Plan of the groundwater and surficial water monitoring networks of the Italian site

Deliverable D_3.1.6

Contributing partners:

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1 Introduction

The Interreg Italy-Croatia project MoST (Monitoring Sea-water intrusion in coastal aquifers and Testing pilot projects for its mitigation) aims at testing solutions against saltwater intrusion in agricultural areas, a worldwide problem exacerbated by human activities and climate changes. The regions of interest of the MoST project are the Veneto Region coastal plain south of the Lagoon of Venice (Italy) and the Neretva river mouth (Croatia).

The Activity 3.1 “Site Characterization” aims at characterizing these two regions on the basis of the available knowledge and previous studies with the objective of properly plan the monitoring networks that will support the assessment of the efficiency of the mitigation strategies.

This report includes the contribution to the Deliverable D_3.1.6 “Plan of the groundwater and surficial water monitoring networks of the Italian site” in the framework of WP3 “Studying”.

The groundwater and surface water monitoring networks play the following main important roles in the MoST project:

- Assess the water quality before the intervention for saltwater mitigation,
- Improve understanding of the saltwater intrusion process,
- Address the mitigation plan,
- Evaluate the water quality after adopting the saltwater mitigation intervention.

This report summarizes through a set of maps and tables:

- the availability of previous monitoring data and information including the position of measuring sites (both groundwater and surficial waters).
- the set up of the MoST groundwater and surficial water monitoring networks in the Italian pilot test site updated by June 2020.

2 Materials and methods

The study area encompasses the territory between the southern Venice lagoon border and the final stretch of the Adige River and, specifically, the pilot test area is located just south of the Brenta and Bacchiglione rivers in a low-lying farmland.

The plan of the groundwater and surficial water monitoring networks of the Italian site has been based on the following information:

- Data collected from previous investigations;
- New monitoring points through the installation of the MoST piezometers;

Data obtained by previous investigations refer to the following.

- Projects: ISES, BRENTA, CARG, Corila Research Lines 3.1 and 3.10, GeoRisk.
- Databases: http://webgis.cittametropolitana.ve.it/geologia, http://difesasuolo.provincia.venezia.it/DifesaSuolo/Index?pagina=1&id=banca_dati_idrogeologica (Città Metropolitana Venezia); http://www.isprambiente.gov.it/Media/carg/veneto.html (Istituto Superiore per la Protezione e la Ricerca Ambientale); http://cigno.atlantedellalaguna.it (CNR); http://gisgeologia.regione.veneto.it/website/venezia-10k/viewer.htm (Regione del Veneto).
- Publications: Carbognin and Tosi, 2003; Rizzetto et al., 2003; Carbognin et al., 2006; Carbognin et al., 2010; Mayer et al., 2006; Tosi et al., 2007; de Franco et al., 2009; Tosi et al., 2009; Teatini et al., 2010; Viezzoli et al., 2010; Teatini et al., 2011; Tosi et al., 2011; Da Lio et al., 2013; Da Lio et al., 2015; Tosi et al., 2018.

The collected information on previous monitoring sites amounted to about 200 wells and 60 sites in watercourses distributed between the southern edge of the lagoon and the Adige River. The collected data include:

- Location of the measuring points (e.g., geographic coordinates, maps);
- Main characteristics of the measuring points (e.g., well diameter and screened interval or water column depths, reference benchmarks);
- Previously recorded measurements (e.g., EC and water level, Temperature), even though not regularly acquired.

The analysis of the datasets available highlighted the strength and weakness of the groundwater and watercourse monitoring network previously used for the saltwater intrusion in the Italian pilot area. In May 2020, six new MoST piezometers have been installed in the Italian pilot site in order to:

- provide the initial hydrogeological condition before the setup of the saltwater mitigation actions;
- monitor the hydrologic condition changes during the test of freshwater recharge;
- define the guidelines for the mitigation procedures and irrigation management.

This report contains a set of maps showing:

- the distributions of wells / piezometers and measurement sites in the watercourses used in the past, of which previous datasets are available;
- the distributions of wells / piezometers and measurement sites used in the past and still existing;
- the MoST groundwater monitoring network updated by June 2020;
- the MoST surficial waters monitoring network updated by June 2020.

For the selection of the most suitable existing measuring sites among the ones built/managed by the different water authorities in the region of interest, the following project documents have been considered:

- MoST-CNR 3.1-001 (hydrogeological settings)
- MoST-CNR 3.1-002 (geomorphological settings)
- MoST-CNR 3.2-001 (sediment cores: lithostratigraphy).

3 Previous measuring sites

The existing monitoring points have been categorized according to their suitability to provide the picture of the salinization process occurred in the past and eventually to be included in the MoST saltwater monitoring network. The following maps show the positions of the existing measuring sites and provide an overview of the spatial coverage of the network.

3.1 The groundwater monitoring network used in the past

The groundwater monitoring network used in the past was (Carbognin and Tosi, 2003) formed by about 200 well/piezometers (Fig. 1). About 30 of them were equipped with piezometers filtered from the ground surface to 10 and 20 m depth for the specific monitoring the saltwater contamination of the shallow aquifers affecting farmlands (ISES Project and GeoRisk Project).

