IWRM INDICATORS

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As we ascertained earlier, integrated water resources management is a system that is characterized by specific principles and involves a number of key interrelated components. First, this is available water resource itself with all it's characteristics (indicators) and engineering infrastructure for water abstraction, storage and delivery to water consumers and water users. Management envisages the obligatory water requirement assessments, procedures for water allocation based on the constant balance of water supplies and demands, direct services on water delivery, and finally, the management of the water use process. Water quality control and meeting environmental requirements can also be add to above activities.

Table 3.1. Components and Indicators of Water Resources Management Process

WRM Components		Tasks	Indicators
Available water resources	Governance	Monitoring Development Protection	Amount, quality, regime, renewability, variability
Infrastructure		O&M	Costs / efficiency / cost recovery
Water requirement		Evaluation Demand management	Level/amount/quality/time/location
Water balance and allocation		Participation Plan (schedule) Regulations	Norm for flow rate Equitability & rationality criterion (rights / share / quota / limit)
Water delivery		Secured water supply	Sufficiency of water supply, uniformity, sustainability, minimum unproductive losses
Water use and productivity		Output and water saving	Productivity (more crop per a water drop)
Water use impacts (MDGs)		Sustainable development	Sustainable use index
Management assets		Maintaining waterworks in operational conditions	Operational indicators
Water quality & ecological flows management		Meeting the environmental requirements	Quality indicators and ecological flow rates
Monitoring & Evaluation		Day-to-day management	Availability of on-line information from all key points of water delivery and distribution
Long-term planning		Adaptation to long-term changes	Water requirements over the planned period are met

In addition, management has to forecast long-term changes of key factors and water balance components, as well as specify a mechanism for adaptation of the water use system to these changes. Naturally, outcomes and efficiency of management should be regularly monitored and evaluated. Water management also covers a number of additional components related to financing, procurement process, recruitment and appointment of personnel, etc. Each component is aimed at solving specific tasks and can be evaluated with the use of relevant indicators that allows assessment of the actual progress. Key components of water management, their tasks, and proposed indicators for M&E are given in Table 3.1.

Monitoring, assessment, protection and development of available water resources (surface and ground water available for use) are key objectives of the first component. A key indicator, which demonstrates the progress of achieving established objectives is the 'renewability' of water resources with regards to it's reserves or level at the source, water quality, and variability of these parameters over the time. One of key objective related to engineering infrastructure (reservoirs, irrigation and drainage canals, hydraulic structures, water supply network, etc,.) is proper operation and maintenance (O&M), including the maintenance of necessary operational regimes and design parameters of structures; their repairs, up-grads, and, if necessary, reconstruction. At present, such indicators as costs (financial and material), cost recovery, efficiency and operational life of the infrastructure define the quality of O&M. Next component of water management process (water requirements) is aimed at assessing the needs of all stakeholders in water resources and managing these requirements based on available water resources. Major indicators of this component are a record keeping on all points of water delivery, required amount and time of delivery (some water users may be interested in maintaining necessary water levels or water quality in their systems). After specifying available water resources and water requirements, the next component – water allocation – has to be implemented. In other words, this is the process of drawing up a balance, taking into consideration available water resources and water demands. Here, major objectives are maximum possible involvement of all stakeholders in the process of negotiations (coordinating water allocation) and development of acceptable for all procedures (rules) for water allocation. The proposed indicator for this component is criteria of equity and rationality in establishing quotas or limits for water use. The next component of the water management process – water delivery from a source to water users (water supply) – is water delivery services. Proposed indicators for evaluating the quality of these services are a uniformity and sustainability of water supply with minimum non-productive water losses. Finally, the last key component is water use, including irrevocable water consumption. Here, a major objective is to produce maximum output by using water or its optimal utilization. The proposed indicator is '*specific water productivity*' i.e. the amount of water consumed per unit output – product. Producing output and using water, we should be guided by the principles of sustainable development (providing opportunities for future generations to use water in the same extent as today); and a proposed indicator can be a sustainable use index, and exceeding it is unacceptable.

