Technical Report No. 6

REVIEW OF CURRENT DROUGHT MONITORING SYSTEMS AND IDENTIFICATION OF (FURTHER) MONITORING REQUIREMENTS

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Photo: Combined Drought Indicator map, European Drought Observatory, accessed on 25/2/13
Preface

This report provides an overview of the existing drought monitoring and early warning systems in the DROUGHT-R&SPI Case Studies. This activity was undertaken as part of Task 2.7 “Identification of relevant indicators at CS scale, monitoring, forecasting and early warning” in an effort to compare drought monitoring practices across Europe and scales and to examine whether the established systems in the Case Studies can support drought management in terms of impact minimization and mitigation. In particular, the aim was to collect information about:

- The types of drought monitored (meteorological, hydrological, agricultural);
- Indicators used for monitoring and the relevant thresholds;
- The methodology for the estimation of the monitoring indicators;
- The relevance/link of monitoring indicators to drought impacts in the Case Study area;
- The framework for disseminating and exchanging drought information among authorities, target groups and the general public;
- Drought declaration processes; and
- The assessment of the capabilities and effectiveness of the existing monitoring system.

The information has been collected by the corresponding Case Study partners and is being summarised in this report. The authors would like to thank Ms Claudia Vezzani (Po River Basin Authority) for her significant input regarding the drought monitoring system in the Po River Basin.
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1 Introduction

One of the WP2 objectives is the “assessment of the applicability of drought monitoring and early warning indicators at different scales (local, river basin and national), and the development of recommendations for their refinement to support decision-making”. One of the activities undertaken towards achieving this objective was the review of current drought monitoring systems, in order to describe the monitoring systems and indicators already in place and identify (further) monitoring requirements.

A template has been developed for mapping drought monitoring and early warning at the Case Study level that was organized in four parts:

- Part A involved a brief description of the existing or foreseen Drought Monitoring Systems (DMS);
- Part B focused on the operation of the DMS, concerning relevant drought indicators and thresholds, data inputs and outputs and the users of current DMS;
- Part C was dedicated to the drought declaration processes in the Case Studies; and
- Part D involved an overall assessment of the capabilities and effectiveness of the existing monitoring system, taking into account past impacts, the efforts undertaken for their mitigation and the dissemination of drought related information.

The information collected for each Case Study (Table 1) is given in Sections 2 to 7, whereas Section 8 provides a comparative description of the existing Drought Monitoring Systems.

Table 1: Brief overview of the drought monitoring systems in the DROUGHT-R&SPI Case Studies

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Existing drought monitoring systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>Drought monitoring as part of the National Water Monitoring Network.</td>
</tr>
<tr>
<td>Portugal</td>
<td>Two Drought Monitoring Systems managed by two different entities: Drought Observatory &amp; National Information System for Water.</td>
</tr>
<tr>
<td>Switzerland</td>
<td>Currently no formal drought monitoring system is operating.</td>
</tr>
<tr>
<td>Jucar River Basin</td>
<td>Drought monitoring system in place.</td>
</tr>
<tr>
<td>Po River Basin</td>
<td>Drought monitoring system in place.</td>
</tr>
<tr>
<td>Syros</td>
<td>A drought monitoring system is not operating.</td>
</tr>
</tbody>
</table>
2 Drought Monitoring & Early Warning in The Netherlands

2.1 Introduction

The “Water Management Centre the Netherlands” (WMCN), under the Ministry of Infrastructure and Environment, is the information centre for the Dutch water system and it bundles all products and services concerning information about water. The Water Management Centre provides daily information to users of the Dutch water system regarding water levels, flood risks and (bathing) water quality. In extreme situations, including water shortages, water pollution and the threat of flooding, the Water Management Centre provides advice to the national and regional water authorities about the expected condition of the water. The national and regional departments of the Directorate General of Public Works and Water Management (Rijkswaterstaat) work together in the Water Management Centre and as a result there is better information provision and forecasts.

WMCB consists of five divisions:

1. The Waterkamer (Water Chamber) is responsible for providing reliable and useful national information about water levels, flood risks and water quality. Under normal conditions and in special situations: 24 hours a day, 365 days a year.

2. The National Coordination Committees come into action in extreme situations, including threats of flooding, water shortages or water pollution. From the Water Management Centre, the committees coordinate the news coverage and arrange reliable and useful information about the expected condition of the water. When situations develop, the crisis experts advise the national and regional water authorities about the measures to take and arrange the coordination with the parties involved. The committee responsible for dealing with drought is the National Water Distribution Committee.

3. Helpdesk Water is the knowledge centre for professionals who are involved in water policy, water management and water safety. These professionals can contact Helpdesk Water every working day with questions related to these subjects.

4. The Water Management Centre has a public meeting area where groups of water professionals and press representatives can be received. The centre offers its visitors insight into the operation and organisation of the Dutch water system and water safety, the management of this system and the role that the Water Management Centre and the cooperating partners play.

5. Regular training courses are given to water professionals in the Water Management Centre’s well-equipped training and innovation centre to enable them to develop their competency with respect to the primary processes of crisis management. The centre also offers a platform for new developments and technology in the area of water management and water safety.

The National Water Monitoring Network (Landelijk Meetnet Water) derives measurement data about water quantity from the water system, whereas the water quality is measured by measuring stations and laboratories. All measurement data ends up at the Water Management Centre, where the data are interpreted and enhanced with weather forecasts from the KNMI and Deltares models. The Water Boards in The Netherlands monitor the regional and local water systems.

Cooperation is an important precondition for integrated water management. Many parties are involved in managing the Dutch water system, as Figure 1 shows. When executing its task, the Water Management Centre closely cooperates with the Regional Departments of Rijkswaterstaat, the Department for Traffic Information and Traffic Management (VCNL), the Shipping Centre (SVC), the Water policy board of the Ministry of Infrastructure and the Environment, the KNMI (the Royal Netherlands Meteorological Institute), the water boards, the provinces and the safety regions.
Figure 1: Overview of the National Water Monitoring Network (Landelijk Meetnet Water) in The Netherlands

Based on the measured data, the Water Management Centre provides water information to users and water reports to the water authorities based on which they can intervene in the water system through their pumping stations, locks and weirs. After the water authorities have intervened in the water system, the water quantity and water quality are once more measured and the process starts again. Under special circumstances, activities are also coordinated with the Departmental Coordination centre for Crisis control (DCC) of the Ministry of Infrastructure and the Environment and the Navigation Traffic Center (SVC, ScheepvaartVerkeersCentrum) and the Traffic Centre Netherlands (VCNL Verkeerscentrum Nederland). Advice is provided to the safety regions via the regional water authorities.

The National Monitoring Network collects and stores data from over 400 locations. It originates from bringing together three existing measurement networks:

- Monitoring system water (like canals and rivers)
- Network North Sea (oil platforms and North Sea canals)
- Zeeland tidal monitoring network.

The Data-ICT-Service of “Rijkswaterstaat” continuously works on improving and optimising the collection and management of data, to fulfil the requirements of the customers. Data are being delivered to both the government (Sea Barrages; Hydro-Meteo Centers; Municipal harbour company’s (e.g. Rotterdam) as well as other parties (e.g. Shell, the Royal Meteorological Institute; FLIWAS (Flood Information and Warning System); individuals).

Although drought monitoring is relatively new in The Netherlands, monitoring of water systems has always been important for The Netherlands. Already for decades now, both the main, regional, and local water systems are closely monitored in The Netherlands. The 1976 drought gave rise to the first ‘drought policy’, i.e. a priority ranking of water allocation in times of drought. Changes in water allocation on basis of priority requirement are only possible because of an insight in water quantities at various key locations and knowing the possibilities to change water flows at such locations.

In The Netherlands, drought is neither monitored nor declared. However, the 1st of April each year is defined as the time when the “drought season” starts. This implies monitoring of the evaporation surplus (i.e. precipitation minus evaporation) and the continuous monitoring of the temperature and discharge of the rivers entering the country. The monitoring results are available to the public in the corresponding website (http://www.rijkswaterstaat.nl/water/waterdata_waterberichtgeving/index.aspx) by means of “drought messages”. Such a message includes on overview of relevant information on the water system at that point in time and includes both descriptions of the “start conditions” as well as forecasts of river discharge, precipitation and temperature (an example is given in Appendix 1).
“Rijkswaterstaat” (an Agency within the Ministry of Infrastructure and Environment) measures water levels, wave height and water quality, daily. As well, forecasts are prepared for water levels and waves. On basis of these water data, Rijkswaterstaat produces statistics, forecasts, and advice. This is done under normal as well as exceptional circumstances, as floods, droughts and pollution. The Website “Water data and water reporting” (in Dutch) shows “Messages”, that are publicly available on the web (in Dutch), for “storm floods” as well as for “drought”.