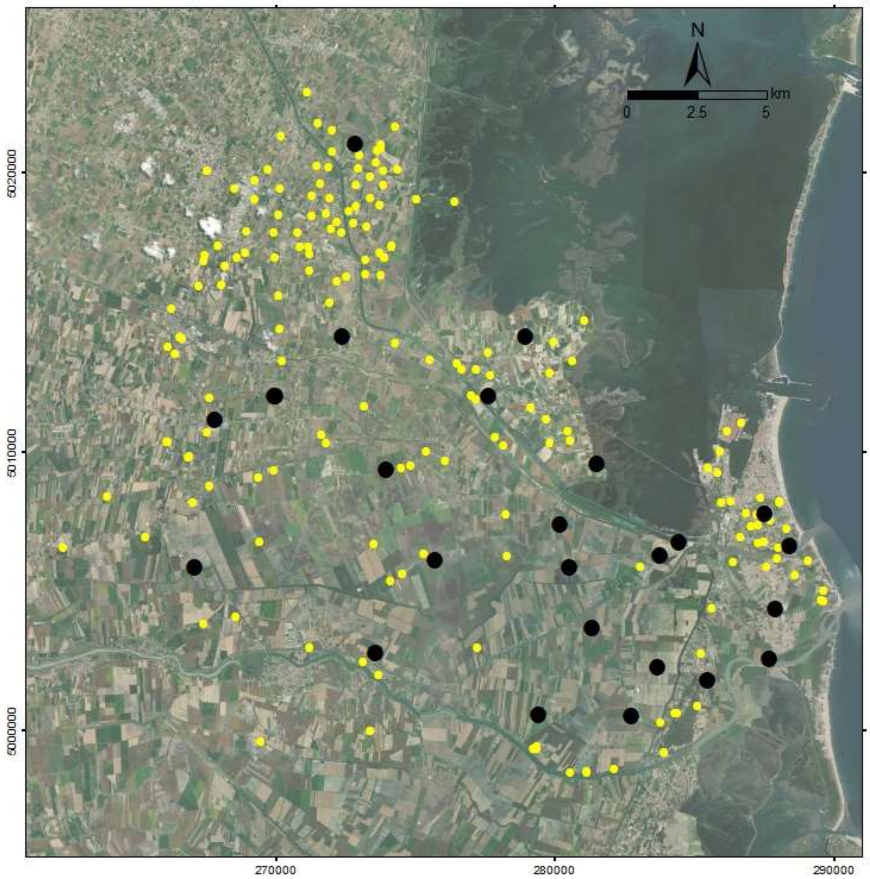


Fig. 1 - Positions of the groundwater monitoring sites (about 200) between the southern lagoon and the Adige River. Black dots indicate the piezometers ad hoc installed in the past for the monitoring of the saltwater contamination.

3.2 The surface waters monitoring network used in the past

The monitoring points with available previous records in the last 20 years are about 60 (Fig. 2). They are located in the Brenta, Bacchiglione and Adige rivers, and in a dozen of drainage and reclamation channels.

Fig. 2 - Positions of the sites (about 60) used in the past for the monitoring of the watercourses between the southern margin of the lagoon and the Adige River.

4 Planning the MoST groundwater and surficial water monitoring networks

The plan of the groundwater and surficial water monitoring networks consisted in establishing a number of sites capable to detect salinity changes due to natural conditions and resulting from the mitigation actions and suitable to carry out regular measurements and install sensors for a continuous data recording.

The plan of the MoST monitoring network was properly designed based on the following:

- The results of field inspections aimed at finding the monitoring points used in the past and verifying their conservation state. This action was essential to reduce time-consuming, cost of drilling new wells and carry out complementary in-situ surveys. In addition, the availability of background information on the salinization process will allow to depict the evolution of the process by comparing new and past datasets;
- The position of the pipe that will be installed inside the sandy buried geomorphologic body for mitigating the saline intrusion in the farmland;
- The need to acquire new hydrologic data for the numerical models simulating the salinization process and the scenarios of mitigation actions;
- The hydrological and geological setting of the study area, e.g., saltwater sources and driving process, seasonal variability of water level and EC, heterogeneity of the subsoil;
- The site accessibility together with the possibility of piezometer damages due to the agricultural works and the potential instrument theft.

4.1 The MoST groundwater monitoring network updated by June 2020

The preliminary groundwater monitoring network designed in December 2019 for the MoST pilot area has been updated in June 2020 to better respond to the scope of the project needs.
Specifically, the activities were the following:

- searching piezometers used in the past and still existing;
- verifying the suitability of existing piezometers to be included in the MoST monitoring network;
- installation of 6 new piezometers in correspondence of the intervention planned for salinity mitigation in the pilot site.

The selection of piezometers used in the past suitable for MoST groundwater monitoring network is shown in Fig. 3.

Fig. 3 - Selection of piezometers used in the past, still existing and suitable for their inclusion in MoST groundwater monitoring network.

It is composed of 12 piezometers suitable for the characterization of the phreatic aquifer and two confined aquifers down to 50 m depth (ISES03, ISES06, ISES09, ISES10, ISES20, CA20, CA50, S1, S2, S3, S4, S5 piezometers).
A lot of time has been spent searching for the piezometers used in the past for monitoring the saltwater contamination (Fig. 4). Because they were abandoned for a long time, most of them have been buried by several centimeters of soil and rubble.

Fig. 4 – Search for existing piezometers used in the past to monitor the saline intrusion and subsequently abandoned.

Once they were found, the existing piezometers were cleaned and restored in order to guarantee a good quality of the measurements (Fig. 5, Fig. 6, and Fig. 7).

Fig. 5 – Examples of old piezometers used in the past, before and after restoration to be included in the MoST project.

Fig. 6 – Examples of old piezometers cleaning.

Fig. 7– a-c) Detail of the screw top with ring used to fix the cable of the sensors; example of protection measures adopted to avoid S1 piezometer damage during the farmland works: d) previous inadequate method with simple thin white pipe, e) new steel pole red-colored, and concrete square manhole.

In May 2020, the groundwater monitoring network was extended by the installation of 6 new piezometers in the pilot site (Fig. 8, Fig. 9, Fig. 10, Fig. 11), i.e. MoST 1A, MoST 1B, MoST 2, MoST 3, MoST 4, MoST 5.

The positions of the new MoST piezometers is shown in Fig. 12 while the MoST groundwater monitoring network updated by June 2020 in Fig. 13.

Fig. 8 – Drilling machine used for the installation of the new MoST piezometers.

Fig. 9 – Screened pipe and gravel used to fill the pipe soil interspace in new MoST piezometers.

Fig. 10 – a) cleaning of a new piezometer (MoST2), b) final setup of MoST1a and MoST1b piezometers.

Fig. 11 – a) piezometer with underground tap and still full floor cover adopted in MoST5 to prevent damage to the animals of the farm.

Fig. 12 - Position of the new piezometers established in May 2020 for the proper groundwater monitoring in the MoST pilot site.

Fig. 13 –MoST groundwater monitoring network updated by June 2020.

Today, the MoST groundwater monitoring network is formed by 18 piezometers, which main characteristics are reported in Table 1 and Fig. 14 to 28

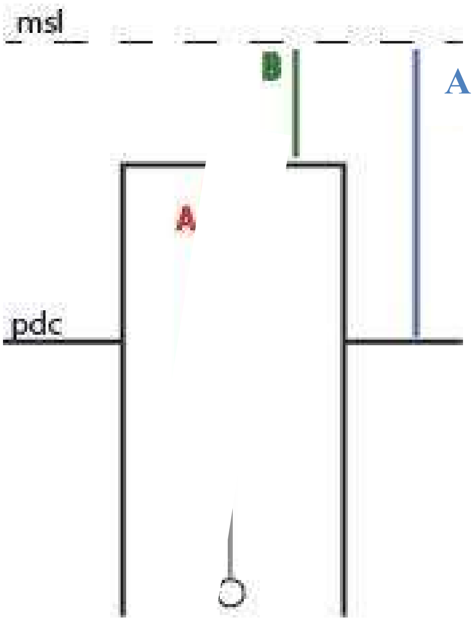
Piezometer	Approximately screened depth range (m below ground surface)	Installation date	Reference Project
ISES3	2-20	2001	ISES
ISES6	2-20	2001	ISES
ISES9	2-20	2001	ISES
ISES10	2-5	2001	ISES
ISES20	14-20	2001	ISES
CA20	15-20	2006	CoRILA
CA50	45-50	2006	CoRILA
S1	2-10	2020	MoST
S2	2-10	2020	MoST
S3	2-10	2020	MoST
S4	2-14	2020	MoST
S5	14-20	2020	MoST
MoST1a	19-21	2020	MoST
MoST1b	2-10	2020	MoST
MoST2	2-10	2020	MoST
MoST3	2-10	2020	MoST
MoST4	2-10	2020	MoST
MoST5	2-10	2020	MoST

Table 1 - Main characteristics of the piezometers forming the MoST groundwater monitoring network.