Additional indicators:

- indicators related 'operation capacities', for such activities as management of procurements necessary for rehabilitation and repairing works, indicators of depreciation and renewal of assets, staffing (in the number and skill), sufficiency of financial resources, required training, etc,;

- Indicators of scientific and technological advances: an adequacy of existing technical facilities of O&M organizations to the world standards (computerization, SCADA systems, communications etc.);
- Environmental indicators reflecting an adequacy of the actual water quality compared to standards; providing ecological flows; the status of glaciers and erosion-affected zones; indicators of bio-productivity – an existence of representative animal units etc.

A proper governance system is needed to cover all components of the water management process as shown in Table 3.1.

Management quality indicators are of special importance.

In the IWRM-Fergana Project, as was described in Section 1.8, the information management system (IMS) that includes the model of water allocation planning, software and database (DB) and allows calculating, in particular, indicators of water services quality (water delivery and distribution) [17] was developed. In particular, the following indicators:

$$\textbf{Water supply factor (WSF)} = \frac{\textbf{Actual water supply}}{\textbf{Planned water supply}} \qquad \textbf{(3.1)}$$

The situation is considered optimal (from the biological point of view) when a water supply factor equal to 1. In practice, a water supply factor not always reflects the extent of water sufficiency for crops. Depending on purpose of the analysis, a water supply factor[1] is calculated for different levels of water management hierarchy top-down, including the end users.

A diurnal stability factor (DSF) can be estimated for each off-take as follows:

DSF = a standard deviation of diurnal flow rates from an average daily flow rate / an average daily flow rate **(3.2)**

A maximum value of the diurnal stability factor equals to 1.

[1] All factors are unitless, and to express them in percents (%) it is necessary to multiply their values by 100.

A ten-day stability factor (TDSF) is calculated in the same manner for each intake structure (water diversion into an irrigation canal)

$$\text{TDSF} = 1 - \frac{\text{A standard deviation of an average daily flow rates from an average ten-day period flow rate}}{\text{an average ten-day period flow rate}} \quad \textbf{(3.3)}$$

Water supply uniformity factor (WSUF) for one off-take or a group of off-takes (a farm, WUA, district, province etc.) is calculated as follows:

$$\text{WSUF} = 1 - \frac{\text{An absolute value of the difference between a WSF of an off-take (or a group of off-takes) and a WSF of an irrigation canal}}{\text{WSF of an irrigation canal}} \quad \textbf{(3.4)}$$

At present, a fundamental principle of water allocation coming from the principle of social equity is a proportionality principle. A criterion of assessing social equity of actual water allocation among water users is a water supply uniformity factor. A maximum value of water supply uniformity factor equals to 1. The higher the value of water supply uniformity factor the more equitable water allocation process.

A coefficient of water supply uniformity from a canal = an arithmetical mean value of coefficients of water supply uniformity to water users in the canal's command area **(3.5)**

A "from head to tail" uniformity factor

In the practice of water allocation, as a rule, there is so-called "from head to tail" problem, when upstream water users are supplied by irrigation water better than downstream water users. A "from head to tail" uniformity factor reflects the equity of water distribution along all length of an irrigation canal.

A "from head to tail" uniformity factor = 1 – (An absolute value of the difference between a WSF of 25% of downstream water users and 25% of upstream water users) /(a WSF of 25% of downstream water users) **(3.6)**

Technical efficiency factor (TEF)

$$\textbf{TEF} = \frac{\textbf{Water supply + transit flow + outflow}}{\textbf{Head water diversion + side inflow}} \qquad \textbf{(3.7)}$$

In principle, a maximum value of the TEF cannot be more than 1. However, sometimes there are cases in the practice of water distribution, when the TEF is more than 1 due to the fact that it is very difficult to estimate dispersed water inflow into the irrigation canal.

Indicators of water allocation should be used for the assessment of the quality of water management. In the IWRM-Fergana Project, such an assessment is conducted on a regular basis. A fragment of such an assessment is given below. This assessment is done by comparing key indicators over the period of 2003 to 2007 (Table 3.2).