## 2.2 Drought monitoring

The indicators and indices used by the DMS are relatively straightforward. The National Committee Water Distribution (responsible to deal with drought) will be engaged when there is low-water situation in the Rhine or Meuse rivers and when there is a thermal overload in the Rhine. It concerns the following situations:

- **Low flow:** there is a time-dependent ‘trigger’ value for ‘low-flow’ because a low-water-level situation cannot always be related straightforwardly to a discharge. The National Committee Water Distribution is called in when discharges fall below the following values and there is an expectation that this will last longer than 3 days:
  - 1400 m³/s in May
  - 1300 m³/s in June
  - 1200 m³/s in July
  - 1100 m³/s in August
  - 1000 m³/s in September and October

- **For the Meuse River,** the discharge of the river at the Eysden location should fall under the 25 m³/s value in order to call for a first meeting of the National Water Distribution Committee for a special session in the south of the country.

- **As well,** a first meeting of the National Water Distribution Committee is called when the temperature of the Rhine River at the Lobith location (entering the country from Germany) is below 23°C.

In The Netherlands, there is no definition of drought in terms of increasing severity like: normal, dry, until extreme. Measures are considered and eventually taken on basis of real-time values of river flows, river temperature and evaporation surplus (i.e. precipitation minus evaporation).

The capability of the mentioned indicators of the DMS to characterise drought impacts is not straightforward, as low river flows have a completely different impact on the drought situation depending on their occurrence in the early season or late season.

The Royal Netherlands Meteorological Institute measures rainfall already for a long time. There are about 325 rainfall measurement stations fitted with a standard precipitation meter that is read every day at 09:00 hrs. The observers (volunteers) report the measured values by an automated telephone system. The measured values are presented on a map of the same day and some previous days. Such rainfall maps show a preliminary overview. In the drought season, the evaporation surplus is calculated from the rainfall values and the reference crop evapotranspiration.

Validated precipitation and evaporation data are elaborated by the Institute and published in “Monthly overview Precipitation and Evaporation in The Netherlands” reports.
Rijkswaterstaat continuously checks the water in The Netherlands, on issues as water level, wave height, and water quality. In the main system there are 3 measuring programmes:

- **Water quantity**: On 450 locations (near the coast, in rivers, canals, and lakes) measurements are being done (from the shore, on buoys, and posts in the water) on e.g.: levels; discharge; waves; temperature; salinity; turbidity.

- **Water quality**: Clean water is one of the most important pillars of Rijkswaterstaat and that is the basis for collection of biological and chemical data.

- **Elevation of bottom level of water bodies**: Regularly the elevation levels of the bottom of water bodies are measured. Frequency of measurement depends on the function and dynamics of the water body bottom.

### Table 2: Data collection in support of drought monitoring in The Netherlands

<table>
<thead>
<tr>
<th>Precipitation and evaporation</th>
<th>Royal Netherlands Meteorological Institute</th>
<th>Daily</th>
<th>Stored in a centralised system and mostly publicly available</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water quantity (and levels)</td>
<td>Rijkswaterstaat</td>
<td>Daily</td>
<td>-ditto-</td>
</tr>
<tr>
<td>Water quality</td>
<td>Rijkswaterstaat</td>
<td>Daily-monthly</td>
<td>-ditto-</td>
</tr>
<tr>
<td>Bottom level of water bodies</td>
<td>Rijkswaterstaat</td>
<td>regularly</td>
<td>-ditto-</td>
</tr>
</tbody>
</table>

The Water Management Centre Netherlands issues “drought messages” that include relevant information on the water system at that point in time. It also includes forecasts of river discharge, precipitation and temperature.

These drought messages (in Dutch) are available for the public on the web-site of ‘Rijkswaterstaat’: http://www.rws.nl/water/waterdata_waterberichtgeving/waterberichten/droogteberichten/.

The final users of the drought-related information include representatives of stakeholders and also the general public in as far as interested. These users, to whom all information is available through the drought messages at the public web-site, include:

- Decision makers/Managers: National Committee Water Distribution; Inter-provincial Consultation; Association of Regional Water Authorities (Water Boards); Regional Water Board
- Users: Power Grid company (Tenet); Regional Agriculture and Horticulture Organisation (LTO); VEVIN - Drinking water; Royal Schuttevaer (Navigation); Nature Organisations (Natuurmonumenten and Staatsbosbeheer); National Programme Forest Fires
- Others: Royal Netherlands Meteorological Institute; Knowledge Institutes

### 2.3 Drought declaration

Although there is not a specific moment when a “drought” is declared, the National Committee Water Distribution (responsible for drought management) will start meetings when:

- The inflow of the Rhine at the border with Germany is below a certain threshold (depending on the month of the year, e.g. 1400 m³/s in May and 1000 m³/s in September and October);
- The inflow of the Meuse at the border with Belgium is less than 25 m³/s;
- The temperature of the Rhine water inflow from Germany is over 23°C.
During such meetings, the results of the drought monitoring and measures are discussed. The responsibility starts with the Ministry of Infrastructure and Environment, which has established the National Committee Water Distribution. The Ministry of Infrastructure and Environment issues all measures that have been agreed in the National Committee Water Distribution, in which all stakeholders and interests are represented. The actions advised by the National Water Distribution Committee (and taken under the authority of the Ministry of Infrastructure and Environment) constitute the “Drought management Plan”. This is not a fixed plan, but a conglomerate of actions are taken on the basis of real-time conditions and discussed with stakeholders and authorities.

The series of actions foreseen include e.g. restricting irrigation, washing cars, spraying gardens; increasing water buffers; re-directing available flow; operate reversible pumping stations; restrict navigation; preventing water temperature getting too high; supplying water to high-value nature areas (see Appendix 1).

2.4 Assessment of the DMS

The monitoring system is efficient for the needs of the region. It is also integrated in the regular monitoring system in place for the main water system in the country, which secures its sustainability. The foregoing operation of the system, i.e. regular monitoring; publishing all data (actual and forecasts); meeting(s) of the responsible Committee (including all interests and stakeholders); actions advised by the Committee; follow-up of conditions; and drought evaluation, shows that authorities have taken all necessary care.

Although the system seems sufficient, droughts in The Netherlands are not of such severity and frequency that the system is really tested. If the drought conditions of 1976 will happen in the future, reality will show that society in the second decade of this millennium will pose different demands on the water system than it did in 1976. In such a next drought, nature will be dealt with differently; certain nature (when there would be irreversible damage due to drought/ dryness) has risen in the ‘ranking of priority water use’. As well, ‘utilities’ has also risen in the ranking, mainly because of the need for uninterrupted power supply.

In the long term, the interests of the stakeholders cannot be served as before despite all measures taken, due to climate change. Even if enough water could be supplied, the question will be with water quality. Especially the combination of quantity and quality will show that water management has its limits. At regional level, provinces, municipalities and water managers have to identify to which changes this should lead. There is a need to identify the required structural measures (at national as well as local scale) that need to be taken to limit drought impact and drought damage in the future.
3 Drought Monitoring & Early Warning in Portugal

3.1 Introduction

There are two Drought Monitoring Systems in Portugal managed by two different entities: The Drought Observatory and the National Information System for Water Resources.

The Drought Observatory (“Observatório de Secas”) was established in 2009 and is coordinated by the Meteorology Institute (IM, Ministry Education and Science). Data (precipitation and temperature) is collected from a national network of meteorological stations that belong to IM and from another network of stations that belong to the Water Institute (INAG). The occurrence of meteorological droughts is based on calculations of SPI (Standardized Precipitation Index) and PDSI (Palmer Drought Severity Index) averaged for main river basins and for mainland Portugal, and agricultural droughts based on soil water content (%). Drought is forecasted with the PDSI for the following month based on 3 scenarios of precipitation occurrence. PDSI has been used since 2001 and SPI has been used since 2005. Since 2002 the Meteorology Institute also calculates daily for Portugal the Fire Weather Index (FWI). The Drought Observatory can be consulted online at http://www.meteo.pt/pt/oclima/observatoriosecas/, with information on SPI and PDSI (maps, graphs and figures). Information on PDSI is also included in the monthly climate reports edited by IM.

