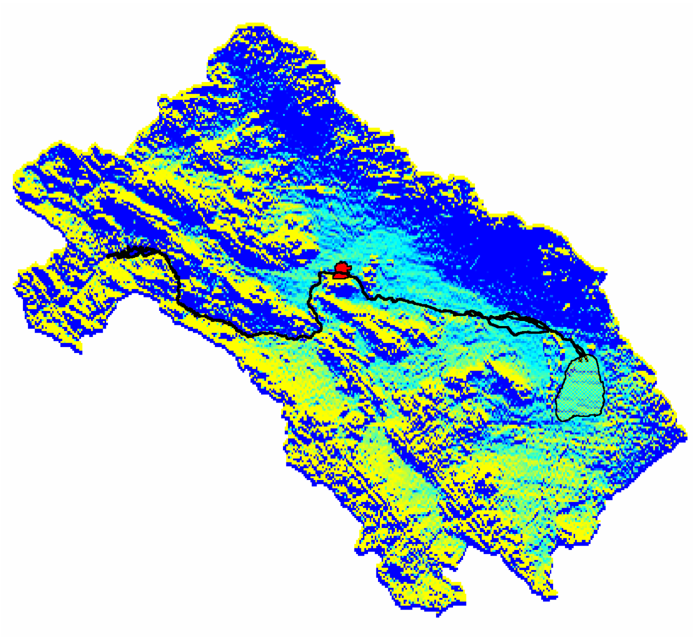
Sustainable Irrigation and Water Management in the Zayandeh Rud Basin, Iran

Water Supply and Demand Forecasting in the Zayandeh Rud basin, Iran

H.R. Salemi, H. Murray-Rust



Research Report No. 13

Iranian **A**gricultural **E**ngineering **R**esearch **I**nstitute
Esfahan **A**gricultural **R**esearch **C**enter
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IAERI EARC IWMI

Salemi, H.R. and H Murray-Rust. 2002. Water Supply and Demand Forecasting in the Zayandeh Rud basin, Iran. IAERI-IWMI Research Reports 13.

Keywords: Water resources development, basin, supply and demand, drought, water scarcity, water allocation

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The IAERI-EARC-IWMI collaborative project is a multi-year program of research, training and information dissemination fully funded by the Government of the Islamic Republic of Iran that commenced in 1998. The main purpose of the project is to foster integrated approaches to managing water resources at basin, irrigation system and farm levels, and thereby contribute to promoting and sustaining agriculture in the country. The project is currently using the Zayendeh Rud basin in Esfahan province as a pilot study site. This research report series is intended as a means of sharing the results and findings of the project with a view to obtaining critical feedback and suggestions that will lead to strengthening the project outputs. Comments should be addressed to:

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Water Supply and Demand Forecasting in the Zayandeh Rud basin, Iran

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Abstract

This paper examines present and future demand for water in the Zayandeh Rud basin, and determines the extent to which water will be available for agricultural use by the year 2020. Current demand and supply were more or less in balance in 2000 but by 2010 there will be an increase in supply of some 28% due to the completion of a third transbasin diversion and development of other local water sources.

If growth in all sectors is assumed to be 2% p.a. then demand will exceed supply by 2010 and the basin will go into severe deficit by 2020. The same is true if demand only grows at 1% a year. As it is unlikely that urban, industrial and environmental demands will decrease, the only way to keep supply and demand in balance is to reduce allocations to agriculture. By 2020 agriculture will only have 5% more water than at present despite the transbasin diversions, and will shrink from 2025 onwards. However, in years when water supply is only 90% of normal then agriculture will have to shrink in order to keep other sectors supplied.

1. Scenario Development in the Zayandeh Rud

The Zayandeh Rud is a closed basin with marked water shortages in recent years that have drastically curtailed water supplies for irrigation. Yet demand for water is growing for multiple uses within the basin that place the currently fragile situation under even greater threat.

Under the Iran-IWMI Collaborative Research Project a number of studies have been undertaken that provide the basis for developing realistic scenarios for future water supply and demand in the basin that can help guide policy makers and planners to a desirable solution on how to manage the basin water resources.

Scenarios are estimations of different combinations of supply and demand based on assumptions that reflect current and expected conditions in the future. They are not wild guess but are designed to offer policy makers and planners a set of alternatives from which to choose. A simple scenario might to be increase demand for water by all users by 10% a year, while complex scenarios might have different combinations of increases and decreases in demand alongside a different set of assumptions about supply. Many of the assumptions made in this paper are the result of various discussions held with representatives of the Esfahan Regional Office of the Ministry of Energy, the Master Plan Organization of Esfahan Province, and the Ministry of Jehad-e-Agriculture.

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To help policy makers and planners in this process different models can be used that will enable us to assess the probable impact of different supply and demand. In the case of the Zayandeh Rud study the primary focus is on agricultural and environmental impacts, notably the effect on production of different crops in different parts of the basin, and the risk of increased salinization in lower portions of the basin.

