Ecohydrology guidelines
"How to fill in a ecohydrology demonstration site card":
Low cost advanced methodology for mitigation impacts
from molecular to catchment scale

Introduction

In 2011, the Ecohydrology Programme of UNESCO IHP made a call for proposal for the establishment of a worldwide network of "*demonstration sites*" where ecohydrological approaches are implemented. There are three key objectives of this network:

- Synthesize knowledge gaps for addressing ecohydrological issues related to critical water ecosystems, such as those in arid and semiarid zones, coastal areas and estuaries, and urbanized areas.
- Showcase how better knowledge of the interrelationships between the hydrological cycle, livelihoods and ecosystems can contribute to more cost-effective and environmental-friendly water management.
- Demonstrate system solutions and technology transfer opportunities through North-South and South-South linkages.

Each demonstration site aims to show an application of ecohydrology to deal with issues such as nutrients concentrations, water purification, diverse aquatic habitats like wetlands, marshes, mangroves, cyanobacterial blooms, among others, in order to find long-term solutions integrating social components. The demonstration sites integrate the concept of enhanced ecosystem potential with ecohydrological strategies to achieve sustainability of ecosystems closely related with water to improve IWRM on specific areas. This is termed WBSR (w-water, b-biodiversity, s-ecosystem services, and r-resilience) containing the four elements that should be taken into consideration while trying to improve the ecosystems potential. Through the dissemination of this initiative, it is expected to contribute to the development of research and knowledge-sharing of ecohydrology.

The efforts to develop the initiative continued throughout further ecohydrology conferences (Jakarta 2011, 2013 and Paris 2014) establishing a network of ecohydrology demonstration projects. After the conferences, the UNESCO-IHP Ecohydrology programme developed the so-called "*demonstration site cards"*. It was developed to provide a summary of the demonstration site on one page. This card is a standardized, simplified overview of information -*main characteristics, life zones, ecohydrology implementation principles, ecohydrology engineering solutions, major issues, social-ecohydrological system, results, additional references and pictures*- on the actual state of demonstration sites.

In addition to the current projects, new potential demonstration sites around the world are now welcomed to join the ecohydrology network by applying through the web-platform. Application to become a UNESCO Ecohydrology Demonstration site will be done through the web platform and "demo cards" will be constructed through an automatic user friendly process. To facilitate this process, the following guideline was designed to provide a detailed explanation on completing a demonstration site card. You may follow each step of the 10 sections in the guideline and complete the necessary information. Once it is completed and submitted online, the data will be reviewed by the Ecohydrology Scientific Advisory Committee to be approved or declined for further development.

1. Description of the demonstration site

Section 1 describes the demonstration site through the following elements:

1.1

- One map locating the demonstration site within the country.
- One map/sketch of the demonstration site itself to have a more precise view of the site and major issues occurring (farming, industry, etc.). It would be better if any relevant information about land cover or water uses can be placed on this map/sketch. **Don't forget to** include the legend, the title of the map/sketch, the North indicator, the scale and the reference.
- Provide the geographical coordinates of the demonstration site. If it is a basin, provide geographical coordinates for only one point.
- Information about the lithology and geochemistry of the demonstration site area (e.g: Granitic and gneiss-granitic bedrock covered by clay deposits and mostly thin till deposits, etc.).
- Characteristics of the demonstration site (*Main description*):

We expect a brief paragraph (max. 40 words)[1] describing the location of the demonstration site and its main characteristics. See Table 1 for further explanation, we categorized according to the type of each demonstration site. On one hand, if the demonstration site that you propose is only a part of a basin , please write the characteristics indicated in one of the four types of sites “Rivers”, “Wetlands”, “Lakes/Ponds” and “Estuaries/Coastal Water”.

On the other hand, if the demonstration site that you propose takes into account the whole basin, please write the characteristics indicated in the type of demonstration site called “Basins”. If it is necessary, choose one main characteristic from the other types of demonstration sites. Feel free to add other characteristics that you consider are relevant.

Table 1. Examples of some characteristics according with the type of demonstration sites.

Type of demonstration sites	**Characteristics**
BASINS	Number of inhabitants; Main rivers; Main city near the site; Importance of the basin.
RIVERS	Length of the river; Main city near the site; Presence of floodplains.
WETLANDS	Location; Presence of reservoirs close to the wetlands; Main city near the site.
LAKES/PONDS	Location of the site; Name of the basin which the lake/pond belongs to; Name of the lake/pond; Main city near the lake/pond; Rivers linked to the lake/pond.
ESTUARIES/COASTAL WATER	Name of the main river which flows to coastal area; Name of the marine area.

