (99.8%)	8.3 (99.7%)	4

Biological Health: Bio-assessment of base flow stream health also revealed considerable contrasts in stream conditions. Except for the lowest site on the Zomar/Alexander (“M-up” site), all other sites showed little variation in community attributes and biological integrity and were assessed as having “very poor” to “fairly poor” health condition (table 8). The “M-up” site was assessed as “very poor” on one occasion and as “good” on another. This is an indication of the variation in water quality conditions and a demonstration of the instability of effluent discharges in the Zomar/Alexander stream. As in the Hebron/Besor watershed the macroinvertebrate community of the upper tributaries of the Zomar/Alexander (Nablus/Shekhem stream) was also in very poor condition. The only taxa found in these sites were diptera larvae which are tolerant to the raw sewage conditions. Accordingly these sites were clearly dissimilar from the other sites in the watershed (figure 7).

Table 8: Range values of macroinvertebrate metrics, calculated B-IBI and respective stream health of the Zomar / Alexander stream over the study period (n = number of samples in each site).

Site	B-Dn	AS-Up	AS-Dn	H-Can*	H-IBrd	Ely.	M-Up
samples (n)	2	3	3	2	2	3	3
Chironomidae (%)	20-99%	38-63%	35-97%	2-50%	47-82%	4-79%	9-73%
Odonata (%)	0-2%	7-14%	0.7-12%	0-4%	0.1-2%	0.3-14%	2-18%
Ephemeroptera (%)	0-4%	0.2-0.9%	0.0-0.1%	0-33%	0.00%	0.4-1%	0-13%
Taxa richness	4-9	11-19	10-24	9-13	11-18	10-17	4-13
TSI	2.1-3	2.4-3.2	2.0-2.4	3.0-4.3	2.2-2.8	2.7-3.0	2.4-3.0
Eveness (J)	0.03-0.5	0.37-0.54	0.07-0.55	0.34-0.63	0.28-0.48	0.23-0.60	0.48-0.73
Calculated B-IBI 6	**27-60%**	**53-60%**	**40-47%**	**47-80%**	**40-47%**	**47-60%**	**33-83%**
Stream health	**very poor - fairly poor**	**fairly poor**	**poor - fairly poor**	**fairly poor - good**	**poor - fairly poor**	**fairly poor**	**very poor - good**

* Springs located outside the main channel.

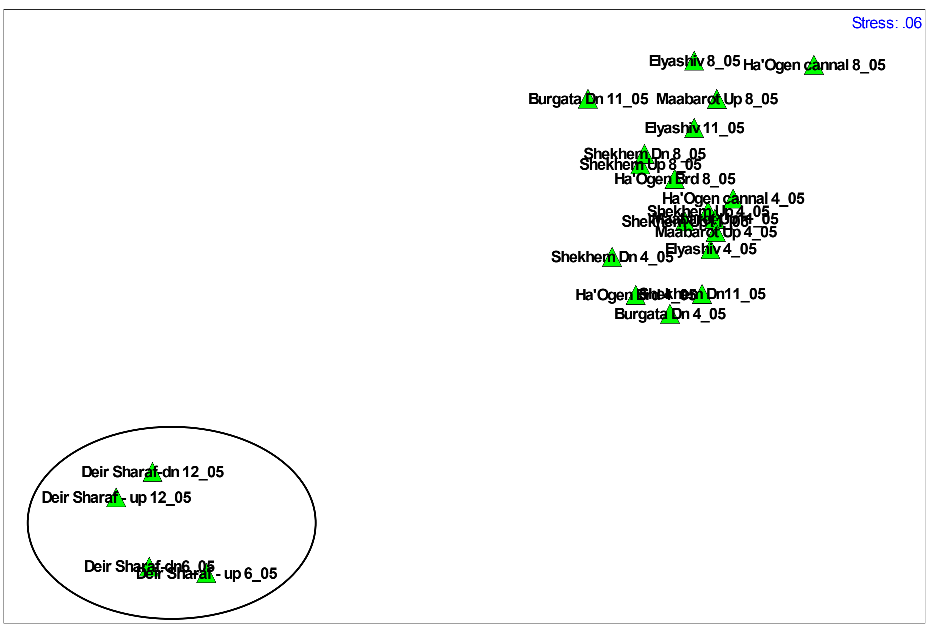


Figure 7. Multidimensional scaling of similarity analysis (Bray-Curtis) of macroinvertebrate assemblages sampled along the Zomar / Alexander watershed. Circled group indicates sites located in Nablus/Shekhem stream.

