Rethinking Design for Monitoring

Addressing Coastal Monitoring Challenges in Developing Areas

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The majority of the world's population lives in low-lying river deltas. The great fertility and good accessibility of these areas has historically led to the rise of the most important settlements, which have evolved into today's metropoles. Ongoing urbanization adds to this trend. At the same time, these low-lying cities at the mouth of large river systems are prone to natural disasters, mostly originating from their large exposure to water. Storms and heavy rainfall can lead to flooding of the built environment and result in economic damage, human displacement and loss of life. While this exposure to the forces of nature exists naturally in delta areas, it is aggravated by climate change, accelerated sea level rise and human-induced land subsidence.

Our ability to understand and deal with these threats is undergoing impressive development. Levees and barriers are safeguarding areas that would otherwise suffer from frequent flooding. Sand nourishment schemes

Flooding around Amanzimtoti Estuary in April 2019 as a result of intense rainfall and high river discharge.

The Power & Telemetry Module with a built-in radar sensor makes for a completely wireless, low-maintenance water level gauge. (Below) A wave buoy deployed off the Durban coastline.

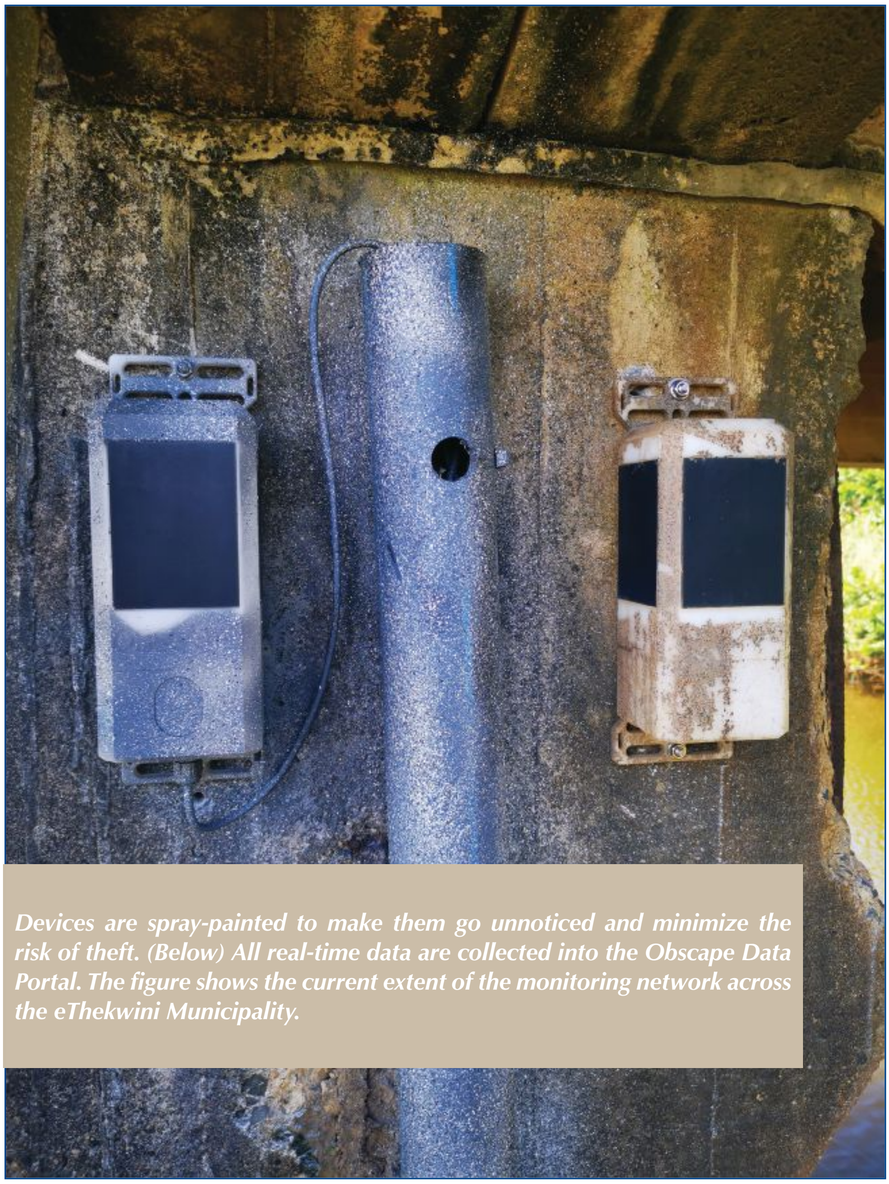
create stable coastlines that would otherwise be subject to rapid erosion. Computer models can forecast hazardous conditions multiple days ahead, enabling us to anticipate and take precautions. However, design and construction of flood defenses and the development of accurate forecasting models heavily depend on the availability of environmental observation data. Especially in the developing world, collection of long-term operational environmental data sets receives little attention. Its importance is either overlooked, or it cannot be achieved for various practical and economic reasons.

