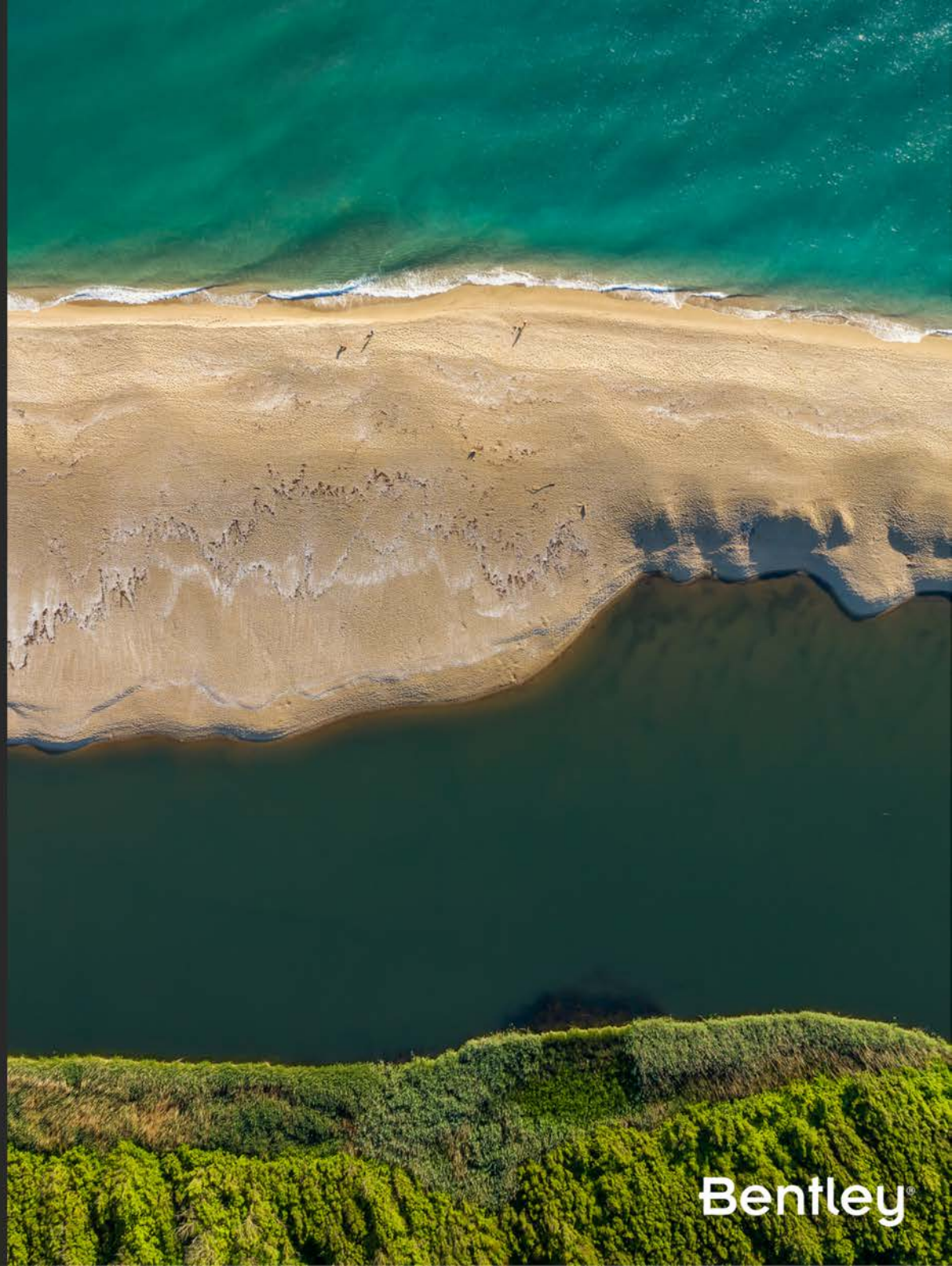


# State of Condition Monitoring

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2022



Bentley®



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This report has been prepared by Argos.io Pty Ltd (eagle.io), now a part of Bentley Systems. The data was collected via an industry-wide survey conducted between 15/09/2021 and 22/10/2021 of 208 participants within the Condition Monitoring industry. This report must not be copied, reproduced, distributed, or used in whole or in part for any purpose other than with written permission by Bentley Systems.





# Executive Summary

**Applications and technologies for monitoring are evolving rapidly. We're seeing a rapid increase in enabling technologies and tools in the form of IoT platforms, sensors, connectivity, and protocols. Regulators and stakeholders are increasingly demanding more data transparency and access to real-time conditions.**

This report provides a snapshot of industry direction and understanding of the current landscape, formed by the expert opinions of over 200 scientists, engineers, and industry specialists.

End-users are moving to real-time with more than a quarter of end-users reporting an upcoming move in 2022 to real-time and three quarters expecting they will be monitoring predominantly remotely by 2025. According to responses, this is largely (41.3%) driven by organizational needs for real-time data in decision-making processes.

Given this real-time drive, almost a third (30%) of end-users are already reporting a shortage of talent as their most pressing challenge. This skills gap could be addressable by connecting organizations with technical sensor deployment skills to these end-users switching to real-time methods.

Respondents also identified multiple limitations in sensing hardware inhibiting broader uptake of remote monitoring, from maintenance costs to lack of suitable sensors for their analyses.

Expect to see monitoring programs expand in 2022 as over thirty per cent (31.5%) of respondents reported an increase in parameters as their biggest upcoming change for the year.



# KEY INSIGHTS

**Demand  
for access**

**28%**

**reported increasing  
demand for real-time  
data access as the top  
upcoming challenge**

**Now the  
norm**

**76%**

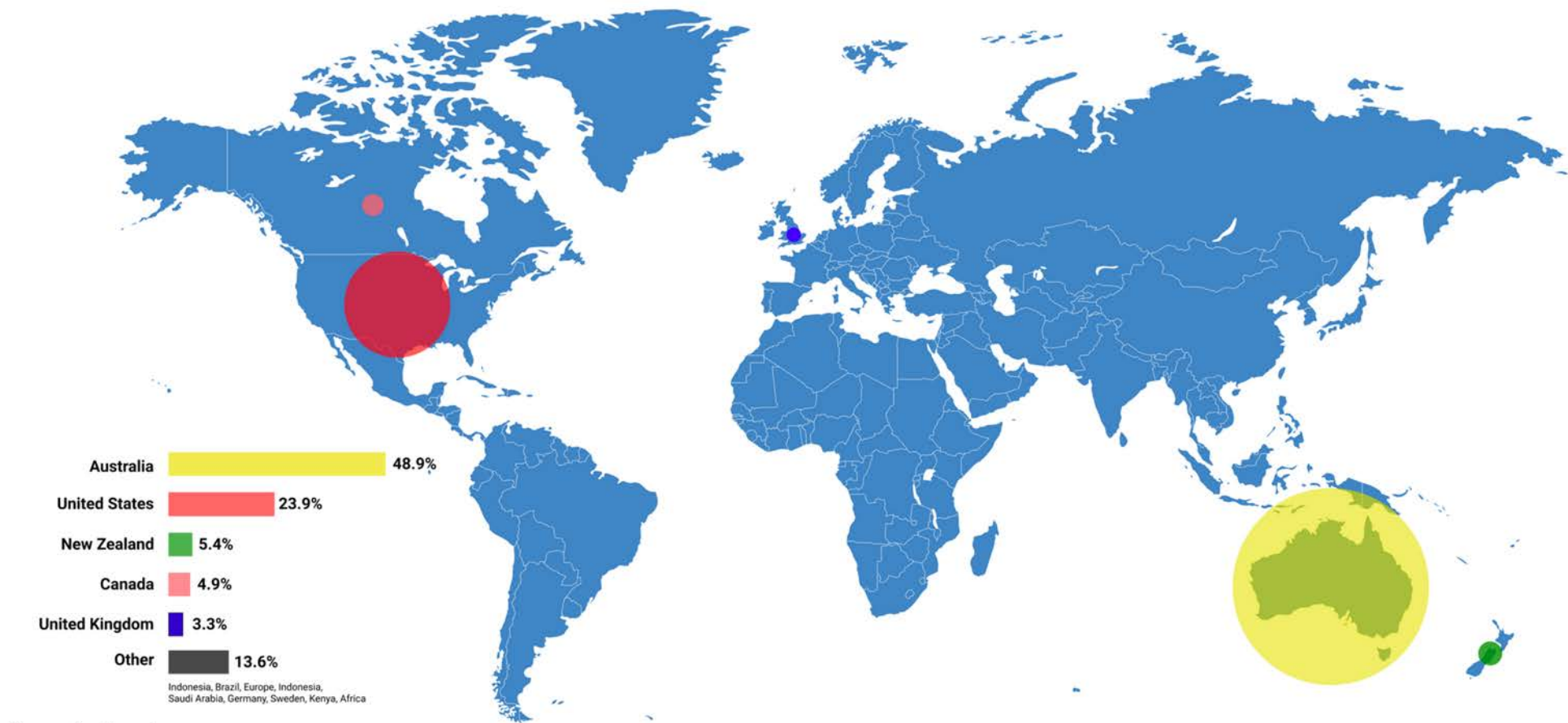
**reported using  
real-time and remote  
monitoring in their  
organization**

**Broader  
parameters**

**33%**

**reported their biggest  
change will be  
monitoring more  
parameters in 2022**

# Survey Demographics



## Organization type



**Service providers include:** consultants and hardware integrators  
**Product providers:** Hardware & software vendors  
**End-users:** Construction, Mining, Oil and Gas, Transport (Rail/road/tunnels/ports), government sectors

Of 208 survey responses, almost half the participants (48.9%) were located in Australia, just under a quarter (23.9%) in the United States and the remaining distributed across Canada, the UK, New Zealand with outliers such as Brazil, Indonesia, Germany, Sweden, and Kenya.