Conclusions: Contrasting Conditions in the Two Watersheds

The habitat and ecological systems of both streams pay a heavy toll for the many years of pollution and dramatic modification of the natural hydrological regime. This is evident in the relatively poor macroinvertebrates biodiversity, dominance of a single or a few taxa (low Evenness index), and overall poor stream health (low percent biological integrity or low value of assemblage sensitivity index).

The ubiquitous dipterans, with their tolerance for extreme environmental conditions suggest that large sections of the stream remain uninhabitable and inappropriate for a range of recreational and other uses. Many dipterans are tolerant of extreme environmental conditions and their presence reflects high levels of waste water contamination. This proved true also in the present study. Two dipteran groups are especially good bioindicators for the degree of organic pollution. The first one includes moth-flies (family Psychodidae) and hover-flies (family Syrphidae) that were found only in the grossly polluted (raw sewage) tributaries of both the Alexander (Shekhem/Zomar) and of Hebron/Besor. The other group includes the non-biting midge larvae (Chironomidae, mostly *Chironomus* sp.) that were frequently highly dominant reflecting the enrichment by organic matter (mostly municipal effluent). The clear relationship between organic pollution (represented as total ammonia concentration) and the percent diptera larva indicates a threshold of 40mg/L ammonia, from which the community is totally dominated by tolerant diptera larva (Figure 8).

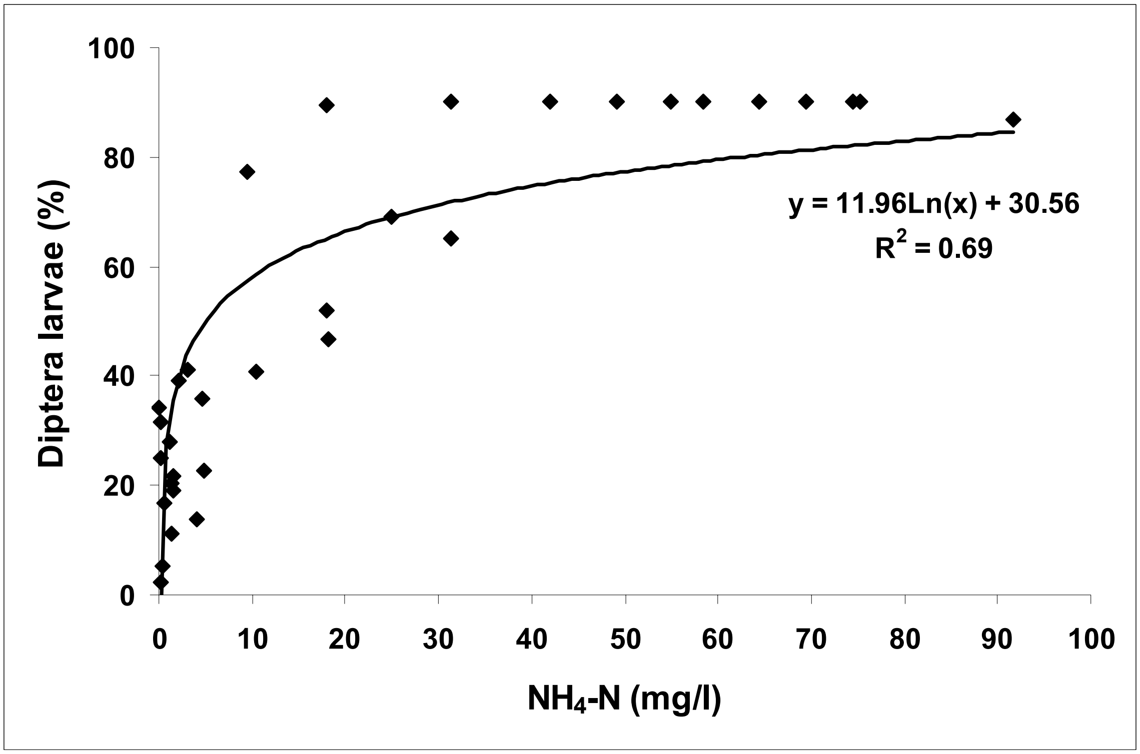


Figure 8. Relationship between proportion of diptera larvae in the assemblage and ammonia level (Alexander and Besor streams and tributaries

