

FROM ASSUMPTIONS TO FACTS, SHIFTING THE CONVERSATION TO BETTER MANAGE TIME, EFFORT, AND MONEY

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ABSTRACT (500 WORDS MAXIMUM)

Integrating visual Artificial Intelligence (visual AI) with the analysis of real-time physical water quality parameters facilitates the precise monitoring of stormwater systems, enhancing data integration and ultimately improving environmental management and response. . This paper explores the benefits and applications of this innovative methodology, focusing on how it can revolutionise stormwater management practices and be used to develop intelligent, fact-based investment strategies.

The crux of our approach lies in the utilisation of visual AI to provide real-time, accurate observations of stormwater systems and using machine learning and large language models to integrate the data provided by continuous physical water quality information. This technology enables us to visually monitor critical aspects such as trash rack management, underground gross pollutant traps, and combined sewer overflows.

By correlating these insights, we gain a comprehensive understanding of the stormwater system's health and functionality. Case studies are presented to illustrate the effectiveness of this method. These include managing trash racks more efficiently by identifying clogging events in real-time, monitoring underground gross pollutant traps to assess their effectiveness, and observing combined sewer overflows to mitigate pollution risks. Each case study highlights how visual AI enhances our ability to respond promptly and accurately to various challenges in stormwater systems. We will also look at how we can leverage the data that we already have access to, delve into how large-scale data, collected through visual AI and water quality sensors, is used to model, and predict system behaviors based on real time understanding, rather than intermittent and incomplete grab samples.

This data-driven approach married with practical analysis allows for the development of management strategies that are not only based on factual evidence but also tailored to specific environmental conditions and challenges. The predictive models that can be generated from this extensive data aid in optimising investment decisions, ensuring that resources are directed towards the most impactful solutions. Providing detailed, real-time insights into the physical state of water systems, their infrastructure, and their quality, this method allows for more informed, effective, and sustainable management practices.

KEYWORDS

#WaterMonitoring
#FreshwaterManagement
#EmergingTechnology
#Collaboration
#IntegratedWaterManagement
#Sustainability
#VisualAIinWaterManagement

1 INTRODUCTION

Stormwater management is a critical aspect of urban infrastructure, essential for preventing flooding, controlling pollution, and maintaining public health and safety. As urbanisation continues to grow, the demands on stormwater
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systems increase, necessitating innovative solutions to manage runoff effectively. Traditionally, stormwater management has relied on manual inspections and intermittent sampling, leading to gaps in data and delayed responses to emerging issues. This paper explores the potential of integrating visual Artificial Intelligence with the analysis of physical water quality parameters, providing a more comprehensive and efficient approach to stormwater management.

The integration of visual AI into stormwater management practices has gained traction in recent years, offering a new paradigm for monitoring and maintaining urban water systems. By leveraging the power of artificial intelligence and machine learning, visual AI allows for real-time observation and analysis of stormwater systems. This technology provides a unique opportunity to shift from reactive to proactive stormwater management, enabling stakeholders to make informed decisions based on factual evidence.

One of the key benefits of visual AI is its ability to collect and analyse large volumes of data in real-time. Unlike traditional methods that rely on periodic grab samples, visual AI continuously monitors stormwater systems, providing a constant stream of information. This continuous monitoring capability allows for early detection of issues such as trash rack clogging, underground gross pollutant traps reaching capacity, and combined sewer overflows. By identifying these problems early, stakeholders can respond promptly, reducing the risk of flooding and pollution.

Moreover, visual AI enhances the accuracy of stormwater monitoring by providing detailed visual data. Through advanced image recognition techniques, the technology can identify and classify various elements within the stormwater system. This detailed analysis allows for a more comprehensive understanding of system health and functionality, leading to better targeted management strategies. Additionally, by correlating visual data with continuous physical water quality information, visual AI enables a holistic view of stormwater systems, facilitating the identification of underlying trends and patterns.

