Water-tightness Airborne Detection Implementation

D6.1 - Operational and surveillance demonstrations on water supply and irrigation mains in Portugal - update

Authors: ONERA, GG, AM, SGI, EDIA

31st May, 2020

Technical references

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PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

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Executive Summary

The objective of this report is to show the results from the airborne operational demonstration on a multipurpose water infrastructure presenting a wide variety of water networks (water supply and irrigation mains) at EDIA's multiple sites in Alentejo (Portugal). The flights aim mainly at performing "Operational" validation tests, meaning having all equipment working over the actual water networks and gathering data in different conditions. In particular, the purpose is to:

- Perform real flight tests over different type of water supply infrastructure site using the instrumented aircraft and UAV; and
- Provide data for a comparative assessment of WADI solution with a typical ground leak detection technique (acoustic); and
- Collect airborne measurement data and flight parameters for data processing and results analysis.
- Validate the improvements for the sensor system and data processing implemented after the demonstration test performed on SCP Network.

Three sites have been selected by EDIA as potential validation sites for the activities under WP6: Monto Novo, Ferreira and Vale de Gaio. The selection was carried out in accordance with two main criteria:

- The possibility to isolate the sites
- The network performance in terms of water balance.

As regards the performance of the sites, even though no Active Leakage Control is systematically carried out by EDIA, it is estimated because of the late infrastructure that the current NRW rate is a good (low) value, compared to most European water supply systems. The description of the sites and the proposed methodology for carrying out the step testing activities are reported herewith.

After the sites selection, the involved partners worked in the administrative clearances for flying over the different pipelines network, at this point GG had to homologue their legal RPAS operator documentation in Spain to the national authority in Portugal, and studying which sites have restrictions or not for flying the RPAS. It was scheduled to fly during May and September both platforms (manned and the unmanned aircraft).

During the foreseen period, a field campaign has been developed by SGI and EDIA using step testing technique whereby leakage volumes in each of the sectors comprising a water supply network (generally called a Leakage Control Zone) are determined. After the analysis from this field campaign, the sectors have been ranked in accordance with the performance indicators Leak/Length (in m3/km/year) and Infrastructure Leakage Index (ILI).

The manned aircraft and RPAS aerial flight campaigns from May to September in 2019 has delivered multispectral and thermal orthomosaics of the pipeline section and has demonstrated the good performance of sensors integration done in the WADI aircraft vectors and the correct performance of the selected processing software including the GeFolki tool from Onera. We have obtained a clear water leak detection maps after completing the processing of the campaign in Portugal.

The present report contains three further reports, which describe in greater detail what is covered in the document:

- Preparation-Note-WADI-5-Campaign-WP6-v2.0.pdf
- WADI-SynthesisAMFlightCampaign-EDIA-15-16may2019.pdf
- WADI-SynthesisAMFlightCampaign-EDIA-11-12sept2019.pdf

Table of Content

List of Acronyms

BPT	Break Pressure Tank
BS	Booster Station
CI	Cast Iron
d/s	Downstream
DI	Ductile Iron
EU	European Union
GL	Ground Level
HDPE	High-Density PolyEthylene
MNF	Minimum Night Flow
NIR	Near InfraRed
NRW	Non Revenue Water
PRV	Pressure Reducing Valve
PS	Pump Station
PVC	PolyVinyl Chloride
SR	Storage Reservoir
TIR	Thermal InfraRed
u/s	Upstream
WP*n*	Work Package *n*
RPAS	Remotely Piloted Aircraft System
UAV	Unmanned Aerial Vehicle
GNSS	Global Navigation Satellite System
IMU	Inertial Measurement Unit
VLOS	Visual Line of Sight
NOTAM	Notice to Airmen
CTR	Controlled Traffic Region
DGAC	Direction Générale de l'Aviation Civile
DSM	Digital Surface Model
DEM	Digital Elevation Model
GCP	Ground Control Point
AGL	Above Ground Level
GIS	Geographic Information System

1 Preparation of operational and surveillance demonstrations

1.1 Identification and description of the demonstration sites

1.1.1 Monto Novo

The Monto Novo site for operational and aerial surveillance leak detection is located around the small town of São Manços, near Evora city located in Alentejo area of Portugal. It extends from 7°43’ W to 7°47’ W in longitude, and from 38°26’ N to 38°28’ N in latitude. The site map is reported in Annex.

The Monte Novo area has been selected by EDIA as potential validation sites for the activities under WP6: Monto Novo - Bloco2. The selection was carried out in accordance with three main criteria:

- Network with some leaks in the past
- Area with high percentage of network
- Area with some materials in the network
- Area near the airport

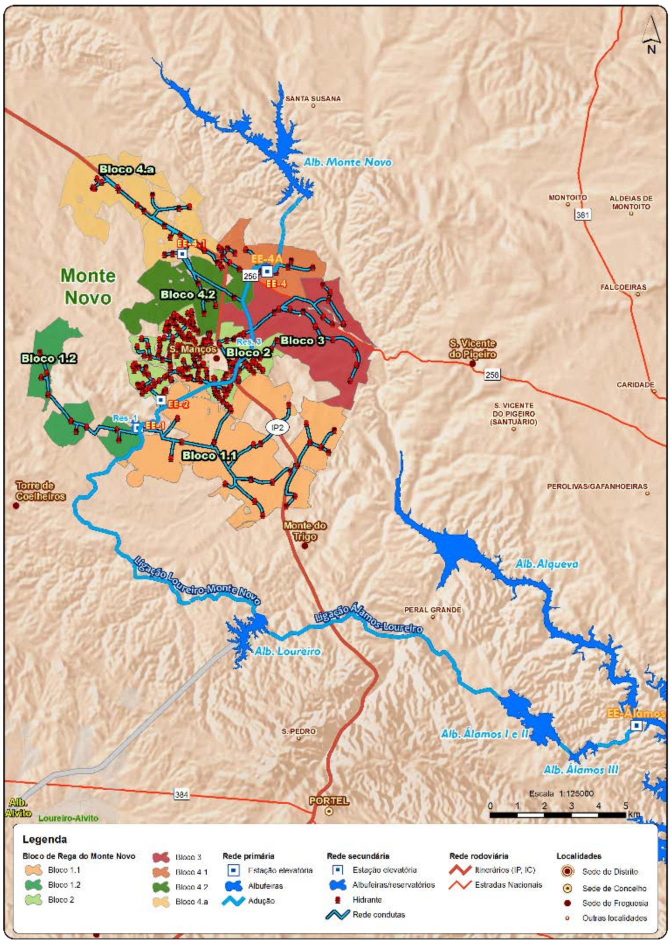


Figure 1 : Monte Novo Area

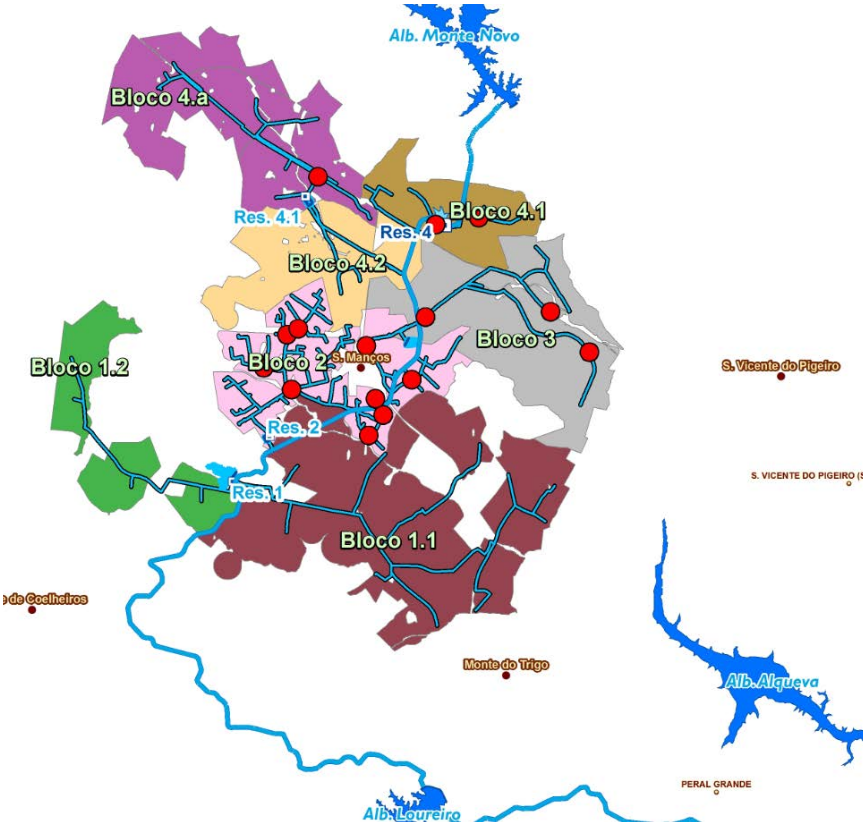


Figure 2 : Localization of the leaks in the Mont Novo Bloc

The main characteristics of network of bloc 2:

Name	Bloc 2
Total pipe length (km)	32,6
Min/Max D (mm)	90 / 1200
Metallic pipes (km)	6,8
Plastic pipes (km)	25,8

Artificial Leaks

In Block 2 two artificial leaks were created, one in an area with more clay soils and the other in an area of sandy soil.

The leaks were performed by attaching a microtube to the fire hydrant in one of the three-way pilots. The pipe diameter is 8mm. These leaks were made 6 days before the drone and plane detection campaign. The artificial leaks were in the hydrant H11 and H5.5.

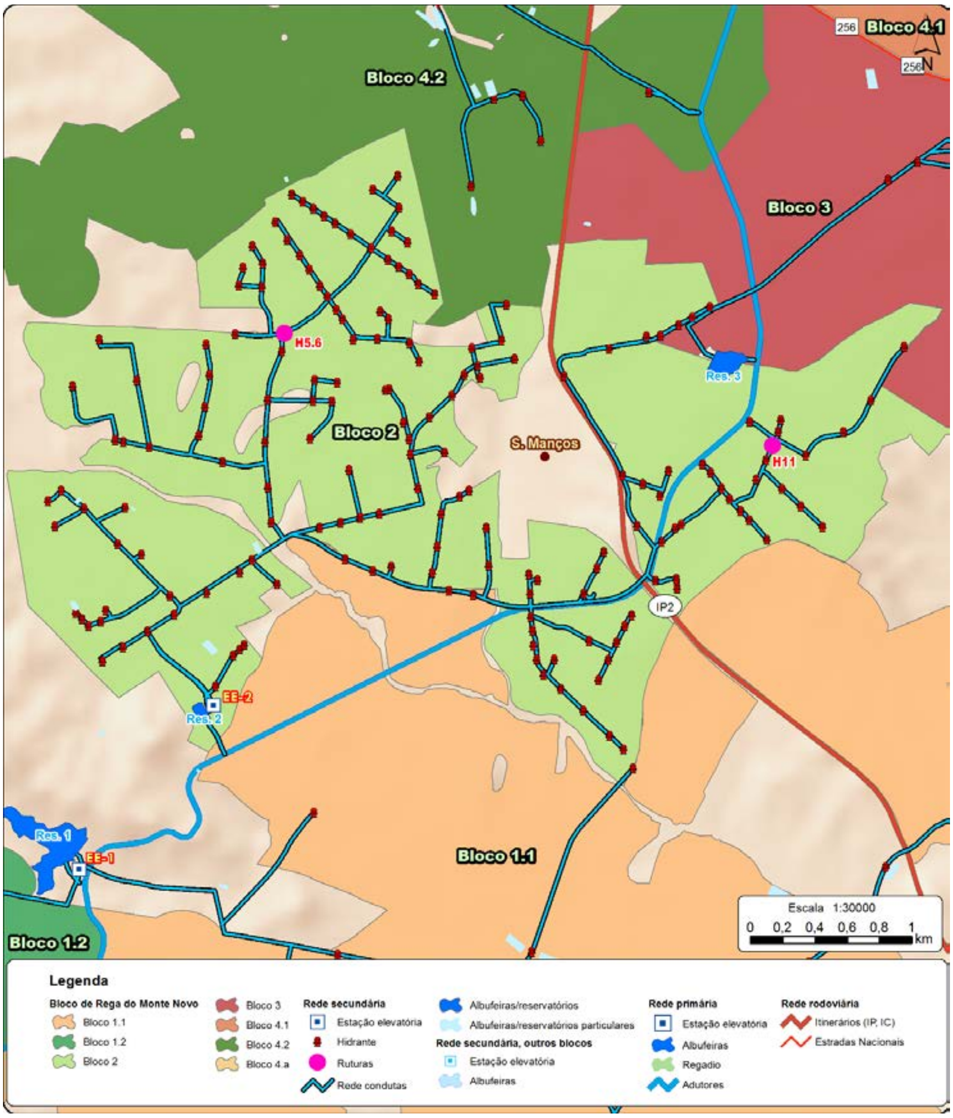


Figure 3 : Location of the artificial leaks

2 operations was performed in May and September 2019 in this area

1.1.2 Ferreira

The Ferreira site for operational and aerial surveillance leak detection is located West to the town of Ferreira do Alentejo, near Beja city located in Alentejo region of Portugal. It extends from 8°12' W to 8°17' W in longitude, and from 38°03' N to 38°06' N in latitude. The site map is reported in Annex.

In the 2nd campaign, Ferreira Block was defined, as it is the Block that currently has the most problems with leaks.

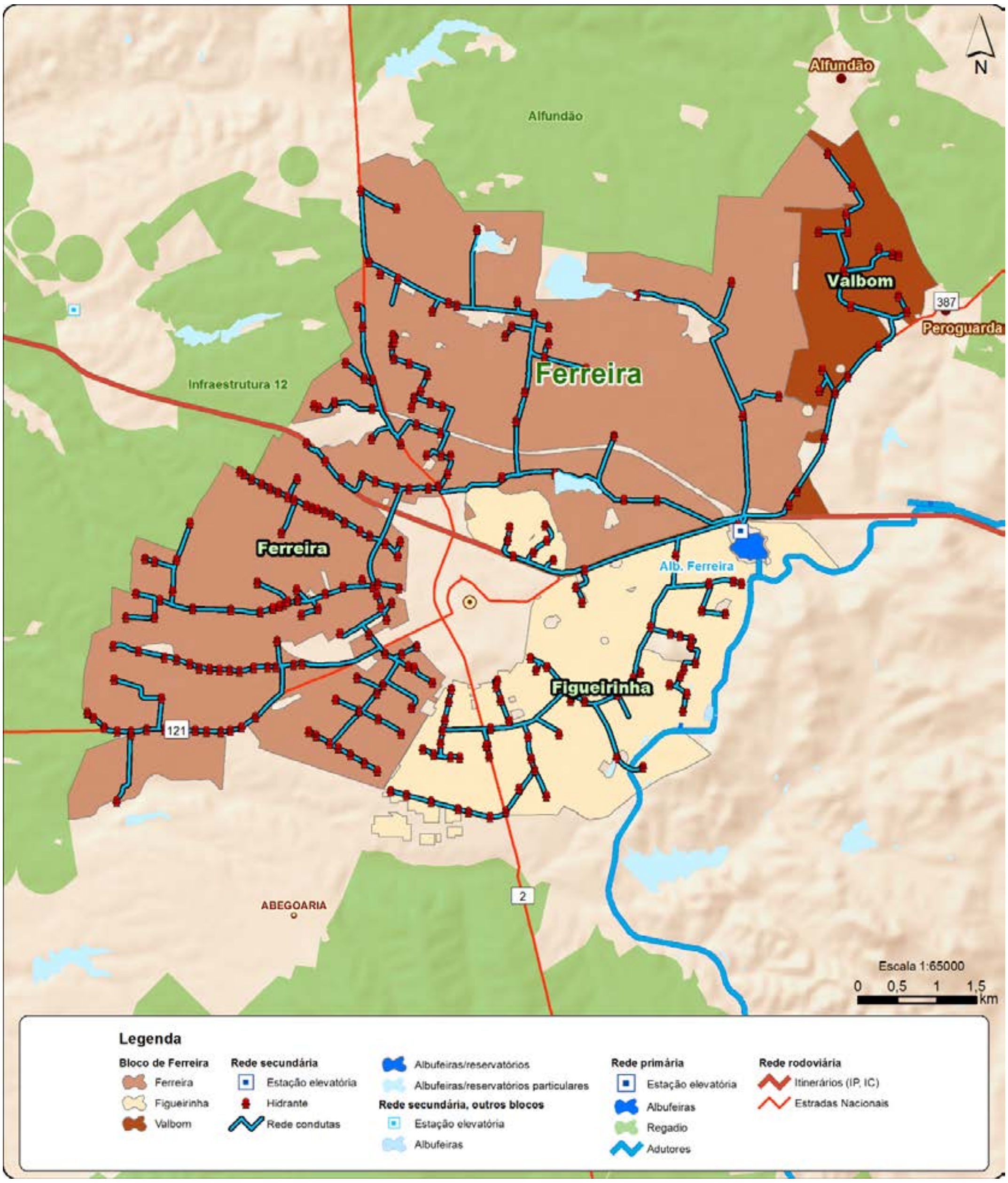


Figure 4 : Ferreira Bloc Area

Name	Ferreira
Total pipe length (km)	55,21
Min/Max Diam (mm)	90/1800
Concret pipes (km)	6,57
Plastic pipes (km)	43,31

This area was chosen because of the more leaks in the last years.

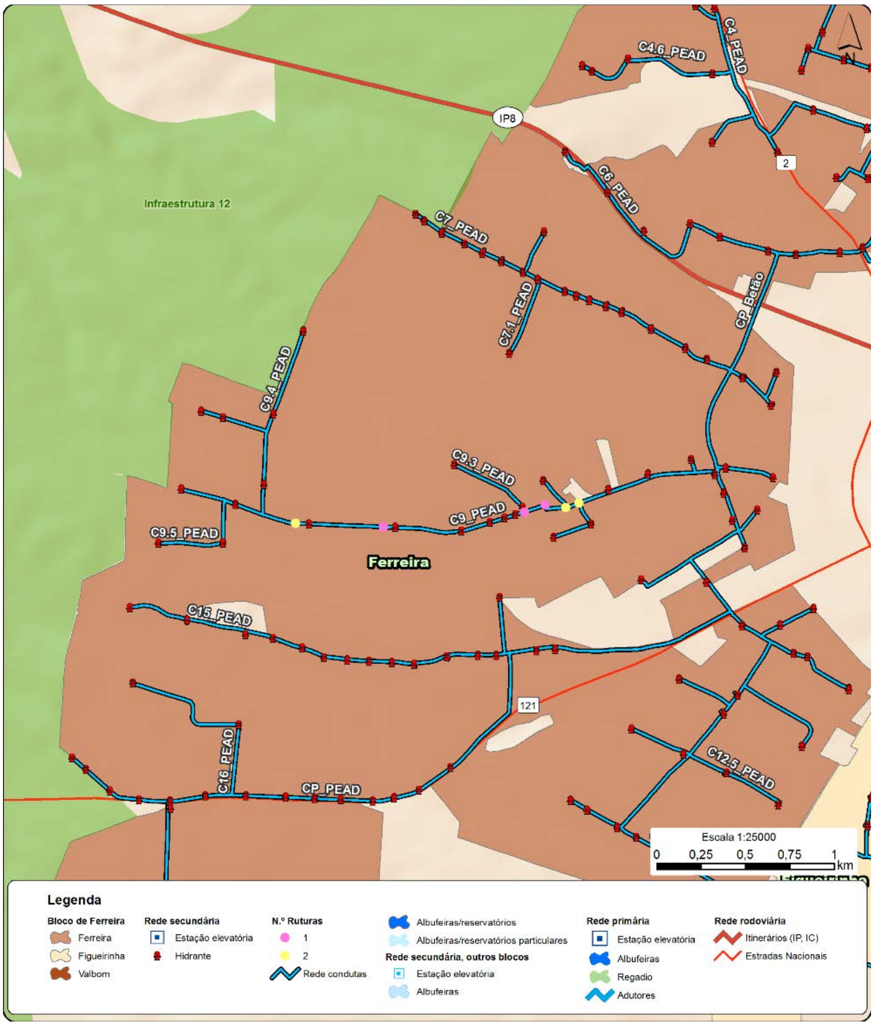


Figure 5 : Leaks in the network of Ferreira Bloc

Three pipes were chosen with various materials and diameters.

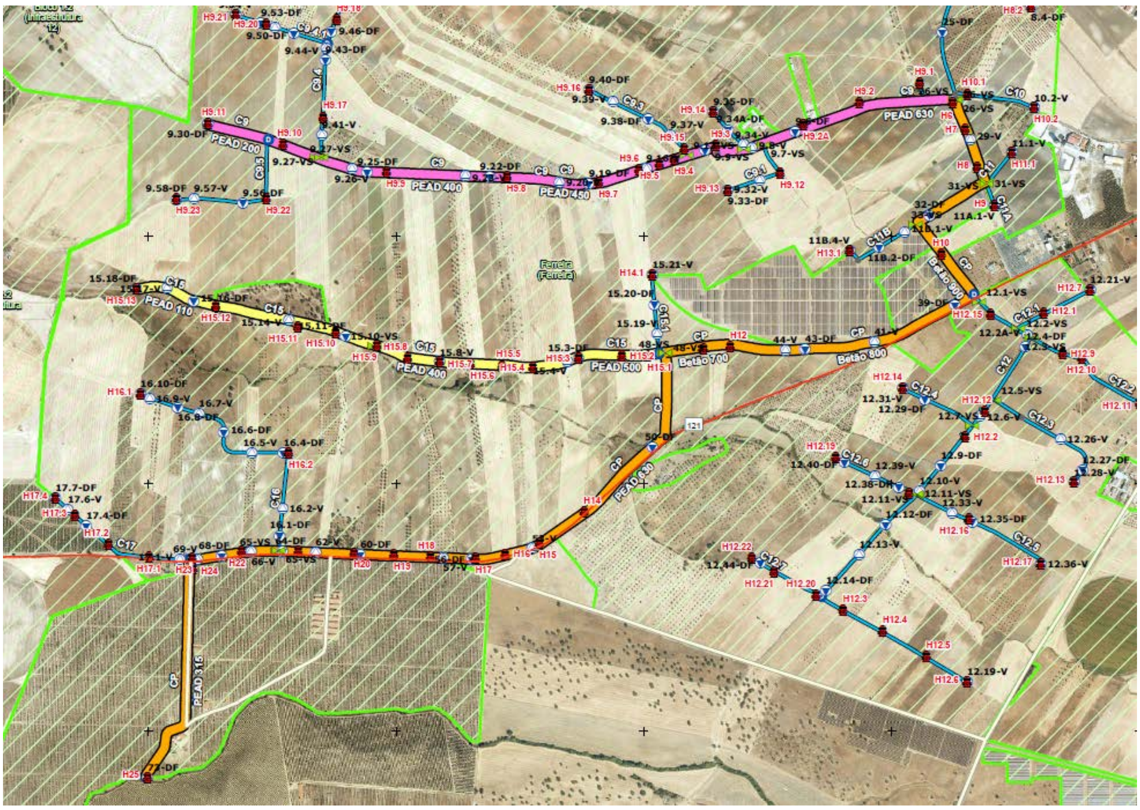


Figure 6 : Zone of Network in Ferreira Bloc

In this zone, two leaks were also performed near the hydrants H9.7 and H16. These leaks were performed in the same way, connected to the hydrant.

In this area, these hydrants were chosen because one of the areas had the land prepared for sowing and the other just had a rainfed crop where the soil was more compacted.

1 operation was performed in September 2019 in this area

1.1.3 Vale de Gaio - Barras reservoir zone

The Vale de Gaio site for operational and aerial surveillance leak detection is located North to the town of Ferreira do Alentejo, near Beja city located in Alentejo area of Portugal. It extends from 8°09' W to 8°11' W in longitude, and from 38°25' N to 38°26' N in latitude. The site map is reported in Annex.

EDIA wanted to make sure that there was an area with water loss near the Barras reservoir, as the area is near the Ferreira area, ie in between the aerodrome and the Ferreira zone, was asked to fly in that area with the drone and with the plane.

Figure 7 : Barras Reservoir

EDIA did a campaign to detect these leaks with the correlate, but no data were obtained. Detection of leaks with the correlator was not possible as the difference levels quotas are very small, so it is difficult to do with this system.

Areas with water appearance problems are near bottom discharge (N58) upstream of the reservoir and near bottom discharge (N4) downstream of the reservoir.

The pipes are large in diameter, the pipe upstream reservoir is DN 1600 in steel core concrete and the downstream the pipe is DN 1300 and the material is steel.

1 operation was performed in September 2019 in this area

1.2 Administrative clearances

According to the pertinent flight regulations and other legislative requirements identified within WP 2.3, the partner EDIA have given institutional support to AM and GG in the process of obtaining necessary authorisations/permits to carry out flights over Monto Novo area.

For the Subtask 6.1.3 Administrative clearances, AM and GG started their application process to get the flight authorizations from the Portuguese regulator DGAC and from the Air Force.

AM already obtained the right for DATA Capture in the Monto Novo area from the Portuguese Air Force (27/03/2019) and from the military basis to fly into the airspace R51 BN (1000Ft AGL / FL 105) located 4 Nm in the 120° from Evora airport.

The flight operations were scheduled during the week 20 and 37 of 2019.

The characteristics of the Evora-Beja air space are quite restrictive for flights in the most of the site areas and especially for the manned aircraft flights. As we can see in the following picture, the area contains a military airport.

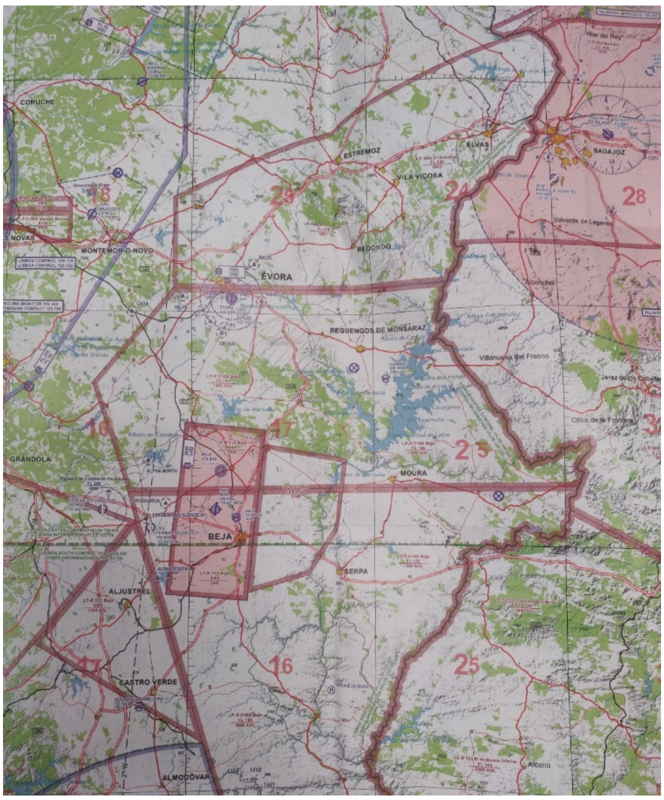


Figure 8 : Area chart of the Evora-Beja air space

Ref. in Annex the flight authorisation documents.

1.3 Manned aircraft operation air base

Operations were performed from the Evora airport:

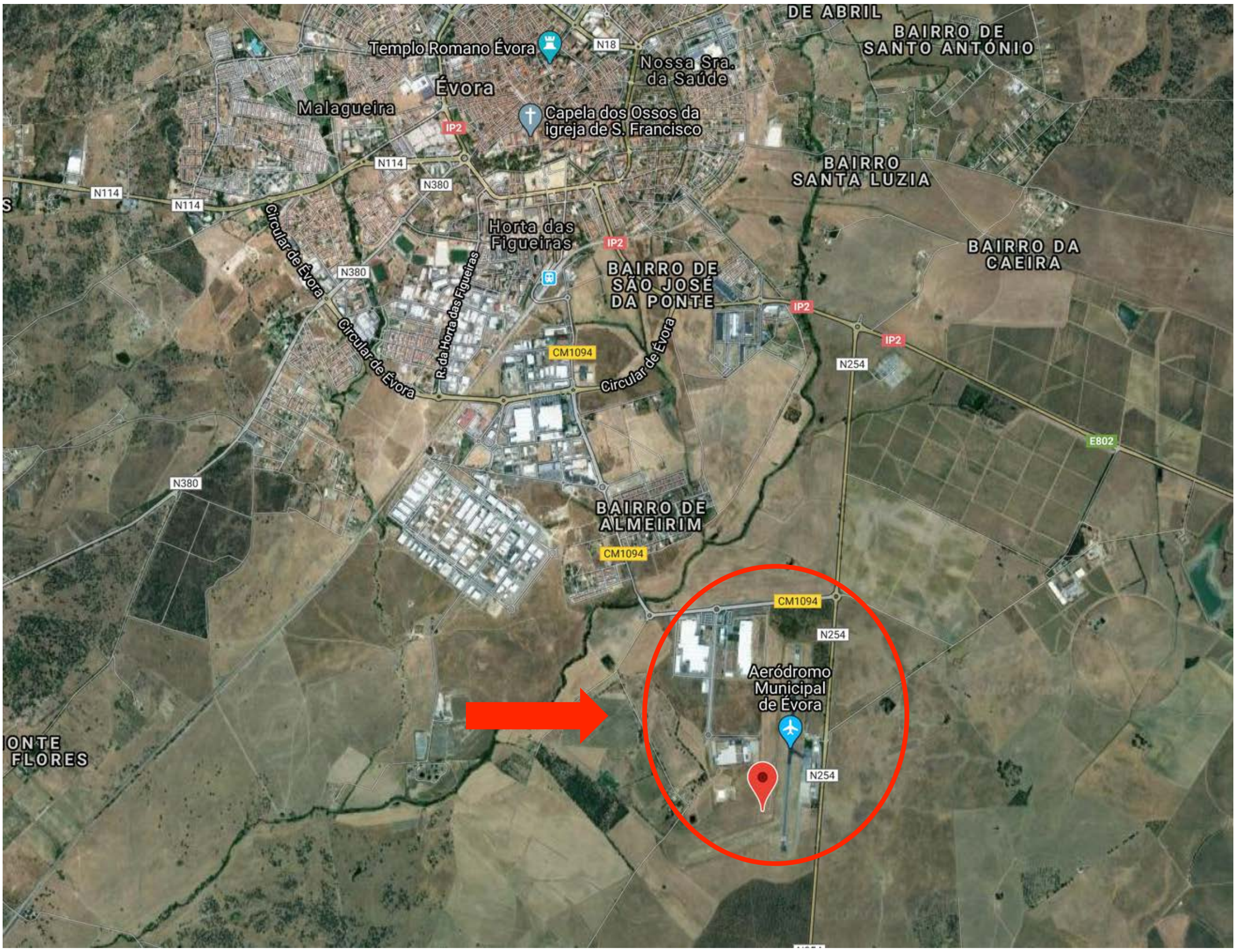


Figure 9 : Evora airport map

The aircraft operated from the air base in May and September 2019. The pilot debrief room was opened to WADI team by the airport management.


aerodromo
Portaria e Zona de Ar
Direção do Aeródromo
Operações Aeroportuárias
Skydive Portugal
Aeroclube de Évora
Ass. Aeronáutica de Évora
INEM - ANPC/ GNR-GIPS

Figure 10 : Evora airport pictures during WADI operations

2 Demonstration techniques

2.1 Ground leakage fetching technique: Step testing

Step testing is a technique whereby leakage volumes in each of the sectors comprising a water supply network (generally called a Leakage Control Zone) are determined. Such technique can be considered as a *pre-leak detection* activity, as it allows to identify the area(s) of leakage so that the actual leak detection for pinpointing leaks can be more efficiently addressed where most needed, as opposed to surveying the whole system in detail, therefore reducing the time on site and the associated costs.

When planning a step test, the valves that need to be operated to isolate the several sectors of the network are to be identified. Then, during the actual implementation of the step test, these valves will have to be closed following a specified order, whilst simultaneously measurements of the rate of flow are being made. The resultant reduction in flow rate following the closure of a particular valve indicates the total leakage (plus legitimate night consumption) in that sector of the distribution system. If the resultant reduction is greater than anticipated, taking into account the number and type of customers in the isolated sector, then it is an indication of a leak.

Step tests are generally undertaken during the period of minimum night flow (often between 02.00 a.m. and 04.00 a.m.), to avoid supply problems to the majority of customers. Hence, given the short time available, a step test needs to be carefully planned and the number of valves to be operated carefully considered.

The size of the individual steps depends on the size of the Leakage Control Zone. Typically, in an urban zone of 1500 connection a step size of approximately 150 connections is often considered. **Errore. L'origine riferimento non è stata trovata.** As is shown, the plan for a step test actually carried out in central Italy, consisting of 10 sectors isolated through 9 subsequent steps, each step consisting in the closure of 1 or 2 valves at a time.

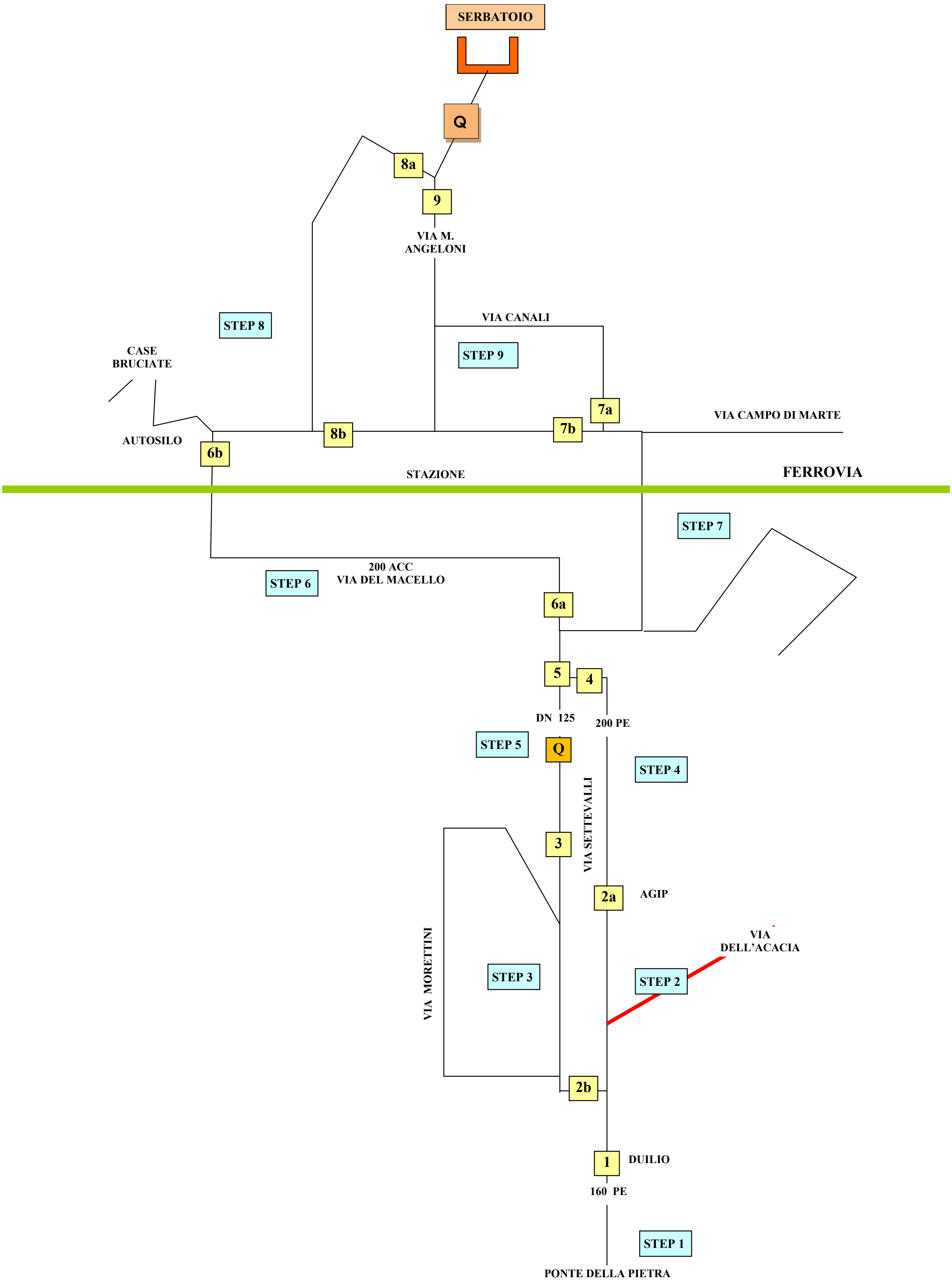


Figure 11 : Example of a step test plan

There are two main methods of carrying out a step test:

1) The isolation method

This method involves the successive closing of valves starting from the furthest point from the meter resulting in less of the zone being supplied by the meter. The sequence of closing valves is progressively carried out working back to the meter where the flow should drop to zero. Whilst potential leaks are identified by this method there is one major disadvantage and that is that the system is de-pressurised for some time and this can cause backsiphonage or the risk of infiltration of ground water.

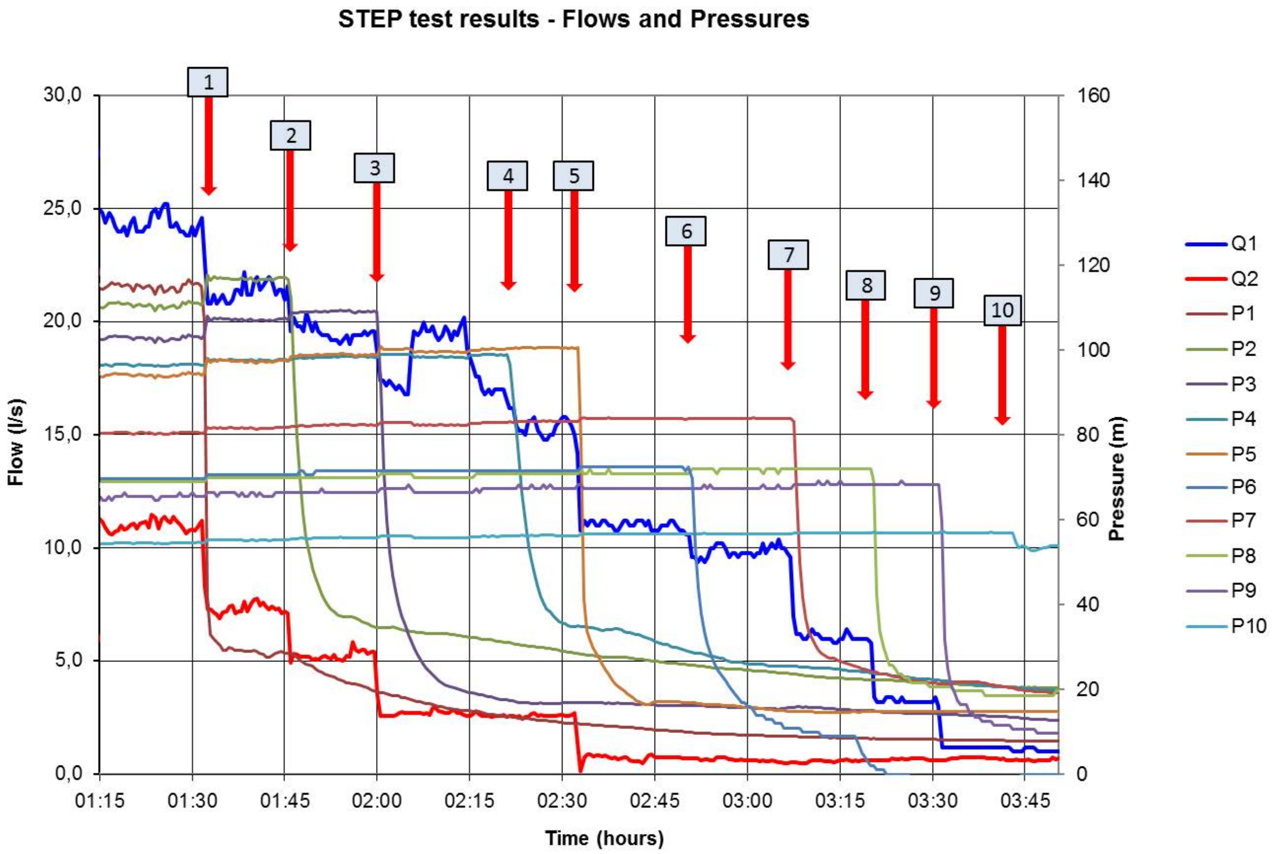


Figure 12 : Expected results of a step test carried out with the isolation method

2) The close and open method

This method involves closing valves to isolate each individual step and once the reduction of flow has been recorded the valves are reopened. This method does avoid parts of the system being without water for a period of time. However, it does have the disadvantage that the reduction in flow rate from some steps can include flow from previous steps recharging, thus making interpretation much more difficult, if not impossible.

For this reason, it is recommended that the step tests in the site of Monto Novo, is carried out by following the *isolation method*.

2.1.1 Step Testing Equipment

1) Flowmeter (clamp-on ultrasonic type)

In case a fixed flowmeter is not installed at the Leakage Control Zone's inlet, one can resort to the use of portable flowmeters such as a clamp-on ultrasonic type.

A clamp-on ultrasonic flowmeter consists of a pair of transducers and an electronic part. The transducers are to be fixed outside the pipe. Each transducer acts as both a receiver (i.e. it converts the ultrasonic pulses to electrical energy) and a transmitter (vice versa), since a series of ultrasonic pulses is alternately sent upstream and then downstream through the pipe. The meter measures the time required for the sound pulse to travel between the transducers and the velocity of the fluid is computed from these two time readings. Knowing the pipe internal diameter, the flow is calculated. The accuracy is good (typically 1 to 2%) and the installation is easy as no tapings are required.

The input values required by the clamp-on ultrasonic flowmeter are: pipe outer diameter or circumference (can be easily found using a measuring tape), wall thickness (if unknown, it can be measured using an ultrasonic thickness meter), and pipe material (i.e. the soundspeed in that particular solid, according to which the instrument calculates the flow).

Most manufacturers suggest that an ideal installation of the clamp-on ultrasonic flowmeters is to be done after a minimum 10 diameters-length and before a minimum 5 diameters-length of straight pipe.

If not already inbuilt in the instrument, the flowmeter will have to be connected to an external data logger for recording the flow readings during the step test and allow the subsequent data analysis.

Figure 13 : Clamp-on ultrasonic flowmter installed on a horizontal pipe (Two-Traverse installation)

2) Pressure loggers

Data loggers can be used to log both flow (if connected to a flowmeter) and pressure measurements. When they already have an integrated pressure transducer, they are commonly referred to as *pressure loggers*. The inbuilt pressure transducer allows to measure and record pressure measurements by just connecting the logger to the quick-fit port inserted on the pipeline whose pressure has to be monitored, usually via a flexible spiral hose such as the one previously shown.

Figure 14 : Data logger able to log both flow and pressure simultaneously (left) and flexible spiral hose to connect the pressure logger to the pipeline (right)

2.2 Ground-based technique: soil moisture measurements

The instrumentation used for ground truth measurements is listed below.

