March 2022

Drones Supporting Coastal Erosion Monitoring & Protection

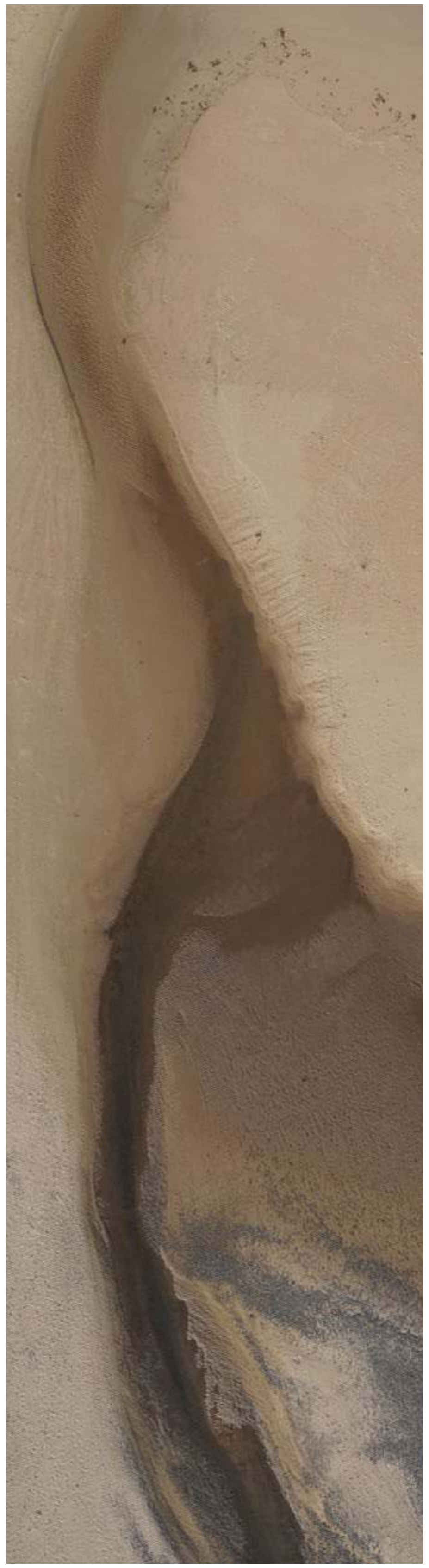
CATAPULT
Connected Places

The UK coastline is an evolving landscape, shaped by physical, climatic and anthropogenic factors. The effects of climate change, such as increased storm intensity and sea level rise, are threatening vulnerable coastlines and putting communities, businesses and infrastructure at greater risk from flooding and erosion.

This case study outlines the economic, social and environmental benefits of using drones for coastal change surveying. With the help of the Environment Agency's Anglian Coastal Monitoring Programme, it shows how drones could enhance the current suite of coastal survey techniques and explores the benefits of drone gathered data. Property, asset, infrastructure, and local authority officers who read this document will gain awareness of the capabilities and potential opportunities for drones in environmental monitoring.

Key takeaways

- In England, 520,000 properties (including 370,000 homes) are located in areas with a 0.5% or greater annual risk from coastal flooding and 8,900 properties are located in areas at risk from coastal erosion[a]. Direct economic damages from flooding and erosion are over £260 million per year[a]. Climate change will exacerbate this issue over time.
- Connected Places Catapult worked with SurveyAR and the Environment Agency to organise coastal drone surveys to highlight how the Environment Agency, local Risk Management Authorities and other environmental organisations could benefit from using drones.
- SurveyAR showed how the data captured from drones fitted with LiDAR or hi-spec cameras could be rapidly deployed pre- and post- storm event to capture high resolution imagery and spatially continuous data, over short temporal period. This could be used to inform coastal management decision-making as well as record the coastal response to specific storm events.
- Collecting data with drones could lead to significant efficiencies in coastal monitoring, management and maintenance. Accurate data helps evaluate flood protection scheme performance or improve effectiveness of erosion mitigation measures. Robust data improves managers' confidence when talking to affected communities, and drone captured imagery helps stakeholder engagement.
- Environmental monitoring organisations could work with a company like SurveyAR to improve the quality and density of their data and timeliness of delivery, without investing in drone pilots and equipment in-house.



The case for drones in coastal monitoring

The UK's coastline is continually changing, putting pressure on coastal communities

According to the Committee on Climate Change[a] direct economic damages from flooding and erosion are over £260 million per year. In England, 520,000 properties (including 370,000 homes) are located in areas with a 0.5% or greater annual risk from coastal flooding and 8,900 properties are located in areas at risk from coastal erosion, not taking into account coastal defences.

The impact on coastal regions is to be exacerbated by climate change, and is therefore set to get worse over time

By the 2080s, up to 1.5 million properties (including 1.2 million homes) may be in areas with a 0.5% of greater annual level of flood risk and over 100,000 properties may be at risk from coastal erosion[a].

According to the 2022 IPCC WGII Sixth Assessment Report the "population potentially exposed to a 100-year coastal flood is projected to increase by about 20% if global mean sea level rises by 0.15 m relative to 2020 levels"[b] This magnitude of rise is predicted to occur by 2060 for the UK[c].