Furthermore, the piezometers S1-S5, MoST1-MoST5 and CA20-CA50 have been quoted in respect to the mean sea level. Both the ground level next to each piezometer and the top of each well have been quoted in order to have a reference system to which report the data measured in the aquifer. Fig. 14 to 26 illustrate:

- the location of S1-S5 and MoST1-MoST5 wells,
- a picture of the well,
- a scheme of each well reporting the heights of both ground level and top of the well.

MoST1a



B = -1,06 m
C = -1,75 m

Fig. 14 –MoST1a well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

MoST1b

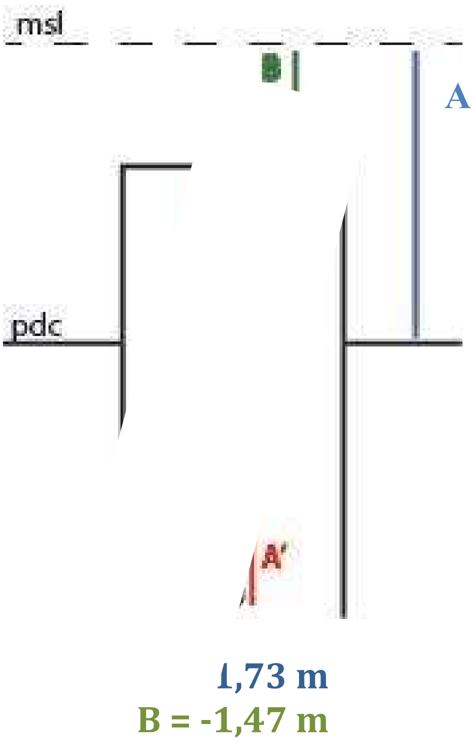
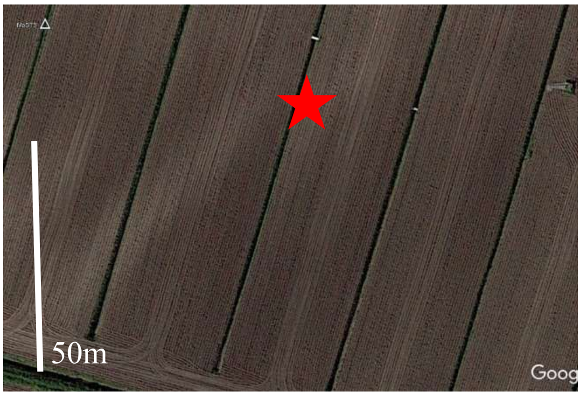


Fig. 15 –MoST1b well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

MoST2



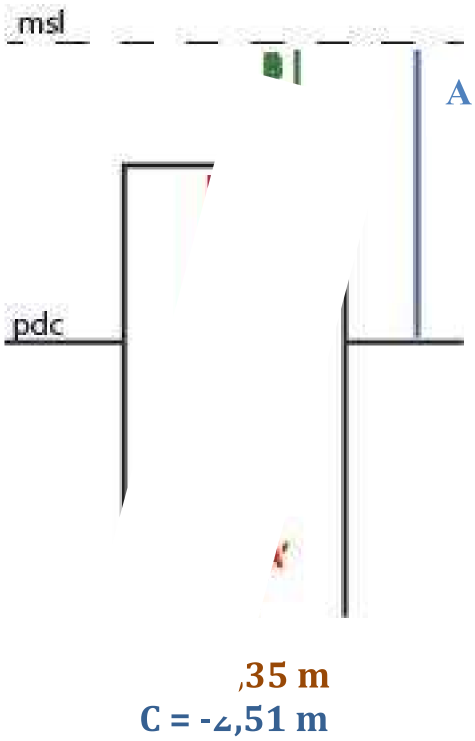
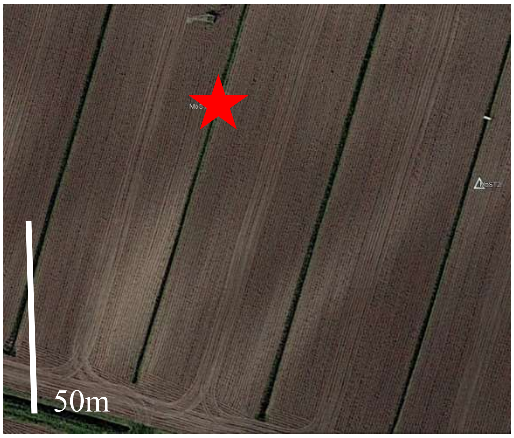


Fig. 16 –MoST2 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

MoST3



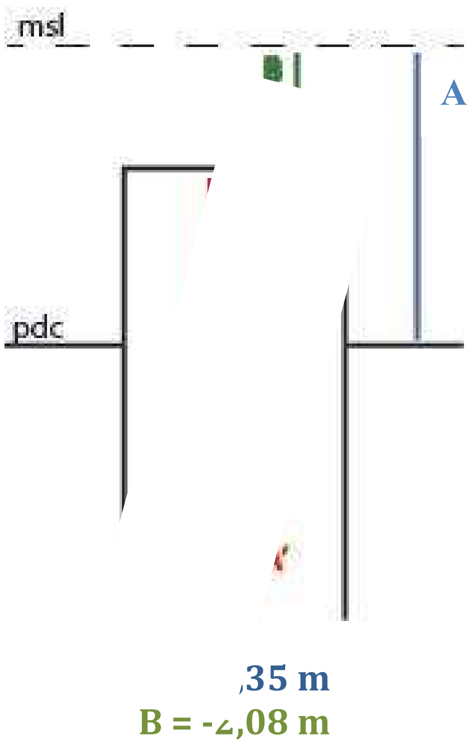
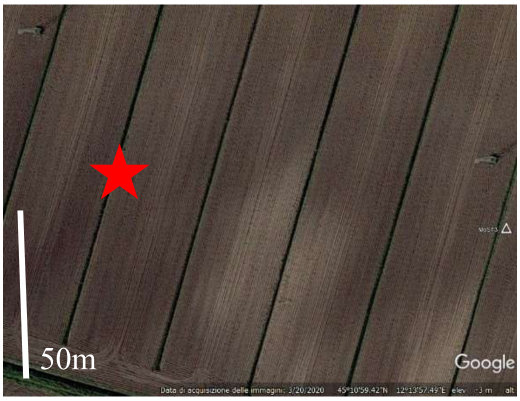


