4.8. Hydrologic assessment of the Zayandeh Rud

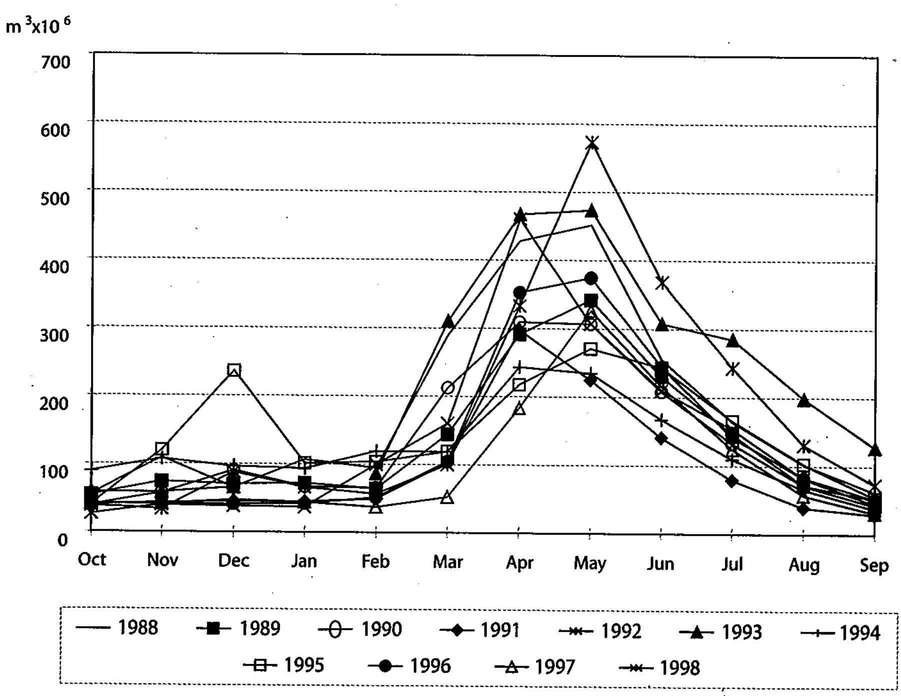
H. Murray-Rust, H. Sally, H.R. Salemi and A. Mamanpoush

Understanding the hydrology of the Zayandeh Rud is essential to any development of scenarios of future opportunities. Planners and water managers must have a clear idea both of total water availability and its likely variation. The nature of the Zayandeh Rud makes this process comparatively simple, because the Chadegan Reservoir lies at the point below which there is no significant natural flow in the critical summer months when water is at its scarcest. The lower flows in winter months generated below Chadegan are sufficient to meet current needs between January and March but cannot be stored unless there is a program of aquifer augmentation (Zahabsanei 2000).

4.8.1. Inflow Assessment

Flows into the Chadegan Reservoir have been determined using a simple water balance that excludes transbasin diversions. The inflows during the period 1989-1998 are stable, with little year-to-year variation, and we can treat these conditions as being typical for a baseline scenario (figure 4.25.). Total annual inflows ranged from just under 1,200 MCM to a maximum of 2,500 MCM during this baseline period.

