Technical details for the floodX urban flash flood experiments

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1   Hydraulic components

The principal hydraulic components are represented in Figure 1 and Figure 2, and are provided with detail in the plan "Plan of experimental setup and hydraulic components.pdf".
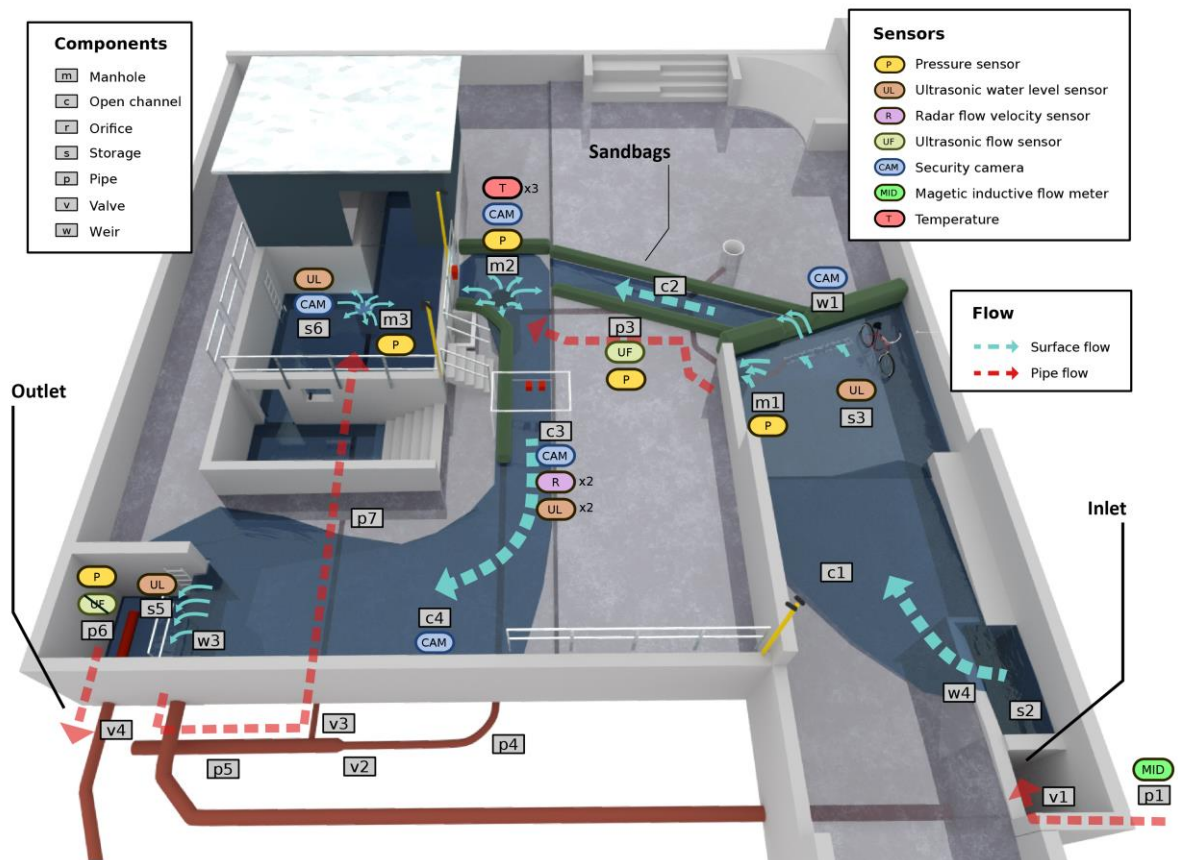

Figure 1: 3D rendering of flood facility, with approximate locations of sensors.
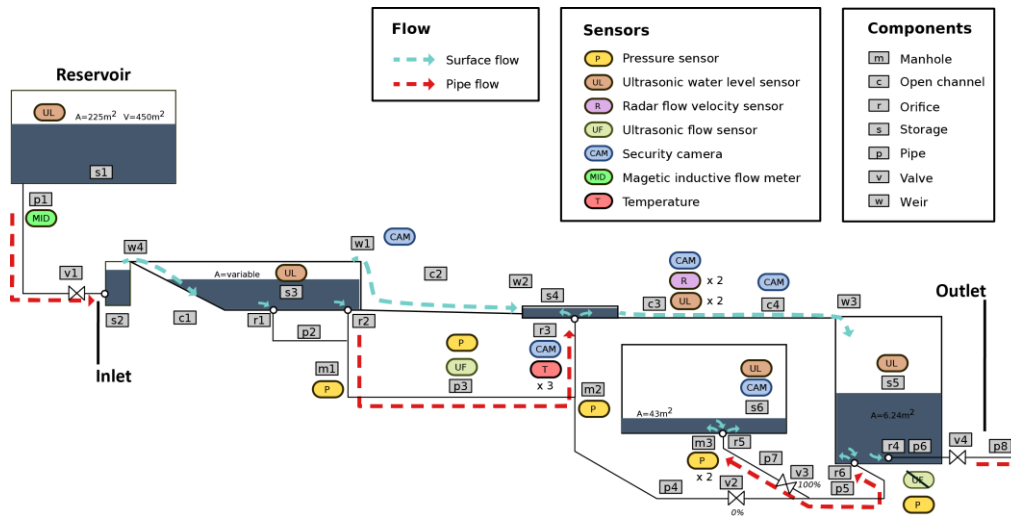
Figure 2: Diagram of hydraulic network, including components and sensors.

1.1 Storage nodes

Storage nodes are ponds and shafts in which water can accumulate and in which the flow direction is not strictly defined. In the following tables and figures, information about storage nodes is provided. For storages s3 and s5, more information is

Table 1: Key figures for storage nodes.

Name	Inflows	Invert elevation [m]	Max Depth [m]	Storage function
S1	Yes	427.28	2.15	Vol [m^3] = 225 [m^2] * water level [m]
S2	No	417.75	3.0	Vol [m^3] = 2.94 [m^2] * water level [m]
S3	No	419.94	0.7	See Table 2
S4	No	419.76	0.2	Vol [m^3] = 7.81 [m^2] * water level [m]
S5	No	417.94	1.2	See Figure 4
S6	No	418.44	0.2	Vol [m^3] = 43 [m^2] * water level [m]

Table 2: Level-volume table for storage s3.

Water level [m]	Volume [m3]
0	0
0.25	2.13
0.7	6.17

Figure 3: Pipe p6 in shaft s5 in which the flow meter p6_q&h_p_nivus is located. Ultrasonic water level s5_h_us_maxbotix_1 can be seen on the right.
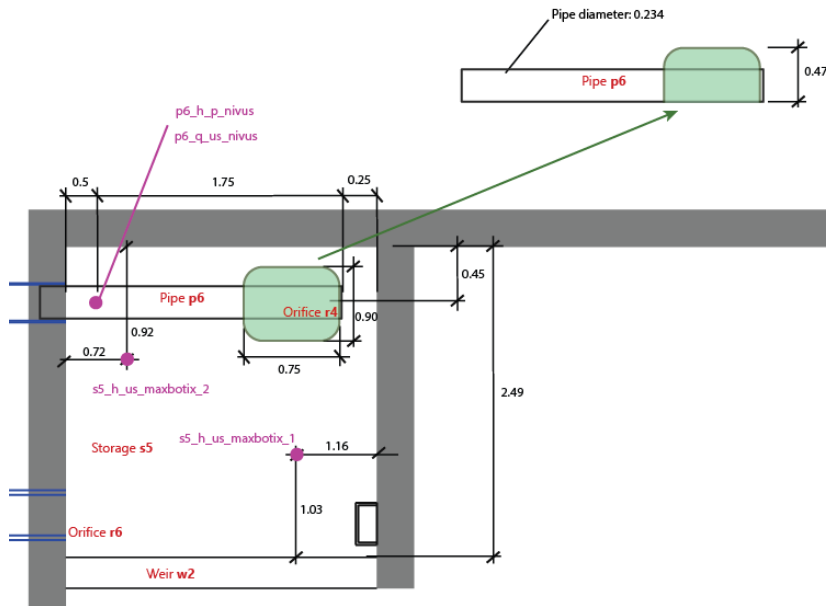

Figure 4: Shaft s5 with approximate locations of sensors and dimensions of sandbag pile. Units are meters unless indicated otherwise.