The geographic spread was skewed by eagle.io's operations across Australia, New Zealand and the United States. We believe the resulting findings retain broad multi-national application due to the maturity of these markets.

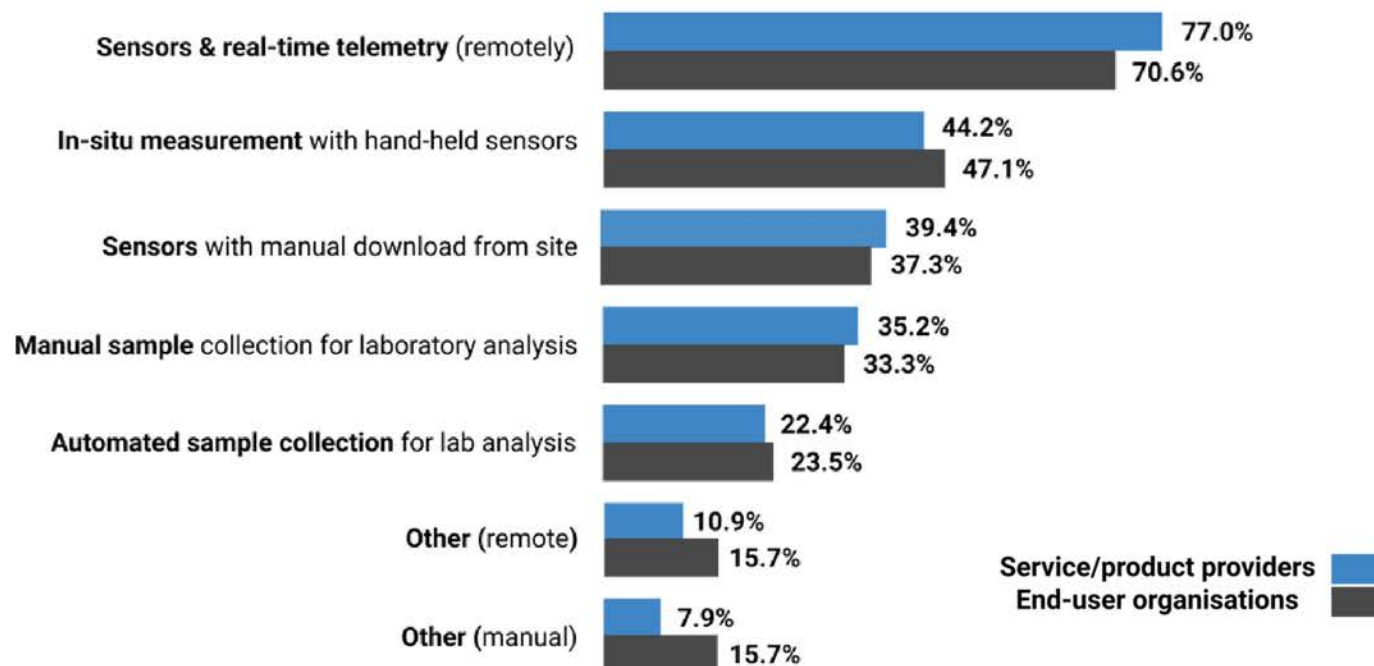


# Going real-time

Real-time monitoring via remote sensors was the most prevalent monitoring method across the industry. However, a large proportion of both service providers and end-users still feature manual monitoring methods in their practice. This suggests the industry is in a transition period from manual to real-time, with several factors driving and inhibiting remote adoption covered later in this report.

## Monitoring method adoption

The distribution was also heavily skewed towards sensor monitored methods vs sample collection.



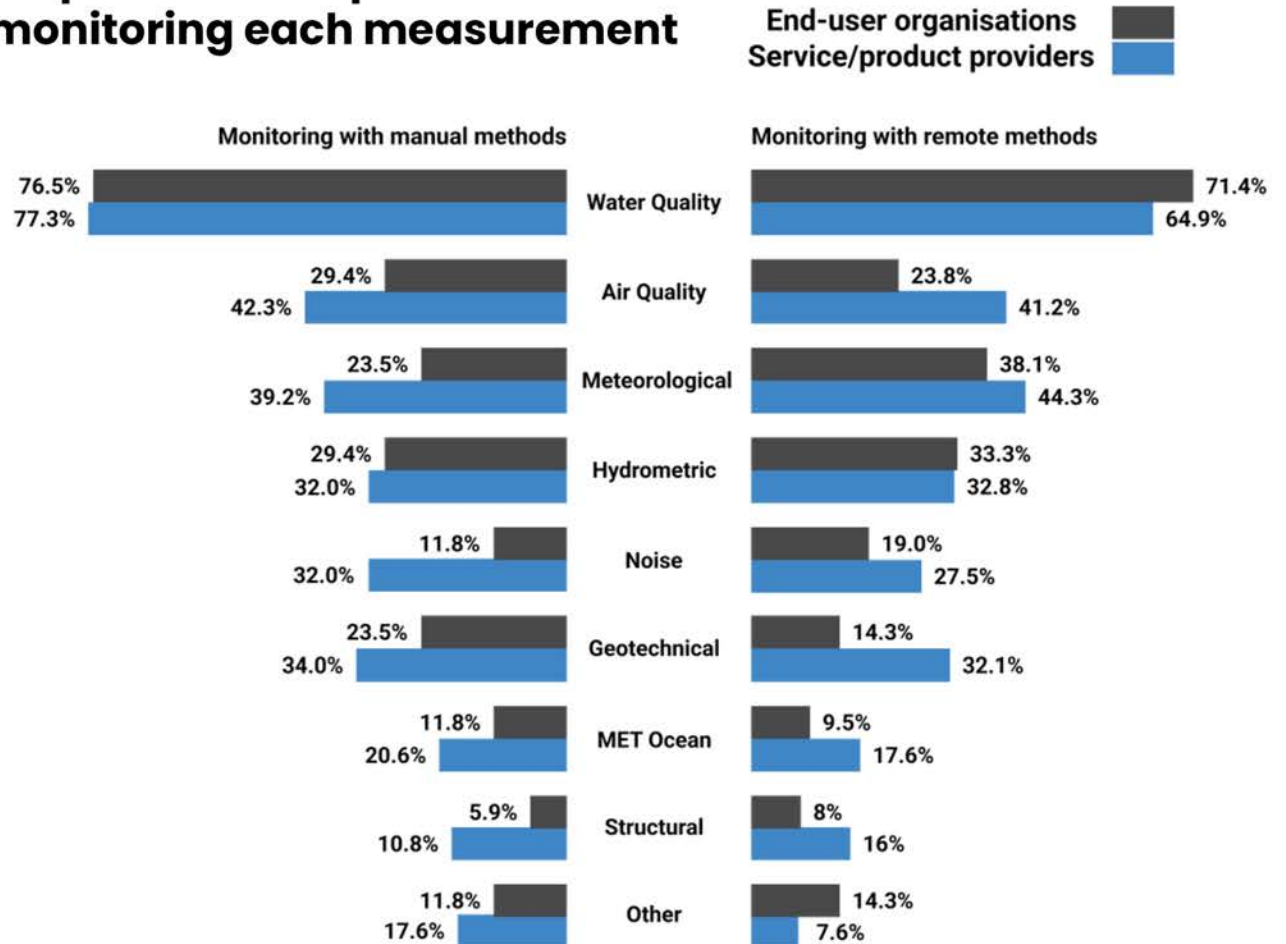
# What's measured

Water, Air (quality and meteorological) and Hydrometric (ground and surface water level measurement) were the most commonly monitored analytics across respondents.

With remote sensor talent shortages reported in both Air and Water Quality by end-users, there's a market opportunity for providers who have these capabilities to service end-user demand.

A note of caution on extrapolating market size from this count data, although there are fewer companies and end-users undertaking structural or geotechnical monitoring by count, the number of sensors and scale of these monitoring systems when deployed can be very large.