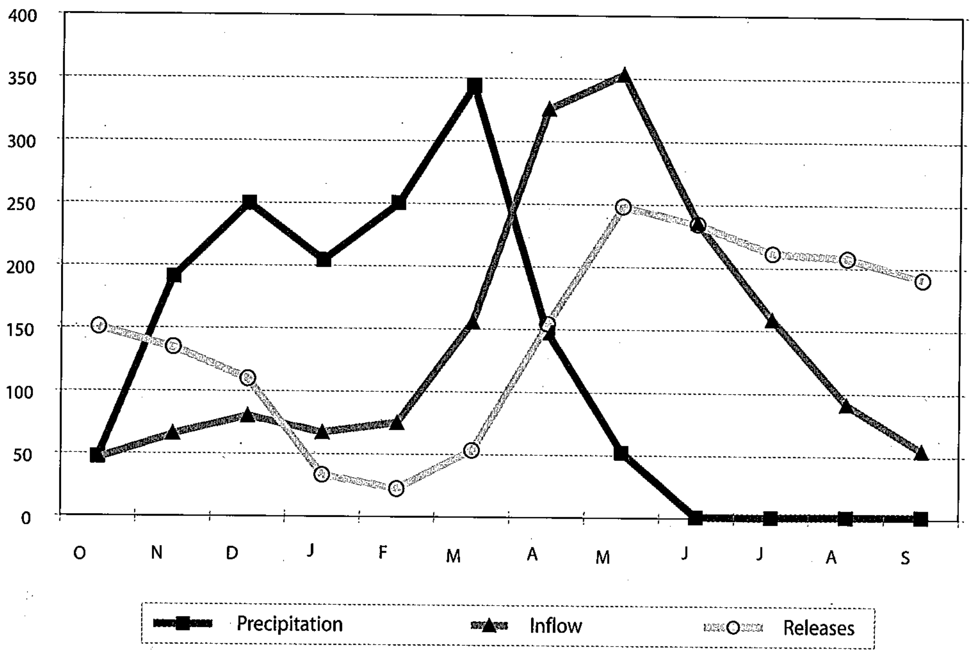
Figure 4.25. Monthly inflows into the Chadegan Reservoir, 1989-1998.



The inflow pattern is quite different to the precipitation pattern for either Esfahan or Kuhrang (figure 4.26.), because most inflow is derived from snow-melt during the spring and early summer. The peak inflows of April and May do not match crop water demand in the later part of the summer.

In addition to natural inflow into the reservoir, two tunnels have been constructed through the Zagros Mountains from the Kuhrang River with a total annual capacity of 540 MCM, and a third tunnel under construction will be able to convey a further 250 MCMyr^{-1}. These tunnels cannot flow full throughout the year, and it is estimated that the total contribution from these tunnels will not exceed more than 50 percent of natural flows in a typical year.

Figure 4.26. Precipitation at Kuhrang (mm), Inflows and Releases (m^3 x 10^6/month) at the Chadegan Reservoir, average for 1989-1998.



4.8.2. Releases from the Chadegan Reservoir

Apart from flood releases in early spring, releases from the Chadegan Reservoir are closely matched to downstream demands, and the entire river is regulated from the reservoir downwards. The release pattern is also quite simple.

An important aspect of the capacity of the Chadegan Reservoir is that it has little or no capacity to store water from one year to the next—virtually all inflow is released for irrigation and other uses during the summer, and the system is therefore highly vulnerable to low winter snowfall that means the reservoir fails to fill up completely before April.