Fig. 17 –MoST3 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

MoST4



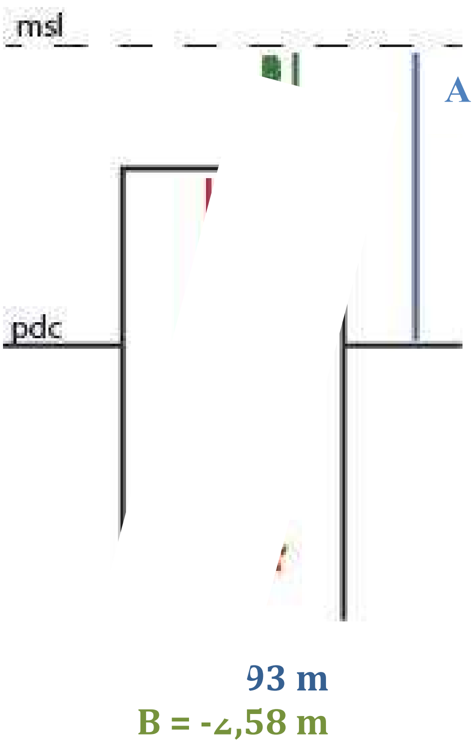
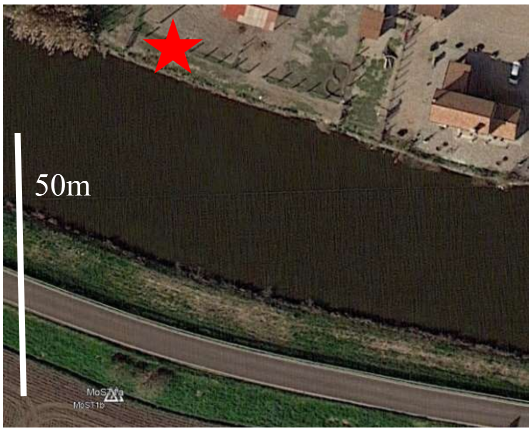
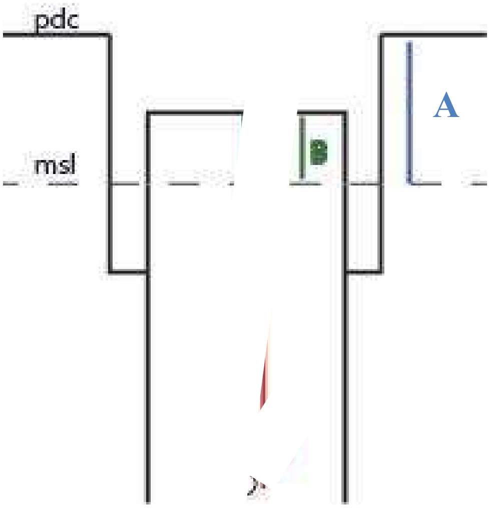


Fig. 18 –MoST4 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

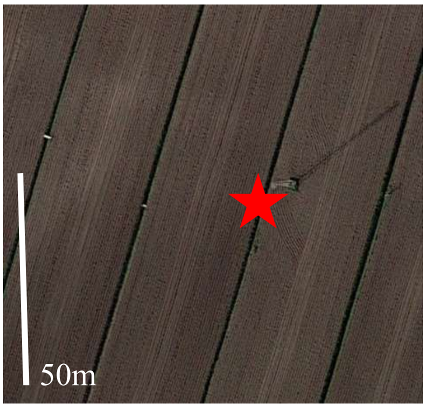
MoST5





A = 1,12 m
B = 0,96 m

Fig. 19 –MoST5 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

<table>
<tr><th colspan="2">S1</th></tr>
<tr><td>
</td><td>
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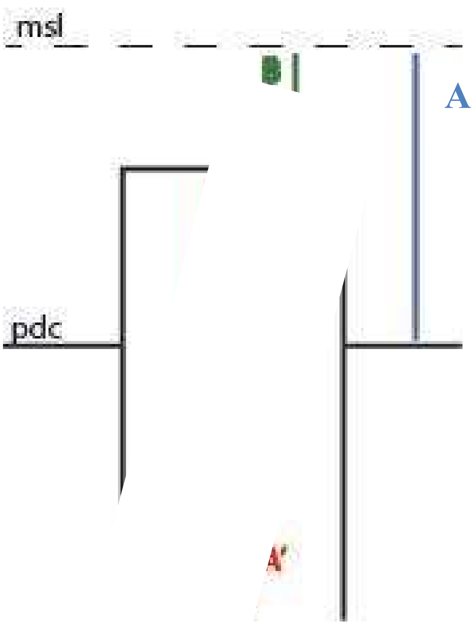
<tr><td>

,75 m
B = -2,60 m</td><td></td></tr>
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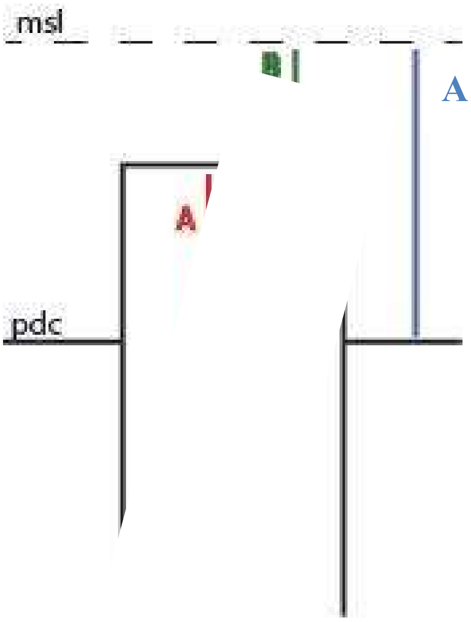
Fig. 20 –S1 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