- Principal ecosystem services provided by the demonstration site (also including the positive externalities): please indicate which ones out of the list are provided by the demonstration site (Table 2), and explain which ones are enhanced and maintained, if any (max. 30 words). Do not hesitate to be explicit while referring to the Integrated Water Resource Management applied.

[1] *Please **keep in mind** that not all the information related to the demonstration site can be placed on the demonstration site card due to spatial limitation.*

Table 2: List of the ecosystem services (TEEB, 2010).

Provisioning Services	Regulating Services	Cultural Services
Services that describe the material outputs from ecosystems	*Services that ecosystems provide by acting as regulators*	*Include the non-material benefits people obtain from contact with ecosystems*
• Food • Raw materials • Fresh water • Medicinal resources	• Local climate and air quality regulation • Carbon sequestration and storage • Moderation of extreme events • Waste-water treatment • Erosion prevention and maintenance of soil fertility • Pollination • Biological control	• Recreation and mental and physical health • Tourism • Aesthetic appreciation and inspiration for culture, art and design • Spiritual experience and sense of place
Habitat or Supporting Services		
Underpin almost all other services. Ecosystems provide living spaces for plants or animals; they also maintain a diversity of different breeds of plants and animals		
• Habitats for species • Maintenance of genetic diversity		

- List of related International/National Conventions or Programs, if any. Please explain their aims and their influence on the demosite (20 words).

1.2

Classification of the demonstration sites into categories divided according to their level of interventions is shown in Table 3. This table should be completed by filling in each column with either “YES” or “NO” to define what type of system the Ecohydrology processes are being applied to. As a project manager, you should understand the three types of systems that this guideline is referring to:

- **Natural ecosystems** are the pristine ecosystems maintained by natural ecosystem processes (e.g: self-denitrification in wetlands natural regulation between flow and biota, etc.).

- **Novel ecosystems** refer to the anthropogenically highly modified portions of catchments. They contain species compositions and relative abundances that have not occurred previously within a given biome (Hobbs *et al*., 2006) and they are the result of active or/and passive human action[2].

- **High impacted systems** (e.g: dams; intensive farmlands) are those ecosystems that are being manipulated in such way that pollution is higher than the law and regulation recommend, but demonstration sites can implement complementary ecohydrological processes (e.g: remediation).

[2] *However, it is hard, if not impossible, to completely remove the human footprint from many ecosystems. The difference between Natural and Novel ecosystems is made by the degree of human impact.*

Table 3: Different categories of intervention

Conserve Ecohydrological processes in natural ecosystems	Enhance Ecohydrological processes in novel ecosystems	Apply complementary Ecohydrological processes in high impacted systems
YES/NO	YES/NO	YES/NO

For more information, refer to the references (Hobbs et al., 2006; Hobbs et al., 2009; Morse, N. B. et al., 2014)

2. Life zones

Section 2 based on Holdridge (1967) defines the most representative life zone inside each demonstration site; thus, the Holdridge life zone system was used (figure 1). It is a global bioclimatic scheme for classification of land areas containing ecological and ecophysiological constraints such as:

A. Average annual air temperature defined as the actual biotemperature –Tbio- (in °C) of the demonstration site

B. Average annual precipitation of the demonstration site –PPT- (in mm/yr)

From these two data (A and B), the potential evapotranspiration ratio value (PET) can be calculated using the following formula: **PET ratio= (Tbio *58.93)/PPT.** This value could be plotted on figure 1 through a line drawn along its value on the corresponding scales on the left.

C. Elevation of the demonstration site (in m)

If the altitude is not significant to determine the life zone, the actual Tbio (taking account the altitudinal belt) and the potential sea-level -T_0bio- are equal then the altitude is considered as basal belt (Holdridge, 1967, fig.2 in p.21).

If the elevation is significant, refer to Table 4 in order to determine the altitudinal belt to be used. **You must define the altitudinal belt using Tbio and the latitudinal region using T_0bio!**

Thus, the method of determining the correct life zone for an elevated point is to calculate T_0bio below the point. This can be done by considering a rough equivalence of **6°C for each 1000 meters of elevation**. For example, in the case of 1200 meters, the calculation would be 1.2 x 6 = 7.2 which when added to the actual temperature of 8°C would equal 15.2°C**,** the potential temperature corresponding to a sea level temperature at that point. The sea level point would correspond to the Warm Temperate region and the elevated site would **fall in the Warm Temperate Montane steppe life zone**.