## Proportion of respondents monitoring each measurement





# State of Manual Monitoring





## Manual remains relevant

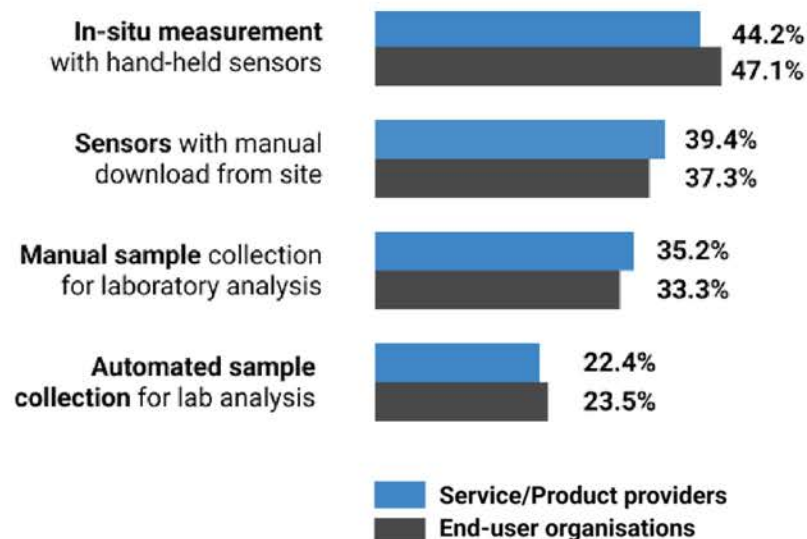
More than half of respondents reported some form of manual monitoring method still in use within their organization, with Water Quality (22.4%) being the most manually monitored media.

But this seems set to shift as nearly three-quarters of monitoring professionals (71% end-users and 74% of service providers) reported intent to switch some or all of their manual monitoring to real-time in the next 4 years.

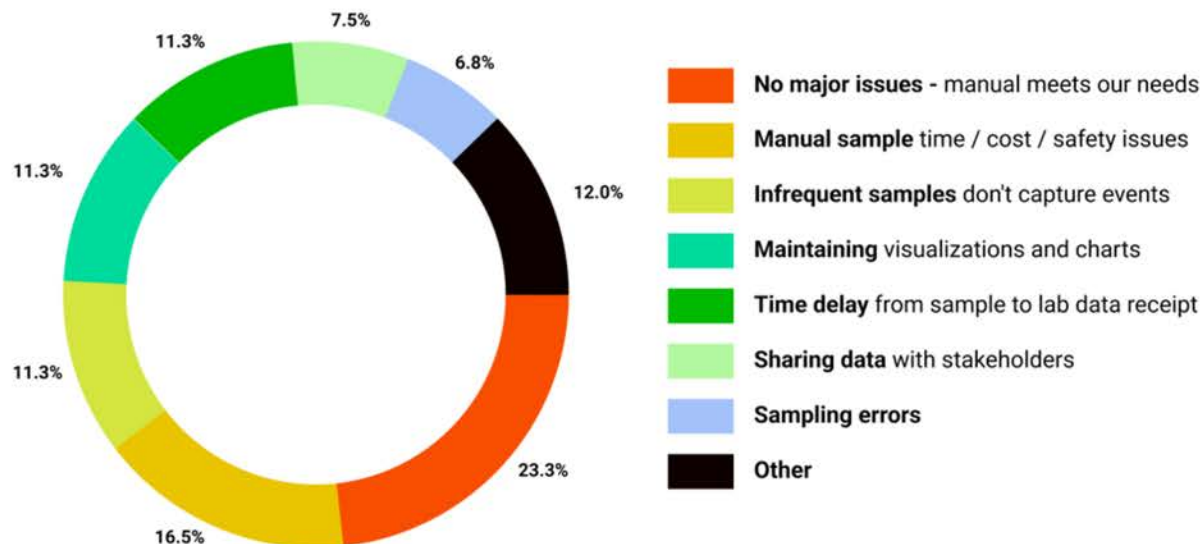
The strongest drivers moving respondents away from manual monitoring were the time/cost/safety issues, poor sampling density (missing events), maintaining data charts and time delays.

Even given these difficulties, a quarter of respondents were completely satisfied with their manual monitoring.

## Manual methods by usage



## Biggest challenges in manual monitoring





# State of Remote Monitoring





# Remote, widespread

According to responses, remote monitoring is already widely adopted across multiple industries and sectors.

Of the 208 respondents, almost three-quarters of end-user organizations (70%) and more than three-quarters of product/service providers (77%) reported using some form of remote monitoring.

The pull factors driving the adoption of remote monitoring included operational needs (benefits), cost reductions, and legislative requirements.

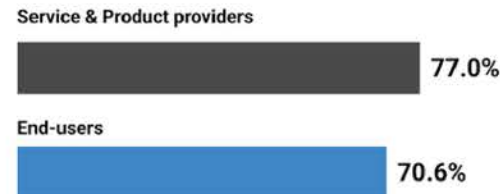
The survey responses indicate an industry sentiment that we will continue to see a rise in remote monitoring over the next few years.

Almost half (48%) of consultants who responded said in 5 years time (2026), remote monitoring will be a significant part of their operations.

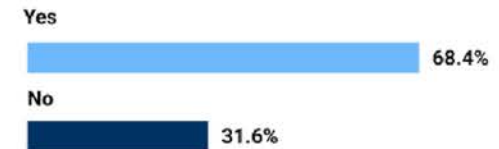
Operators and professionals who prepare for this shift may position themselves to succeed as remote monitoring proliferates.

## Real-time adoption

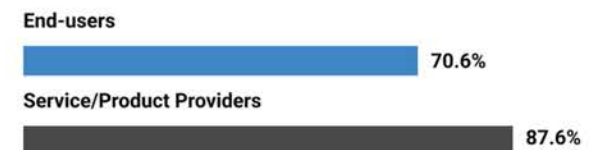
### Currently monitoring remotely



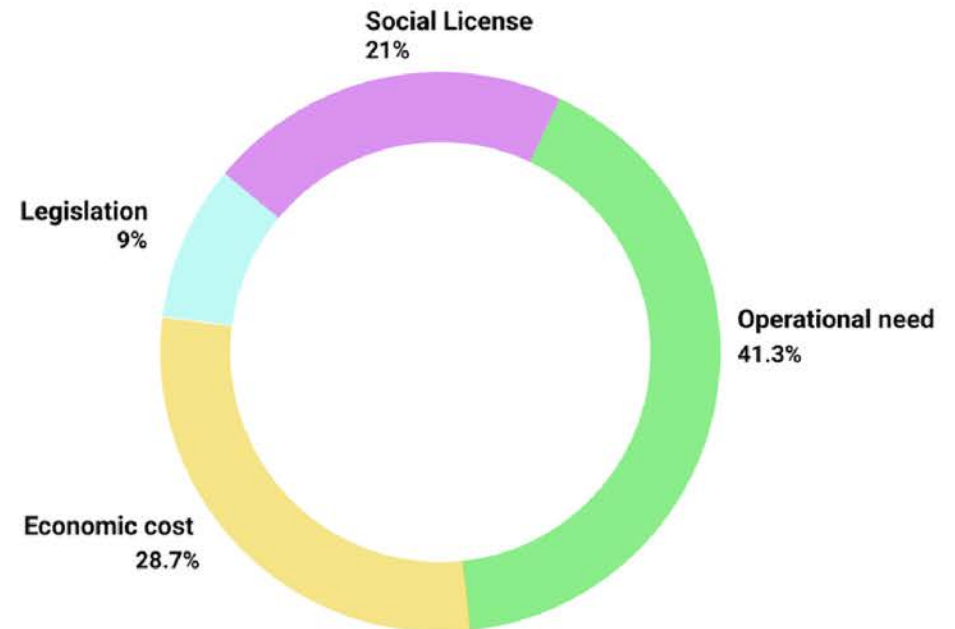
### Considering switching to remote



### Able to monitor parameters remotely



## Factors driving adoption







## Addressable challenges to remote adoption

**Skills** - although a second-tier barrier to hardware limitations, the identified skills gap is solvable today primarily via the connection of those organizations with the technical sensor deployment skills required, and the engineers, scientists and end-users seeking this capacity.

**Sensing Hardware** - respondents identified a number of hardware-related limitations inhibiting the broader uptake of remote monitoring, including direct and maintenance cost of sensors and telemetry units and lack of commercial availability of sensors for analytes of interest.

There is a clear need for lower cost, more robust sensor and hardware solutions, presenting a large market opportunity for new instrumentation startups to play a role in further adoption.



# Water Quality & Hydrometric

The survey revealed a massive demand for real-time Water Quality telemetry services in the next three years, requiring a strong response from engineering and environmental services to build capability and capacity in deploy and maintain real-time systems.

