

# Metrology in Urban Drainage and Stormwater Management: Plug and Pray

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# Metrology in Urban Drainage and Stormwater Management: Plug and Pray

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Edited by

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# Preface

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Optimism is a precious state of mind when starting an enterprise like writing a book with 50 international contributors without budget nor hard deadlines. Between the very first discussion related to this initiative, during the conference dinner at the UDM – Urban Drainage Modelling conference 2015 in Montreal, Canada, and the presentation of this book more than five years have passed. Of course, in those five years many things happened in the personal lives of people contributing to this book: job changes, hospitalization, bike accidents and last but not least: the Corona crisis. Nevertheless, the enthusiasm, energy and dedication of our colleagues that found time in their busy schedules to share their expertise kept things going. It is no exaggeration to state that all three phases of ambitious projects were encountered and sustained: uninformed optimism, informed pessimism and, finally, informed optimism.

This book, titled *Metrology in Urban Drainage and Stormwater Management: Plug & Pray*, aims at bringing together experience obtained by many people and organizations on the subject over the past decades, while summarizing and popularizing the latest research results to practitioners and engineers. Monitoring in urban drainage and stormwater management systems is challenging for many reasons. Apart from the obviously unfavourable physical/chemical/biological conditions encountered, keeping multidisciplinary teams going in organizational and sometimes politically complex environments that do not always offer optimal conditions, is no trivial task at all. We aim to supply scientists and practitioners with information, methods, examples, case studies and a comprehensive list of references that can be used to avoid (costly) mistakes/pitfalls from the initiative phase of a monitoring project down to the operation of monitoring networks and the validation of data collected for various predefined applications.

Obviously, a book on a subject like this cannot cover all related topics in great detail, therefore we do not claim to present all possible techniques and/or experiences; even worse, we don't even pretend that there are no mistakes or errors in the book. Therefore, the reader is encouraged to supply the editors with remarks, corrections and/or supplementary material that may be incorporated in future updates.

IWA Publishing is sincerely acknowledged for allowing this book to be Open Access, which is in line with the motivation of the editors and the contributing authors to freely share their experience and knowledge. We hope the

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book will contribute to increasing the quality of monitoring projects in the future and will be helpful in increasing appreciation of the added value monitoring has for managing urban drainage and stormwater management systems on the one hand, and supply data as a basis for a better understanding of the processes that drive the behaviour of these systems, on the other.

**Jean-Luc Bertrand-Krajewski, Francois Clemens-Meyer and Mathieu Lepot**

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**Jean-Luc Bertrand-Krajewski, Francois Clemens-Meyer and Mathieu Lepot**

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# List of Acronyms

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<b>Acronym</b>	<b>Meaning</b>
2D	Two dimensions
3D	Three dimensions
ACF	Auto Correlation Function
ADF	Acoustic Doppler Flowmeter
AET	Actual EvapoTranspiration
AI	Artificial Intelligence
AIC	Akaike Information Criterion
AMP	Asset Management Plan
API	Application Programming Interface
APUSS	Assessing Infiltration and Exfiltration on the Performance of Urban Sewer Systems
AR	Auto Regressive
ARI	Average Recurrence Interval
ARIMA	Auto Regressive Integrated Moving Average
ARMA	Auto Regressive Moving Average
ASCII	American Standard Code for Information Interchange
ATEX	ATmosphere EXplosible
AWS	Anglian Water Services
BDOH	Base de Données pour les Observatoires en Hydrologie (Database for Hydrologic Observatories)
BIPM	Bureau International des Poids et Mesures
BMPs	Best Management Practices
BOD	Biological Oxygen Demand
CAPEX	Capital Expenditures
CCTV	Closed Circuit Tele Vision