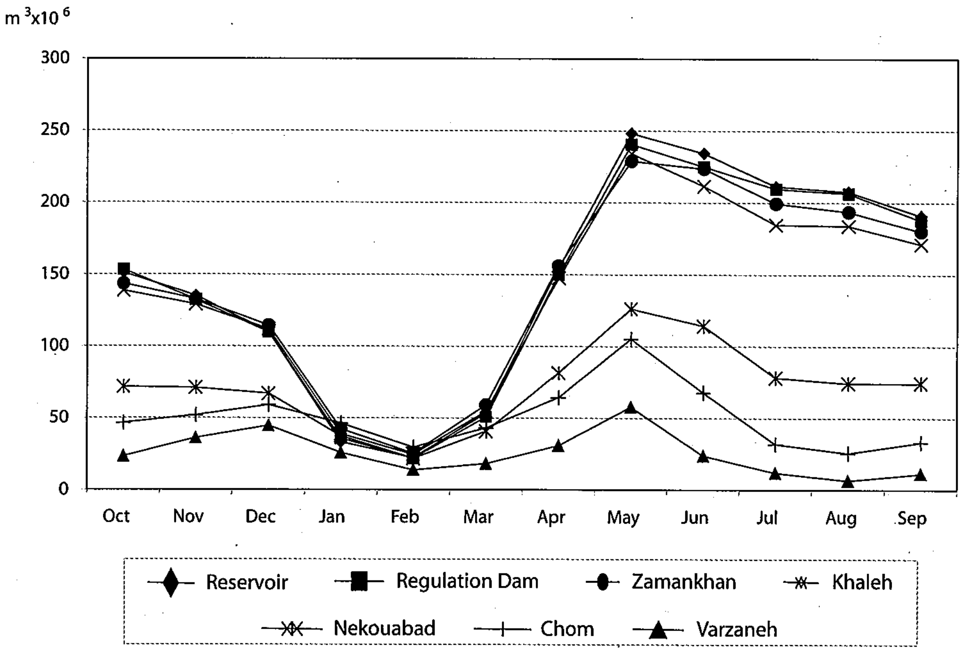
Releases, other than those needed to route floods through the reservoir, are kept at a minimum until late March and then are increased to enable the irrigation season to commence on 1 April. By May, releases have reached their peak and are kept more or less within the range of 200-250 MCM month^{-1} until September. After October 1, releases are cut substantially and gradually decline to their minimum in February. As a result of these operations, the hydrology of the remainder of the Zayandeh Rud is sufficiently simple to allow it to be modeled using a simple spreadsheet accounting approach rather than having to have a more detailed hydrologic model.

4.8.3. Flows in the Zayandeh Rud downstream of the Chadegan Reservoir

There are several gauging stations along the Zayandeh Rud that provide enough information to estimate flows along the river under different discharge conditions.

The flow pattern outside the low-flow months of January and February is practically identical at all the observation points (figure 4.27.). There are only limited extractions between the Chadegan Reservoir and the Regulating Dam just downstream, and the Regulating Dam and the Zamankhan measuring point. Downstream of Pol-e-Kalleh, however, water extraction begins in earnest. The extractions along the reach from Pol-e-Kalleh to the Nekouabad regulator, plus the extractions for irrigation at Nekouabad itself, account for almost half of the flow released from Chadegan. The same pattern is repeated between Nekouabad and Chom, when more than half the remaining flow is extracted from the river, either for urban and industrial use in Esfahan or for irrigation in the Abshar irrigation systems.

Figure 4.27. Average flows (MCM month^{-1}) along the Zayandeh Rud, 1989-1998.



Irrigation extractions dominate water use in the Zayandeh Rud basin and they have a disproportionate impact in the summer when irrigation demand is low. Although releases decline from May to September, the amount extracted upstream of Nekoubad remains almost constant, and actually increases upstream of Chom. As a result, the percentage of total releases reaching Varzaneh decreases dramatically from April to August and only recovers again once irrigation demand slackens and less water is extracted above the Nekouabad and Chom regulators.

Further extractions for irrigation below Chom for the Rudasht irrigation systems reduce flows at Varzaneh to almost nothing, apart from floodwater or drainage releases that may reach this point. In fact, average monthly measured discharges at Varzaneh have fallen below 1 m^3/sec on numerous occasions. Worse, the quality of water reaching Varzaneh is extremely poor with high salt content and many non-agricultural pollutants. Below Varzaneh, there is some return flow of drainage water from the Rudasht irrigation systems, but this effluent is also of very poor quality. As a result, water entering the Gavkhouni salt flats often consists of salinity as high as sea-water.

4.8.4. The importance of return flows in the Zayandeh Rud

The consistency of flows means that it is possible to make reasonably accurate estimates of return flows along each portion of the river. To do this, we need some estimates of total water extractions from the river.