Then, the climatic associations (e.g. moist forest, steppe, and desert) can be determined by the hexagon centroid in the triangle of the figure 1[3].

Life zones remarks

- T0bio defines the latitudinal region if the altitude is not considered as basalt belt.
- Use the climatic association of the altitudinal belt with the following climatic data: PPT, Tbio and PET ratio.

[3] *See also Lugo et al., 1999 for other examples with different life zones in the United States.*

Ex: PPT=650mm, Tbio=11°C -> PETratio=0.99

Life zone groupings:

- *cool temperate (latitudinal)*
- *basal belt (altitudinal)*
- *moist forest (climatic association)*
- *humid (humidity province)*

***Life zone of the site**: cool temperate moist forest (humid)*

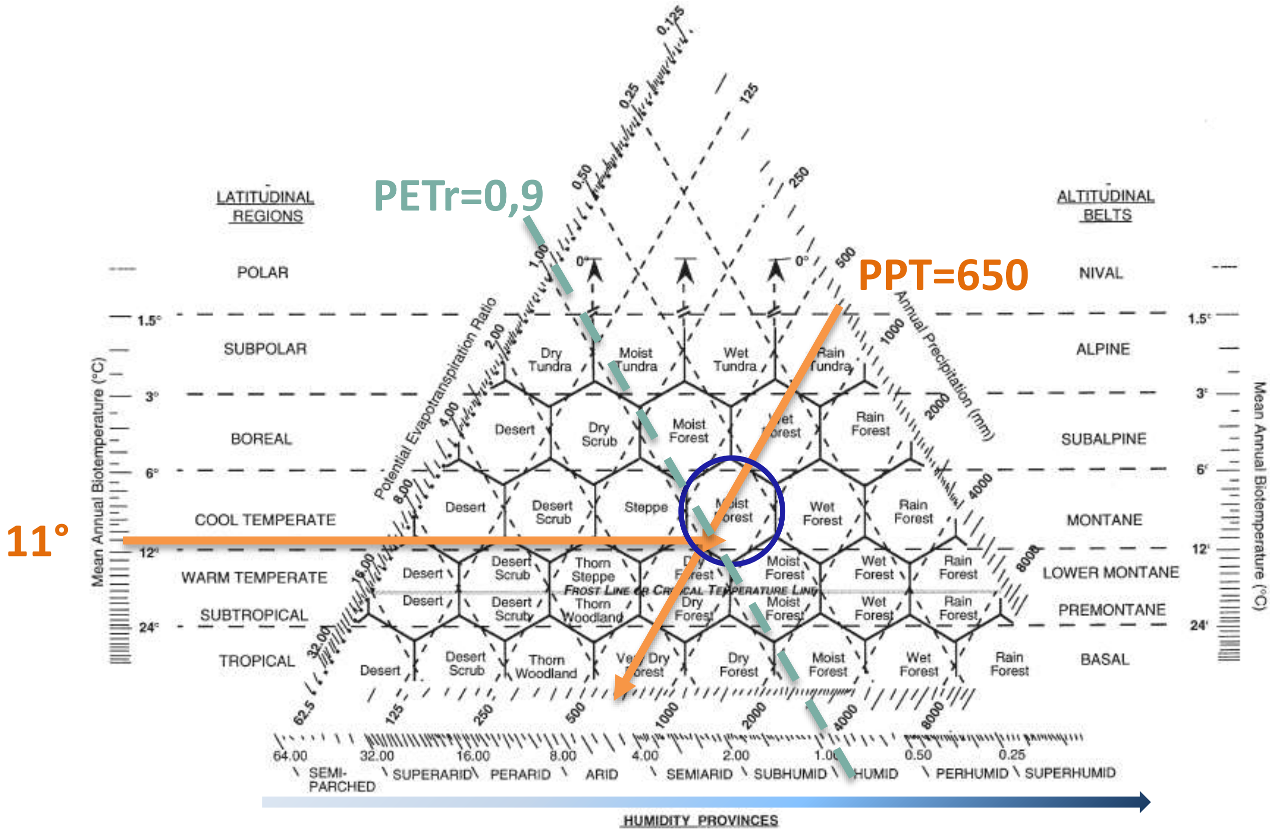

Figure 1. Holdrige life zones system[4].