Instrumentation	Retrieved parameters	Where?
Optris portable infrared thermometer LS	Temperature	At each outdoor background characterization
GPS	Coordinates of particular elements in the areas of interest	At each flight acquisition and outdoor background characterization
Nikon camera	Pictures of the areas of interest	At each flight acquisition and outdoor background characterization
Soil moisture sensor	Soil humidity	At each outdoor background characterization

Table 1 - List of instrumentation participating to the ground truth measurements

Figures below present part of the ground instrumentation:

Soil moisture sensor

IR thermometer

2.3 Aerial technique: Photogrammetry

Photogrammetry is a set of techniques to determine the shape, size, position in space of an object from photographs. The general principle is based on the human perception of relief by stereoscopic viewing. In aerial photogrammetry the sensor is on-board a satellite, manned aircraft, or a drone and is usually pointed vertically down toward the ground. When the sensor is pointed straight down it is referred to as vertical or nadir imagery. Multiple overlapping images are collected as the sensor flies along a flight path. The imagery is processed to produce digital elevation data and ortho- imagery mosaics, which are called ortho-maps. Imagery has perspective geometry that results in distortions that are unique to each image. Ortho-images have been geometrically corrected so that the resulting image has the geometric integrity of a map. Other products can be produced resulting in vector GIS layers with features such as roads, buildings, hydrology, and other ground features.

2.3.1 Ortho-imagery

Ortho-rectification is a process that corrects for geometric distortion inherent in remotely sensed imagery to produce a map-accurate ortho-image. You can then stitch a group of ortho-images together into one layer called an ortho-mosaic. To accomplish this, you need imagery with known sensor positions, attitudes, and a calibrated geometric model for the sensor along with a digital terrain model (DTM). Sometimes the known positions and attitudes accompany the imagery when it is delivered to the user. If not, the imagery will need to be adjusted to ground control. The adjustment processes utilize the sensor calibration, sensor orientation information, ground control points, tie points, and a DTM to produce the accurate attitudes and positions. This in turn enables the building of map-accurate ortho-images. The individual ortho-images are then edgematched and color balanced to produce a seamless ortho-image map. This ortho-image mosaic is accurate to a specified map scale accuracy and can be used to make measurements as well as generate and update GIS feature class layers.

Digital aerial images, scanned aerial images, and satellite imagery are important in general mapping and in GIS data generation and visualization. In fact, the information contained in most maps and GIS layers was generated from imagery. First, the imagery serves as a backdrop that gives GIS layers important context from which to make geospatial associations. Second, imagery is used to create or revise maps and GIS layers by digitizing and attributing features of interest such as roads, buildings, hydrology, and vegetation.

Before this geospatial information can be digitized from imagery, the imagery needs to be corrected for different types of errors and distortions inherent in the way imagery is collected. There are two main types of distortion affecting remotely sensed imagery: radiometric and geometric. Radiometric distortion is the inaccurate translation of ground reflectance values to grey values in the image. Sometimes these values are called digital numbers (DNs), which are induced by atmospheric influences and sensor limitations. Geometric distortions are introduced due to perspective projections and instrumentation. Common kinds of distortions affecting raw remotely sensed imagery include platform and sensor errors, earth curvature, and relief displacement as well as radiometric and sun angle effects. Each of these types of distortions are removed in the ortho-rectification and mapping process. Ortho-rectification refers to the removal of geometric distortion induced by the platform, sensor, and especially terrain displacement. Mapping refers to the edgematching, cutline generation, and colour balancing of multiple images to produce an ortho-mosaic dataset. These combined processes are referred to as ortho-mapping.

Once the distortions affecting imagery are removed and individual images or scenes are mosaicked together to produce an ortho-mosaic image map, it may be used like a symbolic or thematic map to make accurate distance and angle measurements. The advantage of the ortho-image map is that it contains all the information visible in the imagery, not just the features and GIS layers extracted from the image and symbolized on a map.

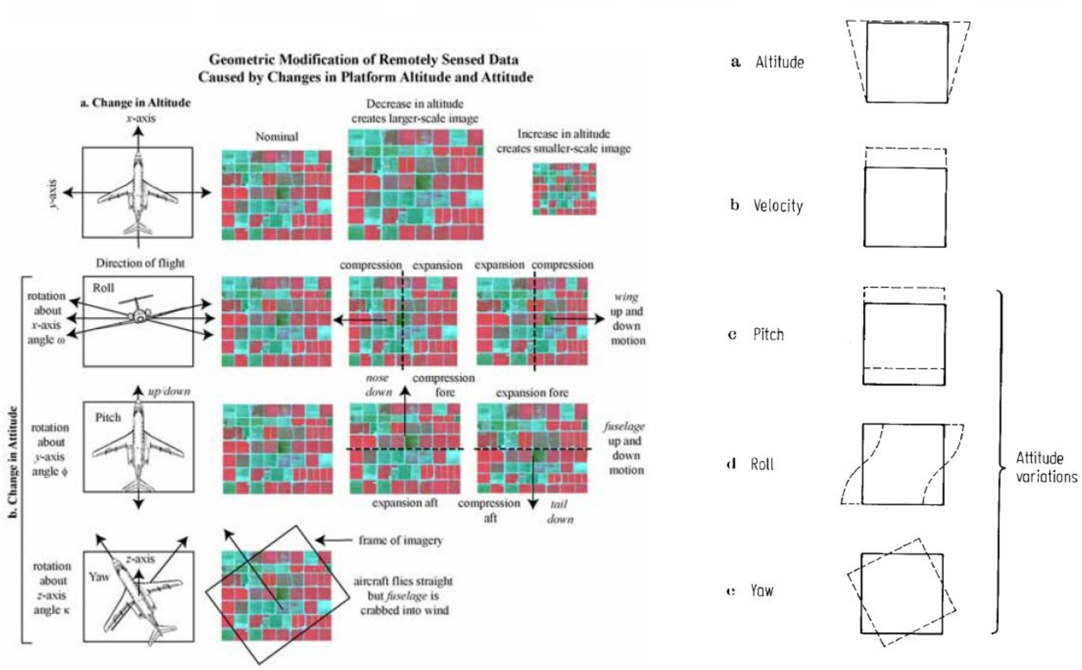


Figure 15 : Geometric distortions of imagery from airborne sensors

2.3.2 Elevation data

If suitable digital elevation data exists, it can be used in the ortho-rectification process. Otherwise, the elevation datasets, such as digital surface models (DSMs), need to be derived from stereo imagery. Stereo imagery is created from two or more images of the same feature collected from different geolocation positions. The overlapping images are collected from different points of view. This overlapping area is referred to as stereo imagery, which is suitable for generating digital elevation datasets. The model for generating these 3D datasets requires a collection of multiple overlapping images with no gaps in overlap, sensor calibration and orientation information, and ground control and tie points. The 3D datasets are then created automatically using a process called image matching, where overlapping imagery is cross-correlated to generate 3D points defined by geolocation (latitude, longitude) and elevation.

2.3.3 The ortho-rectification process

Ortho-rectification is the process of removing the effects of image distortion induced by the sensor, viewing perspective, and relief for the purpose of creating a planimetrically correct image. The resulting ortho-rectified images have a constant scale such that features are represented in their true positions in relation to their ground position. This enables accurate measurement of distances, angles, and areas in the ortho-image. There are several requirements to produce an ortho-image map or ortho-mosaic from raw imagery:

- Digital imagery, which can be in the form of a digital airborne image, scanned image, or satellite imagery.
- Camera calibration file that includes measurements of sensor characteristics, such as focal length, size and shape of the imaging plane, pixel size, and lens distortion parameters. In photogrammetry, the measurement of these parameters is called interior orientation (IO), and they are encapsulated in a camera model file. High-precision aerial mapping cameras, called metric cameras, are analyzed to provide camera calibration information in a report used to compute a camera model. Other cameras and sensors are calibrated by those operating the cameras, or they can be calibrated during the adjustment processes during ortho-rectification.
- Rational Polynomial Coefficients (RPC) supplied by satellite imagery providers. RPCs are computed for each image and describe the transformation from 2D image coordinates to 3D earth surface coordinates in a mathematical sensor model that is expressed as the ratio of two cubic polynomial expressions. The coefficients of these two rational polynomials are computed by the satellite company from the satellite's orbital position and orientation and the rigorous physical sensor model. RPCs replace the need for a rigorous camera model and are often referred to as replacement sensor models if the error covariance matrices are included.
- Adjustment points, which are composed of ground control points, image tie points, and check points.
  - Ground control points (GCP) are usually from ground survey. Secondary control points can also be utilized created from a map or existing ortho-image with known accuracy, as long as the known accuracy exceeds the expected outcome accuracy by a linear factor of three to five times. These points on the ground need to be visible in the imagery.
  - Image tie points generated in the overlap areas between adjacent images composing the mosaic. These are usually generated automatically using image matching techniques.
  - Check points used for assessing the accuracy of the ortho-rectification process. These are ground control survey points not used in computing the photogrammetric solution.

The information above is used to compute an image orientation needed to produce a digital elevation model (DEM) and an ortho-rectified image mosaic from imagery. The derived image orientation parameters include the position of the sensor at the instant of image capture in some global reference system such as latitude, longitude, and altitude (x, y, z). The attitude of the sensor is expressed as omega, phi, and kappa (pitch, roll, heading).

2.3.4 Image ortho-rectification

Ortho-rectification is the process of removing the effects of image distortion induced by the sensor, viewing perspective, and relief for the purpose of creating a planimetrically correct image. This is accomplished by establishing the relationship of the x,y image coordinates to the real-world GCP to determine the algorithm for resampling the image. Similarly, the mathematical relationship between the ground coordinates represented by the DEM and the image is computed and used to determine the proper position of each pixel in the source image. The generation of the ortho-image involves warping the source image so that distance and area are uniform in relationship to real-world measurements. Thus, features measured in the ortho-images match the measurement, scale, and angle of the same features on the ground, regardless of whether they exist on steep terrain or on level ground. The resulting accuracy of the ortho-image is based on the accuracy of the triangulation, the resolution of the source image, and the accuracy of the elevation model.

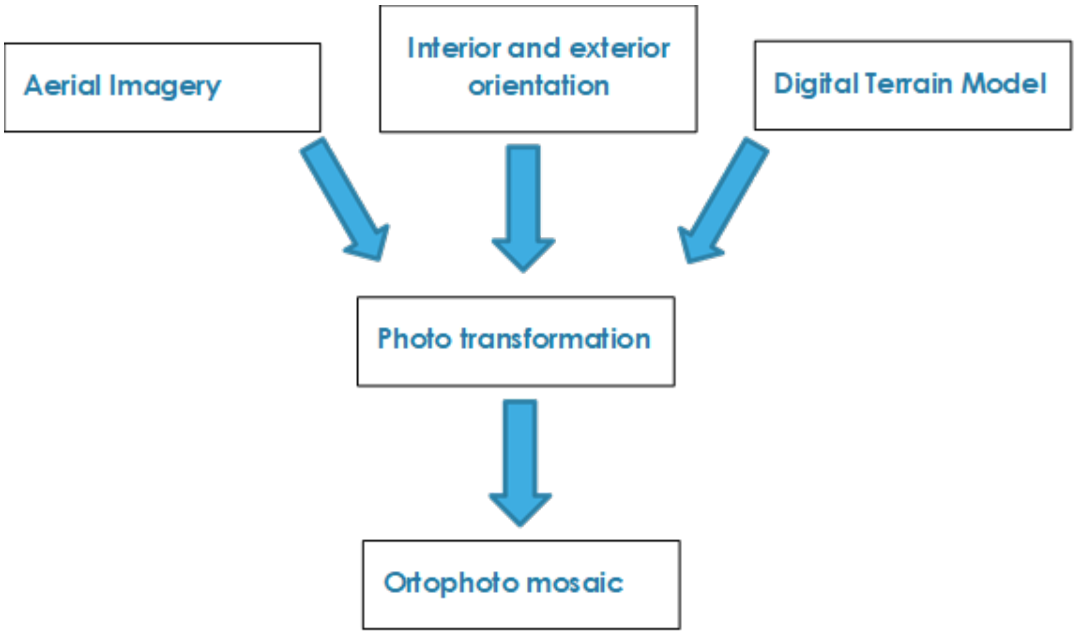
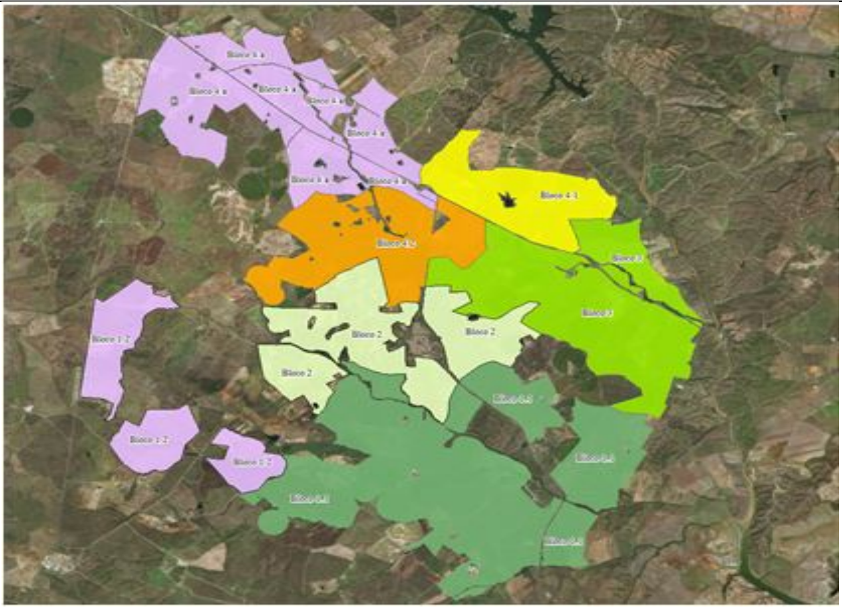


Figure 16 : Data processing protocol

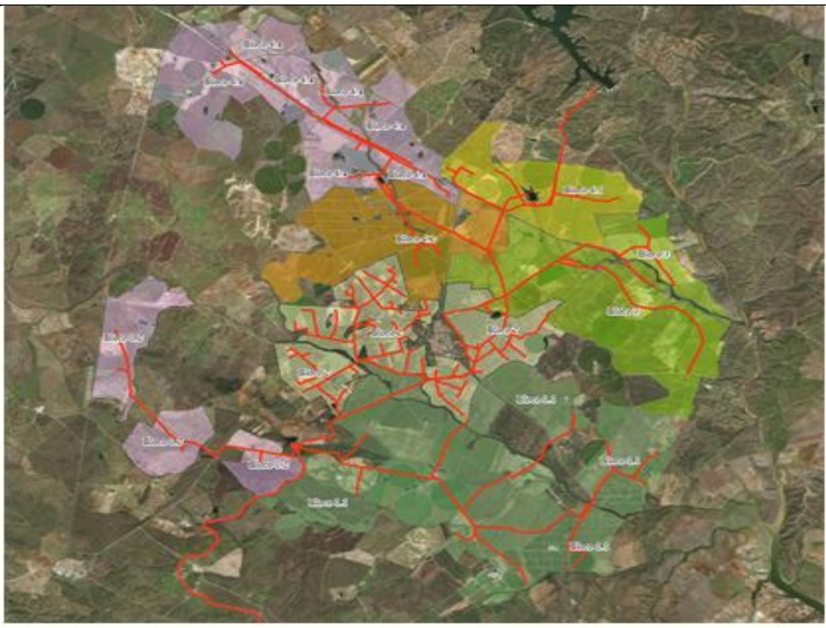
3 Operational and Surveillance demonstrations campaign

3.1 Ground leakage detection campaign

Among the EDIA's network sites, MonteNovo block was selected to be object of test.



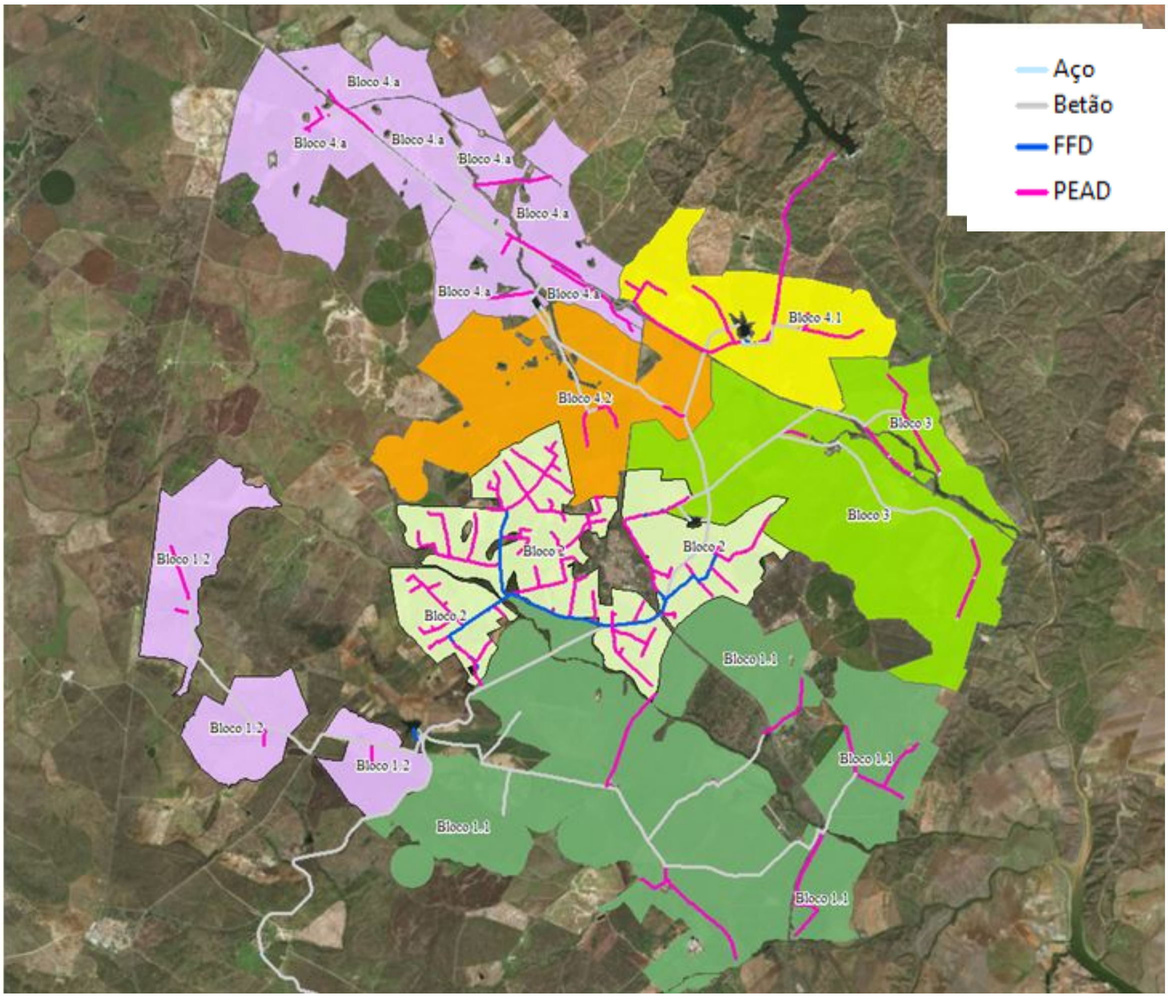
BLOCK	AREA [ha]
Bloco 4.2	791.8992
Bloco 1.1	2311.114
Bloco 4.a	1273.236
Bloco 3	1293.556
Bloco 2	1030.543
Bloco 1.2	634.1743
Bloco 4.1	539.2303



BLOCK	PIPE LENGHT [m]
Bloco 1.1	21,712
Bloco 1.2	6,715
Bloco 2	33,910
Bloco 3	13,034
Bloco 4.1	6,508
Bloco 4.2	6,113
Bloco 4.a	13,012
	27,262
Grand Total	**128,267**

Figure 17 : MonteNovo blocks description

Within MonteNovo block the majority of 130 km pipes material is cement and PEAD which sum in about 93%; less than 0.5% is steel pipe while about 6% is ductile iron. Such information is relevant since for ground leak detection methods, metallic pipes are the preferable condition; classic sound-based methods work also for plastic pipes with less efficiency.



MATERIAL	LENGHT [m]
Aço	358
Betão	61,855
FFD	7,615
PEAD	58,216
Grand Total	**128,267**

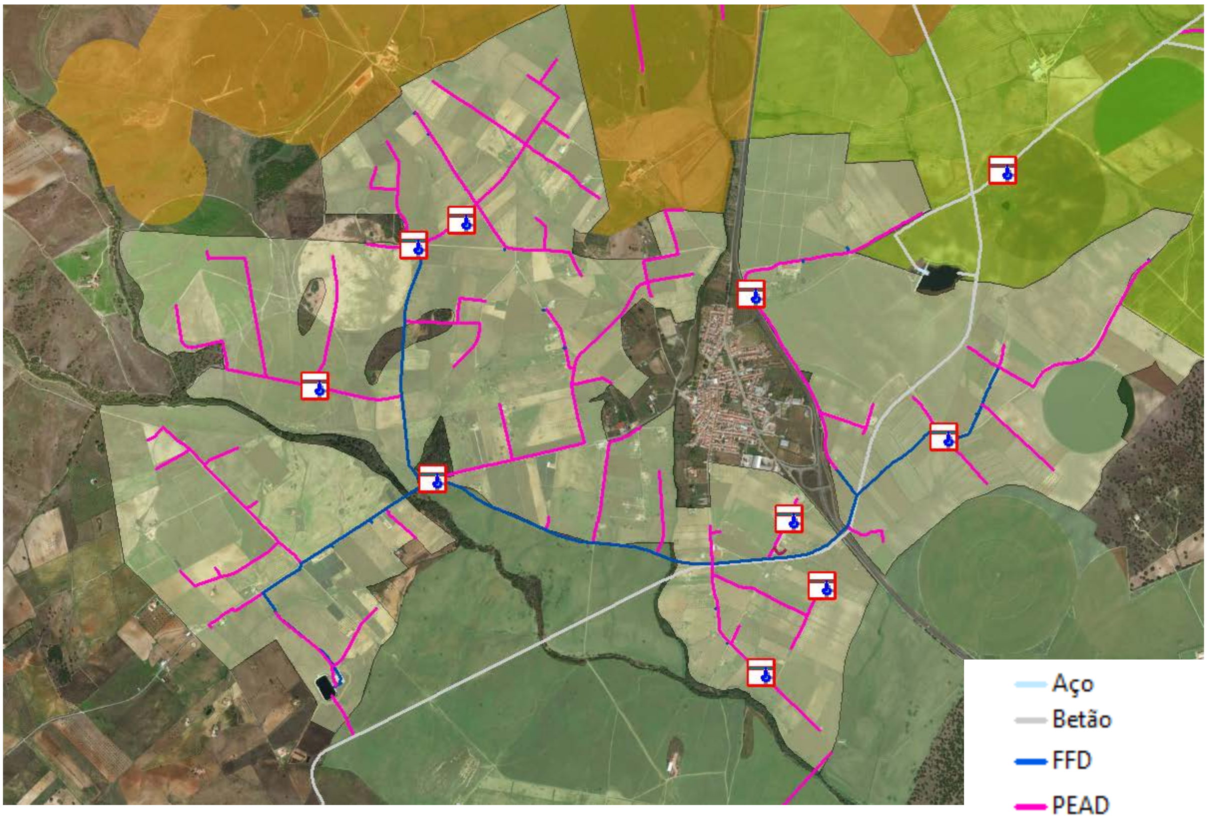
MATERIAL	%
Aço	0.3%
Betão	48.2%
FFD	5.9%
PEAD	45.4%

Figure 18: Material description on Monte Novo

Contrary to SCP site, EDIA's network does no present proper characteristics to carry out a classic water balance, due to unavailability of meters at the inlet/outlet of the blocks.

To select the area where to carry-out the test for WADI, it was asked to EDIA the historical records of leak repair to understand which block had a higher probability to present issues: within Block n.2, 9 repairments have been reported since 2012 which potentially indicated an area where leakages could occur with higher possibilities.

Another object of assessment regarded the material; as mentioned metallic pipes are the best field of application for ground leakage detection acoustic methods and as already expressed the majority of EDIA's pipe are in cement and plastic, but Block n.2 presents also a good percentage of metallic pipe (ductile iron). Figure below shows the pipe material and the location of historical leak for Block n.2.



	Steel	Ductile Iron	PEAD	TOTAL
Length [m]	7	7,199	26,332	**33,911**
%	0.02%	21.23%	77.65%	**100%**

Figure 19 : material & location historical leaks on block N°2, Monte Novo

Block n.2 was selected as area to test WADI also after considerations related to the flights' potential constrains (UAV/MAV) like presence of vegetation, proximity of irrigated field, presence of shades, restriction to flight over the area.

In agreement with EDIA's staff only part of the network was investigated through the acoustic campaign, namely 7.2 km of metallic pipe and 7.9 km of plastic pipe for a total of 15 km out of 33 km. The campaign was carried out in April-May 2019 for a first part and concluded in July 2019. Highlighted mains in the Figure 20 below shows the investigated pipes.

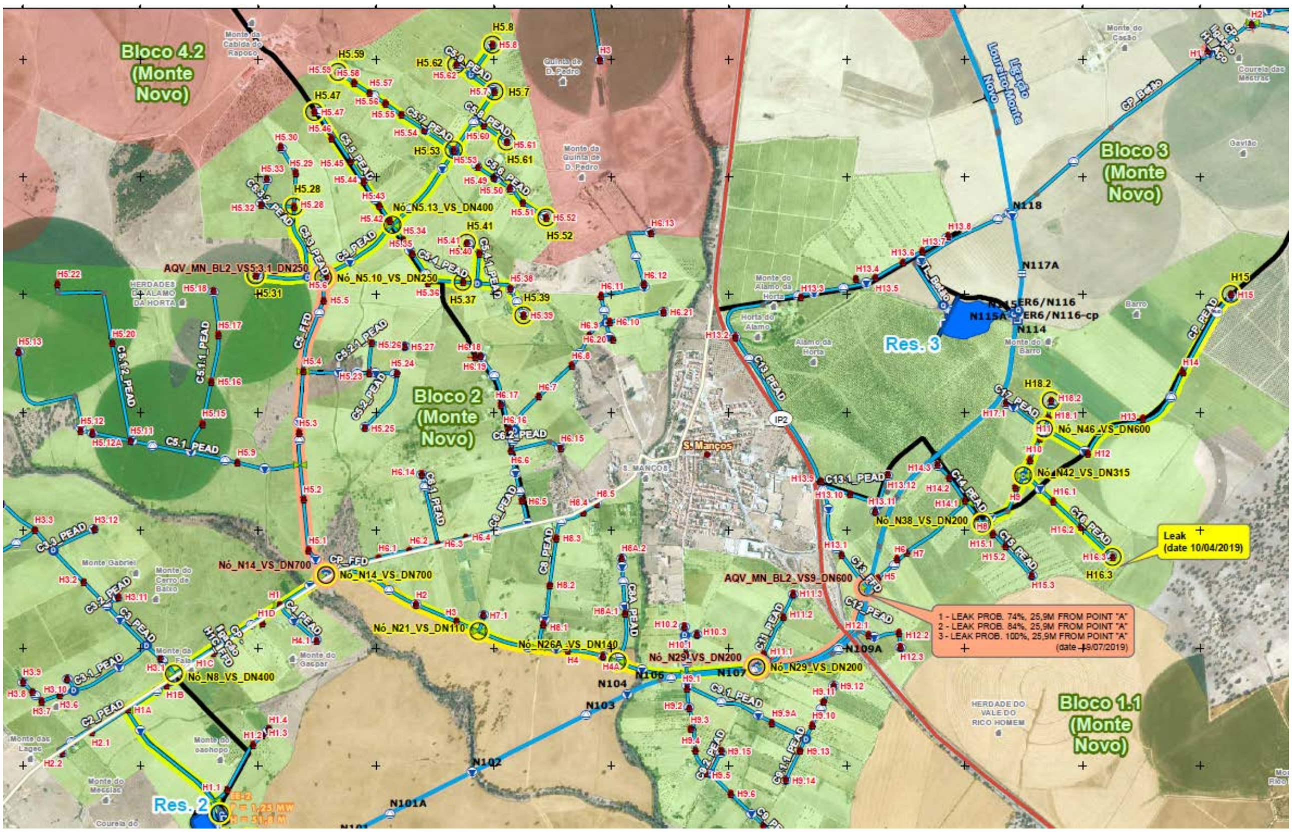


Figure 20 : investigated pipes on GLD campaign, Monte Novo

One positive result was registered, on Hydrant H16.3, which was identified as a small superficial leak (in a tube on the hydrant, and not in an underground pipe).

Also, 3 other correlations signalled and confirmed a leak in the same location, even reaching a 100% probability of leakage. This leak candidate is located 25.9 meters from GIS node reference "Nó_N31_VS9", which is an air valve on water pipe (see Figure 21 below).

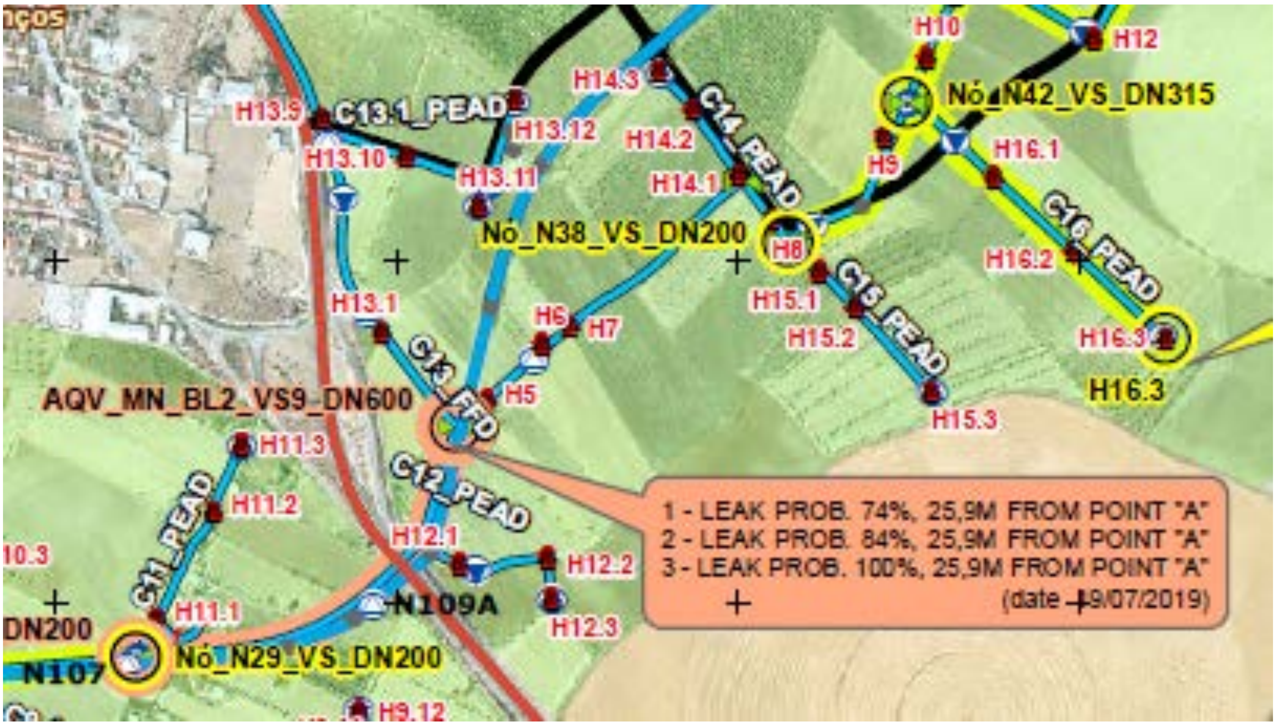


Figure 21 : positive results on block 2, Monte Novo

3.2 Ground-based soil moisture measurements

3.2.1 Artificial leaks May 2019

3.2.1.1 Artificial leak site N°1: H10 & H11

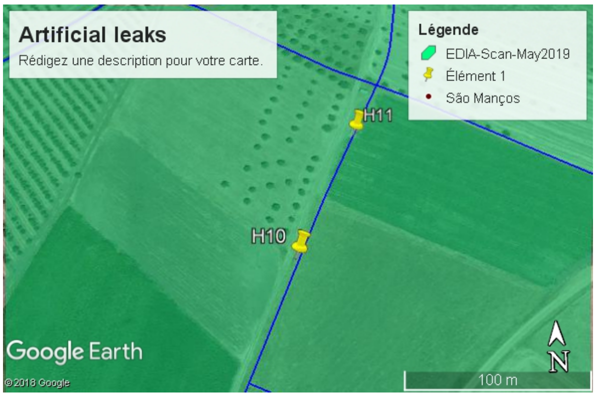


Figure 22 : Artificial leaks localization in zone Block 2 (H10 & H11), Monte Novo

- H11 (dry bare soil) for drone
- H10 (soil with vegetation) for MAV & UAV

<table>
<tr><td></td><td></td></tr>
<tr><td></td><td></td></tr>
<tr><td></td><td>North</td></tr>
<tr><td></td><td></td></tr>
<tr><td>East</td><td>South</td></tr>
</table>

	
West	

Figure 23 : Photos of the H11 area, Monte Novo

Figure 24 : sky conditions on H11 area, Monte Novo

3.2.1.1.1 Midday measurement 14/05/2019: H11 - 12h05

- Before the leak by water hydrant – Additional Valve closed
- Soil Humidity measurements (probe N°1) : Universal soil
- Tools : Smartphone GPS – Explorer software EDIA

Time	Zone	Humidity (%)	Soil Temperature (°C)	Surface temp (°C), emissivity=1	Localization
11h15	Point N°1	5.1	29.4	52	At the leak 38.459591 lon -7.734220 lat
12h25	Point N°2	13	49.0	50	2m from the leak – East 38.45963 lon -7.734178 lat
12h28	Point N°3	8.3	48.5	50	7m from the leak – East 38.45959 lon

					-7.734194 lat
12h33	Point N°4	8.2	47.7	50	12m from the leak – East 38.459579 lon -7.734063 lat
12h37	Point N°5	7	47.0	50	17m from the leak – East 38.459474 lon -7.733968 lat
12h40	Point N°6	4	47.0	50	23m from the leak – East 38.459500 lon -7.733901 lat
12h43	Point N°7	5	47.0	50	23m from the leak – East 15m from the leak – North 38.459388 lon -7.733940 lat
12h46	Point N°8	8	47.0	50	23m from the leak – East 15m from the leak – South 38.459587 lon -7.733860 lat

Table 2 : Measurement on H11 area, Monte Novo

3.2.1.1.2 1st Afternoon measurement 14/05/2019: H11 - 12h51

- After the leak by water hydrant (1/2 h) – Additional valve opened
- Soil Humidity measurements (probe N°1) : Universal soil
- Measurement before the drone flight

Time	Zone	Humidity (%)	Soil Temperature (°C)	Surface temp (°C), emissivity=1	Localization
13h04	1			30 – 35	At the leak
13h08	2	32	41	32	1m from the leak – East
13h09	3	57	41	32	2.5m from the leak – East
13h10	4	37	40	32	5.5m from the leak – East

Table 3 : Measurement on H11 area, Monte Novo

3.2.1.1.3 1st Afternoon measurement 14/05/2019: H11 (bare soil) - 13h29

- leak by buried pipe (3 days before) – Additional valve closed
- Soil Humidity measurements (probe N°1): Universal soil
- Measurement before the drone flight

Time	Zone	Humidity (%)	Soil Temperature	Surface temp (°C),	Localization

			(°C)	emissivity=1	
13h37	1	56	33	33	1m from the leak – East
13h38	2	12	33	40	3m from the leak – East
13h39	3	11	33	50	5m from the leak – East

Table 4 : Measurement on H10 area, Monte Novo

3.2.1.1.4 2nd Afternoon measurement 14/05/2019: H10 (soil with vegetation) - 14h07

- Soil Humidity measurements (probe N°1) : Universal soil

Time	Zone	Humidity (%)	Soil Temperature (°C)	Surface temp (°C), emissivity=1	Localization
14h00	1	32	35	30	2m from the leak – East
	2	12	33	40	7m from the leak – East
	3	11	33	50	13m from the leak – East
	4	10	35	60	18m from the leak – East
	5	6	35	60	23m from the leak – East
	6	31	36	31	2m from the leak – East 10m from the leak – South

Table 5 : Measurement on H11 area, Monte Novo

3.2.1.1.5 3rd Afternoon measurement 14/05/2019: H11 - 15h13

- After the leak by water hydrant (1/2 h) – Additional valve opened for the leak
- Soil Humidity measurements (probe N°1): Universal soil
- Measurement before the drone flight

Time	Zone	Humidity (%)	Soil Temperature (°C)	Surface temp (°C), emissivity=1	Localization
15h28	1	36	29	33	2m from the leak – East
	2	35	29	33	6m from the leak – East
	3	34	29	34	8m from the leak – East
	4	10	29	60	13m from the leak – East
	5	7	30	60	18m from the leak – East
	6	7	30	60	23m from the leak – East
	7	29	30	34	2m from the leak – East 10m from the leak – South

Table 6 : Measurement on H11 area, Monte Novo

3.2.1.2 Artificial leak site N°2 – H5.6

- Zone Block 2 Artificial leak N°2 HP5.6 (vegetation)

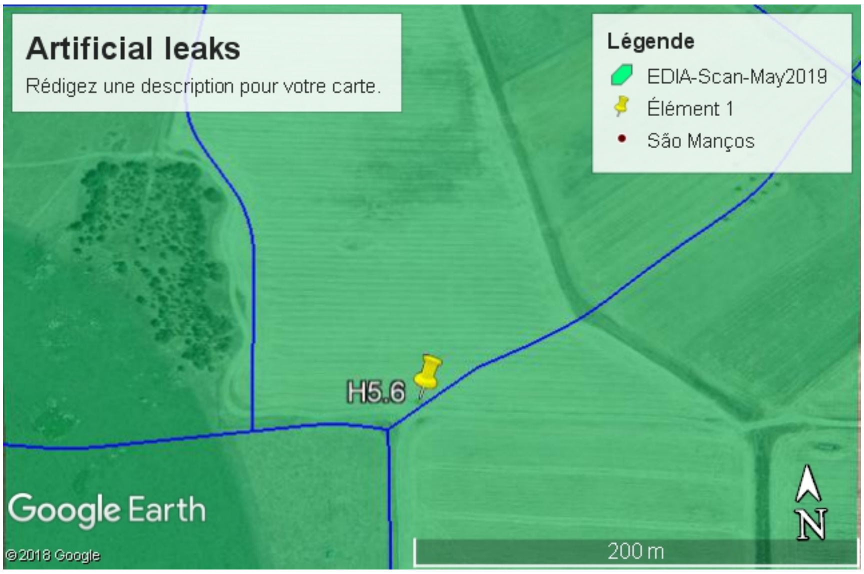


Figure 25 : HP5.6 artificial leak, Monte Novo

	
West	North
	
East	South

Figure 26 : Photos from H5.6 area, Monte Novo

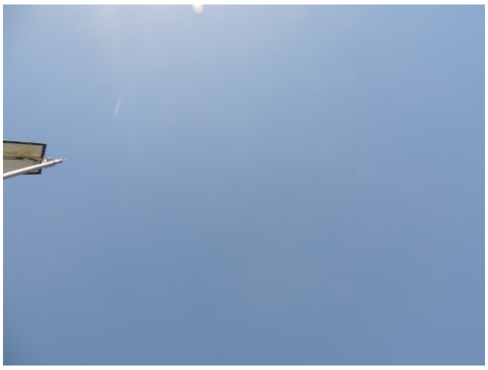


Figure 27 : sky condition (sky zenith), Monte Novo

3.2.1.2.1 Midday measurement 15/05/2019: Artificial leak N°2 H5.6 - 12h15

- tap: 10h44 (open) 11h21 (closed) – elapsed time : 37 mn irrigation
- Wet area: 6m in front of the pipe, 3m left, 5 m right
- Airplane take-off from Evora : 11h37
- Airplane altitudes : 800 – 1000 – 1200 m
- Soil Humidity measurements (probe N°1) : Universal soil
- GPS + tablet
- After the leak

Figure 28 : Location of measurement on H5.6 area, Monte Novo

Time	Measurement point	Humidity (%)	Soil Temperature (°C)	Surface temp (°C), emissivity=1	Localization
11h31	A	33	22	26	1m from the leak In front of the pipe
12h36	B	30	25	26	6m from the leak In front of the pipe
11h40	C	22	27	30	3m on the left
11h44	D	34	29	30	6m on the right

Table 7 : Soil moisture measurement on H5.6, Monte Novo

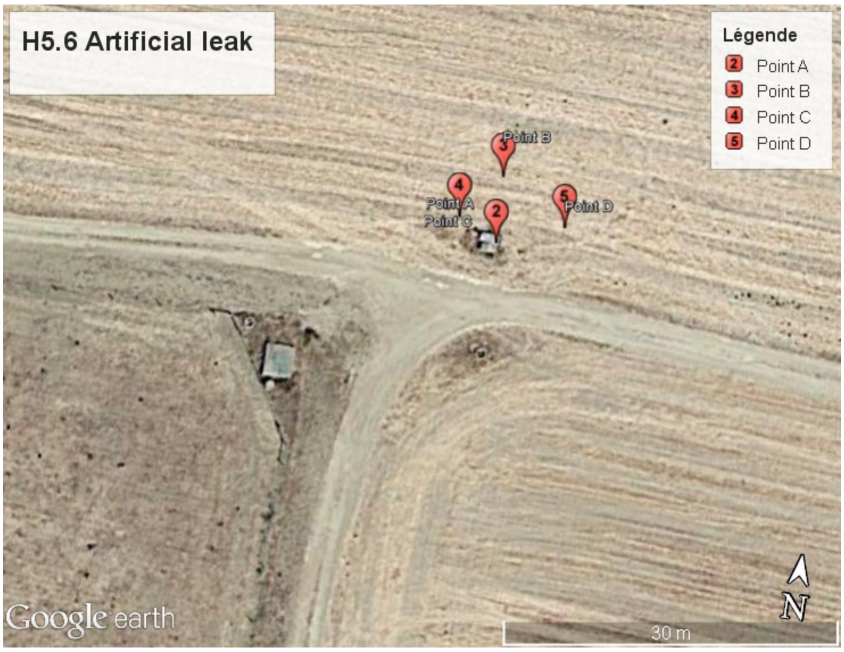


Figure 29 : Legend of soil moisture measurement on H5.6, Monte Novo

Number	Measurement point	Altitude (m, Sea Level)	Longitude (°)	Latitude (°)
2	A	254,181	-7,76883258	38,4659547
3	B	253,349	-7,76883519	38,4660104
4	C	254,071	-7,76887478	38,465972
5	D	253,691	-7,76876337	38,4659754