The National Information System for Water Resources (“Sistema Nacional de Informação de Recursos Hídricos” – SNIRH) is coordinated and managed by the Water Institute (INAG/APA, Ministry of Agriculture, Sea, Environment and Spatial Planning) since 1995. SNIRH monitors water resources through a national network of stations, which includes the following types of stations:

- Meteorological network, with stations that only register precipitation, and stations that register precipitation, temperature, humidity, wind speed, among other variables (742 stations, about 8.32 stations/1000 km²);
- Hydrometric network, with stations that register streamflow, river and reservoir water levels, and reservoir volumes (419 stations, about 4.7 stations/1000 km²);
- Superficial water quality network, with stations that register physical, chemical and biological water properties (275 stations, about 3.1 stations/1000 km², from which 113 are coincident with stations from the hydrometric network);
- Groundwater network, with stations that register groundwater quantity (770 stations) and groundwater quality (717 stations).

Collected data can be freely consulted online and downloaded from http://snirh.pt.

A subsystem for Drought Monitoring and Early Warning (“Sistema de Vigilância e Alerta de Secas” - SVAS) was developed by INAG/APA within the National Information System for Water Resources. Meteorological and hydrological droughts are monitored based on precipitation, streamflow, reservoir storage, and groundwater storage and water quality, analyzed and presented at http://snirh.pt. This information (including maps, graphs and tables) is published at monthly reports on hydric resources edited by INAG/APA.

3.2 Drought monitoring

Indices used for drought monitoring in Portugal are:

- SPI (Meteorology Institute);
- PDSI (Meteorology Institute);
• % of soil water content (Meteorology Institute);

• Regional Drought Distribution Model, a statistical model that calculates the spatial distribution of droughts associated with their risk of occurrence, in order to compare drought intensity with Severity-Area-Frequency (SAF) curves and estimate the return period of regional drought (Henriques and Santos 1999), using a drought threshold equal to the 0.20 quantile of the normal distribution for precipitation (Water Institute);

• Streamflow, reservoir water storage and groundwater storage (the drought threshold is defined by a percentile of long-term monthly average data) (Water Institute);

• Water quality parameters (Water Institute).

Drought indices have not officially been linked to drought impacts, whereas the different severity levels are given in Table 3.

Table 3: Definition of drought severity levels based on the individual indicator values in Portugal

<table>
<thead>
<tr>
<th>Drought severity level</th>
<th>SPI</th>
<th>PDSI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>0.49 &lt; -0.49</td>
<td>0.49 &lt; -0.49</td>
</tr>
<tr>
<td>Dry</td>
<td>-0.5 &lt; -0.99</td>
<td>-0.5 &lt; -1.99</td>
</tr>
<tr>
<td>Moderate</td>
<td>-1 &lt; -1.49</td>
<td>-2 &lt; -2.99</td>
</tr>
<tr>
<td>Severe</td>
<td>-1.5 &lt; -1.99</td>
<td>-3 &lt; -3.99</td>
</tr>
<tr>
<td>Extreme</td>
<td>≤ -2</td>
<td>≤ -4</td>
</tr>
</tbody>
</table>

Type of data collected (input data for drought monitoring) are presented in Table 4. Drought and its severity are evaluated four times along the hydrological year, namely:

1. End of January, to evaluate autumn precipitation (intermediary analysis);
2. End of March, to evaluate wet semester precipitation (intermediary analysis);
3. May, to confirm drought severity of the current year;
4. End of September, to calculate a statistical analysis of precipitation occurrence for the past hydrological year.

Table 4: Data collection in support of drought monitoring in Portugal

<table>
<thead>
<tr>
<th>Data category</th>
<th>Authority in charge</th>
<th>Frequency of data collection</th>
<th>Means for data exchange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation, temperature (monthly data for drought monitoring)</td>
<td>IM(SPI and PDSI calculations)</td>
<td>Monthly, daily and hourly data</td>
<td>Website Monthly reports</td>
</tr>
<tr>
<td>Precipitation</td>
<td>INAG/APA</td>
<td>Monthly, daily and hourly data</td>
<td>Website Monthly reports</td>
</tr>
<tr>
<td>Streamflow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water storage in reservoirs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Groundwater storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water quality parameters (monthly data for drought monitoring)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The Drought Observatory (IM) provides information (http://www.meteo.pt/pt/oclima/observatoriosecas/), including maps and figures on:

- Historic evolution (1942-2010) of SPI3, SPI6, SPI9 and SPI12 for mainland Portugal, Douro, Tejo and Guadiana river basins (the three largest river basins);
- Historic evolution for the last decade (2002-2012) of SPI3, SPI6, SPI9 and SPI12 for main river basins for mainland Portugal;
- Monitoring of SPI3, SPI6, SPI9 and SPI12 for the current hydrological year for main river basins for mainland Portugal;
- Historic evolution of monthly averaged PDSI (1961-2000) and identification of major drought events for mainland Portugal;
- Monitoring of PDSI for the last 12 months of the current hydrological year for mainland Portugal;
- Forecasting of PDSI for the following month based on 3 scenarios for the occurrence of precipitation;
- Soil water content (%) for the last month of the current hydrological year for mainland Portugal;
- FWI for mainland Portugal for the current day and forecasting for the next 24h.

The Drought Monitoring and Early Warning System (INAG/APA) provides raw and synthesized data collected by its monitoring network and the resulting drought indices, (maps, graphs and tables), which can be downloaded from http://snirh.pt.

Available information from monitoring is used by other agencies such as the National Authority for Civil Protection (ANPC), the General Directorate of Agriculture and Rural Development (DGADR), the Regulatory Entity for Water and Waste (ERSAR), and the National Forest Authority (AFN), which need the information to support their planning and decision-making. Such entities access the information through (1) the internet/reports (e.g. AFN during the fire season), (2) official contacts, and (3) the National Commission for Reservoir Management, which is a national permanent commission that follows drought/flood situations through periodical meetings and includes reservoir main user entities and some of the quoted agencies. During a drought period, information is exchanged among entities through the Drought Commission.

### 3.3 Drought declaration

There is no officially approved drought declaration process in Portugal. The process adopted in the last two drought events (2005 and 2012) is the following:

- **Before the Drought:**
  - Before a drought period is detected and declared, both Meteorology Institute (IM) and the Water Institute (INAG/APA) monitor the climate variables used for drought indices as described before. The National Commission for Reservoir Management follows the situation through periodical meetings and regional sub-commissions.
  - When a meteorological drought is detected by IM, this entity informs the Commission for Reservoir Management who analyzes the situation, based essentially on the water storage levels in some reservoirs, particularly multi-purpose reservoirs and the imbalance between water availability and water demand prediction. If the decision is for the presence of a drought, this Commission proposes the Government to declare a state of drought and a Drought Monitoring and Impact Mitigating Program should be drawn up.
• During the Drought
  o After governmental approval, an institutional solution for managing the drought is established and organized. The organizational solution comprises two action levels: the Drought Commission for the political and strategic issues, and the Technical Secretariat for the technical and operational issues. The operation of the organizational model is focused on the permanent availability of information to all authorities, economic agents and the public in general, using information and communication technology. A page on the internet is set up and managed for this purpose. The members of the Secretariat also use this page to exchange documents for decision-making purposes.
  o The drought evolution is evaluated at real time with the quantification of the water availability in rivers, reservoirs and groundwater and the water requested by the different water users, with different levels of priority and restrictions. The water storage in reservoirs and aquifers is subjected to detailed monitoring during the drought and appropriate measures are taken. Incentives to the issue of permits for the survey and abstraction of water are analyzed.
  o The secretariat establishes intense contacts with the main users to evaluate the technical and economic measures to mitigate the drought impacts, with particular attention to the urban water supply that could imply road water transport and its individual distribution in extreme cases. Exceptional measures as building of emergency infrastructures and new wells can be implemented according to the needs.

• After the Drought
  o When the results of drought monitoring show a normal situation based on precipitation and reservoir storage levels, the Commission for Reservoir Management proposes the end of the drought. After governmental approval, climate monitoring in normal situation begins (performed by the Meteorology Institute and the Water Institute, as described before). The Drought Commission finally elaborates a Drought Balance Report, with the main results and lessons obtained.

After the end of the drought in 2005, the Drought Commission was extinct. In 2012 the recently created Drought Commission (of a smaller and more centralized structure) is a permanent Commission. Figure 2 presents the scheme of drought declaration in Portugal.
3.4 Assessment of the DMS

Current outputs from the monitoring system are reliable and of good quality and have been efficiently used to monitor the last severe drought event (2005). However, budget for monitoring has been decreasing in the last years and today there is almost no investment on data monitoring. After 2008, regular maintenance of monitoring stations decreased sharply and about 70% of INAG/APA’s monitoring network stopped functioning (according to personal information from a stakeholder), particularly for hydrological and water quality stations.