This paper addresses the issue of forecasting of water demands for different sectors at basin level, and proposes a number of scenarios that can be used as inputs into the different models adopted by the project team. These forecasts are based on a simply budgeting process rather than strict water balance because the interest is in assessing the impact on agriculture of water allocation between different sectors and uses.

2. Current Water Supply in the Zayandeh Rud

There are several sources of water supply in the basin that need to be included in scenario assessment. Each one is discussed in terms of the available information primarily obtained from the Ministry of Energy. Additional information has been obtained from Momtazpur, M. (1996), Zahabsanei, A. (2000) and Yekom Consulting (1998). A fuller description of the hydrology of the basin is available in Murray-Rust et al. (2000).

a) Natural Inflow in Chadegan Reservoir

The natural hydrology of the Zayandeh Rud upstream of Chadegan Reservoir is well understood because there are daily observations of water levels and releases. On an annual basis the long-term historical yield over the past 30 years is approximately 900 MCM, but there is considerable annual variation due to differences in winter snowfall in the Zagros Mountains that are the natural watershed for the reservoir.

b) Transbasin diversions

The Ministry of Energy has invested considerable resources into development of three tunnels to transfer water from the Kurang River into the catchment of Chadegan Reservoir. The first two tunnels are already open. The earliest, supplying 337 MCM each year was constructed in 1953, while the second was completed in 1986 and delivers 250 MCM each year. The third tunnel, currently under construction, will deliver an additional 280 MCM per year.

The importance of these tunnels to the Zayandeh Rud cannot be underestimated. When the last tunnel is completed transbasin inflows into Chadegan reservoir will exceed natural inflows into Chadegan Reservoir. Without the tunnels current levels of economic development in the Zayandeh Rud basin could not be sustained.

c) Other Water Sources

There are a few springs and other natural sources of water that are still available for development, with a total annual yield of about 150 MCM. Plans exist to tap these resources during the present decade.

These three water sources can at present deliver in the order of 1487 MCM in an average year, and this will rise to 1913 MCM when the third Kurang tunnel is completed and local water sources fully developed. As far as can be estimated, this represents the maximum available water supply to the basin into the foreseeable future.

The water supplies to Zayandeh Rud are shown in Figure 1 for current and future conditions.

3. Current Demand (2000) for Water in Zayandeh Rud Basin

Estimating demand for water is much more difficult because many water abstractions are only estimates, and there has to be a set of assumptions about return flows into the river from different uses. The figures below are our best estimate of current demand patterns based on figures for 2000.

a) Greater Esfahan Urban Demand

At present greater Esfahan and surrounding areas is estimated to have a population of about 2.3 m people. At present the per capita water availability is high, as much as 250 l/day. This translates to 210 MCM per year, some from river extractions, some from groundwater. The high per capita figure is explained in part by high conveyance losses in transmission, high demand during the height of summer when temperatures are high, and demands from small-scale industries incorporated into the urban water supply.

The urban supplies come from a number of sources: roughly two-thirds comes from the Babar Shakh Ali treatment plant which obtains water directly from the Zayandeh Rud diversion upstream of Esfahan, the remaining one-third coming from the Felman wellfield which is recharged by Zayandeh Rud water.

However, there are significant return flows to the river from urban areas which can be used by downstream irrigation systems, and these are estimated at about 50% of total diversions for urban demand. This is lower than often used in return flow estimates because a considerable volume of wastewater is used to grow trees around Esfahan and major industrial areas. This wastewater is applied through surface and drip systems, although some areas have to use road tankers.

b) Other Urban Demand

There are several other significant communities in the basin, primarily at Shahrekord, which will be incorporated into the basin water resources before 2010. At present no account is made for the water supply to Shahrekord.

c) Industrial Demand

Although the urban demand estimates given above allow for some industrial use, there are specific large water users in the basin who have their own water requirements. These include cement works, steel works, iron smelter, oil refinery, polyacrylic plant and electricity generation. The current estimate for their water requirements is 100 MCM.
Agricultural Demand

d) Agricultural Demand

There are approximately 100,000 ha of irrigated land in the basin. On average water extractions for agriculture are in the order of 1500 mm, or a total annual demand of 1500 MCM. This makes agriculture by far the largest single demand for water in the basin.

Like urban areas, there is high return flow from irrigated lands to the river, and we estimate this to be in the order of 20% of total abstractions. Upstream return flows are probably much higher than this, but are offset by rather low return flows in tail end systems. This means that agriculture is a net user of some 1200 MCM.

e) Environmental Demand

At present there is no specific allocation of water for in-stream needs or for protection of Gavkhouni Swamp, but the Environment Organization of Esfahan calls for a minimum flow into Gavkhouni Swamp of 70 MCM per year.

f) Transbasin Diversion

Part of the justification of construction of new water resource development projects has been the development of water supplies to Yazd, east of Esfahan, and to Kashan At present only 34 MCM can be delivered to Yazd, but this will rise to 80 MCM before 2010. Kashan is planned to receive 45 MCM by 2010.

g) Unaccounted losses

Inevitably there are unaccounted losses in any large basin, from evaporation from the reservoir, the river surface and other non-beneficial depletions. It is anyone's guess what this figure actually is, and we estimate it to be 75 MCM, or about 5% of the total flow in the river.