Table 8 : Location of soil moisture measurement on H5.6, Monte Novo

3.2.1.2.2 Midday measurement 15/05/2019: Artificial leak N°1 H10 - 12h15

- Zone Block 2 Artificial leak N°1 H10 with vegetation

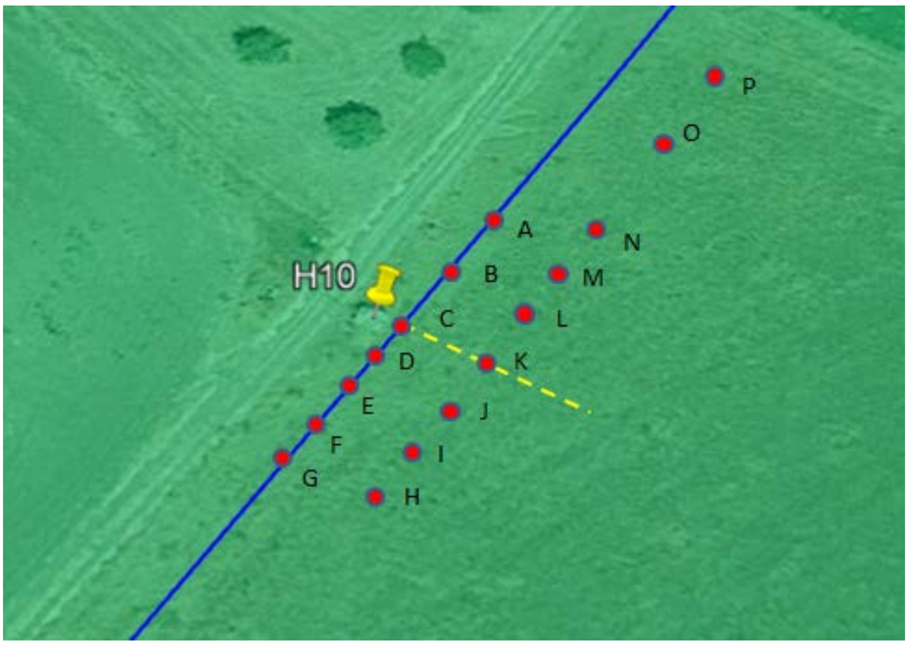


Figure 30 : location of moisture and temperature measurements, Monte Novo

- Distance between 2 points : 1.75 m, except O and P

Point measurement	Humidity (%)	Soil Temperature (°C)
A	12	30
B	36	30
C	40	31
D	43	32
E	32	32
F	14	33
G	6	33
H	10	34
I	41	34
J	40	34
K	38	35
L	36	35
M	14	36
N	12	36
O	21	37
P	14	37

Table 9 : Point of measurement on H10, Monte Novo

3.2.1.3 Artificial leak site N°2: H5.6

- Zone Block 2 Artificial leak N°2 H5.6 (vegetation) – Morning

	
	
Sky East view	Sky North view
	
Sky West view	Sky South view

Figure 31 : Photos from H5.6 area, Monte Novo

3.2.1.3.1 Artificial leak N°2 H5.6 measurement: 16/05/2019 - 11h30

- Tap: 09h45 (open) 10h48 (closed) – elapsed time : 63 mn irrigation
- Wet area: 6 m in front of the pipe, 3m left, 30 m right
- Airplane take-off from Evora : 10h48
- Airplane altitude: 1200 m
- Soil Humidity measurements (probe N°1) : Universal soil
- After the leak

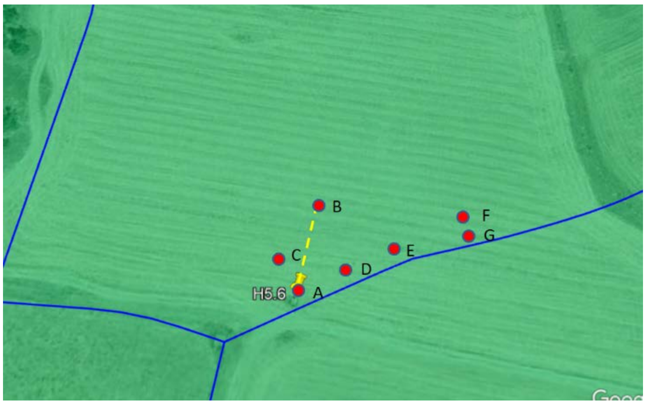


Figure 32 : - localizations (not at the scale of the map), Monte Novo

Time	Measurement point	Humidity (%)	Soil Temperature (°C)	Surface temp (°C), emissivity=1	Localization
11h23	A	31	22	25	1m from the leak In front of the pipe
11h24	B	19	22	24	6m from the leak In front of the pipe
11h25	C	20	23	28	3m on the left
11h26	D	40	23	27	6m on the right
11h26	E	34	23	28	15m on the right
11h28	F	29	24	31	30m on the right
11h29	G	8	24	46	30m on the right Dry soil

Table 10 : Humidity & temperature soil measurements, Monte Novo

3.2.1.3.2 Artificial leak N°2 H5.6 (vegetation) measurement: 16/05/2019 - 15h00

- Clear sky conditions
- Tap: 14h46 (open) 14h56 (closed) – elapsed time : 10 mn irrigation
- Wet area: 6 m in front of the pipe, 3m left, 30 m right
- Airplane take-off from Evora : 14h55
- Airplane altitude : 1200 m
- Soil Humidity measurements (probe N°1) : Universal soil
- After the leak

Time	Zone	Humidity (%)	Soil Temperature (°C)	Surface temp (°C), emissivity=1	Localization

15h54	A	38	30	23	1m from the leak In front of the pipe
15h54	B	24	30	27	6m from the leak In front of the pipe
15h56	C	21	30	29	3m on the left
15h57	D	35	30	28	6m on the right
15h58	E	33	30	27	15m on the right
15h59	F	31	30	29	30m on the right
16h00	G	0	30	40	30m on the right Dry soil

Table 11 : Humidity & temperature soil measurements, Monte Novo

3.2.1.3.3 Artificial leak N°1 H10 (vegetation) measurement: 16/05/2019- 14h42

- Clear sky conditions
- Tap: 14h46 (open) 14h56 (closed) – elapsed time : 10 mn irrigation
- Wet area: 6 m in front of the pipe, 3m left, 30 m right
- Airplane take-off from Evora : 14h55
- Airplane altitude : 1200 m
- Soil Humidity measurements (probe N°1) : Universal soil
- After the leak

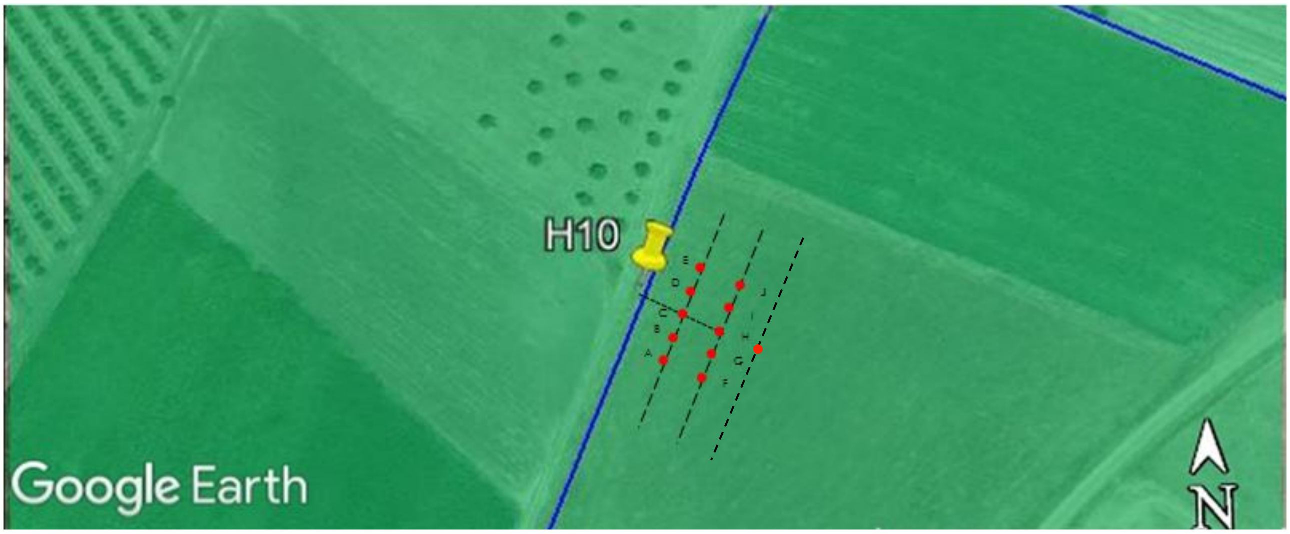


Figure 33 : 1st Humidity & temperature soil measurements localizations, Monte Novo

Zone	Humidity (%)	Soil Temperature (°C)	Localization

A	12.68	24.8	1m from the leak In front of the pipe, 5m on the left
B	29.2	24.5	1m from the leak In front of the pipe, 2.5m on the left
C	39.28	24.1	1m from the leak In front of the pipe
D	18.78	23.50	1m from the leak In front of the pipe, 2.5m on the right
E	28.98	23.3	1m from the leak In front of the pipe, 5m on the right
F	37.31	25.3	1m from the leak In front of the pipe, 5m on the left
G	38.28	25.8	1m from the leak In front of the pipe, 2.5m on the left
H	41.06	26.1	1m from the leak In front of the pipe
I	35.9	26.6	1m from the leak In front of the pipe, 2.5m on the right
J	11.91	26.8	1m from the leak In front of the pipe, 5m on the right

Table 12 : 1st Humidity & temperature soil measurements, Monte Novo

3.2.1.3.4 Artificial leak N°1 H10 (vegetation) measurement: 16/05/2019- 14h50

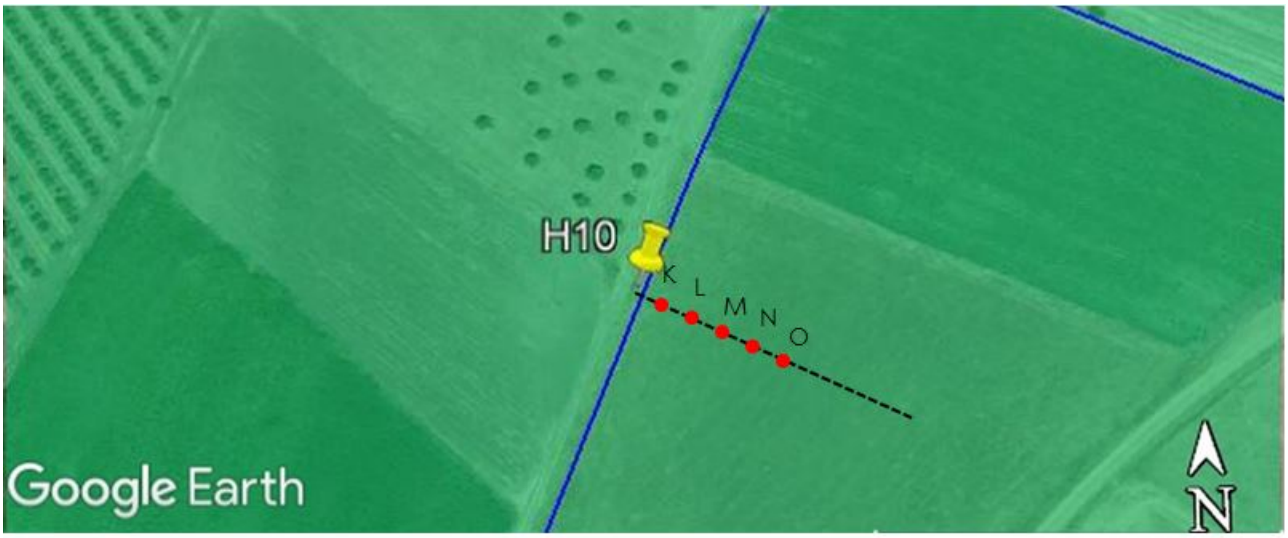


Figure 34 : 2nd Humidity & temperature soil measurements localizations, Monte Novo

Zone	Humidity (%)	Soil Temperature (°C)	Localization
K	68.45	27.2	1m from the leak In front of the pipe
L	52.62	28.1	3.5m from the leak In front of the pipe
M	41.08	28.0	6m from the leak In front of the pipe
N	42.87	23.50	8.5m from the leak In front of the pipe
O	33.51	28.3	

Table 13 : 2nd Humidity & temperature soil measurements, Monte Novo

3.2.2 Artificial leaks Sept. 2019

3.2.2.1 Tuesday 2019-09-10: drone flights

- Monte Novo artificial leak Zone H10 (dry grass soil, 14h45)

At the leak: SMC= 7%, Tsoil = 34°C

- Monte Novo artificial leak Zone H11 (dry earthy soil, 14h55)

At the leak: SMC = 30%, Tsoil = 33°C

10 m far from the leak : SMC = 10%

Figure 35: H10 site, Monte Novo.

Figure 36: H11 site, Monte Novo.

- Ferreira artificial leak Zone H9.7

Leak dimensions: 3 m x 3 m.

3.2.2.2 Thursday 2019-09-12: drone + aircraft flights

Aircraft flying above H9.7 leak at 12h15.

Drone flight: take-off at 12h57, landing at 13h06, height above ground: 30 m, drone speed: 10 km/h.

Zone	SMC (%)	Soil Temperature (°C)
Point N°1	51	32.7
Point N°2	43	32.8
Point N°3	37	32.8
Point N°4	38	32.8
Point N°5	41	32.8
Point N°6	30	32.9
Point N°7	40	32.9

Table 14 : SMC & temperature measurement on H9.7, Ferreira

Ground temperatures (measured by pyranometer): 27°C (at the exit of the green pipe), 24°C (in the middle of the leak), 30°C (at the end of the leak), 29°C (on the right side of the leak when seen from the green pipe), 44°C at 5 m on the right of the right side of the leak, 25°C (on the left side of the leak), 34°C (dry grass), 38°C (top of concrete block), 40°C (green metal plate), 42°C (earthy track).

Figure 37 : Photos from H9.7 artificial leak, Ferreira

Zone	SMC (%)	Soil Temperature (°C)	Surface temp (°C), emissivity=1
Point N°1	30	34.0	44
Point N°2	52	34.3	31.5
Point N°3	41	34.9	31
Point N°4	42	35.2	38
Point N°5	37	36.3	35
Point N°6	42	35.4	35
Point N°7	11	35.6	33
Point N°8	38	35.8	29.5

Table 15 : SMC & temperature measurement on H9.7, Ferreira

Ground temperatures (measured by pyranometer): 44°C (dry grass), 40°C (top of concrete block), 39°C (green metal plate), 33°C (vegetation), 48°C (bare soil), 41°C (concrete gutter along the road).

- Ferreira artificial leak Zone H16

End of ground measurements (just before drone take-off): 14h00.

Figure 38: Zone H16, point N°1, Ferreira.

Figure 39: Zone H16, point N°2, Ferreira.

Figure 40: Zone H16, point N°3, Ferreira.

Figure 41: Zone H16, point N°4, Ferreira.

Figure 42: Zone H16, point N°5, Ferreira.

Figure 43: Zone H16, point N°6, Ferreira.

Figure 44: Zone H16, point N°7, Ferreira.

Figure 45: Zone H16, point N°8, Ferreira.

3.2.3 Natural leaks Sept. 2019

- Monte Novo « natural leak » Zone H5 (dry grass soil, 14h45)

Platform left side (when looking in direction of the leak) oriented at 120° from the North.

GPS reference point: rear left corner of the platform (when looking in direction of the leak).

Reference point for the measurements: front left corner of the platform (when looking in direction of the leak).

Figure 46: H5 site, Monte Novo.

Figure 47: H5 site, view of the sky, Monte Novo.

Time	Zone	Humidity RH (%)	Soil Temperature (°C)	Localization
15h30	Point N°0	11	34.7	Front left corner of platform – South-East (reference point) 38;27;14.31 lon 7;44;33.5 lat 222 m altitude
	Point N°1	6	34.5	5 m from front ref. point – SE
	Point N°2	12	34.5	10 m from front ref. point – SE
	Point N°3	8	34.4	15 m from front ref. point – SE
	Point N°4	6	34.4	20 m from front ref. point – SE
	Point N°5	23	34.3	25 m from front ref. point – SE
	Point N°6	16	34.3	30 m from front ref. point – SE
	Point N°7	19	34.3	35m from front ref. point – SE
	Point N°8	8	34.2	40 m from front ref. point – SE
	Point N°9	10	34.2	45 m from front ref. point – SE

	Point N°10	15	34.2	50 m from front ref. point – SE
	Point N°11	7	34.2	55 m from front ref. point – SE
	Point N°12	12	34.3	60 m from front ref. point – SE
15h57	Point N°13	23	34.4	65 m from front ref. point – SE 38;27;12.57 lon 7;44;31.5 lat 243 m altitude
	Point N°14	3	34.5	65 m from front ref. point – SE 5 m on the right of pt N°14 when looking from the platform
	Point N°15	9	34.6	5 m from pt N°14 in direction of the platform → 60 m from the ref. point on platform
	Point N°16	12	34.5	55 m from front ref. point – SE
	Point N°17	13	34.5	50 m from front ref. point – SE
	Point N°18	9	34.6	45 m from front ref. point – SE
	Point N°19	7	34.8	40 m from front ref. point – SE
	Point N°20	4	34.9	35m from front ref. point – SE
	Point N°21	9	35.0	30 m from front ref. point – SE
	Point N°22	4	35.0	25 m from front ref. point – SE
	Point N°23	8	35.0	20 m from front ref. point – SE
	Point N°24	6	35.0	15 m from front ref. point – SE
	Point N°25	28	35.0	10 m from front ref. point – SE 38;27;14.35 lon 7;44;34.1 lat 214 m altitude

Table 16 : SMC measurement on H5, Monte-Novo

1st drone flight: take-off at 16h02, landing at 16h15.

2nd drone flight: take-off at 18h10. Flight cancelled because of a disalignment of one propeller.

3rd drone flight: take-off at 18h10.

4th drone flight: take-off at 20h00.

3.2.4 Wednesday 2019-09-11: Natural leak Vale de Gaio (Barras reservoir)

- potential leak at Barras reservoir (drone flights + aircraft flight)
- 1st drone flight : Barras reservoir

Drone GPS coordinates at take-off:
- Lat: 38.2590421468265
- Long: -8.10657978057861
- Alt: 177.84 m

Take-off at 13h05, drone height above ground: 100 m, v = 20 km/h, FOV: 83 m x 67 m.

- 2nd drone flight : Vale de Gaio "natural leak" 1 north-ouest of the reservoir

Drone GPS coordinates at take-off :
- Lat: 38.2611236572266
- Long: -8.10413455963135
- Alt: 161.2 m

Take-off at 14h02, drone height above ground: 50 m, v = 20 km/h, FOV: 83 m x 67 m.

Time	Zone	Humidity SMC (%)	Soil Temperature (°C)
14h20	Point N°1	30	35.7
	Point N°2	43	35.7
	Point N°3	34	35.6
	Point N°4	39	35.6
	Point N°5	37	35.7
	Point N°6	47	35.7
	Point N°7	42	35.5

Table 17 : SMC measurement on Barras reservoir

Figure 48: Vale de Gaio "natural leak" 1 north east of the reservoir. Picture in north direction (left) and in south direction (right).


Figure 49: Vale de Gaio "natural leak" 1 north east of the reservoir. View of the sky (left) and point N°1 (right).


Figure 50: Vale de Gaio "natural leak" 1 north east of the reservoir. Point N°2 (left) and point N°3 (right).


Figure 51: Vale de Gaio "natural leak" 1 north east of the reservoir. Point N°4 (left) and point N°5 (right).

Figure 52: Vale de Gaio "natural leak" 1 north east of the reservoir. Point N°6 (left) and point N°7 (right).

Vale de Gaio "natural leak" 2 (west from the reservoir).

Leak orientation: N-S, dimensions : ~ 60 m x 15 m

Drone take-off at 15h07.

Figure 53: Vale de Gaio "natural leak" 2, west from the reservoir. Leak as seen from the reservoir (left) and close up of the leak (right).

Figure 54: Vale de Gaio "natural leak" 2, west from the reservoir. Close up of the leak (left) and measurement point N°1 (right).

Figure 55: Vale de Gaio "natural leak" 2, west from the reservoir. Point N°2 (left) and measurement point N°3 (right).

Time	Zone	SMC (%)	Soil Temperature (°C)
14h45	Point N°1	42	35.4
	Point N°2	50	35.4
	Point N°3	47	35.4

Table 18 : SMC measurement on West natural leak, Vale de Gaio

3.3 Flight campaign

3.3.1 Manned Aircraft / UAV operational and surveillance flights plan

An airborne and UAV remote sensing campaign were carried out on May and September 2019 over several areas belonging to the water network infrastructure of EDIA. The aircraft is a Tecnam P2006T operated by Air Marine and instrumented with a VNIR multispectral camera (SpectroCam with 8 custom selected filters: 425, 550, 640, 660, 724, 820, 832.5 and 840 nm), a cooled TIR camera (Noxant NoxCam: 7.7 – 9.3 µm) and a custom made acquisition software (WadiFl). The flights with the manned platform were performed at an altitude between 1000m and 1200 m above ground level which led to a spatial resolution of 0.30 m for the Spectrocam camera and 0.48 m for the Noxant camera. For aircraft manoeuvrability reasons, the flight passes within the same sector were performed with a separation around 170 m.

Figure 56 : Tecnam P2006T owned and operated by Air Marine

Fiche Mission Client

WADI CAMPAGNE Portugal MAI-JUIN

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DONNEES GENERALES				
Nom du projet/mission	WADI Campagne Portugal Mai-Juin			
Lieu	Portugal / Commune de EVORA			
Temps estimé	1 semaine			
Date d'intervention	S19	RATTRAPPAGE	S20	
Contact opérationnel	**EDIA→ Alexandra Carvalho** : ONERA → Christian Chatelard : **Galileo Geosystem → Javier Sanchis :**			
Chef de mission	TBD	Localité :	EVORA	
Référent Géomaticien	Javier Sanchis (WADI)	Localité :	EVORA	
Référent Autorisation		Localité :	TBD	

MISSION - LIVRABLE	
Type de Mission	**Type** : Mosaïquage d'un réseau aqueduc en avion **Commentaires :**
Taille	**112 Km2 (environ)**
Description et contraintes techniques de la mission	Travail estimé : - Récupération de photos multispectrale et IR géoréférencées ; - Traitement informatique (Mosaïquage) dès atterrissage par Javier ou AM (tbd) ; - Restitution des données à Javier Condition météo : - Acquisition entre 11H et 16H lorsque l'ensoleillement est le meilleur ; - Pas d'ombre au sol et aérologie calme Environnement aéronautique : - Aérodrome d'Evora situé à 5Nm de la zone de capture - Zone de capture dans la R 51 BN Support au sol : - Possibilité d'avoir accès à la salle pilote d'EVORA Temps estimé : 4 à 6 vols de 2H00
Délai rendu livrable	A la sortie de l'avion grâce à un Disque Dur Rackable

Fiche Mission Client

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Avion et Capteur	P2006 et SpectroCam + NoxCam		
Hauteur de vol – résolution native	TBD		
Scénario réglementaire	**N/A**		
Perche GPS	**N/A**	**Assistant(s) :**	**N/A**

ENVIRONNEMENT / CONTRAINTES	
Autorisation d'accès au site	Selon autorisation DGAC/armée Portugaise
Environnement aéro. MACH 7	Zone de survol dans la R51 BN (1000Ft AGL / FL 105) et située à 4 Nm dans le 120° du l'aérodrome d'Evora (ne croise pas les axes)
Coordination avec client	Départ mission à J-1 en coordination avec l'ONERA, Gaglileo Geosystem et Edia.
Contrainte particulière	Environnement aéronautique
Spécifications de l'acquisition	**Zone de 9400m sur le petit côté**

Interbandes SpectroCam en mètres

	30%	40%	50%	60%
600 Ft	149	128	107	85
700 Ft	174	149	124	100
800 Ft	199	171	142	114

GSD NoxCam:

	GSD
600 Ft	36
700 Ft	42
800 Ft	48

Cartes et photos (A définir avec EDIA)

Photo Google Earth emprise
Emprise du vol validée par le client
Carte protection MACH7 avec transparence OACI 1/500 000

Figure 57 : Air Marine Mission preparation sheet

The UAV is a custom designed multicopter operated by Galileo Geosystems. It was instrumented with a VNIR multispectral camera (Micasense RedEdge 3 with five bands: 475, 560, 668, 717 and 840 nm) and a microbolometer uncooled TIR camera (FLIR Vue Pro R: 7.5 – 13.5 µm). The flights with the unmanned platform were performed at an altitude of 50 m above ground level which led to a spatial resolution of 3.4 cm for the Micasense camera and 6.5 cm for the FLIR camera.

Figure 58 : Multicopter with on-board multispectral and thermal infrared cameras operated by Galileo Geosystems

All the flight plans would ideally be prepared to ensure a front and side image overlap of at least 80%. Unfortunately, achieving a side overlap of an 80% is way too hard in the case of the manned aircraft as far as the flight passes are required to have a distance too short to be operatively possible. The alternance of flight passes is an alternative method to increase the side overlap but has also some drawbacks like the excessive change in the illumination geometry between side passes do to the relative movement of the Earth with respect to the Sun.

3.3.2 MAV – May-September 2019

The manned aircraft flights were scheduled in May and September 2019 with a Tecnam P2006T following the mission plans presented in section 3. As mentioned before, the payload was composed by a VNIR multispectral camera (SpectroCam with 8 custom selected filters: 425, 550, 640, 660, 724, 820, 832.5 and 840 nm), a cooled TIR camera (Noxant NoxCam: 7.7 – 9.3 µm) and an on-board computer with a custom made acquisition software (WadiFI). The band 4 (RED: 660 nm), the band 7 (NIR: 832.5 nm) and the thermal infrared (TIR: 7.7 – 9.3 µm) have been selected for the present study.

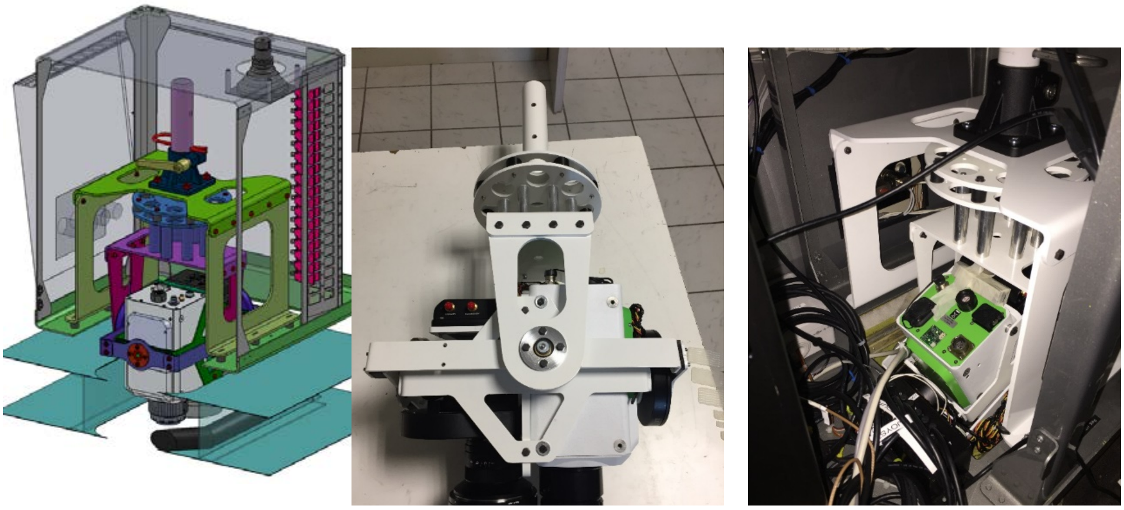

Figure 5.1.1 Gimbal integrated into the AIRMON console of the Air Marine TECNAM

The acquired data was preprocessed with Pix4D, a photogrammetric grade mosaicking software, to obtain raw (from uncalibrated multispectral data) and brightness temperature (TIR radiometric brightness temperature data) ortho-mosaics. The ortho-mosaics were created separately and co-registered by Wadileaks, the custom processing software developed in the frame of the WADI project. Wadileaks makes use of Gefolki, an opensource software developed by ONERA, to do the co-registering. With all the spectral ortho-mosaics co-registered, it is possible to follow the processing pipeline established to calculate the water index ortho-mosaic necessary to find waterleaks.

The vegetation areas are dark in the bands where the light is absorbed due to photosynthetic processes (red band). These areas are clearer in the ortho-mosaic corresponding to the NIR band.

More than 500 Gb of image data were acquired during the campaign with the manned aircraft. The most representative acquired is presented in this section.

For the preparation of the manned aircraft operation, refer to the Annex: "Preparation-Note-WADI-5-Campaign-WP6-v2.0.pdf"

For the result analysis during the manned aircraft operation, refer to the Annexes:

- "WADI-SynthesisAMFlightCampaign-EDIA-15-16may2019.pdf"
- "WADI-SynthesisAMFlightCampaign-EDIA-11-12sept2019.pdf"

3.3.2.1 Overflown area – May 2019

The MAV remote sensing campaign was carried out on May 2019 over the EDIA network infrastructure at Monte Novo (Sao Manços). 3 flights have been performed over the H5.6, H10 and H11 tap areas and in the block 2 of Monte Novo (Block 2) near Sao Manços.

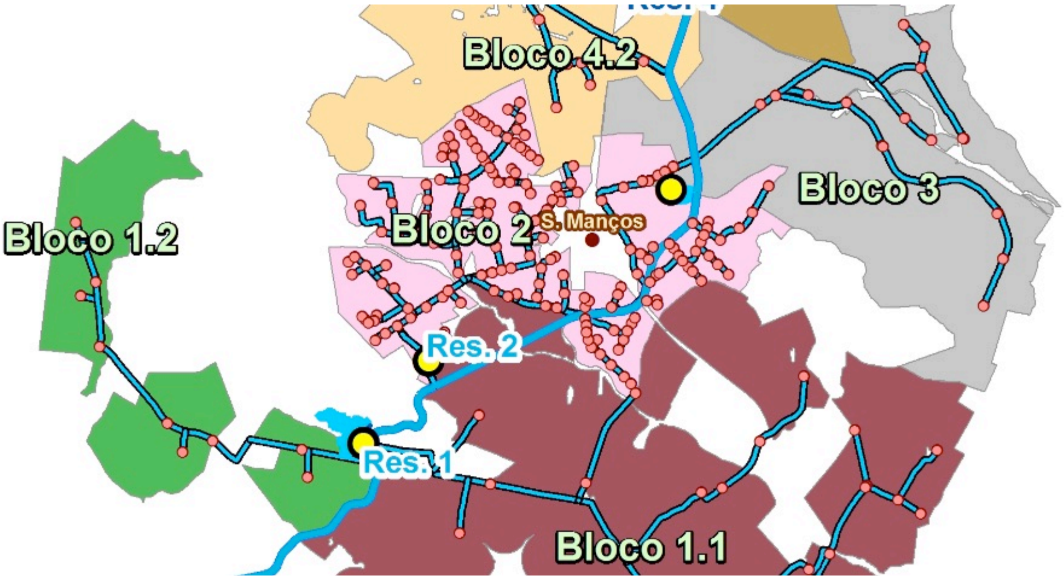

Figure 59 : Water network of Monte Novo. MAV flights performed in the Block 2 area.

Date	Area (km2)	Alt AGL (m)	MS GSD (cm)	TIR GSD (cm)
15-05-2019 - 12:15	18	800, 1000, 1200	0.30@800m, 0.36@1000m, 0.43@1200m	0.46@800m, 0.60@1000m, 0.72@1200m
16-05-2019 - 11:30	18	1200	0.43@1200m	0.72@1200m
16-05-2019 - 14:57	18	1200	0.43@1200m	0.72@1200m

Table 19 : List of MAV flights carried out in Monte Novo (Sao Manços).

3.3.2.2 Areas where comparison analysis can be done –May 2019

Date	Area (km2)	Alt AGL (m)	MS GSD (cm)	TIR GSD (cm)
16-05-	18	1200	0.43@1200m	0.72@1200m

2019 - 11:30				
16-05-2019 - 14:57	18	1200	0.43@1200m	0.72@1200m

Table 20 : List of MAV flights carried out in Monte Novo (Sao Manços).

3.3.2.3 Overflown area – September 2019

The MAV remote sensing campaign was carried out on Sept. 2019 over the EDIA network infrastructure near Sao Manços, Ferreira do Alentejo and Vale de Gaio. 2 large flights have been performed over the "real leak" identified near Sao Mancos during the previous flight campaign in May (ref. Bloco 2, near H5) and the "real leaks" indicated by EDIA in Vale de Gaio (ref. reservoir North to Ferreira) + the artificial leaks in the west sector from Ferreira (ref. H16 and H9.7).

<u>Sao Mancos area:</u>

Figure 60 : Water network of Monte Novo. MAV flights performed in the Block 2 area.

Date	Area (km2)	Alt AGL (m)	MS GSD (cm)	TIR GSD (cm)
11-09-2019 10:45 – 11:00	1.5	1200	0.43@1200m	0.72@1200m
12-09-2019 12:50 – 13:00	1.5	1200	0.43@1200m	0.72@1200m

Table 21 : List of MAV flights carried out in Monte Novo (Sao Manços).

<u>Ferreira do Alentejo area:</u>

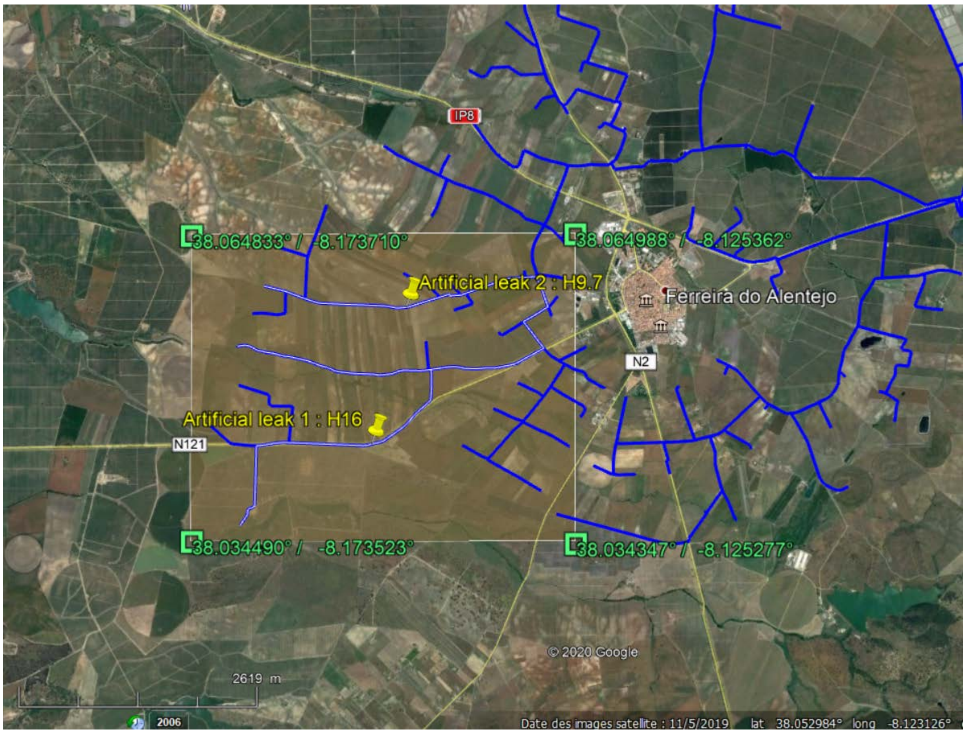

Figure 61 : Water network of Ferreira area. MAV flights performed in the west part.

Date	Area (km2)	Alt AGL (m)	MS GSD (cm)	TIR GSD (cm)
12-09-2019 10:35 – 12:23	15	1200	0.43@1200m	0.72@1200m

Table 22 : List of MAV flights carried out in Ferreira area.

Vale de Gaio area:

Figure 62 : Water network of Vale de Gaio. MAV flights performed in the reservoir area.

Date	Area (km2)	Alt AGL (m)	MS GSD (cm)	TIR GSD (cm)

11-09-2019 15:05 – 15:15	0.58	1200	0.43@1200m	0.72@1200m
12-09-2019 13:30 – 13:37	0.58	1200	0.43@1200m	0.72@1200m

Table 23 : List of MAV flights carried out in Vale de Gaio (North Ferreira).

3.3.2.4 Areas where comparison analysis can be done –September 2019

Date	Area (km2)	Alt AGL (m)	MS GSD (cm)	TIR GSD (cm)
12-09-2019 12:50 – 13:00	1.5	1200	0.43@1200m	0.72@1200m
12-09-2019 10:35 – 12:23	15	1200	0.43@1200m	0.72@1200m
12-09-2019 13:30 – 13:37	0.58	1200	0.43@1200m	0.72@1200m

Table 24 : List of MAV flights carried out in Monte Novo (Sao Manços), Ferreira and Vale de Gaio.

3.3.2.5 Results

See the 3.4 section.

3.3.3 UAV– May & September 2019

An UAV remote sensing campaign was performed in May and September 2019 over an area belonging to the water network infrastructure of EDIA.

The UAV used in this remote sensing survey is the same one used during the SCP campaigns in July and October 2018. It is a custom designed multicopter operated by Galileo Geosystems, instrumented with a VNIR multispectral camera (Micasense RedEdge 3 with five bands: 475, 560, 668, 717 and 840 nm) and a microbolometer uncooled TIR camera (FLIR Vue Pro R: 7.5 – 13.5 µm).

The flights were performed in the block 2 of Monte Novo (Bloco 2) near S. Manços and in the Ferreira area. These areas were selected taking into account the restriction to fly urban areas and looking to maximize safety.

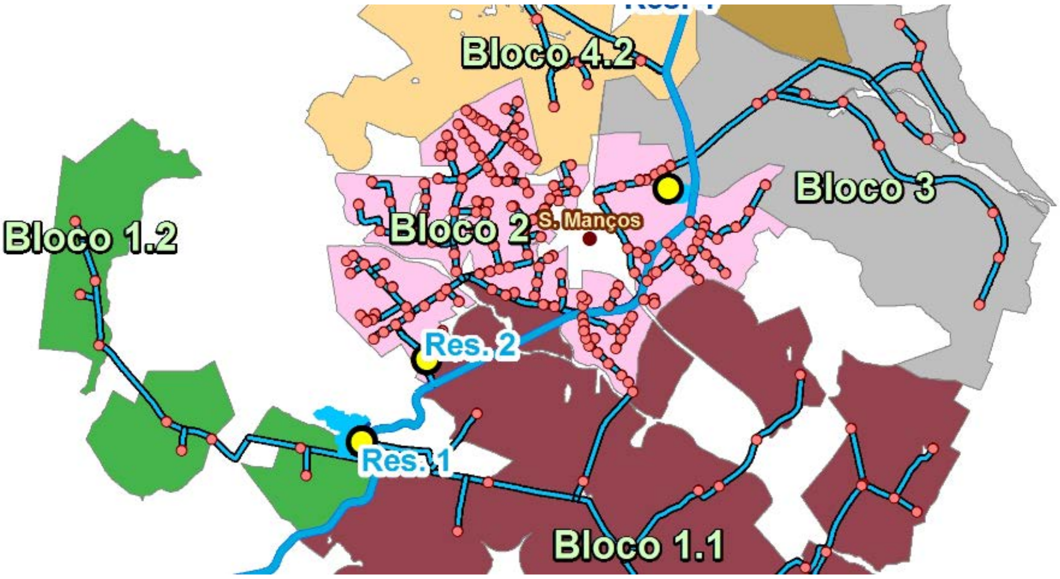

Figure 5.2.1 - Water network of Monte Novo. UAV flights will be performed in the Block 2 area.

The selection of the areas of interest within the block 2 and the final mission planning was done in field depending on the vegetation, dryness terrain conditions and available leaks information.

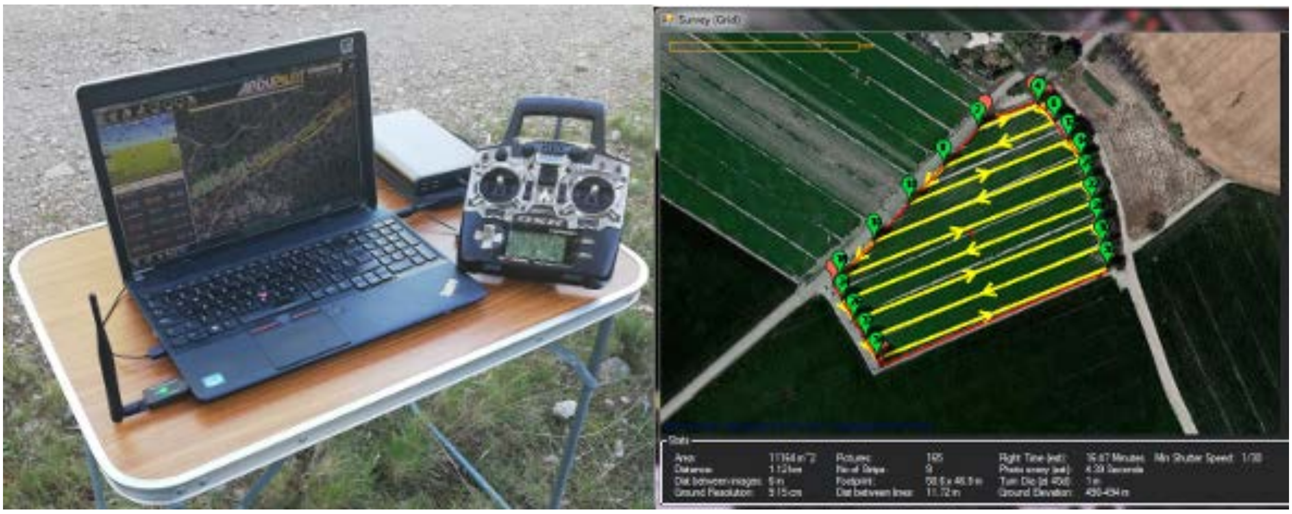

Figure 5.2.2 - UAV control ground station and mission planning.

The flights with the unmanned platform were performed at different altitudes depending on the final flight permits. The Table 25 shows the resolution calculated for different altitudes above ground level for both cameras. Predictably the flights will be carried out at 50m and 120m above ground level.

	Altitude (m AGL)							
Camera	**50**	60	70	80	90	100	110	**120**
Micasense RedEdge 3 (5.5mm)	**3.41**	4.09	4.77	5.45	6.14	6.82	7.5	**8.18**
Flir Vue Pro R	**6.54**	7.85	9.15	10.46	11.77	13.08	14.38	**15.69**

(13mm)								

Table 25 - Resolution of both cameras at different altitudes. In bold the selected altitudes for the survey.

The pilot "home" was chosen for each fly to ensure that the UAV remains during all the flight at no more than 200 meters from the pilot.

The selected area and the minimum flights' altitude have been established taking into account the avoidance of lower obstacles while having complete control of the aircraft and a good image resolution. The flight plan was designed to capture the area of interest in each case. At the end of the flight, the UAV returned to the home position and landed automatically.

Even with an automatic flight, the pilot is aware all the time so that in the event of a problem, he could immediately take the controls of the aircraft.

All the flight plans would ideally be prepared to ensure a front and side image overlap of at least 80% in order to comply with the requirements of the ortho-mosaicing process.

3.3.3.1 Overflown area – May 2019 -

The UAV remote sensing campaign was carried out on May 2019 over the EDIA network infrastructure at Monte Novo (Sao Manços). 11 flights have been performed over mainly over the H5.6, H10 and H11 tap areas.

Date	Area (ha)	Alt AGL (m)	MS GSD (cm)	TIR GSD (cm)	Description
14-05-2019 - 12:05	2.761	50	3.54	6.47	H11 tap area before the artificial leak.
14-05-2019 - 12:51	2.675	50	3.59	6.43	H11 tap area after the leak.
14-05-2019 - 13:29	2.675	50	3.59	6.43	H11 tap area 40 minutes after the leak.
14-05-2019 - 14:07	2.466	50	3.76	6.87	H10 tap area after the leak.
14-05-2019 - 14:33	1.804	50	3.67	6.63	Bare soil field.
14-05-2019 - 14:57	2.769	50	3.85	6.97	First phenologic stages of a drop by drop corn irrigated field.
14-05-2019 - 15:13	2.675	50	3.59	6.43	H11 tap area 2h30 after the leak.
16-05-2019 - 12:50	2.466	50	3.76	6.87	H10 tap area aborted flight.
16-05-2019 - 14:36	2.466	50	3.76	6.87	H10 tap area after the artificial leak.
16-05-2019 - 14:57	2.952	50	3.78	6.96	H10 tap area mixed pixel.
16-05-2019 - 16:19	2.39	50	3.49	6.28	H5.6 tap area artificial leak.