Furthermore, SNIRH is more oriented for flood evaluation and does not allow drought evaluation with a unique and global classification. The implementation of a system for early warning and drought management based on evaluation indicators is currently being developed by INAG/APA but has not been applied yet (Do Ó 2011, Vivas and Maia 2011). It is also underway a study to create and calibrate a global indicator to identify droughts, using not only meteorological and hydrological data, but also drought impact indicators. However, this global indicator was not yet officially published and applied.

Until now Portugal did not develop drought management plans, there is not a policy or plan developed specifically for droughts and droughts are still managed as a crisis. River basin management plans do not include drought management plans and there is a lack of national preventive planning and measures for droughts. Furthermore, measures established for the protection and sustainable use of Portuguese-Spanish river basins (transboundary waters) are very generic and lack a harmonization of methodologies for water resources monitoring and management, based on constant exchange of information, establishment of common objectives, monitoring networks and socio-economic indicators.

Further requirements to improve operational drought management and drought monitoring, forecasting and early warning in Portugal include:

- Monitoring programs with well-structured information networks (particularly for transboundary waters);
- A permanent system for drought forecasting, early-warning and monitoring (currently under development by INAG/APA);
- Contingency plans for each public water management entity (with a harmonized approach), supervised by the Commission for Reservoir Management to ensure a coordinated approach and common criteria;

- An information system on available water resources (superficial water and groundwater, quantity and quality) and quantity/temporal variation of water uses for each sector (this information is available within SNIRH for reservoir water but very incomplete for groundwater);

- Link drought indices with drought impacts to develop a global drought indicator.
4 Drought Monitoring & Early Warning in Switzerland

4.1 Introduction

Switzerland is dominated by a humid climate and consequently the abundance of water characterizes the many economic and societal practices. Although recent dry episodes have increased awareness of the impact of dry conditions (e.g. the 2003 and 2011 droughts), drought is not a primary topic in Switzerland. Consequently there is to date no operational Drought monitoring system. However, Switzerland has a dense network of monitoring stations observing related environmental variables including an array of meteorological and hydrological observables. The most important monitoring networks are coordinated under the umbrella of governmental agencies: The “Federal Office of Meteorology and Climatology” (MeteoSwiss) maintains a national network for meteorological variables (http://www.meteoschweiz.admin.ch/web/en.html) and the “Federal office of the Environment, FOEN” focuses on hydrological variables (http://www.bafu.admin.ch/index.html?lang=en). Furthermore, the “Swiss Federal Institute for Forest, Snow and Landscape Research WSL” collects some relevant environmental variables (http://www.wsl.ch/index_EN). These monitoring networks are supplemented by a number of smaller systems, including the recently established “Swiss Soil Moisture Experiment” (SwissSMEX), which is hosted by the ETH in Zürich (http://www.iac.ethz.ch/groups/seneviratne/research/SwissSMEX). Most of the governmental networks have been operational for decades and information on relevant issues is communicated to the public through several channels including home pages, reports and press releases.

4.2 Drought monitoring

Drought-related information is derived from measurements that are readily available from operational environmental and meteorological monitoring networks. This is currently done in an ad-hoc fashion, often by comparing the current conditions to the climatology. As part of the Swiss National Foundation (SNF) Program NRP61, the project DROUGHT-CH, coordinated by ETH Zurich and involving Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), the University of Zurich and the University of Freiburg in Breisgau (http://www.nfp61.ch/E/projects/cluster-hydrology/droughts/Pages/default.aspx), is currently developing a prototype research-based drought information platform.

Data are collected, processed and archived by the organizations operating the meteorological and hydrological monitoring systems. Relevant observations include precipitation, temperature, soil moisture and river flow (Table 5).
### 4.3 Drought declaration

There is to date no formal drought declaration procedure in Switzerland. In a recently published national political strategy document there is no mention of "drought", but of ‘a water scarcity-problem, which is characterized by an imbalance between water supply and water demand.’ Also, water scarcity is considered to be – also in the future - a regionally and spatially limited problem (no Swiss-wide water scarcities are expected in the future). Hence, a declaration of a scarcity problem has to take place at the regional level by the regional authorities. Subsidiarity, taking into account regional differences, and proportionality are considered basics for any decision taking and measures in this political strategy. Hence, there will not be a “drought declaration” in the future.

Following the Swiss constitution, cantons dispose of water resources, i.e. they distribute water rights and regulate water use. The cantons can delegate these rights or parts of them to the municipalities. Hence, water management is very different in the cantons. It is cantons who would identify water scarcity. However, for the case of emergencies, such as regional water scarcity, the federal government disposes of laws and regulations that either would skip regulations applying to normal situations such as residual flows in rivers, use of ground water or that would command certain management measures to cantons such as providing an inventory of water supply facilities.

In case of severe water scarcity – or drought – the Federal Office of the Environment (FOEN) would declare emergency based on the consent of the cantons. Then, the federal government could issue emergency measures (see above).

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4.4 Assessment of the DMS

So far, there is no drought monitoring system in Switzerland. Yet, the above-mentioned strategy document envisions assessing the development and introduction of an early detection and warning system. Relevant authorities, research institutions including the meteorological service should be involved. The mentioned SNF-funded DROUGHT-CH project develops a prototype of a web-based information platform (“Informationsplattform Trockenheit”). It collects relevant observational and model based data, aiming at providing practitioners with information on the current drought status.

In a workshop (2010) with relevant stakeholders the following indicators for early detection have been recommended: soil moisture, humidity of forest litter, river streamflow, groundwater table, water-level of water bodies (lakes, rivers), water temperature, evapotranspiration, air moisture, air temperature, amount of precipitation, wind speed, snow depth, snow cover, snow water equivalent. Several of these indicators are only relevant for certain sectors.

In a second workshop (2012) with relevant stakeholders and various representatives of federal and cantonal authorities, the design and content of the planned information platform was discussed.

One major question is whether there should be any drought warning. Appropriate warning is difficult to provide at the regional level because of the existence of large geographical variations and the fact that such a warning requires more than just data – it needs also practical experience and interpretation of data. Another question is the proper identification of the end users for such a drought information platform: i.e. should it be rather aimed at practitioners (farmers, foresters etc.) or rather authorities and associations who will filter the data and provide interpretations to practitioners. In this context, practitioners tend to prefer short-term information (for the next few weeks), while authorities are also interested in more long-term information (from one season to another).

The participants recommended including: topical articles from newspapers, a news-ticker, information on measures taken by the authorities, a reference list regarding codes of practice, links to institutions that could help in drought situations, pixel presentation of the situations into the platform.

It has not yet been decided who will get access to the platform. In principle there is nothing against public access, however, in this case, the provision of data may be more restricted to avoid misinterpretations, and the presentation will have to be very easy understandable. Several of the data that will be included are already accessible by the public but would simply be collected at this single site.

Overall, there are already quite some indicators that can be used for a drought information platform. So far, they are presented at various other sites (meteorological site, flood information etc.). On-going research on drought in Switzerland will be ready in the near future to provide modelling results regarding drought.
5 Drought Monitoring & Early Warning in Jucar River Basin, Spain

5.1 Introduction

In year 2000 the Office for Hydrologic Planning of the CHJ (Jucar River Basin Agency), following the directions given by the General Subdirection of Hydrologic Planning, started a system of indicators for drought monitoring. Since that moment, the system has allowed control and surveillance of the hydrological status of the different “exploitation” systems (water resource systems) (WRS) in the basin and the preparation of periodical reports.

The indicators system has a hydrologic character, i.e., its purpose is characterizing the hydrologic drought (or rather, the operative or WRS drought), since its practical interest resides in its function as instrument for supporting decision taking regarding the management of water resources in the basin. There are 34 point indicators evenly distributed along the Jucar River Basin Agency Territory as can be seen in Figure 3. Indicators from 17 to 28, inclusive, correspond to the Jucar River basin.

![Distribution of indicators in the Jucar river Basin Agency Territory](image)

Figure 3: Distribution of indicators in the Jucar river Basin Agency Territory


5.2 Drought monitoring

The following methodology was followed to develop the indicators system:

- Identification of the origin zones of the water resources associated with demand unit;
- Selection of the most representative indicator of the water resources;
- Compilation of the hydrologic series associated with indicator;
- Weighting of the different indicators to obtain representative aggregated indicators of the drought situation at each of the WRS defined in the CHJ Hydrologic Plan;
- Validation of indicators by continuous monitoring of hydrologic series according to the corresponding reports.