Based on all of these estimates, total current demand is estimated to be 1513 MCM

4. Baseline Scenario: Conditions in 2000

Based on these figures we can now present the baseline scenario for 2000 levels of water supply and demand. These are shown in Table 3, from which it is perfectly clear that even with average flows the basin is in deficit, in the order of 26 MCM, or roughly 2% of total available water in a normal year.

The baseline scenario can be used to justify the need to increase transbasin diversions because present water resources are clearly inadequate to sustain current levels of economic development, let alone permit continued growth.

5. Future Scenarios based on average conditions

Obviously there is a wide range of potential scenarios available but it is useful to pick ones that enable us to make realistic choices for planners and policy makers.

We propose two additions to the demand estimations of the baseline scenario. First, we assume the water allocation to Yazd will rise as planned from 34 MCM per year to 80 MCM per year, and an additional 45 MCM is used for Kashan water supply. Neither of these systems generate return flow to the Zayandeh Rud. Second, we assume that there will be an implemented environmental demand to maintain in-stream flows along the river and increase the flow into Gavkouni Swamp. This has been fixed at 70 MCM per year. These two additional water demands remain constant throughout all of the scenarios, and result in an additional demand over the baseline scenario of 161 MCM per year.

To compensate for this on the supply side, however, we assume the third tunnel at Kurang will be completed and function as designed, providing an additional 280 MCM per year, and locally developed springs will provide an additional 150 MCM, for a total increase in supply of 430 MCM, increasing the total water available to the basin under average conditions from 1487 MCM to 1917 MCM.

The effect of these one-off changes in supply and demand result in net annual increase of 259 MCM (430 increase in supply less 171 MCM increase in demand to transbasin and environmental commitments). We assume this is the maximum additional water availability we can expect under average conditions.

5.1 Scenario 1: All sectors grow at 2% per annum

In this scenario we assume that all sectors (i.e. urban, industrial and agriculture) all grow at 2% a year for the next 20 years. The estimated changes in supply, which include appropriate allowance for increased return flows from both urban and agricultural sectors are shown in Table 4.

Under this scenario it is clear that despite increases in supply, the basin will continue to be in deficit in both 2010 and 2020. In 2010 the deficit is slightly larger than that currently experienced, at 67 MCM or 3% of total supply. By 2020, however, the deficit reaches 406 MCM, or 17% of available supply.

This scenario appears unsustainable and is rejected as a realistic option.

5.2 Scenario 2: All sectors grow at 1% per annum

In this scenario we assume that all sectors only grow at 1% per annum over the next 20 years. The results, shown in Table 5, show that in 2010 the additional water from Kurang and local sources is sufficient to meet increased demand, and there is even a 4% surplus of supply over demand. By 2020, however, the deficit will be similar to that experienced at present.

This is considered to be a realistic scenario in terms of supply but it has implications economically due to very low growth of Esfahan. To expect current rapid growth of the city and its surroundings to fall to only 1% a year would require a great deal of intervention, and may not be feasible.

5.3 Scenario 3: High urban growth, moderate growth in other sectors

In this scenario we assume there will be a much greater increase in urban demand than in other sectors. Urban demand is estimated to rise by 25% each decade, while industrial and agriculture grow by only 10% each decade. Recent growth rates for Esfahan have been high, and we feel that water consumption patterns will also change over time.

We therefore anticipate an increase in urban demand from 210 MCM at present to 273MCM in 2010 and 355 MCM in 2020. In addition a total of 15 MCM will be required for Shahrekord in 2010, rising to 20 MCM in 2020. Full details are provided in Table 6.

Under these assumptions, the basin will be able to meet all water demands in 2010 but will drop into substantial deficit by 2020.

	2000			2010			2020		
Scenario	Supply	Demand	Surplus /Deficit	Supply	Demand	Surplus /Deficit	Supply	Demand	Surplus /Deficit
1	1487	1513	-26	1917	1984	-67	1917	2323	-406
2	1487	1513	-26	1917	1844	73	1917	1999	-82
3	1487	1513	-26	1917	1865	52	1917	2051	-134

Table 1: Basin level surplus/deficit of water under different growth scenarios

Table 1 summarizes the impacts of these three scenarios on overall basin surpluses and deficits. Although the overall situation is favorable for scenarios 2 and 3 in 2010, all are in substantial deficit by 2020 and it is felt that none of these scenarios is really realistic.

We therefore propose an alternative approach, illustrated in scenario 4.

5.4 Scenario 4: High urban growth, modest industrial growth, agricultural demand adjusted to balance out overall basin level supply and demand

In this scenario we assume increase in urban demand as in scenario 3, a 1% growth rate in industrial water demand, and a balanced supply and demand for water at basin level. This is accomplished by adjusting the water available for agriculture so as to obtain a proper balance between supply and demand.

In 2010 the increases in water supply allow for an increase in the net water allocation for water for agriculture up to 1372 MCM, a growth of about 1.4% per annum over current levels, but by 2020 the residual available to agriculture would be back to about 1318 MCM, or an overall growth of only 0.5% per year over current levels. Details are provided in Table 7.