S2



98 m
B = -1,98 m

Fig. 21 –S2 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

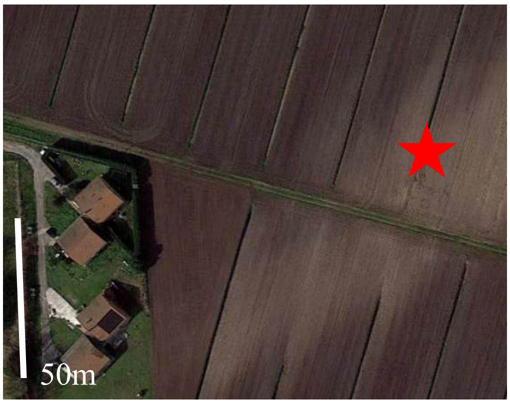
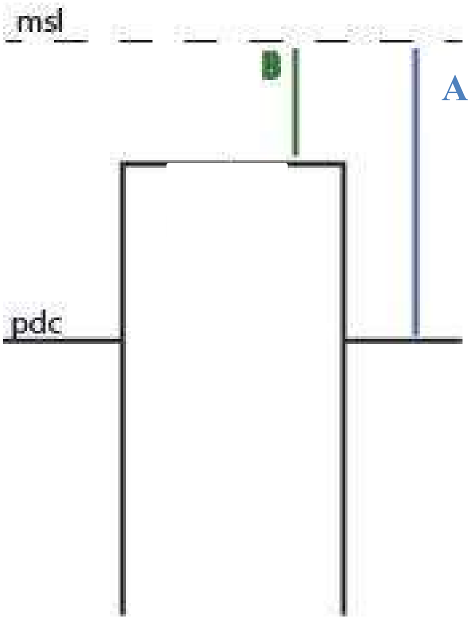
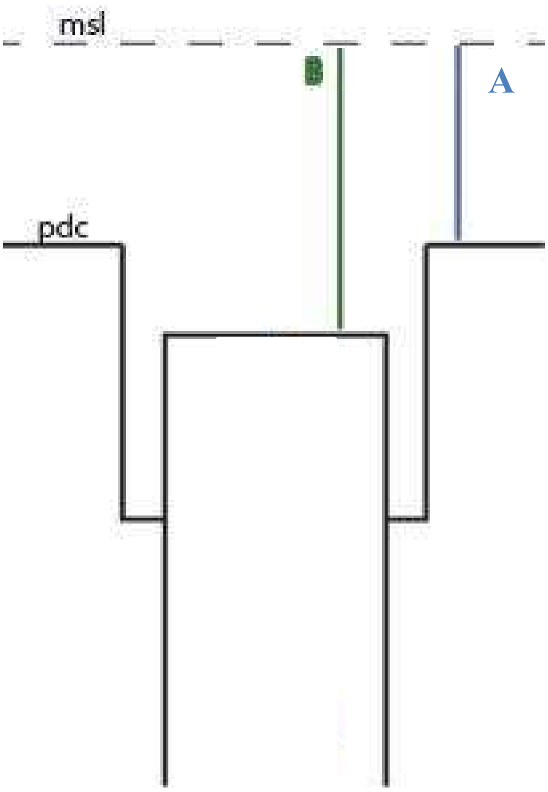
S3	
	
 **A = -2,82 m** **B = -2,62 m**	

Fig. 22 –S3 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

S4



A = -2,46 m
B = -2,64 m

Fig. 23 –S4 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

S5

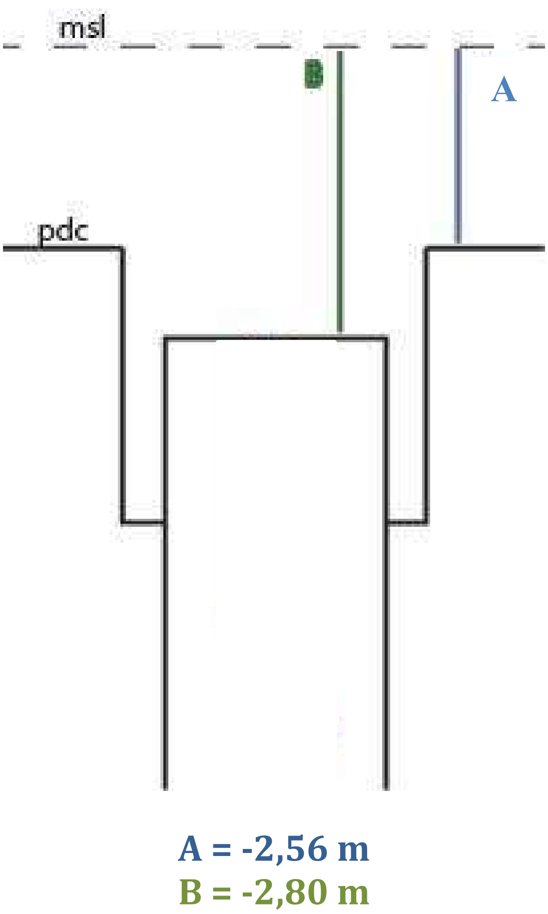
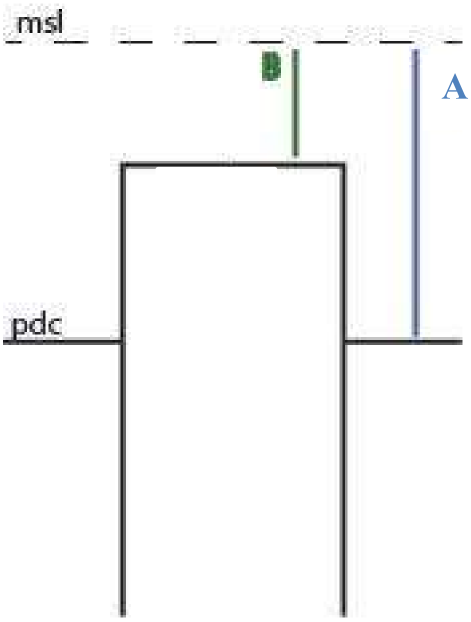