This paper aims to explore the application of visual AI in stormwater management through a series of case studies that demonstrate its effectiveness in addressing common challenges. The case studies will illustrate how visual AI can revolutionise stormwater management practices by providing accurate, real-time insights. In particular, the focus will be on three key applications: managing trash racks to prevent clogging events, monitoring underground gross pollutant traps to assess their efficiency, and observing combined sewer overflows to mitigate pollution risks.

By leveraging the data collected through visual AI, this paper will demonstrate how large-scale data analysis can inform predictive models that forecast system behaviors. These predictive models play a crucial role in optimising investment decisions, allowing stakeholders to allocate resources where they will have the most significant impact. Furthermore, the data-driven approach promotes collaboration and information sharing among stakeholders, breaking down traditional silos and encouraging a more cohesive approach to stormwater management.

As we delve deeper into the benefits and applications of visual AI in stormwater management, this paper will highlight the importance of embracing innovative technologies to address the evolving needs of urban infrastructure. The ultimate goal is to shift water management from assumptions to facts, enabling stakeholders to make data-driven decisions that lead to better stormwater management and environmental outcomes.

2 BENEFITS OF VISUAL AI AND INTEGRATED BIG DATA IN STORMWATER MANAGEMENT

Visual Artificial Intelligence is transforming stormwater management by enabling real-time monitoring, enhancing accuracy, and improving response times to emerging issues. This technology's benefits are driven by the advanced analysis of visual data and its correlation with physical water quality parameters. Here, we explore the key benefits of visual AI in stormwater management, focusing on real-time data collection, enhanced accuracy, and improved detection and response to stormwater issues.

2.1 REAL-TIME DATA COLLECTION AND MONITORING

Visual AI allows for continuous data collection, offering a significant advantage over traditional stormwater monitoring methods. Instead of relying on intermittent grab samples, which can lead to incomplete data and delayed responses, visual AI provides real-time observations of stormwater systems, allowing for a comprehensive view of system health and performance.

The ability to collect data in real time has a profound impact on stormwater management. It allows for early detection of issues, enabling stakeholders to take swift action to mitigate problems. For example, visual AI can monitor trash racks for clogging events, providing immediate alerts when maintenance is required (Ureta et al., 2021). This rapid response reduces the risk of flooding and other adverse effects.

2.2 ENHANCED ACCURACY AND DETAIL IN OBSERVATIONS

Visual AI enhances the accuracy of stormwater monitoring by offering detailed visual data. Through advanced image recognition techniques, the technology can identify and classify various elements within the stormwater system, providing a deeper understanding of system health and functionality. This level of detail is crucial for developing effective stormwater management strategies.

The accuracy of visual AI also allows for a more comprehensive analysis of stormwater systems, facilitating the correlation of visual data with other continuous physical water quality information. This correlation can reveal underlying trends and patterns, aiding in the identification of root causes of stormwater issues (Gao et al., 2018). By combining visual data with physical water quality analysis, stakeholders can make more informed decisions and develop targeted solutions.

2.3 IMPROVED ABILITY TO DETECT AND RESPOND TO STORMWATER ISSUES

Visual AI's ability to detect and respond to stormwater issues is a key benefit, as it allows for proactive stormwater management. The technology can monitor critical aspects such as underground gross pollutant traps, providing real-time insights into their effectiveness. By identifying when these traps are reaching capacity, stakeholders can schedule maintenance and avoid system failures (Chaffin et al., 2019).

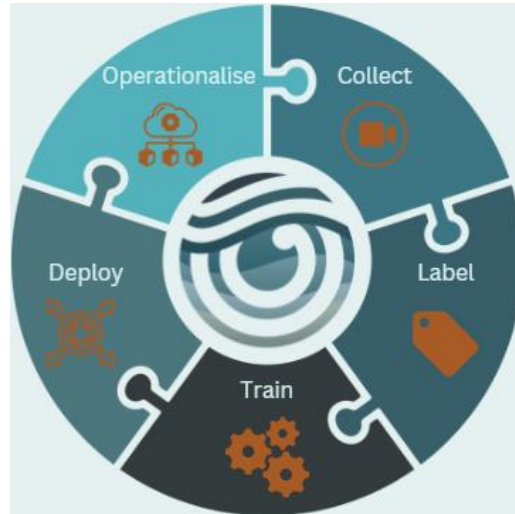
Additionally, visual AI can observe combined sewer overflows, helping to mitigate pollution risks by providing immediate alerts when these events occur. This real-time monitoring capability improves stakeholders' ability to respond promptly, reducing the environmental impact of stormwater issues (Monaghan et al., 2016).