To help you in this step, four distinct lists are available on the application form:

- Choose one latitudinal region among the Latitudinal Regions list: Polar; Subpolar; Boreal; Cool temperate; Warm temperate; Subtropical; Tropical.
- Choose one altitudinal belt among the Altitudinal Belts list: Nival; Alpine; Subalpine; Montane; Lower montane; Premontane; Basal belt (*[5]).

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[4] *The life zone system should not pretend to delineate homogeneous communities or associations of vegetation. It is a climatic division defined by biotemperature, precipitation, potential evapotranspiration and elevation in a logarithmic system which makes all zones equivalent in significance. Within each life zone there may be several vegetation associations dependent on soils, lesser climatic variables and the presence or absence of open water. The one climatic association of each life zone wherein none of the secondary variations are significant corresponds to a zonal soil and zonal climate (Lugo et al., 1999).*

[5] *(*) If basal belt is selected, nothing is written in the demonstration site-card for the second list.*

- Choose one climatic association among the Climatic Associations list : Dry tundra; Moist tundra; Wet tundra; Rain tundra; Desert; Dry scrub; Moist forest; Wet forest; Rain forest; Desert scrub; Steppe; Thorn steppe; Dry forest; Thorn woodland; Very dry forest.
- Choose one humidity province among the humidity provinces list: Semiparched; Superarid; Perarid; Arid; Semi-arid; Sub-humid; Humid; Perhumid; Superhumid.

Table 4: Classification of the data used to determine the life zone on a site

Altitudinal Belts	Latitudinal Belts	Climatic Associations	Mean Annual Biotemperature (°C)	Potential Evapotranspiration Ratio (PETratio)	Humidity Province	Average Total Annual Precipitation (mm/yr)
Nival	Polar		<1,5	0,125-1,5		62,5-750
Alpine	Subpolar	Dry Tundra	1,5-3,0	1,0-2,0	Sub-humid	62,5-125
		Moist Tundra	1,5-3,0	0,5-1,0	Humid	125-250
		Wet Tundra	1,5-3,0	0,25-0,50	Perhumid	250-500
		Rain Tundra	1,5-3,0	0,125-0,25	Superhumid	500-1000
Subalpine	Boreal	Desert	3,0-6,0	2,0-4,0	Semi-arid	62,5-125
		Dry Scrub	3,0-6,0	1,0-2,0	Sub-humid	125-250
		Moist Forest	3,0-6,0	0,5-1,0	Humid	250-500
		Wet Forest	3,0-6,0	0,25-0,5	Perhumid	500-1000
		Rain Forest	3,0-6,0	0,125-0,25	Superhumid	1000-2000
Montane	Cool Temperate	Desert	6,0-12,0	4,0-8,0	Arid	62,5-125
		Desert Scrub	6,0-12,0	2,0-4,0	Semi-arid	125-250
		Steppe	6,0-12,0	1,0-2,0	Sub-humid	250-500
		Moist Forest	6,0-12,0	0,5-1,0	Humid	500-1000
		Wet Forest	6,0-12,0	0,25-0,5	Perhumid	1000-2000
		Rain Forest	6,0-12,0	0,125-0,25	Superhumid	2000-4000
Lower Montane	Warm Temperate	Desert	12,0-17,0	8,0-16,0	Perarid	62,5-125
		Desert Scrub	12,0-17,0	4,0-8,0	Arid	125-250
		Thorn Steppe	12,0-17,0	2,0-4,0	Semi-arid	250-500
		Dry Forest	12,0-17,0	1,0-2,0	Sub-humid	500-1000
		Moist Forest	12,0-17,0	0,5-1,0	Humid	1000-2000
		Wet Forest	12,0-17,0	0,25-0,5	Perhumid	2000-4000
		Rain Forest	12,0-17,0	0,125-0,25	Superhumid	4000-8000
Premontane	Subtropical	Desert	17,0-24,0	8,0-16,0	Perarid	62,5-125
		Desert Scrub	17,0-24,0	4,0-8,0	Arid	125-250
		Thorn Woodland	17,0-24,0	2,0-4,0	Semi-arid	250-500
		Dry Forest	17,0-24,0	1,0-2,0	Sub-humid	500-1000
		Moist Forest	17,0-24,0	0,5-1,0	Humid	1000-2000
		Wet Forest	17,0-24,0	0,25-0,5	Perhumid	2000-4000
		Rain Forest	17,0-24,0	0,125-0,25	Superhumid	4000-8000
	Tropical	Desert	>24	16-32	Superarid	62,5-125
		Desert Scrub	>24	8,0-16	Perarid	125-250
		Thorn Woodland	>24	4,0-8,0	Arid	250-500
		Very Dry Forest	>24	2,0-4,0	Semi-arid	500-1000
		Dry Forest	>24	1,0-2,0	Sub-humid	1000-2000
		Moist Forest	>24	0,5-1,0	Humid	2000-4000
		Wet Forest	>24	0,25-0,5	Perhumid	4000-8000
		Rain Forest	>24	0,125-0,25	Superhumid	>8000