Table 26 : List of UAV flights carried out in Monte Novo (Sao Manços).

3.3.3.2 Areas where comparison analysis can be done – May 2019

<table>
<tr><th>Date</th><th>Comments</th></tr>
<tr><td>14-05-2019 - 12:06</td><td rowspan="3">The H11 tap area artificial leak was only surveyed with UAV. The survey consisted on one flight before the water leak occurrence and three flights at three different times after the leak occurrence.</td></tr>
<tr><td>14-05-2019 - 12:51</td></tr>
<tr><td>14-05-2019 - 13:29</td></tr>
<tr><td>14-05-2019 - 14:07</td><td>The H10 tap area artificial leak was only surveyed with UAV.</td></tr>
<tr><td>14-05-2019 - 14:33</td><td>The flight over the bare soil field can be compared with the MAV flight results.</td></tr>
<tr><td>14-05-2019 - 14:57</td><td>The corn irrigated field can be compared with the MAV flight results.</td></tr>
<tr><td>14-05-2019 - 15:13</td><td>See the first comment.</td></tr>
<tr><td>16-05-2019 - 12:50</td><td>H10 tap area aborted flight.</td></tr>
<tr><td>16-05-2019 - 14:36</td><td>H10 tap area artificial leak can be compared with the MAV flight results.</td></tr>
<tr><td>16-05-2019 - 14:57</td><td>H10 tap area mixed pixel. This dataset contains diverse soil types in the same flight. The results can be compared with the MAV flight results.</td></tr>
<tr><td>16-05-2019 - 16:19</td><td>H5.6 tap area artificial leak. The results can be compared with the MAV flight results.</td></tr>
</table>

Table 27 : Comments about the UAV flights carried out in Monte Novo (Sao Manços).

3.3.3.3 Overflown area – September 2019 -

This last UAV remote sensing campaign was carried out on September 2019 over the EDIA network infrastructure at three different areas, Monte Novo (Sao Manços), Vale do Gaio and Ferreira. 9 flights have been performed mainly over the H5.6, H10 and H11 tap areas.

<table>
<tr><th>Date</th><th>Area (ha)</th><th>Alt AGL (m)</th><th>MS GSD (cm)</th><th>TIR GSD (cm)</th><th>Description</th></tr>
<tr><td>10-09-2019</td><td colspan="5" rowspan="4">The H5 area was flown by the UAV and the MAV. The leak is visible in the images acquired with both platforms.</td></tr>
<tr><td>10-09-2019</td></tr>
<tr><td>10-09-2019</td></tr>
<tr><td>10-09-2019</td></tr>
<tr><td>11-09-2019</td><td colspan="5">The Vale do Gaio reservoir area was flown by the UAV and the MAV. The reservoir and its surrounding is visible in the images acquired with both platforms.</td></tr>
</table>

11-09-2019	The Vale do Gaio north east natural leak area was flown by the UAV and the MAV. The leak is visible in the images acquired with both platforms.
11-09-2019	The Vale do Gaio west natural leak area was flown by the UAV and the MAV. The leak is visible in the images acquired with both platforms.
12-09-2019	The H9.7 artificial leak (Ferreira) flown by the UAV and the MAV. The artificial leak is visible in the images acquired with both platforms.
12-09-2019	The H16 artificial leak (Ferreira) flown by the UAV and the MAV. The artificial leak is visible in the images acquired with both platforms.

Table 28 : List of UAV flights carried out in September 2019 in Vale de Gaio & Ferreira

3.3.3.4 Areas where comparison analysis can be done – Sept 2019

Date	Area (ha)	Alt AGL (m)	MS GSD (cm)	TIR GSD (cm)	Description
10-09-2019	2.37	50	3.53	6.46	Flight over H5 (Sao Manços) performed at 4 different day times (16:01).
10-09-2019	2.37	50	3.53	6.46	Flight over H5 (Sao Manços) performed at 4 different day times (18:11).
10-09-2019	2.37	50	3.53	6.46	Flight over H5 (Sao Manços) performed at 4 different day times (19:47).
10-09-2019	2.37	50	3.53	6.46	Flight over H5 (Sao Manços) performed at 4 different day times (20:00).
11-09-2019	1.8	50	3.58	6.59	Flight over the Vale do Gaio reservoir.
11-09-2019	2.33	50	3.63	6.47	Flight over the north east leak close to Vale do Gaio reservoir.
11-09-2019	2.43	50	3.52	6.41	Flight over the west leak close to Vale do Gaio reservoir.
12-09-2019	2.37	50	3.43	6.52	Flight over the H9.7 artificial leak in the Ferreira area.
12-09-2019	2.21	50	3.48	6.55	Flight over the H16 artificial leak in the Ferreira area.

Table 29 : Comments about the UAV flights carried out inVale de Gaio & Ferreira.

3.3.3.5 Results

See the 3.4 section.

3.4 Comparison between ground campaign and flight campaign

3.4.1 MAV –May 2019

The triangle method was applied to infer a moisture map from a set of images obtained in the Visible+Near Infrared+Thermal Infrared spectrum. A vegetation index (VI) was first obtained by combining the images recorded at Visible and Near Infrared wavelengths. Then, a 2D scatterplot was drawn from the pair of values obtained for each pixel related to the VI on one side and to the Thermal Infrared signal on the other side. Three different set of boundaries (dry edge + wet edge) were tested. The boundaries were chosen to exclude or not “abnormal” patches in the scatterplot that are probably related to urban areas and roads. Nevertheless, this choice has no significant impact on the visual aspect of the final map of the moisture index.

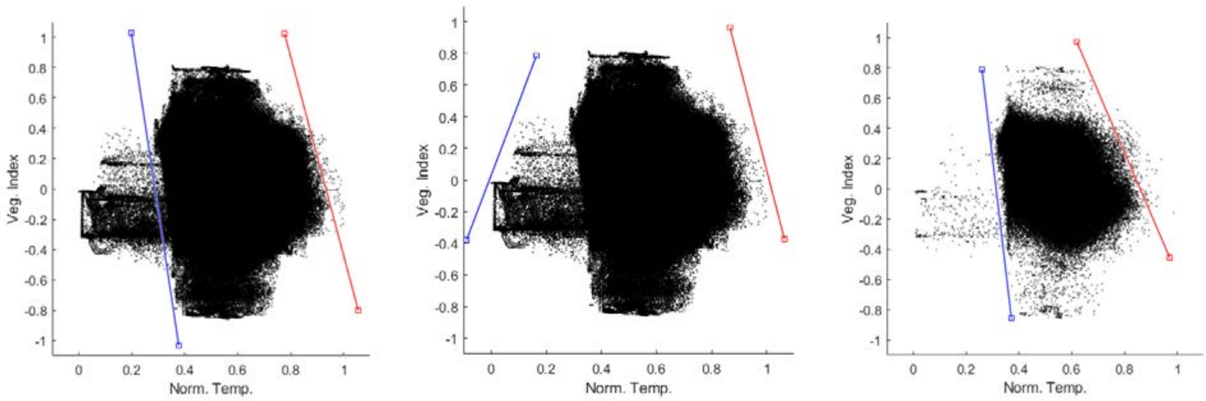

Figure 63 : Scatterplots normalized temperature vs VI

Scatterplot of the normalized temperature (as inferred from the Thermal infrared signal) versus the Vegetation index. From left to right, three different selections of the wet (blue) and dry (boundaries) which correspond to Processing 1, 2 and 3.

Figure 64 : Moisture maps around H10 & H11 according to Processing 1, 2 and 3 (from left to right). The leaks H10 and H11 are clearly seen.

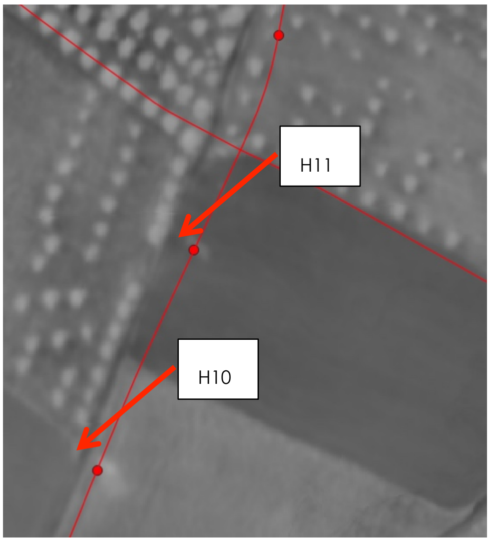

Figure 65 : Moisture map around H10 & H11 together with the pipeline

Figure 66 : Moisture maps (close up in the area of the artificial leak H5.6) as obtained according to Processing 1, 2 and 3 (from top to bottom). The leak H5.6 is clearly seen.

Figure 67 : Moisture map (close up in the area of the artificial leak H5.6) as obtained according to Processing 3, together with the pipeline.

Figure 68 : Excerpt of the moisture map east of the village Sao Manços. Orange ellipses, close to hydrant H5, indicate areas with excess moisture that have been interpreted to be due to runoff from an uphill irrigated field (see the next figure for more details). The yellow ellipse indicates an irrigated corn field.

A yellow ellipse in Figure 68 is highlighting a broad area with very high moisture, north-west of H9, which is the consequence of drop by drop irrigation of that particular field at the time the flight was done (corn field). In the left side inside the yellow circle we can see a tongue of intense moisture due to a leak of a surface pipe.

In the moisture map in Figure 68 the rightmost orange ellipse is highlighting a trapezoidal area showing a high moisture index, oriented south-east from the water pipe, starting from the location marked with an pink arrow in the map (Figure 20) describing the ground measurements (at the junction between H12.1, H5 and H13.1). Indeed, in this area was found a potential leak (it is located 25.9 meters from GIS node reference “VS13.1VS9”, which is an air valve on the water pipe), see a close-up in Figure 69. The areas with high water index delineated with three orange ellipses in Figure 68 and in Figure 69 are actually interpreted as areas of higher moisture originating from runoff from the north-west uphill irrigated field.

A close-up of the moisture map near the air valve VS13.1VS9 is given in the next figure together with the pipelines.

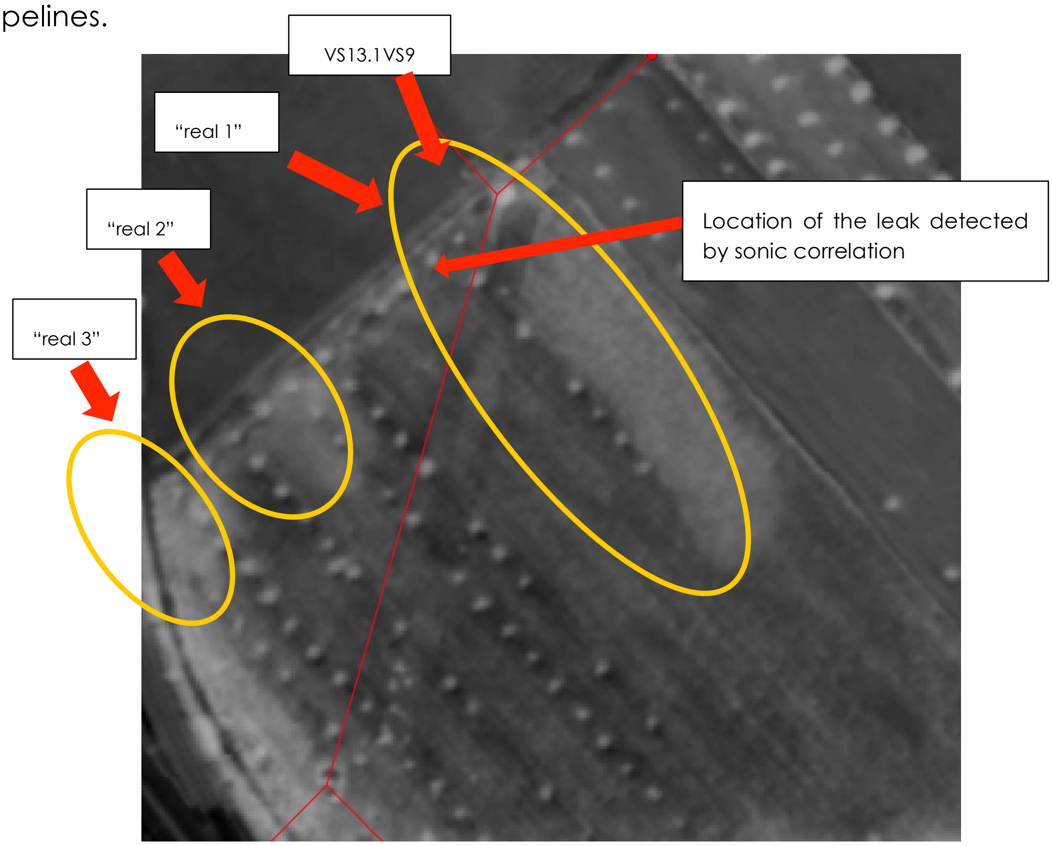

Figure 69 : Close up of the moisture map near air valve VS13.1VS9. Orange ellipses indicate areas with excess moisture that have been interpreted to be due to runoff from the irrigated field uphill in the north-west. A water leak was detected by SGI (sonic correlation) 25.9m south of VS13.1VS9 which roughly corresponds to the first olive tree along the pipe. Since the slope is downhill from north-west to south-east, the bright area (high WI) called “"real1" could be interpreted as a leak from VS13.1VS9; it should thus be classified as “false positive”. On the other side, since the bright areas called "real2" and “real3" are uphill from the pipe, they should be classified as “true negative”.

Other anomalies were found in the WI image as described in the following excerpts.

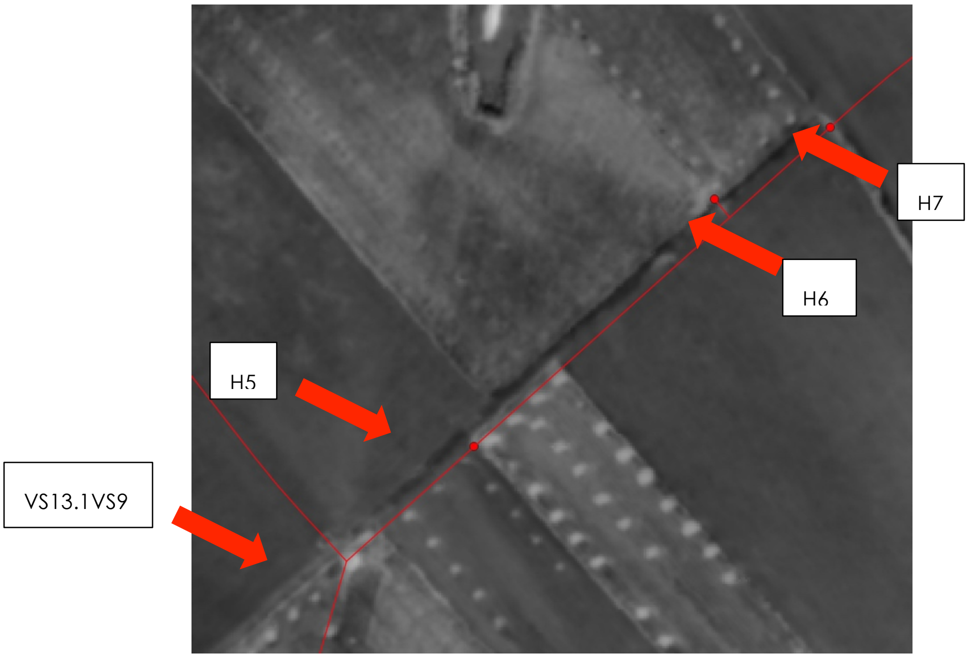

Figure 70 : WI map in the vicinity of hydrants H5, H6, H7. Moisture is significantly higher near H6; this high moisture area spreads in the north-west direction.

Figure 71 : WI map in the vicinity of hydrant H16.3. A small leak was detected by SGI at this hydrant. A slight moisture contrast (light grey) can indeed be seen in close vicinity of H16.3.

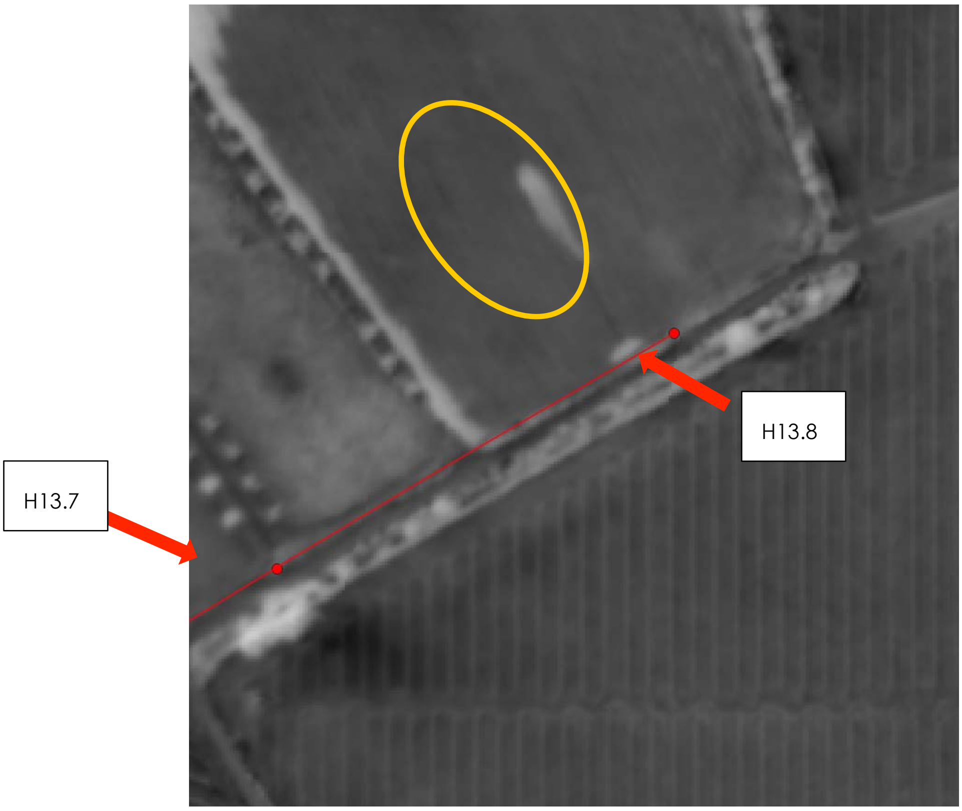

Figure 72 : WI map in the vicinity of hydrant H13.7 and H13.8. The bright spot south of H13.7 corresponds to a tree. A bright spot can also be seen close to H13.8, running south-west along the pipeline. Another elongated bright spot is highlighted by a yellow ellipse, in the north field. These two anomalies are not related to high vegetation and could thus be attributed to higher soil moisture. The presence of leak should be checked.

Figure 73 : WI map in the vicinity of hydrant H5.40 (left). The light grey area in the WI image around H5.40 is most probably related to the presence of denser or greener vegetation (as revealed on Google Earth image –right). A small water leak could thus be suspected.

Figure 74 : WI map in the vicinity of hydrant H5.55 and H5.56. Both concrete blocks have the same size, however, the water index reveals a brighter spot around H5.55 as compared to H5.56. It should be checked if there is a difference in soil coverage (green grass as compared to dry grass or bare soil?), which could be interpreted as the presence of a small water leak.

3.4.2 MAV –September 2019

3.4.2.1 MAV –September 2019 MONTE NOVO

The final results (i.e. the water index) over the Sao Manços area (Monte Novo bloc 2) are displayed below.

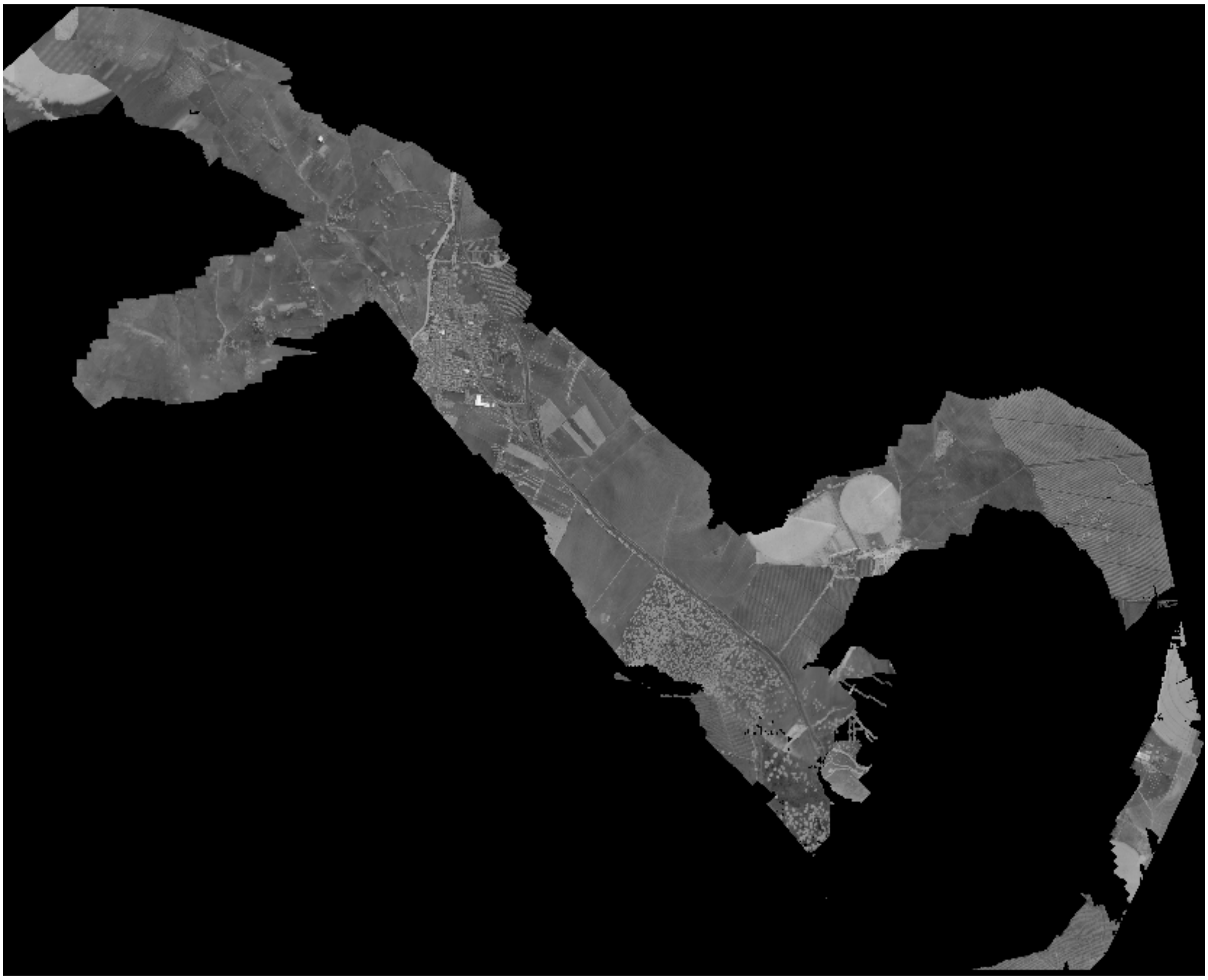

Figure 75 : Water index map over the Sao Manços area obtained on Sept. 11.

Below is a close-up over the suspected leak. It should be compared with Figure 43 of the moisture map obtained in May 2019. A "wet" area can be observed in September at the same place as what was suspected to be a leak in May (orange ellipses in fig. 43 and in the next figure). The "wet" area in September is however thinner than the bright area in May (in May the moist field extended from one olive line to the next one; in September it doesn't reach the west olive line). However, in September, two additional "wet" areas could be seen (as highlighted with a blue ellipse and a green ellipse), whereas nothing abnormal could be detected at these places in May. Notice also two other anomalies in the violet and red ellipses.

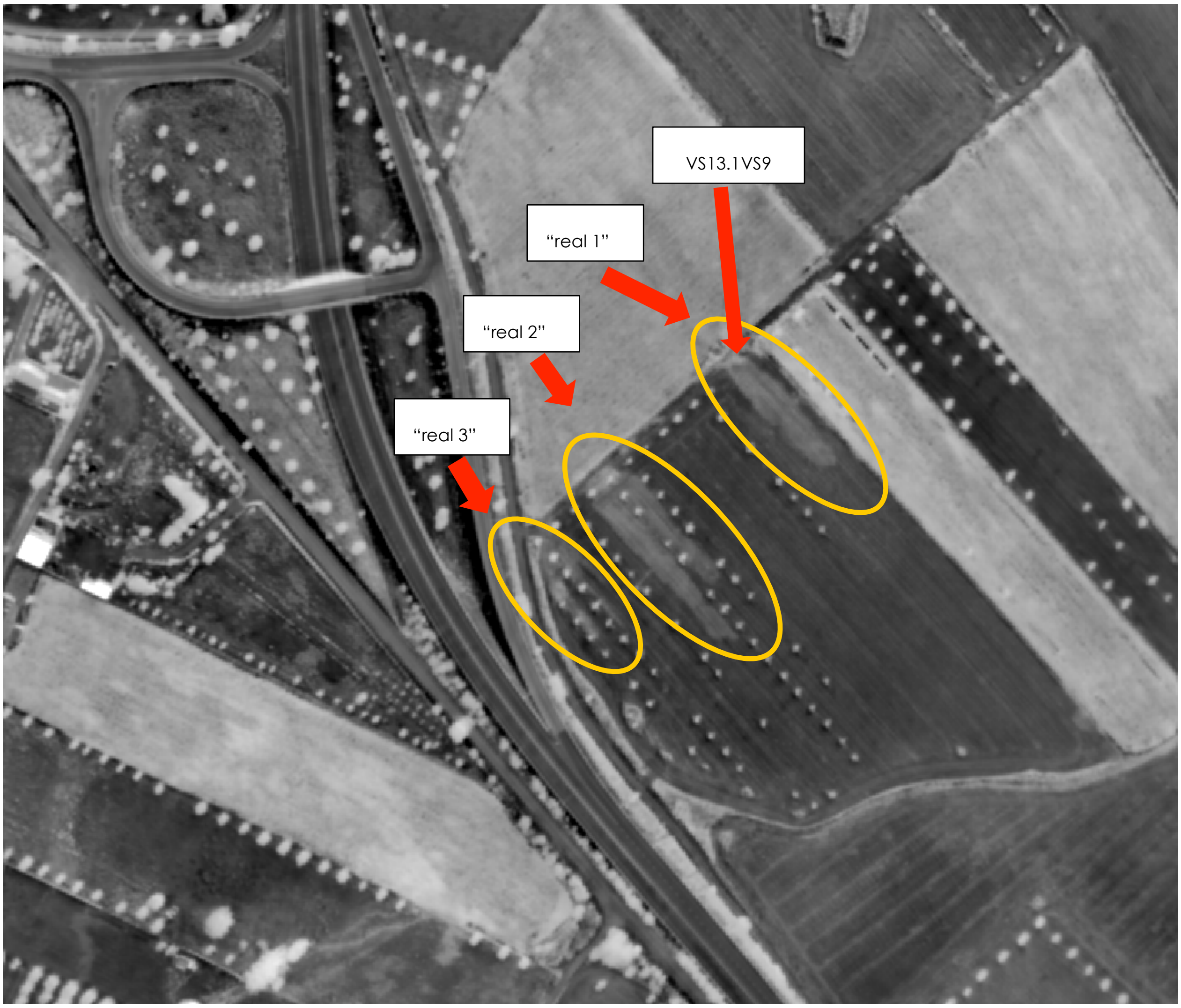

Figure 76 : Close-up of the WI map over the suspected leak area (Sept 11), Sao Manços

The Thermal infrared image obtained over the Sao Mancos area (before georeferencing and mozaïcking) is reported thereafter. It should be compared with Figure 68, Figure 69 of the moisture map obtained in May 2019 (beware the contrast in a thermal image and a water index image is of opposite sign!).

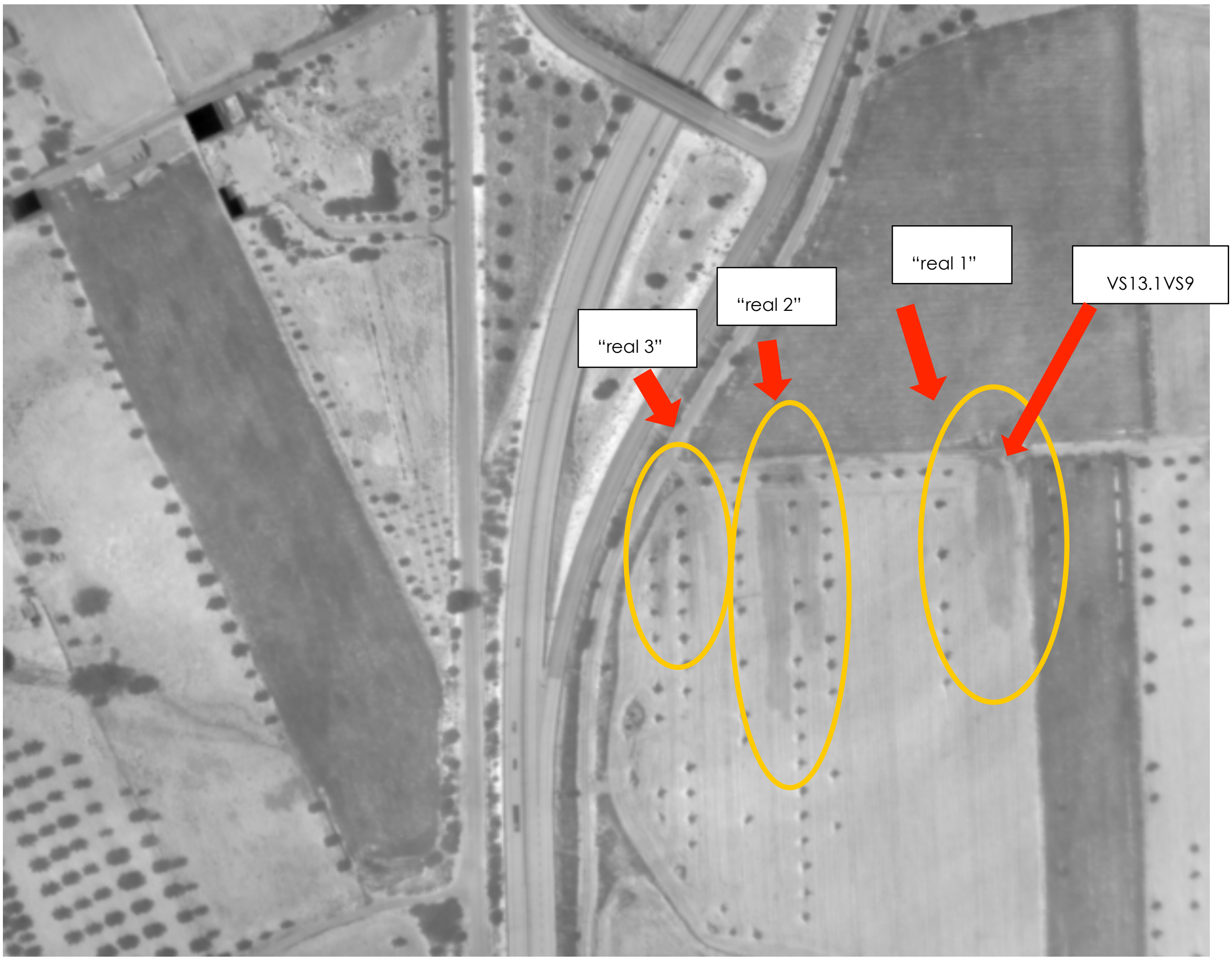

Figure 77 : Raw thermal image over the suspected leak area (Sept 11)

The results obtained after the flight performed the next day are reported below; they are quite similar.

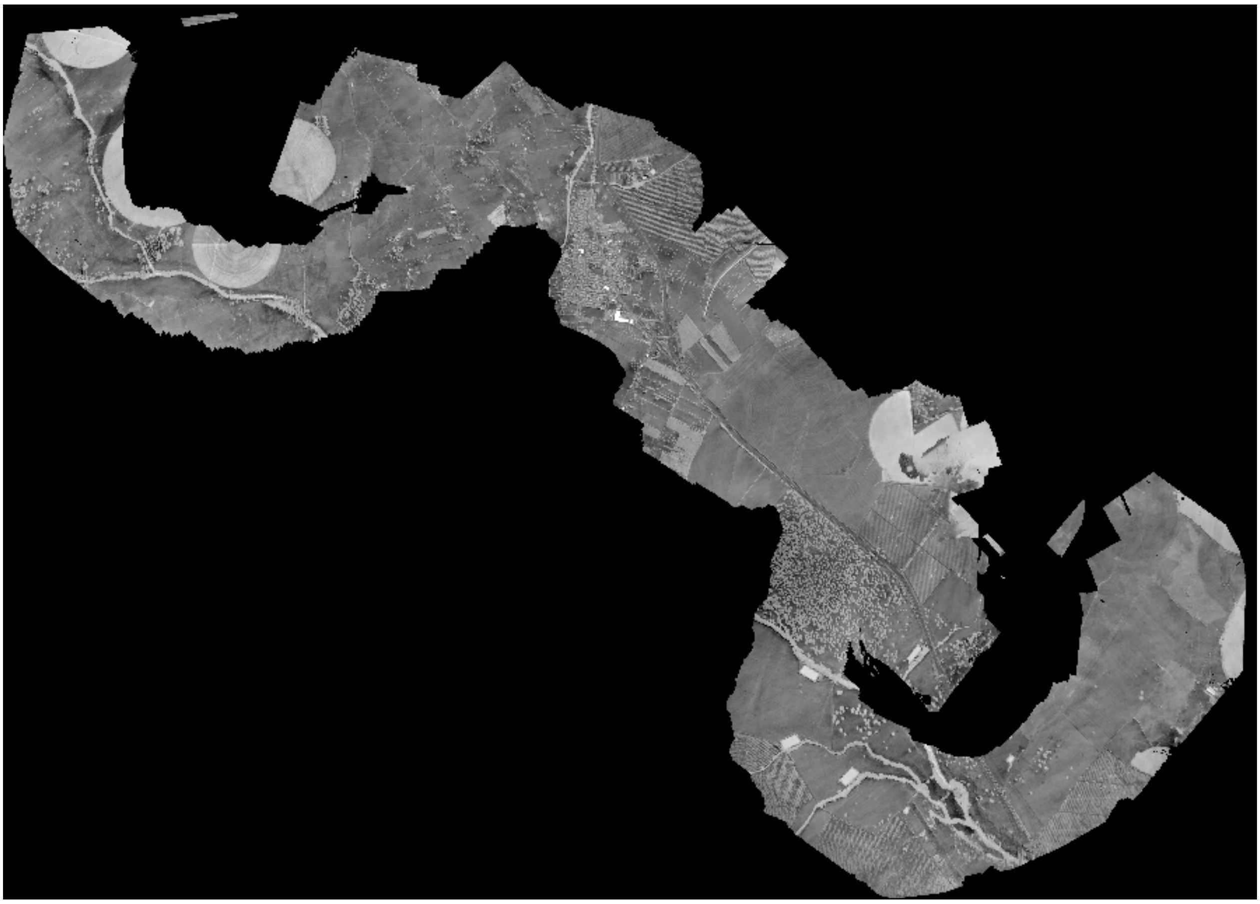

Figure 78 : Water index map over the Sao Manços area obtained on Sept. 12.

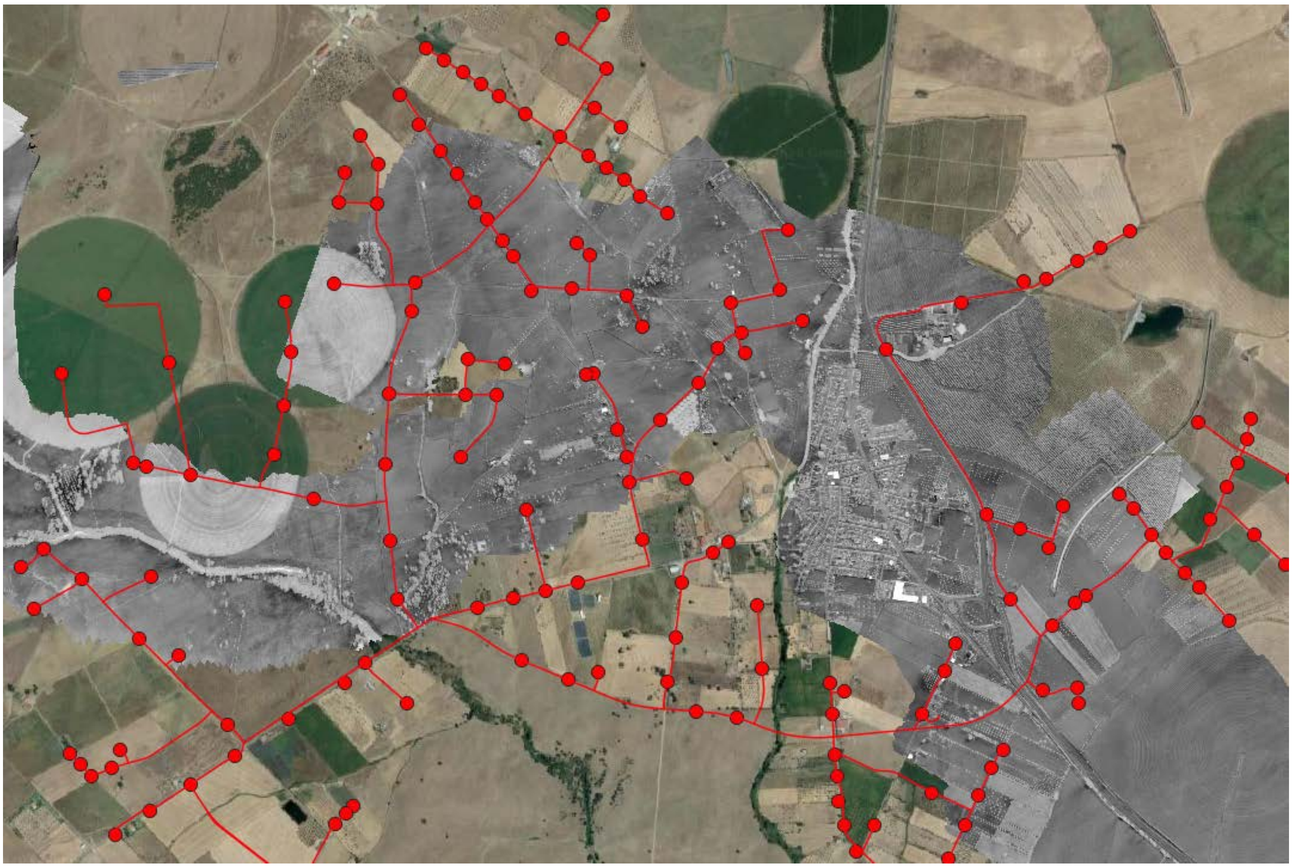

Figure 79 : Water index map (grey tone) over the Sao Manços area obtained on Sept. 12 together with the pipeline network (red lines with red dots for hydrants).

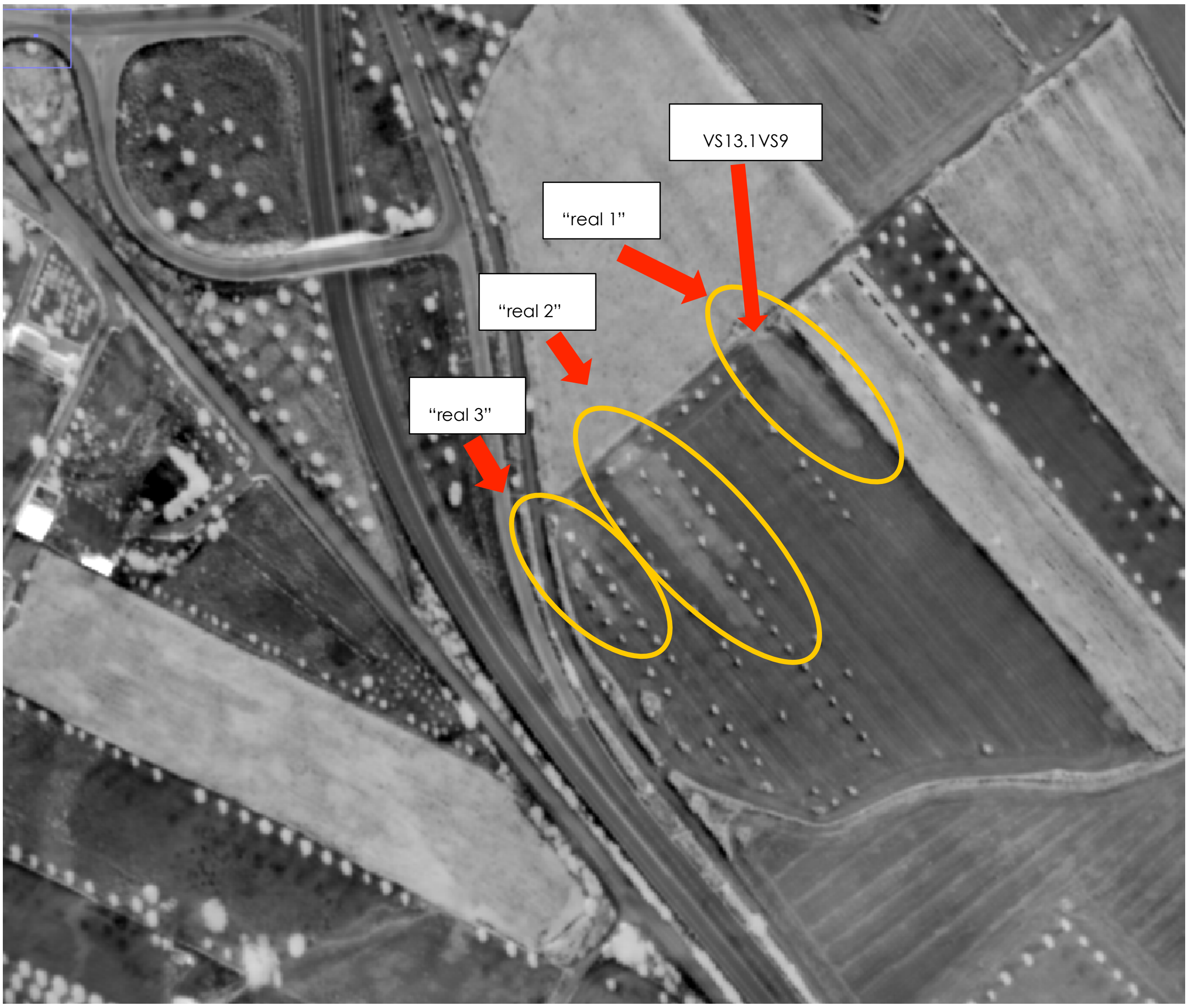

Figure 80 : Close-up of the WI map over the suspected leak area (Sept. 12). Notice that, as compared to the results obtained in May (see Figure 69), the area showing high water index called “real 1” is less elongated whereas it is the opposite for the areas called “real2” and “real3” (the most elongated of all three is now “real2”).

Figure 81 : Picture of the area close to the air valve VS13.1VS9, which is located in the concrete block at left.