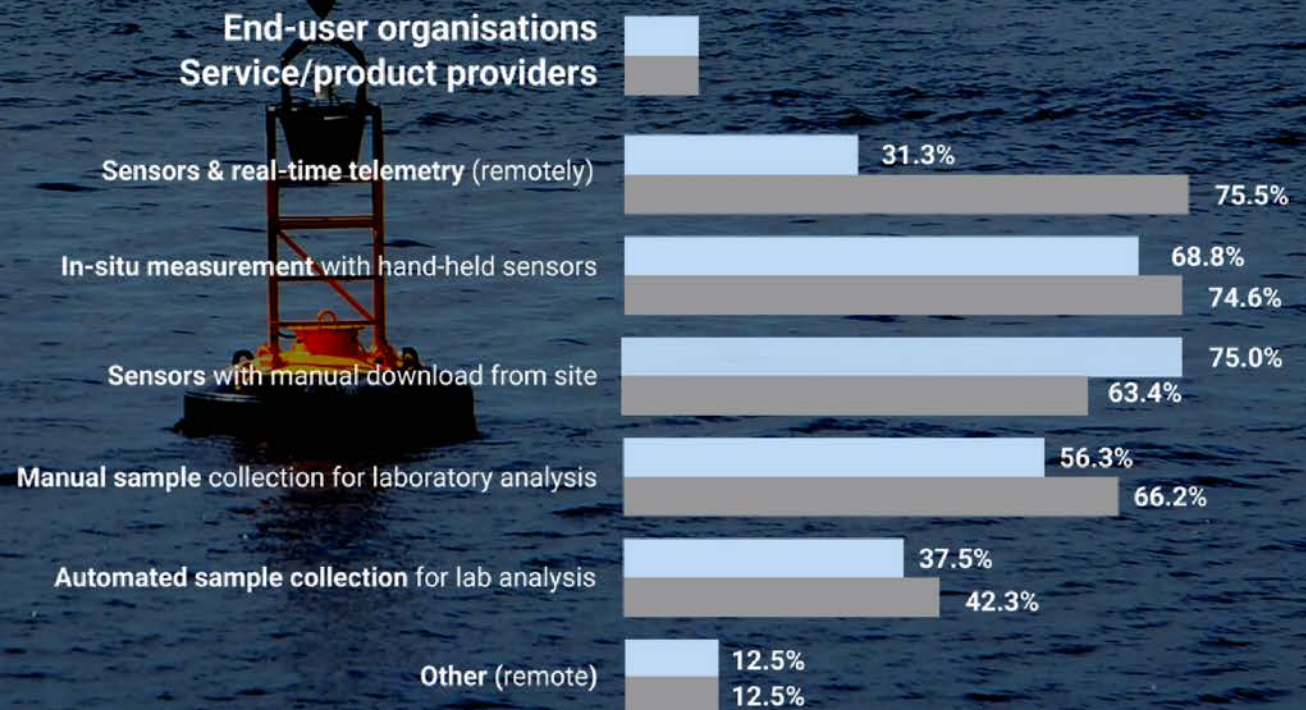
Currently only 25% of end-user companies surveyed use telemetry to collect sensor data in real-time - but this is set to change. By 2025 100% of end-user respondents predicted they would move completely to remote monitoring.

However this is not without challenges.

A shortage of in-house expertise to deploy remote monitoring systems was the primary barrier to further adoption of remote monitoring reported by end-users, along with high perceived costs of real-time operations.

This planned uptake of remote monitoring by end users presents a market opportunity to engineering consultants and environmental service organizations to meet demand.

## Monitoring methods in Water Quality & Hydrometric





# Reported Parameters, Vendors & Instrumentation

## HARDWARE VENDORS



## Parameters

Providers	End-users	
VOC	VOC	pH
NAPL	NAPL	Level
ph	TSS	Switch
TSS	DO	Stormwater
DO	EC	Groundwater
EC	Flow	Potable Water
Flow	Level	Trade Waste
Level	Pressure	Dust deposition
Pressure	Particulate	Biosecurity
Particulate	Turbidity	E coli
Turbidity	TRC	Conductivity
TRC	TN	Microplastics
TN	TP	SO4
TP	Chlorine	Cl
Chlorine	NTU	Hardness
NTU	Waves	Metals (dissolved
Waves	Currents	and total
Currents	Depth	concentrations)
Depth	Salinity	
Salinity	Temp	
Temp	OH	

## Instruments

Providers	End-users
YSI meters	YSI meters
Handheld PID	Handheld PID
Waterlevel loggers	Water level loggers
pH meters	pH meters
Convertors	Convertors
Handheld (electrodes)	Handheld (electrodes)
Multi-probes sensor	Turbidity sensors
Water level meters	Salinity sensors
Pressure loggers	Multi-meters
ADP's	WQM
Turbidity sensors	IP
Salinity sensors	SLM
Multi-meters	Turbidimeter
WQM	Sondes
SLM	Piezometer
Turbidimeter	Ultrasonic flow meters
Sondes	Multibeam TSS
	Submersible pressure sensors
	HVAS

## Sensors (parameters)

### Providers

**Xylem multi-probe** (Level, Rain, EC, Temp., Turb., DO, pH)  
**YSI Meters** (Temp, EC, pH, DO, Redox, Turb.)  
**Valeport** (Tidal, Weather, Water Quality)  
**Hydralab MS5 sonde** (Temp, DO, pH, Turb., Salinity/EC)  
**YSI Pro DSS** (pH, EC, DO)  
**Sontek M9/Flow tracker** (Turb., Flow)  
**YSI multiparameter sonde** (Turb., EC, pH, DO, Temp),  
**YSI Multiprobe** (pH, ORP, DO, Temp, Conductivity)  
**SignalFire Ranger** (Flow, Level, Pressure)  
**Sontek ADCPs** (Stage, Velocity, Discharge, WQ Big 5)

### End-users

**YSI water meters** (HVAS, Stormwater, Groundwater, Potable Water, Trade Waste)  
**EXO2/OPUS/OTT** (TSS, NOx, N, P, Pesticides, Water Level, Discharge)  
**Multi-parameter probes with lab analysis:** (pH, EC, SO4, Cl, Hardness, Dissolved metals)



# Air Quality

## Skill shortages in Air Quality

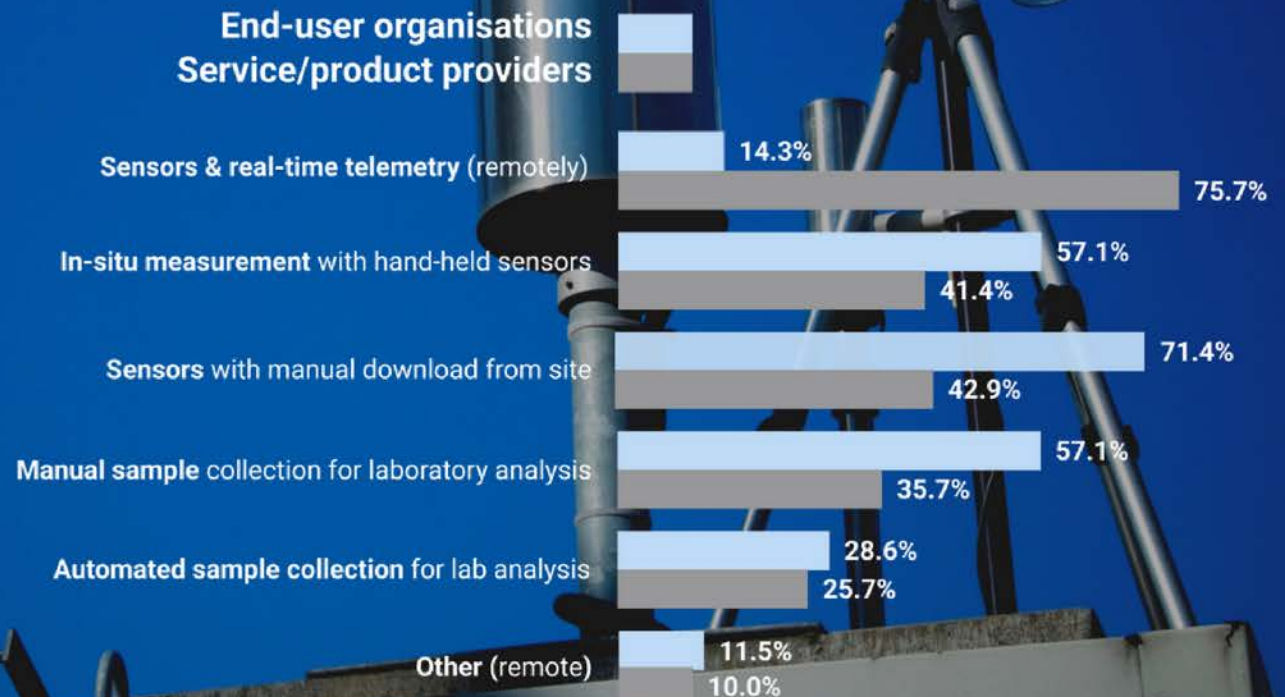
In-house Air Quality monitoring is still largely manual, with just over a quarter (25.8%) of end-users monitoring remotely and most respondents reporting on-site manual downloads from sensors or in-situ measurements.