Unpalatable as this may seem for the agriculture, this scenario appears the most realistic, and forms the basis for assessing the impact of deviations from average. The allocations by sector for 2000 to 2020 are shown in Figure 2.

	2000			2010			2020		
Scenario	Basin Supply	Supply to Agri-culture	Change from 2000	Basin Supply	Supply to Agri-culture	Change from 2000	Basin Supply	Supply to Agri-culture	Change from 2000
4	1487	1200	0	1917	1372	172	1917	1318	118
4a	1338	1032	-168	1726	1190	-20	1726	1136	-64
4b	1190	891	-309	1534	1008	-192	1534	954	-246

Table 2. Effect on agriculture sector allocations when supply and demand are balanced out.

6. Scenario Development for deviations in supply from average conditions

In reality, there is rarely an "average" year with supplies ranging significantly on a year-to-year basis. To illustrate the impact of this, we have adapted Scenario 4 to allow for two different levels of water deficit and one of surplus.

The urban, industrial, environmental and transbasin diversion requirements all remain the same, the impact being absorbed entirely by the agricultural sector.

One critical asumption made here is that transbasin diversions into the basin will reflect the overall changes in water supply through natural flows. This has indeed occurred over the years so that in years of low rainfall and snowfall the tunnels at Kurang cannot run at full discharge.

Scenario 4.1: 10% drop in discharge into Chadegan Reservoir

The impact of a 10% flow into Chadegan is substantial. Under present conditions this would mean a drop in supply from 1487 to 1338 MCM, and a drop from 1917 MCM to 1725 MCM once all water sources have been developed. Deatiles are given in Table 8.

If agriculture takes the full impact of this reduction then present day net allocation to agriculture would be only 1032 MCM, rising to 1190 MCM in 2010 and falling again to 1136 MCM by 2020. Thus a 10% reduction in supply means that there will never be as much water for agriculture than under present day conditions.

Scenario 4.2: 20% drop in discharge into Chadegan Reservoir

The impact of a 20% flow into Chadegan is substantial, and means agriculture will get about 25% less water than under the assumptions of Scenario 5.4 Under present conditions this would mean a drop in basin level supply from 1487 to 1190 MCM, and a drop from 1917 MCM to 1534 MCM once all water sources have been developed (Table 9).

If agriculture takes the full impact of this reduction then present day net allocation would be only 891 MCM, rising to 1008 MCM in 2010 and falling again to 954 MCM by 2020. The net diversions by sector under this scenario are shown in Figure 4.

This means that with a 20% reduction in net allocations to agriculture there will be major impacts on productivity and profitability of irrigated agriculture.

To put this into perspective, inflows during the 1998-2001 period were only about 1250 MCM in both 1998-99 and 1999-2000, and were only a meagre 250 MCM in 2000-2001. These are way below the pessimistic assumption of a 20% decline in overall water availability.

7. Conclusions

Without transbasin diversions the Zayandeh Rud basin would be unable to meet existing demand for water. Already some 587 MCM are delivered into the basin from the Kurang River, and this will rise to 867MCM when the third tunnel is completed in the next few years.

However, the analysis of several scenarios shows that as long as the urban, industrial and agriculture sectors continue to grow the basin will be unable to meet water demand before 2020. The growth rates assumed are all modest: with annual growth rates of 20% per decade in all sectors the basin will be in deficit before 2010 despite additional water resources, and so it is inevitable that either current rapid growth will have to shrink rapidly, or certain sectors will have to give up water to other uses.

In the most realistic scenarios we have balanced out basin level supply and demand by adjusting the supply to the agricultural sector, allowing urban growth of 25% per decade and industrial growth of 10% per decade. Under these conditions agriculture can experience a modest growth as long as supplies are at historic normal levels.

Once supplies drop below historic averages, however, agriculture takes a significant cut in water supplies. If total supplies are only 10% below average then even in 2010, the most favorable year in our scenario, total water supplies for agriculture will be less than at the present day.

A 20% drop in supply means agricultural water allocations will drop by up to 25% compared to present allocations. The implications of these trends for agricultural sustainability are disturbing, because it means that in simple language, there will be a lot less water for food production than at present.

Acknowledgements

We are deeply indebted to Engineer Lotfollah Ziaie of Zayandab Consult, Ghloamhosein Heydarpur and Mehdi Eslami from Esfahan Regional Water Authority who provided us with much of the data used in this paper. Additional thanks go to the Esfahan staff of the Ministry of Energy, the Department of Environment and the Master Plan Organization. Finaincing of the Iran-IWMI Collaborative Research Project is provided by the Government of the Islamic Republic of Iran through the Agricultural Research, Extension and Education Organization of the Ministry of Jehad-e-Agriculture.

