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Infiltration Detection using Acoustic Sensing & AI-based Data Analysis

Skills and Digital

Tuesday 17 September 2024

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Infiltration!.....the “hidden problem.”

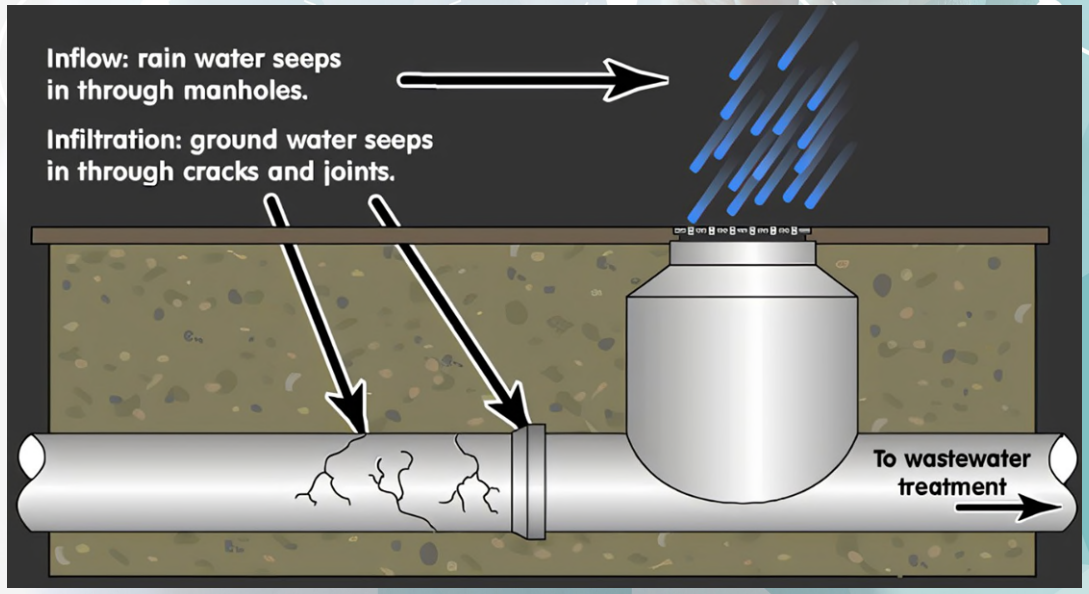
Infiltration: Ingress of water into the pipe network from surrounding surface and groundwater.

*“Future Impacts on Sewer Systems in England and Wales” prepared for Ofwat, the study suggests that ‘typical infiltration rates are about **40% of domestic flow**’.*

This is a significant amount extra water that can overwhelm the sewer infrastructure, it occupies space in the sewer pipes that would otherwise be available for transporting wastewater, thereby reducing the system's ability to handle normal flow rates.

Impacts:

- Pressure on existing ageing infrastructure.
- Reduced capacity
- Pressure on pump stations and sewage treatment works.
- More regular CSO spills.



Benefits: Conventional v.s. Acoustic Sensing

Benefits of the proposed method vs traditional methods

1. **Reduction in Time & Cost:**
   - ✓ Acoustic sensors don't require flow logging/observation.
   - ✓ Easily deployable allows for larger catchment investigation.

2. **Uses methods that have already been validated.**
   - ✓ Traditional flow loggers- Data needs to be validated by manual analysis.
   - ✓ AI analysis: machine learning approach with Subspace Method.
   - ✓ A method certified by the Ministry of Land, Infrastructure, Transport and Tourism Japan, with many recorded usages in Japan.
   - ✓ Applicable to sewer pipes outside Japan.

3. **No need to enter manholes, ensuring safety during data collection/ on site.**
   - ✓ No interaction with flow, no mechanical or digital level with chance of clogging.