3. Ecohydrology implementation principles

Section 3 summarizes the concept of ecohydrology in three principles. The principles are to be implemented to complete the objectives of the research in ecohydrology on the demonstration site.

Ecohydrological implementation principles (Zalewski, 2000, 2002; Zalewski *et al.* [eds.], 2004 ; Chicharo, Zalewski *et al.* [eds.], 2009) are:

- **Quantification** of the hydrological processes at catchment scale and mapping the impacts.
- **Identification** of potential areas for enhancement of sustainability potential (carrying capacity).
- **Managing** biota to control hydrological processes and vice versa (ecological engineering).

4. Ecohydrology engineering solutions

Section 4 shows the ecohydrological methods, tools and measures implemented on the demonstration site. Four groups of ecohydrology engineering solutions were developed:

- **Ecohydrological infrastructure** (Capobianco and Stive, 2000; Zalewski, 2015) is based on ecohydrology and ecological engineering methodologies (e.g. Management of wetlands for water purification from excessive nutrient loads based on ecological theory and mathematical modelling).

This engineering solution includes 4 measures[6]:
- Dual regulation.
- Biotechnologies[7].
- Self-design[8].
- Ecosystem conservation: the ecological engineer depends on species and ecosystems.

- **Faunatechnology** is based on the use of fauna to regulate water quality.

- **Phytotechnology** is the most commonly used technology in our current network of EH demonstration sites in enhancing the ecosystem's carrying capacity.
  Specific plants are used to:
  -increase water retentiveness
  -enhance aquatic resilience
  -regulate nutrient dynamics in catchment

- **Hydrological flow** is the quantification of hydrological cycles and processes in a basin through modelling to regulate and/or stimulate ecological status (Tharme, 2003; Bunn and Arthington, 2002).

[6] *Few demosites use hydrotechnical infrastructure as a complementary to the ecohydrological infrastructure.*
[7] *According to OECD (2002), biotechnology is considered as "the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services.*
[8] *Ecotechnology is based on the self-designing and the self-regulating capabilities of ecosystems. Even polluted ecosystems have a certain regeneration power by substituting and adapting species and reorganizing food chains and energy fluxes.*

To help the demonstration sites managers to choose the appropriate categorization according to EH implementation principles and EH engineering solutions Table 5 is provided below.

Table 5: EH implementation principles and ecological engineering solutions

EH engineering solutions	**EH implementation principles**		
	<u>Quantification</u> of the hydrological processes at catchment scale and mapping the impacts	**<u>Identification</u>** of potential areas for enhancement of sustainability potential (carrying capacity)	**<u>Managing</u>** biota to control hydrological processes and vice versa (ecological engineering)
Faunatechnology		√	
Ecohydrological infrastructure			√
Phytotechnology	√	√	√
Hydrological flow	√		√

5. Major issues

8 major issues can appear on the demonstration sites and you should choose one or more among the list, the category “others” is available for other issues:

- Pollutants and Nutrients
- Intensive land use
- Water over abstraction
- Floods
- Invasive species
- Droughts
- Habitat loss
- Loss of retention capacity of vegetation
- Other

Then, for the major issues selected above, please write a short explanation on how it is affecting the area, their causes and consequences (10 words each).

6. Social-ecohydrological system

The Section 6 highlights the social-ecohydrological system composed of two sub-systems **Catchment Sociological sub-system** and **Catchment Ecohydrological sub-system** which interact together.

Inside the first sub-system, **Catchment Ecohydrological sub-system**, two boxes must be completed:

- EH Objectives:

With reference to WBSR we ask the user to decide, by selecting one or more squares, the relevance of the EH Objectives. Bearing in mind that Ecohydrology is becoming an important component for an integrative approach (IWRM) all the 4 options, W for water, B for biodiversity, S for ecosystem services and R for resilience should be envisaged. Please indicate approximately the degree of relationship that the Demonstration site has between each option and the Ecohydrology Objectives (Very low: 1 square; Low: 2 squares; Medium: 3 squares; High: 4 squares; Very high: 5 squares).