Taking into account that the point indicators should reflect the availability of water resources in a homogeneous form, the following categories were considered:

- Stored volume in reservoirs
- Piezometric levels in aquifers
- Fluvial flows in natural regime
- Areal rainfall

No parameters of strictly environmental character (diversity of macro invertebrates, riparian forest status, etc.) were used in a direct form due to lack of enough data to establish temporary series. Nevertheless, from the monitoring of the proposed indicators, of hydrologic character, it is possible to derive a great part of this information, since it is directly related to their values or their tendency. On the other hand, there is an Environmental Monitoring Plan, associated to the Drought Plan of the CHJ, in which there are also defined monitoring measures for water bodies with associated protected areas vulnerable or highly vulnerable to drought. In this case, monitoring is not done on the drought episode but on its effects.

In the case of the Jucar River Basin, the regionalization study of demand zones and representative control elements allowed distributing the territory of the basin into 12 homogeneous zones with their corresponding indicators (Table 6).

<table>
<thead>
<tr>
<th>Zone</th>
<th>Indicator</th>
<th>Demand Classification</th>
<th>Weight factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Jucar Resources</td>
<td>Gauging station 08032. Cuenca</td>
<td>D</td>
<td>0.05</td>
</tr>
<tr>
<td>Upper Cabriel Resources</td>
<td>Gauging station 08090. Pajarorcillo</td>
<td>D</td>
<td>0.05</td>
</tr>
<tr>
<td>Groundwater resources Utiel-Requena</td>
<td>Piezometer 08.24.005. Utiel</td>
<td>C</td>
<td>0.04</td>
</tr>
<tr>
<td>Resources from rivers Jardín and Lezuza</td>
<td>Gauging station 08138. Balazote</td>
<td>D</td>
<td>0.06</td>
</tr>
<tr>
<td>Flowing resources Eastern Mancha</td>
<td>Gauging stations 08144 and 08036</td>
<td>D</td>
<td>0.05</td>
</tr>
<tr>
<td>Flowing resources Mid Gabriel</td>
<td>Areal pluviometers in Mid Gabriel Zone</td>
<td>D</td>
<td>0.05</td>
</tr>
<tr>
<td>Groundwater Resources Eastern Mancha</td>
<td>Piezometer 08.29.053. Cenizate</td>
<td>A</td>
<td>0.19</td>
</tr>
<tr>
<td>Resources regulated by the Forata reservoir</td>
<td>Storage level in Forata reservoir</td>
<td>C</td>
<td>0.05</td>
</tr>
<tr>
<td>Flowing resources Embarcaderos-Tous</td>
<td>Areal pluviometer in Tous Reservoir</td>
<td>D</td>
<td>0.06</td>
</tr>
<tr>
<td>Resources regulated by the reservoirs of Alarcón, Contras and Tous</td>
<td>Sum of volumes stored in the three reservoirs</td>
<td>A</td>
<td>0.23</td>
</tr>
<tr>
<td>Groundwater resources Caroch</td>
<td>Piezometer 08.28.007. Montesa</td>
<td>B</td>
<td>0.08</td>
</tr>
<tr>
<td>Flowing resources of rivers Albaida and Cañoles</td>
<td>Areal pluviometers in L’Olleria zone</td>
<td>D</td>
<td>0.08</td>
</tr>
</tbody>
</table>
The proposed zoning includes water resources areas of various magnitudes according to the demands supplied. To provide homogeneity, a classification of areas was done depending on the magnitude of the supplied demands \((D)\) from each zone, with the following separation:

- **A**: \(D>100 \text{ hm}^3/\text{year}\)
- **B**: \(100 \text{ hm}^3/\text{year}>D>50 \text{ hm}^3/\text{year}\)
- **C**: \(50 \text{ hm}^3/\text{year}>D>10 \text{ hm}^3/\text{year}\)
- **D**: \(D<10 \text{ hm}^3/\text{year}\)

The values of the control elements corresponding to each of the indicators cannot be compared straightforward, since they represent different phases of the hydrological cycle with a different memory effect. Because of this, the memory effect has been homogenised by value accumulation in precipitations and inflows.

Thus, given that their significant memory effect (years or months), are compared:

- The measured storage volumes (\(\text{hm}^3\)) with a series built from the stored volumes in the same month during the whole historic period
- The cycle-tendency value of piezometric levels (m) with the historic cycle-tendency built with the classic method
- The accumulated precipitation of the last 12 months (mm) with the accumulated precipitation obtained from analogous calculations in the same month during the whole historic period
- The average of measured inflows (\(\text{hm}^3\)) in the last three months with a series built from the historic series in an analogous form

Each indicator has associated 4 different levels of drought severity, which are established according to the so-called "State Index" (Ie), defined taking into account the following criteria:

- Mean value is one of the most robust statistics, and one of the simplest. Hence, a comparison of the data of the indicator with the average of the historical series considered will adjust more conveniently, in principle, to the real drought situation of the zone selected. However, also the maximum and minimum historic values must be taken into account.
- The necessity of homogenising the indicators into a dimensionless numeric value capable of quantifying the current situation regarding the historic series, and enabling the quantitative comparison between the different indicators selected. Thus, the State Index is calculated with a formula in which the values of the index vary between 0 (the minimum historic value) and 1 (the maximum historic value).

The formula of the State Index is as follows:

\[
If \ V_i \geq V_{med} \rightarrow I_e = \frac{1}{2} \left[ 1 + \frac{V_i - V_{med}}{V_{max} - V_{med}} \right] \\
If \ V_i < V_{med} \rightarrow I_e = \frac{V_i - V_{min}}{2(V_{med} - V_{min})} \quad (1)
\]

Where \(V_i\) the value of the indicator in the corresponding month, \(V_{med}\) the average value of the historic series of the indicator, \(V_{max}\) the maximum historic value, and \(V_{min}\) the minimum historic value.

When the value considered is between the average of the historic series and its maximum, the value of the State Index will vary between 0.5 and 1. On the other hand, when the value is between the average and the minimum value of the historic series, the State Index will vary between 0 and 0.5.
In the case of groundwater the usefulness of the state index is that it provides the filling level of the aquifer and assesses the exploitation regime of the aquifer with regard to the variations of the piezometric level, although it does not quantify the storage level. It is obvious that an index having minimum values does not mean that there are not resources available in the aquifer. However, it has been considered that it can be adequate as an indicator of the renewable resources.

The State Index of the whole system is calculated as a weighted sum of the State Indexes of each indicator. The weights chosen for each indicator depend on the demand volume which should be supplied by the water resource characterized by each indicator. For the Jucar River basin, the weight of each indicator can be seen in Table 6.

Depending on the values taken by the State Index, it is possible to define four different Drought Scenarios. Each of these scenarios has different characteristics and the measures and action to take vary between each of them:

- **Normality Scenario:** It is a state of normality during which the resources availability is above the historic average. It is guaranteed the supply of all the demands for one year and all the urban demands for a period superior to 4 years. It corresponds to the phase of hydrological planning when the measures carried out are long term strategic with an infrastructural character, i.e., building of structures for storage and regulation, unconventional resources facilities, development of normative and regulation of uses, or other measures that require a long period for its implementation. Measures started in this scenario are not strictly considered part of drought management (part of the Drought Plan), but may serve for improving the water bodies status and the reliability of the water resources system, therefore, for delaying the entry of the next scenarios, in which urgency measures are carried out.

- **Pre-alert Scenario:** The water resources available cannot guarantee the supply of all the demands. It is set as an objective to guaranteeing urban demands for between 2 and 4 years, and agricultural demands for one year with a supply deficit lower than 17%. The objective is preventing the deterioration of the water bodies status recommending action that move the system away from a integral failure, what would mean, besides not supplying demands, some of them vital such as urban demand, that aquatic ecosystems and other dependent ecosystems would suffer a serious impact. In general, the measures activated are informative and of monitoring nature.

- **Alert Scenario:** The water resources available cannot guarantee the supply of all the demands. It is set as an objective guaranteeing the urban demands for 1 or 2 years, and agricultural demands for one year with a supply deficit lower than 32%. This scenario is an intensification of pre-alert, both in progression of drought and in measures approach, which also should chase preventing the deterioration of water bodies. Measures are addressed to resources conservation, reduction of demand and higher vigilance of zones with high environmental value.

- **Emergency Scenario:** The water resources available cannot guarantee the supply of all the demands. It is set as an objective guaranteeing the urban demands for at least 1 year. Measures in this scenario are oriented to minimise the deterioration of water bodies. At the same time, when moving from this scenario towards normality, measures for fast recovery of the water bodies must be anticipated. This scenario includes supply restrictions to non-urban demands.