1.2   Manholes and orifices

Three manholes were active in the experimental setup, whereby manhole m1 is more of a gully pot (Table 3). Besides the orifices of the manholes, an additional orifice r1 is installed in storage s3 (Table 4).

Table 3: Characteristics of manholes.

Name	Invert elevation [m]	Cover elevation [m]	Cover	Diameter [m]
M1	418.34	419.94	Grate	0.6
M2	417.41	419.76	None	0.8

| M3 | 417.44 | 418.44 | None | 0.6 |

Table 4: Characteristics of orifices.

Name	Elevation [m]	Cover	Type	Shape	Height [m]	Width [m]	Comments
R1	419.94	Grate	Bottom	Rectangular	0.2	2	Long grate
R2	419.94	Grate	Bottom	Rectangular	0.6	0.6	Orifice of manhole m1
R3	419.76	None	Bottom	Circular	0.6	0.6	Orifice of manhole m2
R4	418.44	None	Bottom	Circular	0.6	0.6	Orifice of manhole m3

1.3 Open channels and pipes

Table 5 and Table 6 provide information about the open channels and pipes.

Table 5: Characteristics of open channels

Name	Max depth [m]	Length [m]	Surface	Flow	Shape	Width [m]	Start elevation	End elevation
C1	0.7	7.2	Pavement	1D	rectangular	5.5	420.48	419.94
C2	0.2	7.3	Pavement	1D	rectangular	1	419.94	419.91
C3	No	4.63	Pavement	1D	rectangular	1.06	419.76	419.69
C4	No	11	Pavement	2D	Ill-defined	variable	419.69	419.47

Table 6: Characteristics of pipes

Name	Start element	Start elevation	End element	End elevation	Length [m]	Inner Diameter [mm]	Outer Diameter [mm]	Material
P1	S1	427.78	V1	417.94	101.0	352.6	400	PE
P2	R1	unknown	M1	419.68	1.44	176.2	200	PE
P3	M1	419.14	M2	419.09	8.5	176.2	200	PE
P4	M2	417.41	V2	417.26	15.65	184	225	PE
P5	V3	417.26	R6	417.94	4.63	327.2	400	PE
P6	R4	417.94	V4	417.94	2.35	234	???	PE
P7	M3	417.44	V3	417.35	13	147.2	180	PE
P8	V4	417.94	outlet	417.74	40.9	291	315	PE

1.4 Valves

Two valves were operated during execution of the flood experiments: valve v1 controlled how much water entered the system via pipe p1, and valve v4 controls the rate at which water can leave the system.

Valves v1 and v4 are DESPONIA butterfly valves, for which the flow factors at different degrees of opening are provided in Table 7 and photos in Figure 5. In the experiment metadata, it is referred to the opening of the valves not in degrees but in notches (0° = notch 0, 90° = notch 12).

Table 7: Flow factor K_v [m^3h^{-1}] for different degrees of opening.

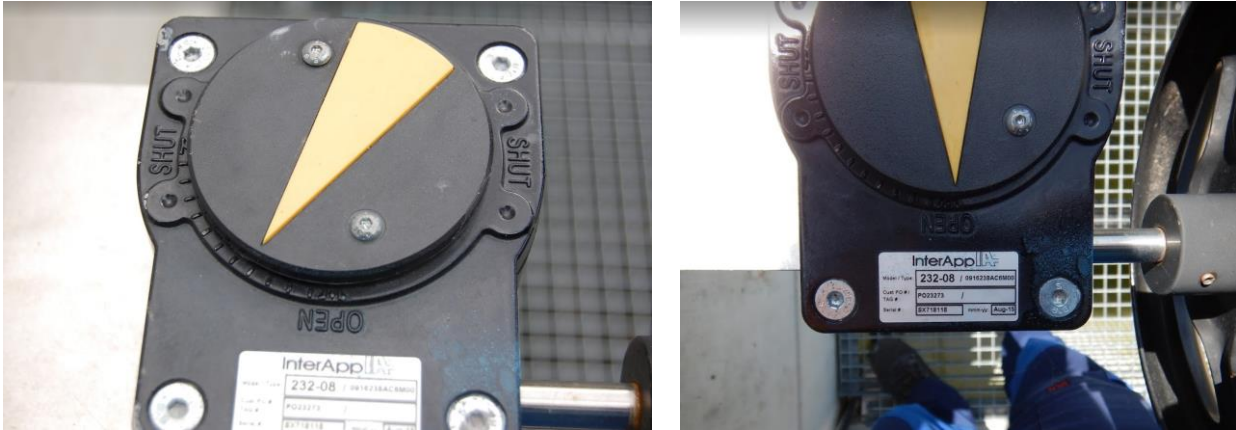| Degree of opening	20°	30°	40°	50°	60°	70°	80°	90°
Valve v4 (DESPONIA plus PN 10 DN 300)	200	505	890	1450	2100	3800	5960	6800
Valve v1 (DESPONIA plus PN 10 DN 400)	365	860	1500	2490	3980	6600	10200	11700

Figure 5: Gauges for valves v1 (left, set to the 8th notch) and v4 (right, fully open on the 12th notch).

1.5 Weirs

There are four weirs in the experiment (see Figure 6 and Table 8).

(a) Weir w1

(b) Weir w2

(c) Weir w3

(d) Weir w4

Figure 6: Weirs in hydraulic network.

Table 8: Key figures for weirs in network.

	Length [m]	Elevation min [m]	Elevation max [m]
w1	0.78	420.45	420.50
w2	1.16	419.88	419.88
w3	2.5	419.47	419.47
w4	3.64 (poorly defined edge)	420.48	420.79

2   Data sources

For purpose of clarity, we define the term "datasource" as a sensor mounted at a given location with data being saved by a given logger. A total of 36 datasources are involved in the floodX experiments (Table 15). The naming system for datasources is as follows:

[p1]_[q]_[mid]_[endress]_[logi]

- **p1**: location of measurement (see Figure 2 for complete list of hydraulic components, each of which is a possible location)
- **q**: physical variable measured by sensor. Can be one of: **q** (flow), **h** (water level), **v** (surface velocity), **t** (temperature)
- **mid**: measuring principle of the sensor, one of: **mid** (magnetic-inductive), **p** (barometric), **us** (ultrasound) **radar** (Doppler radar)
- **endress**: make of the sensor, one of: **endress (for Endress+Hauser)**, **maxbotix**, **nivus**, **hach**, **onset**, **instar**
- **logi**: optional appendix for logging method or number to distinguish multiple sensors at same location; see floodX documentation for details

This formula applies to all sensors, with exception of the video cameras and temperature sensors for which the measurement principle is lacking.