End-user organizations who reported using manual measurement methods for monitoring Air Quality parameters also reported their biggest challenges as a shortage of talent and increased reporting requirements around real-time data obligations.

The survey suggests end-users lack ability to monitor and report on Air Quality remotely, and there may be an opportunity for service providers who are able to assist here.

Interestingly, 31% of service/product providers who monitor Air Quality for their clients indicated that a technical gap in skillsets was the key factor prohibiting expansion of real-time Air Quality monitoring.

## Monitoring methods in Air Quality







## Reported Parameters, Vendors & Instrumentation

### HARDWARE VENDORS

ELSYS.se

CAMPBELL  
SCIENTIFIC  
WHEN MEASUREMENTS MATTER

libelium

aeroqual

hi-tech simplicity

South Coast

ICT  
INTERNATIONAL

munisense

dataTaker

PurpleAir

### Parameters

Particulate	NH3
VOC	No2
Asbestos fibres	COD
Micromet gas	Atmospheric dust
LEL	Gravimetric dust
O2	Particle release
CO	Nitrogens
CO2	Sulfides
H2S	Natural Gas
PM10	BOD Landfill gas
PM2.5	AFM

### Instruments

LPWAN	Convertors
Dust/gas sensor	LFG Meters
Electrochemical	
Sensors	
Optical Particle	
Counters	
Light scatter	
NDIR	
PID Analyzers	
Probes	
Detectors	

### Sensors (parameters)

**Purple Air** (PM10)  
**CEMS with fence line units** (PM O2 CO2 NOx SOx CO THC VOC H2S HCL ETO)  
**Electrochemical Sensors and Optical Particle Counters** (PM1, PM2.5, PM10, O3, NO, NO2, SO2, H2S, CO, CO2, TVOC, Temp, Pressure, Relative Humidity)  
**Light scatter, NDIR, PID** (Particulates, Gases)



# Structural & Geotechnical

## Ahead of the curve

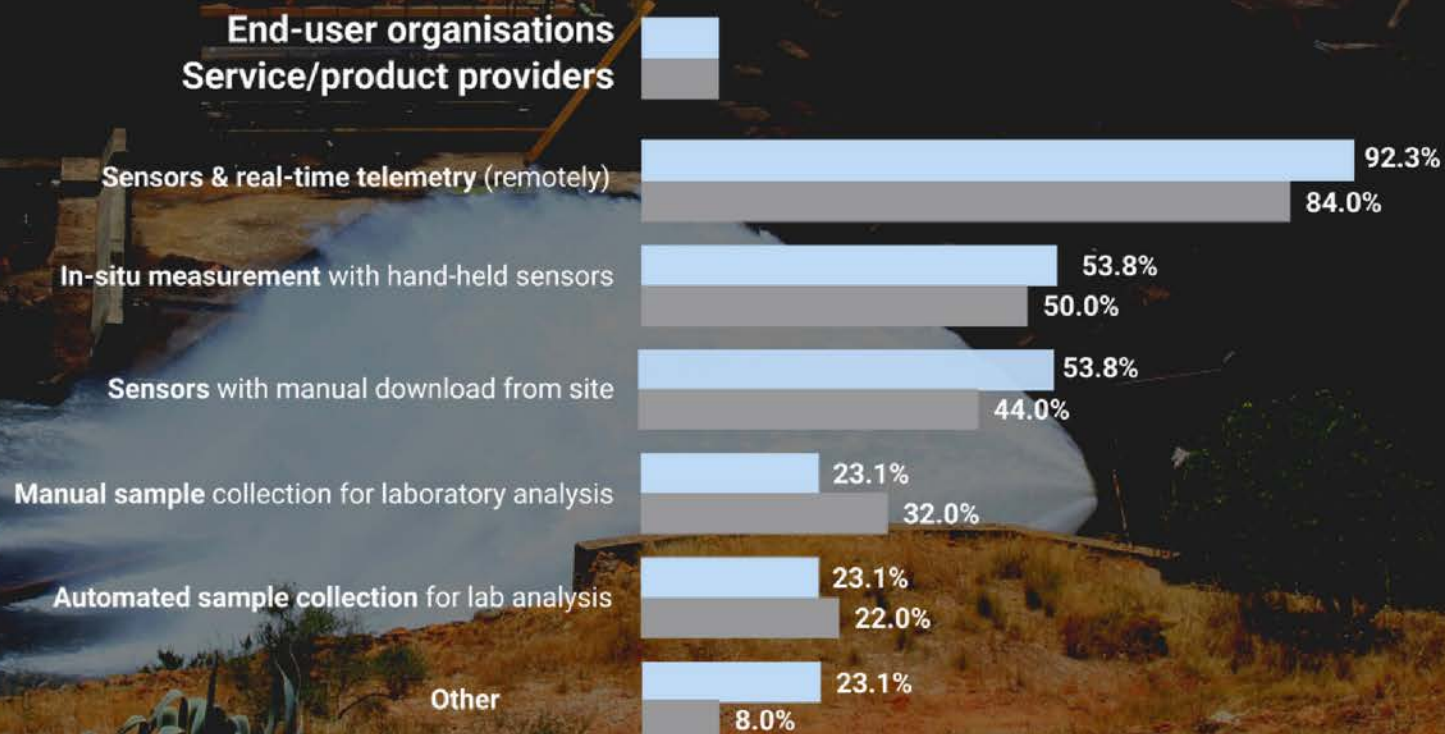
Both organization types monitoring Structural & Geotechnical parameters reported higher levels of sensor & real-time telemetry (84% and 92.3%) than the industry average (73%).

Service and Product providers also reported the top upcoming challenge to expanding remote monitoring services (34%) as a shortage of talent. Even with the advanced stage of this industry, talent remains scarce.

End-user organizations reported increased reporting requirements (50%) and monitoring a broader array of parameters and analytes (50%) as two upcoming challenges and changes in their practices.

## Monitoring methods in Structural & Geotechnical

36% of Structural & Geotechnical providers reported their biggest change in operations for 2022 is monitoring more parameters





# Reported Parameters, Vendors & Instrumentation

## HARDWARE VENDORS



## Parameters

### Providers

Vibration  
Displacement  
Crack  
Noise  
Strain  
Deflection  
Load  
Ground Displacement  
Structure Displacement  
Geomatics  
Pore Pressure  
Pressure

### End-user

Vibration  
Displacement  
Crack  
Noise  
Slope monitoring  
Strain  
Deflection  
Load  
Ground Displacement  
Structure Displacement

## Instruments

### Providers

Optical  
Instantel  
Crack gauge  
Vibrating Wire devices  
Shape arrays  
RADAR  
Manual inclinometer  
Probes  
Pressure depth sensors  
Piezometer  
Accelerometer  
Geophone

### End-users

Piezometer  
Tilt sensors  
Inclinometers  
Handheld probes  
RADAR  
Scanner  
Submersible pressure sensors  
HVAS

## Sensors (parameters)

VW Piezometers and 4-20m Amp sensors  
(Pore pressure)

