Climate change: Towards an adaptive water management in Slovenia

B. Đurović*, A. Bizjak*, M. Kobold**
* Institute for water of the Republic of Slovenia, Hajdrihova ul. 28c, SI-1000 Ljubljana (E-mail: blazo.djurovic@izvrs.si; ales.bizjak@izvrs.si)
** Environmental Agency of the Republic of Slovenia, Vojkova c. 1b, SI-1000 Ljubljana (E-mail: mira.kobold@gov.si)

INŠTITUT ZA VODE REPUBLIKE SLOVENIJE | Institute for Water of the Republic of Slovenia

Abstract
The changes in climate indicators induce hydrometeorological circumstances, which are very likely to influence current water management regimes in a significant manner. Thus, particularly water balance and water related natural hazards should be thoroughly considered. The adaptation to extreme water quantity situations is becoming the key water management issue worldwide. This paper gives an overview on climate change related risks in Slovenia. A way towards an adaptive water management is taken by identifying the key issues of the future national adaptation strategy, which should be introduced into the existing programmes for the implementation of the EU Directive 2000/60/EC (Water Framework Directive) through the next planning cycles, taking in consideration the climate change hazard indicators, impact vulnerability factors, risk levels and corresponding adaptation measures.

Keywords
Climate change; Water management; National adaptation strategy

CHANGE OF CLIMATE INDICATORS
Climate change will strongly influence social, economic and environmental systems, including surface water and groundwater bodies and their catchment areas. Relying solely on climate change mitigation measures (improving energy efficiency and lowering emissions of greenhouse gases and aerosols) will not be enough since we are facing the change of climate also due to the pressure from the past, and consistent complementary adaptation measures could override the uncertainty of climate change evolution (Figure 1). The global temperature shift is causing regional and local change of spatial and temporal variability of climate parameters. Higher average air temperatures, higher evapotranspiration rate, more variable quantity of precipitation, and shorter duration of snow cover can be expected in Slovenia (Table 1). According to the regional climate change scenarios the air temperature in Slovenia will increase from 0,5 °C to 2,5 °C (2001-2030), from 1 °C to 3,5 °C (2031-2060) and from 1,5 °C to 6,5 °C (2061-2090) comparing to the period 1961-1990 (Bergant & Kajfež-Bogataj, 2004).

A precipitation increase is expected in winter (+10 %) and decrease in summer (−10 %) comparing periods 1961-1990 and 2071-2100 (PRUDENCE, 2005). Changes in a yearly precipitation amount are estimated from +10 % to −30 % (MKGP RS, 2008) causing changes in river discharges (Table 2). Climate scenarios also predict the maximum precipitation intensity increase by 20 %, thus increasing the flood peaks in alpine and pre-alpine region up to 30 % by the year 2050/75 (Rogelj, 1999). Slovenia is a water abundant country although in the last thirty years the decline of water quantities in rivers is notable, especially in the last decade when we have had droughts in late spring and summer and floods in fall (Kobold, 2007).

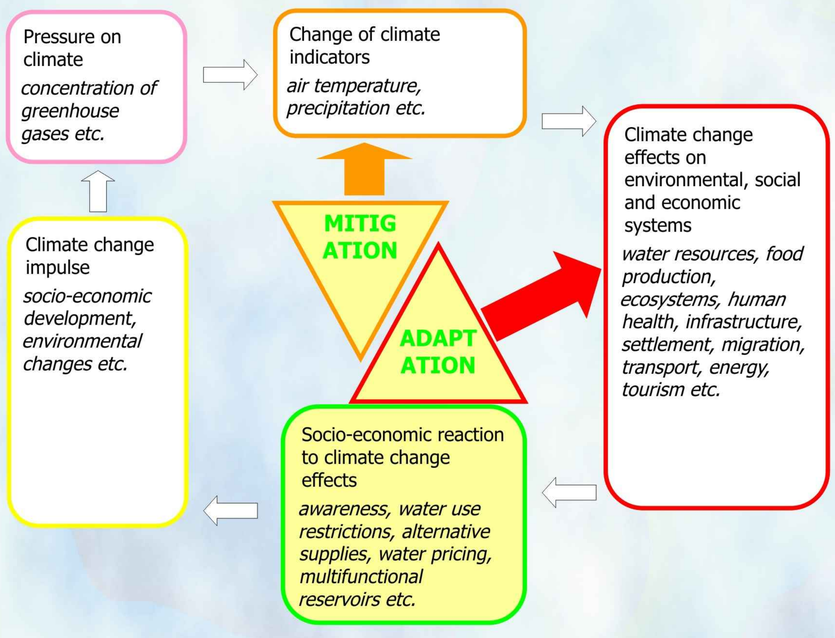

Figure 1. Climate change cycle.