After the WADI airborne campaign, EDIA dug the soil a few tens of meters south of VS13.1VS9, in the zone corresponding to "real 1". Below the surface, the soil was found dry as seen on the picture. Hence, the high water index in the zone "real 1" in Figure 69 and Figure 80 cannot be attributed to a real leak originating from the pipe at air valve VS13.1VS9.

3.4.2.2 MAV –September 2019 VALE DE GAIO

The mozaic of the water index in the Vale de Gaio area is given next (Sept 11 and Sept 12).

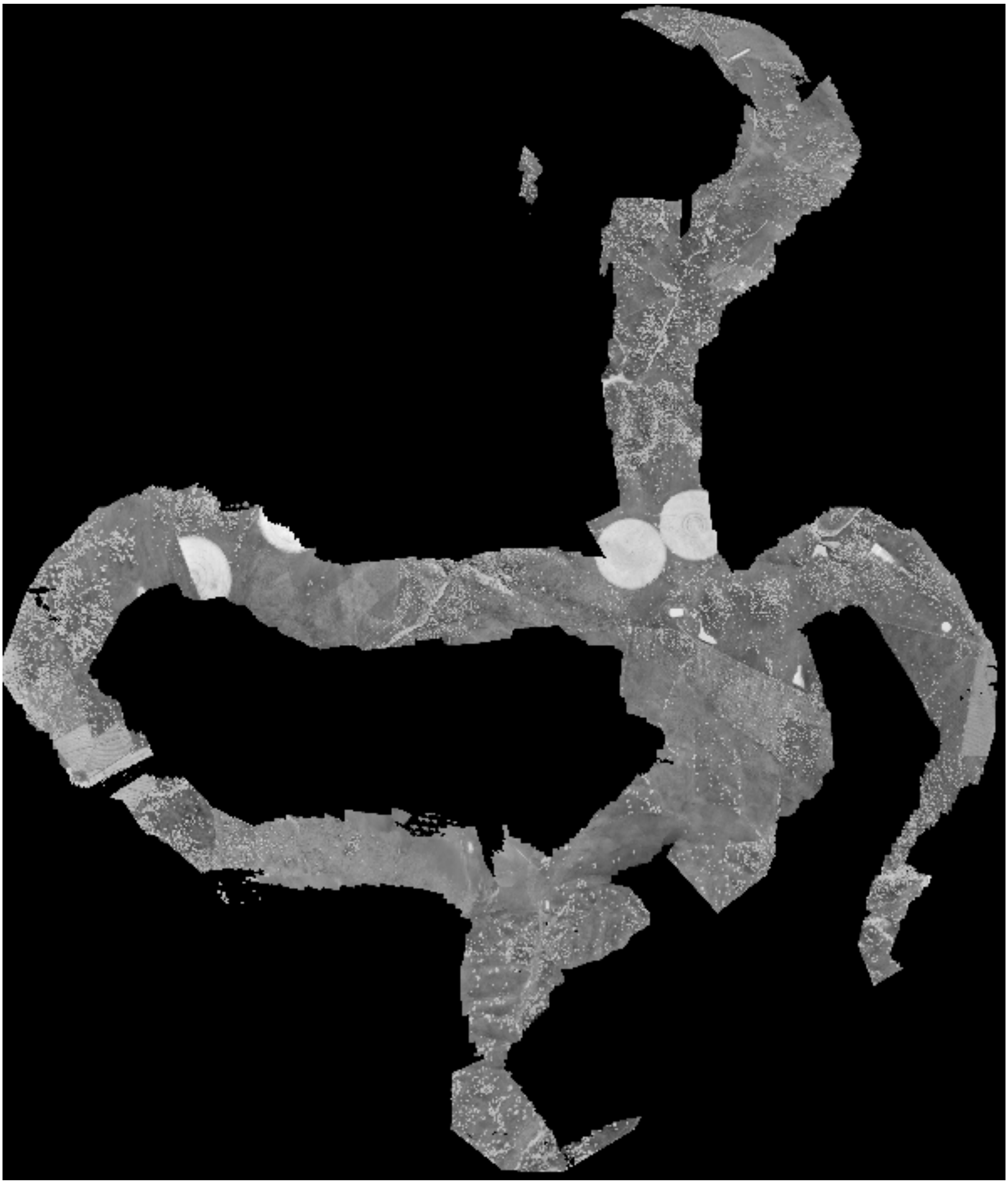

Figure 82 : WI map over Vale do Gaio area (Sept 11).

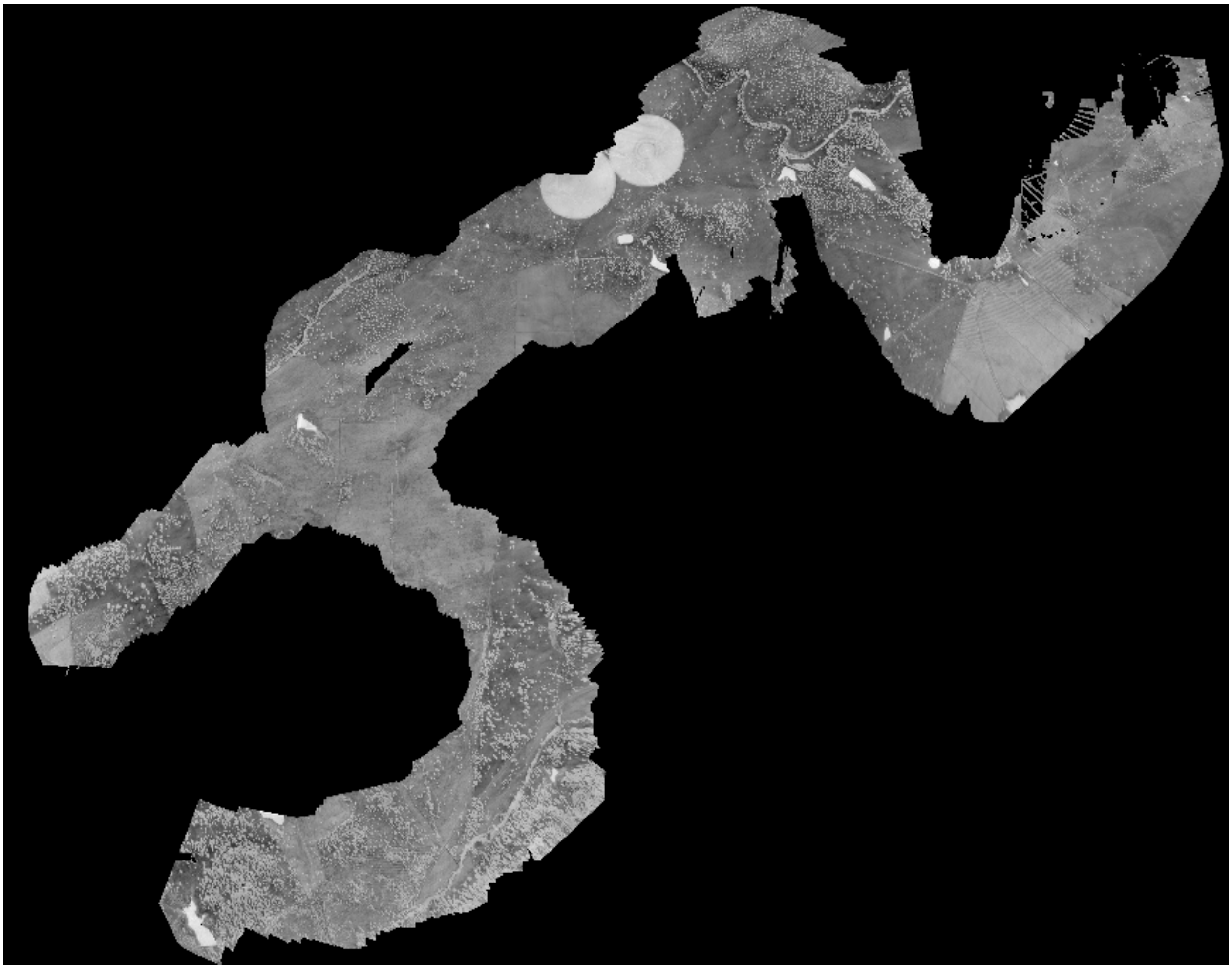

Figure 83 : WI map over Vale de Gaio area (Sept 12).

An excerpt of the area of Vale de Gaio reservoir is displayed below together with the water pipe network.

Figure 84 : Sept 11th. 2019, MAV flight, Close-up of the WI map near the reservoir. Two suspected leaks are highlighted with orange ellipses, Vale de Gaio.

Two areas highlighted by orange ellipses have shown high water index. A zoom is provided in the next two figures.

These areas have been interpreted as natural water flows originating from the water table, downhill of the reservoir.

Two other areas as revealed by magenta and green closed curves in Figure 84, south and south-east of the reservoir, showed a very low temperature.

Figure 85 : Vale de Gaio. WI image (Sept. 11th) of a suspected leak west of the reservoir.

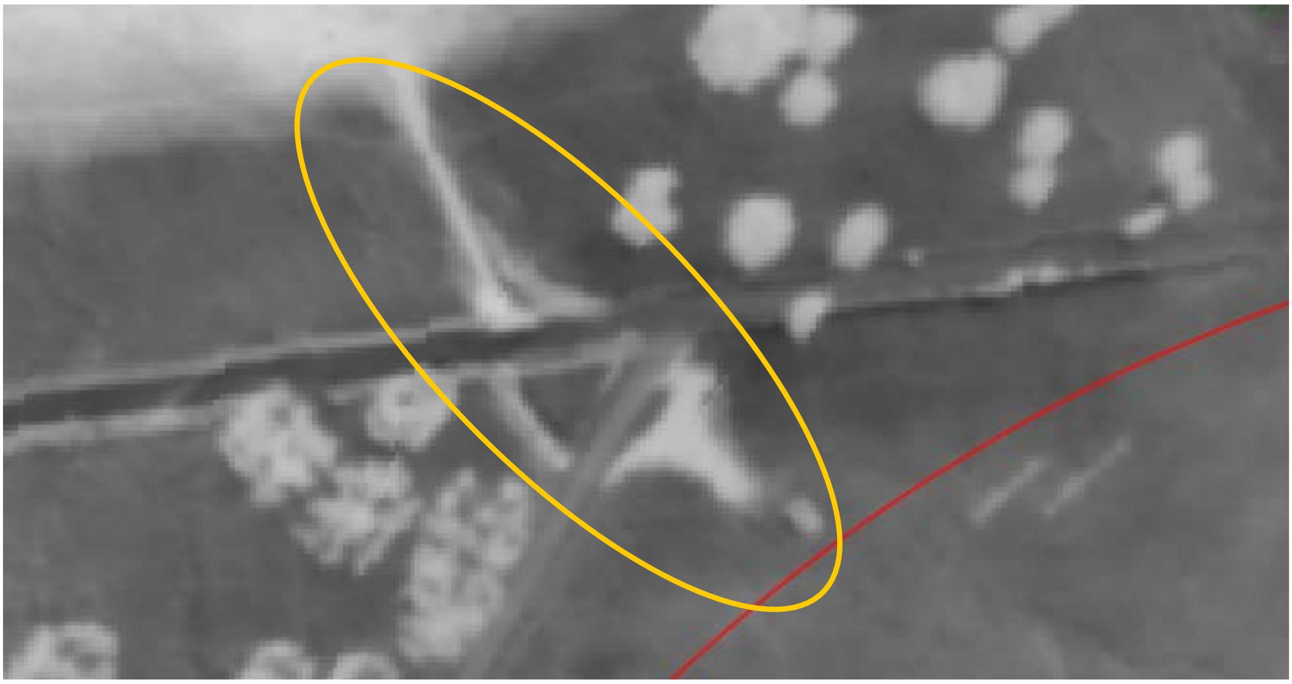

Figure 86 : Vale de Gaio. WI image (Sept. 11th) of a suspected leak north-east of the reservoir.

Water flow is running north-west from the concrete block and splits in two arms (light grey mark in the orange ellipse). The two arms run below the road and join downstream before reaching the irrigated circular area in the north.

Figure 87 : Picture of the area close to the air valve north east of the reservoir.

After the WADI airborne campaign, EDIA dug the soil close to the air valve, at the origin of the water flow seen on the surface and reported in Figure 86. The water flow was not attributed to a leak of the pipe running nearby. As a matter of fact, water was found in the hole that EDIA dug. Then During two weeks EDIA emptied the adductor and the reservoir but the water did not disappear in the dug hole, it kept the same level. A few days later, it rained and the level increased in the dug hole. The final interpretation is that the observed water is originating from the water table.

The next figure is a thermal infrared image of the area just south of the reservoir. It shows a strip of low temperature (hence the possible presence of water) along a path running south in the same direction as the pipeline.

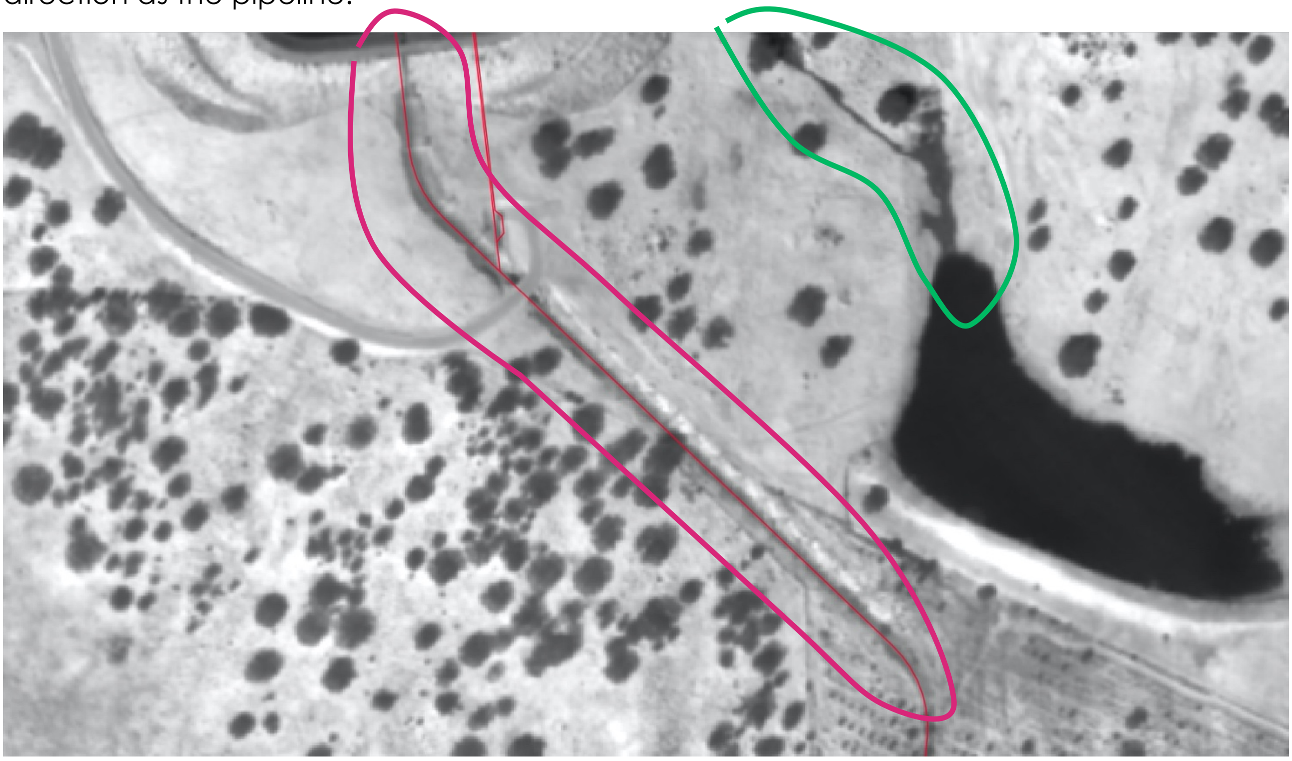

Figure 88 : Vale de Gaio. Thermal infrared image (top) (Sept. 11th) showing two anomalies with excessively low temperature running south and south-east of the reservoir.

A low signal (which means low temperature, hence a possible presence of water) is seen running along the spillway of the reservoir, starting south of the reservoir and then turning in south-east direction (see the magenta closed curve). Another “cold line” is observed south-east and is running towards a pond (see the green ellipse). A GoogleEarth image of the same area is provided at bottom.

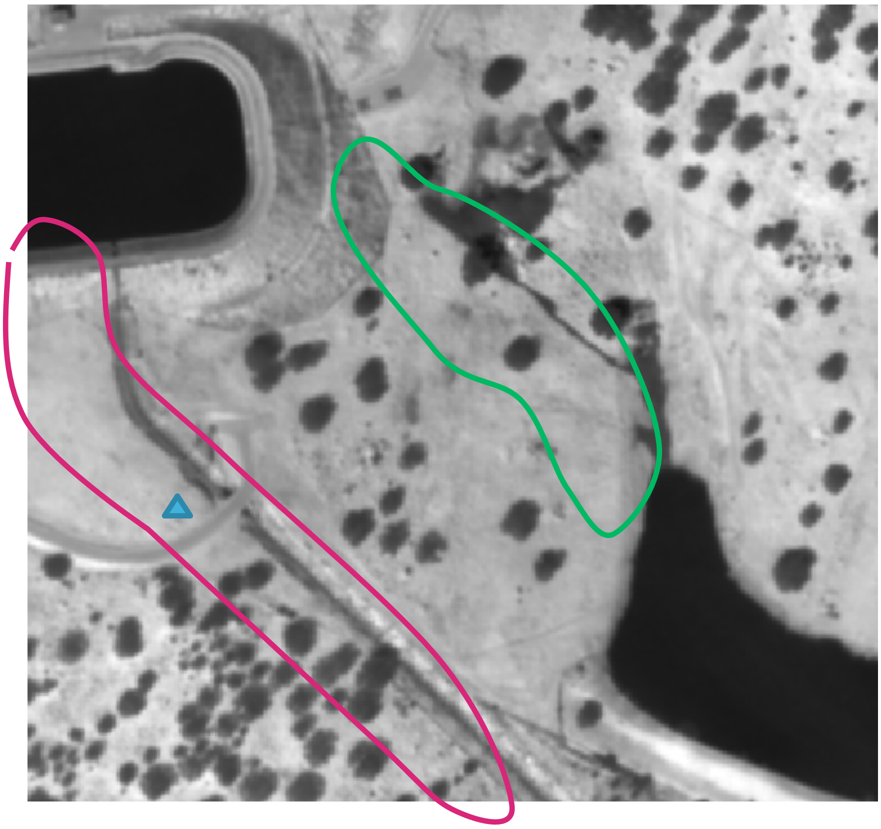

Figure 89 : Vale de Gaio. Thermal infrared image (Sept. 11th)

This figure is showing two anomalies (excessively low temperature) as delineated by magenta and green closed curves. The green closed curve shows a natural stream that flows south-east of the reservoir towards the pond below.

Figure 90 : Vale de Gaio. Picture taken from the road (see the blue triangle in Figure 89) in south-east direction.

It shows the spillway of the reservoir.

Figure 91 : Vale de Gaio. Picture taken in the direction of the pond, southeast of the reservoir.

The natural stream comes from the left in the picture and ends in the pond.

3.4.2.3 MAV –September 2019 FERREIRA

The next image provides a global view of the area that was covered by the MAV flight lines on Sept. 2019.

Figure 92 : Ferreira area, Sept 2019. MAV flights. WI image together with the water pipe network.

The next two figures are close-up images of the water index around the hydrants where an artificial leak was introduced (H9.7 and H16). Despite the low resolution, a clear contrast can be observed.

Next, by carefully analyzing the water index composite image of the whole "Ferreira" area, other spots were detected showing contrast anomalies, namely showing a water index level substantially higher than in the surroundings. This could be related to potential leaks. Therefore, EDIA was asked to go and check onsite if the unexpectedly high water index was really revealing a water leak at those places.

A field visit was made on April 16th, 2020. The weather conditions were good; however, it rained around 30 mm during the previous 24 hours. It's very important to stress that the actual soil occupation, weather conditions and soil moisture are totally different from the conditions found when the WADI flights were made back in September 2019.

In order to have reliable results and information it is absolutely mandatory that the time between the flights and the field verification must be less than one month so that conditions are as equal as possible at both moments.

Figure 93 : Ferreira area. Hydrant H9.7 (artificial leak).

A high contrast is observed in the water index image which is attributed to the high moisture of the soil near the hydrant.

Figure 94 : Ferreira area. Hydrant H9.7. Photo taken on April 16, 2020 in west direction (see Figure 37 for a picture taken in Sept. 2019).

The hydrant was not used for irrigation last campaign in Sept. 2019 but it was used for simulating a leak. The presence of vigorous weeds seven months later might indicate the existence of a possible *real leak* but at the same time it is normal to find this kind of vegetation near the infrastructures due to the absence of herbicides or soil harrowing.

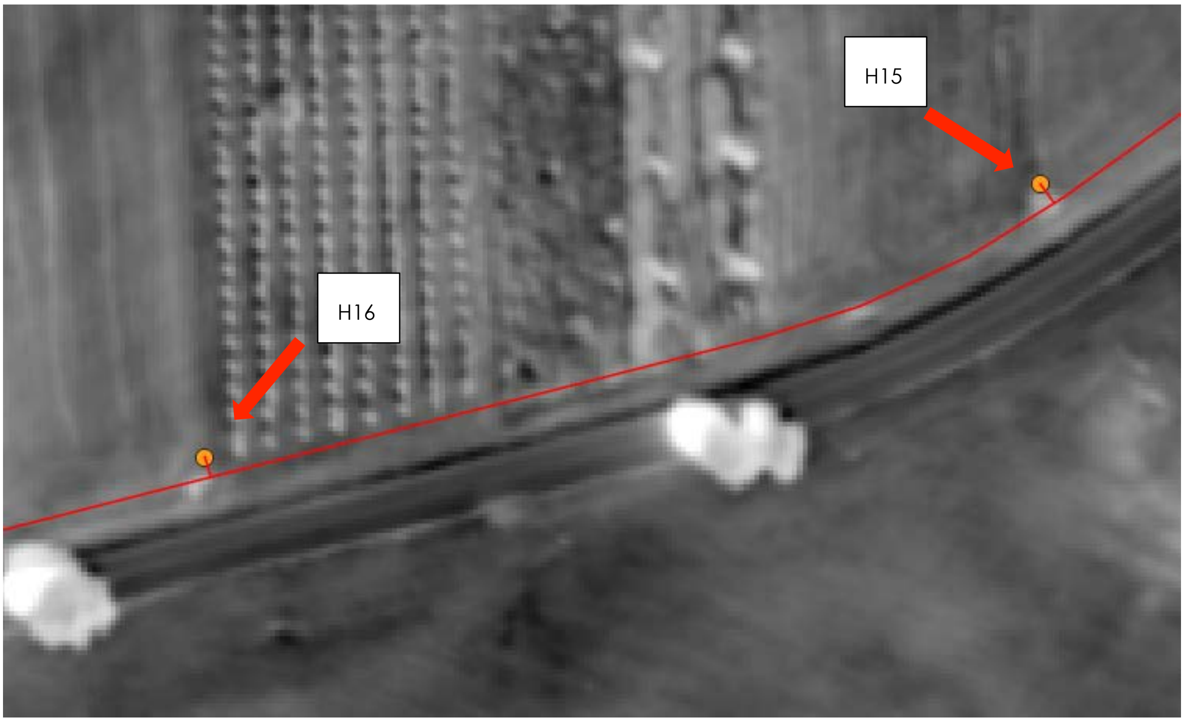

Figure 95 : Ferreira area. Artificial "leak" at hydrant H16 (left).

A significant contrast of the water index is observed in close proximity (it is nevertheless lower than at hydrant H9.7 – compare with the previous figure). A significant contrast is also observed near hydrant H15 (right). This anomaly should be checked for a potential leak.

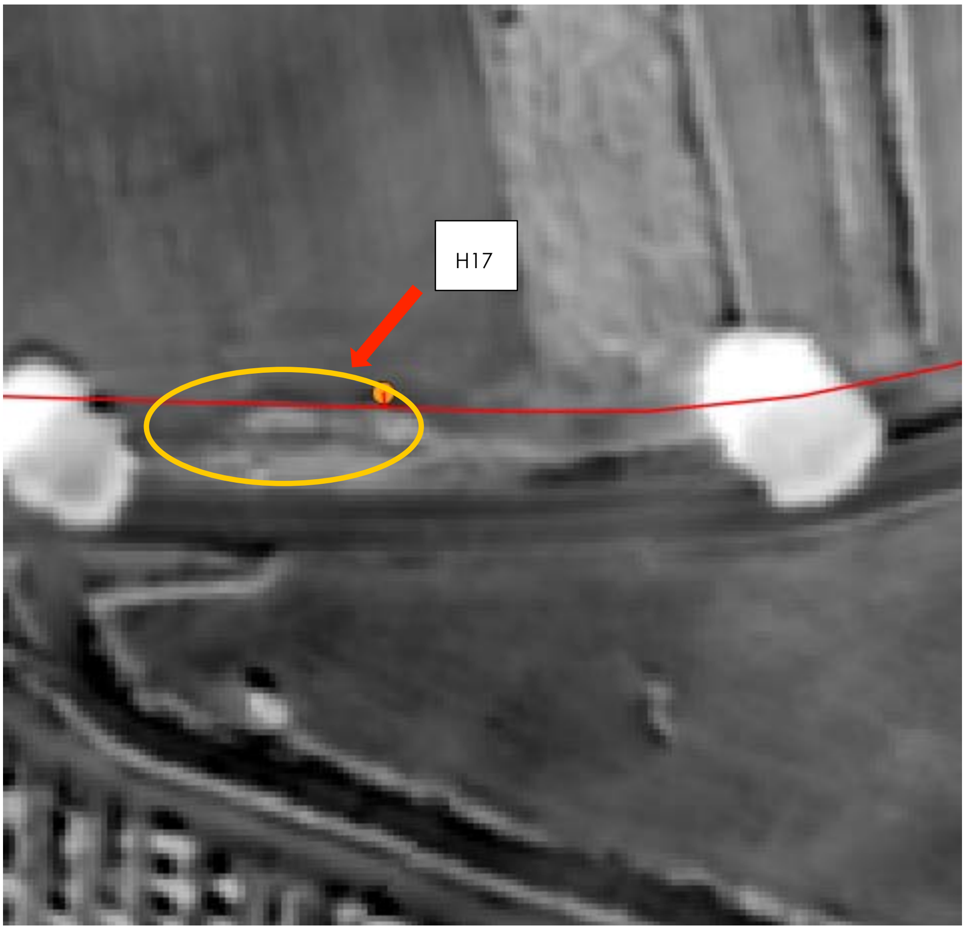

Figure 96 : Ferreira area. Hydrant H17.

A large area with high water index is seen spreading on both sides of H17 (see the orange ellipse). This anomaly was checked for a potential leak.

Figure 97 : Ferreira area. Hydrant H17. Photos taken on April 16, 2020 in northwest and north direction.

The hydrant is located in a low point which can lead to water accumulation at this spot, from rain and irrigation water (see the puddle south of the left bloc). The presence of weeds in the interval between the two concrete blocks might indicate the existence of a possible leak but at the same time it is normal to find it here due to the absence of herbicides or soil harrowing.

Figure 98 : Ferreira area. Hydrant H12.20.

The water index image shows very high contrast over a large area extending north-east from hydrant H12.20. This anomaly was checked for a potential leak.

Figure 99 : Ferreira area. Hydrant H12.20. GoogleEarth image from July 16th 2019.

In this summer day, a dark area is seen which is fully correlated with the high water index area in the previous figure, northeast from the hydrant (the dark area could be due to green vegetation or to moist bare soil).

Figure 100 : Ferreira area. Photo of Hydrant H12.20 taken on April 16, 2020 in north direction.

It's very clear that the water accumulation detected is due to a soil depression that keeps water from the area.

Figure 101 : Ferreira area. Hydrant H15.7.

The water index image shows high contrast over a large area extending south from hydrant H15.7 towards the road. This anomaly should be checked for a potential leak. Remark: the bright area on the other side of the road corresponds to a group of trees and ruins.

Figure 102 : Ferreira area. Photo of hydrant H15.7

Picture taken on April 16, 2020 in south direction, with trees and an abandoned house on the other side of the road. The hydrant was used for irrigation last campaign. There might been a leak from the connections between the hydrant and the farmer's infrastructure.

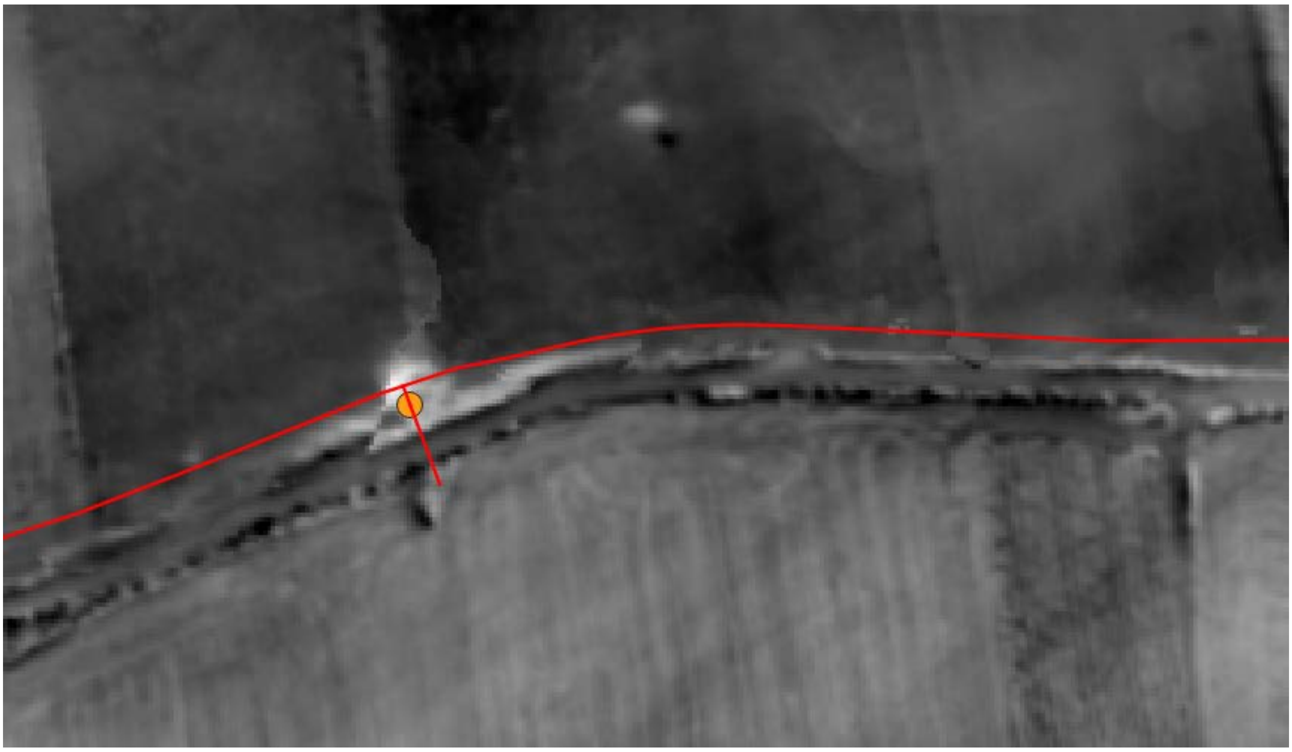

Figure 103 : Ferreira area. Hydrant H15.3.

The water index image shows high contrast over a large area extending north of the hydrant H15.3. This anomaly should be checked for a potential real leak. Remark: the cut running north east and then waving in the north direction is a stitching artifact of the mosaicking process.

Figure 104 : Ferreira area.

Photos of hydrant H15.3 taken on April 16, 2020 in northeast and north directions. The hydrant was used for irrigation during last campaign. It is located at a low point which can lead to water accumulation at this spot, from rain or irrigation water.

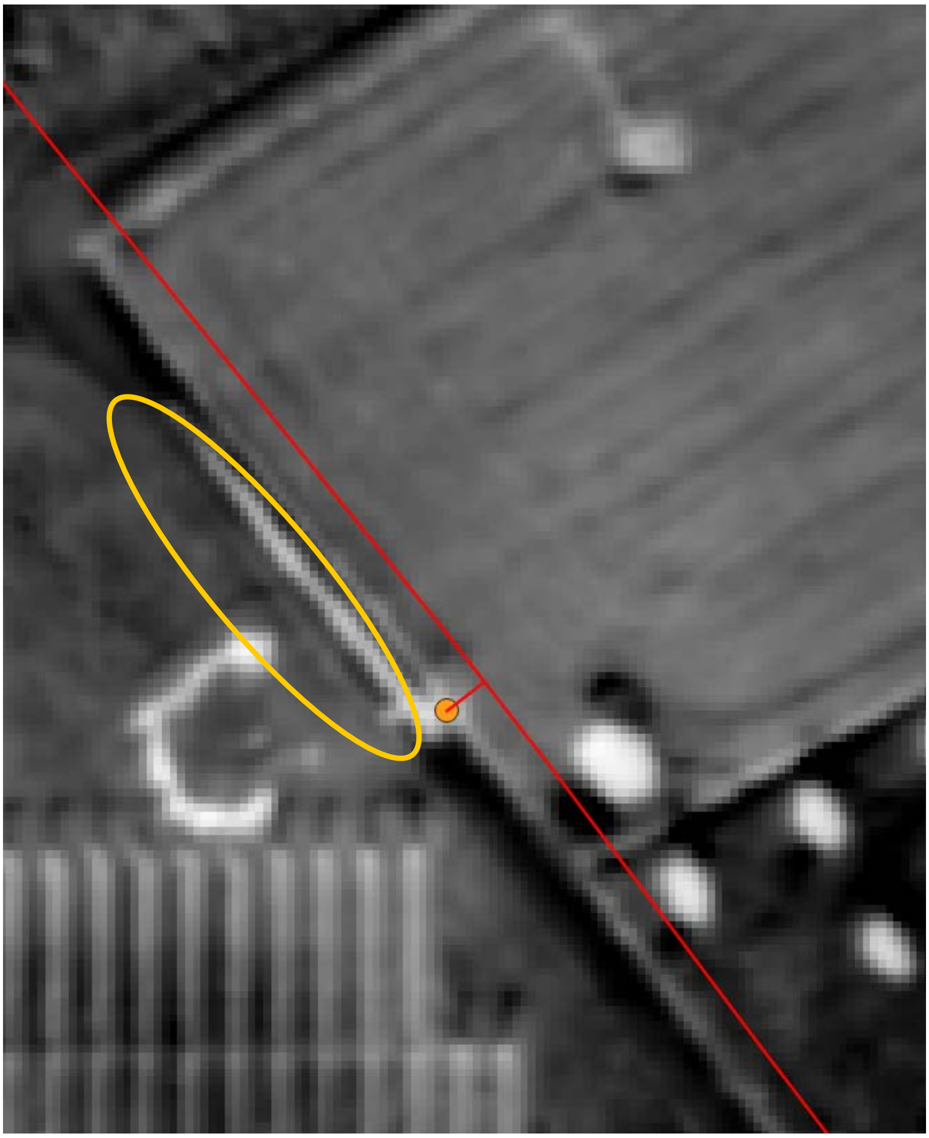

Figure 105 : Ferreira area. Hydrant H10.

The water index image shows high contrast over a stripe running north east from hydrant H10 (see inside the orange ellipse). This anomaly should be checked for a potential leak (unfortunately, on April 16, 2020, there was no access to this area). Remark: the vertical stripes in the bottom left corner of the image correspond to solar panels. The very bright arc north of them is of unknown origin.

Figure 106 : Ferreira area. Hydrant H7.

The bright spot in the WI image (left) near Valve 29-V is probably due to high vegetation (see GoogleEarth image on right). An elongated area showing high moisture, running south from hydrant H7 (see inside the orange ellipse) is perhaps due to water leak which should be checked.

Figure 107 : Ferreira area. Photo of hydrant H7 taken on April 16, 2020 in northwest direction.

The detected possible leak is inside the social area of the farm. It can be related to some material or some natural pond from washing water.

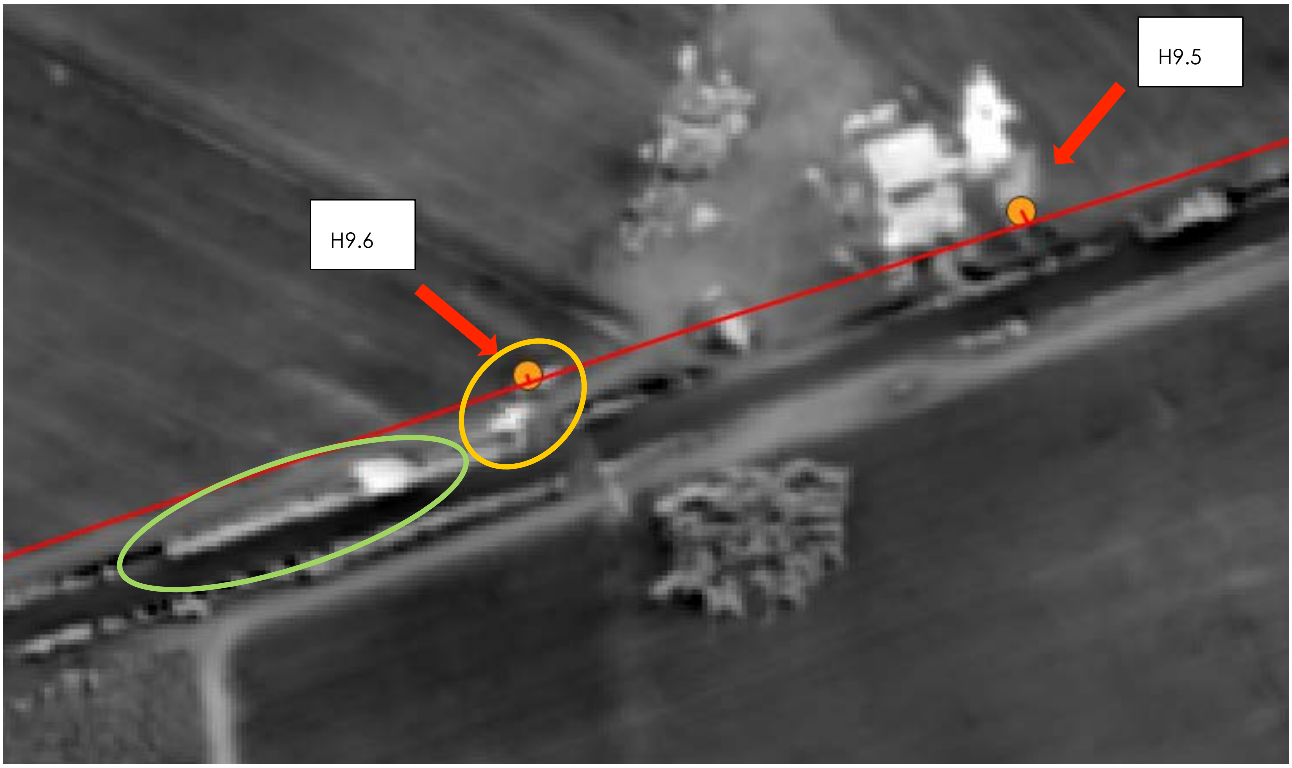

Figure 108 : Ferreira area. Hydrants H9.6 and H9.5.

The water index image shows a few areas with high contrast south west from hydrant H9.6. The one highlighted with an orange ellipse could be attributed to soil moisture and should be checked for a potential leak. The area highlighted with a green ellipse is most probably related to high vegetation (bushes) and shadows.

Figure 109 : Ferreira area. Photo of hydrant H9.6 taken on April 16, 2020 in west direction (H9.7 is at background on the top of the picture).

The hydrant was used for the irrigation of melon during last campaign. The presence of canes along the road suggest a permanent source of water at that spot which is almost certainly due to its low position where water accumulates from the surroundings, from rain or irrigation water (on April 16Th, after 30mm of rain during the past 24 hours, a large puddle can be seen between the hydrant and the road).

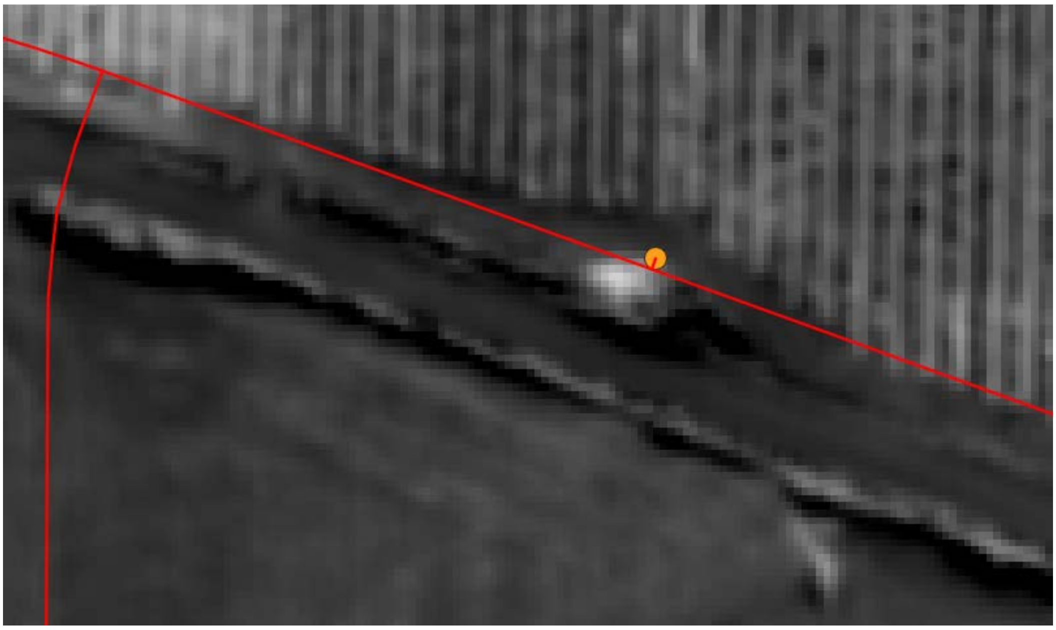

Figure 110 : Ferreira area. Hydrant H9.10.

The water index image shows high contrast over an area spreading south from hydrant H9.10 to the road. This anomaly should be checked for a potential leak.

Figure 111 : Ferreira area. Photo of hydrant H9.10 taken on April 16, 2020 in west direction.

The hydrant was not used for irrigation during last campaign.

