TRANSBOUNDARY STREAM RESTORATION IN ISRAEL AND THE PALESTINIAN AUTHORITY

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Abstract: Within Israel and the West Bank and Gaza Strip (WBGS), there are 15 streams that cross the Palestinian/Israeli Green Line. All originate in watersheds located in the Palestinian Authority, or in lands that will eventually be outside Israeli jurisdiction, and then flow into Israel toward the Mediterranean Sea, flow east to the Dead Sea, or the Jordan River. These transboundary streams of Israel and Palestine are plagued by severe pollution, posing a serious health hazard to humans and devastating the natural ecosystems.

Several factors have contributed to the severity of pollution in these streams. For many years, most streams were transformed into sewage conduits collecting raw sewage or low-quality effluent all year round. The region's climate is semiarid and increasing demand for water has led to overpumping of the available groundwater, drying up of the headwaters of many streams. A range of pollutants, including nonpoint agricultural runoff, urban stormwater, and discharge from industrial sites can also be found in many streams.

In 1994, the Ministry of the Environment established the River Restoration Administration as a coordinating body for actions taken by various governmental and nongovernmental bodies to restore or at least rehabilitate damaged streams. Although stream restoration constitutes a paramount environmental priority for both parties, the lack of a clear and relevant model that identifies and quantifies the key parameters for stream restoration including water flow, nutrient concentrations, and other contaminant loadings from nonpoint and point sources on a catchment scale across the virtual borders has frustrated all

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previous restoration attempts. The ultimate aim of the current research is to lay the foundations for an effective river restoration strategy for Israel and the Palestinian Authority. Using a "catchment scale chemical and biological monitoring network," the total pollution loadings into two transboundary streams whose geographic boundaries cross over the Israeli/Palestinian Green Line (the Zomar/Alexander and Hebron/Besor/Gaza) are to be characterized. This will for the first time enable a more systematic and comprehensive assessment of intervention options, their affect on stream restoration, and relative cost-effectiveness.

Keywords: stream restoration; water pollution; Israel; Palestine

1. Introduction

Within Israel and the West Bank and Gaza Strip (WBGS) there are 15 streams that cross the Palestinian/Israeli Green Line. Twelve of these are major streams that flow year-round in a westward direction toward the Mediterranean Sea and the other three flow east to the Dead Sea or the Jordan River. All of them originate in watersheds located in the Palestinian Authority, or in lands that will eventually be outside Israeli jurisdiction, and then flow into Israel (these include: the Na'aman, Zipori, Kishon, Taninim, Hadera, Alexander, Yarkon, Ayalon, Soreq, Lachish, Besor, and Beer Sheva streams). At least part of each of these streams can be defined as highly polluted, posing a health hazard to users, endangering flora and fauna and unfit for recreational or consumptive uses (see Figure 1).

Several factors have contributed to the severity of pollution in these streams. The region's climate is semiarid with minimal exploitable surface water to support the region's rapid population growth and urbanization. Increasing demand for water has led to overpumping of the available groundwater and thus a drying up of the headwaters of many streams. A range of pollutants, including nonpoint agricultural runoff, urban stormwater, and discharge from industrial sites, can be found in many streams. River restoration and the recovery of the river's environmental and social functions have taken an increasingly important place on Israel's public agenda in recent years. River restoration, planning, and management are meant to achieve a wide range of targets in different and varied aspects (Kaplan, 2004).

Accumulated experience shows that river restoration is a lengthy process, lasting many years. It involves multipurpose activities, including the cessation of sewage discharge, cleanup of riverbeds, re-creation of flow paths, and the