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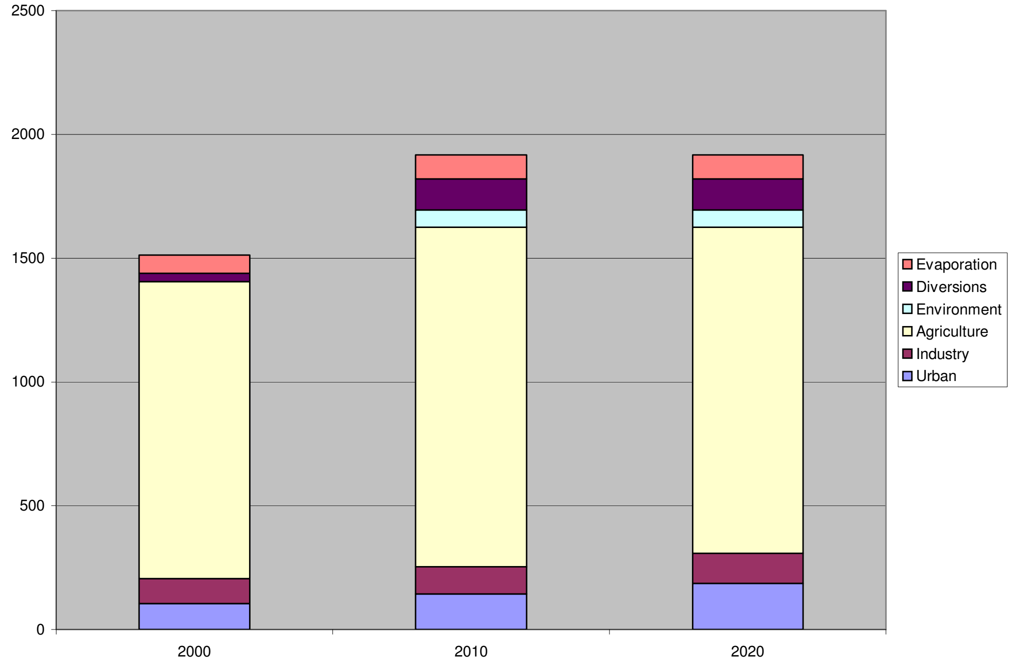

Figure 1: Water supplies into Zayandeh Rub basin in 2000, and projected supplies for 2010 and 2020, under average inflow conditions

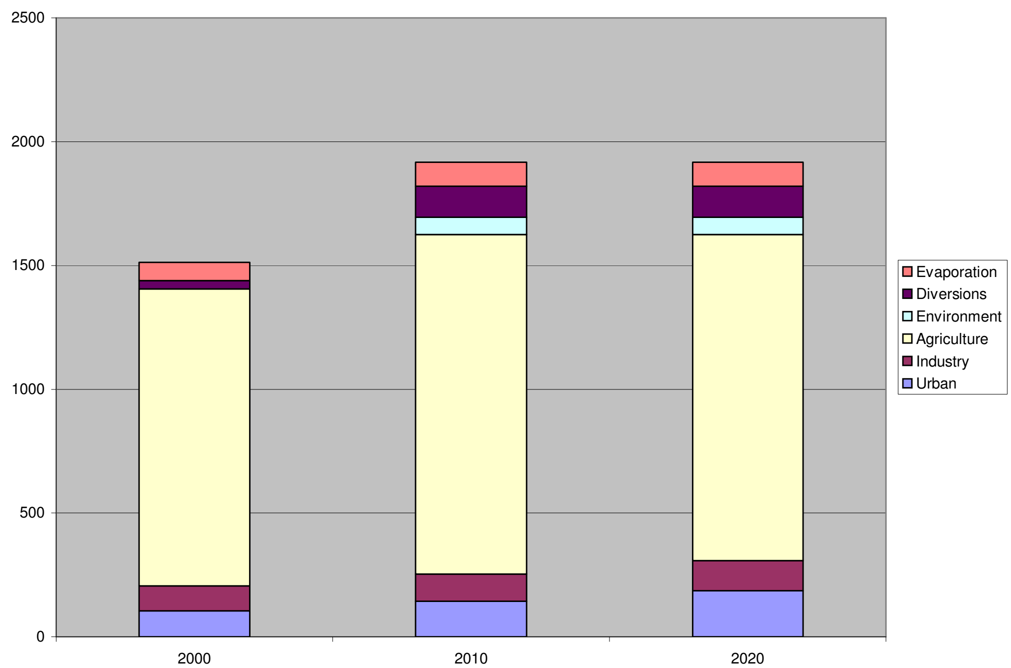

Figure 2: Net water allocations by sector when water supplies are average (return flows have been deducted from urban and agricultural allocations)