Overall, visual AI offers significant benefits to stormwater management by providing real-time data collection, enhanced accuracy, and improved detection and response to stormwater issues. This technology's potential to revolutionise stormwater management practices is evident, offering a pathway toward more effective and sustainable approaches to managing urban water systems.

3 METHODOLOGY FOR AQUAWATCH VISUAL AI SYSTEM IN STORMWATER MANAGEMENT

3.1 EXPLANATION OF THE AQUAWATCH VISUAL AI SYSTEM AND ITS COMPONENTS

The AquaWatch visual AI system consists of several key components, including visual sensors, easy to deploy real time water quality monitoring devices, machine learning algorithms, and large language models. These components work in unison to collect, analyse, and interpret stormwater data, enabling stakeholders to make data-driven decisions for stormwater management.



3.1.1 VISUAL SENSORS:

The system uses edge computing cameras as visual sensors to capture images and videos of stormwater systems. These sensors are strategically placed at critical points, such as trash racks, underground gross pollutant traps, and combined sewer overflows. The visual data collected is used to monitor the condition of the stormwater infrastructure and detect issues in real-time (Erickson et al., 2013).

3.1.2 MACHINE LEARNING ALGORITHMS:

Machine learning algorithms play a crucial role in processing the visual data collected by the sensors. The algorithms are trained to identify patterns, classify objects, and detect anomalies within the stormwater system. This allows the system to provide real-time alerts when maintenance or corrective actions are required (Mullapudi et al., 2020).

3.1.3 LARGE LANGUAGE MODELS:

Large language models are then used to interpret and extract meaningful insights from the data collected by the system. These models can correlate visual data with continuous water quality monitoring, enabling a holistic view of the stormwater system. They also facilitate communication between stakeholders, providing clear and concise information for decision-making (Shishegar et al., 2019).

3.1.4 DESCRIPTION OF HOW MACHINE LEARNING AND LARGE LANGUAGE MODELS ARE USED

Machine learning algorithms are employed to analyse the visual data collected by the AquaWatch system. These algorithms are trained using historical stormwater data and can detect anomalies, classify objects, and recognise patterns. For instance, they can identify when trash racks are clogged or when underground gross pollutant traps are reaching capacity. This capability allows stakeholders to take immediate action, reducing the risk of flooding and pollution (Mullapudi et al., 2018).

Large language models are used to interpret the insights gained from the visual data and continuous water quality monitoring. These models can process large volumes of data and generate reports that are easy to understand, making it easier for stakeholders to make informed decisions. By correlating visual data with other water quality parameters, the models can help identify trends and predict future issues, enabling a more proactive approach to stormwater management (Edelman et al., 2023).

The AquaWatch visual AI system uses an active learning training system to quickly train custom image classification models to enable complete control of training models, with classes agreed with the customer, and

fine-tuning of models as additional data becomes available. This modular approach enables layered solutions alongside the specific CSO incidence monitoring. The capabilities of the AI Camera provide the ability to measure water levels, identify rubbish, measure speed of flow, detect floating elements, and identify pollutants. Monitoring algorithms can also complement the physical water parameters gathered in real time by the AquaWatch Waka, adding to a more complete picture of the health of waterways in real-time (Jessup, 2024).

3.2 INTEGRATION WITH CONTINUOUS WATER QUALITY MONITORING SYSTEMS

The AquaWatch visual AI system integrates with continuous water quality monitoring systems to provide a comprehensive view of the stormwater system's health. This integration allows for real-time correlation between visual data and water quality parameters such as pH, turbidity, and chemical pollutants. By combining visual monitoring with continuous water quality data, stakeholders can gain a more detailed understanding of the stormwater system's performance (Shetye et al., 2023).