Local authorities who manage the coastline need data to make effective decisions

The Anglian Coastal Monitoring Programme (ACMP) supports the Risk Management Authorities by providing systematically collected and processed survey data for identification of long, medium and short-term trends of coastal change.
Coastal management is a devolved policy area, guided in England by the Flooding and Coastal Erosion Risk Management (FCERM) strategy[d]. The National Network of Regional Coastal Monitoring Programmes collect and distribute the necessary data to underpin evidence-based decisions regarding strategic and local level FCERM. Funding for the Programmes is secured in six-year cycles from DEFRA and administrated through the Environment Agency's FD GiA[e].

Existing coastal monitoring methods are well established, but none is without limitation

The Environment Agency currently monitors coastlines using a combination of direct and remote survey methods. These various approaches have inherent strengths and weaknesses - it is about selecting the most appropriate and affordable approach for the extent of coastline to monitor. Current methods include:

- Walked topographic surveys that yield highly accurate but spatially sparse data, especially over actively eroding cliff face areas where access on foot is limited
- Crewed aircraft lidar and aerial photography that is accurate but costly, and therefore uneconomical to use over small areas
- Boat-based hydrographic and bathymetric surveys which are suitable for nearshore seabed and sandbanks

Drones can complement existing coastal monitoring methods

Drones collect a higher density of data per unit of surface area than ACMP's current survey methods, which allows richer outputs. Complete 3D area coverage can replace roughly interpolated data between 2D walked transects. Compared to other aerial methods, drones offer more responsive operations and higher resolution outputs over smaller survey areas. Just like other methods, collected data is geo-tagged so that changes can be accurately mapped via repeated surveys.

Organisations do not need in-house experience or capability to benefit

Any coastal or environmental monitoring agency could work with a company like SurveyAR to improve the richness and timeliness of environmental data, without having to invest in in-house drone pilots and equipment.

Ultimately, better data from drones will allow environmental management organisations to work more effectively

From coastlines to inland flood plains, gaining a more accurate and accessible view of our environment using drones will help organisations manage and adapt to environmental pressures as climate change increasingly affects the UK.

Drone survey approach

CPC partnered with SurveyAR Ltd who carried out drone-based surveys along a dynamic area on the Anglian coastline to showcase drone capabilities, workflows and sensors for coastal monitoring applications. The surveys included:

- 3D mapping using drone-based photogrammetry and LiDAR
- Multispectral imaging, (wide bands of the electromagnetic spectrum) allowing the capture of light beyond the visible spectrum for the purpose of assessing vegetation, water features and sediment classes.

Different rotary-wing drones were used, including a DJI Mavic 2 pro (20Mp camera) and a custom build heavy lift system for multi-spectral and high resolution (60Mp) RGB photogrammetry, and LiDAR deployment. More than 18 Ground Control Points (GCPs) per survey zone were used, mapped to <10mm accuracy.

Two areas were surveyed during site visits in November, December 2021 and January 2022. A narrow beach backed by an actively eroding cliff area (1.2km long) and an adjacent cuspate foreland, or Ness, which herein is known as the sediment deposition area (1km x 500m). Both areas are a subset of a much larger monitoring cell that has a >30-year survey history.

Drone flight operational workflows complied with Civil Aviation Authority guidelines and permissions and the necessary insurance was in place. Site specific risks, such as proximity to cliffs, danger from tides and managing public spaces were assessed and managed.

Further survey techniques that weren't used on this occasion include the use of thermal (radiometric) imaging for the assessment of heat effect due to water features/sand conditions, sonar for bathymetry, hyperspectral for mineralisation assessment (or even microplastics) and geophysics (ground probing radar, magnetometer etc) for assessing ground conditions and stability.

Anglian Coastal Monitoring Programme (ACMP)

ACMP are a small team within the Environment Agency (EA) that co-ordinate the monitoring of 1082km of coastline between Grimsby in Lincolnshire and Southend in Essex.

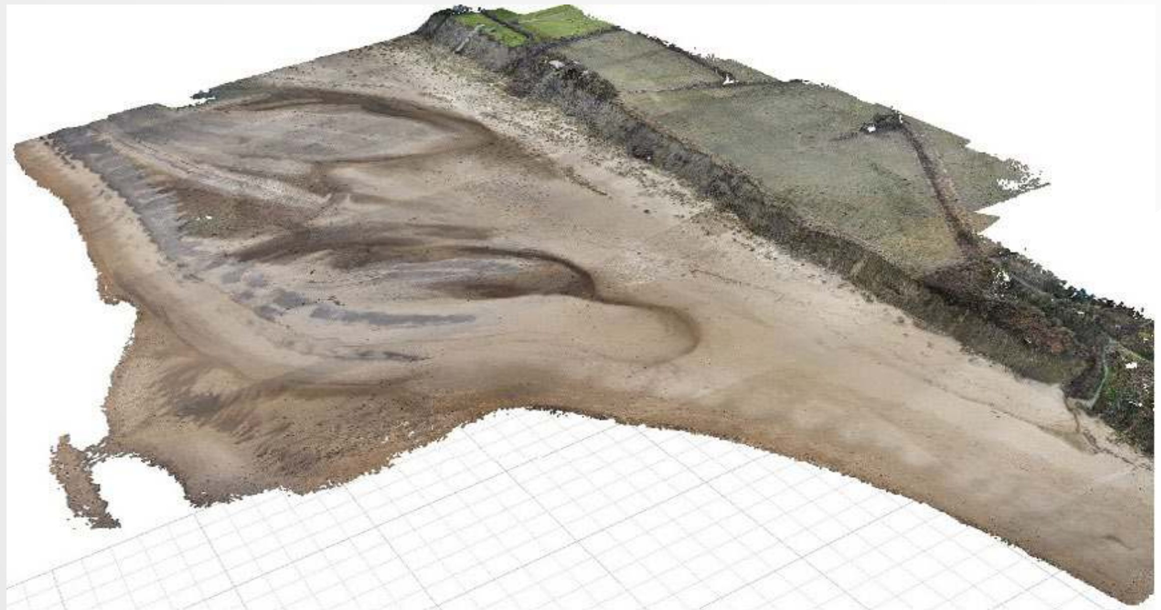
The objective of ACMP is to provide evidence to support Flood and Coastal Erosion Risk Management (FCERM) decision making.