2.1   Surveillance cameras

All surveillance cameras used were INSTAR IN-5907HD, which were fastened to masts and tethered if needed. For calibrating the cameras, marks were made on the ground and their positions were taken in a local reference system. An image with the marks visible, as well as the relative positions of the marks and camera, are provided for the cameras for which flow is visible.

2.1.1   Video camera for storage area s3 and weir w1 (s3_cam1_instar)

Camera s3_cam1_instar is an INSTAR IN-5907HD positioned to record the water level in the storage area s3. However, the camera can also see weir w1 and open channel c2 (see Figure 7 below).

ε: 0.15 @ (9.776,4.99,4.035), (0.88,0.99,1.53), 0.0099,-0.135,0, (x), (ω), f, k1·1e6, k2·1e9

Figure 7: View from camera s3_cam1_instar, in which storage s3, weir w1, and channel c2 can be seen.

Table 9: Relative coordinates of camera CAM1 and calibration points.

	X	Y	Z
CAM1	9.776	4.990	4.035
point 1	0.016	0.001	0.030
point 2	0.778	1.126	0.019
point 3	0.629	1.955	0.010
point 4	0.067	2.984	0.000
point 5	2.322	0.886	0.017
point 6	2.101	2.140	0.015
point 7	1.500	3.631	0.002
point 8	3.720	1.693	0.034
point 9	2.510	3.352	-0.002
point 10	2.789	4.292	-0.012
point 11	4.072	2.924	0.014
point 12	3.665	3.685	-0.003

Two methods are suggested for visually determining the water level in the storage area: First, regularly spaced markings were placed on the far wall (Figure 9) and second, a bicycle of known dimensions was placed in the storage area (Figure 8).

Figure 8: Dimensions of bicycle that was placed in storage area s3.

Figure 9: Wall markings in storage area s3.

2.1.2 Video camera for manhole opening r3 (r3_cam2_instar)

Camera r3_cam2_instar is an INSTAR IN-5907HD positioned to detect water overflowing out of manhole m2 (Figure 10).

ε: 0.19 @ (11.409,7.318,4.913), (0.64,1.25,1.93), 0.0099,-0.135,0, (x), (ω), f, k1·1e6, k2·1e9

Figure 10: Calibration points and camera parameters of CAM2.

Table 10: Relative coordinates of camera CAM2 and calibration points.

	X	Y	Z
CAM2	11.409	7.318	4.913
point 1	1.092	0.804	0.024
point 2	0.000	1.848	0.014
point 3	0.596	3.831	0.156
point 4	2.435	2.131	0.009
point 5	2.498	3.105	0.138
point 6	3.950	1.966	0.004
point 7	4.381	3.146	0.134
point 8	4.409	4.500	0.155
point 9	4.243	0.043	-0.100
point 10	6.672	0.000	-0.084
point 11	5.759	2.401	-0.028

2.1.3 Video camera for channel c3 (c3_cam3_instar)

Camera c3_cam3_instar is an INSTAR IN-5907HD positioned to view water flowing in channel c3.

Figure 11: Calibration points and camera parameters of CAM3.

Table 11: Relative coordinates of camera CAM3 and calibration points.

	x	y	z
CAM3	0.685	-1.508	3.596
point 1	1.141	2.435	0.147
point 2	2.335	2.131	0.147
point 3	0.513	1.301	0.000
point 4	1.630	1.347	0.003
point 5	2.787	1.260	-0.003
point 6	3.721	1.261	-0.004
point 7	1.073	0.516	0.013
point 8	1.799	0.475	0.017
point 9	2.715	0.592	-0.009
point 10	3.804	0.507	-0.049

Importantly, this camera view allows direct comparison to the measurements provided by the two radar systems mounted in parallel over channel c3. In Figure 12, the approximate measurement locations for velocity and water level are drawn. The same zones are provided as pixel ranges in Table 12.

Figure 12: Approximate locations of radar and ultrasonic measurements in image of camera CAM3.

Table 12: Pixel ranges corresponding to measurement zones in channel c3.

	x_{min}	x_{max}	y_{min}	y_{max}
c3_v_radar_nivus	453	671	328	451
c3_v_radar_hach	535	750	377	501
c3_h_us_nivus	641	644	339	354
c3_h_us_hach	863	885	311	326

2.1.4   Video camera for manhole opening c4 (c4_cam4_instar)

Camera c4_cam4_instar is an INSTAR IN-5907HD positioned to detect water flowing in channel c4.

ε: 0.27 @ (2.818,-4.183,3.853), (1.02,0.12,0.15), 0.0099,-0.147,0, (x), (ω), f, k1·1e6, k2·1e9

Figure 13: Calibration points and camera parameters of CAM4.

Table 13: Relative coordinates of camera CAM4 and calibration points

	X	Y	Z
CAM4	2.82	-4.18	3.85
point 1	1.617	4.265	-0.003
point 2	3.963	4.313	-0.004
point 3	0.497	3.139	0.004
point 4	2.243	3.358	-0.001
point 5	1.204	2.111	0.001
point 6	3.270	2.175	-0.001
point 7	-0.021	1.739	0.022
point 8	1.183	0.736	0.005
point 9	0.000	0.007	0.039
point 10	0.706	-0.009	0.016
point 11	2.545	0.387	-0.011

2.1.5   Video camera for basement s6 (s6_cam5_instar)

Camera s6_cam5_instar is an INSTAR IN-5907HD positioned to detect water accumulating in the basement s6. On 6/10/2016 a marked rod was placed in the manhole in order to visually quantify the rise and fall of water. The dimensions of the rod are provided in the additional material.

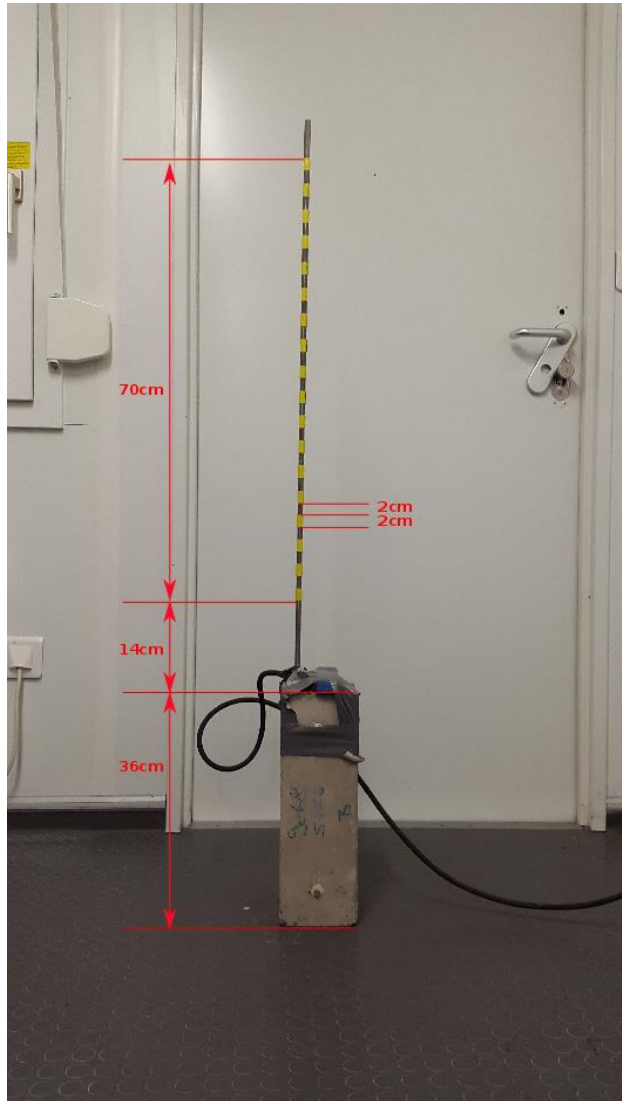**Figure 14: View from CAM5 of manhole m3, with ruler pole system emerging from hole.**

Figure 15: Dimensions of ruler pole system placed in manhole m3. The pressure probe `m3_h_p_hach` can be seen in blue at the top of the cement block.

