ECOS

GREEN REPORT

State Environmental Agency Modernization — Leveraging Unmanned Aerial Systems to Improve Environmental Results

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INTRODUCTION

Unmanned aerial systems (UAS) have emerged as an important tool for state environmental agencies to quickly obtain data, more effectively respond to emergencies, and ensure worker safety while improving environmental results. UAS encompasses unmanned aerial vehicles (UAVs) (without a human pilot on board), commonly referred to as drones, as well as the person controlling the flight on the ground and a system of communications between the two. State environmental agencies have long been drivers of innovative approaches and programs to maximize environmental protection. ECOS has highlighted many examples through its annual State Program Innovation Awards, including modernized document management systems, new ways to interface with communities and share data, self-auditing programs, and more effective inspection and permitting programs. Use of UAS contributes to the continued evolution of state environmental agency approaches.

This *ECOS Green Report* focuses on state environmental agency use of UAS,[1] actual and potential benefits, and current and planned uses by the spotlighted state agencies. Each identified state environmental agency drone program is highlighted in more detail in the latter part of this report, including a summary of each state program along with benefits, current and planned activities, application highlights, lessons learned, state contacts, and links and resources.

[1] In this report, the term "drone," UAS, and UAV are used interchangeably or depending upon state preference. Also, the terms "aerial" and "aircraft" are used interchangeably.

UNMANNED AERIAL SYSTEMS OPERATIONS

The Federal Aviation Administration (FAA) 14 CFR Part 107 rules went into effect on August 29, 2016 for both civil and public use of drones. While a few state environmental agencies began to use UAS prior to the FAA's rule adoption, more states began their drone use following adoption. Most of the drone operators fall under Part 107, which in general allows small drones to operate with restrictions such as visual line-of-sight only, under 55 pounds, daylight only use, maximum ground speed of 100 miles per hour, maximum altitude of 400 feet above the ground or structure, and other restrictions. Certified remote pilots may fly drones for work or business by following the three main steps of learning all the rules, becoming an FAA-Certified Drone Pilot by passing the "Knowledge Test," and registering their drone with the FAA.

There are various types of drones available including fixed wing, rotary wing (helicopter), multirotor, and hybrid. More detailed information about drone advantages and disadvantages is available in the Interstate Technology & Regulatory Council (ITRC) document noted in the "Further Information" section of this report. For the purposes of this report, the type of drone used by each state environmental agency is noted when this information is provided.

For states that are just beginning to consider setting up a drone program, the lessons learned section in the case studies, as well as resource links, may be of great value. For instance, several states – including Delaware, Michigan, Oklahoma, and Texas – recommend using low-cost drones for training and to boost confidence on the part of the drone pilot. Links to checklists are included for Montana and Oklahoma. Sample standard operating procedure links may be found in the North Carolina and South Carolina case studies, and this information for the U.S. Environmental Protection Agency (EPA) is in the "Further Information" section. In addition, Montana and Oklahoma have shared a sample bid packet. Wisconsin notes it is important to have one software program and operating system that is compatible with all equipment. North Carolina has chosen not to use its drone manufacturer's software. While most states have chosen to develop in-house drone programs, Kansas and Wyoming have contracted for drone services. Kansas has shared its request for proposals in its case study links. All states have noted the importance of considering privacy concerns and appropriate communication and coordination with their drone programs.

As to drone selection, costs can vary significantly, from a small training drone at a few hundred dollars to larger drones at a thousand to several thousand dollars that may be used for sampling and other activities. Fixed-wing drones can range from $5,000 to $25,000 or more and have the ability to fly considerably longer distances, covering about 400-500 acres in an hour and possibly used for mapping purposes. Large drones may be used for air and water sampling or to carry payloads, including ground penetrating radar, optical gas imaging cameras, magnetometers, and any other sort of sensor. Some states such as Oklahoma recommend having a second drone on-hand along with extra batteries during missions should the first drone not operate correctly once onsite. Figure 1 provides a snapshot of some state special drone equipment. Kentucky's case study includes links to four different drone specifications.

Figure 1: Sample State Drone Special Equipment or Approach

State	Special Equipment, Approach
Alaska	Using a thermal sensor to detect liquid volume in tanks, gas leaks, groundwater-surface water interactions
Arizona	Planning to purchase drones to assist in chemical fires
Arkansas	Contracted for commercial pilot training
Kansas	Conducted work under a services contract
Kentucky	Built an in-house high-altitude performance drone with air monitoring equipment; has a drone boat for bathymetric pilot study with echo sounder, along with a hazardous air pollution sampler and equipment for sampling pond impoundments for metals and measuring pool depths
Louisiana	Using a multispectral camera, fixed wing drone
Michigan	Using a Forward Looking Infrared camera
Montana	Enhancing water sampling capabilities
New York	Has an underwater capability drone; developing in 2021 custom-built drone equipment and instrumentation to detect magnetic signatures of aging and abandoned oil and gas well casings. Once located, the well casings are plugged to prevent fugitive methane releases to the environment
Texas	Using DroneSense Platform, for flight operations, which is a third-party encrypted software
Wyoming	Using consultants to fly on state's behalf