Table 7 presents the thresholds of different Drought Scenarios taking into account the State Index values.
Table 7: The link between drought scenarios and State Index Values in the Jucar River Basin

<table>
<thead>
<tr>
<th>Values of the State Index</th>
<th>Entry to scenario</th>
<th>Exit from scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>During</td>
<td>Condition</td>
</tr>
<tr>
<td>Normality</td>
<td>-</td>
<td>≥0.50</td>
</tr>
<tr>
<td>Pre-Alert</td>
<td>3 consecutive months</td>
<td>[0.50 – 0.30]</td>
</tr>
<tr>
<td>Alert</td>
<td>2 consecutive months</td>
<td>[0.30 – 0.15]</td>
</tr>
<tr>
<td>Emergency</td>
<td>2 consecutive months</td>
<td>&lt;0.15</td>
</tr>
</tbody>
</table>

The estimation of the existing indicators based on the four main types of data: (a) Rainfall, (b) Runoff, (c) Storage and (d) Piezometry. The Jucar River Basin Authority is responsible of maintaining a monitoring network in all the infrastructures and aspects related to water in its territory.

The Office for Hydrological Planning from the Jucar River Basin Agency is responsible of monitoring the evolution of the drought indicators. This information is shared with the different Reservoir Withdrawal Commissions. The results are made publicly available by means of the website of the Basin Agency.

Additionally, the Exploitation Area of the CHJ, prepares weekly reports on the water resources available that include information about rainfall, hydrology and the status of the systems in the previous week and its evolution with regard to the beginning of the year. This report includes relevant information for the management of systems in drought situation and it is publicized in the website of the basin agency.

5.3 Drought declaration

In the current version of the Special Drought Plan, the official drought emergency declaration occurs during the emergency scenario, and has administrative and legal consequences, such as the activation of a Permanent Drought Committee (PDC), with exceptional power. Figure 4 shows the actions done in each scenario until reaching the drought declaration.
5.4 Assessment of the DMS

The temporary evolution of the indicators system allowed knowing the variation of drought through time. Additionally to the official drought indicators presented above, during the last drought episode in the Jucar River basin (2005-2008) there were also indicators of the meteorological and hydrological situation of the basin. Meteorological indicators were calculated as the relation between the accumulated rainfall since the beginning of one year and the average value correspondent to the same period. Hydrological indicators consisted in the comparison between the accumulated monthly hydrological inflows in natural regime and the historic series.

The weekly report of water resources was also useful to manage the drought situation. Its contents evolved during and after the drought development so its usefulness was higher for monitoring the drought and its impacts. This report was complemented with more detailed reports on different aspects of drought.

With the current indicators system and the thresholds defined to move between scenarios, during the drought episode of 2005-2008, the Jucar River system entered in the alert scenario in June 2005, and in the emergency scenario in January 2006 until September 2007, coming back to the alert scenario until November 2008. The Extraordinary Situation Decree (Drought Declaration) was approved in October 2005, and the Permanent Drought Commission (PDC) met for the first time in December of the same year. Then, the action plan for mitigation the drought effects was approved in February 2006. It must be noted that the Official Drought Declaration and the establishment of the PDC occurred before the Jucar system entered in the emergency scenario, which afterwards proved to be very convenient for the anticipation of measures to prepare for the emergency scenario (more proactive approach than in past drought episodes).

Along the whole drought episode the state index in the Jucar system oscillated around 0.1 due, in part, to the existence of stored water in case the drought evolved to a more negative situation. In this sense, it has been proposed that future versions of the Special Drought Management Plan might consider that
the declaration of official drought and the establishment of the PDC take place once the system enters the Alert scenario.

Improving the drought monitoring and forecasting system, as well as the public participation, are key elements to confront future drought episodes. In this sense, it has also been proposed modifying the thresholds of the Alert and Emergency scenarios.

A review of the indicators system has also been proposed by reviewing the variables and the weights used to calculate them. An analysis of the 2005-2008 drought episode in the Jucar River system might indicate the necessity of including new variables to improve anticipation. Moreover, including meteorological and hydrological indicators would improve the anticipation process too in the application of the drought mitigation measures.

Apart from reviewing the indicators and thresholds, it would be convenient to develop special indicators for water resource systems with strong connections, and which can work together (like de Jucar-Turia systems for urban supply), so it is possible activating measures that affect both systems with a better timing.

It is also proposed the elaboration of monthly reports on the hydro-meteorological state of the basin, in which there are included meteorological, edaphic, and hydrological drought indicators. Also previsions, both deterministic and probabilistic, of the future evolution of reservoirs and their state at the end of the campaign, of accomplishment of environmental flows and supply to users, so it is possible to know future evolution and the risks of entering in an operative drought.
6 Drought Monitoring & Early Warning in Po River Basin, Italy

6.1 Introduction

In the Po river basin an early warning system, called “DEWS-Po: Drought Early Warning System for the Po River” has been developed to manage at a first time flood’s events, and afterwards it was upgraded with skillsnesses and tools to enable its use along with drought events. The DEWS-PO is already four years in operation and mainly involves monitoring of meteorological and hydrological droughts.

The DEWS-Po is a numerical modelling system providing advanced tools to simulate natural hydrology and water use that affect river flows, allowing managing events through real-time evaluations. The system architecture is designed to receive hydro-meteorological input, actually observed and forecasted variables: deterministic meteorological forecasts with a fifteen days lead time, probabilistic meteorological forecasts with a three month lead time (seasonal forecast), withdrawals data for different uses, natural an artificial reservoirs storage and release data.

For forecasting purposes, the input consists in meteorological data from the European Centre for Medium-Range Weather Forecasts. The ECMWF forecasts are used as input for the model in the form of a suitable combination of temperature and precipitation fields, obtained from long term forecasting, to obtain a seasonal horizon covering the Po basin with a 16 Km grid, with a daily step for rainfall and six hours step for temperature.

The weather input feeds a physically based hydrological rainfall-runoff model, the Topkapy model, which has been implemented for the whole river basin and calibrated over each available gauging station. The Topkapy’s generated output feeds subsequently a hydraulic balance mode, realized through the software RIBASIM (Deltares – MITSIM MIT). In the RIBASIM schematic, all withdrawals points are described and queryable (Irrigation, industrial, civil supply, hydropower production). Artificial reservoirs are simulated through a series of rules describing plant’s functioning on the base of the characteristics of lake and spillways. RIBASIM comprises a special module for the simulation of groundwater balance. A special model software is implemented to provide salt intrusion simulation at the Po delta.

The DEWS-Po covers the whole river basin (particularly the Italian regions Vall D’ Aosta, Piemonte, Lombardia, Liguria, Emilia Romagna, Toscana and Veneto). It is part of wider monitoring system that includes also early warning for floods and the Romagna region, which is not part of the Po River Basin. The Po River Basin Authority is responsible for the operation of the DEWS – Po, whereas the Arpa SIM Emilia Romagna / AIPO are responsible for the technical maintenance and development.

Figure 5 illustrates the schematization of Po basin region in the DEWS Po Monitoring System. The DEWS-Po can be assessed in the website: http://www.adbpo.it/BilancioIdrico.html.
6.2 Drought monitoring

DEWS-Po is supported by a high density observational network, connected with telemetry systems, recording the following parameters:

- Rainfall
- Temperature
- Water level/discharge

The network includes about 600 water level gauges, 1000 raingauges and 750 thermometers. Also weather-radar input is provided to the DMS.

In addition, data collected as input in DEWS-Po system are: (i) river levels and discharges (rating curves are available), (ii) water storage levels in reservoirs, and (iii) water uses. The frequency of data collection is daily (or shorter depending on the nature of examined parameter). The authorities in charge for data collection are Agenzia Regionali ARPA and AIPO. The means and processes for data sharing are not well defined.

Drought monitoring system is based on a set of hydrological or meteorological indices that are calculated at real time and for forecasting purposes. The drought indices used are the following:

- Standard Precipitation Index (SPI)
- Standard Runoff Index (SRI)
- Length of the dry period (without rainfall)
- Return period of the dry period
- Return period of the hydrological drought though the “run method”

Concerning threshold levels, drought characterization follows the standard scale for the SPI index, whereas thresholds are not yet defined for the other parameters. During drought events, the evaluation is carried out usually based on “experts judgment”, jointly analyzing information reported, weekly of
even more frequently, by different stakeholders including agricultural operators, hydro-power producers, reservoirs managers

Only for the parameter “Po discharge measured at Pontelagoscuro station” a “shared”, even if not formalized, threshold value is actually taken as a reference for minimum allowable value, being related to salt intrusion and to ecosystem health: 400 m³/s. This value is anyway not the final one, since under the Water Balance Plan, actually in course of development, it’s being verified and revised versus ecosystem health and “Ecological flow” EU requirements.