As both watersheds receive no rain during the summer and have trivial spring flow, their water quality is dominated by sewage discharges. The greater precipitation during the rainy season and associated dilution in the Zomar/Alexander basin do not affect this dynamic. Nor does a decade of efforts to reduce point sources and partially treat sewage from the West Bank. Both streams are heavily polluted as reflected in water quality variables and by the biological health category This is especially noteworthy given the steady growth in the number of residents living in the watershed, particularly among the Palestinian population. Although the geomorphology of the two streams differs greatly as does their climatic setting and conditions, the ecological state of their upper tributaries (reflected by the ASI) are identical ("very poor").

V. Discussion – Implications for Transboundary Stream Restoration and Management

Despite widespread restoration efforts, the water quality in many segments of the Hebron/ Besor Stream is unsatisfactory. While the Zomar/Alexander stream has shown some improvement, monitoring suggests that point and nonpoint source pollution continue to affect stream water quality. To a great extent, stream restoration is a painfully slow process, where patience is required and incremental improvement is the best expected outcome. The fact that these watersheds are shared the Palestinians and Israelis makes the implementation of a coordinated management strategy even more complex.

In general there is some basis for optimism. When efforts are based on a coordinated Masterplan, environmental progress is discernible. The stream monitoring division in Israel's Nature and Parks Authority has been in charge of monitoring Israeli streams, including the Alexander stream since the 1970's. Their monitoring program includes spring and fall sampling along different stations in the Alexander stream. Assessment of their data suggests that there has been a marked improvement in stream conditions over the past decade. (Figure 7) All parameters -- BOD, COD and NH4 concentrations -- were considerably lower in 2005-2006 than in the year 1995, suggesting that water quality has improved dramatically since the initiation of restoration activities. However, the data also show that the decline in pollution concentration parameters is inconsistent and for some parameters, such as ammonia, progress has slowed or leveled off since 2003.

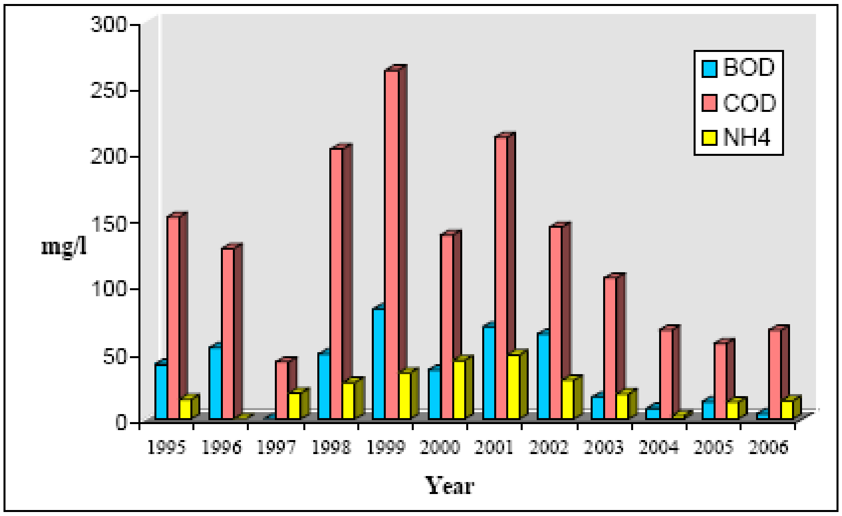


Figure 7: BOD, COD and NH4 averages concentration in the Alexander stream from 1995-2006 (data from Israel Nature and Parks Authority)

Further progress in attaining restoration objectives will not be meaningful in the watersheds studied, as well as in managing other transboundary resources in the region, until a number of fundamental changes in present dynamics and approaches are adopted. In this section, the implications of the monitoring results for future, transboundary, restoration efforts are presented.