The highly specialized nature of conventional environmental monitoring equipment leads to a high price level in this market. The number of manufacturers is limited, and the products are the result of a long-running, costly R&D trajectory that, especially in the past, involved highly skilled specialists in the fields of electronics, oceanography, chemistry, etc. Due to the complexity and vulnerability of the equipment, skilled and experienced staff are required to keep it operational in the field over long periods of time. This strongly limits the possibilities to collect environmental data where they are most needed: coastal areas in the developing world.

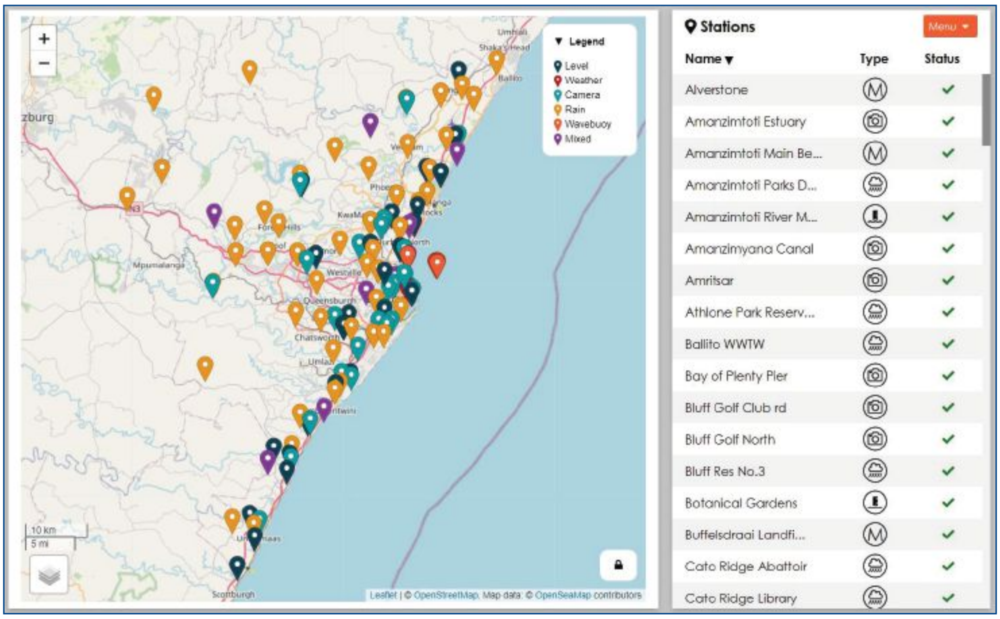
Obscape, a Netherlands-based environmental monitoring equipment manufacturer, has identified and experienced the issues discussed above during its long-standing collaboration with the eThekwini Municipality (city of Durban) in South Africa. It inspired them to come up with a new design philosophy for their products, which is aimed at the development of affordable, robust and easy-to-use environmental monitoring equipment. The company aims to remove existing barriers for the collection of long-term environmental data sets, making environmental observations available to anyone who needs them.

Challenges of Environmental Monitoring in Durban

Zane Thackeray (co-author of this article) and Rio Leuci started a local survey company in Durban, South Africa, in 2006. Soon after, they were contracted by the eThekwini Municipality to conduct beach surveys in order to keep track of structural erosion of local beaches.



Devices are spray-painted to make them go unnoticed and minimize the risk of theft. (Below) All real-time data are collected into the Obscape Data Portal. The figure shows the current extent of the monitoring network across the eThekwini Municipality.