BENEFITS AND USES

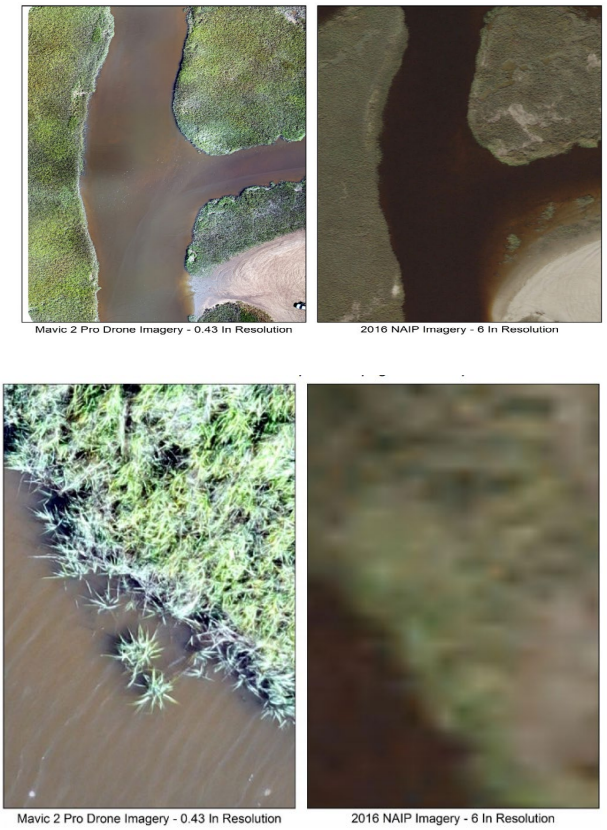
Each state environmental agency has its own reasons for deploying drones. State environmental agencies use a number of drone tools to support mapping, compliance monitoring, restoration, emergency response, and other activities. Figure 2 provides a snapshot of the ways the 19 states highlighted in this report are deploying drones. The most noted use of drones is for emergency response by twelve states with drones used for water monitoring, mapping, and mining by eight states. Drones and their associated imagery and data collection have allowed states to augment and leverage personnel in the field for far more efficient, safe, and full ability to assess on-the-ground conditions, most often in much less time. Below are lists of sample benefits and uses, as well as more specific examples that draw from the expanded case studies that follow.

Drone Use Benefits:

1. More productive staff time
2. Increased staff safety
3. Cost savings on gas, salary, and supply costs due to reduced staff teams, faster site visits, or reduced return visits
4. Advanced cameras and platforms
5. Reduced impacts to sensitive ecosystems
6. Greater ability to oversee and monitor large areas such as forests and abandoned or reclaimed mine land
7. Easier access to tough terrain

8. Ability to monitor sites over time
9. Ability to monitor sites that may be too hazardous
10. Ability to move projects forward more quickly and manage them more effectively
11. Ability to conduct more accurate volumetric reporting, resulting in reclamation bonds that are more accurately calculated
12. Ability to perform safe and rapid documentation supporting site assessments
13. Better presentation (from aerial perspective) of before, during, and after cleanup documentation and review
14. Very high-resolution images
15. Better and more accurate data collection
16. Real-time results
17. Ability of drones to fly on cloudy days, whereas regular planes cannot
18. Improved environmental results through improved monitoring and inspections
19. Ability to reference photos once back in the office and avoid revisiting a site
20. Effective tool in making more informed decisions about environmental problems
21. Significant enhancement of situational awareness where safety is of the utmost importance
22. More efficient inspection of confined spaces (for example, trailers storing hazardous materials)

Samples of improved image resolution with drones (North Carolina)



Tire Pile Estimation. Michigan notes that in the past, three to five inspectors would work together and climb several tire piles, manually measuring the volume and providing the information for calculations. Their scrap tire program staff now routinely flies drones and generates maps of tires on sites throughout the state, allowing the agency to generate an estimation of volume for tire piles without having to climb the piles. As tire piles are not always perfectly shaped, which complicates volume calculations, drones provide 3D imagery of map tire piles, significantly improving the volume determination.

Estuarine Benthic Habitat Mapping. North Carolina notes that with its Estuarine Benthic Habitat Mapping program, a two-person team using a DJI Phantom 4 Pro drone can produce data for 600 acres per day compared to traditional methods of 10 acres per day, saving approximately $400,000 and boosting performance by 5,900%. The state reports that it took 30 years to map the first 90% of the state's estuaries and 12.5 days to map the final 10% as a result of using drones.

Shoreline Erosion. New York notes that in 2017, at a particular area along Lake Ontario following an extremely high water with heavy winds event that eroded dunes, its team was able in one afternoon – and just 30 minutes in the sky – to acquire all necessary data regarding an area of shoreline. Before using drones, a two-week survey/mission would have been necessary to obtain a proper and accurate assessment.