Transboundary Planning: To ensure long-term cooperation meaningful environmental results, the sides must remain committed to executing restoration plans for transboundary watershed restoration. The violent political dynamics of the Middle East and the associated obstacles for cooperation on the ground add a level of complexity to implementation which cannot be underestimated. The achievements attained heretofore, through the myriad initiatives on both sides, reflect a pragmatism that implicitly recognizes that the perfect river rehabilitation plan may indeed be the enemy of the “good” one. Incremental improvements, through projects like the Yad Hanah waste treatment plant reduce contamination in the field and maintain a sense of momentum. But improvements in the landscape and in water quality to date have only set the stage for the more comprehensive environmental progress that is needed. The time has come to move to the next level where real recreational and ecological benefits can be enjoyed by both Israelis and Palestinians.

The existing plans for pollution reduction and improvement of the watershed, prepared as a result of cooperation spawned by the Oslo peace accords should be amended to include greater emphasis on controlling nonpoint pollution sources. Clear interim and long-term goals regarding the use of different segments of the streams, with greater resolution defining common and differentiated responsibilities for implementation by the parties should be set according to the preferences of stakeholders on both sides. For example, the study included a survey of Israeli stakeholders regarding expressed preferences for future designated uses of streams. Swimming was deemed, an admirable, but very distant and presently unrealistic objective. Recreational boating and fishing, however, were identified as more practical and readily attained. Palestinians expressed a clear preference for directing treated effluents to stream flow and restoration, rather sending the waste water directly for irrigation in agriculture. Plans must translate these inclinations into operational objectives with time-tables and funding mechanisms.

Common "In-Stream" Standards and Pollution Reduction Goals: To date, neither Palestinians nor Israelis have set formal, legally binding stream standards for water quality in the streams located in the two watersheds studied. Israel has begun to phase in new discharge standards for waste water treatment discharged into the stream and Palestinians have agreed to meet a "20/30" BOD/Suspended solids, secondary treatment level. Yet, these "discharge" standards fall short of full in-stream criteria, including biological indicators. For successfully implementation, transboundary plans must contain detailed, quantitative criteria to monitor progress. These chemical and biological parameters should be driven by the stream-uses that have been prioritized. Pollution levels can be ratcheted down with time as interim milestones are attained and ultimate water quality objectives pursued.

Once standards are established, clear objectives must be set for source and nonpoint pollution source reductions. Table 7 includes site-specific / pollution-specific objectives based on monitoring results and present Israeli recommendations for in-stream quality in the Alexander Stream.

Table 7: Pollution Load Reduction Needed to Meet Water Quality Standards*

Date	Station	Pollution loads			Required load			%Reduction TP	%Reduction NH_4
		TN	TP	NH_4	TN	TP	NH_4		
16-19.12.05	Elyashiv	2265	1323	1961		426	639	68	67
24-26.12.05	Elyashiv	6871	3006	6129		1104	1656	63	73
14-16.1.06	Elyashiv	1142	741	545		389	584	48	0
24-26.1.06	Elyashiv	2411	2012	1629		581	873	71	46
9.2-10.2.06	Elyashiv	17562	5529	17236		3252	4878	41	72
24-26.12.05	R-57	3841	2045	4609		1152	1728	44	63
16-19.12.05	R-57	3122	2832	1934		743	1116	74	42
9.2-10.2.06	R-57	4660	2654	4495		1450	2175	45	52
24-26.12.05	Nablus	2009	321	2777		214	322	33	88
24-26.1.06	Nablus	319	53	332		39	59	26	82
9.2-10.2.06	Nablus	6492	818	6438	5455	546	818	33	87

**Based on Israeli water quality standards: TN=10 mg/L; TP= 1 mg/L; NH_4= 1.5 mg/L*

The Proximity Principle: The establishment of Israeli treatment facilities in both watersheds that are designed to capture and treat Palestinian sewage as it crosses the border was originally a pragmatic response to the environmental paralysis produced by political instability. Given the lack of symmetry in economic capacity and present levels of governance, Israel took proactive action to intercept and reduce the predominant pollution sources reaching the streams in its jurisdiction. This policy was an exigency; it does not constitute an effective, long-term, hydrological strategy.

While treatment plants can successfully reduce organic loading in the streams and improve water quality, they cannot offer a comprehensive solution. In the Zomar/Alexander watershed, capturing the discharge of the olive oil production has not been effective. While plans are in the work for better treatment of this waste stream, considerable quantities of waste water continue to percolate into ground water after leaving Nablus stream. (Brandeis, 2003) In certain extreme rain events the flow is overwhelming. The result is the transport of extremely high levels of organic materials which often exceed present capacity at the treatment facility which in turn leads to "emergency" bypass discharges that result in periodic fish kills and general deterioration in ambient stream conditions.