2.2 Pressure sensors

Waterpilot FMX21 barometric probes from Endress+Hauser were used to record the water level in manholes m1, m2, and m3. The measurements were logged with three Minilog RDL10, meant for operational situations, which had to be supplemented with imaging devices in order to obtain a higher recording frequency (as for p1_q_mid_endress). In contrast with the solution implemented for p1_q_mid_endress, the imaging devices could not record the display of the sensor but had to record the displays of the Minilog RDL10 logger, on which instantaneous values appear intermittently instead of constantly. Additionally, only one Logitech c920 webcam and one COOLPIX AW100 were used to record all three logger displays. The data from the different logging systems are named in the following way:

- **m[1,2,3]_h_p_endress_minilog**: Minilog RDL10 logger, saves one value every minute which is the average water level of the past 60 seconds

- **m[1,2,3]_h_p_endress _logi**: one-second interval images from a Logitech c920 webcam, installed on 6/10/2016
- **m[1,2,3]_h_p_endress _coolpix**: high-definition video recordings with a COOLPIX AW100 point-and-shoot camera.

2.2.1   m1_h_p_endress

Figure 16: Sensor m1_h_p_endress that was placed in manhole m1.

By post-analyzing the data from this sensor, we were able to determine that the reference elevation of the probe was 418.42 meters above sea level.
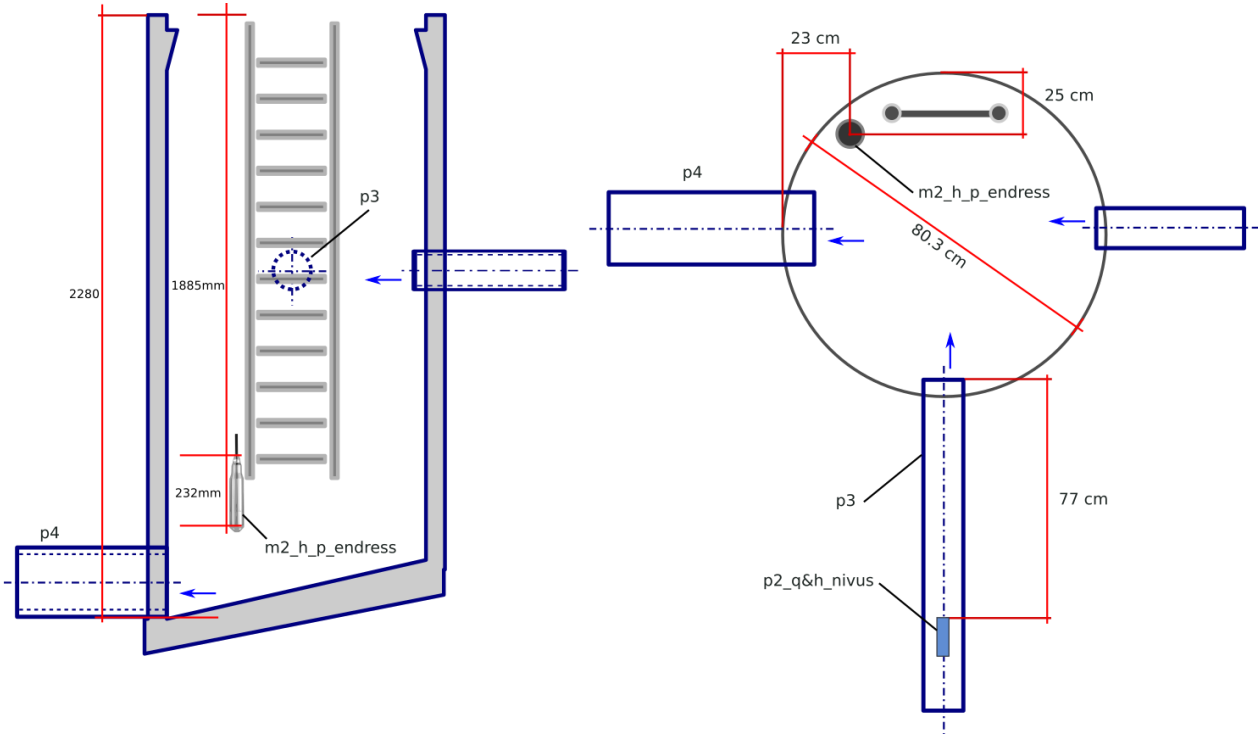
2.2.2 m2_h_p_endress

Figure 17: Position of m2_h_p_endress in manhole m2 and p3_q&h_nivus in pipe p3. View from the side (left) and from above (right)

Figure 18: Installation of m2_h_p_endress in manhole m2.

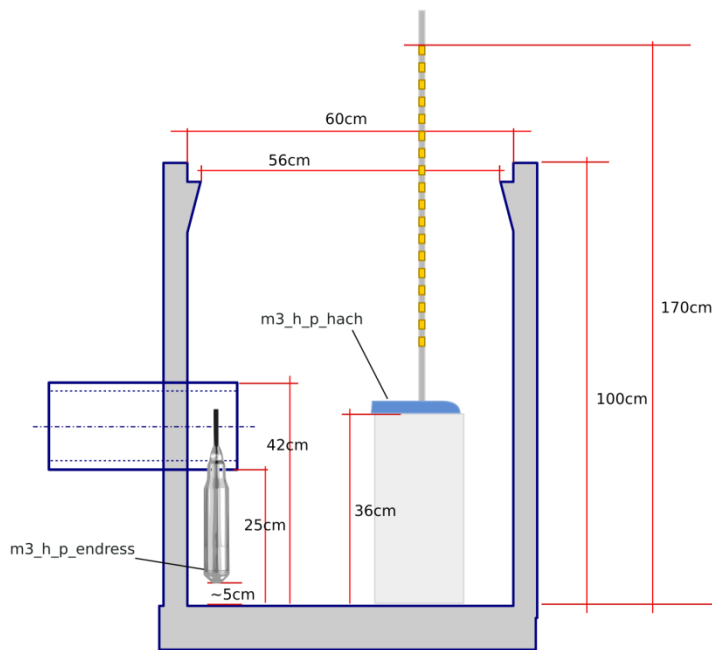### 2.2.3   m3_h_p_endress and m3_h_p_hach

Figure 19: Placement of sensors m3_h_p_endress and m3_h_p_hach in manhole m3.

2.2.4   Barometric water level sensor in manhole m3 (m3_h_p_hach)

A Hach AV9000 was used in manhole m3 to measure the water level in the basement of the house. Like the other Hach device, the logging frequency of m3_h_p_hach was one minute.

2.3   Temperature probes at opening r3 of manhole m2 (r3_t_onset_1/2/3/4)

Four Onset TMC6-HD temperature probes were placed at the opening r3 of manhole m2 in order to detect manhole overflows (Figure 20).