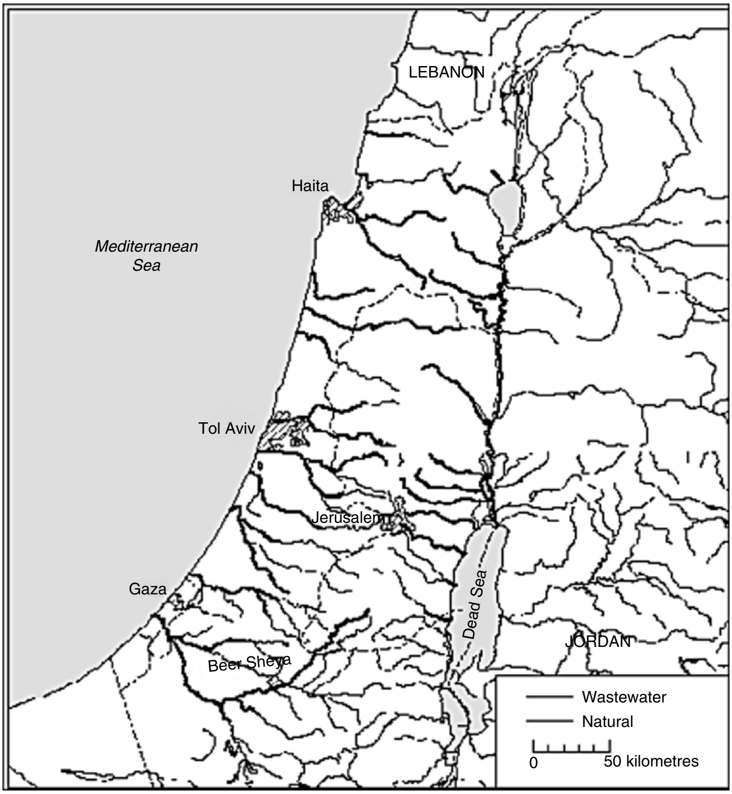

Figure 1. A general location map showing some of the ephemeral stream in Israel and the Palestinian Territories that have been affected by wastewater flow. (From Hassan and Egozi, 2001).

facilitation of the natural processes of habitat renewal. Restoration of water to rivers is an absolute necessity, with primary ecological and landscape impacts, and with high value in terms of its contribution to leisure, quality of life, and tourism services (Bar Or, 2000).

Stream restoration ostensibly constitutes a paramount environmental priority to both parties. Yet, there is insufficient cooperation between Israel and the Palestinian Authority. The cooperation is hampered by the security and political instability in the region and absence of a direct mechanism to manage the transboundary catchment across the political boundaries. There is a need of a clear and relevant watershed framework that identifies and quantifies the key parameters for stream management. These should include water flow, nutrient concentrations, and other contaminant loadings from nonpoint and point sources on a catchment scale across the virtual borders. The lack of such a model has frustrated previous restoration efforts.

The present research was designed to lay the foundations for an effective river restoration strategy for Israel and the Palestinian Authority. Specific research objectives were defined:

- To identify and quantify the key parameters for stream restoration including water flow, nutrient, and other contaminant loadings from nonpoint and point sources, and discharge limits (especially from municipal wastewater treatment facilities).
- To extrapolate the maximum loading limits for the transboundary streams evaluated.
- To establish a monitoring program that will offer a more thorough characterization of ecological health in local transboundary streams and offer baseline values to assess future reduction strategies.

1.1. THE HEBRON/BESOR DRAINAGE BASIN AS A CASE STUDY

The Hebron/Besor drainage basin is the largest in Israel or the Palestinian Authority (3,500 km^2). It is located in the south of Israel in the northern Negev (Figure 2) as well as the south of the West Bank and parts of Gaza. The Hebron/Besor basin area varies spatially in geography, climate, geology, land use, and vegetation. The drainage basin spreads from the southern Hebron Mountains in the north within the Palestinian Authority to Sde-Boqer in Israel in the south and from the northern Negev in its central section to the Mediterranean Sea in the west where the stream estuary is located in the Gaza Strip.

The climate in this basin is semiarid to Mediterranean, characterized by a long dry season and short wet seasons with two short transition periods during the spring and fall. The wet season occurs during the winter, influenced by Mediterranean fronts (Alexandrov et al., 2003). These are characterized by long rainfall duration and low rainfall intensity. Precipitation in the basin is not evenly distributed, with mean annual precipitation of 500 mm in the northern part of the basin, 300 mm in the west, and less than 70 mm in the south. During the transitional seasons there is influence from the Red Sea trough (convective rain), characterized by short rainfall durations and higher intensity that cause most of the flood events in the Negev (Godreich, 1998; Kahana et al., 2002). On average, there are two to three flood events per year, while some years may have no floods at all (Kahana et al., 2002).

The main land uses in the watershed are undeveloped lands, agricultural, and urban areas. Yet, industry, mining, quarrying, and manufacturing are important activities that influence the watershed and the stream water quality. The major point pollution source is raw sewage discharge from the city of Hebron into the Hebron Stream. The Hebron Stream drains the domestic sewage of the city of Hebron and the Israeli settlement of Qiryat Arba (together approximately 200,000 residents). In addition, untreated sewage as well as the wastewater from almost 100 industrial facilities reach the stream. These sources change the fundamental nature of the ephemeral stream, converting it into a de facto sewage conduct with a permanent base flow that continues for more than 100 km downstream. Additional point pollution sources on the Israeli side of the watershed are very low-quality treated effluents that are discharged from Dimona into the Ar'ara – Beer Sheva Stream; untreated wastewater discharges from Ofakim into the Patish Stream; and on occasion, treated wastewater leaks out of municipal waste facilities in the city of Beer Sheva into the Beer Sheva Stream (The Ministry of Environment, 2003).