Any parameter calculated or used by the DEWS-Po System can be used for further use, as it is stored in the system. There are no agreed products that are shared or disseminated regularly coming straightforward from the DEWS-Po, since information and outputs are yet regarded as “insiders products”, and communication takes place primarily during the meetings of the technical-political-stakeholder board, which is a very active “governance tool” established in 2008 through a “Memorandum of understanding”. Drought-related information is disseminated to a wider audience through a Bulletin that is prepared at intervals during drought events.

All the final users of the information take part at the cited board, called “cabina di regia”. The final users are agricultural operators, hydro-power producers, regulated alpine lakes managers, irrigation consortia, water civil supply services, industry and other facing category representatives, environmental associations, all together with regulatory public administrations and civil protection.

6.3 Drought declaration

The “drought declaration” comes from the governance process, as a shared decision, when all possible and agreed voluntary measures are taken and the situation keep getting worse for essential supplies or the ecosystem. The Civil Protection has the power and the competence to declare and “deactivate” the emergency declaration.

Drought Management Plans have not yet developed or implemented, but are included in the Water Balance Plan’s measures. In the DMPs, different “groups” of action are foreseen depending on the severity of the situation and on the territorial/administrative level, based on vulnerability/impacts assessment (to be still carried out).

6.4 Assessment of the DMS

The DEWS-Po is operating for a few years (four). It has been tested also for drought characterisation in the past and the experience so far shows that DESW-Po outputs are reliable and sufficient for drought monitoring of the Po River basin. The set of indicators being used represent the water system and can provide an early warning in case of extreme events: (i) the SPI index is estimated for different time scales covering the needs of meteorological drought monitoring, (ii) the SRI index provides crucial information for the river regime of the region, (iii) the outputs of frequency analysis can contribute to forecasting activities, and (iv) furthermore, the analysis of salt intrusion on the Po Delta is very helpful for the control of ecosystem balance.

However, a challenge remains the definition of drought severity thresholds for the whole set of parameters, that can be subsequently linked to “management indicators” and actions for each drought severity level (an activity under development within the Po water balance plan). The aim is to develop a shared and participatory framework for drought management, on the basis of technical board called “the control room”, active since 2003.
The DEWS-Po can be seen as a decision support system for emergency and proactive drought planning. Long-term planning can be based on the simulation of “what if” scenarios considering different anticipated conditions for the region. On the other hand, operational planning can be supported by the simulation of different options of water allocation. Another use of the information provided by the DEWS-Po system could be the drought impact analysis and vulnerability assessments.
7 Drought Monitoring & Early Warning in Syros Island, Greece

7.1 Introduction

A monitoring and early warning system does not exist in Syros Island or in Greece, despite the increased vulnerability to drought. Information about the use of indicators for drought monitoring has been extracted from the literature and concern research undertaken for different regions of Greece.

7.2 Drought monitoring

Vassiliadis (2010) uses SPI as an indicator for drought monitoring and early warning in Pinios river basin. Particularly, the application of the early warning drought system shows that reliable and accurate predictions of drought characteristics (severity, duration and area) are estimated for medium term prediction intervals at larger timescales of SPI (SPI-9, SPI-12, SPI-24) and for short term prediction intervals at smaller SPI timescales (SPI-3, SPI-6).

Another attempt was made by Tigkas (2008) for establishing a drought monitoring system in four drought prone areas of Greece (Thessaly, Athens, Cyclades and Eastern Crete) using as drought indicator the RDI (Reconnaissance Drought Index).

7.3 Drought declaration

A crisis management approach is typically followed. In case of drought conditions (i.e. rainfall less than normal) less water is stored in cisterns resulting to an increase in water demand from desalination. This is monitored by the Municipal Enterprise of Water Supply and Sewerage of Hermoupolis-Syros that informs the mayor that problems in water supply may occur and measures should be taken. Typically, the mayors of Syros Island make relevant statements to the Region of South Aegean in order to declare the island in a state of emergency.

7.4 Assessment of the DMS

The analysis of past drought characteristics in Syros (for 1970-2010) indicated that as the timescale of SPI estimation increases the ability of the SPI to describe drought events (in terms of duration and intensity) is increased, as well. Therefore, the SPI-12 index can be used as a meteorological indicator of drought for Syros.

However, besides the climate conditions, drought monitoring and declaration processes should reflect, water sources and uses, and drought vulnerabilities in the Syros island. In this regard, drought monitoring cannot be solely based on indicators using precipitation data. As groundwater is a main source of water (particularly for irrigation), composite indices that include information about the water reserves in the island should be developed and implemented.

In line with the provisions of the Water Framework Directive, the Ministry of Environment, Energy and Climate Change has established a national monitoring program for the assessment of the status of ground water. The stations located in the Syros Island (as defined in the Joint Ministerial Decision 140384/2011) are illustrated in Figure 6. The data collected from this network could be used for supporting drought monitoring and early warning in Syros, along with data collected from the meteorological station in Syros (operated by the Hellenic National Meteorological Service).
Figure 6: Location of groundwater monitoring stations in Syros Island²

² http://geodata.gov.gr
8 Conclusive Remarks

This section provides an overview of the DMSs in the DROUGHT-R&SPI Case Studies, in terms of (i) exiting drought monitoring systems, (ii) authorities involved in or that can support monitoring, and (iii) recommendations for improving the operation of the current DMS.

Monitoring networks specifically for drought are operating in three out of six Case Studies (Portugal, Jucar and Po River Basins). In The Netherlands data collected on the evaporation surplus, the temperature and discharge of the rivers entering the country are being used for monitoring the conditions of the water system and thus cases of drought. In Switzerland and Syros there are no drought monitoring systems in place. Even though the lack of monitoring may be justified for Switzerland, as drought events are not frequent, this is not the case for Syros Island. Given the absence of a national guiding framework for water and drought management, drought monitoring has not been a priority for the regional authorities.

Official drought declaration process exists only in the Jucar River Basin, whereas unofficial processes are in place in Portugal and Syros Case Studies. In the case of Syros Island, drought declaration is linked to the declaration of a state of emergency in cases when significant water deficits are expected or experienced. In Portugal, drought declaration is related to the operation of the “Drought Commission”.

Overall, drought monitoring has been mainly promoted in the Mediterranean region, where drought events are frequent and have severe impacts on sensitive sectors as agriculture. The indicators used for monitoring have been selected on the basis of available data from existing monitoring networks. No effort has been undertaken to link indicator thresholds to impact; however it is acknowledged that this type of information would be of value for drought management.

In all cases with a DMS in place, the monitoring results are available to the public for dissemination purposes and further use by other authorities.
### Table 8: Drought monitoring and declaration in the Case Studies

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Drought Monitoring</th>
<th>Indicators</th>
<th>Monitoring related to impacts</th>
<th>Public reports on drought conditions</th>
<th>Drought declaration process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>Yes (indirectly)</td>
<td>• Temperature</td>
<td>No</td>
<td>Yes (water system conditions)</td>
<td>No (The National Committee Water Distribution starts to meet when river flow and temperature equals relevant thresholds)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Discharge of river flow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Evaporation surplus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portugal</td>
<td>Yes</td>
<td>• SPI</td>
<td>No</td>
<td>Yes</td>
<td>Yes (not official)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• PDSI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• % of soil water content</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>• Regional Drought Distribution Model</td>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td>• Streamflow, reservoir water storage and groundwater storage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Water quality parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Switzerland</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Jucar River</td>
<td>Yes</td>
<td>• Stored volume in reservoirs</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Basin</td>
<td></td>
<td>• Piezometric levels in aquifers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Fluvial flows in natural regime</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Areal rainfall</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Po River</td>
<td>Yes</td>
<td>• SPI</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Basin</td>
<td></td>
<td>• SRI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Length of the dry period (without rainfall)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Return period of the dry period</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Return period of the hydrological drought though the “run method”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syros</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes (not official)</td>
</tr>
</tbody>
</table>

The authorities that (or may) support drought monitoring in the Case Studies are listed in Table 9. It involves mainly national meteorological services, which provide climate data, and water management authorities, either at national or river basin scale.
Table 9: Authorities involved in drought monitoring in the Case Studies