CD	Compact Disc
CDR	CorelDRAW file format
CEN	Comité Européen de Normalisation - European Committee for Standardization
CEO	Chief Executive Officer
CEPT	European Conference of Postal and Telecommunications Administration
CFD	Computational Fluid Dynamics
CFM	Correction Function Model
CIMO	Commission for Instruments and Methods of Observation
CNN	Convolutional Neural Network
COD	Chemical Oxygen Demand
CRC	Cyclic Redundancy Checks
CSO	Combined Sewer Overflow
CST	Control STation
CSV	Comma Separated Values
CSW	Catalogue Service for the Web
CUAHSI	Consortium of Universities for the Advancement of Hydrologic Science
DACF	Differentiated Auto Correlation Function
DBF	dBase Database File format
DBMS	Data Base Management System
DCM	Doppler Current Meter
DEM	Digital Elevation Model
DEST	Detection of Exfiltration from Sewers using Tracers
DGUV	German Social Accident Insurance
DID	Department of Irrigation and Drainage
DIY	Do It Yourself
DSD	Drop Size Distribution
DST	Daylight Saving Time
DTS	Distributed Temperature Sensing
DV	Data Validation
DVD	Digital Versatile Disc
DWA	German Association for Water, Wastewater and Waste
DWF	Dry Weather Flow
EC	Electrical Conductivity
EM	Electro Magnetic
EMF	Electro Magnetic Flowmeter
EMP	Electro Magnetic Pulse
EMV	Electro Magnetic Velocity meter
ENSO	El Nino Southern Oscillation
ERT	Electrical Resistivity Tomography
ET	EvapoTranspiration
ET <sub>0</sub>	Reference EvapoTranspiration
ETSI	European Telecommunications Standards Institute

EU	European Union
FAIR	Findable, Accessible, Interoperable and Reusable
FAT	Factory Acceptance Test
FCC	Federal Communications Commission
FDI	Fault Detection and Isolation
FDS	Flood Detection System
FDV	FullDome Digital Video
FELL	Focused Electro Leak Location
FEWS	Flood Early Warning System
FMECA	Failure Mode Effects and Criticality Analysis
FOV	Field Of View
FTE	Full Time Equivalent
GB	Giga Byte
GDPR	General Data Protection Regulation
GIS	Geographical Information System
GML	Geography Markup Language
GMT	Greenwich Mean Time
GPR	Ground Penetrating Radar
GPRS	General Packet Radio Service
GPS	Global Positioning System
GRAIE	Groupe de Recherche, Animation technique et Information sur l'Eau
GSM	Global System for Mobile Communication
GUM	Guide for Uncertainty in Measurements
H&S	Health and Safety
IAHR	International Association for Hydro-Environment Engineering and Research
IBM	International Business Machines
IEC	International Electrotechnical Commission
IoT	Internet of Things
IP	Ingress Protection
ISM	Industrial, Scientific and Medical
ISO	International Organization for Standardization
IT	Information Technology
IUD	Integrated Urban Drainage
IWA	International Water Association
JCGM	Joint Committee for Guides in Metrology
JSON	JavaScript Object Notation
KML	Keyhole Markup Language
KMZ	Zipped KML file format
KNMI	Royal Dutch Meteorological Institute
LED	Light Emitting Diode
LID	Low Impact Development
LiDAR	Light Detecting And Ranging

## **xxviii** Metrology in Urban Drainage and Stormwater Management: Plug and Pray

LOCF	Last Observation Carried Forward
LoD	Limit of Detection
LoQ	Limit of Quantification
LORAN	Long Range Area Network
LoRaWAN	Long Range Wide-area network
LPU	Law of Propagation of Uncertainties
LPWAN	Low Power Wide Area Network
LS-PIV	Large Scale Particle Image Velocimetry
LS-PTV	Large Scale Particle Tracking Velocimetry
M2M	Machine to Machine
MA	Mobile Average
MC	Monte Carlo
MCM	Monte Carlo Method
MCP	Monitoring Cycle Plan
MDM	Model Delivery Milestone
MFB	Mean Field Bias
MIF	MapInfo Interchange Format
ML	Machine Learning
MSFM	Multi Sensor Flow Meter
MST	Monitoring STation
NB-IoT	Narrow Band Internet of Things
NC	National Classification
NH <sub>4</sub>	Ammonia
NIST	National Institute of Standards and Technology
NO <sub>3</sub>	Nitrate
NOCB	Next Observation Carried Backward
NoSQL	Not only SQL
NTP	Network Time Protocol
NTU	Nephelometric Turbidity Unit
O&M	Observation & Measurement/Operation & Maintenance
OFWAT	UK Water Services Regulation Authority
OGC	Open Geospatial Consortium
OIML	International Organization of Legal Metrology
OLED	Organic Light-Emitting Diode
OLS	Ordinary Least Squares
OPEX	Operating Expenditures
OTHU	Observatoire de Terrain en Hydrologie Urbaine (Field Observatory on Urban Hydrology)
PC	Personal Computer
PD	Processed Data
PDF	Probability Density Function/Portable Document Format
PDP	Programmed Data Processor