- r3_t_onset_1 is located within the manhole, 21.5 cm below ground level;
- r3_t_onset_2 is located within the manhole, 7.5 cm below ground level;
- r3_t_onset_3 is located 3 cm away from the edge of the manhole, 2.5 cm above ground level;
- r3_t_onset_4 is located in a place where it was not supposed to get wet, in the shade, in a

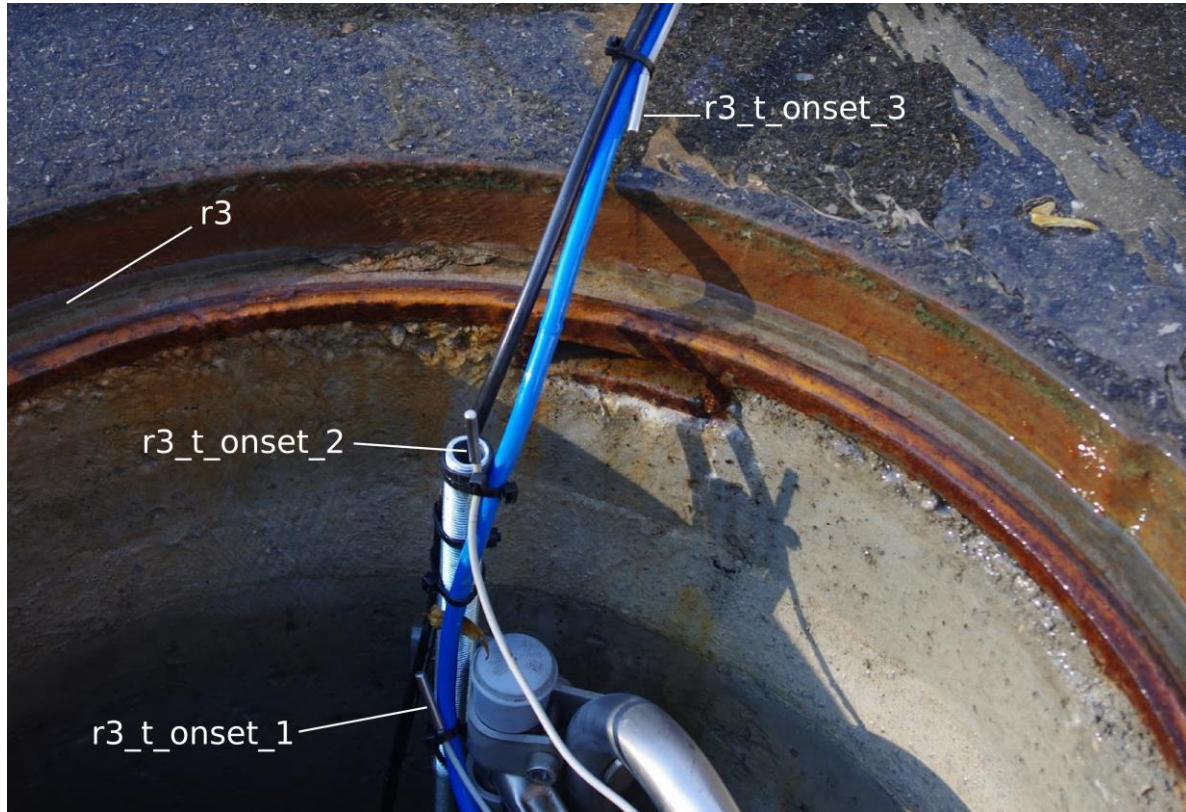The data was logged at one second intervals using a Onset HOBO U12-006 data logger.

Figure 20: temperature sensors r3_t_onset at the orifice r3 of manhole m2. Sensor r3_t_onset_4 is situated away from the orifice, in the shade.

2.4 Magnetic inductive flow sensor in pipe p1 (p1_q_mid_endress)

This Endress+Hauser Proline Promag 53P device was installed in an extension at the entry of pipe p1, in the reservoir s1 (Figure 21). It provides very accurate readings of flow at a high frequency. The extension was necessary because of the geometry of the reservoir and to guarantee a sufficient stabilization of the flow. Because the logger used with this device for operational purposes only logs a mean value every minute, we had to install camera systems to record the display of the logger (Figure 22).

Figure 21: Installation of p1_q_mid_endress in the reservoir s1.

Figure 22: setup and example image for alternative logging of p1_q_mid_endress

The data from the different logging systems are named in the following way:

- **p1_q_mid_endress_minilog**: Minilog RDL10 logger, saves one value every minute which is the average flow of the past 60 seconds
- **p1_q_mid_endress_logi**: One-second interval images from a Logitech c920 webcam, installed on 6/10/2016

2.5 Water level and flow velocity in open channel c3 (c3_v_radar_nivus, c3_h_us_nivus, c3_v_radar_hach and c3_h_us_hach)

Two systems were installed in parallel to measure surface water velocity and level in the channel c3 (Figure 23). The first system is a Nivus OFR Radar sensor (for water velocity) and NivuCompact (ultrasound for water level) while the second is a Hach Flodar that combines radar and ultrasound in one device. The velocity logged by both devices is a bulk velocity and not the surface velocity. The Nivus system logged data at 5 second intervals while the Hach system logged data at 1 minute intervals.

Figure 23: Two radar systems mounted above channel c3: Nivus (left) and Hach (right)

The Hach Flodar has a measurement range of 0.23 m/s-6.1 m/s for the flow velocity and a 0-1.524 m range for the water level. For stationary flow conditions, a measurement error of +/- 5% can be expected, but this will be larger in non-stationary conditions. The Nivus OFR Radar sensor has a velocity measurement range of -1m/s to 6 m/s, and water level range of 0-5 m. The measurement error can be expected to be around 2% for velocity and 2-5% for flow,

depending on hydraulic conditions. However, we can expect a greater error because of the low water level (around 5 cm) and observed drift in water level measurement.

2.6   Ultrasonic flow sensors

The ultrasonic flow sensors used were Nivus CSM-V1D0 devices. The sensor is a small format sensor that combines an ultrasonic velocity profile measurement with a pressure-based water level sensor.

2.6.1   Ultrasonic flow sensor in pipe p2 (p2_q_us_nivus and p2_h_p_nivus)

The first sensor was installed in pipe p2 to measure flow (p2_q_us_nivus). However, the proximity of the sensor to manhole m2 means that the water level estimation (p2_h_p_nivus) at the sensor also tells us something about the water level in the manhole m2 (Figure 17). The data was logged using a Nivus PCM Pro at 5-second intervals.

2.6.2   Ultrasonic flow sensor in pipe p6 (p6_q_us_nivus and p6_h_p_nivus)

The second sensor was installed in pipe p6 (see Figure 28) to measure flow (p6_q_us_nivus). Pressure was also measured (p6_h_p_nivus). The data was logged using a Nivus PCM Pro at 5-second intervals.

2.7   Ultrasonic water level sensors

2.7.1   Ultrasonic water level sensors in reservoir s1 (s1_h_us_maxbotix)

Two Maxbotix MB7369 ultrasonic water level sensors s1_h_us_maxbotix_1 and s1_h_us_maxbotix_2 were installed in the reservoir s1 (Figure 24). However, because an additional water level measurement was required in s3, s1_h_us_maxbotix_2 was removed on the 6/10/2016 in the morning. The readings of these sensors were logged using an in-house LabView program running on a laptop computer. The sensors provide around 6 readings per second that are neither calibrated nor adjusted for temperature changes.

Figure 24: Ultrasonic water level sensors mounted in the reservoir s1: s1_h_us_maxbotix_1 (left) and s1_h_us_maxbotix_2 (right)

2.7.2   Ultrasonic water level sensor in reservoir s3 (s3_h_us_maxbotix)

A Maxbotix MB7369 ultrasonic water level sensor s3_h_us_maxbotix was installed in the reservoir s3 on 6/10/2016 in the morning. The sensor provides around 6 readings per second that are neither calibrated nor adjusted for temperature changes. The readings were logged by an in-house LabView program running on a laptop computer.