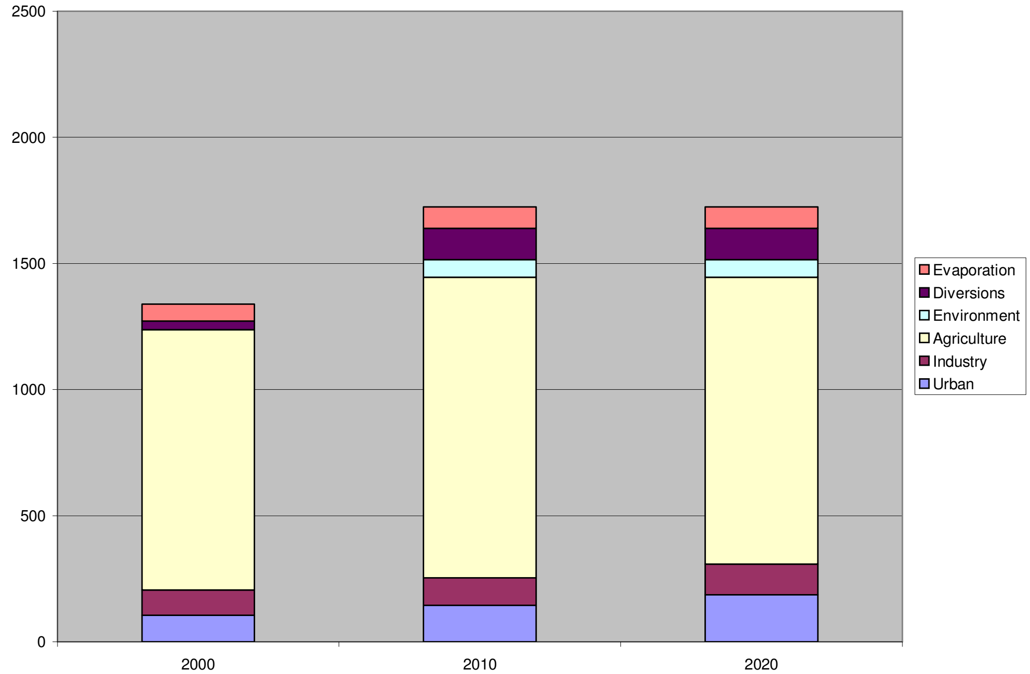

Figure 3: Net water allocations by sector when water supplies are 10% below average (return flows have been deducted from urban and agricultural allocations)

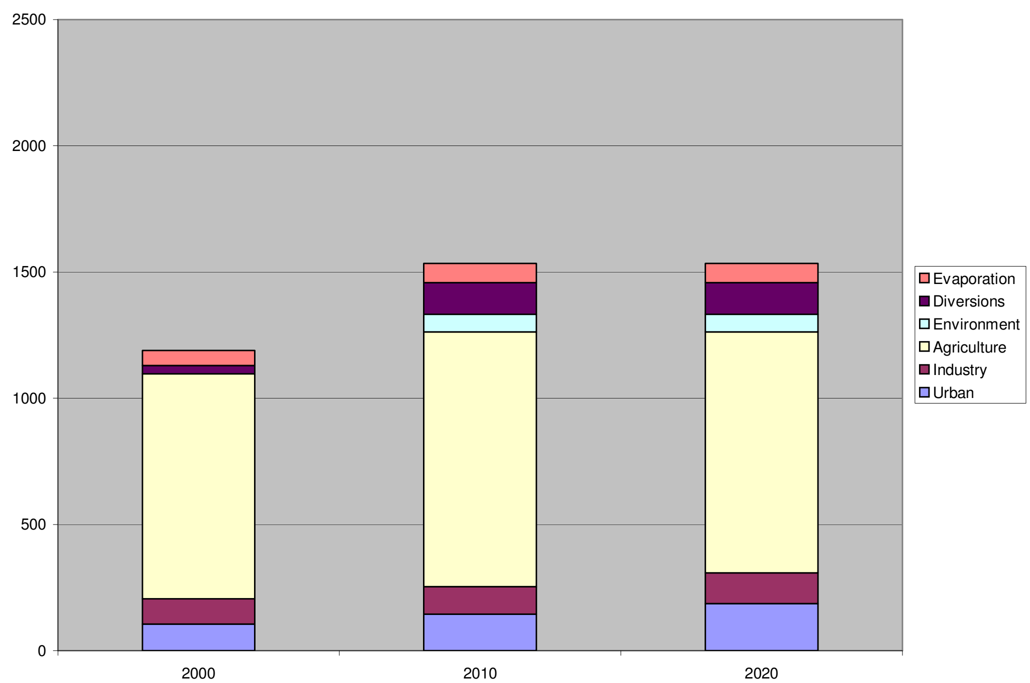

Figure 4: Net water allocations by sector when water supplies are 20% below average (return flows have been deducted from urban and agricultural allocations)

Table 3

WATER BALANCE FOR ZAYANDEH RUD, ESFAHAN - YEAR 2000

SUPPLY ESTIMATIONS	mcm	%	Source/Assumption
Natural Flow of Zayandeh Rud at Chadegan	900	*61*	based on historic average
Kurang Tunnel 1	337	*23*	Ministry of Energy
Kurang Tunnel 2	250	*17*	Ministry of Energy
Kurang Tunnel 3	0	*0*	Ministry of Energy
Langan and Khadangestan Springs	0	*0*	Ministry of Energy
TOTAL SUPPLY	**1487**		