Coastal erosion is just one out of many complexities that local coastal engineers and water managers are faced with. The city of Durban is set in hilly terrain along the Indian Ocean coastline. The municipality comprises no less than 17 separate catchment areas, all of which discharge directly into the Indian Ocean. Estuaries with complex morphodynamics have formed at the mouth of each river. Seasonal closing and breaching of the estuaries are associated with flooding and water quality issues. Furthermore, the humid subtropical climate in Durban is associated with intense rainfall events. Given the hilly, paved urban environment, this regularly triggers flash flooding. During these events, river water levels rise rapidly, inundating infrastructure and informal settlements at the riverbanks. Additionally, Durban's beaches are inundated by high swells on a regular basis. Besides eroding the beaches, this has caused damage to properties along the beachfront.

The eThekwini Municipality is responsible for flood defense and disaster management. This task creates a strong need for real-time environmental observations and forecasts. Thackeray and Leuci aimed to expand their activities for the municipality by installing and maintaining a network of monitoring stations. They soon concluded that this could not be done using off-the-shelf equipment, since the budgetary constraints of the project did not allow for the number of sensors required to achieve sufficient spatial coverage.

In addition, they experienced that several practical disadvantages of existing equipment made field operations difficult and time-consuming. First and foremost, theft rates were unacceptably high. Instrumentation is often given a high-tech, aesthetically pleasing look. Solar panels, which in itself are an important feature if one wants to reduce the maintenance level by omitting regular battery swaps, are often placed on an external bracket, making them clearly identifiable. These factors make monitoring equipment look attractive and valuable and therefore substantially increase the risk of theft in many countries. Second, the use of multi-channel data loggers with several wired external sensors made instrument assembly cumbersome and had an adverse effect on robustness of the system. The latter especially holds for the case of submerged equipment, e.g., a pressure sensor-based water level gauge or a water quality sonde.

Finally, data management was far from trivial. Since no single manufacturer offered a full product suite that matched the project's constraints and requirements, data had to be pulled into a central database from different portals with large variations in user-friendliness and functionality. Furthermore, most portals were associated with a substantial license fee after the initial trial period had expired.

A New Design Philosophy

These drawbacks made Thackeray and Leuci realize that they had to start developing their own real-time monitoring equipment. With input and guidance from Godfrey Vella (senior manager of the Coastal Engineering Division of eThekwini Municipality and co-author of this article), they deployed their first prototypes in 2014. This drew the attention of Max Radermacher (co-author of this article), who was looking for affordable sensors to collect field data for his Ph.D. research at Delft University of Technology in the Netherlands. Thackeray's knowledge of electronics and material processing, Leuci's field experience, and Radermacher's software skills and access to the European market were exactly the right ingredients to start an equipment manufacturing company: Obscape.

The company's design philosophy revolves around three core aspects: affordability, robustness and ease of use. This has condensed into the PTM: the Power & Telemetry Module. In essence, it is a single-channel data logger with integrated solar panels, power management, control and telemetry. Shaped like a 1-L milk carton, it is not necessarily the biggest eye-catcher, but that is exactly what its designers wanted to achieve. Three 1-W solar panels are mounted flush on the vertical faces of the PTM, avoiding the typical theft-sensitive solar panel look. Whenever possible, sensors are integrated into the PTM housing, e.g., a camera module (creating a general purpose time-lapse camera) or a radar sensor (creating a water level gauge). This leads to very compact and robust devices without external cables. Real-time telemetry is taken care of by a built-in cellular modem or an optional satellite modem, ensuring worldwide compatibility and coverage. Paired with a global SIM card, the PTM-based products become truly turnkey environmental monitoring solutions: simply press the power button, close the housing, and mount the device to a wall, pole or tree with the versatile mounting bracket.

The intention is to arrive at a broad but coherent PTM-based product range that includes all commonly required equipment for coastal, estuarine and catchment monitoring. This allows the user to work with a single supplier and have all real-time observation data available under one roof. As it currently stands, Obscape offers a radar-based water level gauge (no submerged parts, thus, robust and low maintenance); a time-lapse camera; a weather station; a rain gauge; a conductivity and temperature sensor (toroidal design, limiting biofouling and maintenance); and a directional wave measurement buoy (lightweight, deployable by hand). While the wave buoy obviously has a different look than the standard PTM, the technical concept and resulting user experience are identical.