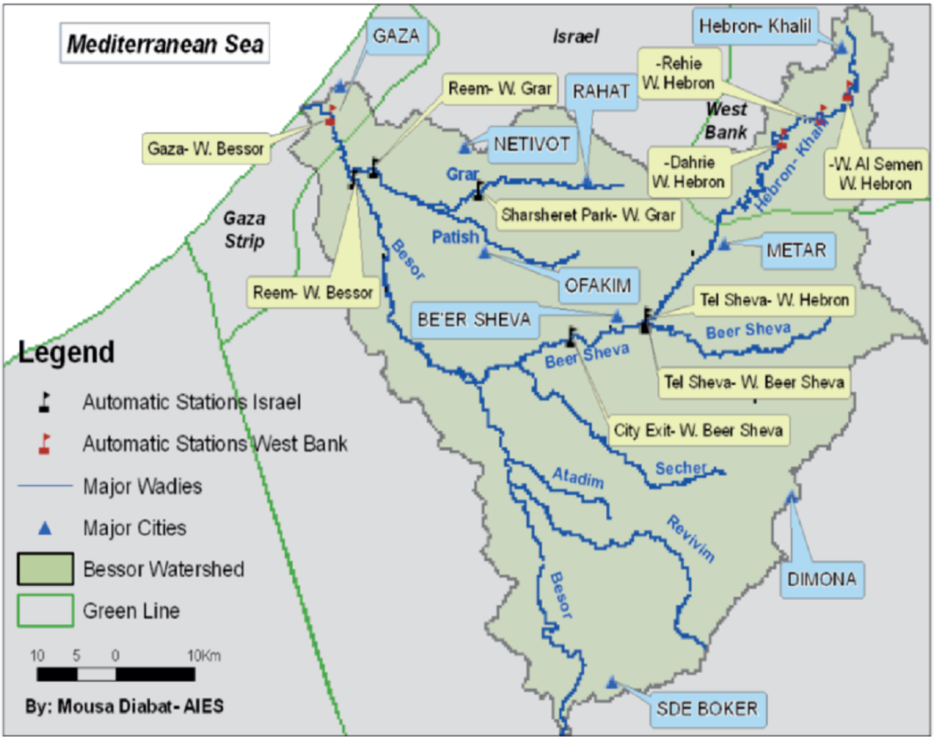

Figure 2. The Hebron/Besor/Gaza Stream streams watershed and the monitoring Network.

2. Methods

2.1. MONITORING AND SAMPLING

In a semiarid setting, the stream channel is active less than 2% of the time, or 7 days/year (Reid et al., 1998) and characterized by flash floods, which makes it difficult to monitor and understand the chemical and biological processes in the stream, as well as its sediment and pollutants transport mechanism. Therefore, in each watershed a detailed monitoring plan was designed and implemented that including the location of six automatic monitoring stations (Figure 2). This stage of the project involved extensive coordination and negotiation with the government authorities who are responsibility for streams in Israel and the Palestinian Authority. In the Hebron/Besor watershed an addition of three stations funded by the Besor Drainage Authority were integrated into the monitoring system. Three monitoring stations are stationed on the Palestinian side: two contiguous to the Hebron Stream (Figure 2) in the West Bank, and in the future one station will be placed in Gaza when political turbulence subsides and the security situation allows.

Each of these hydrometric stations include a pressure transducer (with a resolution of 10 mm), a data logger, a salinity probe, an automatic water sampler activated during floods in the stream, and a cellular communication system. Because the stations measure water from areas of different sizes and land uses, the impact of these characteristics on the quantity and quality of stream water and sediment transport during flow events will be evaluated during the coming winter season (unfortunately, to date there has only been one major storm event since last winter).

2.2. WATER-SAMPLING ANALYSIS

The characteristics of base flow and two flow events in the 2005 winter season were determined by 77 water samples that were taken from various locations. In the field, measurements of water temperature, pH, dissolved oxygen, and electrical conductivity (EC) were taken using electrodes. These samples were analyzed in the laboratory for major components and trace elements. The analysis of major ions was carried out at the laboratory of the Institute for Desert Research, 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 Rehovot. Analyses for trace elements were carried out using inductively coupled plasma-atomic emission spectrometry (ICP-AES) according to EPA method 6010B. 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 determined according to standard methodological procedures.