DEMAND ESTIMATIONS			
Urban Areas			
Greater Esfahan	210		275 l/day/person for 2,100,000 people
Supply for other cities near river	0		
Total Urban Supply	210	*14*	
Return flows from urban areas	-105	*-7*	50% return flow
Industry	100	*7*	Master Plan Organization
Agriculture	1500	*101*	100,000 ha at 1,500 mm/year diversion
Return flows from agriculture	-300	*-20*	20% return flow
Environmental Demand	0	*0*	None
Transbasin Diversion	34	*2*	Ministry of Energy
Evaporation	74	*5*	5% of total river flow
TOTAL DEMAND	**1513**		
DEFICIT	***-26***	*-2*	

Table 4

WATER BALANCE FOR ZAYANDEH RUD, ESFAHAN
SCENARIO 1: all sectors grow by 2% annually

	2000		2010		2020	
SUPPLY ESTIMATIONS	mcm	%	mcm	%	mcm	%
Natural Flow of Zayandeh Rud at Chadegan	900	*61*	900	*47*	900	*47*
Kurang Tunnel 1	337	*23*	337	*18*	337	*18*
Kurang Tunnel 2	250	*17*	250	*13*	250	*13*
Kurang Tunnel 3	0	*0*	280	*15*	280	*15*
Langan and Khadangestan Springs	0	*0*	150	*8*	150	*8*
TOTAL SUPPLY	**1487**		**1917**		**1917**	
DEMAND ESTIMATIONS						
Urban Areas						
Greater Esfahan	210		252		302	
Supply for other cities near river	0		15		18	
Total Urban Supply	210	*14*	267	*14*	320	*17*
Return flows from urban areas	-105	*-7*	-134	*-7*	-160	*-8*
Industry	100	*7*	120	*6*	144	*8*
Agriculture	1500	*101*	1800	*94*	2160	*113*
Return flows from agriculture	-300	*-20*	-360	*-19*	-432	*-23*
Environmental Demand	0	*0*	70	*4*	70	*4*
Transbasin Diversion	34	*2*	125	*7*	125	*7*
Evaporation	74	*5*	96	*5*	96	*5*
TOTAL DEMAND	**1513**		**1984**		**2323**	
DEFICIT	***-26***	*-2*	***-67***	*-3*	***-406***	*-17*

Table 5

WATER BALANCE FOR ZAYANDEH RUD, ESFAHAN
SCENARIO 2: all sectors grow by 1% annually

	2000		2010		2020	
SUPPLY ESTIMATIONS	mcm	%	mcm	%	mcm	%
Natural Flow of Zayandeh Rud at Chadegan	900	*61*	900	*47*	900	*47*
Kurang Tunnel 1	337	*23*	337	*18*	337	*18*
Kurang Tunnel 2	250	*17*	250	*13*	250	*13*
Kurang Tunnel 3	0	*0*	280	*15*	280	*15*
Langan and Khadangestan Springs	0	*0*	150	*8*	150	*8*
TOTAL SUPPLY	**1487**		**1917**		**1917**	
DEMAND ESTIMATIONS						
Urban Areas						
Greater Esfahan	210		231		254	
Supply for other cities near river	0		15		17	
Total Urban Supply	210	*14*	246	*13*	271	*14*
Return flows from urban areas	-105	*-7*	-123	*-6*	-135	*-7*
Industry	100	*7*	110	*6*	121	*6*
Agriculture	1500	*101*	1650	*86*	1815	*95*
Return flows from agriculture	-300	*-20*	-330	*-17*	-363	*-19*
Environmental Demand	0	*0*	70	*4*	70	*4*
Transbasin Diversion	34	*2*	125	*7*	125	*7*
Evaporation	74	*5*	96	*5*	96	*5*
TOTAL DEMAND	**1513**		**1844**		**1999**	

Table 6

WATER BALANCE FOR ZAYANDEH RUD, ESFAHAN
SCENARIO 3: higher urban demand

	2000		2010		2020	
SUPPLY ESTIMATIONS	mcm	%	mcm	%	mcm	%
Natural Flow of Zayandeh Rud at Chadegan	900	*61*	900	*47*	900	*47*
Kurang Tunnel 1	337	*23*	337	*18*	337	*18*
Kurang Tunnel 2	250	*17*	250	*13*	250	*13*
Kurang Tunnel 3	0	*0*	280	*15*	280	*15*
Langan and Khadangestan Springs	0	*0*	150	*8*	150	*8*
TOTAL SUPPLY	**1487**		**1917**		**1917**	
DEMAND ESTIMATIONS						
Urban Areas						
Greater Esfahan	210		273		355	
Supply for other cities near river	0		15		20	
Total Urban Supply	210	*14*	288	*15*	375	*20*
Return flows from urban areas	-105	*-7*	-144	*-8*	-187	*-10*
Industry	100	*7*	110	*6*	121	*6*
Agriculture	1500	*101*	1650	*86*	1815	*95*
Return flows from agriculture	-300	*-20*	-330	*-17*	-363	*-19*
Environmental Demand	0	*0*	70	*4*	70	*4*
Transbasin Diversion	34	*2*	125	*7*	125	*7*
Evaporation	74	*5*	96	*5*	96	*5*
TOTAL DEMAND	**1513**		**1865**		**2051**	
DEFICIT	***-26***	*-2*	***52***	*3*	***-134***	*-7*