In the upper reaches of the Hebron/Besor watershed, the loss of up to 90% of the sewage effluents to infiltration requires a rethinking of present assumptions. The treatment facility currently under construction inside the Israeli border at the Shoket juncture should improve surface water conditions in the stream flowing through the city of Beer Sheva. But in the long-run, ground water resources may still be compromised. While infiltration in the Zomar is somewhat more modest, a full half of the sewage may be contaminating groundwater resources.

It is a basic axiom of environmental management that treatment of wastes of all kinds should take place as close as possible to the source of the discharges. (Faure and Skogh, 2003) While future infrastructure and normative frameworks should consider waste treatment and *utilization* of effluents at a *regional* level, the focus on *treatment* must be local. Alternatively, and in the interim, untreated wastes can be transported to regional treatment centers in pipes to prevent water loss/contamination and the risk of human exposure while it is in transit.

Identifying and Addressing All Point Sources: The findings of the study confirm that despite the improvement in water quality that has been achieved since the beginning of restoration activities, pollution levels contained in the base flows will prevent the attainment of any of the potential uses in transboundary streams. In a justifiable "worst things first" approach, wastewater treatment has been the focus of efforts to date. Yet, additional pollution sources, from the Palestinian olive oil and stone cutting industries -- Israeli industrial zones, fish ponds and fruit juice plants will sabotage water quality progress unless they are systematically identified and abated. Enforcement efforts are now underway in Israel to address these pollution sources, but compliance remains inadequate. The Palestinian regulatory capacity has been considerably weakened in recent years and substantial institutional strengthening will probably be required before results will be seen in improved pollution discharge levels.

Addressing Nonpoint Source Discharges: In most water management schemes there is a natural progression. Initial attention focuses on abating point sources which cause an acute public health or ecological insult – with most strategies for addressing nonpoint sources being as diffused as the pollution sources themselves. Only later, does the imperative of controlling nonpoint runoff become apparent. Past efforts have overlooked the critical contribution of nonpoint sources to water contamination.

This is surely the case for both watersheds considered in this study. While Israel justifiably is concerned about point source discharges in the Palestinian Authority – the study confirms that some 60% of the nonpoint source discharges in the Zomar/Alexander watershed are actually on the Western-side of the green line and can be associated with Israeli runoff. Measurements in the field, show that non-point sources leave enormous pollution loads in the stream: nutrient loads were found to flow through the stream in storm events, contributing 26% and 38% of the yearly loads calculated for total nitrogen and total phosphorous, respectively. While rainfall is less frequent in the Hebron/Besor watershed, during major events, the nonpoint source contribution was also conspicuous.

In the Zomar-Alexander, the nonpoint contribution appears to be dominantly Israeli. Palestinian nonpoint sources include leaching from solid waste disposal sites, runoff from roads etc. But Palestinian agriculture in the watershed is far less intensive than in Israel and is dominated by olive tree plantings which are already based on terracing systems, which were designed for their soil conservation and water pollution prevention qualities. This dynamic is different in the south where roughly half of the total phosphorous in the Hebron/Besor watershed and three-quarter of the suspended solids that reach the stream bed are linked to rain fall events. Palestinian agricultural activity is relatively more intensive in the up-stream, Hebron region and makes a meaningful contribution to loadings. A restoration strategy that ignores the contribution of urban and agricultural runoff will ultimately be unsuccessful.

Cost-effective "point" and "nonpoint" reduction tradeoffs: Facilitating Best Management Practices for nonpoint source controls requires a fundamentally different policy approach than does that involved in controlling point sources. It is axiomatic in public policy that as the number of actors increases, the difficulty of attaining compliance grows exponentially. Nonpoint source controls therefore constitutes an enormous institutional and regulatory challenge. For instance, there is much resistance from farmers at adopting practices such as conservation tillage or filter strips, which in fact may not be in a given farmer's narrow self-interest. (Knopt, 2006)

While command and control regulation of agricultural discharges has proven successful (Rosenthal, 1990) international experience suggests that the agricultural community will be better able to implement pollution controls when it is supported by government agricultural extension services and receives remuneration and compensation for direct investment in infrastructure. (Taylor, 2000) Now, in the central government, institutional support for river restoration has been solely associated with environmental protection agencies. For successful restoration of the Zomar/Alexander and the Hebron/Besor streams, it will be important to engage the respective Ministries of Agriculture as partners.