They employ a risk-based approach to determining the type, frequency and intensity of coastal monitoring, to best serve their partners- the Risk Management Authorities (RMAs).

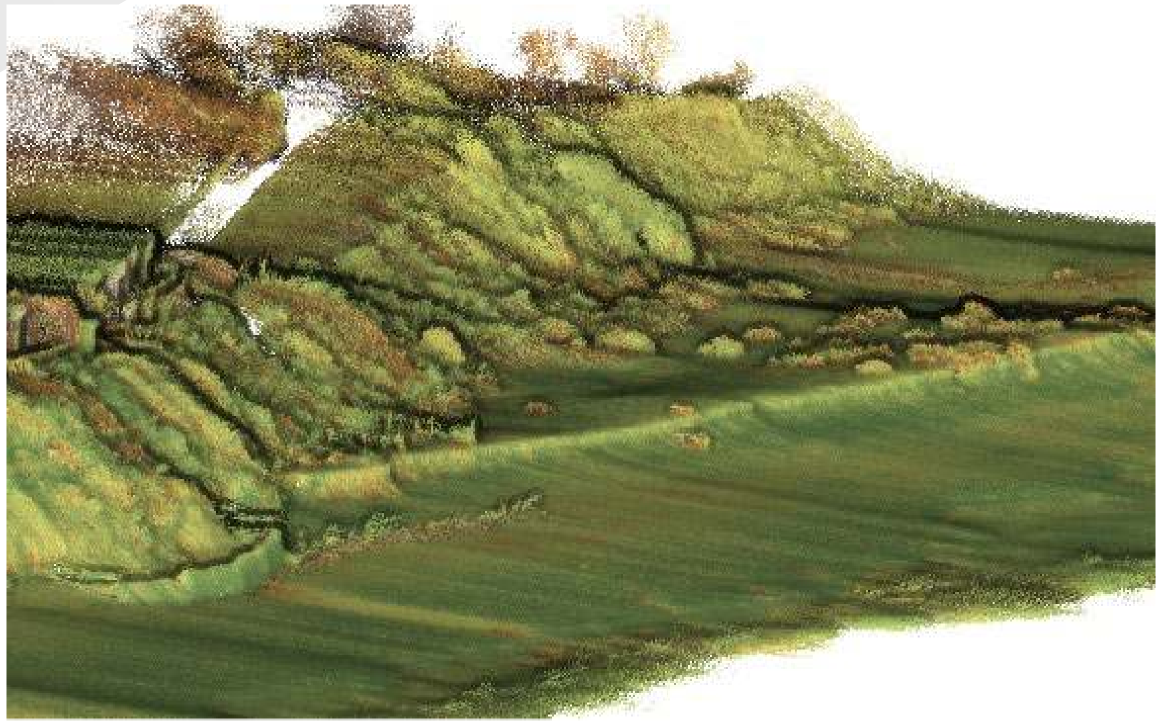
Data Management and Processing

The 5-30 gigabytes (depending on sensors used) of raw data collected from each flight are either overlapping photos (for photogrammetry) or points and flight trajectory data (for lidar). These are calibrated and processed to form a dense point cloud and referenced using Ground Control Points (GCPs) to a real-world coordinate system. Accuracy is assessed to ensure it suitable for the use case and will allow multiple data sets and surveys to be compared.

These georeferenced point clouds are then used to generate Digital Elevation Models (DEMS) and orthorectified images which can be exported into Geographical Information Systems (GIS) packages and rendered into textured 3D models for visualisation (Figure 1). Ground control point positions are used to check and/or reference the model and assess the accuracy. Initial lower density outputs can be rapidly generated in the field if needed, whilst full 3D textured outputs and accuracy assessment can be available within a 24-48 hours, particularly if high speed internet and cloud computing resources are available.



1: Example of photorealistic 3D output from photogrammetric data showing an area 900m x 450m, captured over 2 flight of 25 minutes each at 100m above ground level. This model consists of 54 million faces and is textured using 60Mp images.



2: Lidar Data offers dense point clouds which can collect terrain data under vegetation more effectively than photogrammetry.