The integration also allows for the development of predictive models that can forecast system behavior and detect potential issues before they become critical. This proactive approach to stormwater management can help optimise investment decisions and reduce the risk of flooding and pollution.

4 CASE STUDIES IN STORMWATER MANAGEMENT WITH AQUAWATCH VISUAL AI SYSTEM

4.1 CASE STUDY 1: REAL-TIME MONITORING OF TRASH RACKS FOR CLOGGING EVENTS



4.1.1 PROBLEM ADDRESSED

Trash racks are essential components of stormwater management systems, designed to capture large debris and prevent clogging in downstream infrastructure. However, traditional monitoring methods often involve periodic inspections, leading to delayed detection of clogging events, potentially causing flooding and increased maintenance costs.

4.1.2 DATA COLLECTED AND RESULTS

AquaWatch's AW-108 AI cameras, with 4K quality and 1TB of internal storage, were installed to provide real-time monitoring of trash racks. These cameras recorded high-resolution images of concrete pillars designed to capture significant debris and a fine mesh fence across the creek channel to trap smaller particles. The AI application was trained to analyse these images to detect and categorise debris accumulation on the pillars and fence. It was also programmed to classify water levels and potential flooding.

By processing the visual data in real-time within the camera, the system relayed the information to integrated systems via an API for further action and monitoring. This allowed stakeholders to monitor trash racks continuously, reducing the risk of flooding and allowing for prompt maintenance. Removing the need to send all the images into the cloud reduces the cost of transmission, storage, and reduces carbon footprint.

4.1.3 OUTCOMES AND BENEFITS

Real-time monitoring of trash racks using AquaWatch's AI system has yielded significant benefits including reduced maintenance costs. By allowing stakeholders to detect clogging events as they happen, the system ensures that maintenance is performed only when necessary, eliminating unnecessary and costly routine checks. This targeted approach to maintenance can lead to substantial savings over time.

Another key benefit is improved flood prevention. With early detection of debris accumulation, stakeholders can take prompt action to clear the trash racks, reducing the risk of flooding. This proactive response can prevent the costly damage often associated with flood events.

Additionally, the system's ability to process data at the point of capture provides stakeholders with actionable insights. This real-time analysis allows for more efficient stormwater management, as stakeholders can make informed decisions based on current data. These insights enable more effective resource allocation and help prioritise maintenance activities, contributing to a more resilient and responsive stormwater management system.

4.2 CASE STUDY 2: MONITORING UNDERGROUND GROSS POLLUTANT TRAPS



When we look at the underground screen it seems that it is in need of maintenance.

This is dangerous, and costly.



Our camera has been in place for four months, underwater, and in the dark. It clearly shows the lack of sediment build up, and that there is no maintenance required. We can cross check against weather events to alert as to illegal discharges.

4.2.1 PROBLEM ADDRESSED

Gross pollutant traps (GPTs) are designed to capture large debris and sediment, preventing them from entering stormwater systems. However, traditional monitoring methods often fail to provide accurate information on the effectiveness of these traps, leading to unnecessary maintenance costs and environmental risks.