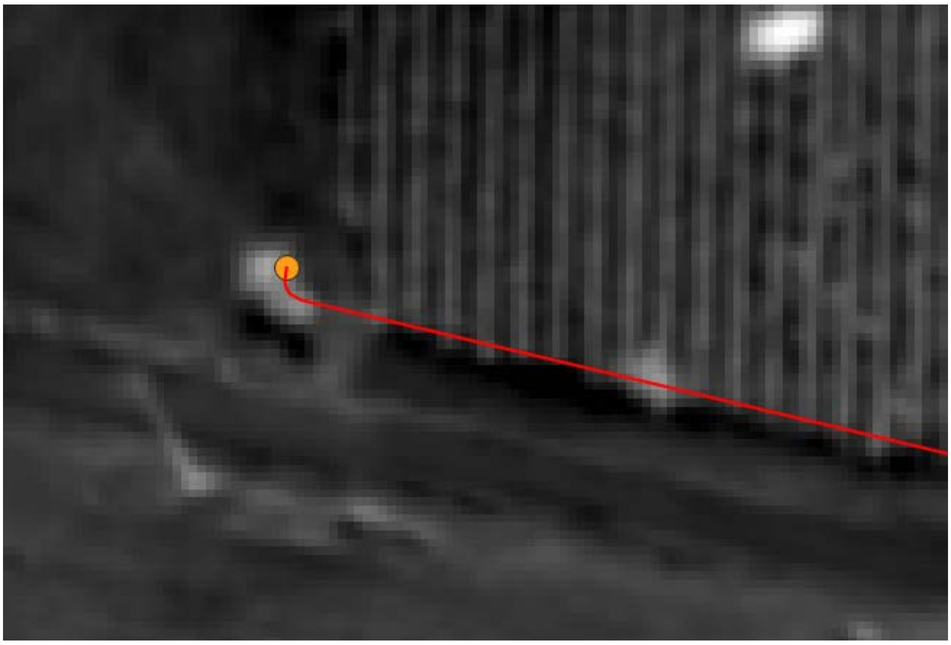

Figure 112 : Ferreira area. Hydrant H9.11.

The water index image (top) shows high contrast over an area spreading south from hydrant H9.11. This anomaly should be checked for a potential leak. There are also two bright spots in the field on the right of H9.10 that are not related to any high vegetation or building in the GoogleEarth image (bottom). The bright spot along the pipeline should be checked for a potential leak.

Figure 113 : Ferreira area. Photos of hydrant H9.11 taken on April 16, 2020 in west and east directions.

The hydrant was not used for irrigation during last campaign. The right picture shows the drip lines of the olive plantation which always lead to water accumulation in the lower spots.

Figure 114 : Ferreira area. Hydrant H9.18.

The water index image (left) shows high contrast near hydrant H9.18. This anomaly should be checked for a potential leak. On right is a GoogleEarth image July 16th, 2019.

Figure 115 : Ferreira area. Photos of hydrant H9.18 taken on April 16, 2020 in northwest and southwest directions.

The hydrant was used for irrigation during last campaign. There might been a leak from the connections between the hydrant and the farmer's infrastructure. At the same time, the hydrant is located in a low point which can lead to water accumulation at this spot, from rain or irrigation water.

Figure 116 : Ferreira area. Hydrant H17.4.

The water index image (left) shows an anomaly between hydrant H17.4 and the road. This anomaly should be checked for a potential leak.

Figure 117 : Ferreira area. Photo of hydrant H17.4 taken on April 16, 2020 in north direction.

Water accumulation close to the hydrant which is located in a low point and right next to the road that acts as a small dam, leading to water accumulation at this spot, from rain or irrigation water.

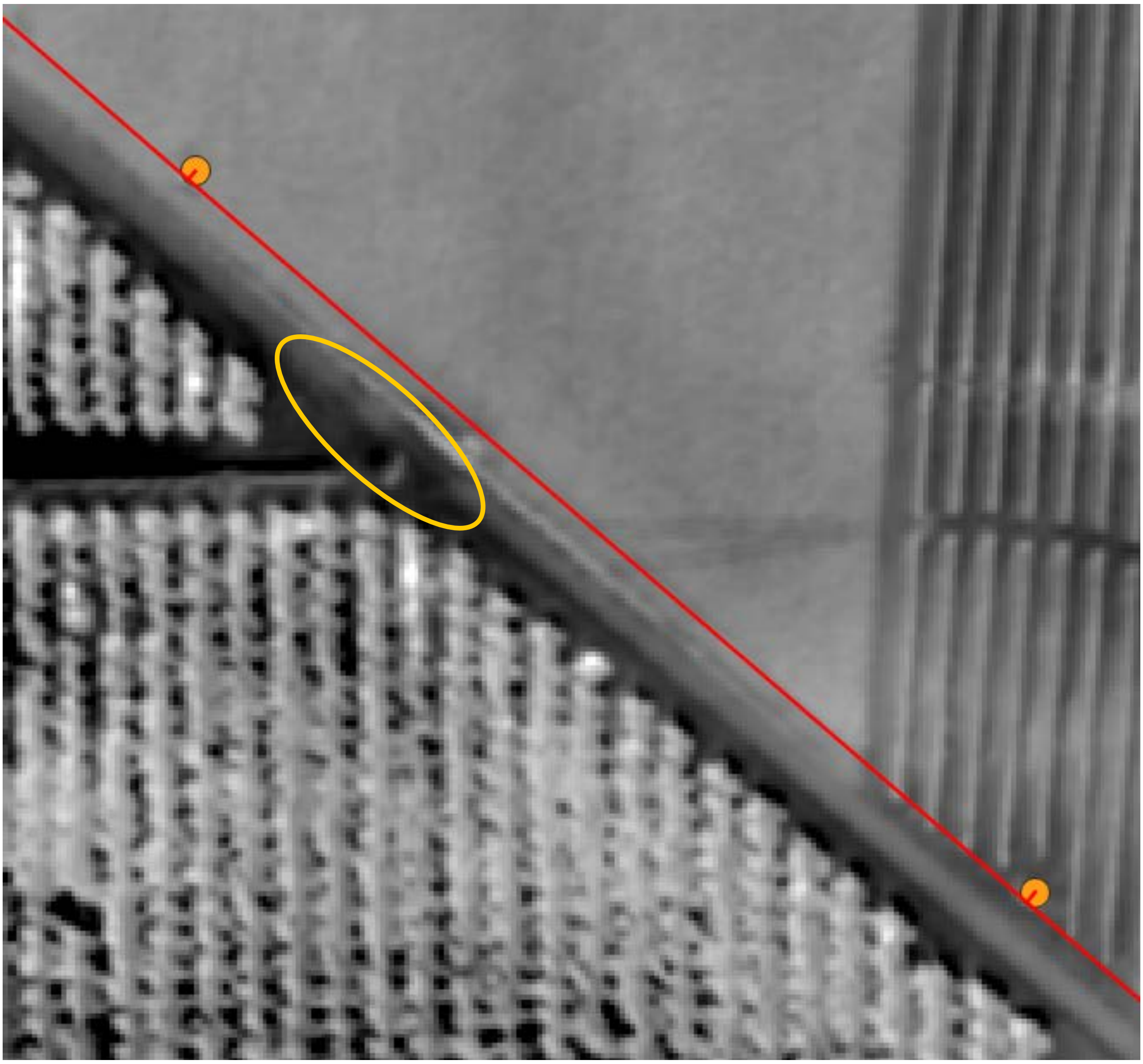

Figure 118 : Ferreira area. Between Hydrant H17.2 (bottom right) and H17.3 (top left).

The water index image shows an anomaly between these two hydrants at the location of valve 17.4-DF (see inside the orange ellipse). This anomaly should be checked for a potential leak.

Figure 119 : Ferreira area. Left: side road along C17 pipe in northwest direction.

In this image we can see water accumulation close to the 17.4DF (discharge valve) near to H17.2. This specific area is located in a low point which can lead to water accumulation at this spot, from rain or irrigation water. Right: same in in southeast direction where we can see H17.4, H17.3 and H17.2.

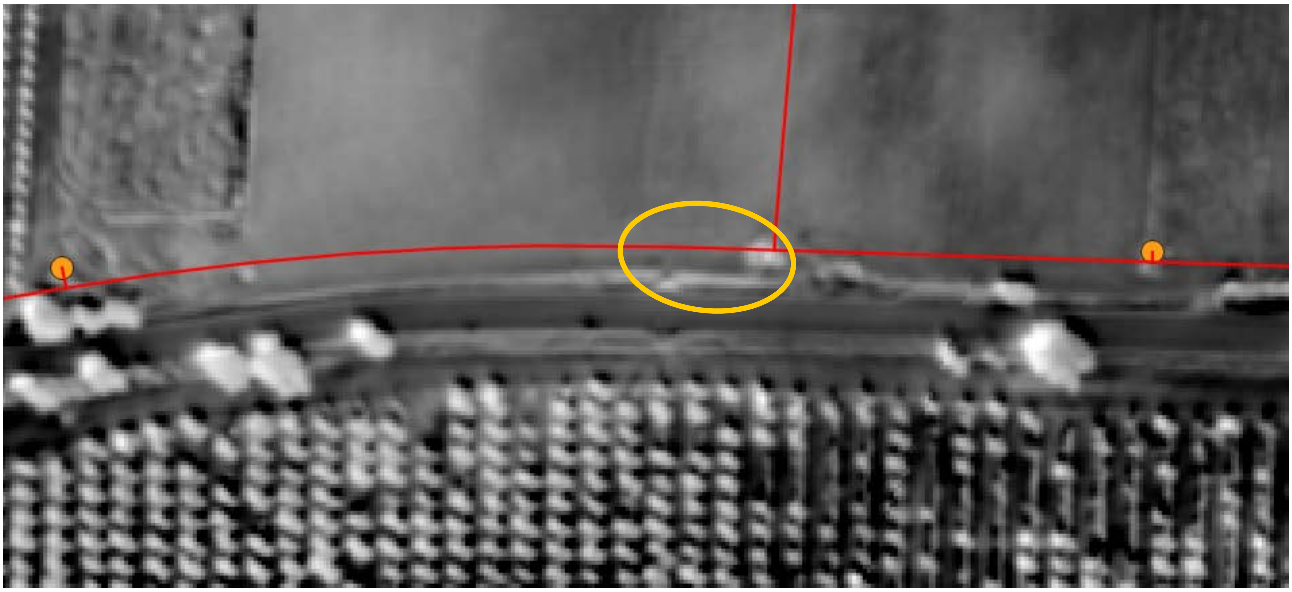

Figure 120 : Ferreira area. Between Hydrant H21 (right) and H22 (left).

The water index image shows an anomaly between these two hydrants at the location of valve 66-V (see inside the orange ellipse). This anomaly should be checked for a potential leak.

Figure 121 : Ferreira area. Photo taken on April 16, 2020 between H21 and H22 in west direction.

No water seems present, yet high vegetation can be seen.

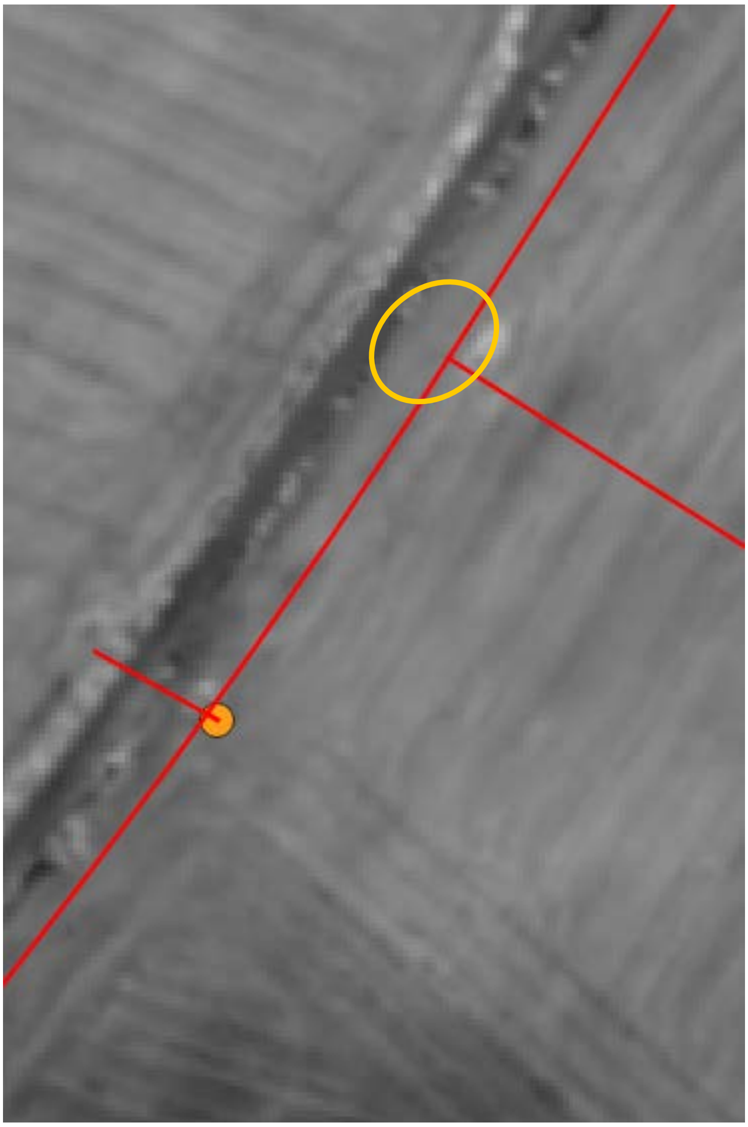

Figure 122 : Ferreira area. Hydrant H12.12.

The water index image shows an anomaly close to the junction north of H12.12, where is located the valve 12.5-VS (see inside the orange ellipse). This anomaly should be checked for a potential leak.

Figure 123 : Ferreira area. Photo taken on April 16, 2020 of the junction 12.5-VS

This area is located at a low point which can lead to water accumulation, from rain or irrigation water.

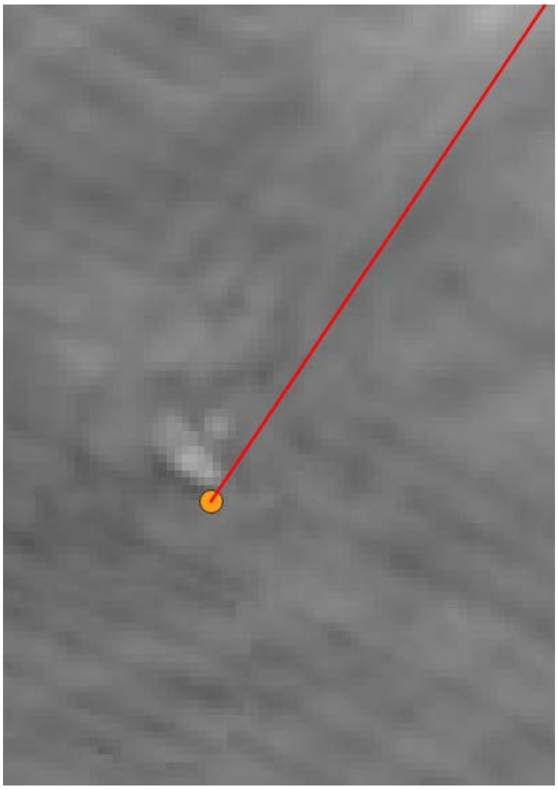

Figure 124 : Ferreira area. Hydrant H12.13.

The water index image shows an anomaly close to the hydrant H12.13. This anomaly should be checked for a potential leak (unfortunately, there was no access on April 16, 2020 to take a picture).

3.4.3 UAV – May 2019

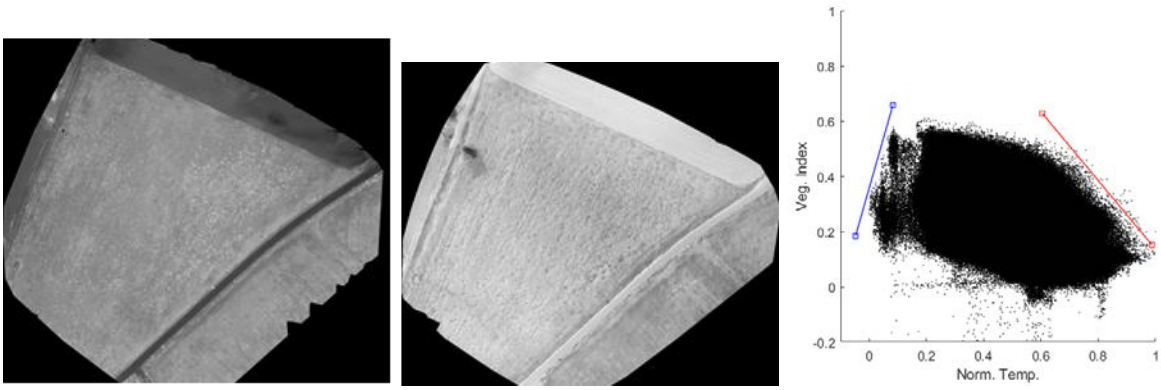

Figure 125 : Artificial leak H10 14-05-2019: 14:07. Left: OSAVI image. Middle: TIR image. Right: Scatterplot of temperature vs. vegetation index.

Figure 126 : Artificial leak H10 (left: 14-05-2019: 14:07– and after the vane was opened – right: 16-05-2019: 14:36).

Map of water index as inferred from TIR and OSAVI images. The presence of moisture is mostly seen in the TIR image. Two moist areas can be observed: one of small extend, oriented east presenting a high contrast (this is the result of the leak performed on the same day), and another one, of larger extent, oriented south-east, with a lower contrast which encompasses the former (this is the result of the leak performed two days before)

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Figure 127 : Map of water index (second flight, on 16-05-2019 - 14:57, H10, Monte Novo

it combines an irrigated corn field in the first phenologic stages, a bare soil field, some trees and the H10 field with vegetation (half a meter high).

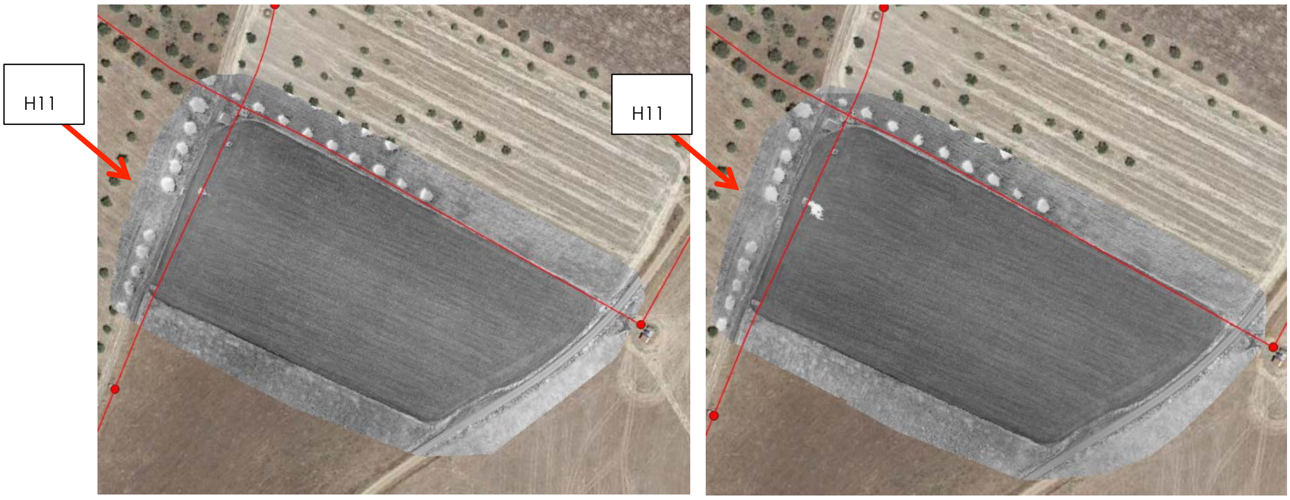


Figure 128 : Artificial leak H11 (water leak on 14-05-2019, the same day as the UAV flight). Left : before, right: after the water leak

Map of water index as inferred from TIR and OSAVI images. The contrast between wet soil and dry soil is very high. The presence of moisture is seen in both OSAVI and TIR images but with a higher contrast in the TIR image.

Figure 129 : Artificial leak H5.6 (16-05-2019 - 16:19)

Map of water index as inferred from TIR and OSAVI images. The presence of moisture is mostly seen in the TIR image.

Figure 130 : Monte Novo. WI image of a corn field with drip irrigation.

3.4.4 UAV – September 2019

3.4.4.1 UAV – September 2019 MONTE NOVO

The UAV was operated in the Monte Novo site over the field crossed by a pipe which was suspected to present a water leak (close to valve VS13.1VS9, west of hydrant H5).

A ground truth measurement, carried out simultaneously, has shown that the mean moisture level was about 13% along the leak area while reaching locally 23%, whereas it was only about 7% a few meters aside. Sparse green vegetation (short grass) could be seen along the leak area, as opposed to dry vegetation away from it.

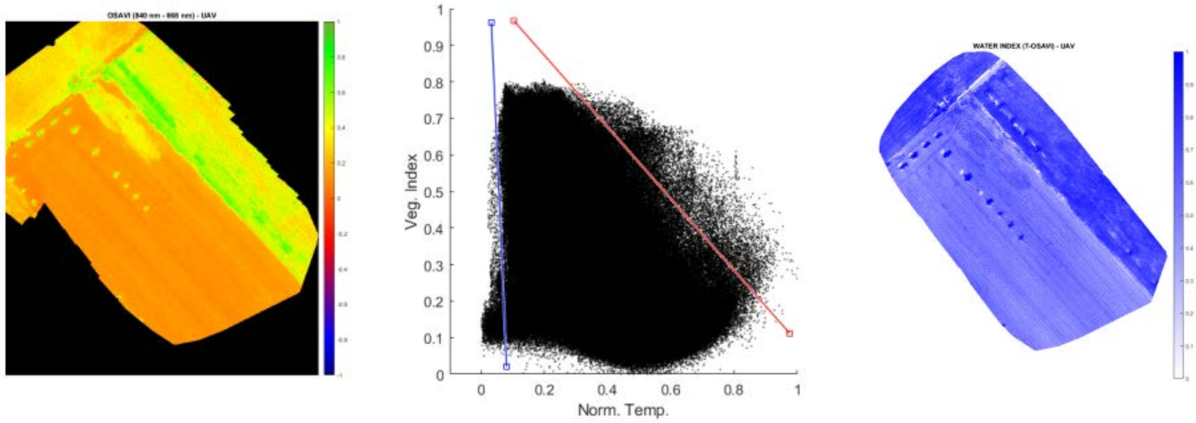


Figure 131 : OSAVI vegetation index map (left), triangle scatterplot (middle) and WI map (right) obtained with the UAV. Sept 10

A multi-temporal analysis was performed with the UAV. In the next three sets of figures are reported the images of OSAVI, brightness temperature and water index (WI) recorded at 16h, at 18h, and just after sunset at 20h. The vegetation index is expected to be constant, yet, due to low signals after sunset, a bias (global decrease) is observed (at left). On the other side, the temperature (negative) contrast over the leak area progressively decreases with time (in the middle). At sunset, it has nearly disappeared. This makes that the water index (positive) contrast disappears as well (at right). Due to competing influences between VI and temperature variations, it seems that the WI contrast is not monotonically decreasing but shows a maximum at 18h. However, at this late time, one faces adverse effects like tree shadows. Moreover, this finding cannot be generalized at present stage since the considered area was too small for building a well populated scatterplot as required in the Triangle method.

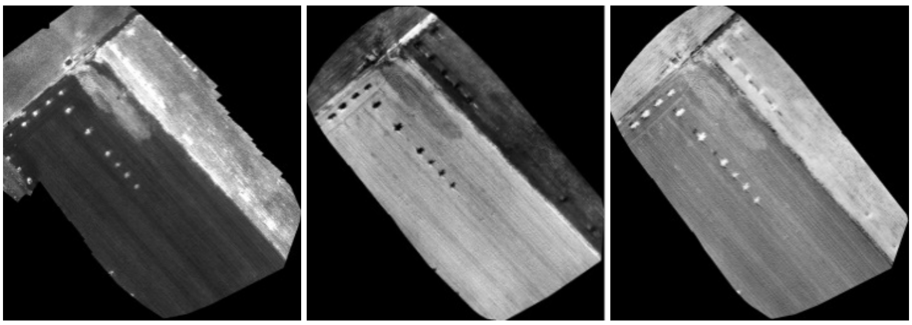


Figure 132 : Results obtained with UAV at 16h, Sept 10. OSAVI (left) Temperature (middle), inferred Water index (right).

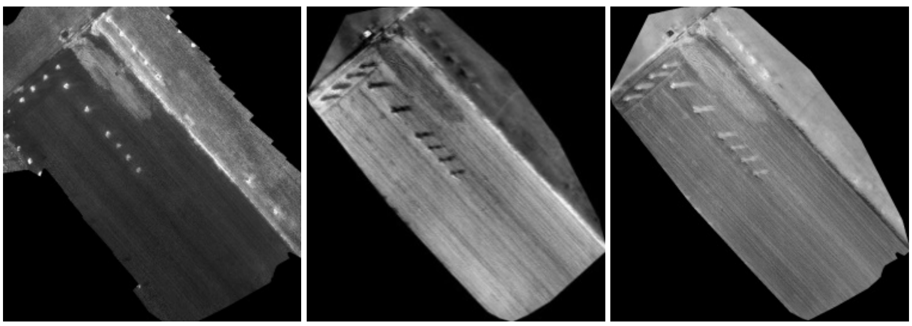


Figure 133 : same at 18h, Sept 10.

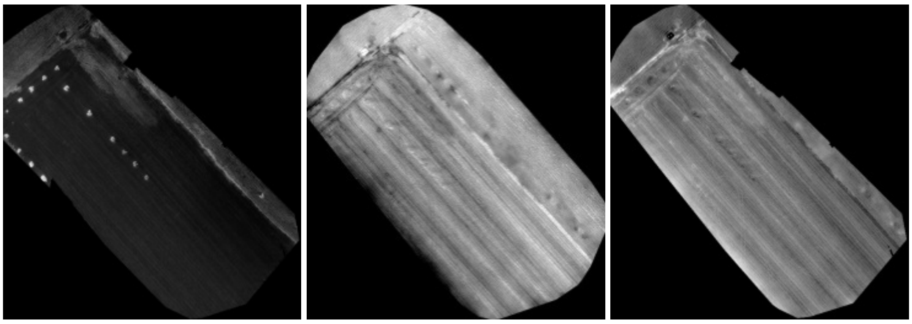


Figure 134 : same at 20h, Sept 10.

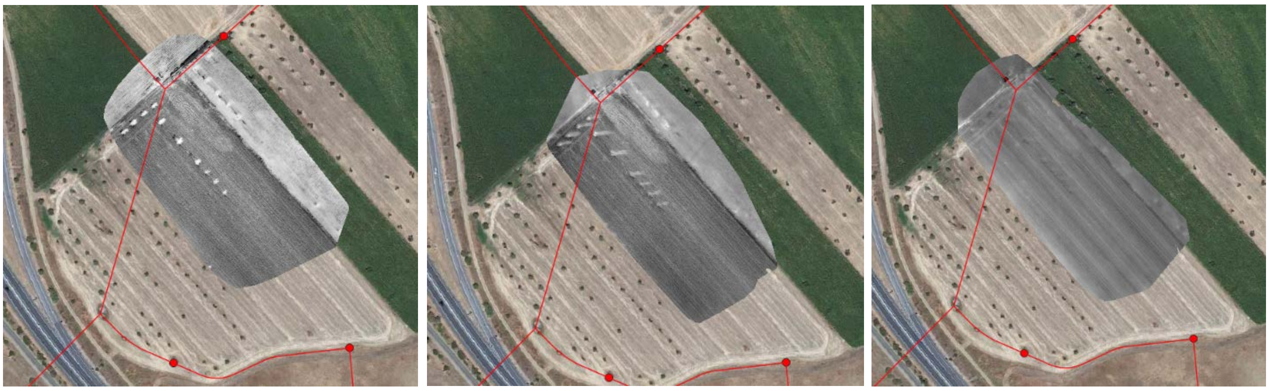


Figure 135 : WI maps at 16h, 18h and 20h (from left to right).

3.4.4.2 UAV – September 2019 VALE DE GAIO

Leaks around the Vale de Gaio reservoir

- 1st drone flight : Barras reservoir

Drone GPS coordinates at take-off :

- Lat: 38.2590421468265
- Long: -8.10657978057861
- Alt: 177.84 m

Take-off at 13h05, drone height above ground: 100 m, v = 20 km/h, FOV: 83 m x 67 m.

- 2nd drone flight : Vale de Gaio leak 1 (north-east of the reservoir)

Drone GPS coordinates at take-off :

- Lat: 38.2611236572266
- Long: -8.10413455963135
- Alt: 161.2 m

Take-off at 14h02, drone height above ground: 50 m, v = 20 km/h, FOV: 83 m x 67 m.

Figure 136 : Vale de Gaio. Water index map of the “leak” north east of the reservoir. Sept 11

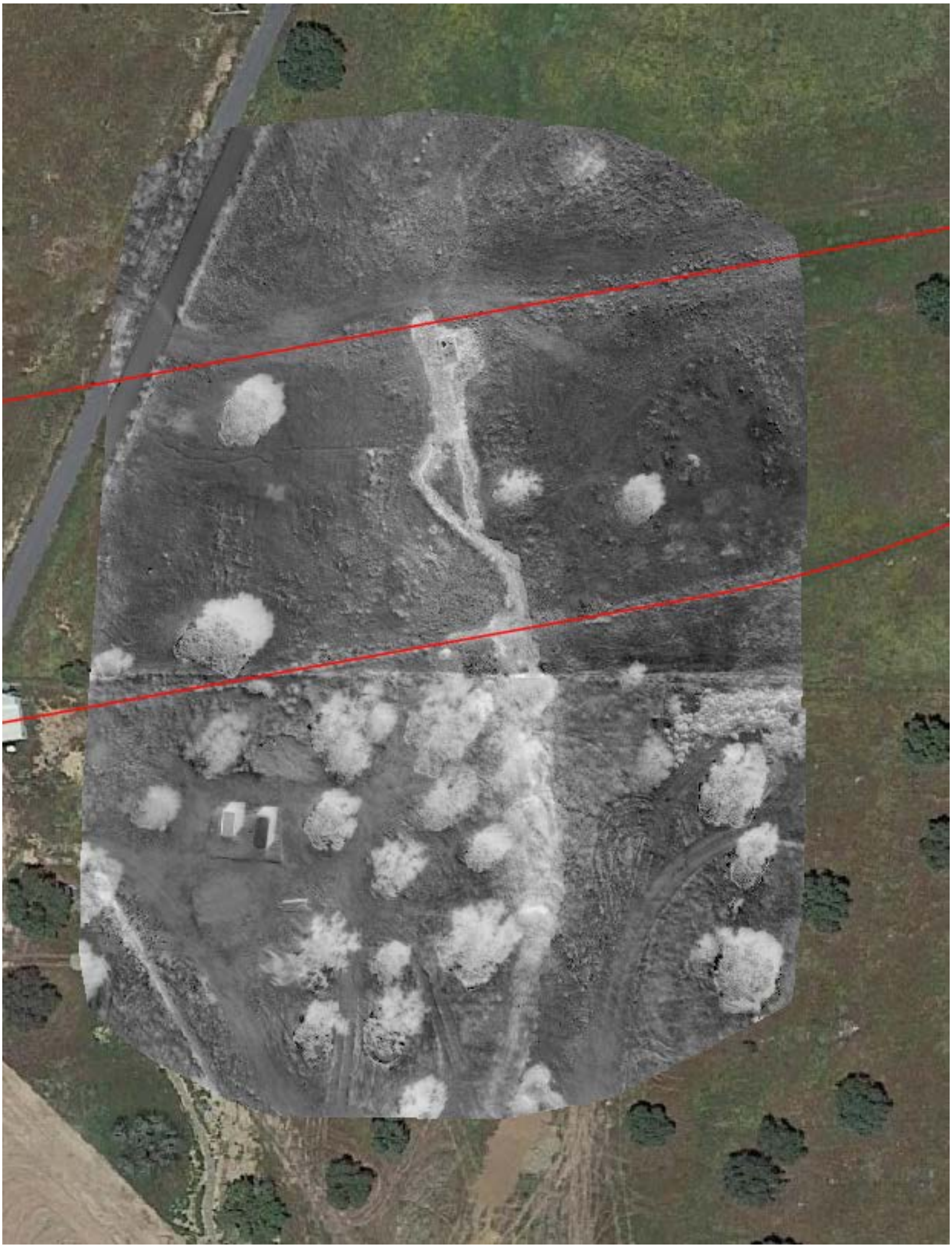


Figure 137 : Vale de Gaio. Water index map of the "leak" west of the reservoir. Sept 11

3.4.4.3 UAV – September 2019 FERREIRA

Two flights were performed in Ferreira area around two artificial leaks performed at hydrants H9.7 and H16.

The results for the water index are reported in the two following images. In both case, a significant contrast was observed in the close vicinity of the hydrants that revealed the excess of water in the soil.

Figure 138 : Ferreira area. Artificial “leak” H9.7, Sept 12.

Figure 139 : Ferreira area. Artificial "leak" H16, Sept 12.

4 Global demonstrations results on EDIA network

After the comparison between ground and flight campaign, the table below lists the characteristics of the environment where leaks have been found (also in case of leaks found in the ground campaign and not found in the flight campaign, or, in case of leaks found in the flight campaign and not found in the ground campaign).

Area	Date	Code	Type	Ground detection	Visible on surface	UAV/MAV	Environment	TP/TN/FP/FN
MonteNovo Bloc 2	2019.5.16	H10	Artificial	----	YES	UAV	Meadow	TP
MonteNovo Bloc 2	2019.5.16	H10	Artificial	----	YES	MAV	Meadow	TP
MonteNovo Bloc 2	2019.5.14	H11	Artificial	----	YES	UAV	Bare soil	TP
MonteNovo Bloc 2	2019.5.16	H11	Artificial	----	YES	MAV	Bare soil	TP
MonteNovo Bloc 2	2019.5.16	H5.6	Artificial	----	YES	UAV	Meadow	TP
MonteNovo Bloc 2	2019.5.16	H5.6	Artificial	----	YES	MAV	Meadow	TP
MonteNovo Bloc 2	2019.5.14	Corn field	Natural (leak at irrigation pipe)	----	YES	UAV	Corn field	TP
MonteNovo Bloc 2	2019.5. 16	Corn field	Natural (leak at irrigation pipe)	----	YES	MAV	Corn field	TP
MonteNovo Bloc 2	2019.5.16	"Natural leak" near H5	Natural	YES (a leak was detected in this area)	unknown	MAV	unknown	FP (it seems there is no leak there, although a leak was detected – sonic measure)
MonteNovo Bloc 2	2019.9.10	"Natural leak" near H5	Natural	YES (a leak was detected in this area)	No, except greener grass	UAV	Dry vegetation residue	FP (it seems there is no leak there, although a leak was detected – sonic measure)
MonteNovo Bloc 2	2019.9.11 2019.9.12	"Natural leak" near H5	Natural	YES (a leak was detected in this area)	No, except greener grass	MAV	Dry vegetation residue	FP (it seems there is no leak there, although a leak was detected – sonic measure)
Vale de Gaio	2019.9.11	Natural flow NORTH of the reservoir	Natural	No test in this area	Moisture and greener grass	UAV	Scarce vegetation	FP (water flow from the water table)
Vale de Gaio	2019.9.11 2019.9.12	Natural flow NORTH of the reservoir	Natural	No test in this area	Moisture and greener grass	MAV	Scarce vegetation	FP (water flow from the water table)

Vale de Gaio	2019.9.11	Natural flow WEST of the reservoir	Natural	No test in this area	Moisture and greener grass	UAV	Scarce vegetation	FP (water flow from the water table)
Vale de Gaio	2019.9.11 2019.9.12	Natural flow WEST of the reservoir	Natural	No test in this area	Moisture and greener grass	MAV	Scarce vegetation	FP (water flow from the water table)
Vale de Gaio	2019.9.11 2019.9.12	Spillway SOUTH of the reservoir	Natural	No test in this area	Moisture	MAV	Scarce vegetation	FP (spillway of the reservoir)
Vale de Gaio	2019.9.11 2019.9.12	Natural flow SOUTHEAST of the reservoir	Natural	No test in this area	Moisture and greener grass	MAV	Scarce vegetation	FP (water flow from the water table)
Ferreira	2019.9.12	H9.7	Artificial	----	Moisture at surface (mud)	UAV	Bare soil	TP
Ferreira	2019.9.12	H9.7	Artificial	----	Moisture at surface (mud)	MAV	Bare soil	TP
Ferreira	2019.9.12	H16	Artificial	----	Moisture at surface (mud)	UAV	Bare soil	TP
Ferreira	2019.9.12	H16	Artificial	----	Moisture at surface (mud)	MAV	Bare soil	TP
Ferreira	2019.9.12	H15, H17, H12.20, H15.7, H15.3, H10, H7, H9.6, H9.10, H9.11, H9.18, H17.4, 17.4-DF, 66-V, 12.5-VS, H12.13	-	----	-	MAV	-	Anomaly in WI image (to be checked onsite)

Table 30 : Leaks found on EDIA network

5 References

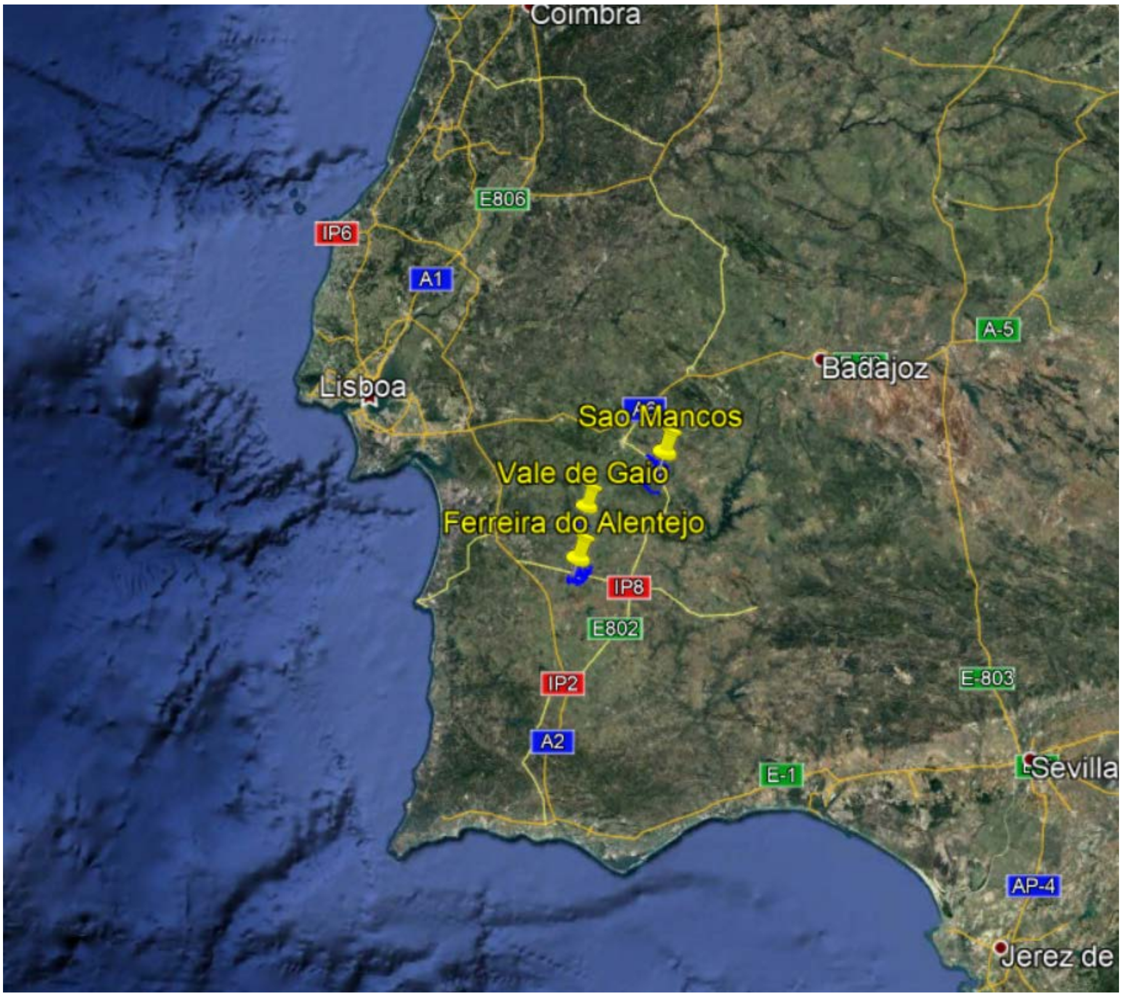
International Water Association. *Leak Location and Repair Guidance Notes. Version 1.* March 2007. London, UK.

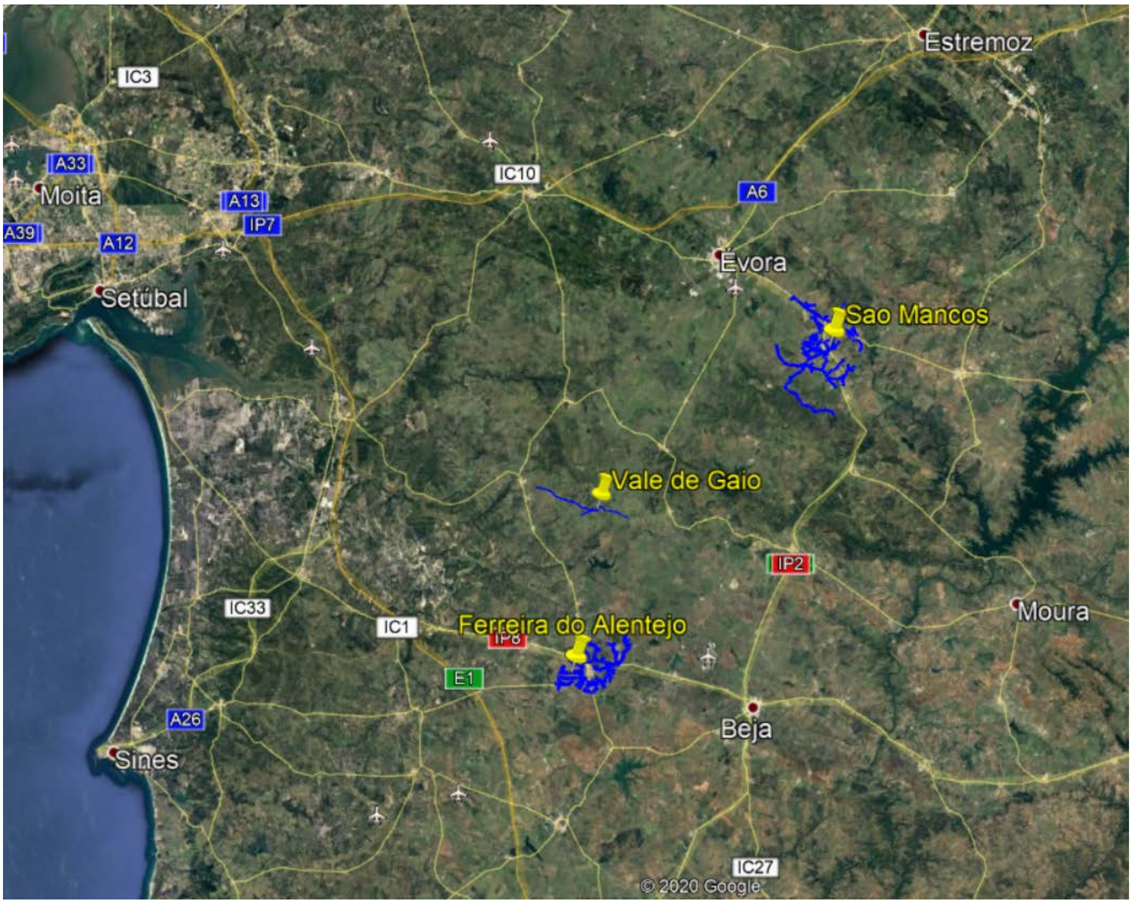
European Commission. *EU Reference document Good Practices on Leakage Management WFD CIS WG PoM. Main Report.* March 2015. European Union.