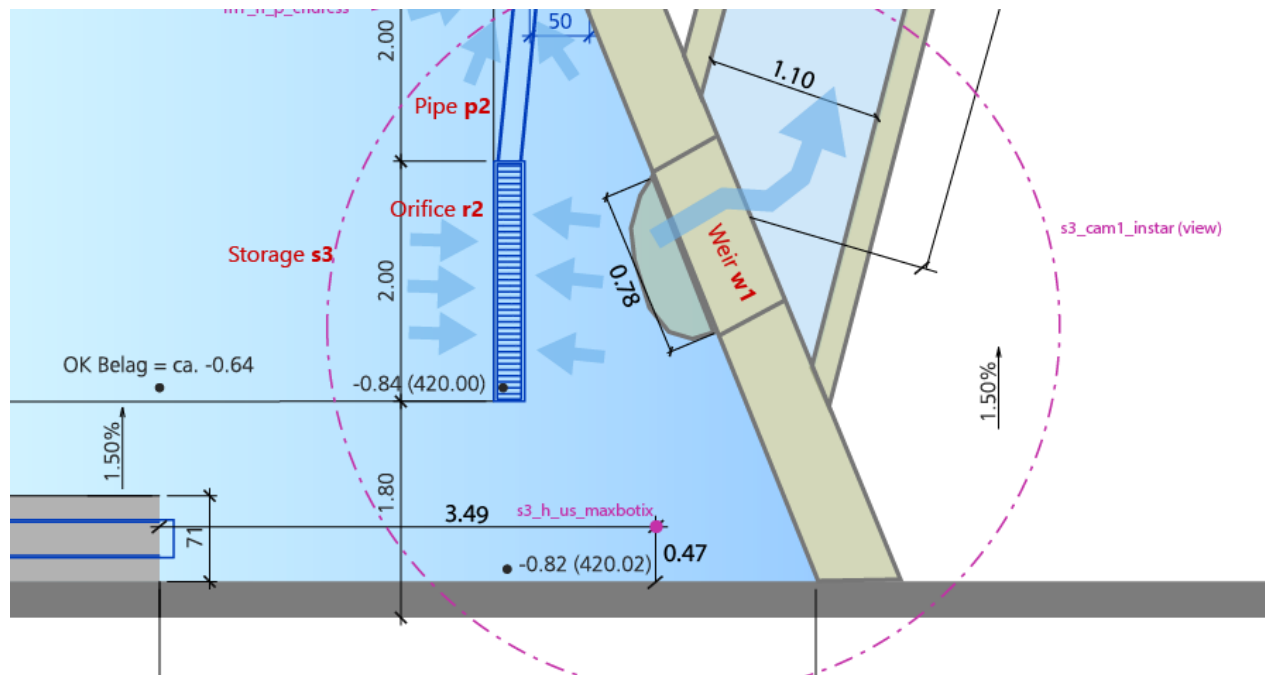**Figure 25: Photo of sensor s3_h_us_maxbotix above storage area s3.**

Figure 26: Sketch describing location of s3_h_us_maxbotix in storage area s3.
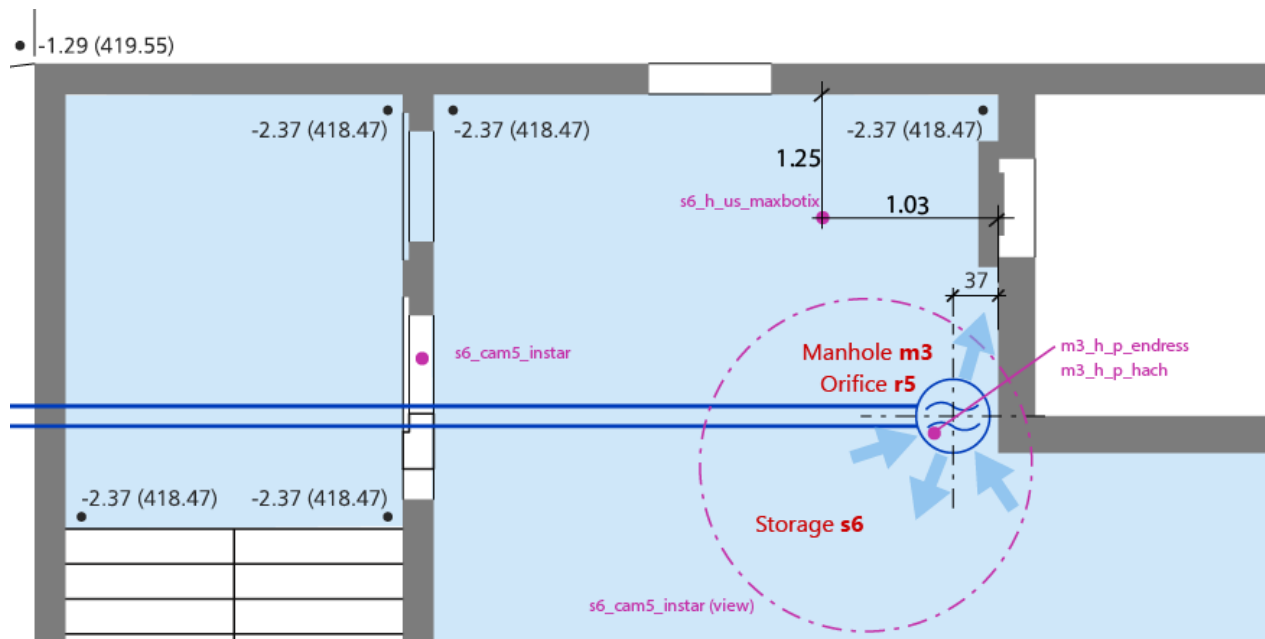
2.7.3   s6_h_us_maxbotix

Figure 27: Placement of sensor s6_h_us_maxbotix in the basement of the house.

2.7.4   Ultrasonic water level measurement in exit shaft (s5_h_us_maxbotix_1 and s5_h_us_maxbotix_2)

A Maxbotix MB7369 ultrasonic water level sensor was installed in exit shaft s5, but it had to be moved from its initial location (where it was called s5_h_us_maxbotix_1) because the measurement was disturbed by water falling into the shaft. In its new location, the sensor carries the name s5_h_us_maxbotix_2.