4.2.2 DATA COLLECTED AND RESULTS

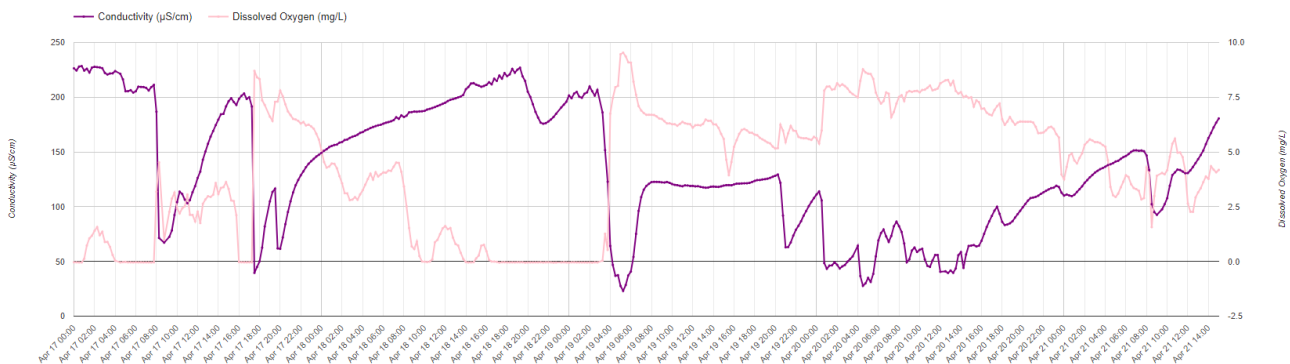
AquaWatch's underwater cameras were installed to monitor underground GPTs. These cameras, placed underwater and in the dark, captured detailed images of the traps over a period of four months. The data collected showed a lack of sediment build-up, indicating that the infrastructure, as it was, did not capture any debris. This finding suggested that the GPT being monitored was ineffective in terms of environmental protection, while still costing the ACT Government thousands of dollars in maintenance each year.

The cause of this ineffectiveness was traced to a combination of factors: a discharge point further up the system and the size of the holes in the screen being too large to capture sediment effectively. The AquaWatch system provided insights that traditional monitoring methods could not, revealing the need for infrastructure improvements.

4.2.3 OUTCOMES AND BENEFITS

AquaWatch's AI system for real-time monitoring of trash racks has produced significant benefits in stormwater management. By allowing stakeholders to detect clogging events in real-time, the system has contributed to reduced maintenance costs, as maintenance could be performed only when needed, avoiding unnecessary expenditures. Furthermore, the early detection of debris accumulation facilitated prompt action, lowering the risk of flooding and its associated impacts. The system's capability to process data at the point of capture delivered actionable insights to stakeholders, enabling more efficient stormwater management and more targeted responses to emerging issues. This combination of cost reduction, flood prevention, and actionable insights underscores the advantages of using advanced AI technology in stormwater management.

4.3 CASE STUDY 3: OBSERVING COMBINED SEWER OVERFLOWS TO MITIGATE POLLUTION RISKS



4.3.1 PROBLEM ADDRESSED

Stormwater discharge points and Combined Sewer Overflows (CSO's) can serve as conduits for illegal industrial discharges and sewerage overflows, posing significant risks to the environment. Traditional methods of monitoring stormwater often fail to detect these unauthorised discharges, leading to serious environmental and public health risks.

4.3.2 DATA COLLECTED AND RESULTS

AquaWatch deployed its Waka monitoring device at a stormwater discharge point in Manukau to collect continuous data on water quality parameters. The Waka, with its robust design and hydrodynamic properties,

allowed for accurate data collection in various conditions, providing real-time insights into the water quality. It collected turbidity and total suspended solids data, which revealed significant fluctuations, indicating the possibility of industrial discharges and untreated sewerage into the stormwater system..

The turbidity and total suspended solids data revealed significant fluctuations, indicating the possibility of industrial discharges and untreated sewerage into the stormwater system, which could have serious environmental impacts.

4.3.3 OUTCOMES AND BENEFITS

The real-time monitoring capability of the Waka enabled stakeholders to detect unusual fluctuations in water quality parameters, which pointed to possible unauthorised industrial discharges. This early detection was instrumental in allowing stakeholders to further investigate the source of these fluctuations and take swift action to address the issue. Continuous data collection by the Waka also provided a comprehensive analysis of stormwater quality, enabling stakeholders to identify patterns and trends that indicated potential environmental risks.

Lastly, the system's ability to process large volumes of data in real-time facilitated proactive environmental management, allowing stakeholders to develop management plans to mitigate the impact of illegal industrial discharges. This proactive approach reduced the risk of long-term environmental damage and ensured compliance with regulatory standards.