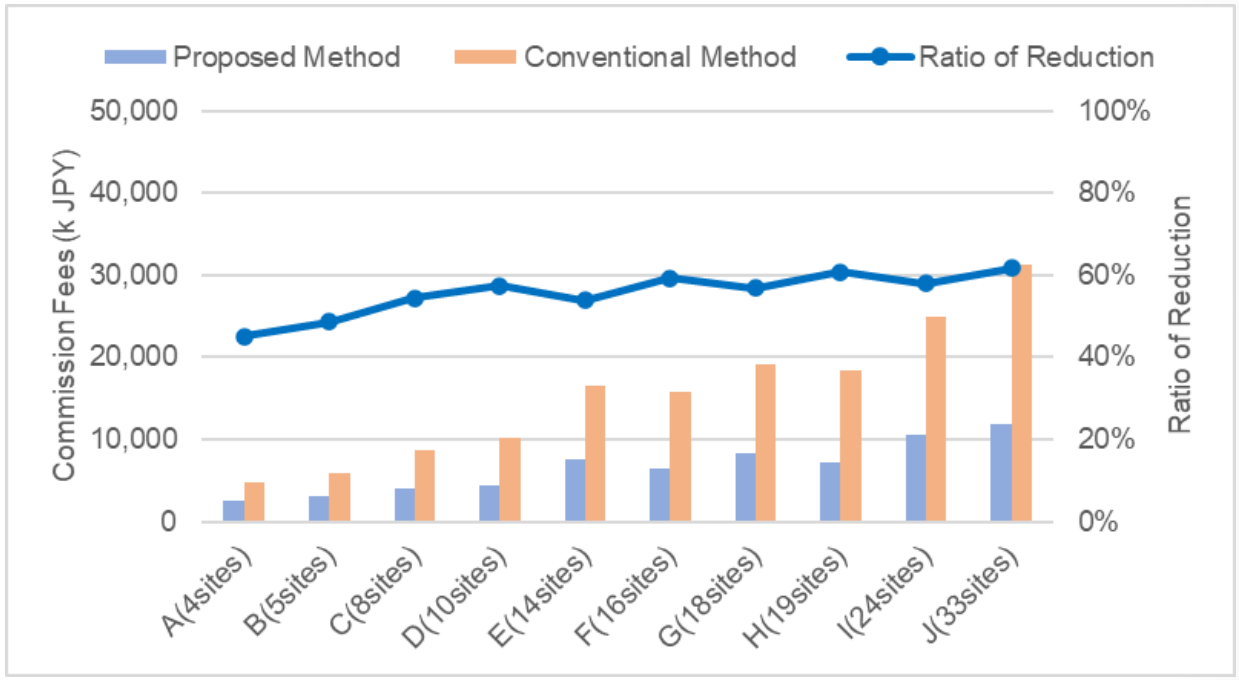
4. **Load reduction on treatment plants.**
   - ✓ Contributing to improvement of sewerage management by reducing costs.
   - ✓ Helps to reduce capacity on the network and risk of CSO spills
   - ✓ Contributing to net zero carbon emission.

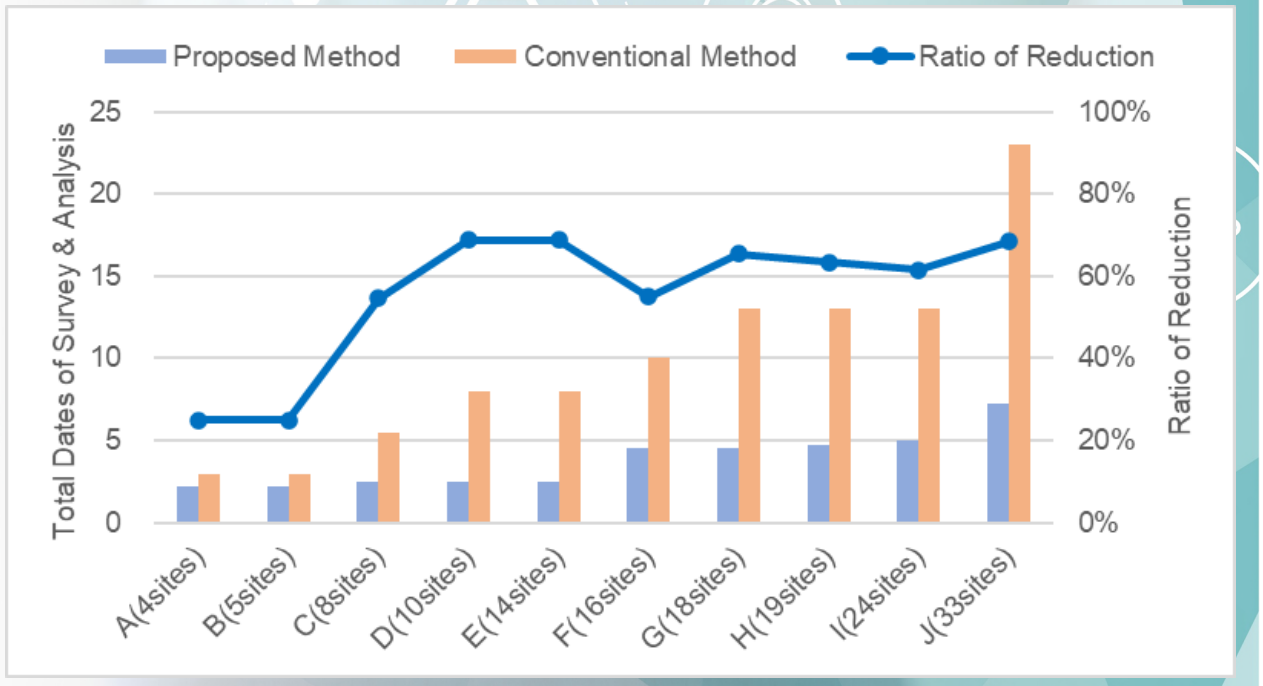
Benefits: Conventional v.s. Acoustic Sensing