Climate parameter	1961–1990	1991–2005	trend
Air temperature (°C)	9,8	11,0	++
Number of days with $T_{min} \leq 0$ °C	89,6	78,8	-
Number of days with $T_{max} \geq 25$ °C	60,6	77,2	+
Relative moisture at 14h (%)	62,4	59,1	-
Duration of insolation (h)	1712	1950	++
Yearly precipitation (mm)	1393	1356	-
Number of days with snow cover at 7h	64,9	49,0	-
Number of days with precipitation ≥ 1.0 mm	114,8	108,0	-

Table 1. Average yearly values of meteorological variables for periods 1961–1990 and 1991–2005 in Ljubljana (Kajfež-Bogataj, 2007).

Air temperature change (°C)	+1 (2025)		+2,5 (2050/75)	
Precipitation change (%)	+10	-10	+10	-10
river basin	runoff change (%)			
Adriatic rivers	10	-26	-2	-37
Mura	10	-69	-34	-114
Drava	10	-33	-7	-50
Sava	10	-24	0	-34
Soča	10	-17	4	-23
Kolpa	10	-24	-1	-35

Table 2. Runoff change scenarios due to temperature increase and precipitation change (Rogelj, 1999).

CLIMATE CHANGE EFFECTS ON THE WATER SECTOR
According to the recent hydrometeorological research even minor changes in spatial and temporal distribution of precipitation in Slovenia could cause heavy regional problems with floods, droughts and water scarcity (Figure 2). Due to anticipated climate change the potentially vulnerable areas in Slovenia are those with drinking water supply problems, drought and erosion-prone areas, sea and river flooding areas, torrential watercourses and deforestated areas (Bizjak, 1999). The changes in climate indicators could impact the water sector in Slovenia predominantly by (Table 3):

- enhanced magnitude and probability of occurrence of extreme hydrological and meteorological events, and
- water scarcity when water demand becomes unable to cope with water availability.

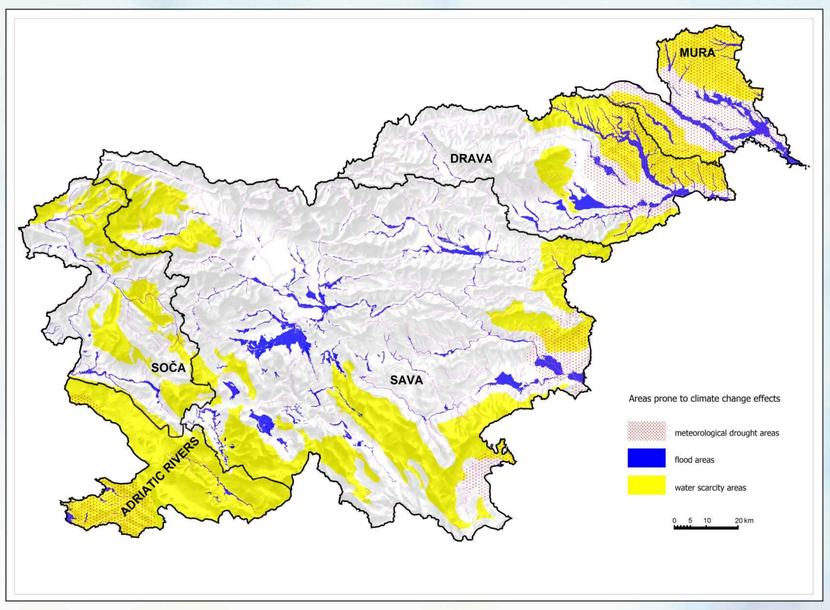

Figure 2. Areas prone to climate change effects (IzVRS, 2007; MOP RS, 2004; Kajfež-Bogataj & Bergant, 2005).