Table 3.2 Water distribution indicators for pilot canals (IWRM-Fergana Project)

Pilot canal	**Year**	**Actual water supply**	**WSF**	**WSUF**	**DSF**	**TEF**	**Specific water supply**
		mln. m^3	**%**	**%**	**%**	**%**	**000’ m^3/ha**
South Fergana Canal	2003	1053	112	60	85	81	12.6
	2004	925	93	89	87	88	11.0
	2005	871	85	94	85	87	10.3
	2006	816	77	94	84	89	9.2
	2007	643	68	92	84	86	7.2
Aravan-Akbura Canal	2003	83	74	45	70	54	13.1
	2004	66	88	63	91	53	9.8
	2005	57	77	69	84	54	8.5
	2006	54	75	74	81	59	8.0
	2007	64	83	82	90	59	8.3

Pilot canal	Year	Actual water supply	WSF	WSUF	DSF	TEF	Specific water supply
		mln. m^3	%	%	%	%	000’ m^3/ha
Khodja-Bakirgan Canal	2003	116	82	36	41	80	14.4
	2004	113	85	82	58	78	15.8
	2005	115	86	73	64	78	16.5
	2006	90	69	80	54	80	12.1
	2007	88	67	77	62	81	11.8

A similar assessment was made for the level of water users associations, too.

Table 3.3. Project Impact Assessment in Pilot WUAs

WUA	Year	Actual water supply, 000’ m^3	WSF, %	WSUF, %	DSF, %	Specific water supply, 000’ m^3/ha
Akbarabad	2004	25.7	88	95	87	9.1
	2005	23.1	80	94	86	8.2
	2006	22.5	75	97	82	8.0
	2007	18.0	64	94	83	5.9
Japalak	2004	11.9	72	82	98	6.3
	2005	9.1	56	73	87	4.9
	2006	10.7	65	88	83	5.7

WUA	Year	Actual water supply, 000' m^3	WSF, %	WSUF, %	DSF, %	Specific water supply, 000' m^3/ha
	2007	12.4	83	99	95	6.6
Zarafshon	2004	6.7	61	72	59	8.3
	2005	7.6	69	81	56	9.4
	2006	7.2	66	96	49	8.9
	2007	5.8	46	69	49	6.5

However, all these indicators reflect water management at the level of irrigation canal, WUA, and at the irrigation system level rather than the IWRM. It is necessary to carry out a comprehensive assessment of IWRM (its effectiveness, economic effects and impacts) on achieving MDGs.

An integrated assessment of the effectiveness may be made combining some indicators, for example, the ratio of actual water productivity and potential water productivity, taking into consideration the same cropping pattern; or a ratio of water volumes supplied at the head of irrigation system and crop water requirements. In the integrated water management system, this indicator can be calculated using the total water diversion and the technological need in water for all water consumers, including water for irrigation.

In the process of planning for the long-term improvements of an irrigation system, it is important to combine these indicators with the MDGs. Such an analysis and subsequent selection of options for developing the water management complex was made in the RIVERTWIN Project for the period of 25 years.

This project envisages the integrated hydro-ecological development of the Chirchik River basin, taking into consideration the requirements of hydropower, water supply, irrigation, and the environment. As a result of the analysis of existing situation and planned measures, which were reflected in modeling variants based on limited water resources, indicators of development were obtained for the period until 2030.

Table 3.4. Indicators of Integrated Water Resources Development Resulting from the Introduction of IWRM in the Chirchik Basin

No	Indicator	Units	Actual, 2003	Estimated values for 2030		
				Without project	Optimistic	Realistic
1.	Mean annual resources	km^3	8.390	8.677	8.973	