**Instantel vibration**  
(Vibration)

**Manual inclinometer probes**  
(Horizontal displacement)

**RADARScanner**  
(Slope monitoring)



# Meteorological

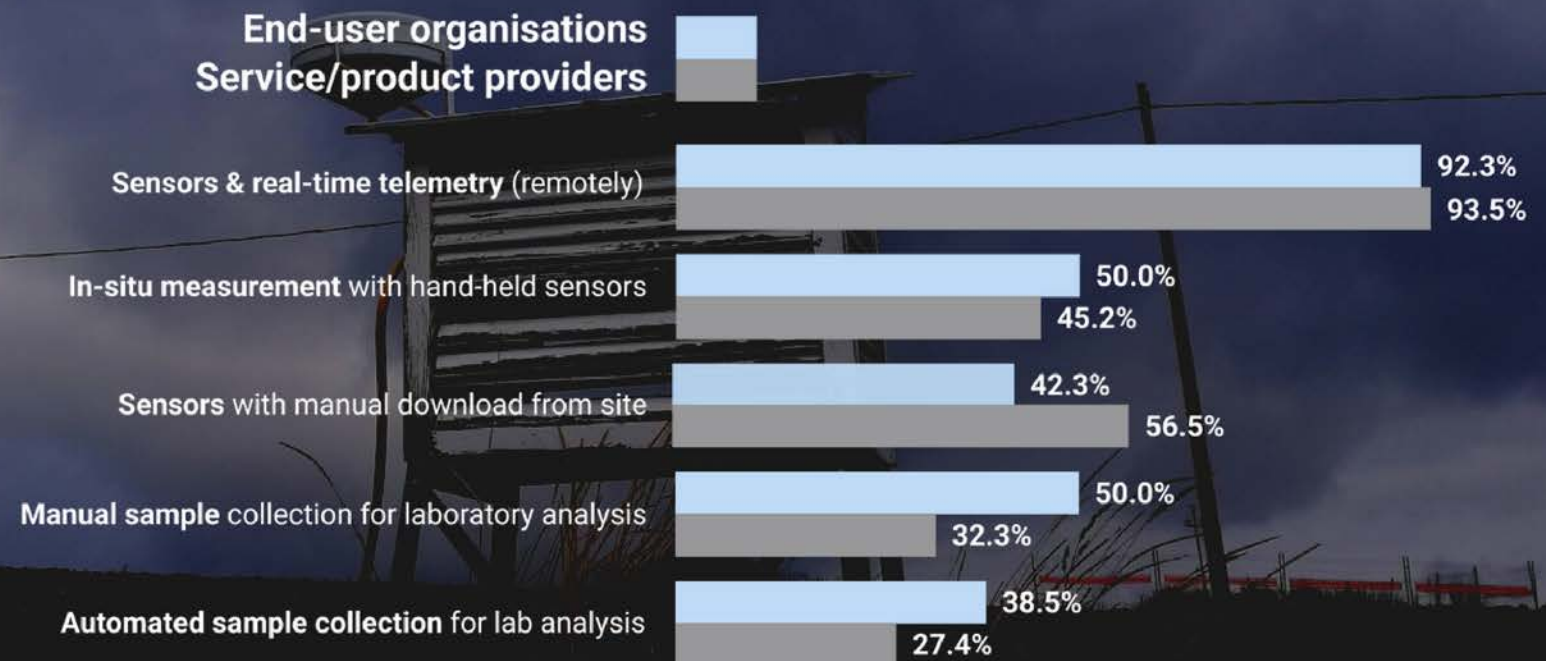
## More real-time coverage

With 84% of respondents reporting they will be monitoring 'mostly remotely' by 2025, a surge in demand for remote Meteorological hardware and monitoring services by integrators is expected.

Others reported the lacking availability of broad-array Weather stations and their cost as challenges, with few listing a lag between standards and technology as possible upcoming issues for their operations.

36% of all respondents who monitor Meteorological reported regulators, community liaisons and internal stakeholders demanding access to real-time data as their top upcoming challenge.

## Monitoring methods in Meteorological





# Reported Parameters, Vendors & Instrumentation



## Parameters

### Providers

Conductivity  
Wind speed  
Wind direction  
BP  
Rainfall  
Air Temperature  
RH  
Snow depth  
Snow Water Equivalency  
Precipitation  
Humidity  
Cloud height  
Visibility  
Global radiation  
Barometric pressure

### End-user

Conductivity  
Wind speed  
Wind direction  
BP Current speed  
Current direction  
Rainfall  
Air Temperature  
RH  
Snow depth  
Snow temperature  
Snow Water Equivalency  
Precipitation

## Instruments

### Providers

Multi-parameter weather station with data logger  
CEMS and fence line units  
Light scatter  
NDIR  
Electrochemical  
PID  
IR radiometers  
Ultrasonic snow depth sensors  
4-way net radiometers  
Snow Pillows  
GNSS Storage Cans  
Pressure Transducers  
Load Cells  
Thermistors

## Sensors (parameters)

### Providers

**MeteoHelix** (Weather)  
**atmos 41** (Weather)  
**Vaisala and Lufft sensors** (Wind speed & direction, Pressure, Temp, Humidity)  
**Kipp & Zonen sun trackers and solar radiation sensors** (Solar energy parameters)  
**Tiny Tag** (Temperature, Humidity)  
**ICT International Devices** (Full SPAC)  
**ClimaVUE** (Weather)



# Noise

With only 25% of integrators monitoring noise, and even fewer end-user organizations, noise was a smaller sub-sector of survey respondents.

Considering this relatively smaller footprint in the monitoring ecosystem,

organizations monitoring noise almost always used remote/real-time methods (93%).

The challenge for this measurement service seems to be communicating this data to stakeholders.

The top challenge (34%) was reported as increasing demand by stakeholders (regulators, community groups, internal departments) for access to real-time data from monitoring programs. We anticipate more demand for noise level alerts and public-facing communication assets.

## Monitoring methods in Noise





# Reported Parameters, Vendors & Instrumentation

## HARDWARE VENDORS

**Airodis**™

 **Sigicom**

 **eRUIDO**  
MONITOREO DE RUIDO ONLINE

**aeroqual**®

 **Cirrus**  
Research plc

  
AVA monitoring®

## Parameters

DB peak noise  
Cumulative noise  
dBA levels  
Vibration in mm/s  
Velocity/Frequency  
Equivalent Noise Pressure Level  
LAeq  
LA90

## Instruments

Environmental Noise Monitors  
Class 1 Condenser Microphones  
Sound level meters  
Noise dosimetry  
Vibrating wire sensors  
Sound Level meters

## Sensors (parameters)

**eRuido Monitor Model U20** (Equivalent Noise Pressure Level)  
**Sigicom** (Vibrations)  
**Aeroqual** (All parameters)  
**01dB fusion** (dB)

 50<sup>P</sup> dB

 41<sup>P</sup> dB



# METocean

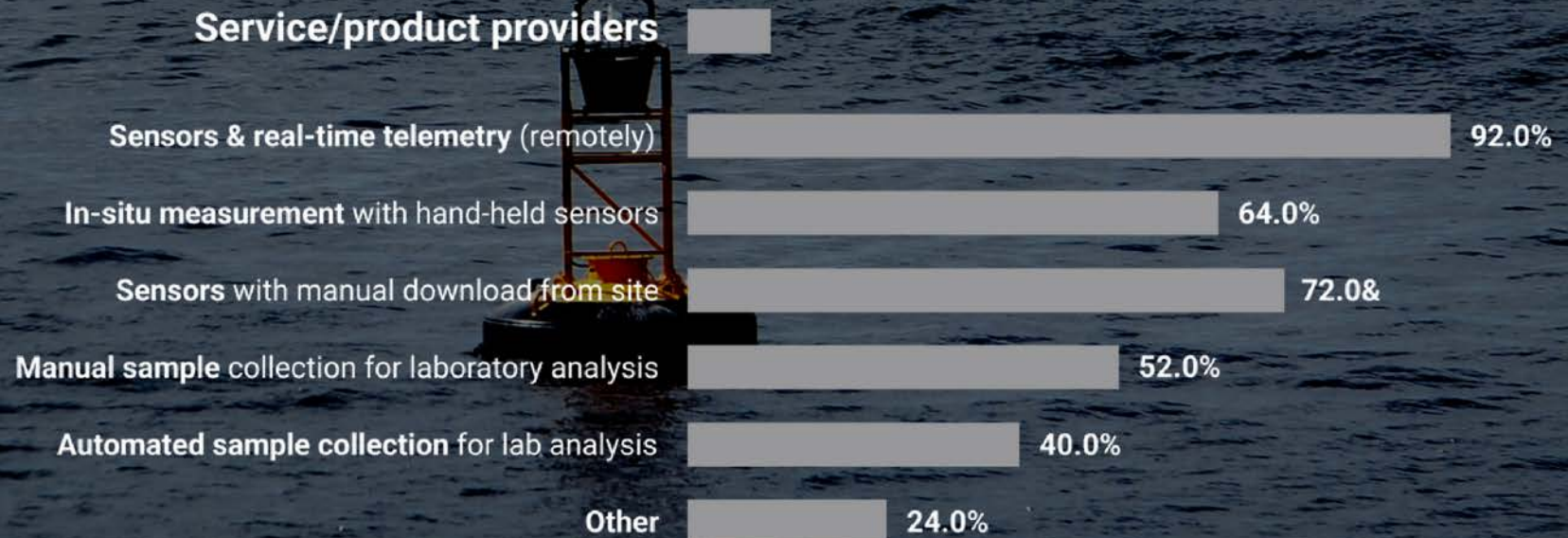
## More parameters

METocean respondents represented a smaller segment of the survey responses (13%). Of this smaller subset, 85% reported monitoring via sensors & real-time telemetry.

32% of respondents reported that expanding the range of parameters measured by sensors and monitored in real-time to meet client demands is the biggest change currently occurring in their organization.

36% responded that their biggest challenge is increasing demand for access to real-time data and visualisations (charts, dashboards) from regulators, community groups, internal departments and partner organizations.