Table 7

WATER BALANCE FOR ZAYANDEH RUD, ESFAHAN
SCENARIO 4: higher urban demand, ag sector adjusted to balance supply and demand

	2000		2010		2020	
SUPPLY ESTIMATIONS	mcm	%	mcm	%	mcm	%
Natural Flow of Zayandeh Rud at Chadegan	900	*61*	900	*47*	900	*47*
Kurang Tunnel 1	337	*23*	337	*18*	337	*18*
Kurang Tunnel 2	250	*17*	250	*13*	250	*13*
Kurang Tunnel 3	0	*0*	280	*15*	280	*15*
Langan and Khadangestan Springs	0	*0*	150	*8*	150	*8*
TOTAL SUPPLY	**1487**		**1917**		**1917**	
DEMAND ESTIMATIONS						
Urban Areas						
Greater Esfahan	210		273		355	
Supply for other cities near river	0		15		20	
Total Urban Supply	210	*14*	288	*15*	375	*20*
Return flows from urban areas	-105	*-7*	-144	*-8*	-187	*-10*
Industry	100	*7*	110	*6*	121	*6*
Agriculture	1500	*101*	1715	*89*	1647	*86*
Return flows from agriculture	-300	*-20*	-343	*-18*	-329	*-17*
Environmental Demand	0	*0*	70	*4*	70	*4*
Transbasin Diversion	34	*2*	125	*7*	125	*7*
Evaporation	74	*5*	96	*5*	96	*5*
TOTAL DEMAND	**1513**		**1917**		**1917**	
DEFICIT	***-26***	*-2*	***0***	*0*	***0***	*0*

Table 8

WATER BALANCE FOR ZAYANDEH RUD, ESFAHAN

SCENARIO 4.1: 10% reduction in overall water supply

	2000		2010		2020	
SUPPLY ESTIMATIONS	mcm	%	mcm	%	mcm	%
Natural Flow of Zayandeh Rud at Chadegan	810	*61*	810	*47*	810	*47*
Kurang Tunnel 1	303	*23*	303	*18*	303	*18*
Kurang Tunnel 2	225	*17*	225	*13*	225	*13*
Kurang Tunnel 3	0	*0*	252	*15*	252	*15*
Langan and Khadangestan Springs	0	*0*	135	*8*	135	*8*
TOTAL SUPPLY	**1338**		**1725**		**1725**	
DEMAND ESTIMATIONS						
Urban Areas						
Greater Esfahan	210		273		355	
Supply for other cities near river	0		15		20	
Total Urban Supply	210	*16*	288	*17*	375	*22*
Return flows from urban areas	-105	*-8*	-144	*-8*	-187	*-11*
Industry	100	*7*	110	*6*	121	*7*
Agriculture	1290	*96*	1488	*86*	1420	*82*
Return flows from agriculture	-258	*-19*	-298	*-17*	-284	*-16*
Environmental Demand	0	*0*	70	*4*	70	*4*
Transbasin Diversion	34	*3*	125	*7*	125	*7*
Evaporation	67	*5*	86	*5*	86	*5*
TOTAL DEMAND	**1338**		**1726**		**1726**	
DEFICIT	***0***	*0*	***0***	*0*	***0***	*0*

Table 9

WATER BALANCE FOR ZAYANDEH RUD, ESFAHAN

SCENARIO 4.2: 20% reduction in overall water supply

	2000		2010		2020	
SUPPLY ESTIMATIONS	mcm	%	mcm	%	mcm	%
Natural Flow of Zayandeh Rud at Chadegan	720	*61*	720	*47*	720	*47*
Kurang Tunnel 1	270	*23*	270	*18*	270	*18*
Kurang Tunnel 2	200	*17*	200	*13*	200	*13*
Kurang Tunnel 3	0	*0*	224	*15*	224	*15*
Langan and Khadangestan Springs	0	*0*	120	*8*	120	*8*
TOTAL SUPPLY	**1190**		**1534**		**1534**	
DEMAND ESTIMATIONS						
Urban Areas						
Greater Esfahan	210		273		355	
Supply for other cities near river	0		15		20	
Total Urban Supply	210	*18*	288	*19*	375	*24*
Return flows from urban areas	-105	*-9*	-144	*-9*	-187	*-12*
Industry	100	*8*	110	*7*	121	*8*
Agriculture	1114	*94*	1260	*82*	1192	*78*
Return flows from agriculture	-223	*-19*	-252	*-16*	-238	*-16*
Environmental Demand	0	*0*	70	*5*	70	*5*
Transbasin Diversion	34	*3*	125	*8*	125	*8*
Evaporation	59	*5*	77	*5*	77	*5*
TOTAL DEMAND	**1190**		**1534**		**1534**	
DEFICIT	***0***	*0*	***0***	*0*	***0***	*0*

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2. **Exploring field scale salinity using simulation modeling, example for Rudasht area, Esfahan Province, Iran.** (2000) P. Droogers, M. Akbari, M. Torabi, E. Pazira.
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15. **Groundwater resources modeling of the Lenjanat aquifer system.** (2002). A. Gieske and M. Miranzadeh.