Rondeaux G., Steven M., Baret F., "Optimization of soil adjusted vegetation indices", Remote Sensing of Environment, vol. 55, 95-107, 1996

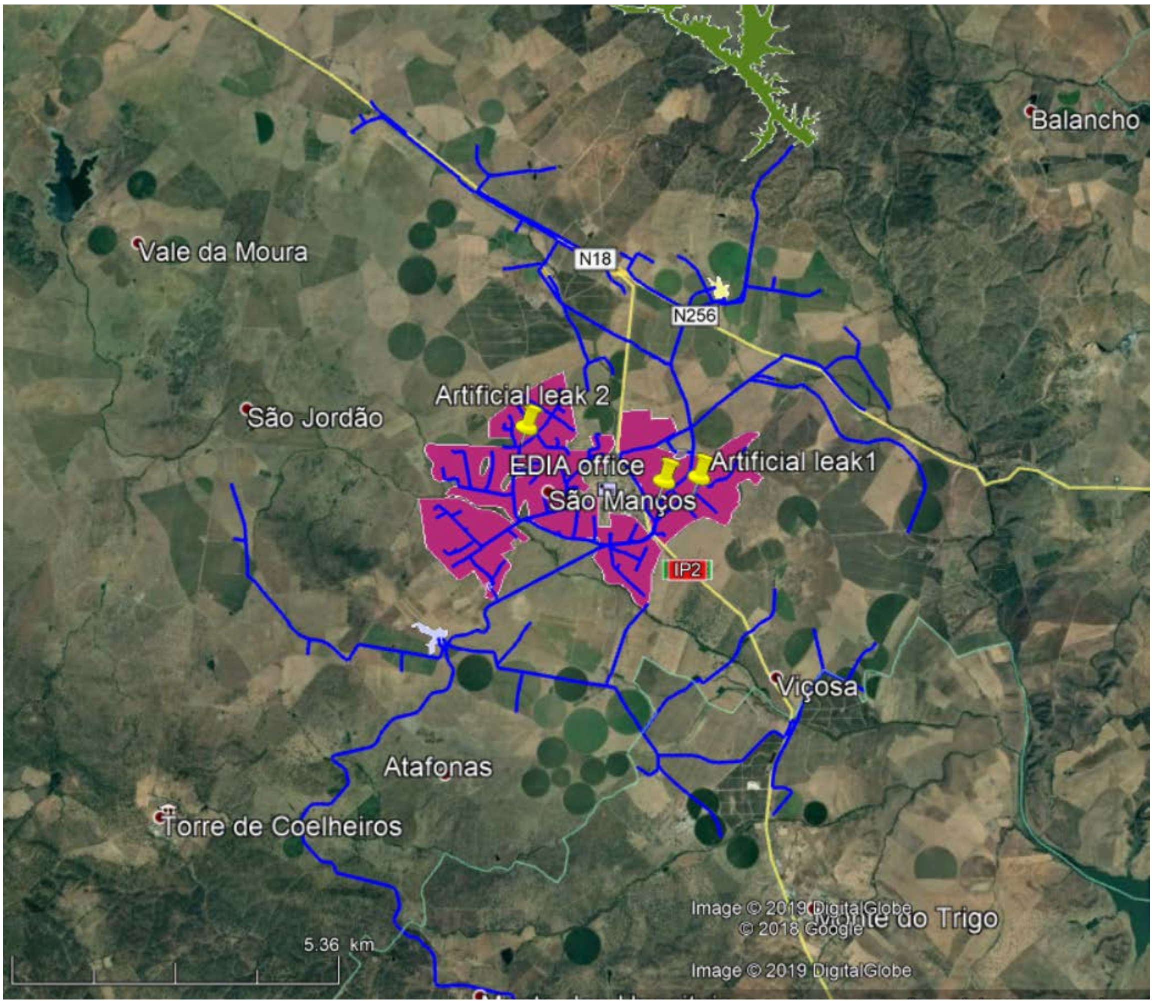
6 Annexes

6.1 EDIA sites network maps

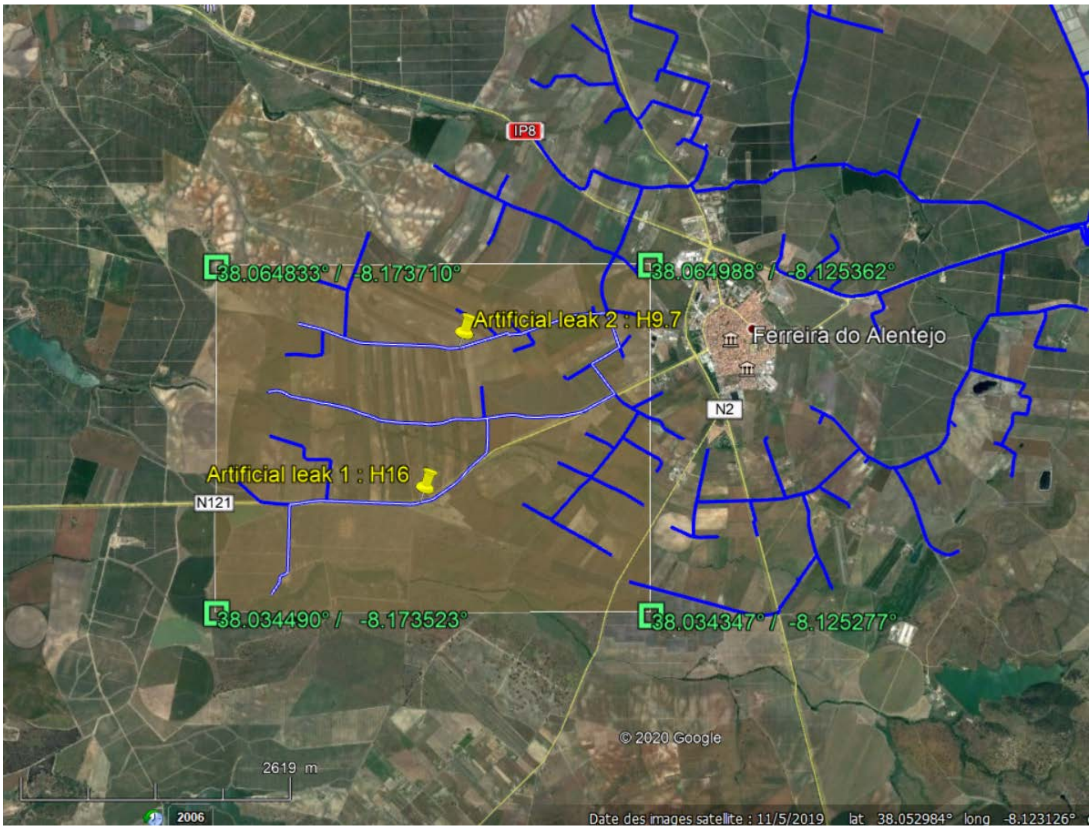



Estremoz
IC3
A33
Moita
A13
IP7
A39
A12
IC10
A6
Évora
Setúbal
Sao Mancos
Vale de Gaio
IP2
Moura
IC33
IC1
Ferreira do Alentejo
IP8
E1
Beja
A26
Sines
IC27
© 2020 Google

Monto Novo:


Balancho
Vale da Moura
N18
N256
São Jordão
Artificial leak 2
EDIA office
Artificial leak1
São Manços
IP2
Viçosa
Atafonas
Torre de Coelheiros
Image © 2019 DigitalGlobe
© 2018 Google
Monte do Trigo
5.36 km
Image © 2019 DigitalGlobe

Ferreira:


IP8
38.064833° / -8.173710°
38.064988° / -8.125362°
Artificial leak 2 : H9.7
Ferreira do Alentejo
N2
Artificial leak 1 : H16
N121
38.034490° / -8.173523°
38.034347° / -8.125277°
© 2020 Google
2619 m
2006
Date des images satellite : 11/5/2019 lat 38.052984° long -8.123126°

Vale de Gaio - Barras reservoir:

6.2 RPAS Flights authorization

Galileo GeoSystems flight authorizations:

S. R.

MINISTÉRIO DA DEFESA NACIONAL
AUTORIDADE AERONÁUTICA NACIONAL
Gabinete da Autoridade Aeronáutica Nacional
Avenida da Força Aérea Portuguesa, nº1
2614-506 Amadora

AUTORIZAÇÃO / AUTHORIZATION N.º AAN 23074/2019

Espaço aéreo sob responsabilidade civil
A AAN, no exercício das suas competências previstas na alínea b), do n.º 3, do art.º 4.º da Lei n.º 28/2013, de 12 de abril, concede, nos termos e condições nela descritos, autorização para efetuar levantamentos aéreos:
OPERADOR / OPERATOR
Galileo Geosystems S.L.
PILOTO(S) REMOTO(S) / REMOTE PILOT(S)
Javier Sanchis Muñoz
AERONAVE(S) NÃO TRIPULADA(S) / UNMANNED AIRCRAFT(S)
Galileo Geosystems - GG-65B01 [AP20150002 / ????????????????]
FINALIDADE DO(S) VOO(S) / FLIGTH(S) PURPOSE
Water leake detection from pipes, for the scientific project WADI from the program Horizon 2020 of the EU.
TIPO DE ÁREA / AREA TYPE
POLIGONAL / POLYGONAL
ÁREA DE VOO AUTORIZADA AUTHORISED FLIGHT AREA

Local Local	Altura (m AGL) Height (m AGL)	Coordenadas Coordinates
Évora - Évora	050	38° 27' 36"N 7° 46' 36.6"W
Évora - Évora	050	38° 27' 52.8"N 7° 46' 56.4"W
Évora - Évora	050	38° 27' 51.6"N 7° 46' 22.2"W

Validade da autorização / Validity of autorization
20 de Maio de 2019 a 24 de Junho de 2019
Periodo horário / Time period: Do nascer ao pôr do sol / From sunrise to sunset
EMISSÃO ISSUE DATE
2019-05-13 16:53:26

A Autoridade Aeronáutica Nacional

General Joaquim Manuel Nunes Borrego

In case of doubt contact: GAAN / Levantamentos Aéreos - Phone: +351 214 717 428 - E-mail: imagens.aereas@aan.pt

S. R.

MINISTÉRIO DA DEFESA NACIONAL
AUTORIDADE AERONÁUTICA NACIONAL
Gabinete da Autoridade Aeronáutica Nacional
Avenida da Força Aérea Portuguesa, nº1
2614-506 Amadora

AUTORIZAÇÃO / AUTHORIZATION N.º AAN 35854/2019

Espaço aéreo sob responsabilidade civil
A AAN, no exercício das suas competências previstas na alínea b), do n.º 3, do art.º 4.º da Lei n.º 28/2013, de 12 de abril, concede, nos termos e condições nela descritos, autorização para efetuar levantamentos aéreos:
OPERADOR / OPERATOR
Galileo Geosystems S.L.
PILOTO(S) REMOTO(S) / REMOTE PILOT(S)
Javier Sanchis Muñoz
AERONAVE(S) NÃO TRIPULADA(S) / UNMANNED AIRCRAFT(S)
Galileo Geosystems - GG-65B01 [AP20150002 / ????????????????]
FINALIDADE DO(S) VOO(S) / FLIGTH(S) PURPOSE
Water leake detection from pipes, for the scientific project WADI from the program Horizon 2020 of the EU.
TIPO DE ÁREA / AREA TYPE
POLIGONAL / POLYGONAL
ÁREA DE VOO AUTORIZADA AUTHORISED FLIGHT AREA

Local Local	Altura (m AGL) Height (m AGL)	Coordenadas Coordinates
Évora - Évora	050	38° 27' 36"N 7° 46' 36.6"W
Évora - Évora	050	38° 27' 52.8"N 7° 46' 56.4"W
Évora - Évora	050	38° 27' 51.6"N 7° 46' 22.2"W

Validade da autorização / Validity of autorization
02 de Setembro de 2019 a 30 de Setembro de 2019
Periodo horário / Time period: Do nascer ao pôr do sol / From sunrise to sunset
EMISSÃO ISSUE DATE
2019-08-23 09:52:49

A Autoridade Aeronáutica Nacional

General Joaquim Manuel Nunes Borrego

In case of doubt contact: GAAN / Levantamentos Aéreos - Phone: +351 214 717 428 - E-mail: imagens.aereas@aan.pt

6.3 Manned aircraft Flights authorization

Air Marine declaration of operation:

MINISTÈRE DE LA TRANSITION ÉCOLOGIQUE ET SOLIDAIRE

N° RS-DEC-F1-V4

DECLARATION D'EXPLOITATION
DECLARATION OF OPERATION

selon les dispositions du règlement (EU) No 965/2012 sur les opérations aériennes
as per the provisions of EU regulation N°965/2012 on air operations

Modèle établi selon l'appendice I de l'annexe III au règlement (EU) n° 965/2012, modifié par la NPA 2015-18
Template drawn up according to appendix I of annex III of EU regulation n° 965/2012, modified by NPA 2015-18

☐ Déclaration initiale *(initial declaration)* ☑ Déclaration suite à modification *(declaration following modifications)*

1. L'exploitant *(The operator)*	
Nom *(Name)* :	AIR MARINE (SARL)
Lieu d'établissement ou de résidence de l'exploitant : *(Place of establishment or residence of the operator)*	305 Avenue de Mont de Marsan, 33850 LEOGNAN
Lieu depuis lequel s'effectue la direction des opérations : *(Place from which the operations are managed)*	305 Avenue de Mont de Marsan, 33850 LEOGNAN
Nom et coordonnées du dirigeant responsable : *(Name and contact details of the accountable manager)*	Gilles OLICHON gilles.olichon@air-marine.fr

2. L'exploitation des aéronefs *(Aircraft operations)*		
Début de l'exploitation / date de mise en application de la modification: *(Start date of operations / date of effect of the modification)*		Dès la date de réception de l'accusé de réception
Type d'activité *(Type(s) of operations)*	☐ Partie-NCC: (préciser s'il s'agit de passagers et/ou de fret) *(Part-NCC: (specify whether passengers and/or freight))*	
	☑ Partie-SPO: (préciser le type d'activité) *(Part-SPO: (specify the type of operations))*	Surveillance aérienne Calibration radar Photographie aérienne

Merci de compléter le tableau ci-dessous[1] avec les informations sur :
Type(s) d'aéronef, MSN aéronef, Immatriculation(s), Base principale, Type(s) exploitation, Organisme responsable de la gestion du maintien de navigabilité
Please complete the table below[1] with the information on:
Type(s) of aircraft, registration(s), main base, type(s) of operations, continuing airworthiness management organisation

MSN aéronef *Aircraft MSN*	**Type aéronef** *Aircraft type*	**Immatriculation** *Registration*	**Base principale** *Main base*	**Type(s) d'exploitation(s)**[2] *Type(s) of operation(s)*[2]	**Organisme responsable de la gestion du maintien de navigabilité**[3] *Continuing airworthiness management organisation*[3]
		VOIR ANNEXE			

Détail des agréments spécifiques détenus (joindre à la déclaration, le cas échéant, la liste des agréments spécifiques)[4] *Details of specific approvals (where appropriate, enclose the list of specific approvals with the declaration)*[4]
N/A

Détail des autorisations d'exploitation spécialisée (joindre les autorisations, le cas échéant) *Details of authorisations for specialised operations (where appropriate, enclose the authorisations)⁴*
Surveillance aérienne à basse hauteur FR.SPO.0129 - Ed 5
Liste des moyens de conformité alternatifs, avec références des AMC qu'ils remplacent (joindre à la déclaration, le cas échéant) *List of alternative means of compliance, with the references of the AMCs they replace (where appropriate, enclose with the declaration)*
2014-10-23 AIROPS AMOC FR N°06 Amdt 2

3. Déclarations de conformité *(cocher les cases) (Declarations of compliance (tick the boxes))*	
☑	La documentation relative au système de gestion, y compris le manuel d'exploitation, satisfait aux exigences applicables énoncées à la Partie-ORO, la Partie-NCC, la Partie-SPO et la Partie-SPA. Tous les vols seront effectués conformément aux procédures et instructions figurant dans le manuel d'exploitation. *The documentation relevant to the management system, including the operations manual, meets the applicable requirements listed in Part-ORO, Part-NCC, Part-SPO and Part-SPA. All flights will be made in accordance with the procedures and instructions contained in the operations manual.*
☑	Tous les aéronefs exploités disposent d'un certificat de navigabilité en cours de validité et sont conformes au règlement (UE) n° 1321/2014 de la Commission. *All operated aircraft have a valid certificate of airworthiness and comply with EU regulation N° 1321/2014 of the Commission.*
☑	Tous les membres d'équipage de conduite et de cabine, selon le cas, sont formés conformément aux exigences applicables. *All flight and cabin crew members are trained in accordance with the applicable requirements.*
☐	(le cas échéant) L'exploitant a mis en œuvre une norme industrielle officiellement reconnue et a démontré qu'il s'y conformait. *(where appropriate)* *The operator has implemented an officially recognised industrial standard and has demonstrated compliance with it.*
Référence de la norme *(Reference of the standard)* :	
Organisme de certification *(Certifying organisation)*:	
Date du dernier contrôle de conformité: *(Date of the last compliance check)*	
☑	Toute modification apportée à l'exploitation qui a une incidence sur les informations figurant dans la présente déclaration sera notifiée à l'Autorité compétente. *Any modification to the operations that affect the information contained in this declaration must be reported to the competent authority.*
☑	L'exploitant confirme que les informations figurant dans la présente déclaration sont correctes. *The operator hereby confirms that the information in this declaration is accurate.*

4. Signature de l'exploitant *(Operator's signature)*		
A :	Leognan	Nom et signature du dirigeant responsable *(Name and signature of the accountable manager)*:
Le: *Date*	06/03/2019	[signature]

1. Si il n'y a pas assez d'espace pour énumérer les informations dans l'espace du tableau, les informations peuvent être listées dans une annexe distincte. L'annexe doit être datée et signée.
If there is not enough space in the table to list all the information, it can be provided in a separate annex. The annex must be dated and signed.

2. « Type(s) d'exploitation(s) » se réfère à des exploitations réalisées avec cet aéronef, tels que :

- les exploitations de transport non commercial, ou
- des types d'exploitations spécialisées (commerciales ou non) telles que : transport de charges externes parhélicoptère, héliportage ou hélitreuillage de personnes, surveillance aérienne, photographie aérienne, prises de vuescinématographiques ou télévisuelles, cartographie/topographie, relevés de données, contrôle de pollution, parachutage etchute libre, épandage agricole, secours d'animaux, regroupement d'animaux, largage de produits vétérinaires, remorquagede planeurs, publicité, remorquage de banderoles, calibration, construction, pose de câbles, élagage, déclenchementd'avalanches, dispersion de cendres funéraires, vols de recherches scientifiques, dispersion de produits déclencheurs deprécipitations, vols de parade, compétitions, vols acrobatiques, vols à sensations, simulations d'opérations militaires, etc.

"Type(s) of operations(s)" refers to the operations performed with this aircraft, such as:

- *non-commercial transport, or*
- *specialised operations (commercial or not), such as: transportation of external loads by helicopter, transportation or hoisting of persons by helicopter, aerial surveillance, aerial photography, filming for cinema or television, mapping/topography, data collection, pollution control, parachuting and free-fall, agricultural spreading, animal rescue, herding of animals, dropping of veterinary products, towing of gliders, advertising, towing of banners, calibration, construction, cable-laying, pruning, avalanche excitation, spreading of ashes, scientific research flights, dispersion of products to produce precipitation, parade flights, competitions, acrobatic flights, recreational flights, simulation of military operations, etc.*

3. Les informations sur l'organisme responsable de la gestion du maintien de navigabilité doivent inclure le nom de l'organisme, son adresse et son numéro d'agrément.
The information on the continuing airworthiness management organisation must include the name of the organisation, its address and its certification number.

4. Les EASA Forms 140 et 151 n'ont pas besoin d'être jointes si l'autorité compétente qui les a délivrées est la même que celle recevant la déclaration.
EASA Forms 140 and 151 do not have to be enclosed if the competent authority that issued them is the authority receiving the declaration.

12/03/2019

ANNEXE : LISTE DES AERONEFS
AIR MARINE

MSN aéronef	Type aéronef	Immatriculation	Base principale	Type d'exploitation	Organisme responsable du gestion de la navigabilité
87	F177 RG	F-BURU	Saucats	SPO (surveillance aérienne, calibration radar Thales Photographie aérienne)	Troyes Aviation FR.MG.0241 Aérodrome de Barberey-Saint-Sulpice BP 10047 10601 LA CHAPELLE-SAINT-LUC - Cedex FRANCE
47	F177 RG	F-HOAM	Saucats	SPO (surveillance aérienne, calibration radar Thales Photographie aérienne)	Troyes Aviation FR.MG.0241 Aérodrome de Barberey-Saint-Sulpice BP 10047 10601 LA CHAPELLE-SAINT-LUC - Cedex FRANCE
51	F177 RG	F-HBAG	Saucats	SPO (surveillance aérienne, calibration radar Thales Photographie aérienne)	Troyes Aviation FR.MG.0241 Aérodrome de Barberey-Saint-Sulpice BP 10047 10601 LA CHAPELLE-SAINT-LUC - Cedex FRANCE
25	Tecnam P2006T	F-HCGO	Saucats	SPO (surveillance aérienne, calibration radar Thales Photographie aérienne)	Troyes Aviation FR.MG.0241 Aérodrome de Barberey-Saint-Sulpice BP 10047 10601 LA CHAPELLE-SAINT-LUC - Cedex FRANCE
27	Tecnam P2006T	F-HCLC	Saucats	SPO (surveillance aérienne, calibration radar Thales Photographie aérienne)	Troyes Aviation FR.MG.0241 Aérodrome de Barberey-Saint-Sulpice BP 10047 10601 LA CHAPELLE-SAINT-LUC - Cedex France

12/03/2019

ANNEXE : LISTE DES AERONEFS
AIR MARINE

111	Tecnam P2006T	F-GSFC	Saucats	SPO (surveillance aérienne, calibration radar Thales Photographie aérienne)	Troyes Aviation FR.MG.0241 Aérodrome de Barberey-Saint-Sulpice BP 10047 10601 LA CHAPELLE-SAINT-LUC - Cedex FRANCE

Date : 06/03/2019
Nom et signature :

Gilles OLICHON

Aerial photography and filming authorisation:

MINISTÉRIO DA DEFESA NACIONAL
AUTORIDADE AERONÁUTICA NACIONAL
Gabinete da Autoridade Aeronáutica Nacional

Autorização/*Permission* N.º AAN 140 / 19

FOTOGRAFIA E FILMAGEM AÉREAS/*AERIAL PHOTOGRAPHY AND FILMING*

1. Requerente/*Applicant*:
Nome/*Name*: EDIA - Empresa de Infraestruturas e Desenvolvimento do Alqueva, S.A.
Actividade Profissional/*Job*: Director Dept. SIG
Morada/*Address*: Rua Zeca Afonso 2
Telefone/*Telephone*: 284315100 Telemóvel/Mobile:
"E-mail": dcarreira@edia.pt

2. Tipo de recolha de imagens aéreas/*Kind of work*:

a. Fotografia/*Photography*	c. Vertical/*Vertical*	e. Panorâmica/*Panoramic*	g. Ortofotos/*Orthophotos*
b. Filmagem/*Filming*	d. Oblíqua/*Oblique*	f. Objectivo/*Objective*	f. Outro/Other:

3. Equipamento a utilizar/*Equipment to be used*:
a. Marca/*Brand name*: NOXANT/SPECTROCAM b. Tipo/*Type*: NOXCAM640L/SPECTROCAM VIS1.4

4. Objectivos ou áreas a fotografar ou filmar/Places or areas involved: São Manços

5. Operador ou entidade para o trabalho em voo/*Flight operator or entity*:
AIR MARINE

6. Aeronave ou plataforma aérea/*Aircraft or other platform*:
a. Tipo(s)/*Type(s)*: TECNAM P2006T
b. Matrícula(s)/*Registration(s)*: F-HCLC or F-HCGO
c. Locais de operação/*Airfields or other operation places*:
LPEV - EVORA AIRPORT

7. Data de início e fim (DDMMMAA)/***Start and finish dates** (DDMMMYY)*: 13 / 05 / 2019 e/*and* 04 / 10 / 2019

8. Finalidade do trabalho/*Purpose of work*: WATER LEAK DETECTION OVER IRRIGATION NETWORK

9. Existirá divulgação das imagens ou produto audiovisual obtido?
***Will there be a broadcast of the images or audiovisual product obtained?*:** Sim – *Yes* / Não – *No*

Local e data (DDMMMAA)/*Place and date (DDMMMYY)* BEJA, 06 / 05 / 2019
Assinatura/Signature Assinado por: DUARTE NUNO MONIZ CAMPOS CARREIRA
Num. de Identificação: BI084658746

Alfragide, 8 **de** maio **de 20**19

p/ **O Chefe do Gabinete da Autoridade Aeronáutica Nacional**

p/ **A Autoridade Aeronáutica Nacional**

Observações e instruções de preenchimento no verso/*Remarks and filling out instructions on the back*

OBSERVAÇÕES E INSTRUÇÕES DE PREENCHIMENTO /

REMARKS AND FILLING OUT INSTRUCTIONS:

Item 1: Os requerentes deverão ser aqueles que pretendem a realização do trabalho e não o executante, a não ser, como é óbvio, nos casos em que sejam uma e a mesma entidade. / *The applicants should be the ones who order the job and not the maker, unless, of course, they are the same.*

Item 2: Riscar o que não for aplicável. / *Cross out the options that are not applicable.*

Item 3: Descrição dos equipamentos a utilizar. / *Description of the equipment to be used.*

Item 4: Descrição detalhada dos objectivos ou locais. / *Detailed description of the objectives or locations.*

Item 5: Designação do Operador Aéreo ou entidade. / *Name of the Flight Operator or similar entity.*

Item 6: Caracterização da aeronave ou plataforma aérea e dos seus locais de operação. / *Characterization of the aircraft or other platform and its operating locations.*

Item 7: A data do início dos trabalhos será, no mínimo, no dia seguinte à formalização do pedido. / *The beginning of the work can only happen, at least, one day after the formal request.*

Item 8: Descrição da finalidade do trabalho aéreo. / *Description of the purpose of the work.*

Item 9: Riscar o que não for aplicável. No caso de haver divulgação do trabalho aéreo, em acréscimo, terá também de ser preenchido o Formulário devido. / *Cross out the options that are not applicable. If broadcasting of the images or audiovisual product is planned, than another Form should be filled out.*

Observações / *Remarks*:

Reitera-se, conforme preconizado pelo Dec. Lei n.º 248/91 de 16 de Julho regulamentado pelas Portarias n.º 837/91 de 16 de Agosto e n.º 362/97 de 2 de Junho, ser absolutamente interdito filmar, fotografar e/ou efectuar sobrevoos a alturas inferiores a 750 metros sobre instalações ligadas a órgãos de soberania e segurança interna.

Relativamente à realização de fotografia e/ou filmagem aéreas em áreas militares, reafirma-se que estão sujeitas às restrições de segurança que forem preconizadas para a especificidade da situação.

/

Please be aware that, in accordance with Law n.º 248/91 of July 16th, Law n.º 837/91 of August 16th and Law n.º 362/97 of June 02nd, is absolutely forbidden to film, photograph and/or perform flights bellow 750 meters over governmental and internal security buildings.

Regarding the act of photograph and/or filming in military areas, it is stressed that it will depend on the specific restrictions that are in place for the specific situation.

6.4 Preparation Note: WADI-5 campaign for WP6

This section related to manned and unmanned aircraft flight campaign was completed by AM & GG after the realization of the mission on site (operations performed during spring 2019).

- "Preparation-Note-WADI-5-Campaign-WP6-v2.0.pdf"

6.5 WADI-Synthesis AM Flight Campaign-EDIA-May-sept 2019

This section related to manned aircraft flight campaign was completed by AM after the realization of the mission on site (operations performed during spring and autumn 2019).

- "WADI-SynthesisAMFlightCampaign-EDIA-15-16may2019.pdf"
- "WADI-SynthesisAMFlightCampaign-EDIA-11-12sept2019.pdf"

Water-tightness Airborne Detection Implementation

Preparation Note : WADI-5 campaign for WP6

Authors: C.Mazel, C.Chatelard

7 march 2019

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689239.

Technical references

Project Acronym	WADI
Project Title	Water-tightness Airborne Detection Implementation
Project Coordinator	Elena Gaboardi, youris.com (YOURIS) elena.gaboardi@youris.com
Project Duration	October 2016 – March 2020 (42 months)
Deliverable No.	
Dissemination level*	
Work Package	WP6
Task	T6.2 - Aircraft and UAV test flights
Lead beneficiary	Air Marine
Contributing beneficiary/ies	ONERA,EDIA,NTGS,GG,SGI
Due date of deliverable	
Actual submission date	

PU = Public

PP = Restricted to other programme participants (including the Commission Services)

RE = Restricted to a group specified by the consortium (including the Commission Services)

CO = Confidential, only for members of the consortium (including the Commission Services)

v	Date	Beneficiary	Author
1.0	7 March 2019	Air Marine	C.Mazel, C. Chatelard
2.0	April 2020	Air Marine	C.Mazel

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 689239.

Executive Summary

This document describes the different zones of interest for the next campaign WADI-5 which will take place in Beja on EDIA site in Portugal as well as the description of the flights and their acquisition with the two platforms (manned & unmanned) linked to the methodology of measurement agreed by the partners at the meeting on EDIA site in February – March in Beja. This campaign will be comprised in three parts over and along the sites of the portuguese water company, EDIA:

- Ground leak detection in April
- 1st part of airborne campaign in May
- 2nd part of airborne campaign in September

1 Table of Content

2 Overview of WADI-5 campaign

2.1 Objective

The objective is to conduct operational demonstration of WADI technique on big scale water supply and irrigation mains. Unlike in WP5, this time the aim is to execute flights in a real operational scenario, meaning a great number of sorties on a vast terrain for several days. In particular, the purpose is to:

• Fine-tune the sensor system adjustments defined in WP5

• Perform operational and surveillance flight tests over the site using manned and unmanned platforms;

• Collect airborne measurement and flight parameters information and cross-check it against ground data for WADI service performance evaluation to be conducted in WP7.

The demonstration plan is to execute 2 missions over the EDIA network in 2019, the first in May and the second in September. It'll allow to cover 2 different season and stage of the vegetation. The option to split the Operational to the surveillance part will let also the time to analyze the result of the first operational flight campaign in order to target specific objectives for the surveillance flight campaign.

The two flights tests will encompass various type of flights over the project demo site with both the aircraft and UAV including:

• Adaptation of flight scenario to EDIA water network specifics

• Executing flight tests (to gather the data itself) using the two platforms, according to the specific mission planning and the available weather forecast

• Collecting and recording data for post flight analysis.

2.2 Region of interest selected

2.2.1 General Description of Monte Novo site

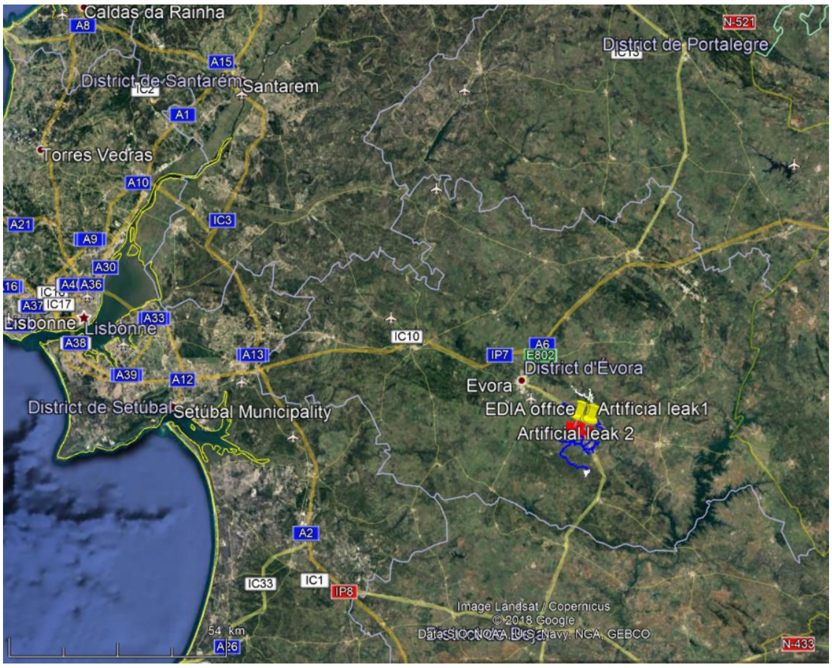


Figure 2.2.1.a - Monte Novo site South-East of Evora (Portugal)

Area of operation: Monto Novo :

- EDIA network around Sào Manços
- Monto Novo network : bloc 2

The site of interest occupies an area of 18 km^2 and has been divided in 2 sectors of interest according to the figure 3.3 (East and West of Sao Manços). The survey over the Monto Novo area will be done in May 2019 with manned and unmanned aircraft.

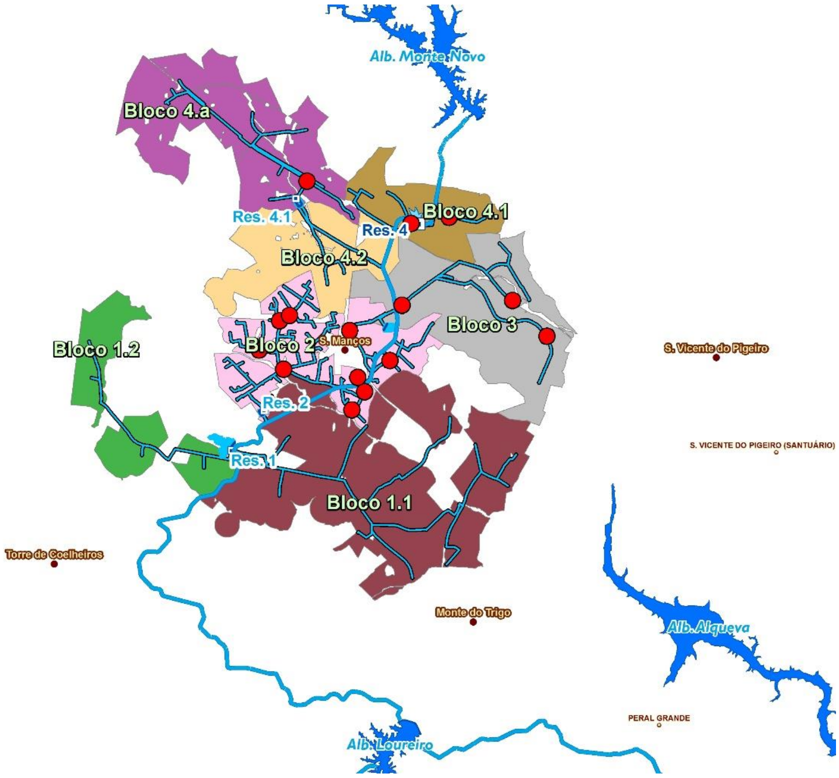
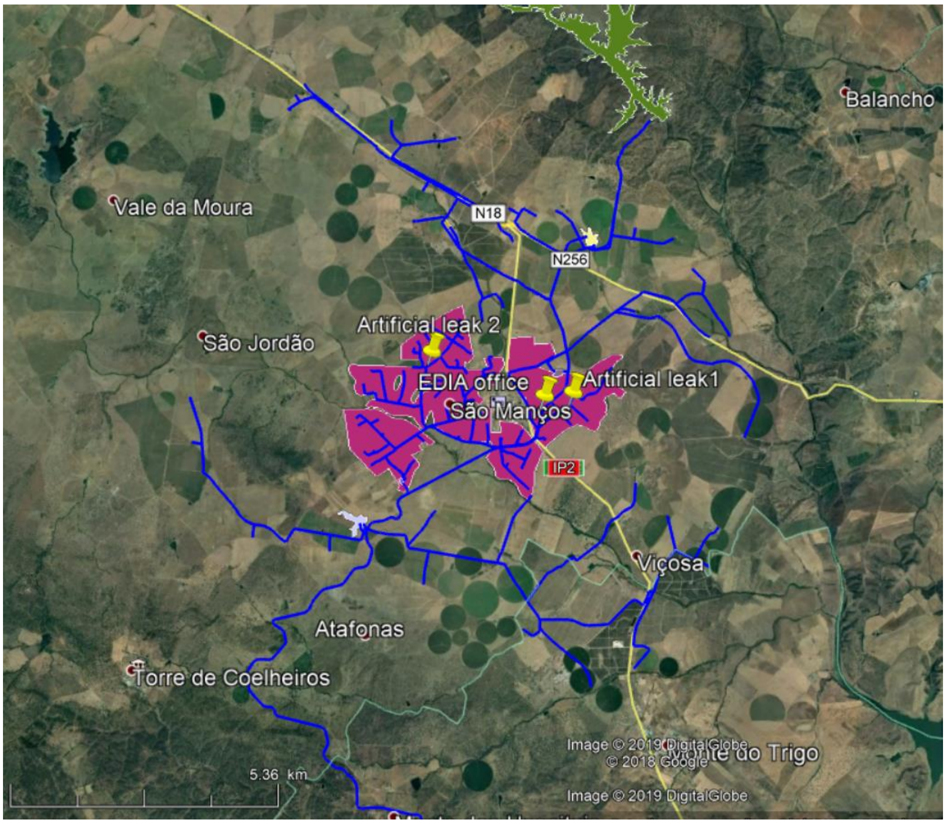
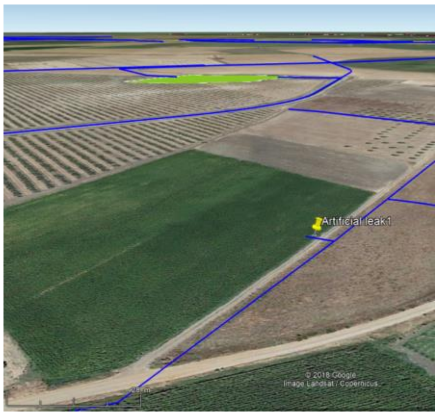


Figure 2.2.1 - Water network of Monte Novo

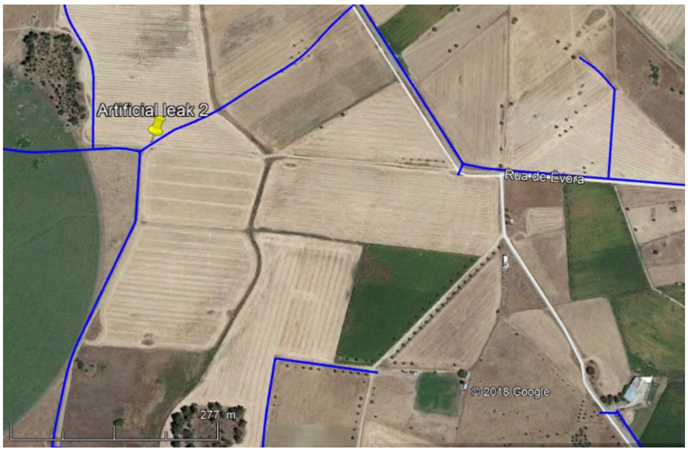
2.2.2 Areas for artificial leaks



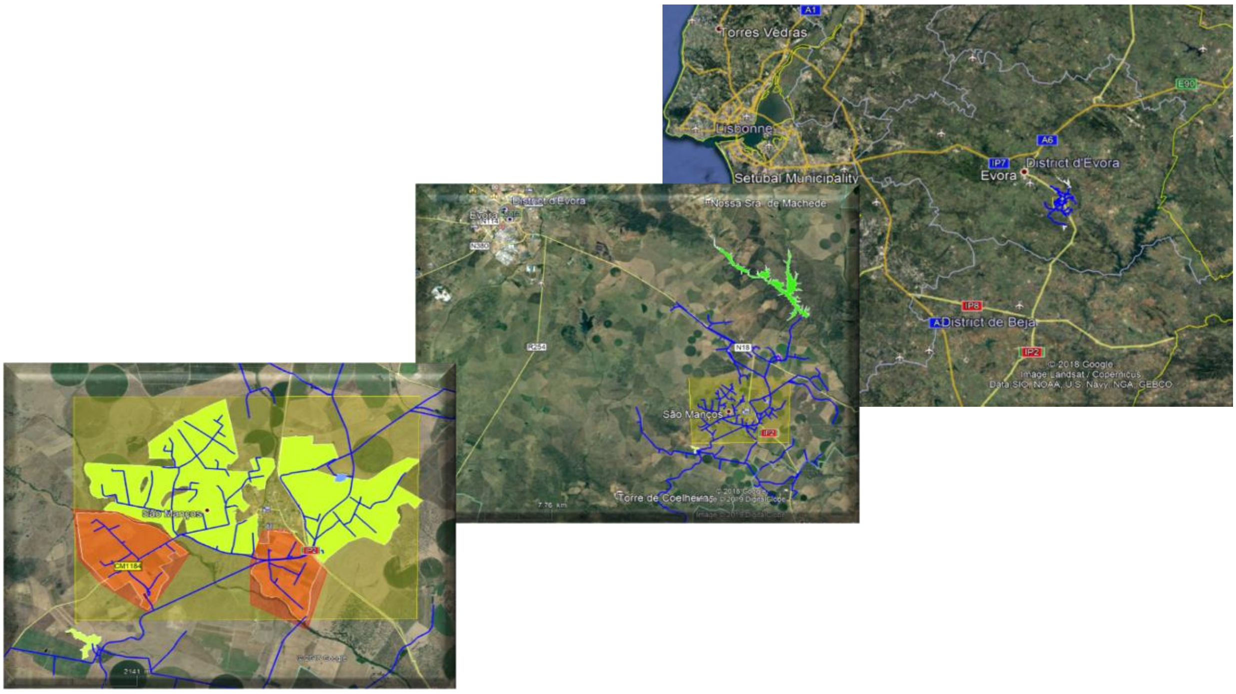
Artificial leak 1 => lat 38.457698° / long -7.735354°



Artificial leak 2 => lat 38.465954 / lon -7.768840



2.2.3 Area for aircraft platform



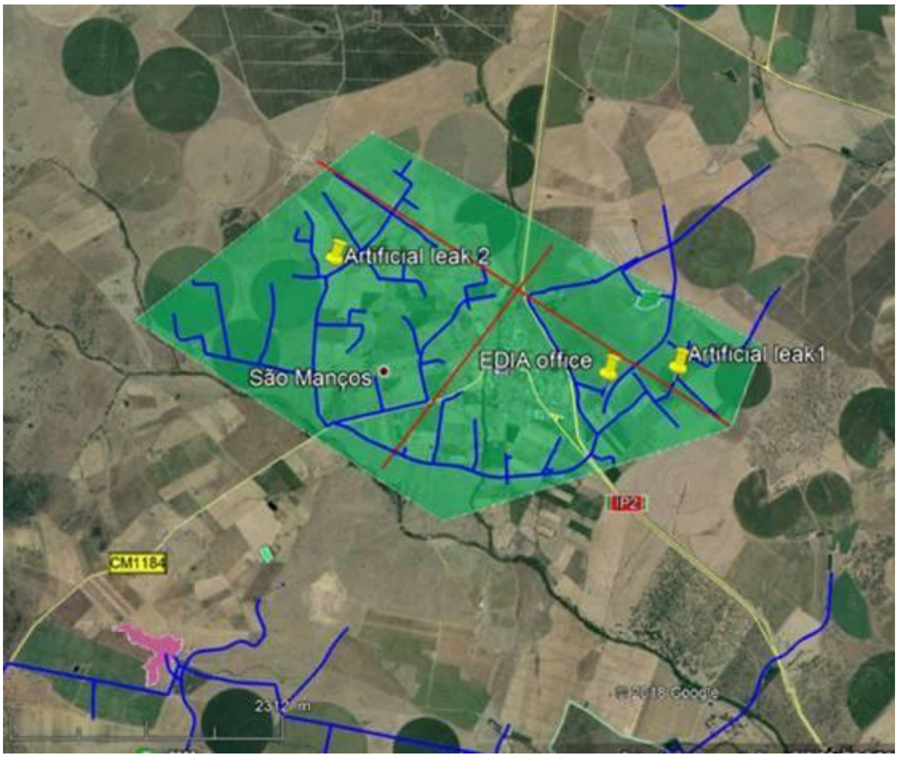


Figure 2.2.3 – Manned aircraft operation area

2.2.4 Area for UAV platform

The flights will be performed in the block 2 of Monte Novo (Bloco 2) near S. Manços. This area has been selected taking into account the restriction to fly urban areas and looking to maximize safety.