Cost:
Cost **reduction by half** or more in flow observation and analysis.

Time:
Field survey and analysis can be shortened significantly.

- Installation of the sensor takes about 10 minutes/site.
- Analysis time is shortened, about 1 hr/site, due to AI analysis.





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Installation of the equipment.

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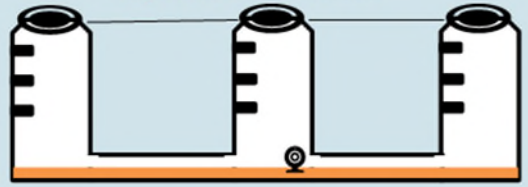
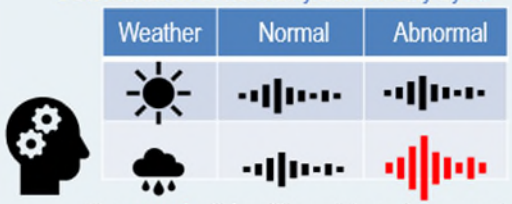
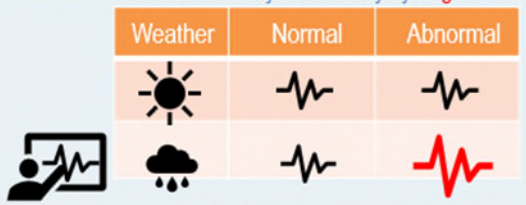
Summary of Benefits: Conventional v.s. Acoustic Sensing

	Proposed Technology	Conventional Technology
Wider survey area through easy deployment of sensors	Multi-point observation over a wide area using inexpensive instruments 	Limited observation due to expensive instruments 
Accurate and quick analysis by AI	Determination of normality/abnormality by AI  The sound will be different from the normal sound due to rainwater entry.	Determination of normality/abnormality by Engineers  The water level (flow) will be different from the normal level due to rainwater entry.
Considerable improvement of safety in field work	 Installation and removal work inside the manhole is not essential.	 Installation and removal work inside the manhole is essential.

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Field survey using acoustic sensor: About one month

- ✓ Installation of acoustic sensors in manholes.
- ✓ Observation of sound of flowing water in pipeline (Approximately 1 month including rainy weather).
- ✓ Collection of observation data.
- ✓ Storing data in CTI data analysis server.

Analysis of data using AI models: One week to one month

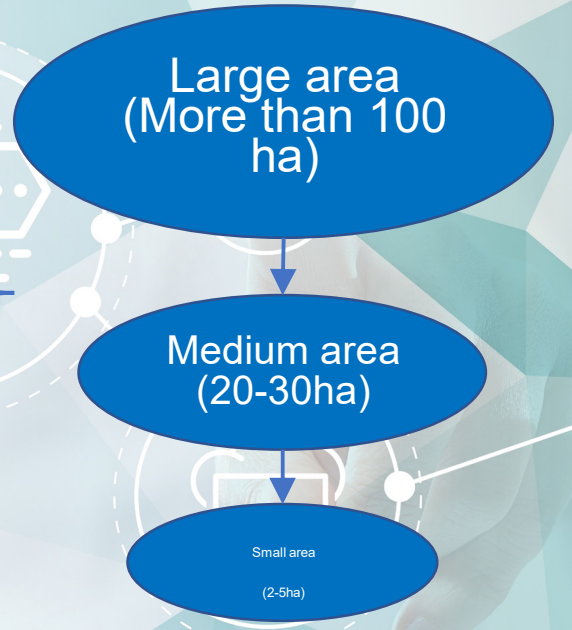
- ✓ Noise reduction.
- ✓ Feature extraction.
- ✓ Development of acoustic pattern model in fine weather.
- ✓ Deviation detection in rainy weather.