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The outputs and what they can tell us

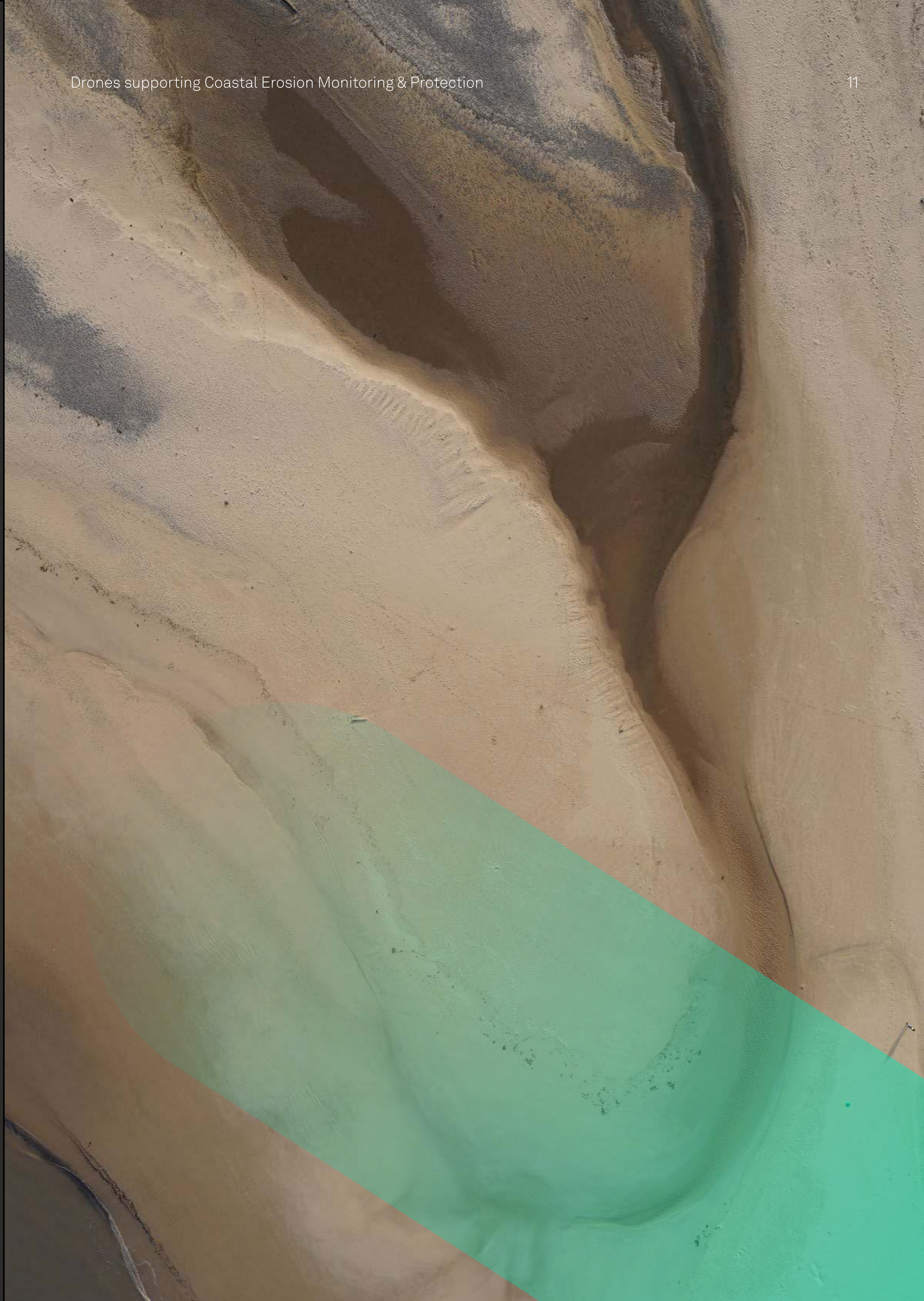
Surveying is the means by which to recognise and record the characteristic behaviour of the coastline - how it's geometry changes seasonally, cyclically and episodically. By measuring the same locations, repeatedly, monitoring agencies such as ACMP can quantify the impact that certain drivers of coastal change (storms, high wave or sea-level events) have had on a sea-front, and equally monitor the recovery time to help mangers decide whether and when intervention is required.