Figure 28: locations of ultrasonic sensor as s5_h_us_maxbotix_1 (left) and s5_h_us_maxbotix_2 (right). Pipe p6 is visible at the bottom of the shaft.
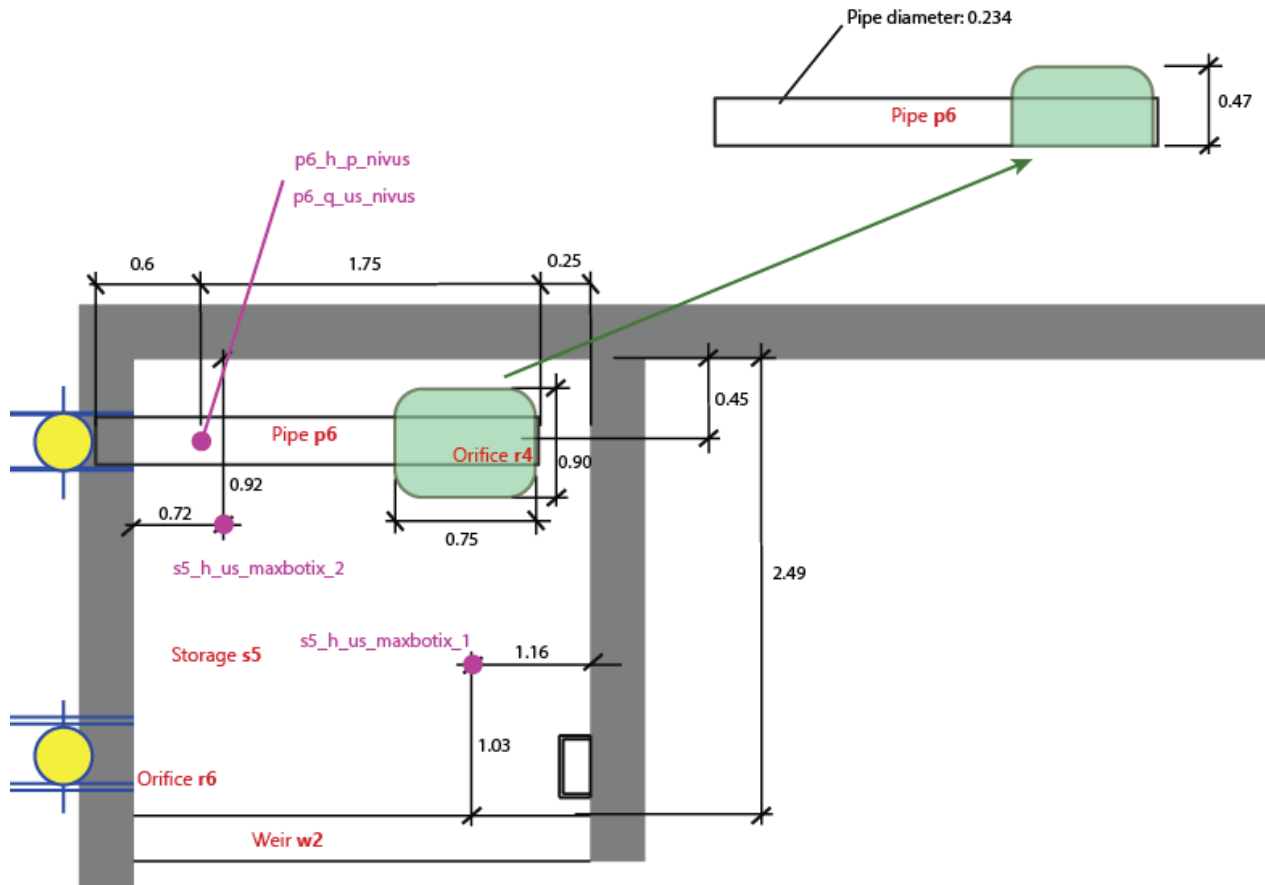
2.8   Shaft s5, pipe p6, and sensors p6_q&h_p_nivus

Figure 29: Shaft s5, containing pipe p6.

3   Data preprocessing

3.1   Standard processing steps

- **Consolidation**: Data for a single sensor but stored in multiple source files are consolidated into a single file. The paths to the source files are contained in the metadata.csv file. The specific formatting of each source file is specified in metadata.csv file.

- **Sorting**: Since the data is consolidated from multiple files, each data entry must be sorted in chronological order.

- **Formatting**: Each data logger uses a particular formatting system for the csv formatting, the date and time, and for null values. These formats are homogenised according to the user preferences defined in settings.py. However, all null values are simply removed from the data.

- **Offsetting**: Ultrasonic water level sensors measure the gap between the water and the sensor. To obtain the water level, this value has to be offset by the distance between the ground and the sensor (ground_level value in metadata.csv).

- **Time shifting**: Delays and time zone differences of logger clocks are corrected (time_shift in metadata.csv).

- **Removal of extreme values**: Impossible values such as negative water levels and extremely large values due to OCR misreading of the sensor displays are adjusted or removed, respectively (max_valid_value and floor_value in metadata.csv). Some data loggers, like those from Nivus and Hach, remove impossible values automatically.

- **Segmentation of data by experiment**: The processed data can be exported either grouped by experiment, for modelling, or ungrouped, for viewing and exploring. The data grouped by experiment are cropped to exclude time between experiments, e.g., when the system is flushed. Export grouping preferences are set by the export_selection option in settings.py.

- **Formatting for time series database**: For viewing and exploring the data, we recommend using CrateDB (https://crate.io/) for a time series database and Grafana (http://grafana.org/) as a graphical dashboard. To import the data into CrateDB, the data must be formatted in a JSON-like fashion. If the write_crateDB option is set to True, then the data will be written in the required JSON format as well.

3.2   Reading sensor display images with optical character recognition

Because of the low logging frequency of the minilog data loggers, which was only discovered in the middle of the experiment campaign, high frequency measurements for sensors p1_q_mid_endress, m1_h_p_endress, m2_h_p_endress, and m3_h_p_endress were only possible by taking images of the sensor or logger displays. These images are provided in the floodX Data Logger Images package (see example in Figure 30).

Figure 30: Example image of the display of the discharge sensor in pipe p1.

To process the images into text data, the preprocessing script makes use of a well-known implementation of optical character recognition (OCR) called tesseract-ocr (Smith et al., 2007), which is called from Python with a wrapper (pytesseract)[1]. The Python script first clips out the area(s) of interest from the image before processing it with OCR. Since the position(s) of the display(s) sometimes changed between recording sessions, the images are grouped by session and are associated with a settings file that indicates the bounding box and rotation of the sensors.

Because the image exposure was sometimes too large, some of the images are an overlay of two values on the display. In some cases, this causes the OCR algorithm to falsely interpret the value and an error is produced. In some

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[1] https://pypi.python.org/pypi/pytesseract

cases, this error is very great and the outlier value can be removed with a simple threshold during data preprocessing. In the future, more advanced filters could be implemented for the data.

While the tesseract-ocr solution is effective for the images of p1_q_mid_endress to log water flow in pipe p1, it does not work with images with the m[1/2/3]_h_p_endress for water levels at manholes, possibly because of the image quality and the small size of the displays that disturb the image segmentation process. No solution for reading pressure measurement images was invested into, since the variation of water level at the manholes is not as rapid as it is for flow in pipe p1. Just in case, additional image material for the pressure sensors has been provided in the form of HD video material (floodX Data Logger Videos package).

3.3 Video and image data

Due to the nature of the video data, it is not possible to modify it in a satisfactory way, e.g. to correct time stamps. For this reason, the temporal shifts of the cameras for each recording session are provided in tabular format (Table 14). (Positive values indicate that the video time is ahead of the reference time)

Table 14: Temporal offset of cameras during the last two days of the floodX experiments.

recording session	cam1	cam2	cam3	cam4	cam5
161005A	00:00:03	00:00:00	00:00:09	-00:00:04	-00:00:07
161005B	00:00:03	00:00:00	00:00:09	-00:00:04	-00:00:07
161006A	00:00:03	00:00:00	00:00:10	-00:00:03	-00:00:10
161006B	00:00:02	00:00:00	00:00:09	-00:00:04	-00:00:11
161007A	-00:00:01	00:00:00	00:00:07	-00:00:11	-00:00:14

4 Tables of hydraulic components and datasources

Table 15: Labeling of hydraulic components.