Narrowing down and identifying inflow points for rainwater intrusion

Informed CCTV investigation and pinpointing infiltration cause and detection

Implementing measures to prevent rainwater infiltration

Narrowing down areas of unknown inflow



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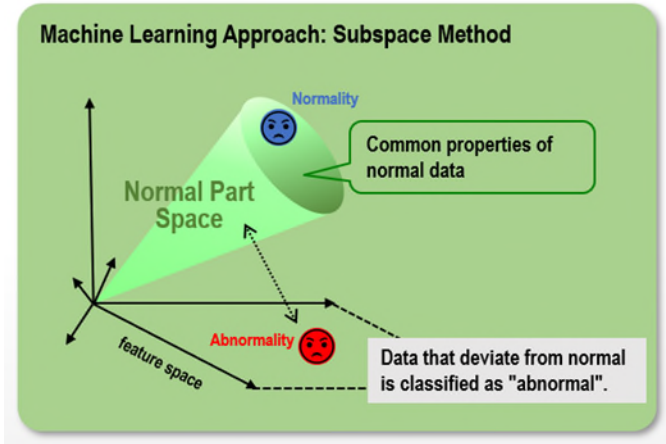
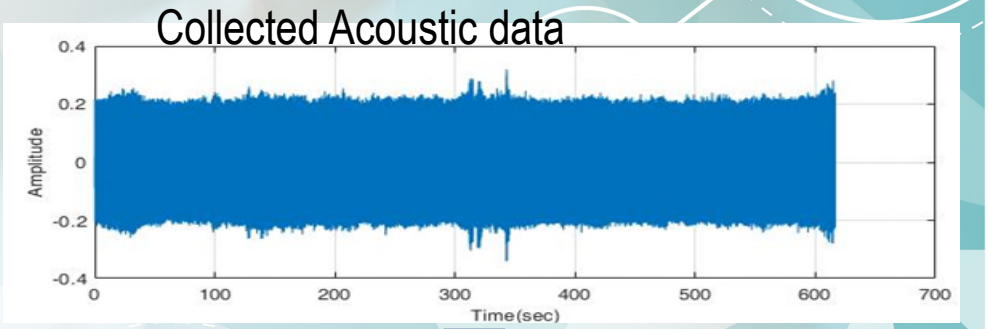
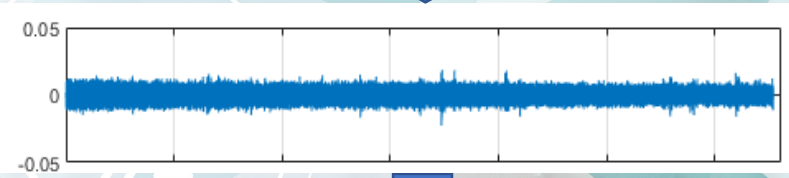
The Brains is in the AI!

- The AI technology uses adaptive learning to provide the results.
- Using patterns of sound taken from dry weather and wet weather scenarios the AI can identify baseline trends.
- When infiltration is present, there is a deviation from the baseline scenarios. The AI then flags that there is a higher possibility of infiltration in this section.
- The more data collected from the catchment = Better AI subspace learning and prediction of infiltration



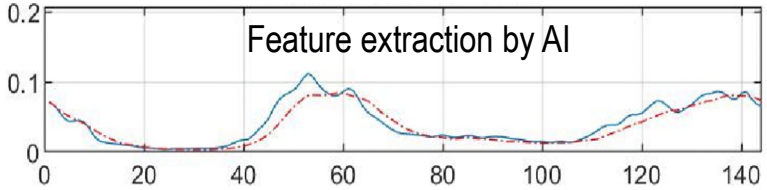


Noise Reduction



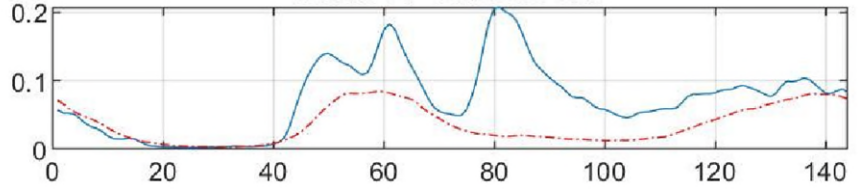
Extract features from about 200 indicators

Red line: Acoustic pattern in fine weather(AI Model)



Blue line: acoustic pattern on survey day (1 day)

Deviation detection



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AI feature pattern (base line) in fine weather

- The recorded fine weather acoustic data is convertec by AI to create a base line dry weather scenario.