Assessing storm impacts

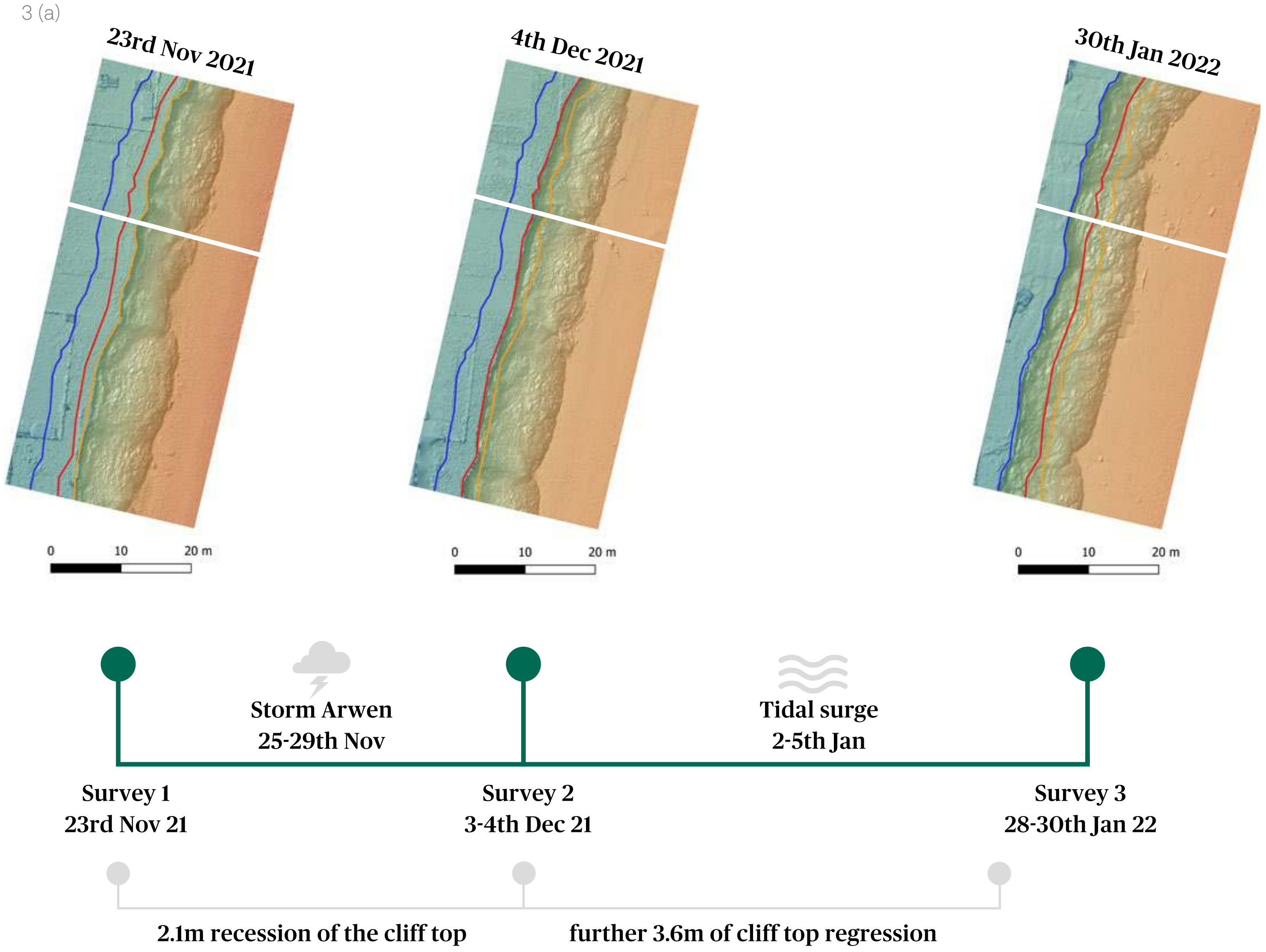
Rapid deployment of drones to collect survey data at key times pre- and post-storms allows for a reliable assessment of specific storm impacts. Storm Arwen occurred between the November and December 2021 drone surveys. The impact of this low-pressure system on this Anglian study area resulted in waves from the northeast direction reaching 4m, exceeding the storm threshold by 0.8m. With the correct local knowledge about when and where to deploy, a drone survey offers a type of remote 'rapid walkover assessment' potentially covering larger and more hazardous areas than could be reached by inspectors on foot.

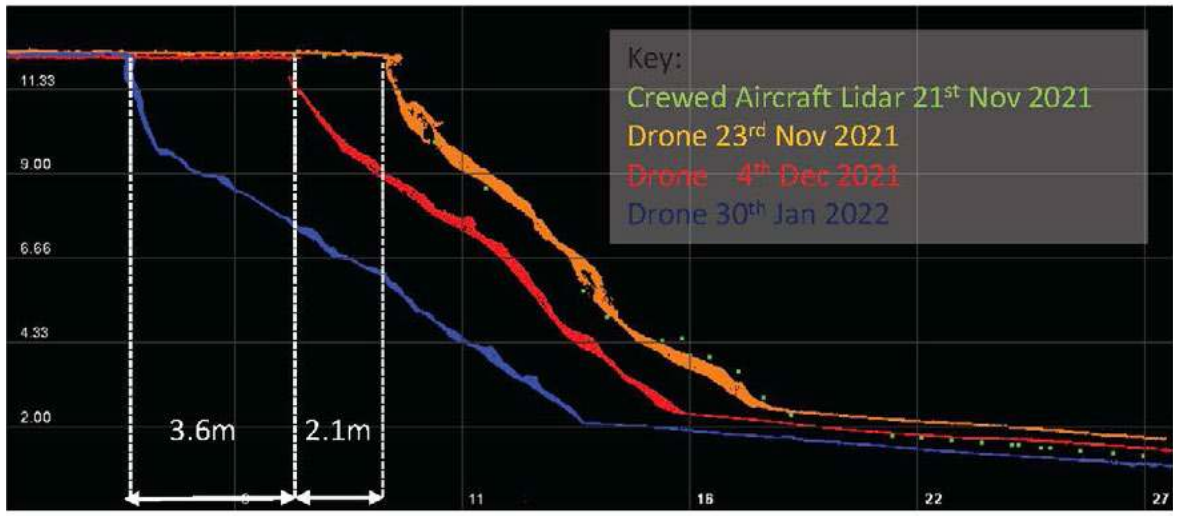
Comparison of the pre- and post-storm survey data indicated a 2.1m recession of the cliff top (Figure 3). In the 57 intervening days between the December 2021 and January 2022 survey a further 3.6m of cliff top regression had occurred at the same location. During 2nd-5th Jan 2022 a prolonged positive surge event caused sea water levels more than 0.5m higher than astronomical predictions over a 4 day period , which contributed towards this further recession.