Label	Type	Description
c1	Open channel	ramp leading to pond n1
c2	Open channel	open channel leading from dam
c3	Channel	Laminar flow channel where radars are placed
c4	Channel	Variable width channel approaching 2D flow
m1	Manhole	manhole to which drain inlets in dam
m2	Manhole	manhole in front of house, which overflows
m3	Manhole	Manhole in basement of house
s1	Storage	Main reservoir
s2	Storage	Shaft into which p1 empties, and which leads to ramp
s3	Storage	Pond formed by dam after ramp, contains bicycle. Drained by r1 and r2
s4	Storage	Pond around overflow manhole
s5	Storage	Exit shaft
s6	Storage	basement of house, that can be flooded
p1	Pipe	connects reservoir to facility, up to valve
p2	Pipe	pipe connecting r1 to m1
p3	Pipe	pipe connecting m1 to m2
p4	Pipe	pipe linking m2 to distribution pipe p5
p5	Pipe	distribution pipe allowing water to communicate between pipes of the sewer network
p6	Pipe	Pipe containing pipe profiler, for measuring flow exiting system
p7	Pipe	Pipe leading from distribution pipe p5 to manhole in basement m3
p8	Pipe	Pipe draining the facility
r1	Orifice	long sewer inlet covered with grating

r2	Orifice	rectangular sewer inlet with a spring-action grating
r3	Orifice	Manhole opening of m2, leading to n4
r4	Orifice	Orifice of pipe containing pipe profiler
r5	Orifice	Manhole opening of m3, in basement
r6	Orifice	orifice between n5 and p9
v1	Valve	main valve that controls how much water enters the facility
v2	Valve	valve between p4 and p5, closed during experiments but opened to empty out water from manhole m2
v3	Valve	Valve between p5 and p7, left open during all experiments
v4	Valve	Valve controlling water exiting system
w1	Weir	weir of dam that forms n3
w2	Weir	curb delimiting c2 and n4
w3	Weir	waterfall from surface to exit shaft n5
w4	Weir	weir between shaft n2 and ramp

Table 16: List of datasources involved in floodX experiments.

Location	datasource	Sensor	Measurement principle	Logger	Parameter	Unit	Interval / Resolution	Installation
s1 (reservoir)	s1_h_us_maxbotix_1	Maxbotix MB7369	Ultrasonic	Labview script	d	mm	6/sec	03.10.16
s1 (reservoir)	s1_h_us_maxbotix_2	Maxbotix MB7369	Ultrasonic	Labview script	d	mm	6/sec	03.10.16
p1 (pipe from reservoir)	p1_q_mid_endress_minilog	Endress+Hauser Proline Promag 53P	Inductive magnetic field	Minilog RDL10	Q	l/s	1 min	03.10.16
p1 (pipe from reservoir)	p1_q_mid_endress_coolpix	Endress+Hauser Proline Promag 53P	Inductive magnetic field	COOLPIX AW100	Q	l/s	< 1 sec	03.10.16
p1 (pipe from reservoir)	p1_q_mid_endress_logi	Endress+Hauser Proline Promag 53P	Inductive magnetic field	Logitec c920	Q	l/s	1 sec	03.10.16
s3 (artificial lake)	s3_h_us_maxbotix	Maxbotix MB7369	Ultrasonic	Labview script	d	mm	< 1 sec	05.10.16
m1 (manhole in lake)	m1_h_p_endress_minilog	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	Minilog RDL10	h	mm	1 min	03.10.16
m1 (manhole in lake)	m1_h_p_endress_coolpix	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	COOLPIX AW100	h	mm	< 1 sec	05.10.16
m1 (manhole in lake)	m1_h_p_endress_logi	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	Logitec c920	h	mm	1 sec	05.10.16
p2 (leading to overflow	p2_q_us_nivus	Nivus CSM-V1D0	Ultrasonic doppler	Nivus PCM Pro	Q	L/s	5 sec	03.10.16

manhole)								
p2 (leading to overflow manhole)	p2_h_p_nivus	Nivus CSM-V1D0	Hydrostatic pressure	Nivus PCM Pro	h	mm	5 sec	03.10.16
r3 (manhole opening)	r3_t_onset_1	Onset TMC6-HD	Temperature	Onset HOBO U12-006	T	C	1 sec	03.10.16
r3 (manhole opening)	r3_t_onset_2	Onset TMC6-HD	Temperature	Onset HOBO U12-006	T	C	1 sec	03.10.16
r3 (manhole opening)	r3_t_onset_3	Onset TMC6-HD	Temperature	Onset HOBO U12-006	T	C	1 sec	03.10.16
r3 (manhole opening)	r3_t_onset_4	Onset TMC6-HD	Temperature	Onset HOBO U12-006	T	C	1 sec	03.10.16
m2 (overflow manhole)	m2_h_p_endress_minilog	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	Minilog RDL10	h	mm	1 min	03.10.16
m2 (overflow manhole)	m2_h_p_endress_coolpix	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	COOLPIX AW100	h	mm	< 1 sec	05.10.16
m2 (overflow manhole)	m2_h_p_endress_logi	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	Logitec c920	h	mm	1 sec	05.10.16
c3 (laminar channel)	c3_h_us_nivus	NivuCompact 3	Ultrasonic	Nivus OCM Pro CF	h	mm	5 sec	03.10.16
c3 (laminar channel)	c3_v_radar_nivus	Nivus OFR	Radar	Nivus OCM Pro CF	v	m/s	5 sec	03.10.16
c3 (laminar channel)	c3_h_us_hach	Hach Flodar	Radar	Hach logger	h	mm	1 min	03.10.16
c3 (laminar channel)	c3_v_radar_hach	Hach Flodar	Radar	Hach logger	v	m/s	1 min	03.10.16
s5 (exit shaft)	s5_h_us_maxbotix_1	Maxbotix MB7369	Ultrasonic	Labview script	d	mm	6/sec	03.10.16
s5 (exit shaft)	s5_h_us_maxbotix_2	Maxbotix MB7369	Ultrasonic	Labview script	d	mm	6/sec	06.10.16
p6 (exit flow stabilizer)	p6_q_us_nivus	Nivus CSM-V1D0	Ultrasonic doppler	Nivus PCM Pro	Q	l/s	5 sec	03.10.16
p6 (exit flow stabilizer)	p6_h_p_nivus	Nivus CSM-V1D0	Hydrostatic pressure	Nivus PCM Pro	h	m	5 sec	03.10.16
m3 (manhole in basement)	m3_h_p_endress_minilog	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	Minilog RDL10	h	mm	1 min	03.10.16
m3 (manhole in basement)	m3_h_p_endress_coolpix	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	COOLPIX AW100	h	mm	< 1 sec	05.10.16
m3 (manhole in basement)	m3_h_p_endress_logi	Endress+Hauser Waterpilot FMX21	Hydrostatic pressure	Logitec c920	h	mm	1 sec	05.10.16
m3 (manhole in basement)	m3_h_p_hach	Hach AV9000	Hydrostatic pressure	Hach logger	h	mm	1 min	05.10.16
s6 (basement)	s6_h_us_maxbotix	Maxbotix MB7369	Ultrasonic	Labview script	d	mm	6/sec	03.10.16
s3 (artificial lake)	s3_cam1_instar	Instar	Video	Desktop computer	-	-	26/sec	03.10.16
r3 (overflow manhole opening)	r3_cam2_instar	Instar	Video	Desktop computer	-	-	26/sec	03.10.16
c3 (laminar channel)	c3_cam3_instar	Instar	Video	Desktop computer	-	-	26/sec	03.10.16

c4 (2d overland flow)	c4_cam4_instar	Instar	Video	Desktop computer	-	-	26/sec	03.10.16
s6 (basement)	s6_cam5_instar	Instar	Video	Desktop computer	-	-	26/sec	03.10.16