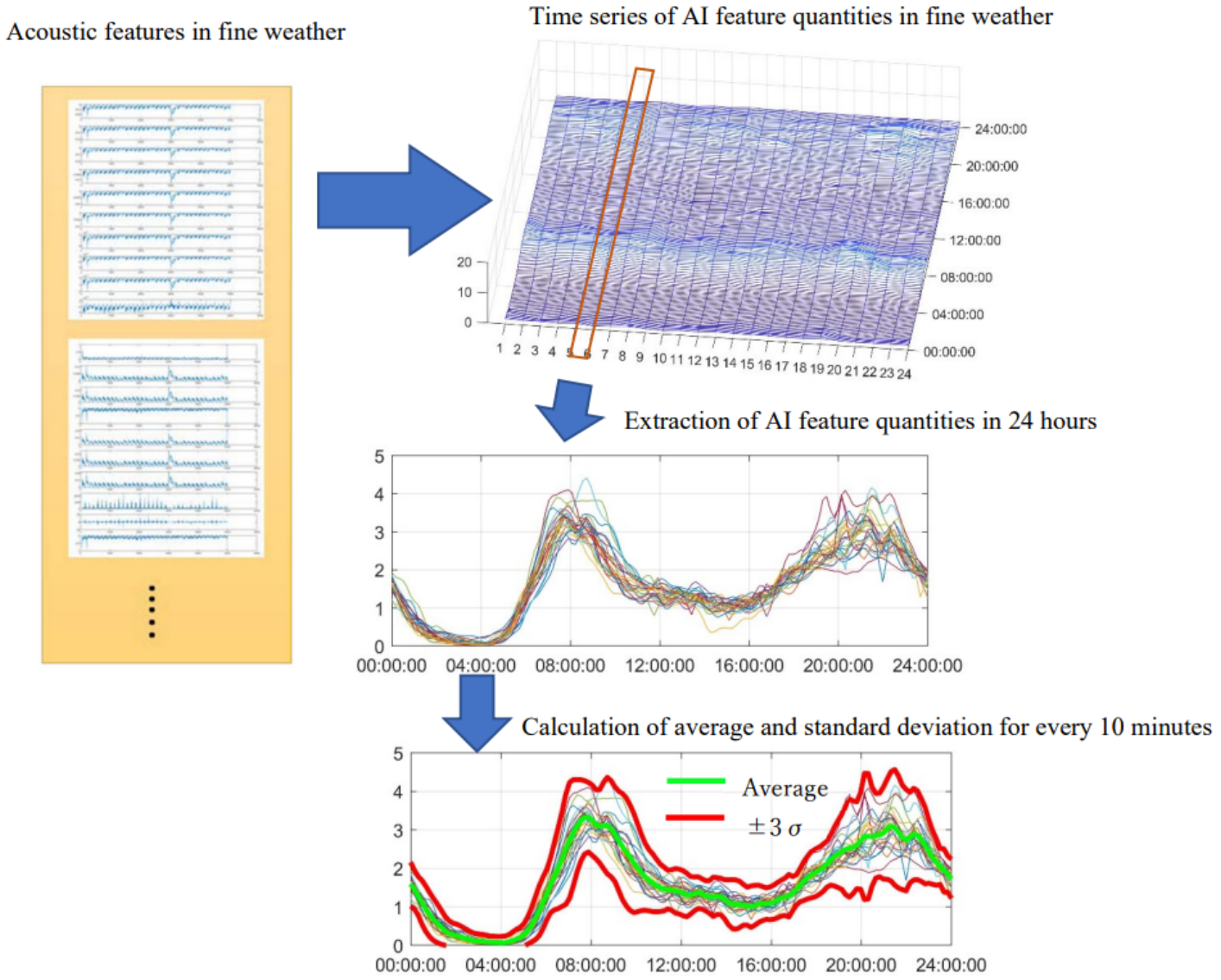
- (base line: time series data of average values and standard deviations) in fine weather.

Limitations to data:

Difficult locations to make a baseline:
- Irregular start-up and shutdown of manhole pumps is repeated.

- Drainage is conducted irregularly from factories/ industrial

- Lateral connections-the sound of flowing water (falling sound) occurs.