PE	People Equivalent
PER	Packet Error Rate
PET	Potential EvapoTranspiration
pH	potential of Hydrogen
PHP	Hypertext Preprocessor
PI	Performance Indicator
PIV	Particle Image Velocimetry
PLC	Programmable Logic Controller
PLS	Partial Least Squares
PPE	Personal Protective Equipment
PPM	Parts Per Million
PS	Pumping Station
PTV	Particle Tracking Velocimetry
PVC	Poly Vinyl Chloride
QPE	Quantitative Precipitation Estimate
QUEST-C	Quantification of Exfiltration from Sewers with the help of Tracers Continuous Dosing
RAID	Redundant Array of Inexpensive Disks
RAMS	Risk Assessments and Method Statements
RAR	Roshal ARchive file format
RD	Raw Data
RDBMS	Relational DataBase Management System
RF	Radio Frequency
RMSE	Root Mean Squared Error
RPM	Rotation Per Minute
RPT	RePeaTer
RS-232	Recommended Standard 232
RS-485	Recommended Standard 485
RTC	Real Time Control
RTU	Remote Telemetry Unit
RZ	Riool Zuid (Southern sewer system)
SAM	Sewer Assessment with Multi-sensor Systems
SAT	Site Acceptance Test
SCADA	Supervisory Control and Data Acquisition
SCM	Stormwater Control Measure
SD	Secure Digital
SELV	Safety Extra-Low Voltage
SHP	Shape file format
SIM	Subscriber Identification Module
SMS	Short Message Service
SNR	Signal to Noise Ratio
SOP	Standard Operational Procedure/Protocol
SOS	Sensor Observation Service

SQL	Structured Query Language
SRD	Short Range Devices
SSH, HTTP	Secure Shell, Hypertext Transfer Protocol
SSL	Secure Sockets Layer
SUDS	Sustainable Urban Drainage Systems
SVG	Scalable Vector Graphics
TAB	MapInfo file format
TBR	Tipping Bucket Rain gauge
TCP/IP	Transmission Control Protocol/Internet Protocol
TDR	Time Domain Reflectometry
TIFF	Tagged Image File Format
TRA	Task Risk Assessment
TSS	Total Suspended Solids
TXT	Text file format
UA	Uncertainty Assessment
UDSM	Urban Drainage and Stormwater Management
US	Ultra Sound
USB	Universal Serial Bus
USGS	United States Geological Survey
UTC	Coordinated Universal Time
UV	Ultra Violet
UV/Vis	Ultra Violet/Visible
UWO	Urban Water Observatory
VES	Vertical Electrical Sounding
VHF/UHF	Very High Frequency/Ultra High Frequency
VIM	International Vocabulary of Metrology
VSI	Vital Sewerage Infrastructure
WaPUG	UK Wastewater Planning Users Group
WDD	Dutch Waterboard 'Waterschap de Dommel'
WERG	Waterways Ecosystems Research Group
WFD	European Water Framework Directive
WFS	Web Feature Service
WG	Working Group
WIS	Water Information System
WLS	Williamson Least Squares
WMO	World Meteorological Organization
WMS	Web Map Service
WR	Weighing Rain gauge
WSUD	Water Sensitive Urban Design
WWTP	WasteWater Treatment Plant
XML	Extensible Markup Language
ZIP	PKZIP file format