## Monitoring methods in METocean





# Reported Parameters, Vendors & Instrumentation

## HARDWARE VENDORS



## Parameters

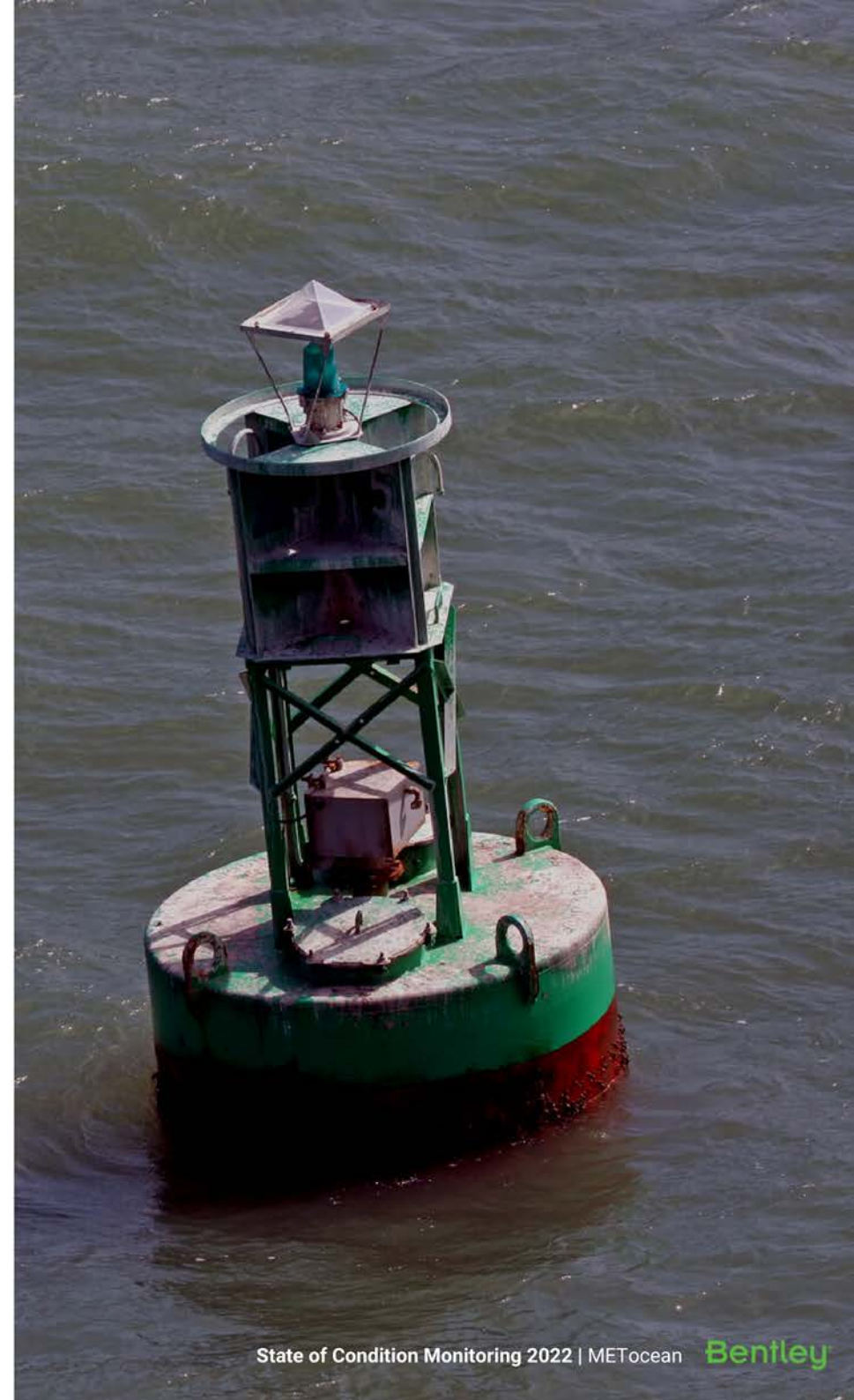
pH  
EC  
DO  
NTU  
PAR  
Depth  
Temperature  
Salinity  
Benthic cover  
Waves  
Currents  
Tides  
Turbidity  
Seabed chemistry  
Flow

## Instruments

YSI meters  
Water level loggers  
pH meters  
Convertors  
Multi-probes  
Flow sensors  
Water level meters  
Pressure loggers  
ADP's  
Turbidity sensors  
Salinity sensors  
Multi-meters  
WQM  
IP  
SLM  
Turbidimeter  
Sondes

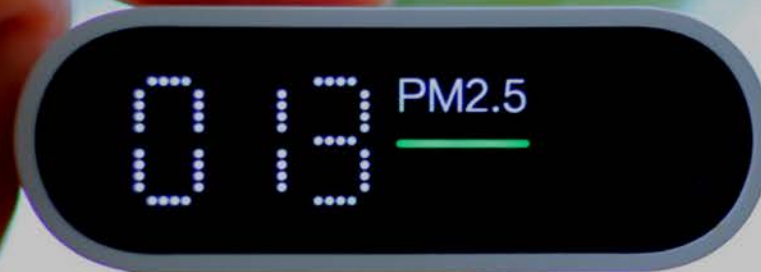
## Sensors

(parameters)  
(parameters)  
YSI Pro DSS (pH, EC, DO, Turb)  
Sontek M9 Flow Tracker (Flow)  
YSI multiparameter sonde (Turb, EC, pH, DO, Temp)  
SignalFire Ranger (Flow, Level, Pre)



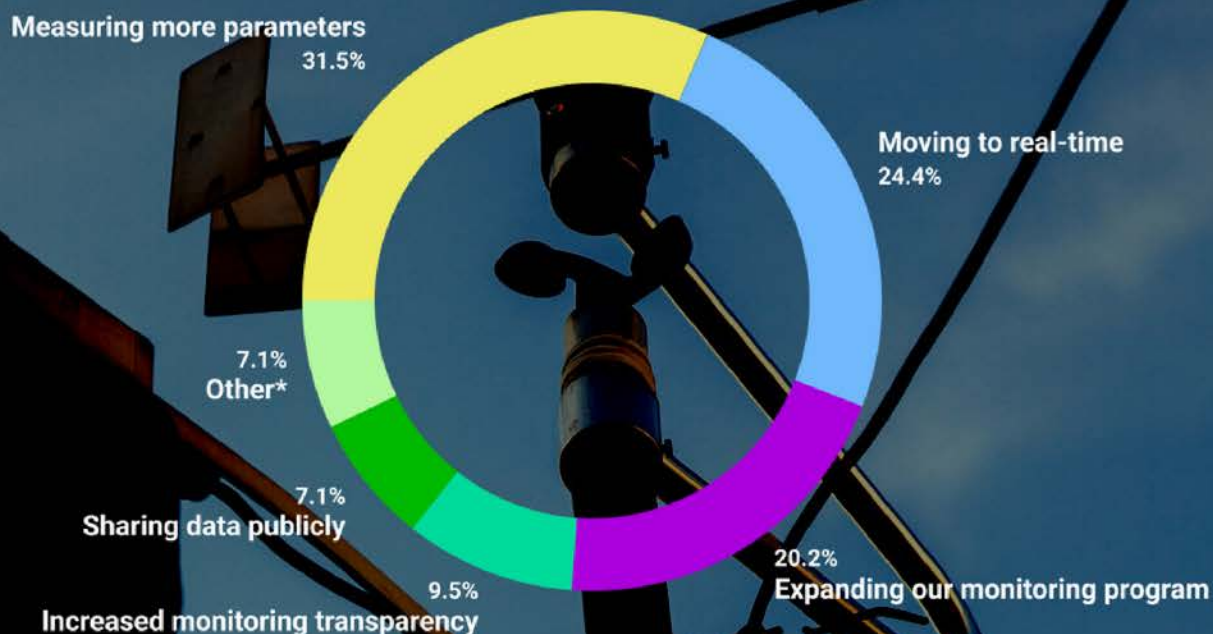


# Industry Trends



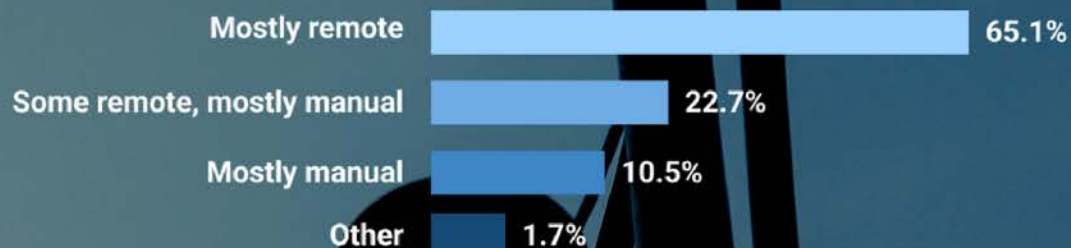


## Reported organizational changes in 2021



\*Citizen science and crowd-sourcing, Cloud based web access for clients, Using DNA and development of chemically derived standards that remove the need for bioassay testing, Finer accuracy measuring lower targets, Investigating new technologies, Regulation, Generation of well documented and defensible data, Artificial Intelligence, Retrieving information from sensor data

## Expected monitoring operation by 2025



## Breaking down trends

Across a series of questions regarding changes in organizations, trends, upcoming challenges and adoption practices, respondents identified these four major industry trends in monitoring:

### 1. Remote monitoring

Over 50% of all end-user organizations and service/product provider respondents reported remote/real-time via IoT and telemetry to be the top upcoming industry trend, with 65% of the industry expecting to be mostly remote by 2025, and 24.4 % of all respondents moving to real-time in 2022.