The value of drones in this case is the highly replicable capture of cliff and beach elevation data post-event. Monitoring more frequently and with improved spatial coverage (compared to walked transect data collected post-event) allows these different episodes of cliff loss to be attributed to different hydrodynamic factors and meteorological conditions. This data could help calibrate models of shoreline evolution and inform shoreline managers, coastal scientists and engineers of how it may change during future events with similar parameters.

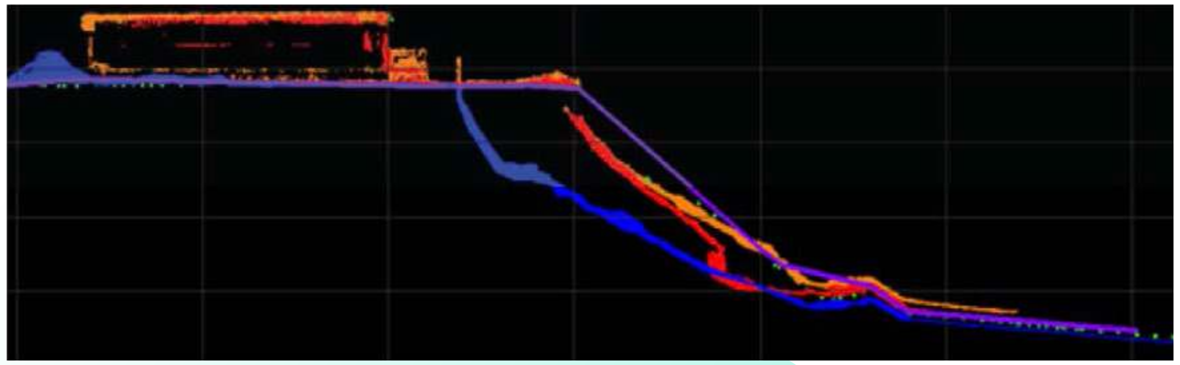


3 (a)





3 (b)



3 (c)

Figure 3: (a) Digital Elevation Models showing the progression of cliff-top erosion between the surveys, coloured by survey date. Cross sections can be drawn at any point to visualise the cliff face and slope, and a cross-section at the location of the white line is shown in (b). with Crewed aircraft lidar from 21st November 2021 is also shown. (c) is a cross section at a ground-based survey transect (purple).

Monitoring change around coastal defences

Monitoring is particularly important along frontages that have coastal defences in place to protect the land and assets behind them from flooding and/or erosion. Interventions may be major, permanent, minor or temporary schemes of work, but surveying is needed alongside all of them to evaluate their feasibility before construction, and their performance afterwards. Another purpose of monitoring is to provide the evidence to inform coastal managers and stakeholders of when environmental conditions are jeopardising existing planning policies, which triggers a strategic review.

Monitoring areas of deposition (growth)

Monitoring the coast involves capturing changes driven by coastal processes, which include transportation and deposition of sediment, not just erosion. Quantifying rates and extents of deposition and beach repair is of equal interest to coastal managers as measuring damage and loss. Some of the sand and gravel deposits, or 'Ness' features on the Anglian coast are highly dynamic and/or heavily designated for their habitat value. The successive drone survey data from this case study has proven precise enough to map the few meters of northward Ness migration between Dec and Jan (see image 4 below). The ability to capture this remote environment, with such clear photography, and look at habitat change using the multispectral imagery, whilst yielding accurate elevation data, is something that existing LiDAR data and Satellite imagery is not able to deliver. This information is also valuable to academics trying to understand the causes and drivers of changing coastal geometry, as well as conservationists assessing the ecological condition.

Figure 4: December and January Surveys of the Ness showing growth on the right 'shoulder' due to transportation and deposition of sediment.

Multispectral outputs

Multispectral cameras 'see' in different parts of the electromagnetic spectrum (such as near-infrared and red-edge bands) and can provide powerful insights into wide range of metrics including vegetation health, water body identification and sediment types. Figure 5 shows a composite coloured model of the deposition area where the normal red, green and blue colours are replaced with near infra-red, red and green channels from the multispectral camera. Bright red colours show healthy vegetation, black corresponds to water, green/grey colours are siltier sediment and white shows sand. For coastal monitoring this can help inform areas of cliff face vegetation (indicators of minimal erosion), areas where vegetation consolidates sediment, water courses and sediment transport areas. Hyperspectral devices can 'see' many more bands and can be used to provide even greater insights (e.g. species level identification).

Figure 5: Multispectral imagery colour composite image. Bright red colours show healthy vegetation, black corresponds to water, green/grey colours are siltier sediment and white shows sand

Games Engine Visualisation

Computer games engine technology allows delivery of data in an accessible format on a variety of platforms and easy to navigate interfaces. This reduces the need for training in bespoke software packages allowing a wide range of stakeholders to access complex data. Overlays can be loaded to quickly show the difference between multiple surveys or multispectral imagery. This can help deliver assessments outcomes to communities in an engaging format. Figure 6 shows an example of how coastal monitoring data can be visualised using this technique.

Figure 6: Computer games engine technology is used to visualise data in an engaging format.