Fig. 24 –S5 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

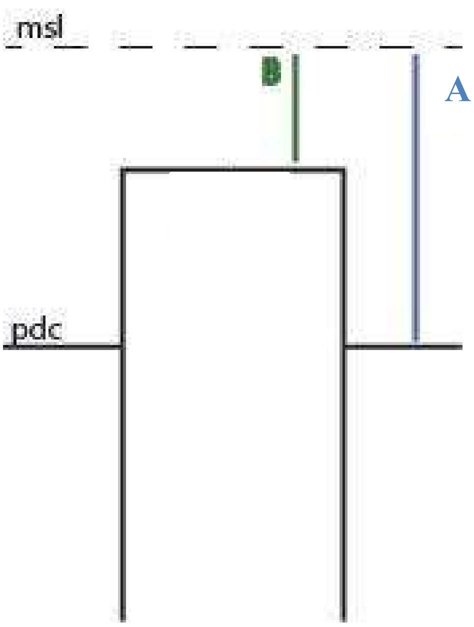
CA20



A = -1,94 m
B = -0,64 m

Fig. 25 –CA20 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

CA50



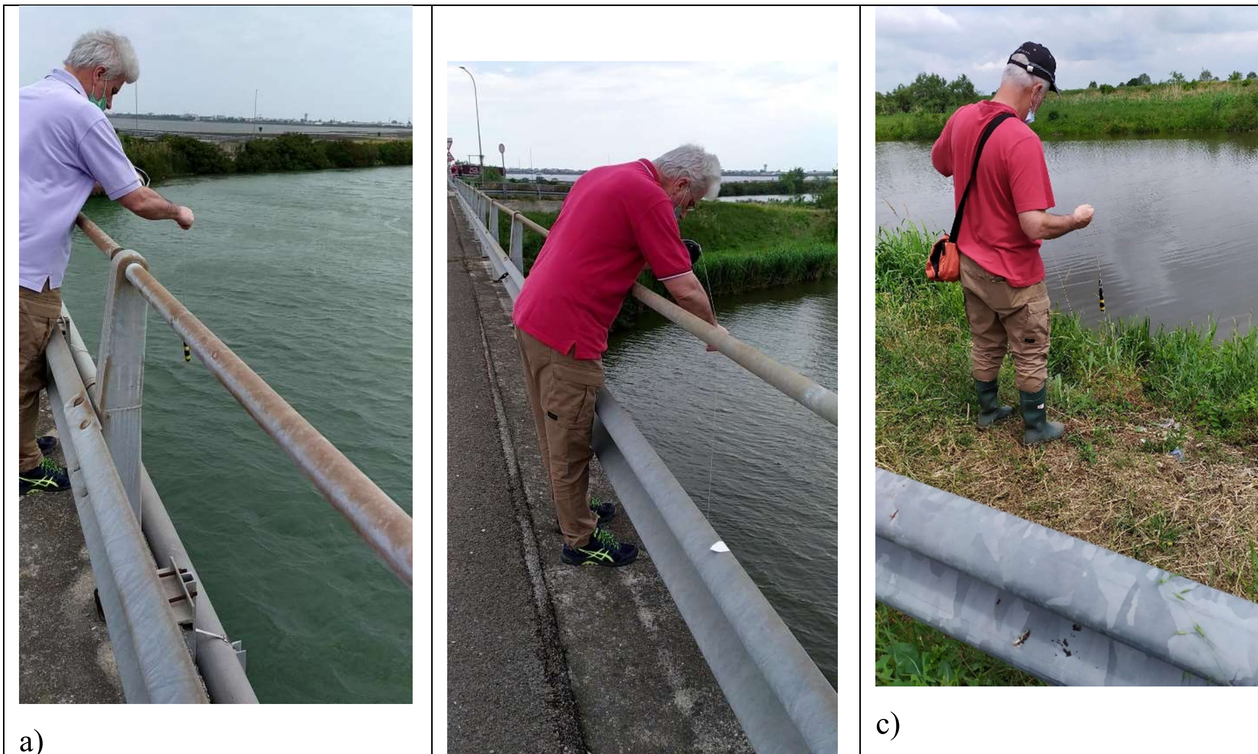
A = -1,99 m
B = -0,64 m

Fig. 26 –CA50 well: localization and scheme reporting the heights of ground level and well top in respect of the mean sea level.

4.2 The MoST surficial water monitoring network updated by June 2021

Five monitoring sites of surficial waters already used within previous projects (ISES, CoRILA, GeoRISK, RITMARE) have been selected and adopted for the monitoring of the salinity in the main watercourses. These sites are located in the Brenta, Bacchiglione rivers and Morto Channel. An additional point is at the inflow of the Casetta pumping station (BRE_PA, BAC_PA, MOR_PA, MOR_CA, CAS_IN. Fig. 26, Fig. 27, Fig. 28, Table 2). The availability of previous dataset of measurements will allow the comparison between the present and past conditions.

BRE_PA, BA_PA and MOR_PA have been quoted in respect to the mean sea level. Both the bridge level next to each monitoring point and the top of the banister have been quoted in order to have a reference system to which report the data measured in the surficial water courses (Fig. 30, Fig. 31, Fig. 32).



a) b) c)

Fig. 27 –Examples of MoST surficial water monitoring points: a) BRE_PA, b) BAC_PA, c) MOR_CA.

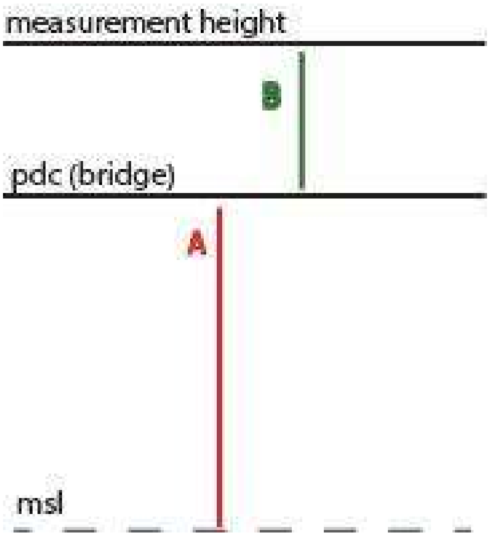
Fig. 28–Examples of MoST surficial water monitoring points: a) BAC_PA, c) MOR_PA.

Fig. 29 –MoST surficial water monitoring network.

Monitoring site		**Measuring depths**
Brenta River at Cà Pasqua bridge	BRE_PA	The entire water column or at surface, mid and bottom
Bacchiglione River at Cà Pasqua bridge	BAC_PA	The entire water column or at surface, mid and bottom
Morto Channel at Cà Pasqua bridge	MOR_PA	The entire water column or at surface, mid and bottom
Morto Channel at Casetta pumping station	CAS_OUT	The entire water column or at surface, mid and bottom
Casetta pumping station inflow	CAS_IN	The entire water column or at surface, mid and bottom

Table 2 – Monitoring points of the MoST surficial water monitoring network.

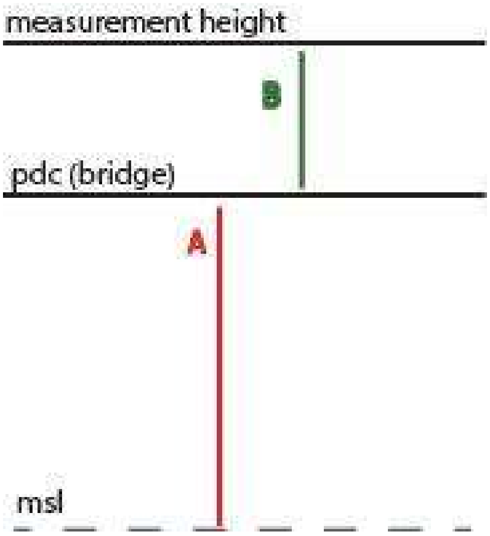
Brenta



A = 6,24 m
B = 1,13 m

Fig. 30 – maps showing the position of the monitoring point BRE_PA, measurement height and bridge height in respect of the mean sea level (on the left), topographical survey with the use of GPS antenna for the acquisition of the measured altitude (on the right)

Bacchiglione



A = 6,28 m
B = 1,13 m

Fig. 31- maps showing the position of the monitoring point BAC_PA, measurement height and bridge height in respect of the mean sea level (on the left), topographical survey with the use of GPS antenna for the acquisition of the measured altitude (on the right)