INDICATOR (alterations in peak and average values)	EFFECT (natural hazards, water resources)	REACTION (water sector)
Air temperature extremes (frequency, intensity, duration)	Frost, heatwave, fire, storm (wind, thunder, hail, shower)	Early warning systems, temporary relocation, improved disaster mitigation
Precipitation extremes (frequency, intensity, duration)	Flash floods, urban floods, drought (meteorological, agricultural), soil erosion, landslides and debris flows	Watershed management, erosion and flood control, redimensioning of sewage systems, water transfer, landslide remedial measures
River discharge extremes, sea level extremes	Drought (hydrological), surface water flooding, streambed and lateral erosion, coastal erosion	Improved water infrastructure protection capacity, detention ponds, spatial planning legislation and zonation, preservation, restoration and reservation of retention areas, awareness and warning systems, insurance
Average air temperature (distribution)	Higher surface water and sea temperature, increased evapotranspiration, increased water demand	Prioritization of water use
Average annual precipitation and snow cover (amount, distribution, extent, duration)	Available water quantity, soil moisture deficiency	Land use, mulching, water supply reservoirs, groundwater recharge, reduction of distribution system leaking, water pricing, use of surface water, recycling water
Average annual river discharge, sea level rise	Change of discharge regimes, sediment transport, coastline migration, groundwater level rise, salinization	Land use, spatial planning, reduction of water use, desalinisation, additional water storage

Table 3. Relations between the indicators and effects of climate change and potential adaptation measures.

TOWARDS AN ADAPTATION STRATEGY
After a profound expert discussion on climate change impacts on the water cycle, resources and quality (EU Commission, 2006) and adaptive water policy dimension (BMU, 2007), the Green Paper (EU Commission, 2007) introduced the options for European action to ensure the coherency in exposing the adaptation challenges and create an appropriate policy response through the four main pillars: early action, external integration, reducing uncertainty and coordinated and comprehensive adaptation strategies.

The adaptation strategy should be based on competency building, improving adaptive capacity and reducing the risks (Figure 3). Competency can be built by integrating the research, improving the decision-making information, and managing the information.

The improved adaptive capacity should be achieved through the integration of sectors and regions by identifying and analysing problems and integrating policy implementation. Implications for other countries are also an important adaptive capacity issue. Preventive management of risks due to water related hazards should cope with scarce water resources, endangered human health and ecosystems, spatial planning policy etc.

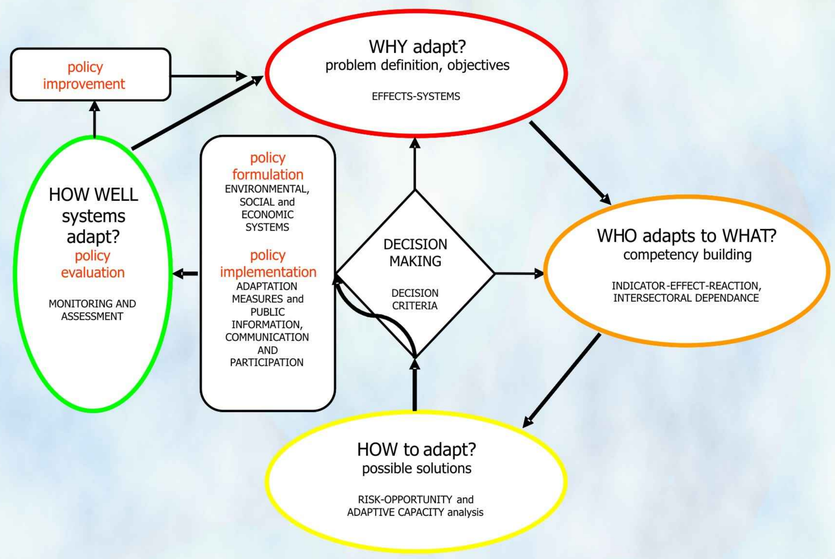

Figure 3. Concept for a national climate change adaptation strategy.