The case study demonstrates the potential effectiveness of AquaWatch's Waka and AW-108 Camera in identifying and addressing illegal industrial discharges. By providing real-time data on stormwater quality, stakeholders were equipped to make informed decisions and take action to protect the environment from unauthorised industrial activities. This example underscores the importance of advanced technology and continuous monitoring in modern stormwater management practices.

5 APPLICATION OF DATA AND PREDICTIVE MODELS AND THE IMPACT ON INVESTMENT STRATEGIES

Data-driven approaches are revolutionising stormwater management by providing real-time insights and predictive models that guide infrastructure investment and resource allocation. The three case studies presented earlier demonstrate how large-scale data collected through visual AI and water quality sensors can be harnessed to improve stormwater management and inform effective investment strategies.

5.1 USE OF LARGE-SCALE DATA COLLECTED THROUGH VISUAL AI AND WATER QUALITY SENSORS

The deployment of visual AI systems and continuous water quality sensors has transformed the way stormwater management is conducted. These systems collect vast amounts of data, allowing stakeholders to gain a comprehensive understanding of stormwater systems and identify areas for improvement.

In Case Study 1, the real-time monitoring of trash racks with AquaWatch's visual AI system provided a wealth of data on debris accumulation and water levels. This continuous data collection allowed for early detection of clogging events, reducing the risk of flooding and lowering maintenance costs. By analyzing this data, stakeholders could predict when maintenance was required and allocate resources more efficiently.

Similarly, Case Study 2, which focused on monitoring underground gross pollutant traps, demonstrated how continuous data collection revealed the ineffectiveness of existing infrastructure. This insight, gained from large-scale data, led to a reevaluation of the maintenance strategy, ultimately resulting in cost savings and improved environmental protection.

5.2 DEVELOPMENT OF PREDICTIVE MODELS TO FORECAST SYSTEM BEHAVIORS

Predictive models derived from continuous, large-scale data can forecast system behaviors and anticipate future stormwater issues. These models, powered by machine learning algorithms, enable stakeholders to move from a reactive approach to a proactive one, focusing on prevention rather than mitigation.

These predictive models are instrumental in guiding stormwater management strategies, allowing stakeholders to optimise infrastructure investment based on factual evidence. By understanding the likely outcomes of different scenarios, stakeholders can make informed decisions that lead to more effective stormwater management.

6 CONCLUSION

Stormwater management is a critical component of urban infrastructure, playing a key role in preventing flooding, reducing pollution, and maintaining public health and safety. As urbanisation continues to expand, the pressures on stormwater systems increase, necessitating innovative approaches and comprehensive strategies. This paper has explored various aspects of stormwater management, focusing on the integration of visual AI, continuous water quality monitoring, and the need to leverage large-scale data and predictive models, to enable stakeholders to resources toward impactful solutions. .

The role of continuous data in enhancing prediction accuracy cannot be overstated. Traditional stormwater monitoring methods often rely on periodic sampling, which can lead to gaps in data and delayed responses to issues. Continuous data collection, as enabled by visual AI systems and water quality sensors, provides a more comprehensive and accurate view of stormwater systems. This continuous data stream allows for the development of predictive models that can forecast system behaviors and identify potential risks. The ability to predict future issues enables stakeholders to take proactive measures, reducing the risk of flooding, pollution, and other adverse impacts.

The data-driven approach also has a significant impact on investment decisions in stormwater management. By providing factual evidence, this approach allows stakeholders to direct resources toward the most impactful solutions. The insights gained from large-scale data and predictive models guide infrastructure investment, ensuring that resources are used efficiently and effectively. This focus on impactful solutions leads to more efficient stormwater management and improved environmental outcomes.

As stormwater management continues to evolve, embracing innovative technologies and collaborative strategies will be crucial. The integration of visual AI with continuous water quality monitoring represents a significant advancement in stormwater management practices. By leveraging these technologies, stakeholders can better manage time, effort, and money, ensuring that stormwater systems remain functional and resilient in the face of growing urbanisation and environmental challenges.

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