Within the IWRM concept, Ecohydrology aims at harmonizing society needs with enhanced ecosystem potential through increasing carrying capacity of ecosystems; it therefore expands the concept of balancing social economic needs by harmonization of the same with enhanced ecosystem potential. Ecohydrology also calls for maintaining notions of conservation for pristine ecosystems and expands efforts for regulation of ecohydrological processes at novel ecosystems (man modified) in order to increase their ecological potential in terms of water resources, biodiversity, ecosystem services and resilience to global change and anthropogenic stress (WBSR, for Water, Biodiversity, Services and Resilience). As such ecohydrology is compliant with the IWRM concept but also provides novel potent tools to achieve sustainability (Zalewski, 2015).

For example, for a project that has a medium degree of relationship between water resources and the Ecohydrology Objectives, a very low degree of relationship between the biodiversity and the Ecohydrology Objectives, a low degree of relationship between the Ecosystem services and the Ecohydrology Objectives and a high degree of relationship between the resilience and the Ecohydrology Objectives, the box should be filled as is showed in Figure 2.

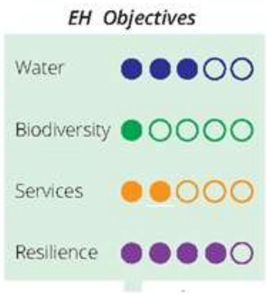

Figure 2. Example of EH Objectives box

- EH methodology

You should complete this box with text explaining what is the ecohydrological methodology used (max. 30 words).[9]

Inside the second sub-system, **Catchment Sociological sub-system**, two boxes must be completed as well:

- Objectives

  Please state honestly what is the reality on the demonstration site in 30 words (We recommend to follow the SMART objectives guideline – Specific, Measurable, Attainable, Relevant, Time-bound).

- Stakeholders

[9] *You can find an example in the paper of Zalewski, 2011.*

You should write maximum of 12 stakeholders that are part of the project. Stakeholders include; government organizations, nongovernment organizations, network structure or monitoring and sanctioning rules (e.g. the government and other organizations that manage the park, the specific rules related to the use of the park, and how these rules are made).

The final box which links the two sub-systems defined above is called “Activities” and you should write a text to summarize the main activities carried out on the demonstration site (60 words).

7. Results

Section 7 presents the results or changes obtained on the demonstration site. The part on “Main expected outcome” should explain the outcome expected through the project on the site or the aim of the activities (15 words).

In the box “Latest results”, should be information on actual results attained on the demonstration site -what has been changed; in numerical terms, data, and references- (50 words).

8. References

Section 8 includes *Link to the references* which deal with document references with information on **specific results** and **solution-oriented approaches** of ecohydrology on the demonstration site.

9. Pictures

Please provide two pictures (with title, reference and year):

9.1. One picture that clearly shows the demosite or part of it, including one or more ecoystems where the demosite is located.

9.2. One picture that clearly shows the ecohydrological engineering solutions used (one or more) or the issues occurred (if any).

10. Contact

Please provide name, e-mail address and institute of the person(s) (max.3) mainly in charge of the project. In case there are any related websites of the demonstration sites, their web addresses should be provided as well.
It should also be noted that the logos of the main organizations participating in the demonstration site project are also necessary for the demonstration site card.

References used in the guidelines:

-Bunn S. E. and A. H. Arthington, 2002. **Basic Principles and Ecological Consequences of Altered Flow Regimes for Aquatic Biodiversity**. *Environmental Management* Vol. 30, No. 4: 492–507

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- Zalewski M. *et al.* [eds.], 2004. *Integrated Watershed Management -Ecohydrology & Phytotechnology-Manual*. UNESCO IHP, UNEP, 246p.

-Zalewski M., 2011. **Ecohydrology for implementation of the EU water framework directive**. *Proceedings of the Institution of Civil Engineers* (ICE Publishing): 11p. DOI: 10.1680/wama.1000030

-Zalewski, M., 2015. **Ecohydrology and Hydrologic Engineering: Regulation of Hydrology-Biota Interactions for Sustainability**. *Journal of Hydrologic Engineering.* 20 (1), 14p.