In the absence of pollution control BMPs on site, buffer strips along the stream bank are a promising approach to addressing nonpoint source loadings. Establishing parks along the stream is an important stage in enlisting the public and transforming streams from a perceived hazard to an attractive recreational resource. Funding to this end may take the form of support for beautification and recreational projects. Palestinian park infrastructure along the stream beds, however, by comparison to that in Israel remains minimal. Promoting beautification and park projects should be a focus of international assistance, both for domestic Palestinian quality of life reasons as well as transboundary ecological ones.

Focus on Phosphorus: Any strategy for addressing total loadings in the watershed needs to partition nutrient discharges into its different components. While nitrogen / nitrate concentrations have seen a significant drop, phosphorus remains a key parameter which still contributes to pollution of both watersheds. The nonpoint source contribution is particularly important in this context, with increased P concentrations arising during and after storm events. Existing water quality in base-flow and storm-water does not comply with any of the national or international standards that might be adopted in these streams. If in-stream standards are to be met, P levels should not be higher than 1.0 mg/l. This will require a total reduction of between 45-74% for total phosphorus.

This focus on phosphorus should drive the technologies which are employed and encouraged as part of the future management plan. For example, constructed wetlands have enormous advantages as nutrient sinks and as natural recreational sites. Yet, they are not an effective way for reducing phosphorus concentrations in surface waters. (Osborne & Kovacic, 1993) Other management practices will be needed to achieve this.

Long-Term Monitoring: To monitor progress, rehabilitation efforts must be accompanied by a program of continuous monitoring of base flow and storm events. Progress in reducing point and nonpoint sources should be essential. And in addition to chemical monitoring, biological monitoring should be integrated into long-term monitoring plans.

Ephemeral streams have never been a meaningful source of drinking water and their transformation into perennial effluent streams will not change that. Yet, the new water bodies can sustain ecological systems and monitoring should be designed to reflect progress (or deterioration) in this dimension. The sensitivity of macroinverebrates to contrasting environmental conditions makes this group the most appropriate indicator for assessing streams' ecological health. The technical plan should also be flexibly designed in order to expand the involvement of the local populations (students and adults) in monitoring efforts.

The Imperative of Cooperation: This research suggests that stream restoration in semi-arid watersheds is made more complex by the addition of wastewater that transforms a "ephemeral" into a "perennial" stream. Yet, many would argue that if wastewater is treated appropriately, these unnatural sources of water have the potential to create a new resource which improves on the original hydrological regime. When watersheds traverse political boundaries -- and especially boundaries that are characterized by political tensions -- the task of stream restoration is also made more challenging. Yet, the cooperation that a joint restoration strategy requires can also engender unanticipated benefits in terms of confidence building and reduction of tensions.

Experience to date, suggests that cooperation in stream restoration at the local "municipal" level between neighboring cities may be more robust and able to withstand political turbulence than joint environmental efforts at the macro-level between central governments. It was this stamina that contributed to the 2003 awarding of the prestigious international River*prize* in Brisbane, Australia for restoration efforts in the Zomar/Alexander basin. It also appears that international assistance is essential for evening the playing field between Israeli and Palestinian water managers. The German contribution to the Zomar/Alexander watershed and the genearl U.S. commitment to improving Palestinian infrastructure will remain crucial for the foreseeable the future.

The technologies and management strategies *are* certainly available for solving the pollution problems of the two watersheds studied as well as other shared Palestinian-Israeli water resources. The primary obstacles to environmental progress in recent years have been economic and geopolitical. Without sufficient resources for sanitary infrastructure, pre-treatment of industrial facilities and best management practices for nonpoint runoff, progress will remain elusive. Without coordinated efforts and real cooperation, neither side will succeed in restoring its streams. As Israel and its neighbors consider the form of a final peace accord, a pragmatic, cooperative response, based on sound scientific data can strengthen future regional agreements and provide a more sustainable future for their shared natural resources.

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