A deeper dive: Drone Surveys - the economic, social and environmental case

In many cases, drones allow safer, faster and cheaper coastal surveys that can deliver a range of benefits and bolster the business-as-usual approach. This section outlines some of the key economic, social and environmental benefits arising from the use of drones for coastal surveys.

	Business as usual approach		Drone surveys	
	Ground based walked-transect survey	**Crewed Aircraft LiDAR**	**Drone Survey Photogrammetry**	**Drone Survey Lidar**
Description	Walking in transects perpendicular to the shoreline at intervals along the coast	Crewed Aircraft fitted with LiDAR sensors	Uncrewed drone with camera	Uncrewed drone with LiDAR sensor
Limitations	Safety issues around cliffs, restricted to 2D transects	requires more human resource. Long-processing time.	Requires good light and reasonable weather	Requires reasonable weather
Pros	Simple and accurate	Large area coverage in one survey	Fast, high resolution and coverage	Fast, high resolution and coverage. Vegetation penetration
Indicative Surface Resolution	0.001pts/m2	1pt/m2	>500 pts/m2*	>500 pts/m2*
Visualisation options	2D Cross Sections only	Lower resolution, wider area digital elevation model (DEM) and 3D model	High resolution DEM and 3D model	High resolution DEM and 3D model
Accuracy (RMSE)	<2cm	<15cm	<7cm	<5cm
Indicative costs	££	££££	££	£££
Conclusions	Highly detailed survey with low spatial coverage.	Great for providing baseline data over large areas, but limited resolution and operational flexibility.	Cost effective method that can be targeted to smaller bespoke surveys.	Useful solution for small highly detailed surveys.

*Depends on flight altitude and processing.

Economic Case

Cost Savings on Surveys

- The cost of a basic drone capable of photogrammetry (with ground control) is broadly equivalent to a ground-based GPS survey whilst providing much greater coverage, detail, and visualisation.
- Drone surveys offer reduced survey time and rapid deployment capability, therefore can be used frequently and responsively.
- For relatively small areas, lidar, sonar, multispectral and other sensors can be deployed far more cost effectively using a drone than using a helicopter or plane.
- In the near future, the use of fixed wing BVLOS drones could increase the range and survey coverage per flight, making operations even more cost-effective savings on coastal mitigation

Supporting effective decisions

- Better quality data will lead to more effective evidenced-based decision making about how different coastal mitigations are funded.
- The use of drones can be used to survey the effectiveness of existing or new mitigation measures and thereby save millions in unnecessary spend on ineffective programmes

Social Case

Improving the safety of conducting surveys

- Remote drone surveys can reduce the need for ground-based activity in hazardous areas such as steep cliffs, reducing potential risk of injury or death

Contributing to climate change adaption plans

- The combination of spatially continuous survey coverage and detailed visualisation can improve the awareness of property owners threatened by coastal erosion, by offering a different perspective and understanding of how the change is progressing.
- The ability to collect repeated drone data at high temporal and spatial resolution can be used to determine risk probability and forecast short and long-term future change.

Effective communication to public stakeholders

- The outputs of the data are akin to 'normal' aerial maps and images, more easily digested by non-technical audiences, than traditional graphs of beach profiles and data tables. The before and after storm Arwen images, in this case, are very helpful to convey the scientific narrative without any scientific commentary.

Environmental Case

Increased understanding of coastal erosion processes

- Drone survey can provide spatially continuous, dense data coverage of coast which meets the accuracy and precision needed for comparison with other datasets and survey times.
- Providing data on localised erosion and impacts contributes to the overall understanding of costal change in the UK.
- Drone captured imagery can support the reporting on climate change adaptation and mitigation targets, at the local council level and nationwide
- Enhanced surveys using multispectral sensors can remotely measure other environmental factors such as sedimentation changes, habitat mapping, vegetation coverage, and drainage, without the need to step on site

Increased understanding of mitigation measures

- Drone surveys during and after mitigation (alongside comparison with areas of non-mitigation areas) can be used to rapidly demonstrate the effectiveness of mitigation measures and the impacts on the surrounding coast.

Further Coastal Use Cases

There are many further use-cases where drones can provide significant benefit in coastal areas, including:

Bathymetry
Drones (including surface vehicles) can be used to survey near shore sedimentation changes along the coastline, which could enhance the understanding on coastal systems.

Development
Coastal systems are occasionally subject to development (e.g., cable routes for offshore renewables), where drone survey work could prove essential in supporting optimum routes and reducing impacts.

Ecology
Many coastal systems are protected ecological areas. Regular drone-based monitoring could provide an essential solution in determining changes to the ecosystems and habitats. This could be used to support decisions on intervention, enhancement and prevention.

Pollution
Drone based surveys could readily be used to assess the level/extent of litter, fly tipping or pollution events along the coast

And many more...
Drones can be used to support public safety in conjunction with lifeguards, to assess public infrastructure, to provide initial assessment of washed-up suspected WW2 ordnance or to identify invasive species.