WAY FORWARD
The transition from the current management regimes to more adaptive regimes implies a paradigm shift in water management from a prediction and control to a management as a learning approach (Pahl-Wostl, 2007). With a growing sense of climate variability it is important to reassess floods along with droughts and water scarcity as phenomena related through the change of climate conditions. The collision between hazard and damage potential is becoming more probable and more severe, and higher vulnerability and lower adaptive capacity are closely linked to the economic value and total risk. Slovenia should develop a national climate change adaptation strategy to be able to cope with the danger of water scarcity, drought and hydrometeorological natural hazards. The adaptation concept, implemented through the cyclical process of river basin management plans (Table 4) including the flood risk management plans and drought management plans, can realize and resolve regionally characteristic and intersectorally dependant problems of quantity extremes and averages as well as their relations to water quality.

STEP 1 HAZARD AND VULNERABILITY ANALYSIS	**DECISION MAKING** Is RBMP measure sensitive to climate? *A - contributes to adaptation to climate change* *B - brings benefit under changing climate* *C - causes potential problems under changing climate*
STEP 2 DEFINITION OF POSSIBLE ADAPTIVE MODIFICATIONS	**DECISION MAKING** Are adaptations acceptable for stakeholders?
STEP 3 RISK ANALYSIS, CE and CB ANALYSIS	**DECISION MAKING** Are adaptations feasible, effective and benefitial?
STEP 4 FORMULATION, IMPLEMENTATION AND EVALUATION OF ADAPTATIONS	

Table 4. Steps to incorporate climate change into River Basin Management Plans under Water Framework Directive.

REFERENCES
Bergant, K., Kajfež-Bogataj, L. (2004). *Some methods for preparation of regional climate change scenarios* (in Slovene). Acta agriculturae slovenica, 83–2, 273-287
Bizjak, A. (1999). *Climate Changes, Flood Prevention and Water Supply in Slovenia* (in Slovene). Urbani izziv, Vol. 10, No. 1/99, 25-29.
BMU (2007). *Time to adapt, Climate change and the European Water Dimension, Vulnerability-Impacts-Adaptation*. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Symposium report, February 12–14 2007, Berlin.
EU Commission (2006). *Climate change impacts on the water cycle, resources and quality*. Workshop report, September 25–26 2006, Bruxelles.
EU Commission (2007). *Green Paper, Adapting to climate change in Europe – options for EU action*. COM (2007) 354 final.
IzVRS (2007). *Flood hazard index map*. Institute for water of the Republic of Slovenia, Ljubljana.
Kajfež-Bogataj, L., Bergant, K. (2005). *Climate change in Slovenia and drought* (in Slovene). Ujma, No. 19, 37-41.
Kajfež-Bogataj, L. (2007). *Climate change effects on water resources and water supply in Slovenia* (in Slovene). Parliamentary group GLOBE Slovenija and the Council for Environmental Protection of the Republic of Slovenia, 2nd joint session, 20. 3. 2007. Available at: 212.18.47.244/web/portal.nsf/
Kobold, M. (2007). *Climate change effects on Slovenian river discharges* (in Slovene). Symposium proceedings, 18th Mišič water day, Maribor.
MKGP RS (2008). *Adaptation strategy of Slovenian agriculture and forestry to climate change* (in Slovene). Republic of Slovenia, Ministry of agriculture, forestry and food.
MOP RS (2004). *Ordinance on spatial planning strategy of Slovenia* (in Slovene). Republic of Slovenia, Ministry of the environment and spatial planning. Official Journal, No. 76/2004. Available at: http://www.uradni-list.si/1/objava.jsp?urlid=200476&stevilka=3397
Pahl-Wostl, C. (2007). *Transitions towards adaptive management of water facing climate and global change*. Water Resources Management, No. 21, 49-62
PRUDENCE (2005). *Prediction of regional scenarios and uncertainties for defining European climate change risks and effects*. Final project report. Available at: prudence.dmi.dk
Rogelj, D. (1999). *Assessment of climate change effects on hydrological conditions of Slovenian watercourses* (in Slovene). Environmental Agency of the Republic of Slovenia, Ljubljana.