Device purchase comes with unlimited access to the Obscape Data Portal, where all real-time data across all different device types are collected and displayed. While most suppliers have made the shift to a business model that revolves around selling periodic data portal licenses, the company has a strong belief that users should not pay for access to their own measurement data. Instead, a freely available portal with extensive functionality for viewing, downloading, managing and analyzing real-time environmental data combined with affordable instrumentation pricing creates a healthy business model with happily returning clients.

Application in Durban

The environmental monitoring network in the eThekwini Municipality currently entails around 125 stations, which will expand to 200 sites over the current contract period. Among others, the network contains four wave buoys, 25 water level gauges, 55 rain gauges, 28 time-lapse cameras and seven weather stations. The large amount of real-time data that are returned by the network are used by the municipality for coastal, stormwater and catchment management purposes.

For example, the aforementioned cycles of estuarine closing and breaching are closely monitored with a combination of a time-lapse camera at the estuary mouth, water level gauges along the course of the river and upstream rain gauges. This yields a complete overview of upstream rainfall causing rising water levels in the river and the closed-off estuary, while the actual breaching event is captured by the camera.

Alongside the monitoring network, the eThekwini Municipality runs an operational forecast model train, which is capable of forecasting potential disasters several days ahead. It consists of atmospheric, oceanic, coastal and riverine models, as well as stormwater runoff models. The existence of the extensive monitoring network is of critical importance for the value of the model forecasts. On the one hand, observation data are used for calibration and validation of the computer models, while on the other hand the real-time observations provide the ground-truth data for the disaster management team during severe storm events.

The design philosophy has proved its value when installing and operating the monitoring equipment. The compact devices require minimal preparation, and installation has been made easy. The radar-based water level gauges are mounted above water, typically on a bridge deck. The lightweight wave buoys are deployed from a RIB. Maintenance has been low since the first PTM-based devices were installed at the start of 2020. None of the devices experienced serious fouling of sensors or solar panels, and data transmission has been stable. Any settings adjustments or firmware upgrades that were needed could be installed over the air via the built-in cellular modem. Due to the low maintenance level, the field technicians can focus all their attention on further expansion of the network this year.

Future Developments

Over the years to come, the existing product range will expand with a number of new sensors. Based on confirmed requests from existing and potential clients, Obscape has entered into R&D trajectories for water quality monitoring and current monitoring, both buoy-based and mounted to a rigid structure. It is aimed to tackle existing problems in the field of water quality monitoring, such as limiting biofouling and making water quality instrumentation available to projects with a limited budget.

Furthermore, global advances in AI and computer vision are expected to yield a whole new range of applications for the time-lapse camera. Alongside the qualitative time-lapse imagery, this will provide ways to extract all sorts of quantitative information from the images.

Conclusion

In response to practical issues with existing measurement equipment, a new range of instrumentation for environmental observations was developed. The new products were designed to be affordable, robust and easy to use. Deployment of 125 devices across the eThekwini Municipality in South Africa has demonstrated the simplicity of instrument deployment and the robustness of the equipment when it comes to minimizing the need for maintenance and the risk of theft. These efforts make environmental observations easier to conduct and available to a wider community.

Acknowledgments

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Dr. Max Radermacher obtained his M.S. in coastal engineering from Delft University of Technology in the Netherlands. While pursuing his Ph.D. with the same institute, he partnered with Zane Thackeray and Rio Leuci to establish Obscape. Radermacher heads the Dutch offices of Obscape and leads software development and sales.

Zane Thackeray obtained his honors degree in geology from the University of Kwazulu-Natal in Durban, South Africa, and is a registered professional natural scientist. Together with Rio Leuci, he established Enviromap, continuing as Obscape after the entry of Max Radermacher. Thackeray heads the Durban offices of Obscape and leads R&D and production.

Godfrey Vella has worked in the coastal engineering field for over 30 years and is a registered professional technologist. As senior manager of the Coastal Engineering branch for the last 17 years at the eThekwini Municipality (city of Durban), Vella is responsible for all coastal engineering design, implementation and maintenance of coastal infrastructure within the 97 km of coastline, as well as for all monitoring of coastal processes together with Obscape, plus numerical modeling.