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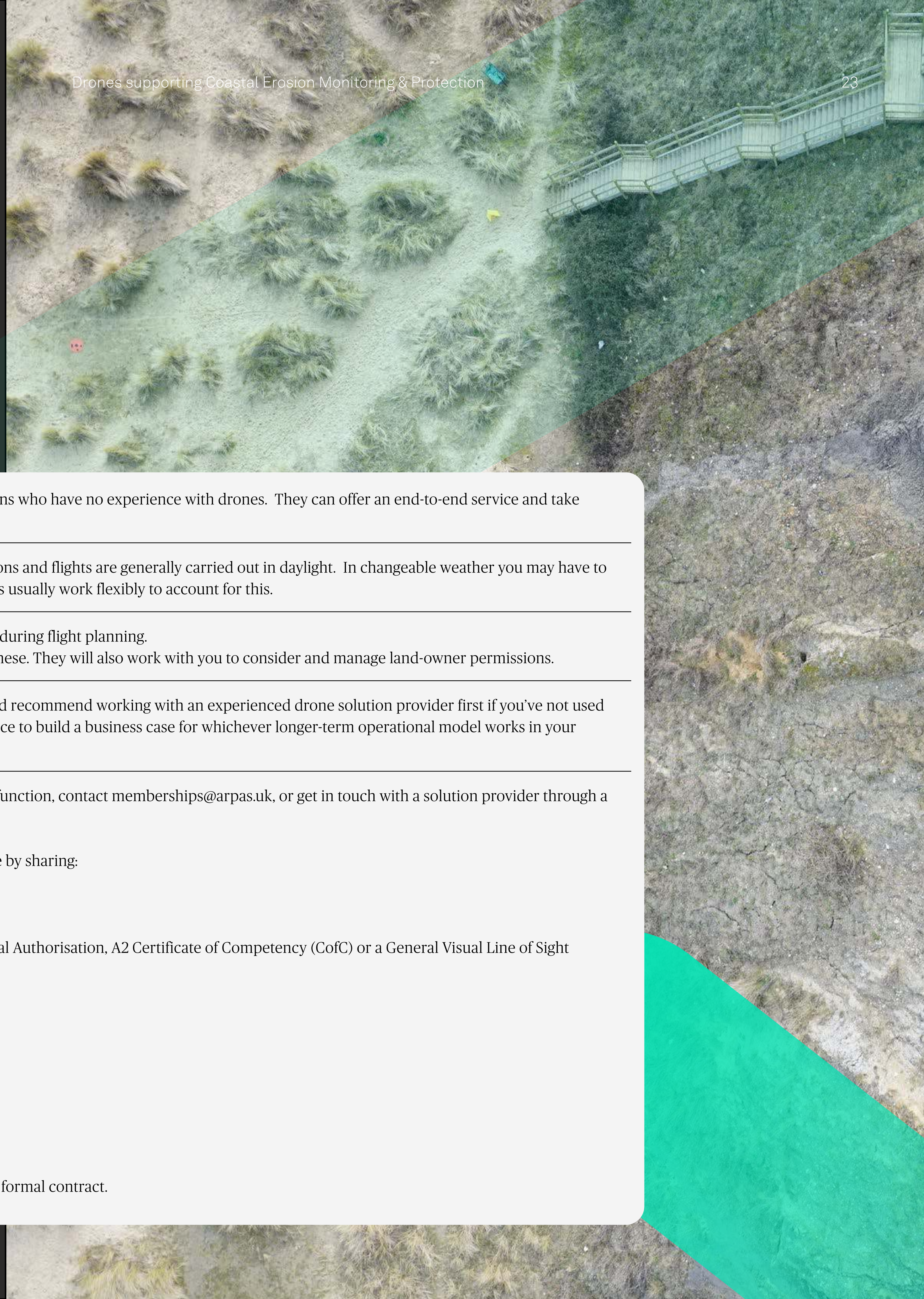

Doing it yourself: common questions

If your organisation has limited experience with drones, you may have questions about where to start. The table below may help you

What if our organisation hasn't used drones before?	Drone solution providers are prepared to work with organisations who have no experience with drones. They can offer an end-to-end service and take individual organisations' needs into account.
How does the weather affect drone inspections?	Just like traditional works, wind or rain can delay drone operations and flights are generally carried out in daylight. In changeable weather you may have to rearrange inspections at short notice. Drone solutions providers usually work flexibly to account for this.
Do we have to consider airspace restrictions or permissions?	The drone solution provider will check for airspace restrictions during flight planning. If there are restrictions, they will advise on the implications of these. They will also work with you to consider and manage land-owner permissions.
Should we buy a drone ourselves?	While many organisations successfully use drones in-house, we'd recommend working with an experienced drone solution provider first if you've not used drones before. This can help you collect evidence and experience to build a business case for whichever longer-term operational model works in your organisation.
How do I find a drone solution provider?	Ask your industry body for advice, use ARPAS's member finder function, contact memberships@arpas.uk, or get in touch with a solution provider through a web search. An experienced provider will be able to prove their competence by sharing: • Their operator ID and flyer ID, • Appropriate qualifications such as a valid PfCO or Operational Authorisation, A2 Certificate of Competency (CofC) or a General Visual Line of Sight Certificate (GVC), • Examples of previous work. • EC 785/2004 compliant insurance • Landowner's permission to take off and land the drone. • Risk assessments for each flight that Is planned, Make sure that the works and deliverables are documented in a formal contract.

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e. https://coastalmonitoring.org/introduction/

f. NTSLF data from Lowestoft tidal gauge during period 2nd - 5th Jan 2022

Get in touch with drones@cp.catapult.org.uk for more information, or if you're a drone service provider visit the Connected Places Catapult Opportunities page.

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