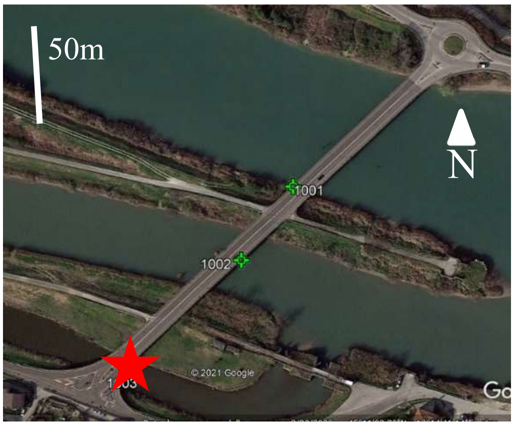
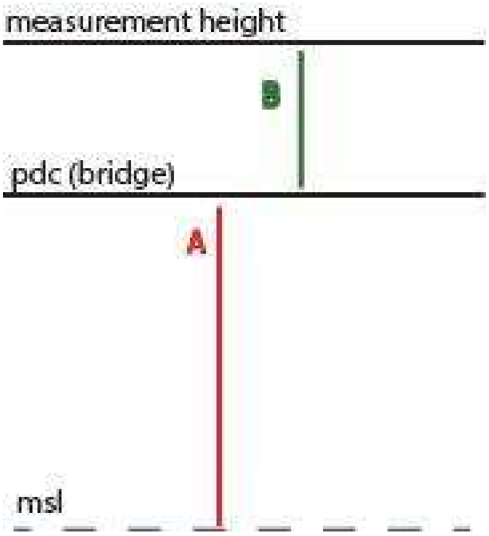
Morto	
	
 **A = 4,65 m** **B = 1,12 m**	

Fig. 32- maps showing the position of the monitoring point MOR_PA, measurement height and bridge height in respect of the mean sea level (on the left), topographical survey with the use of GPS antenna for the acquisition of the measured altitude (on the right)

Considering the position of the sub-irrigation pipe and of the water intake of the system on the Canal Morto, it is recommended to establish another monitoring point at the water intake, in order to monitor the salinity of the water that would be used for the mitigation of the salt-contaminated aquifer. The monitoring could be integrated by the daily measurement of a farmer living just in front of the water intake (yellow stars in Fig. 33)

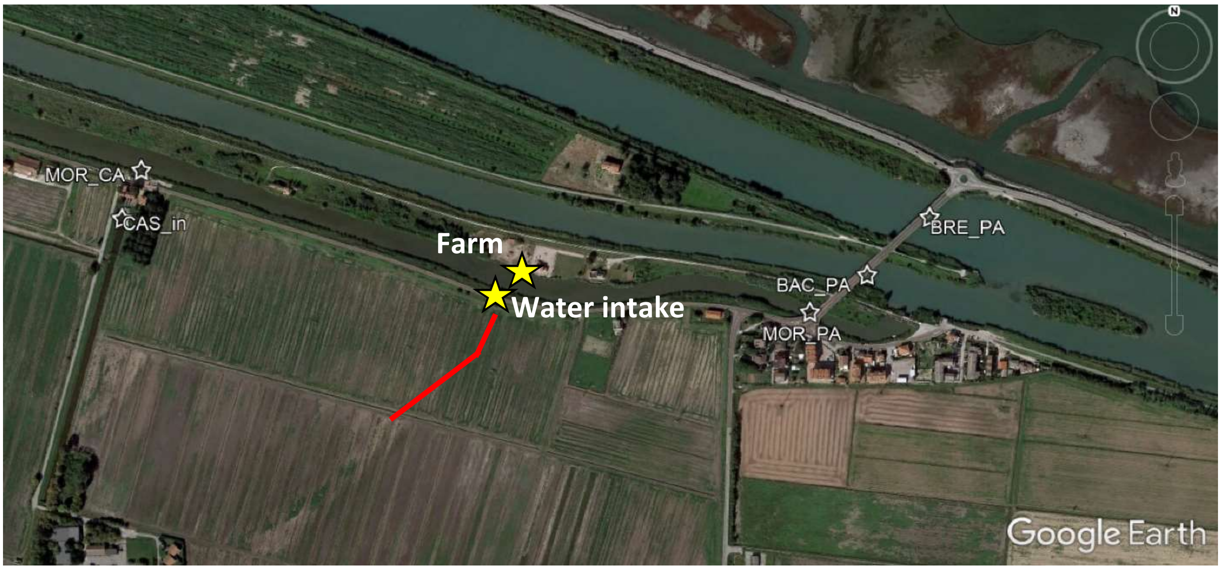


Fig. 33 – location of new recommended monitoring points (yellow stars) and location of the sub-irrigation pipe (red line)

5 Guidelines for the management of the MoST groundwater and surficial water monitoring networks

The installed monitoring network, other than serving to collect the datasets necessary for the MoST project, would be used by the competent bodies as an important instrument that must be kept active and efficient, for the monitoring and the acquisition of new data in the future.

The parameters that must be monitored to control the correct management of the water resources in the area are: the electrical conductivity, as an indirect signal of salinity, the water head (that should be reported to the average sea level using the heights reported in the previous chapters) and the temperature.

The piezometers of the monitoring network (Table 1) could be subdivided in two: a) a first order network, including the three wells located along the path of the sub-irrigation channel (MoST1b, MoST2 and S5), b) a second order network, including all the other wells (MoST1a, MoST3, MoST4, MoST5, S1, S2, S3, S4, CA20, CA50). We recommend monitoring the first order network once a month during autumn and winter and twice a month during spring and summer (from sowing to harvesting of the crop), a period in which the sub-irrigation system must be active. The second order network should be monitored every 3 months, in order to control the groundwater condition of the entire site. We also recommend to program the purging operations of the wells every two years.

The surficial watercourses (Brenta and Bacchiglione rivers and Canal Morto) also need to be monitored. We suggest measuring the EC and water level of the two rivers every 3 months (together with the second order network). The Canal Morto must be monitored together with the first order network, in order to verify the freshness of the water used in the sub-irrigation system.

Together with the monitoring of the piezometers and watercourses we recommend to monitor tides and precipitation, factors that strongly influence the salinity of the aquifers (See Doc MoST-CNR 3.4-003)

6 The field monitoring network

Five monitoring networks consisting of five soil-water stations and one meteorological station was installed during each cropping season (orientatively from May to September) of years 2019,2020, and 2021 with the aim of monitoring water and salinity dynamics inside and outside paleochannels and to assess the effect of those dynamics on agricultural productivity and grain quality (Fig.34).