<table>
<thead>
<tr>
<th>Case Study</th>
<th>List of authorities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>• Royal Netherlands Meteorological Institute (climate data &amp; forecasts)</td>
</tr>
<tr>
<td></td>
<td>• National Water Monitoring Network (water quantity measurements)</td>
</tr>
<tr>
<td></td>
<td>• Rijkswaterstaat (water quantity &amp; quality data, groundwater level data)</td>
</tr>
<tr>
<td></td>
<td>• Water Management Centre the Netherlands (information centre)</td>
</tr>
<tr>
<td></td>
<td>• National Committee Water Distribution (drought management)</td>
</tr>
<tr>
<td>Portugal</td>
<td>• IM (precipitation and temperature data to calculate SPI and PDSI)</td>
</tr>
<tr>
<td></td>
<td>• INAG/APA (Precipitation, Streamflow, Water storage in reservoirs, Groundwater storage, Water quality parameters)</td>
</tr>
<tr>
<td>Switzerland</td>
<td>• Federal Office of Meteorology and Climatology (climate data)</td>
</tr>
<tr>
<td></td>
<td>• Federal office of the Environment (hydrological data)</td>
</tr>
<tr>
<td></td>
<td>• Swiss Federal Institute for Forest, Snow and Landscape Research (environmental measurements)</td>
</tr>
<tr>
<td></td>
<td>• Swiss Soil Moisture Experiment – ETH (soil moisture)</td>
</tr>
<tr>
<td>Jucar River Basin</td>
<td>• Jucar River Basin authority (data collection &amp; processing)</td>
</tr>
<tr>
<td>Po River Basin</td>
<td>• Po River Basin authority (data collection &amp; processing)</td>
</tr>
<tr>
<td>Syros</td>
<td>• Hellenic National Meteorological Service (climate data)</td>
</tr>
<tr>
<td></td>
<td>• Ministry of Environment, Energy and Climate Change (groundwater monitoring)</td>
</tr>
<tr>
<td></td>
<td>• Municipal Enterprise of Water Supply and Sewerage of Hermoupolis-Syros (water demand)</td>
</tr>
</tbody>
</table>

Finally, the recommendations for improving drought monitoring in the DROUGHT-R&SPI Case Studies are summarised in Table 10. Key messages are the need to improve monitoring networks, develop case-specific drought indicators and thresholds and link drought indices with drought impacts.

Table 10: Recommendations for further improving drought monitoring in the Case Studies

<table>
<thead>
<tr>
<th>Case Study</th>
<th>Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Netherlands</td>
<td>• Definition of thresholds for drought severity levels</td>
</tr>
<tr>
<td></td>
<td>• Use of water quantity and quality indicators in monitoring</td>
</tr>
<tr>
<td></td>
<td>• Identification of the required structural measures to limit drought impacts</td>
</tr>
<tr>
<td>Portugal</td>
<td>• Establishment of monitoring programs with well-structured information networks (particularly for transboundary waters)</td>
</tr>
<tr>
<td></td>
<td>• Development of permanent system for drought forecasting, early-warning and monitoring</td>
</tr>
<tr>
<td></td>
<td>• Improvement of monitoring of on available water resources, particularly for groundwater</td>
</tr>
<tr>
<td></td>
<td>• Linking drought indices with drought impacts to develop a global drought indicator</td>
</tr>
<tr>
<td>Switzerland</td>
<td>• Development of a drought monitoring system (on-going consultation with stakeholders on the development of a drought information platform)</td>
</tr>
<tr>
<td>Jucar River Basin</td>
<td>• Review of thresholds for the Alert and Emergency scenarios</td>
</tr>
<tr>
<td></td>
<td>• Review of the indicator’s system (variables &amp; weights) improve the anticipation process</td>
</tr>
<tr>
<td></td>
<td>• Development of special indicators for water resource systems</td>
</tr>
<tr>
<td></td>
<td>• Elaboration of monthly reports on the hydro-meteorological state of the basin</td>
</tr>
<tr>
<td></td>
<td>• Elaboration of reports of the future conditions of the water system in case of an operative drought</td>
</tr>
<tr>
<td>Po River Basin</td>
<td>• Definition of drought severity thresholds for all parameters used in the DEWS-Po</td>
</tr>
<tr>
<td></td>
<td>• Dissemination of drought-related information to a wider audience</td>
</tr>
<tr>
<td></td>
<td>• Use of information in impact analysis and vulnerability assessments</td>
</tr>
<tr>
<td>Syros</td>
<td>• Establishment of a drought monitoring network/process that will adequately consider water scarcity issues, groundwater storage and use.</td>
</tr>
</tbody>
</table>
9 References


10 Appendix 1: Example of a 1\textsuperscript{st} Drought Message in The Netherlands (2011)

The drought season starts on April 1\textsuperscript{st}, and the Drought Message of 24 March 2011, Number 2011-01, has the following information:

**Expectation for discharge, precipitation and temperatures in the summer of 2011**

The chance for low discharge in the Rhine in the next spring and summer is higher than average. For the river Meuse the situation is normal. For 2011, in the Rhine catchment, an increased risk of low river discharge in spring and summer is expected when compared to an average year. This prediction is based on snow cover in the Alps (significantly less than normal), the level of large reservoirs in Switzerland (slightly less than normal) and the current flows in Switzerland and southern Germany (normal). For the Meuse, the situation is normal, and there is no increased risk of low flows.

The groundwater resource is generally on track. The groundwater levels in the south, center and east of the country is normal. The groundwater situation in western and northern Netherlands is not known, but it is expected that this is also close to the average value.

For the precipitation, values around or slightly below the normal values are expected for spring. The temperature (in the experimental forecast for the next three months) will be a half to one degree above normal values.

The experimental seasonal forecast of KNMI for the coming months gives, for rainfall probability, values around or slightly below normal, the temperature in the spring is expected to be 0.5 to 1 degree above normal.

Further headings are:

- Precipitation in The Netherlands (September 2010 through February 2011)
- Autumn 2010
- Winter 2010-2011
- Season expectation (Spring 2011)
- Month expectation
- Groundwater
- Rhine (snow cover; discharge)
- Meuse (discharge)
## Appendix 2: Drought-related Measures in The Netherlands

<table>
<thead>
<tr>
<th>MEASURES</th>
<th>Description</th>
<th>Objectives</th>
<th>Time of activation &amp; duration (planned)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STRATEGIC MEASURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drought management policy</td>
<td>Taking measures on basis of priority ranking</td>
<td>Prevent damage as much as possible</td>
<td>Entire drought</td>
</tr>
<tr>
<td>Information management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drought season monitoring</td>
<td>Measurement of precipitation and river flow</td>
<td>Data gathering</td>
<td>Starting April 1st</td>
</tr>
<tr>
<td>Bi-weekly drought messages</td>
<td>Publication of information on data and measures</td>
<td>Informing all interested parties</td>
<td>When a drought is developing</td>
</tr>
<tr>
<td>Monitoring and evaluation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Measurement of meteorological data</td>
<td>Measurement</td>
<td>Data gathering</td>
<td>Continuous</td>
</tr>
<tr>
<td>Evaluation of the drought, measures and impact</td>
<td>Evaluation</td>
<td>Learning from drought events</td>
<td>After a drought</td>
</tr>
<tr>
<td>National Drought Workshop</td>
<td>Fact-finding from all interested parties</td>
<td>Learning from the drought</td>
<td>After a drought</td>
</tr>
<tr>
<td><strong>OPERATIVE MEASURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Restricting irrigation, washing cars, spraying gardens</td>
<td>Ban on water use</td>
<td>Saving water</td>
<td>During a drought</td>
</tr>
<tr>
<td>Supply management</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increasing water buffers (incl. groundwater)</td>
<td>Raising water levels in lakes and reservoirs</td>
<td>Storing water</td>
<td>On basis of the developing drought</td>
</tr>
<tr>
<td>Re-directing available flow</td>
<td>Re-allocation of water</td>
<td>Limiting damage</td>
<td>During a drought</td>
</tr>
<tr>
<td>Closing certain sluices</td>
<td>Restricting water draining away</td>
<td>Storing water</td>
<td>During a drought</td>
</tr>
<tr>
<td>Operate reversible pumping stations</td>
<td>Drainage pumping stations used for water supply</td>
<td>Re-allocating water</td>
<td>During a drought</td>
</tr>
<tr>
<td>Environmental protection</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preventing water temperature getting too high</td>
<td>Restricting cooling water disposal</td>
<td>Keeping water temperature at agreed limits</td>
<td>During a drought</td>
</tr>
<tr>
<td>Supplying water to high-value nature areas</td>
<td>Re-allocation of water</td>
<td>Preventing irreversible nature damage</td>
<td>During a drought</td>
</tr>
<tr>
<td>Education and awareness campaigns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bi-weekly drought messages</td>
<td>Publication of information on data and measures</td>
<td>Informing all interested parties</td>
<td>When a drought is developing</td>
</tr>
<tr>
<td><strong>RECOVERY MEASURES</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Programme for (conditional) farmer support</td>
<td>Compensation measure</td>
<td>Preventing bankruptcy in agriculture</td>
<td>Following a drought</td>
</tr>
</tbody>
</table>