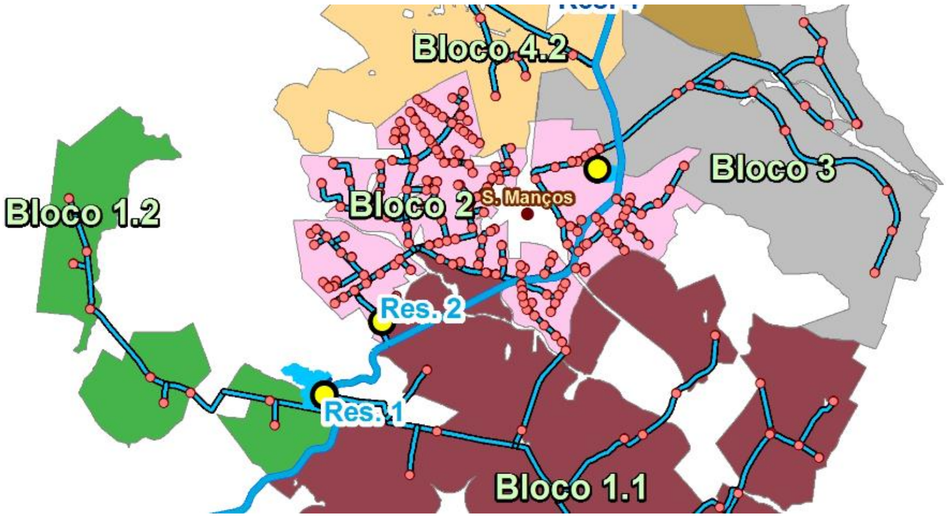


Figure 2.2.4 - Water network of Monte Novo. RPAS flights will be performed in the Block 2 area.

The selection of the areas of interest within the block 2 and the final mission planning will be done in field depending on the vegetation, dryness terrain conditions and available leaks information.

2.3 Instrumentation to be implemented

2.3.1 Ground instruments

The instrumentation used for ground truth measurements is listed below.

Instrumentation	Retrieved parameters	Where?
Optris portable infrared thermometer LS	Temperature	At each outdoor background characterization
GPS	Coordinates of particular elements in the areas of interest	At each flight acquisition and outdoor background characterization
Nikon camera	Pictures of the areas of interest	At each flight acquisition and outdoor background characterization
Soil moisture sensor	Soil humidity	At each outdoor background characterization

Table 1 - List of instrumentation participating to the ground truth measurements

Figures below present the ground instrumentation:

Soil moisture sensor

IR thermometer

2.3.2 Airborne instruments for aircraft platform

The manned aircraft flights are scheduled with a Tecnam P2006T following the mission plans presented in section 6. The payload is composed by a VNIR multispectral camera (SpectroCam with 8 custom selected filters: 425, 550, 640, 660, 724, 820, 832.5 and 840 nm), a cooled TIR camera (Noxant NoxCam: 7.7 – 9.3 µm) and an on-board computer with a custom made acquisition software (WadiFI).

The band 4 (RED: 660 nm), the band 7 (NIR: 832.5 nm) and the thermal infrared (TIR: 7.7 – 9.3 µm) have been selected for the present study.

2.3.3 Airborne instruments for UAV platform

The UAV is a custom designed multicopter operated by Galileo Geosystems. It is instrumented with a VNIR multispectral camera (Micasense RedEdge 3 with five bands: 475, 560, 668, 717 and 840 nm) and a microbolometer uncooled TIR camera (FLIR Vue Pro R: 7.5 – 13.5 µm).

The flights with the unmanned platform are performed at an altitude of 50 m above ground level which led to a spatial resolution of 3.4 cm for the Micasense camera and 6.5 cm for the FLIR camera.

Figure 2.3.3 Multicopter with on-board multispectral and thermal infrared cameras operated by Galileo Geosystems.

All the flight plans are ideally prepared to ensure a front and side image overlap of at least 80%.

3 Instruments for the airborne platform

3.1 Spectrocam & Noxant cameras & IMU

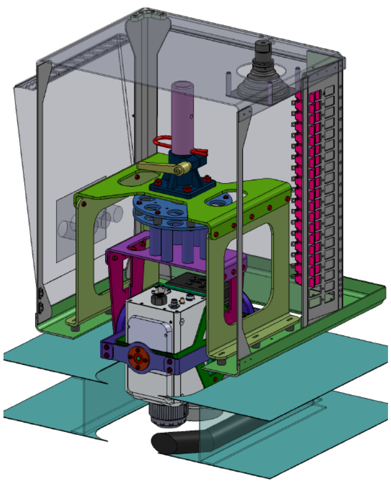
Figure 3.1.a: Pixelteq SpectroCam Vis

Figure 3.1.b Noxcam 640L

Figure 3.1.c Spectrocam + Noxcam

Figure 3.1.d IMU Spatial Dual

3.2 New gyrostabilzed platform



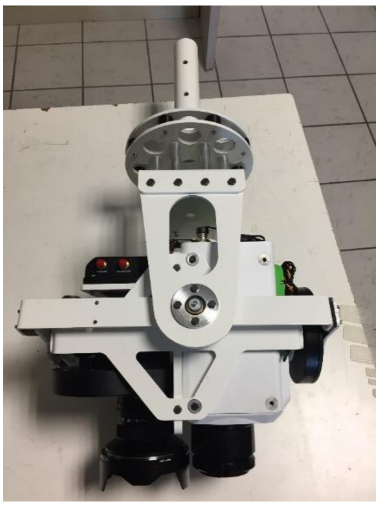


Figure 3.2 WADI gimbal v2

3.3 Installation on aircraft cabin

Figure 2.3.2 Gimbal integrated into the AIRMON console of the Air Marine TECNAM

4 Instruments for the UAV platform

4.1 FLIR & Micasense cameras

4.1.1 Installation on UAV platform

The RPAS which is going to be used in this remote sensing survey is the same one used during the SCP campaigns in July and October 2018. It is a custom designed multicopter operated by Galileo Geosystems, instrumented with a VNIR multispectral camera (Micasense RedEdge 3 with five bands: 475, 560, 668, 717 and 840 nm) and a microbolometer uncooled TIR camera (FLIR Vue Pro R: 7.5 – 13.5 µm).

Figure 5.2.2.a - RPAS instruments

Figure 5.2.2.b - RPAS payload setup

5 Instruments for the ground truth measurement

Each site corresponding to an artificial leak or potential real leak was measured at the same time when the flights (MAV and USA) were performed.

6 Method of operating for the campaign

6.1 Methodolgy recommended by scientific coordinator

- Application (onboard & on ground) of the procedure of implementation of the sensors embedded on each platform (based on ONERA procedure for Busard platform)
- Output of flight sheets after each flight (based on ONERA template for Busard platform)
- Application of a Iterative vs linear Strategy measurement for operational demonstration in Portugal :
  - Set up on **one or two areas** an iterative loop :
    - Zone A : some lines of flight Day1
    - Data processing Day1 + 1
    - 1° results analysis, AM & GG ready to flight Day1 + 2 on Zone A with settings adapted : (altitude/resolution,...), Hour (eliminate errors coming from shadows)
    - some lines of flight Day1 + 3
    - Data processing Day1 + 4
    - Data processing Day1 + 5
    - Etc ....

Loop output : Satisfactory accuracy on water leak area

6.2 Management of the flights

6.2.1 Aircraft platform

Flight and data capture Authorization (Portuguese army):

- zone LP-R 51 BN
- 5 Nm South East from EVORA Airport between 1900 and 2700 Ft AGL
- Obtained from Ministério Da Defesa Nacional / Autoridade Aeronáutica Nacional

Flight management:

- This mission will be divided in 4 or 6 flights lasting 2H00 each between 11:00am and 04:00pm local time

- The mission will happen during the week 20 or 21 (depend of the meteo)
- 1 day for aircraft transit from France to Portugal
- 1 day for filght and payload testing
- 1 or 2 days of operation (flights and data-process after each flight)
- 1 day for aircraft transit from Portugal to France

Human Resources (Air Marine):

- pilot = Michel Trolé michel.trole@air-marine.fr / +33 608 861 664
- operator = Vincent Olichon vincent.olichon@air-marine.fr / +33 684 505 853
- geomatician = Ludovic Dernoncourt ludovic.dernoncourt@air-marine.fr / xxx
- mission director = Christophe Mazel christophe.mazel@air-marine.fr / +33 615 792 255

Flight plan:

- Above 2 artificial leaks prepared by EDIA staff
- Transects and grid approach for area survey 2,5x5 km
- Overlap : 40% to 60% for the grid survey, 60% to 80% for the transects survey
- Altitude (height above the ground) = between 600m and 1200m

NB: achieving a side overlap of an 80% could be hard to achieve for manned aircraft as far as the flight passes are required to have a distance too short to be operatively possible. The interlace flight passes is an alternative method to increase the side overlap but has also some drawbacks like the excessive change in the illumination geometry between side passes do to the relative movement of the Earth with respect to the Sun.

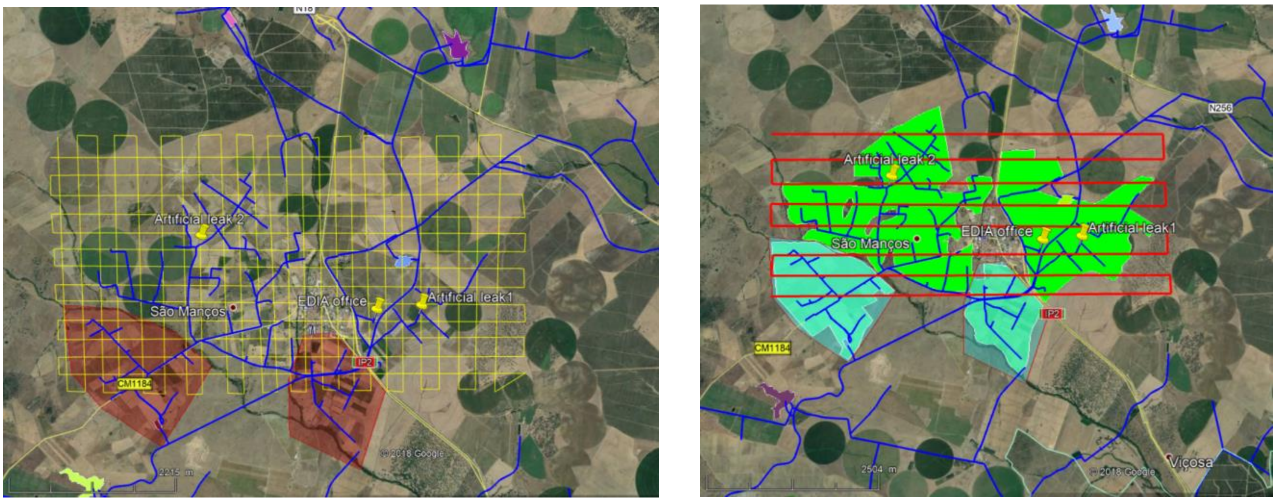


Figure 6.2.1 Mission plan for the Monto Novo area. The flight paths have been established to cover each sector of the water distribution network.

6.2.2 UAV platform

The flights with the unmanned platform will be performed at different altitudes depending on the final flight permits. The Table 6.2. shows the resolution calculated for different altitudes above ground level for both cameras. Predictably the flights will be carried out at 50m and 120m above ground level.

	Altitude (m AGL)							
Camera	**50**	60	70	80	90	100	110	**120**
Micasense RedEdge 3 (5.5mm)	**3.41**	4.09	4.77	5.45	6.14	6.82	7.5	**8.18**
Flir Vue Pro R (13mm)	**6.54**	7.85	9.15	10.46	11.77	13.08	14.38	**15.69**

Table 6.2.2 - Resolution of both cameras at different altitudes. In bold the selected altitudes for the survey.

The pilot "home" will be chosen for each fly to ensure that the RPAS will remain during all the flight at no more than 200 meters from the pilot.

The selected area and the minimum flights' altitude have been established taking into account the avoidance of lower obstacles while having complete control of the aircraft and a good image resolution. The flight plan will be designed to capture the area of interest in each case. At the end of the flight, the RPAS will return to the home position and land automatically.

Even with an automatic flight, the pilot is aware all the time so that in the event of a problem, he could immediately take the controls of the aircraft.

All the flight plans would ideally be prepared to ensure a front and side image overlap of at least 80% in order to comply with the requirements of the orthomosaicing process.

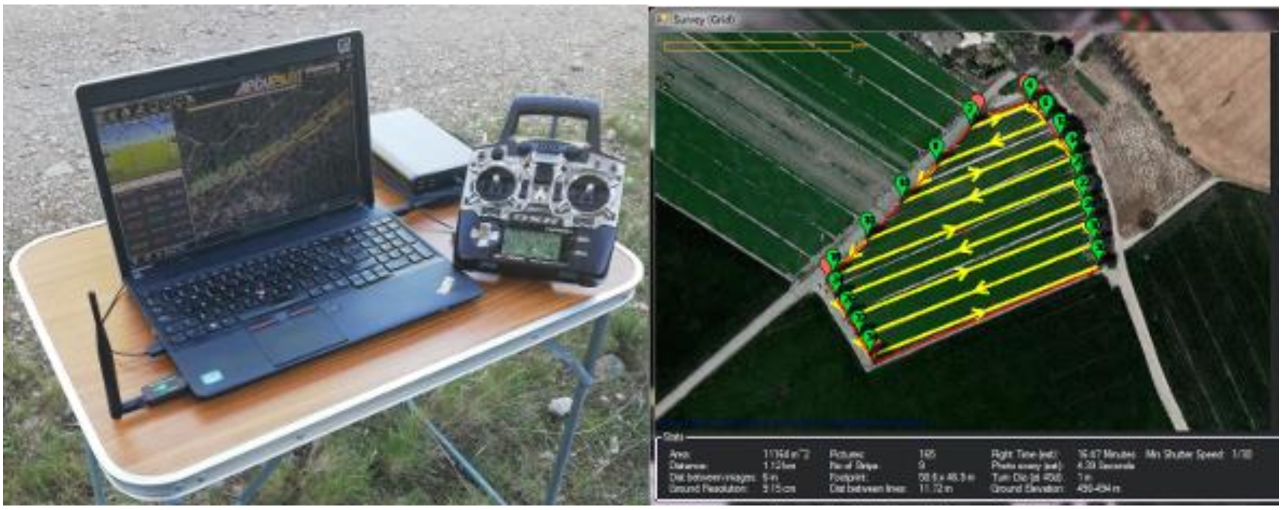


Figure 6.2.2 - RPAS control ground station and mission planning

7 Measurement Validation

The acquired data are preprocessed with Pix4D, a photogrammetric grade mosaicking software, to obtain raw (from uncalibrated multispectral data) and brightness temperature (TIR radiometric brightness temperature data) orthomosaics.

After each flight, the dataset are downloaded from the onboard hard disk to a "shuttle" disk in order to be processed immediately by the Air Marine geomatician. A dedicated hardware was prepared with the suitable HW performances and software (Pix4D and GlobalMapper) + specific apps to process the filename of the dataset.

It is expected to acquire more than 500 Gb of image data during the campaign with the manned aircraft so eventually, only a subset of the data is processed to get a quick view of the data quality.

The orthomosaics are created separately and co-registered by Wadileaks, the custom processing software developed in the frame of the WADI project. Wadileaks makes use of Gefolki, an opensource software developed by ONERA, to do the co-registering.

With all the spectral orthomosaics co-registered, it is possible to follow the processing pipeline established to calculate the water index orthomosaic necessary to find waterleaks.

The vegetation areas are dark in the bands where the light is absorbed due to photosynthetic processes (red band). These areas are clearer in the orthomosaic corresponding to the NIR band.

8 Provisionnal schedule for acquisition

8.1 Ground measurement

Monday 13 :

- Meeting with EDIA partner to prepare tasks for the first two days (Monday, Tuesday) :
  - Access to EDIA site in Monte-Novo (edia office)
  - Assessment of the 2 areas with artificial leaks (irrigation, state of the soil, vegetation...)
- Set-up & implementation equipment for ground truth measurement (2sites with artificial leaks)
- Check of results

Tuesday 14:

- Support to GG partner for drone flights
- GT measurement on site overflew by the drone
- Check & validation of sensors parameters for UAV
- Analysis first results with Wadileaks software
- - Briefing with ONERA and Galileo team in the evening at the hotel Graca (Quinta Branca do Faial, 4, 7005-862 Évora)

Wednesday 15:

- Manned aircraft setup, flight parameters tuning, etc.
- ground truth measurement
- Monitoring and management new measurement methodology with 2 platforms
- analysis first results

Thursday 15 :

- Manned aircraft setup, flight parameters tuning, etc.
- ground truth measurement
- Monitoring and management new measurement methodology with 2 platforms
- analysis first results

Friday 17:
In principle day to perform additional flights with 2 platforms , same program as Thursday

8.2 Aircaft schedule

Monday 13th:
- TECNAM aircraft and ground equipment preparation in Saucats (Air Marine facility) for the operations in Portugal.

Tuesday 14th:
- Transit from Saucats to Evora for the TECNAM with the pilot (Michel) and the operator (Vincent), arrival in the afternoon at Evora airport
- Transit from Bordeaux to Evora (via Lisbon) for Air Marine geomatician (Ludovic) and me, arrival end of the afternoon at Evora airport to pick-up of the crew and to go to the hotel Graca.
- Briefing with ONERA and Galileo team in the evening at the hotel Graca (Quinta Branca do Faial, 4, 7005-862 Évora)

Wednesday 15th:
- Flight operation in Monto Novo to test the area and the acquisition parameters+ specific settings
- Multiple flights expecting and data processing during the day
- Artificial leaks working

Thursday 16th:
- Flight operation in Monto Novo for WADI acquisition / operational demonstration (probably 2 long flights)

Friday 17th:
- Flight operation in Monto Novo for WADI acquisition / operational demonstration (probably 1 long flight)
- Transit back to France for the aircraft and for all the team in the afternoon

8.3 UAV schedule

Tuesday 14:
Two different scenarios:

- Field with bare soil with the possibility to open a tap and make a surface leak in-situ (the field must by dry at first):
    - We perform a flight before provoking the leak.
    - We make the leak (we open the tap some minutes) until there is surface water and we perform a flight over the leak with surface water.
    - We wait until the surface water disapears and we perform a third flight over the wet leak zone.
- Field with vegetation with the possibility to open a tap and make a surface leak in-situ:
    - We do the same procedure as in the case of bare soil.

Wednesday 15 no flight with the drone scheduled and GG will work on the manned aircraft setup, flight parameters tuning, etc.

Thursday 16 drone flight over the two or three artificial leaks areas at least at two different altitudes.

Friday 17 in principle no flight with the drone unless something failed the day before or there is the need to perform additional flights.

9 Logistic

Hotel:
Air Marine and Galileo Geosystems:
hotel Graca (Quinta Branca do Faial, 4, 7005-862 Évora)

ONERA:
Hotel xxx

Flight Trip:
Air Marine :
Tecnam for Michel and Vincent
Easyjet for Ludovic and Christophe
EJU7638 Bordeaux 15:00 – Lisbon 16:00
EJU7639 Lisbon 18:45 – Bordeaux 21:40

ONERA :
Xxx for Christian and xx

Road trip:
Galileo Geosystems :
Valence – Evora for Javier

Air Marine :
Lisbon – Evora for Ludovic and Christophe

WADI : TECNAM Flight results – 2019 September flight campaign

1. **Flight = 11sept2019 / PM**

Flight sheet:

AIR MARINE

DATA ACQUISITION SHEET

Mission: WADI portugal

Flight Date: 12/09/19

Site: Ferreira

Aircraft: F-HCGO

Session: CAMPAIGN N°2

Crew: TCE/OLN

Flight parameters

Elevation (AGL): 1200 m

Nebulosity: CAVOK

Speed: 100 / 160 KT

Start time: 11H35 Loc

Overlap: 60 %

End time: 12H23 Loc

Aerology: Turbulent

Sensors parameters

Sensor 1: MS

Speed: 3

Gain: 100

Focal lens: F16

Other:

Sensor 2: IR

Speed: N/A

Gain: N/A

Focal lens: N/A

Other: Autofocus -> OK
intr cooling -> ok
BLCR -> OK

COMMENTS:
Pas d'autofocus entre axes N/S
Autofocus entre chaque axes pour E/O
un dossier pour Axes N/S et un autre pour Axes E/O
le 6ème axe N/S en partant du Sud est doublé

Sensor parameters:
TIR = NUC num 3 / 0-80
MS = opening 16 and focus 0.7 - Gain = -100 / expo = 3 (no effect)

Area = Sao Mancos:

Alt = 1000 m
Directory = 20190911140725

Real Leak => B4-B7 n°254 / TIR 506

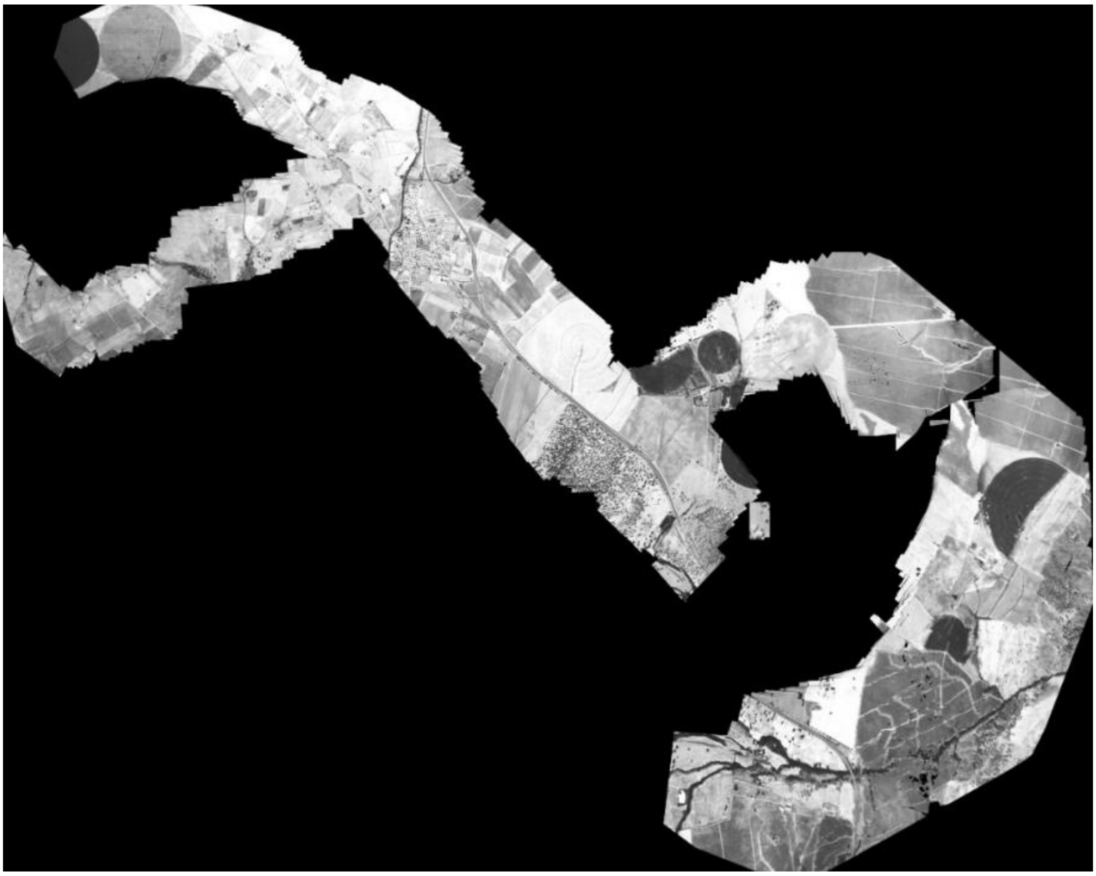
254_B4.tif

254_B7.tif

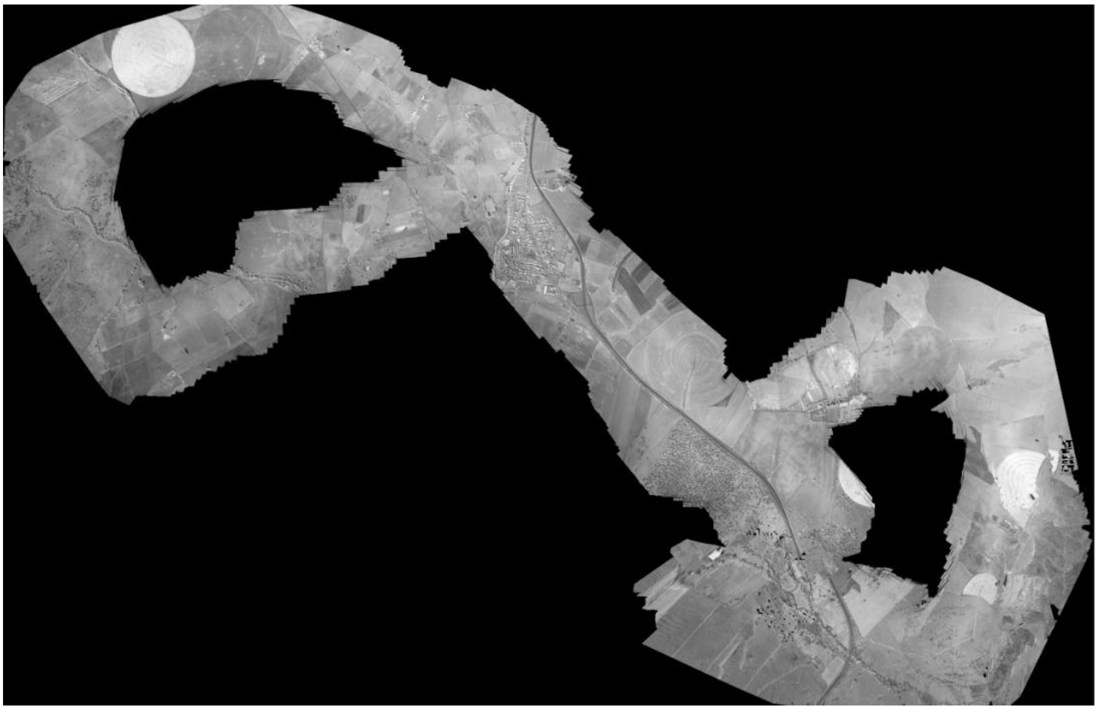
506_TIR.PNG

Mosaics :

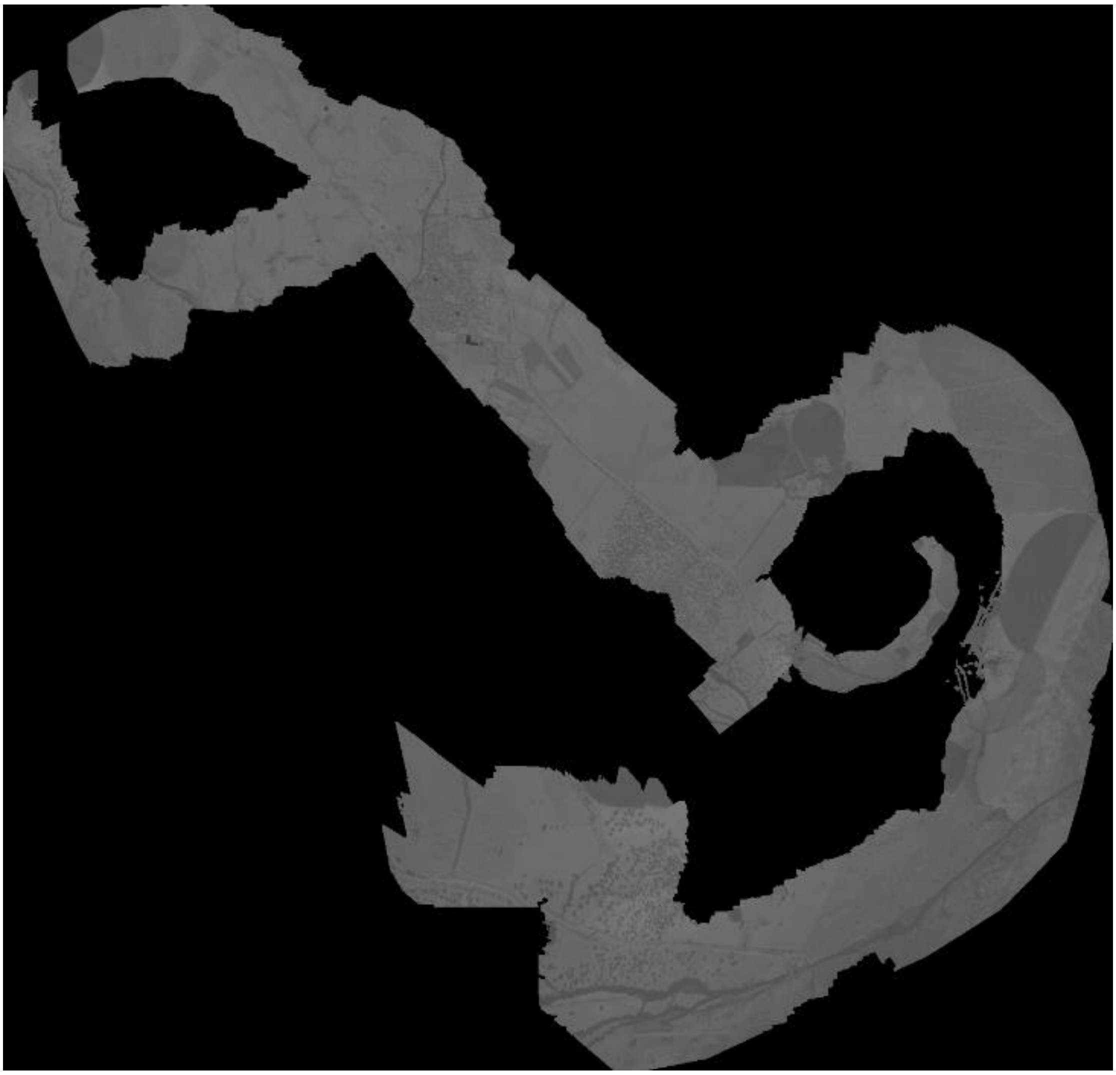
B4:



B7:



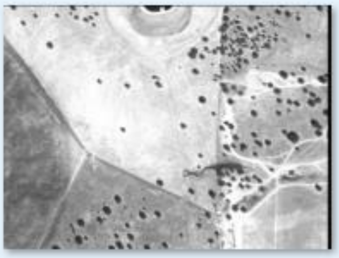
TIR:



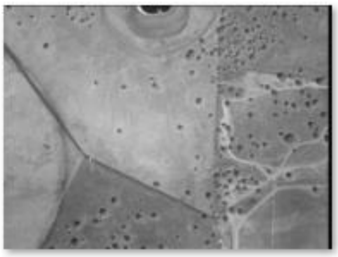
Area = Reservoir North Ferreira:

Alt = 1000 m
Directory = 20190911142446

Real Leak 1 => B4-B7 n°465 / TIR 929



465_B4.tif

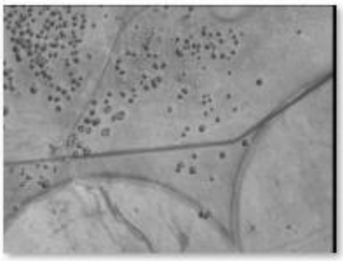


465_B7.tif

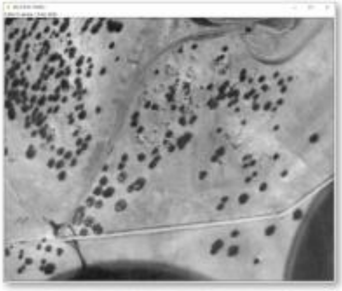
929_TIR.PNG

Real Leak 2 => B4-B7 n°98 / TIR 202

98_B4.tif



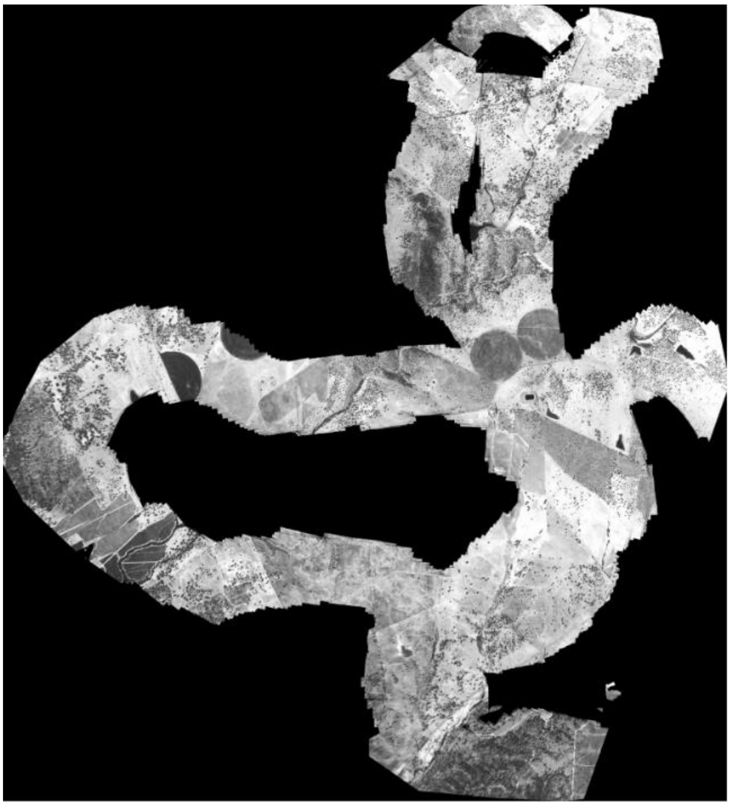
98_B7.tif



202_TIR.PNG

Mosaics :

B4:



B7:

TIR:

2. Flight = 12sept2019 / AM

Flight sheets :

AIR MARINE

DATA ACQUISITION SHEET

Mission: WADI portugal
Site: Ferreira
Session: CAMPAIGN N°2

Flight Date: 12/09/19
Aircraft: F-HCGO
Crew: TLE/OLN

Flight parameters

Elevation (AGL): 1200 m
Speed: 100 / 160 KT
Overlap: 60 %
Aerology: turbulent

Nebulosity: CAVOK
Start time: 11H35 Loc
End time: 12H23 Loc

Sensors parameters

Sensor 1: MS
Speed: 3
Gain: 100
Focal lens: F16
Other:

Sensor 2: IR
Speed: N/A
Gain: N/A
Focal lens: N/A
Other: Autofocus -> OK
intercooling -> ok
BLCR -> Ok

COMMENTS:
Pas d'autofocus entre axes N/S
Autofocus entre chaque axes pour E/O
un dossier pour Axes N/S et un autre pour Axes E/O
le 6ème axe N/S en partant du Sud est doublé

AIR MARINE

DATA ACQUISITION SHEET

Mission: WADI PORTUGAL
Site: SAO MANÇOS
Session: CAMPAIGN N°2

Flight Date: 12/09/19
Aircraft: F-HCGO
Crew: TLE/OLN

Flight parameters

Elevation (AGL): 1200 m
Speed:
Overlap: 60 %
Aerology: turbulent

Nebulosity: CAVOK
Start time: 12H50 Loc
End time: 12H56 Loc

Sensors parameters

Sensor 1: MS
Speed: 3
Gain: 100
Focal lens: F16
Other:

Sensor 2: IR
Speed: N/A
Gain: N/A
Focal lens: N/A
Other: Autofocus -> ok

COMMENTS: Réalisé avec vent de travers (≥ 30KTS) => 30° de dérive par rapport à l'axe
Autofocus

AIR MARINE

DATA ACQUISITION SHEET

Mission: WADI PORTUGAL
Site: FERREIRA Nord Fruits
Session: CAMPAIGN N°2

Flight Date: 12/09/19
Aircraft: F-HCGO
Crew: TLE/OLN

Flight parameters

Elevation (AGL): 1200 m
Speed: 120 KTS
Overlap: 60%
Aerology: turbulent

Nebulosity: CAVOK
Start time: 13H30 Loc
End time: 13H37 Loc

Sensors parameters

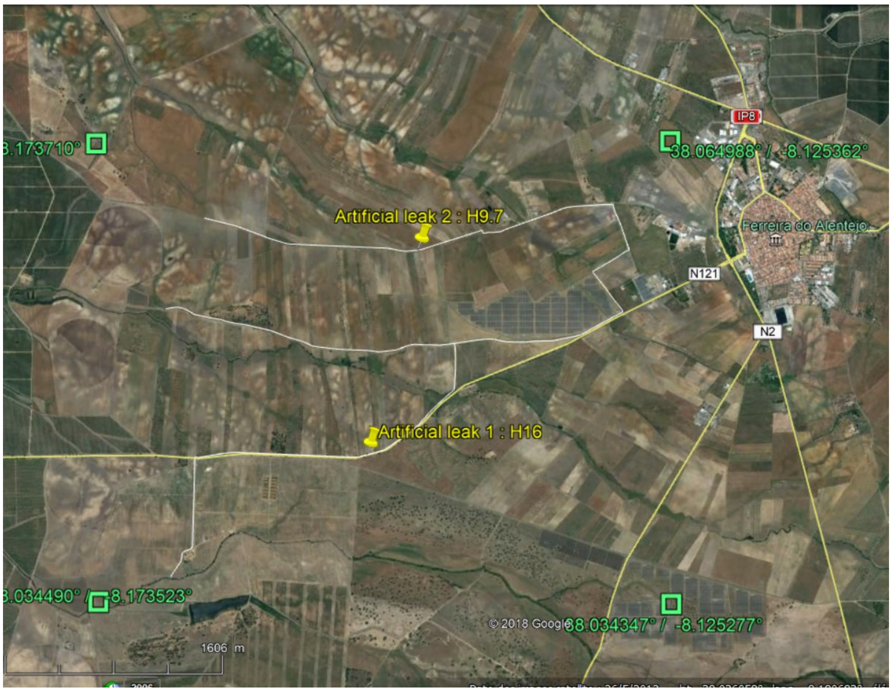
Sensor 1: MS
Speed: 3
Gain: 100
Focal lens: F16
Other:

Sensor 2: IR
Speed: N/A
Gain: N/A
Focal lens: N/A
Other: Autofocus -> OK
intercooling -> OK

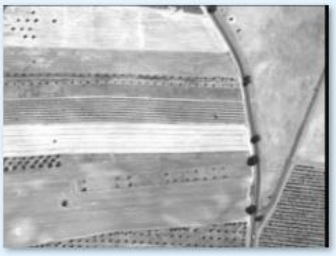
COMMENTS: Axe intermédiaire doublé
Autofocus gérés comme sur le site de Ferreira

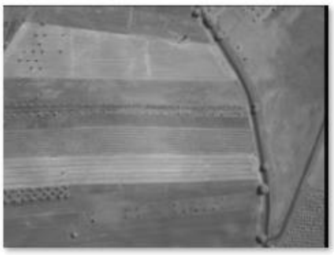
Sensor parameters:
TIR = NUC num 3 / 0-80
MS = opening 16 and focus 0.7 - Gain = -100 / expo = 3 (no effect)

Area = Ferreira :



Alt = 1200 m
Directory = 20190912104423
Artificial Leak 1 => B4-B7 n° 1031 / TIR 2062


1031_B4.tif


1031_B7.tif


2062_TIR.JPG

Artificial Leak 2 => B4-B7 n° 4818 / TIR 9643


20-4818_B4.tif


21-4805_B7.tif


23-9643_TIR.JPG

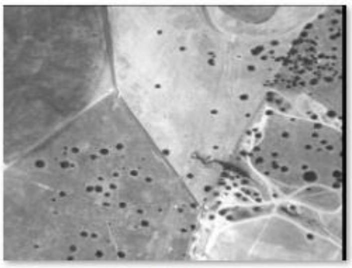
Mosaics :

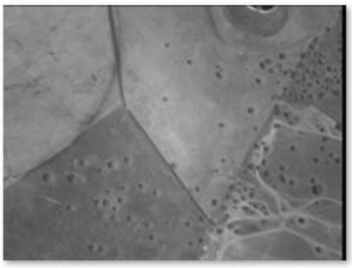
… to be completed

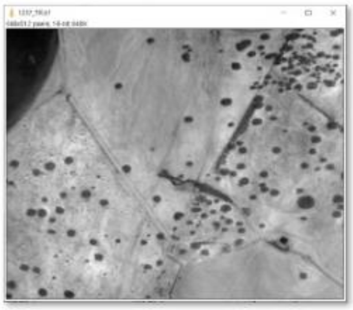
Area = Reservoir North Ferreira:

Alt = 1200 m
Directory = 20190912113253

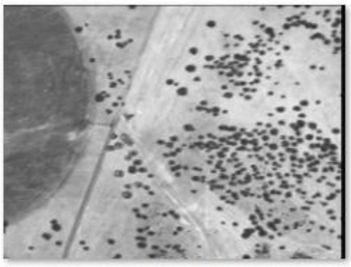
Real Leak 1 => B4-B7 n°620 / TIR 1237

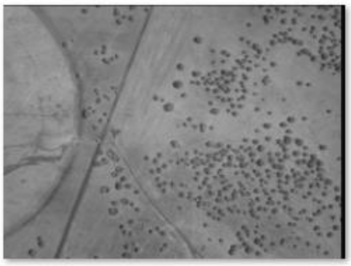

10-620_B4.tif


11-620_B7.tif


12-1237_TIR.JPG

Real Leak 2 => B4-B7 n°652 / TIR 1305


20-652_B4.tif


21-652_B7.tif


23-1305_TIR.JPG

Mosaics :

… to be completed

Sao Mancos:

Alt = 1200 m
Directory = 20190912115230

Real Leak => B4-B7 n°37 / TIR 77

37_B4.tif

37_B7.tif

77_TIR.JPG

Mosaics :

… to be completed

WADI : TECNAM Flight results – May flight campaign

Flight = 15mai2019 / AM

1000 m :
20190515114021
Leak 3 => B4 n°133 / TIR 264

1200 m :
20190515110521
Leak 2 => B4 n° 159 / TIR 319

Flight = 15mai2019 / PM

1200 m :
20190515153354
Leak 3 => B4 n° 1023 / TIR 2047
Leak 2 => B4 n° 1495 / TIR 2987

Config validée :
TIR = NUC num 3 / 0-80
MS = ouverture à 16 et mise au point à 0.7
Gain = -100 / expo = 3 (sans effet)

Flight = 16mai2019 / AM

1200 m :
20190516095617
Leak 3 => B4 n° 2940 / TIR 5886
Leak 2 => B4 n° 5673 / TIR 11385


11385_TIR.tif
640x512 pixels; 16-bit; 640K


5673_B4.tif (50%)
7.04x5.22 inches (1408x1044); 16-bit; 2.8MB