No	Indicator	Units	Actual, 2003	Estimated values for 2030		
				Without project	Optimistic	Realistic
1.1	Surface runoff	km^3	7.890	8.107	8.403	
	including:					
	• Chirchik	km^3	7.000	7.088	7.363	
	• Akhangaran	km^3	0.720	0.729	0.747	
	• Keles	km^3	0.070	0.176	0.176	
1.2.	Ground water	km^3	0.500	0.570	0.570	
2.	Population	ths.	4,930	6 468	6 293	
3.	Gross product	mln. $	2112.88	2398.48	3989.99	2839.24
	▪ industry	mln. $	797.40	676.41	2048.96	898.21
	▪ agro-industry	mln. $	322.14	352.23	352.23	352.23
	▪ agriculture	mln. $	468.35	489.74	1016.69	1016.69
	▪ service sector	mln. $	524.99	880.10	572.11	572.11
4.	GDP	mln. $	1026.47	1280.87	1734.38	1492.73
4.1	GDP per capita	$/person	422.4	377.8	536.79	462.03
5.	Agricultural gross product	000’ tons	468.58	489.74	1016.69	
	• grains		450.03	305.02	627.01	570.5
	• cotton		189.19	142.20	333.49	246.9
	• vegetables		827.50	602.54	1067.37	1584.0
	• fruits		215.19	304.68	993.12	530.0
	• potato		375.39	341.50	464.13	758.0
	• meat		72.10	94.66	197.43	160.0
	• milk		356.17	465.95	972.00	1200.0

No	Indicator	Units	Actual, 2003	Estimated values for 2030		
				Without project	Optimistic	Realistic
6.	Overall crop area	000' ha	380.28	416.1	421.7	
7.	Crop yield	centner/ha				
	▪ cotton		2.01	1.39	3.21	4.0
	▪ grains		4.16	2.43	5.11	6.3
	▪ potato		21.18	11.51	24.78	30.0
	▪ vegetables		22.49	13.08	26.02	29.0
	▪ fruits		3.21	3.03	14.09	11.0
	▪ vineyards		2.38	4.21	17	12.0
	▪ rice		3.96	2.36	5.19	5.5
8.	Total water abstraction	mln. m^3	4110	5509	5977	
	• for irrigation, Uzbekistan		2347	3691	3882	
	• for irrigation, Kazakhstan		489	483	761	
	• public utilities		798	876	876	
	• others (including industry)		476	459	461	
	Transit through HPS		1730	1500	1500	
9.	Return water	mln. m^3	2917	2476	2492	
10.	Food supply factor	%				
	• bread		52	27	56	
	• vegetables		145	80	146	
	• fruits		112	121	405	
	• meat		49	49	105	
	• milk		39	39	83	

No	Indicator	Units	Actual, 2003	Estimated values for 2030		
				Without project	Optimistic	Realistic
11.	Hydropower generation	M kWh	3892	3566	3987	
11.1	including Pskent HPS	M kWh	0	0	344	1200
12.	Capital investments to irrigation	mln. $		237	791.6	

Summarizing our approach concerning IWRM indicators, it is possible to state that they are mainly aimed at improving and developing water governance in line with key IWRM principles, as well as improving the effectiveness of IWRM implementation and outcomes.

In this respect, the major distinction of our approach, from those which were presented in foreign papers related to the use of IWRM indicators, is based on an understanding of the IWRM not as a management system (our principal idea is development!) but as a process of improving a management practice that is not described with clear outcomes and indicators (see our previous publication, devoting IWRM issues). B. Hooper [54], who suggests 115 performance indicators for river basin organizations, which are grouped into ten categories, is a quite interesting summary:

- Coordinated decision-making
- Responsible decision-making;
- Objectives and their achieving, shift in objectives;
- Financial sustainability;
- Organizational framework;
- Legislative base;
- Training and capacity building;
- Information and researches;
- Monitoring and record keeping; and
- Private and public roles;

These indicators are not calculated but provide a qualitative assessment based on scores from 1 to 5, gives a notion about the advance made by water organizations towards IWRM. They evaluate not the effectiveness of achieving certain management principles, but subjective planned forms, within which this process is developing. Their value no doubt, is especially in the making and developing the IWRM system, if they were be clearly specified in terms of quantity. Nevertheless, from the point of view of analysis of the effectiveness, they give nothing [3]. Therefore, it is not accidental that a half of the categories suggested by B. Hooper (financial sustainability, organizational framework, capacity building, and information and monitoring) [54] is represented in our components, but as numerical and auxiliary indicators. A set of indicators suggested by us that correspond to the necessary structure of information and database given in Section 1.8 allows tracking actual outcomes and analyzing measures necessary for achieving planned levels over all stages of introduction and development of IWRM.