2.3. WATER-SAMPLING ANALYSIS

Measurements of base flow water discharges (Q) were conducted at several stations along the Hebron/Besor Stream. Stream flows were calculated using the equation $Q = A*V$, where A is the cross-section area of the stream (m^2) and V is the mean stream water velocity (m/sec). After a cross-section area was chosen and measured, water velocities of the water columns were measured in 0.20 m intervals, using an electromagnetic flow velocity meter – (Marsh-McBirney Inc., flow-mate model 2002). 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 partial discharges from the individual intervals.

3. Results and Discussion

3.1. BASE FLOW WATER DISCHARGES

Initial results show a decrease in the base flow along the stream after the initial upstream sewage discharge (Figure 3). In the summer about 88% is lost from the upstream to downstream. The direct evaporation from the stream estimate appears to be in the order of 7 mm/day in the summer months (Ministry of Agriculture, Gilat). This value can account for only 17% of water loss. It means that about 73% of the water infiltrates into the ground in the summer. The loss of the water in the summer occurs very fast; already, at the upstream of the stream before the entrance to the city of Beer-Sheva, about 50 km from Rihiya, the stream loses 80% of the water when only 10% of the water is lost due to evaporation, and 70% due to infiltration. In the upper part of the stream, there is little vegetation growth on the banks, so even in the wintertime evotranspiration by plants is minimal and for all practical purposes can be neglected. By the time the water reaches Shoket junction (where a sewage treatment plant is currently

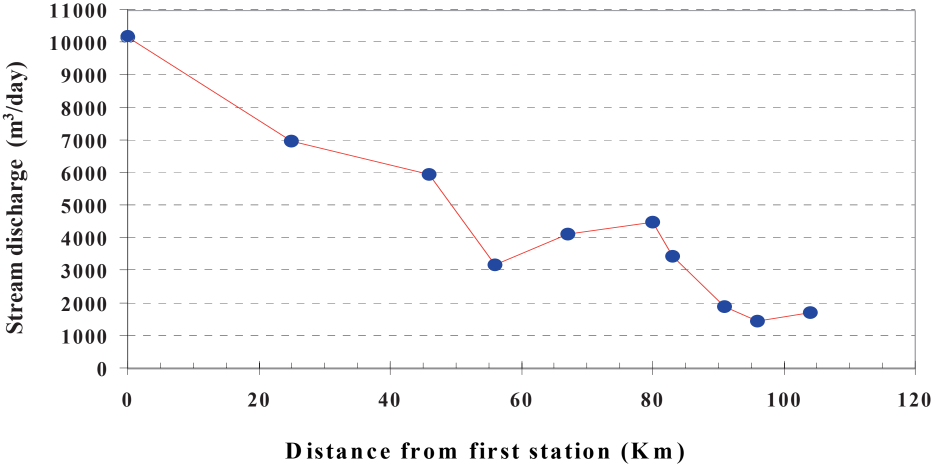

Figure 3. Base flow water discharges along the Besor Stream.

being built for the treatment of Hebron sewage), about 53% of the Hebron sewage infiltrates the ground.

3.2. CHEMICAL CHARACTERISTICS OF BASE FLOW

The base flow in the Hebron/Besor Stream was sampled and analyzed at differrent occasions. The flow in Hebron Stream, as expected, is primarily raw sewage discharged from the city of Hebron and from the marble quarries, which gives the water a whitish–grayish color. The stream flows all year long and can be divided into two segments: One from the city of Hebron to the Green Line in Israel, and the second from the Green Line to Tel-Sheva. Overall, the stream is more polluted upstream near the outlet of Hebron sewage with very high values of COD and BOD (up to 1190 and 1050, respectively; see Table 1). The organic matter in the Hebron/Besor Stream is higher than in the lower part, indicating higher levels of pollution from industrial wastewater and domestic sewage in this section. This situation is probably due to fact that the city of Hebron has a combined sewer collection system, gathering both industrial wastewater and domestic sewage – disposing it untreated into the Wadi.

The Total P and Total N are much higher in the upper part of Hebron Stream. The water running in the Hebron Stream, both on the Palestinian side and on the Israeli side is of extremely low quality and is similar in composition to the raw sewage entering the treatment plant for the city of Beer Sheva and the city of Rahat. Most of the measurements taken along the Hebron Stream fall in the range of raw sewage, while in the case of COD and BOD we can see that the values fall in the lower end of the raw sewage range. The stream does show a limited self-purification mechanism that partially treats the sewage and

TABLE 1. EC, TSS, COD, BOD and TOC values in the Hebron 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)	42–506	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	137.43
TOC (mg/L)	97.2–386	220.2	86–223	141.3

TABLE 2. 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

reduces the organic load in the water (see Figures 4 and 5). Nitrification processes are also seen which are reflected in Figure 5. A sharp decrease in the ammonia level accompanied by a more moderate increase in levels of nitrate in this part of stream begin to occur only downstream from Beer Sheva.