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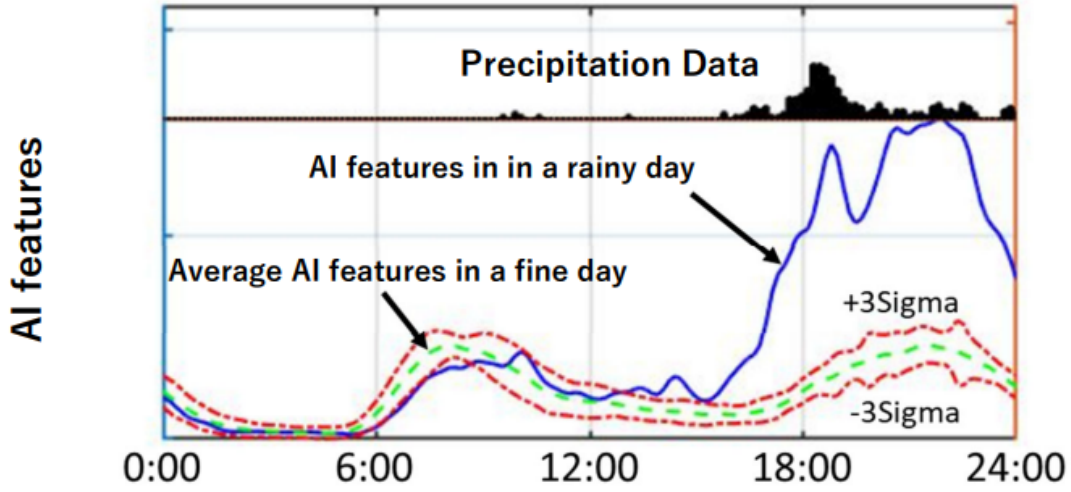
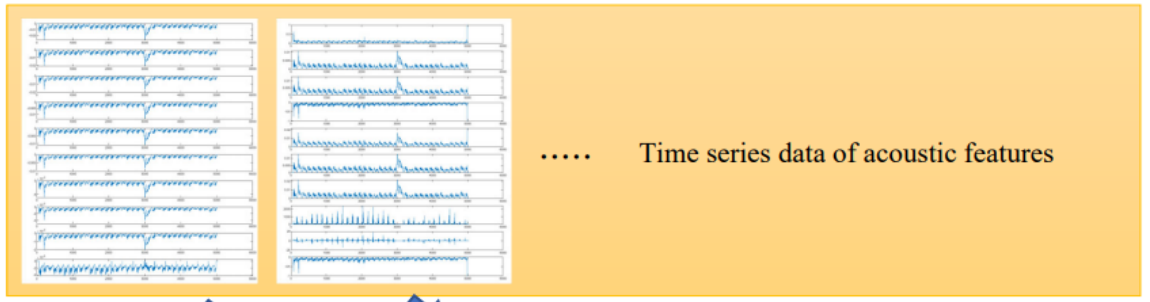
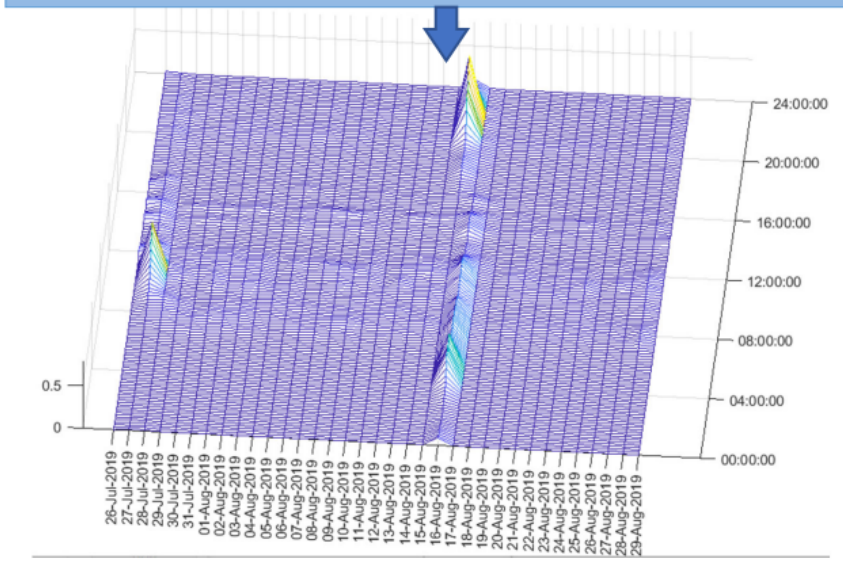
Deviation detection in wet weather scenarios

- All acoustic data including fine & rain weather are converted into AI baselines.
- AI detects the difference and can identify infiltration once compared with the Wet Weather Scenario.
- Infiltration proberbility is then assigned to the section of the network.