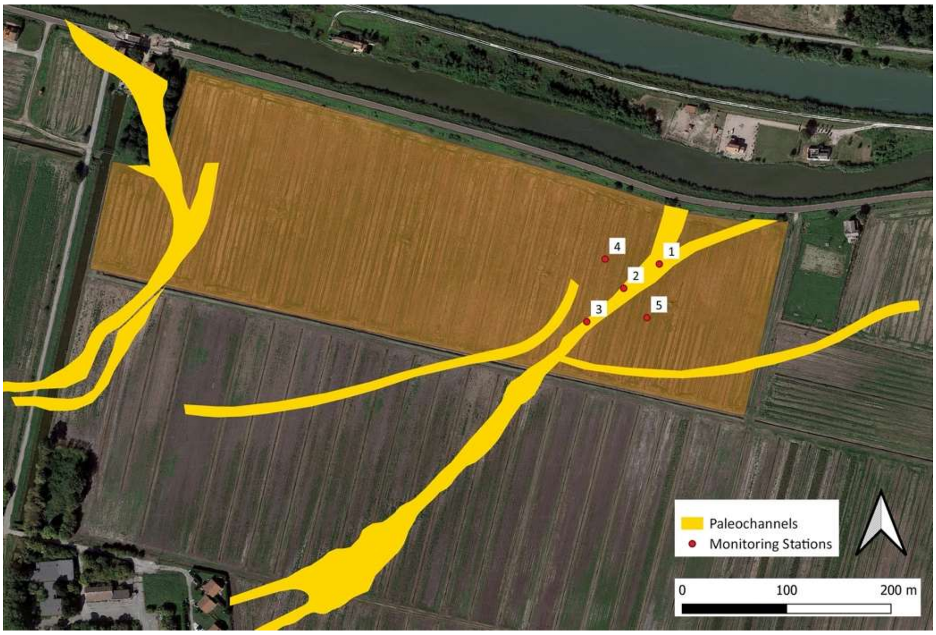


Fig. 34: Experimental site and monitoring station position used in the Venice site during the crop seasons 2019 and 2020

Each of the 5 monitoring stations was equipped with 4 soil moisture and electrical conductivity sensors (Teros 12, METER Group) installed at 4 depths (10, 30, 50 and 70 cm); 2 or 3 tensiometers (T4e, METER Group) installed at 2 or 3 depths (30, 50, 70 cm); 1 piezometer 2 m deep (Fig. 35).

Fig. 35: Monitoring station design

Moreover, the monitoring network was implemented with six additional piezometers (P) (Fig. 35 and Fig. 36) during 2021. S1 and S2 were also equipped with 14m-ERT lines crossing the new drainage infrastructure (Fig. 37).

Fig. 35: Instrumentation used to establish the shallow piezometers (left) and one of the piezometer drilled within the maize field (right).

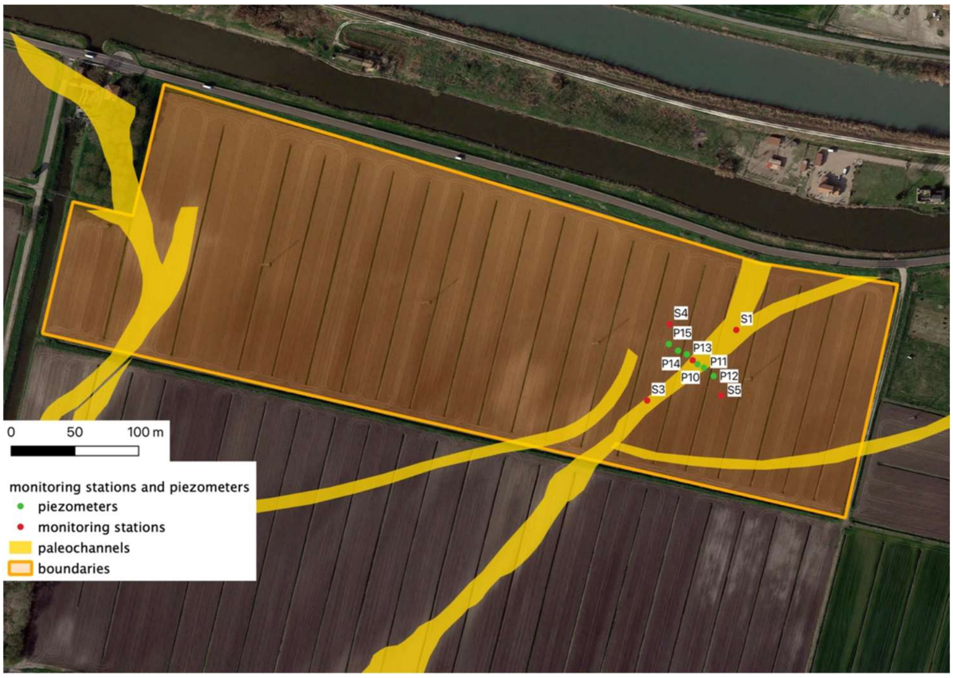


Fig. 36 Monitoring stations and piezometers installed at the Venice site in the 2021 crop season.

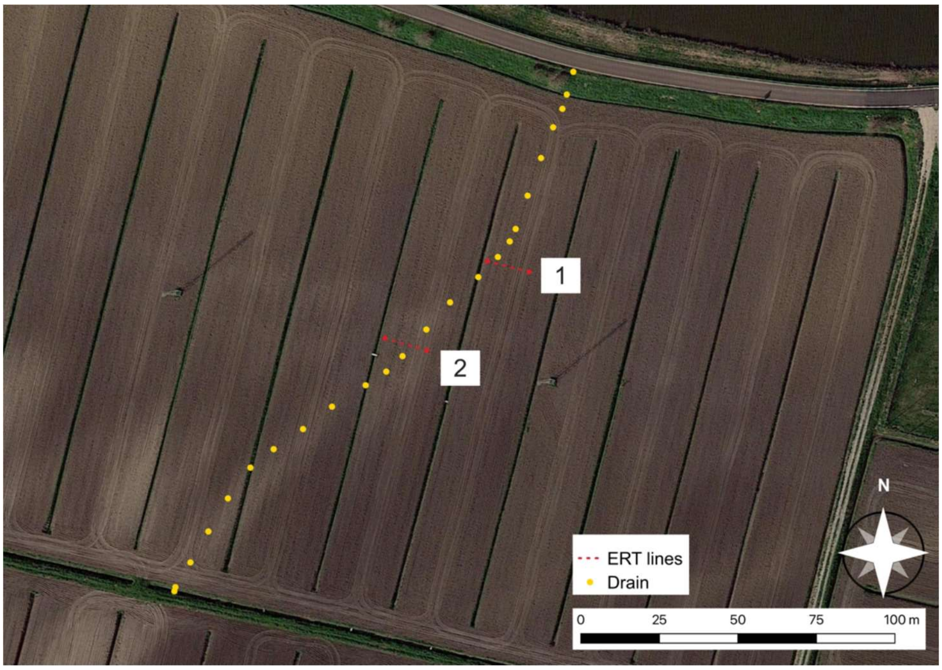


Fig. 37 ERT lines installed at the Venice site crossing the drain pipe.

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