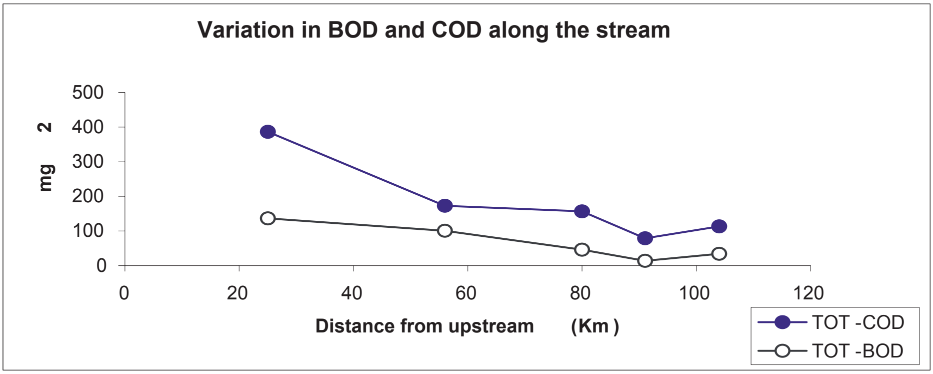

Figure 4. Variation in BOD and COD from upstream to downstream.

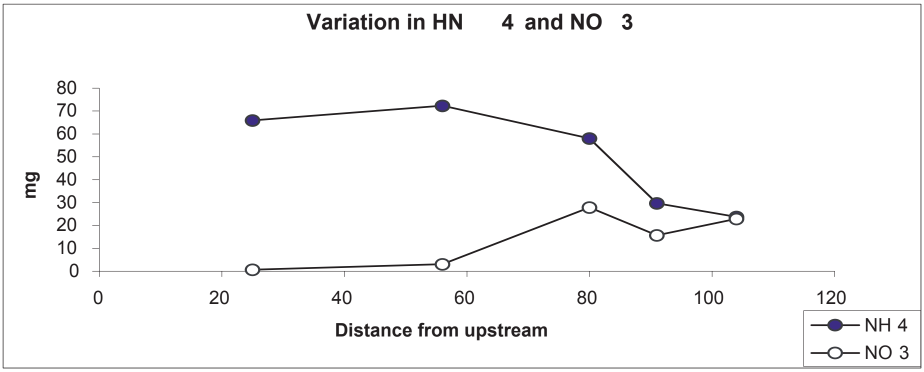

Figure 5. Variation in HN_4 and NO_3 from upstream to downstream.

The Beer Sheva stormwater drainage outlet was sampled during a local rain event (9 March 2005). The drainage outlet is adjacent to the southern industrial area of the city of Beer Sheva, next to the old city. This sample represents the urban and commercial areas' stormwater. It was characterized with lower BOD, COD, TOC, and salinity, as well as lower concentration of major ions. However, the addition of total suspended sediment is quite high and there is a small increase in concentration of some of the trace element such as: Al, 0.27 ppm; Pb, 0.0012 ppm; Sb, 0.0045 ppm; Se, 0.05 ppm; and Sn, 0.0123 ppm. This source may well be problematic especially in the beginning of the rainy season and probably contributes much to the first flush effect.

4. Conclusions

- Base flow water discharge in the Besor watershed decreases downstream by more than 80%. The majority of this loss of water may be attributed to transmission losses in the channel bed, with infiltration of pollution load into the soil and groundwater.
- The major point pollution source is raw sewage discharge from the city of Hebron into the Hebron Stream. This source changes the fundamental nature of the ephemeral stream, converting it into a de facto sewage conduit with permanent baseflow running more than a 120 km downstream.
- The Hebron Stream does show a semi-self-purification mechanism that partly treats the sewage and reduces the organic load in the water.

- A range of pollutants, including nonpoint agricultural runoff, urban stormwater, and discharge from industrial sites have also been identified at many points along the stream.
- The initial research findings about the severity and scope of stream pollution in the Hebron/Besor system confirm the operating assumption of the researchers – that progress in local river restoration requires cooperation between Israelis and Palestinians due to the transboundary nature of the surface water resources.
- Unilateral actions by either side will not return the biological integrity to the streams and may in fact involve wasted resources if there is not a coordinated effort to reduce pollution on a watershed basis. The data collected and models developed in this research underscore the urgent need for ongoing cooperation between Israel and the Palestinian Authority if the challenge posed by surface water contamination is going to be effectively addressed.

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