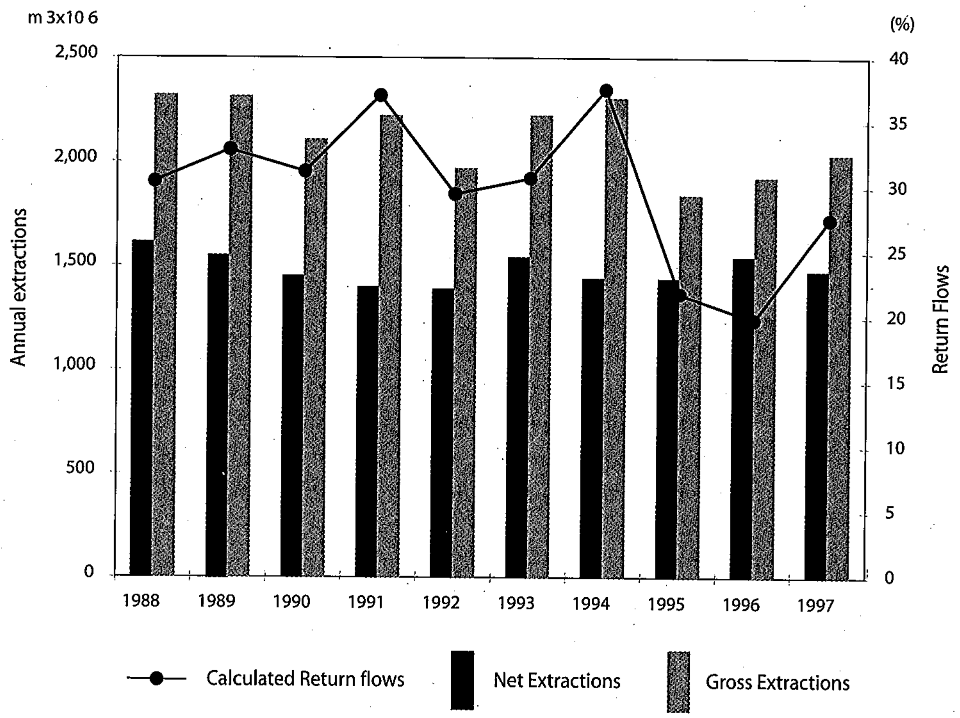
Irrigation deliveries to each of the main irrigation systems are known, based on information collected by the Ministry of Energy at each of the main diversion points. These are the same data as those described earlier in section 4.3. Non-agricultural extractions are harder to quantify. For Esfahan, an average monthly extraction of 4.5 m^3 sec^{-1} is assumed, given a population of 2 million and a daily per capita consumption of 200 l day^{-1}, and an additional 1.9 m^3 sec^{-1} estimated for other urban and industrial uses.

The discharge records and estimates of water use were then entered into a simple spreadsheet-based water accounting model, together with monthly precipitation data adjusted to effective rainfall in areas contributing directly to river discharge. The details of this model and its assumptions concerning all aspects of water extraction are described in Droogers et al. 2000a.

The results indicate that the gross extractions along the river exceed the net extractions calculated from the discharge data. Net extractions are determined by summing the difference in discharge between one gauging station and the next gauging station upstream. Gross extractions are based on the actual extractions plus assumptions about water use in the urban and industrial sectors. Because the difference is substantial, the only way to account for the gap is to assume there are return flows in each section related to the ratio of net to gross extractions. If there were no return flows, gross extractions would exceed net extractions—an impossible situation.

Using this approach, we determine that average annual return flows are in the order of 30 percent, as illustrated in figure 4.28 for each of the 10 years considered. The annual extractions, both net and gross, show little or no year-to-year variation (coefficient of variation = 0.09), suggesting that there is indeed a consistent set of processes that are operating in the baseline condition.

Figure 4.28. Gross and Net Extractions and Estimated Return Flows, Zayandeh Rud, 1988-1997.



The significance of high values for return flows is that apparent inefficiencies in one part of the basin, assumed to be losses when considering the water balance of an irrigation system in isolation, are resulting in increased water for downstream users. This underlines the need to look not only at field and irrigation system levels but also the basin-level water balance in order to understand the interrelationships of water management.

The hydrology of the basin is simple but the demands are complex and growing. As a consequence, it is difficult to see how unchecked urban and industrial growth can continue in the basin despite the transbasin diversion systems currently under development.