Intrusion detection AI engine in rain weather
Input: Time series data of acoustic features
Output: Time-series data of AI features



Time series of AI features

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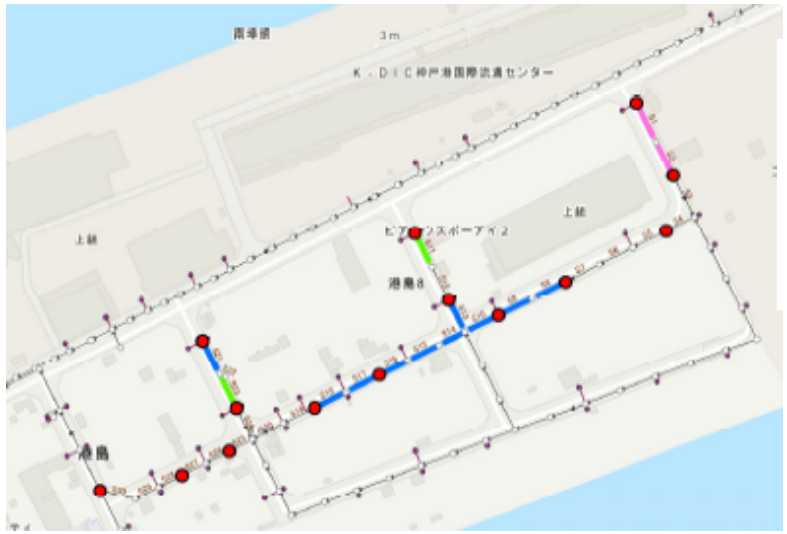
CASE STUDY: Kobe, Japan

- **Client:** Municipal sewerage administrator
- **Term:** 6 months, project ended in 2021
- **Contract value:** Approx. 8million JPY (= £50k GBP)
- **Scope:** Acoustic detection and analysis of deviation of rainwater infiltration into sewer network
  Survey area is 85ha.
  Sensors were installed at 32 locations and observations were conducted for 50 days.



Possibility of rainwater infiltration:
- High
- Medium
- Low
- Acoustic Sensor

Deviation detection ratio:
- Over 50 %
- 40-50 %
- 30-40 %
- 20-30 %

Result of analysis of the deviations

対象降雨No.				1	2	3	異常検知率		降雨量別 異常検知率			
									降雨量20mm以上		降雨量20mm未満	
降雨期間	開始時刻			9/17（金）9:00	10/16（土）19:00	10/25（月）6:00	平均	順位	降雨No.1 降雨No.3		降雨No.2	
	終了時刻			9/18（土）9:00	10/17（日）8:00	10/25（月）20:00						
	降雨時間			24	13	14						
降雨量	総雨量	(mm)		52	12	28.5						
	時間最大	(mm/h)		14.5	2.5	3.5			平均	順位	平均	順位
データ数				174	108	114						
異常検知率	北エリア	①	PN-1	47%	15%	-	31%	14	47%	13	15%	15
			PN-2	59%	7%	54%	40%	11	56%	9	7%	18
			PN-3	22%	7%	0%	10%	26	11%	28	7%	18
			PN-4	32%	1%	19%	17%	22	25%	19	1%	21
			PN-5	13%	0%	0%	4%	30	6%	29	0%	23
		②	PN-7	49%	0%	12%	20%	20	31%	15	0%	23
			PN-8	25%	1%	1%	9%	27	13%	26	1%	21
			PN-9	0%	26%	0%	9%	28	0%	30	26%	11
		③	PN-10	68%	26%	61%	51%	6	64%	4	26%	11
		④	PN-11	43%	18%	5%	22%	19	24%	23	18%	13
			PN-12	16%	0%	-	8%	29	16%	25	0%	23
			PN-13	67%	0%	-	34%	12	67%	3	0%	23
			PN-14	34%	0%	22%	19%	21	28%	18	0%	23
			PN-15	49%	-	-	49%	9	49%	12	-	-
			PN-16	28%	13%	50%	30%	15	39%	14	13%	17
			PN-17	71%	15%	49%	45%	10	60%	6	15%	15
			PN-18	52%	49%	63%	55%	3	58%	7	49%	2
	南エリア	⑤	PS-1	29%	37%	32%	32%	13	30%	16	37%	8
			PS-2	43%	56%	59%	52%	5	51%	11	56%	1
			PS-3	45%	47%	56%	50%	8	51%	10	47%	3
			PS-4	33%	42%	16%	30%	16	24%	21	42%	4
			PS-5	42%	39%	71%	51%	7	57%	8	39%	7
		⑥	PS-6	40%	0%	9%	16%	23	24%	22	0%	23
			PS-7	40%	0%	1%	14%	24	20%	24	0%	23
		⑦	PS-9	65%	42%	70%	59%	1	68%	2	42%	4
		⑧	PS-10	27%	16%	30%	24%	18	28%	17	16%	14
			PS-11	21%	27%	29%	26%	17	25%	20	27%	9
		⑨	PS-12	65%	40%	56%	54%	4	61%	5	40%	6
			PS-13	59%	27%	79%	55%	2	69%	1	27%	9
		⑩	PS-14	0%	5%	25%	10%	25	13%	27	5%	20