### 2. More parameters and data points

31.5% of all respondents reported that monitoring more parameters is their biggest change in their organization for 2022.

### 3. Increasing stakeholder demand for real-time

Pressure from communities, regulators and internal stakeholders around data-transparency and access is increasing, with over 1 in 4 of respondents reporting delivering on these demands as the biggest upcoming challenge in the industry.

### 4. Automation

Respondents reported data-automation and fully-automated monitoring systems as one of the biggest upcoming trends.



## Challenges in industry

Just over 1 in 4 respondents indicated a shortage of talent across the environmental monitoring industry.

This skills shortage was worse in those companies focused on real-time/remote monitoring programs with 30.2% of these respondents reporting a shortage of talent as their biggest upcoming challenge.

For end-user organizations, an increased requirement for reporting from regulators and stakeholders came in as the top challenge. Together with the skill shortage, and appetite for end-user organizations to move to 100% real-time by 2025, this presents an interesting opportunity for service/product providers to meet this supply and demand gap.

Several respondents also list cost factors of hardware (particularly relating to sensors in the water sector) and flagged potential supply issues as challenges on the horizon.

From an industry standpoint, the push to digital data management and increasing demand from stakeholders for data transparency could be set to put pressure on sourcing talent across the industry, with several measurement verticals (Air Quality, Water Quality and Noise Quality) already reporting talent shortages (over 30% of respondents reported this as their biggest challenge).

### Other reported upcoming challenges reported in free-text responses.

- Managing costs coming from rising wages (talent) and upskilling staff
- Automating IoT operations with low-cost solutions
- Supply chain issues with hardware due to a global component shortage driving costs up
- Challenges with the ability of instruments to meet Data Quality objectives and regulatory requirements
- A lag between government standards and technology preventing acceptance of new methods
- A lack of shared best practices applicable

## Reported challenges in industry

### Stakeholder demand for data communication

32.7%

### Shortage of talent

30.0%

### Move to Digital

19.3%

### Reporting

15.3%

### Other

11.1%



## Client demands in 2022

The automation of reporting and data management was the most reported client demand in responses.

Service and product providers also reported the following key demands from clients for 2022: multi-parameter sensors, sensor data and visualisation software integrations with B.I. tools, real-time data transmission from sensors and more advanced sensor data analysis.

Across responses, service and product providers also reported end clients demanding more real-time data access, alarms and alerts, with end clients requesting to integrate their remote-sensor data software into other data tools (BI platforms like Power BI, YellowFin etc) for more advanced modelling and data transformation.

From a service perspective, providers reported rising demand for automated data interpretation (such as automated PDF reports) services.

End clients seem to be seeking more assistance with editing, coding, transforming and reporting on their data. Service/product providers should consider tailoring solution offerings to match demand for this type of done-for-you data service.

## Upcoming trends

According to respondents, we're going to see a rise in data volumes, wider uptake of data analytics and data management over the coming years. This presents opportunities for employees skilled in these specialities, and service/product providers who cater to these needs for organizations. There is also an expectation of improvements in IoT sensor technology - smaller sizes, cheaper costs and higher quality data.

### **Progress in remote/telemetry technology:**

Respondents expect better remote access and setup and low orbit satellites from new companies taking market share from historically strong companies that are over-reliant on past technologies and not able to adapt to remote monitoring.

### **A move to automated systems:**

More organizations transitioning to fully automated IoT systems with data centralisation and self-serve system automation. Respondents also noted the push to 'set & forget' technologies with automated alerts and reporting.

### **Improved IoT sensor technology:**

Respondents anticipate smaller, cheaper devices that use small data packets with wireless sensors to become more affordable and miniaturised with longer battery life.

## Service Opportunities

Reporting and data management

Done-for-you data coding and editing

Multiparameter sensor instalment

Sensor data integration with BI tools

Advanced data analysis/visualisations

Real-time alarms and alerts set-up

## Product Opportunities

Automated reporting (e.g. PDF) tools

User-friendly multi-parameter sensors

Sensor data integration with BI tools

Advanced sensor data analysis tools

Low-cost, low-maintenance IoT sensors



# Bentley Infrastructure IoT

## Architecture Options Matching Your Needs

Self-provision and manage IoT services within your own IT environment or leverage scalable cloud services on demand. Our range of solutions adapts to the current needs of your organization and scales with you.



### Self-Hosted

Installed locally or in your own corporate compute environment. All data stays within the confines of your organization's infrastructure.

- Operate in your own data center
- Deploy on-premise solutions
- Implement custom security policies
- Solve for sites with telecom challenges

### Cloud

Enjoy the convenience, reliability, and scalability of a global cloud solution. Solutions can include:

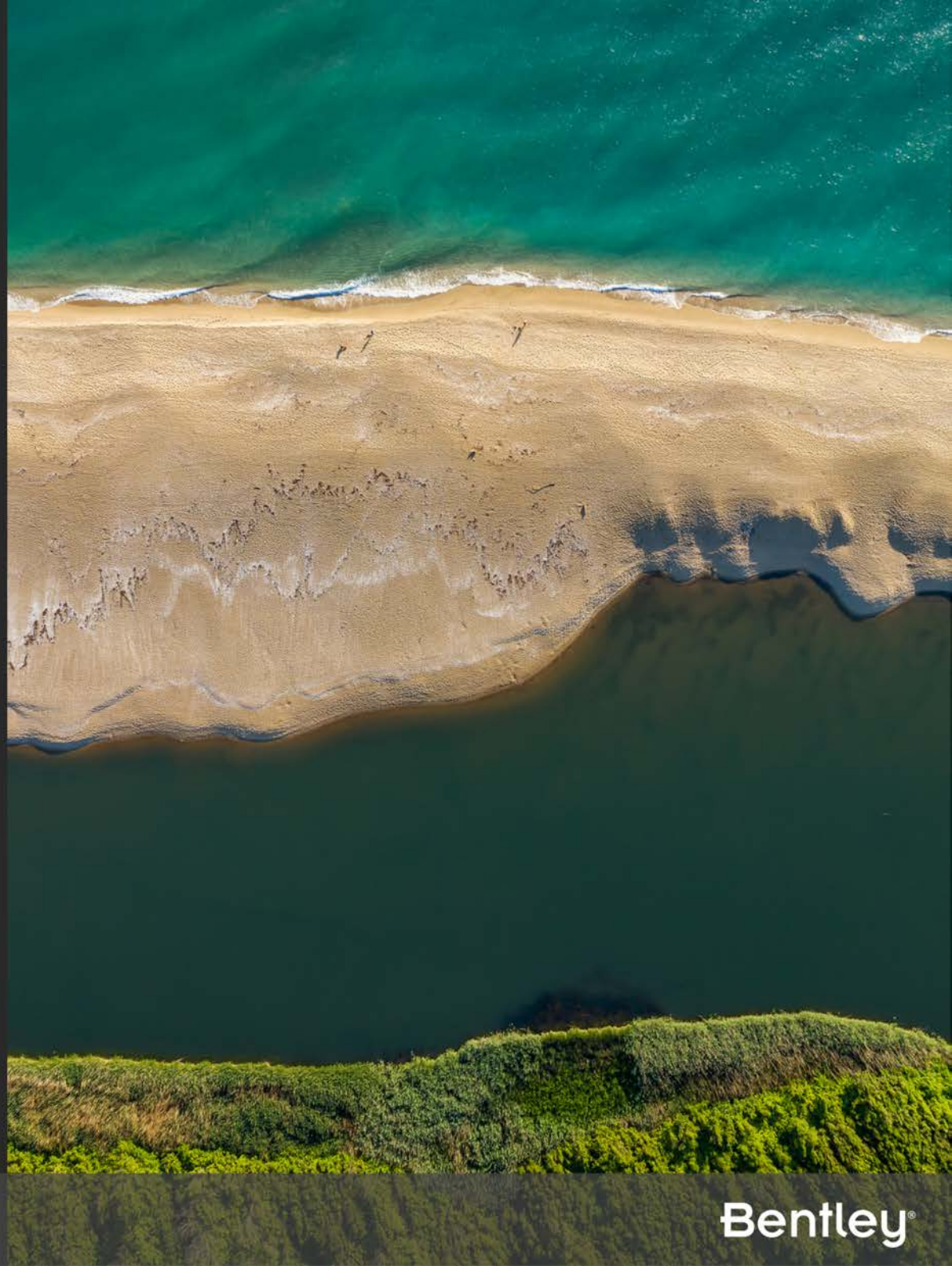
- Industry-leading support for IoT devices
- Guaranteed availability
- Frequent feature enhancements
- Full featured API-based data exchange
- iOS and Android mobile application available



# State of Condition Monitoring

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2022



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