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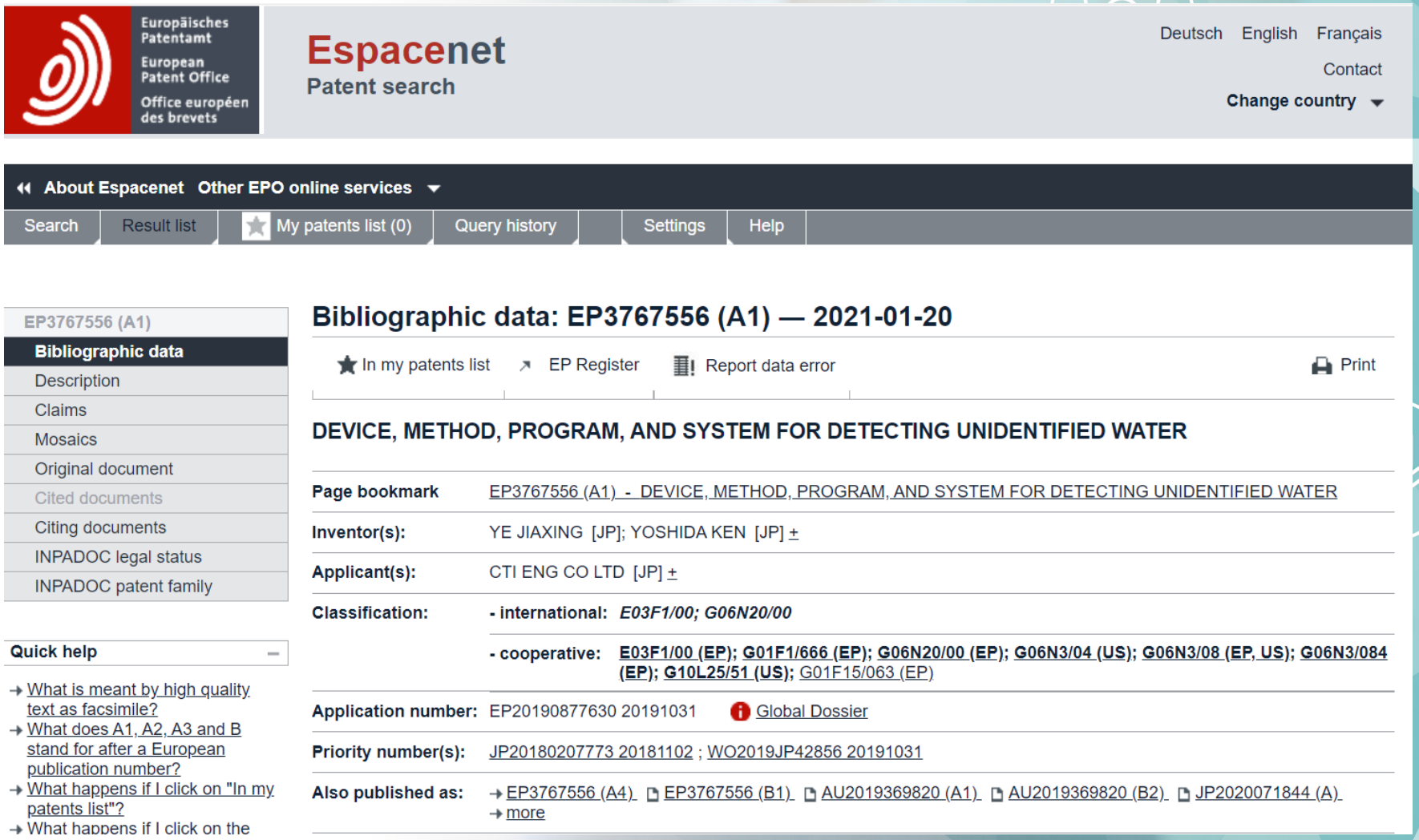
Patent Number in the UK: EP3767556
Title: DEVICE, METHOD, PROGRAM, AND SYSTEM FOR DETECTING UNIDENTIFIED WATER



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Next Steps

We aim to trial this technology in the UK.

- We are currently working with:
  - Anglian Water
  - Severn Trent
  - United Utilities
  - Scottish Water
  - Affinity Water

- We were successful in the SPRING innovation event- One of 9 innovations that made it through the full process.

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Thank You For Listening

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