Improved Inspections. Oklahoma notes there have been several instances where drones have identified finished water storage facilities with open hatches and/or damaged or missing vents and screens. These deficiencies posed a potential pathway for contaminants to enter finished water and would have gone uncorrected as they were not observable from the ground.

Accessing Previously Inaccessible Sites. In Fall 2019, Alaska staff were able to use a small UAS to obtain the first-ever image of an extremely rugged and remote portion of a watershed for a public water system. Routine watershed inspections are required for filtration avoidance drinking water treatment requirements; however, this portion of the watershed has remained inaccessible until now.

More Accurate Reclamation Bond Estimates. Wyoming uses its drone surveys to evaluate current mined surface areas and volumes to update reclamation bond estimates. More accurate volumetric reporting has resulted in more accurate calculation of bonds.

Drone Uses:

1. Pipeline monitoring
2. Water, air, and soil monitoring, sampling, and inspections
3. Emergency response (hurricane, landslide, spills, other)
4. Conservation efforts
5. Well blowouts
6. Tank failures
7. Landfill inspections
8. Waste tire site inspections and estimations
9. Coastal restoration projects
10. Dam safety inspections
11. Water tower inspections
12. Natural resource assessments from oil spills
13. Monitoring conditions of wetland assimilation projects
14. Mapping
15. Reclamation design and monitoring
16. Site characterization
17. Creating/updating aerial site photos
18. Wildfire search and rescue
19. Support of regulatory compliance and enforcement through investigations and evaluations
20. Fish kill investigations
21. Determination of camera site installation
22. Research on harmful algae blooms
23. Pre, during, and post-event site comparisons

Ensuring Permit Conditions Followed. Montana uses a UAV to safely fly over very large sites of several hundred acres to ensure opencut minerals (bentonite, clay, scoria, soil materials, peat, sand, or gravel) are extracted in accordance with the act and rules to provide adequate protection of environmental resources and successful reclamation of the affected land back to a productive post-mining land use.

Harmful Algal Blooms. Arkansas used its drone to study and examine the status of harmful algal blooms, including migration spread and distribution in the state's rivers and streams. New York has a drone with underwater capabilities to conduct marine research on issues such as harmful algal blooms.

PFAS Investigation. Michigan used its drone to determine the best location and height to mount an all-weather camera that will be linked wirelessly to its staff. The drone's Forward Looking Infrared camera was also used to locate groundwater seeps entering a lake that could be carrying PFAS contamination from past firefighting activities at a military base.

Finding "Hidden" Sites. West Virginia notes that drones allowed identification of an early 20th century oil-tank farm in a now heavily wooded area. With the use of drones, even during leaf-on conditions, the agency was able to extract detailed elevation data from the site that revealed tank locations and associated earthworks, and to obtain high-resolution aerial photography.

Expanded Spill Response. In March 2018, an oil spill occurred in Louisiana at a storage tank site at the same time of heavy rainfall that led to fields flooding. The water was too shallow for boats and deep enough to make driving and walking difficult. By using a drone, the team was able to access and inspect the flooding without

compromising the safety of the team and to gather quick observations of the extent of the spill, the location of the product, and the spill's impact.

Groundwater Overflow Flooding. To evaluate the change in extent of a local aufeis (groundwater overflow) flooding event near a public water system, Alaska used aerial imagery to estimate the change in the extent of flooding over time. Without a small UAS drone, this would have only been possible with a cost-prohibitive chartered fixed-wing aircraft or extensive ground-surveying techniques.

Improved Rhodamine dye studies. North Carolina uses its drones to increase the accuracy of tracking the dispersion, timing, and extent of Rhodamine dye studies.

Bathymetric Studies to Estimate Available Water Supply. In March 2020, Kentucky used an unmanned surface catamaran, or drone boat, to perform its first bathymetric pilot study, and has gone on to conduct similar evaluations. An aerial drone was used to map the ridgeline and the elevation of the water surface, and the drone boat equipped with an echo sounder measured the depth of the reservoir and mapped underwater features. Information such as this helps provide a more accurate picture of available water supply.

Cyanobacteria Plumes. Connecticut uses its drones to provide visual support to the water-monitoring program to photo-document cyanobacteria plumes, providing video imagery for the program's sampling protocol.

Fugitive Emissions Release Detection. Following a pilot program in early 2020 to test the technology, New York recently announced a partnership with its energy authority beginning in 2021 to detect fugitive methane releases from aging and abandoned oil and gas infrastructure across the state using $400,000 in custom-built drone equipment and instrumentation. This will help state scientists home in on hidden abandoned wells. The sensing equipment detects magnetic anomalies from the air and maps them using precise GPS equipment. Staff will then compare these maps and target areas by using old lease maps, landowner information, and other data to locate them during field surveys. Once located, these wells can be successfully plugged to stop the fugitive methane releases to the environment.

Citizen Science Sampling. Arizona notes that an Arizona citizen scientist has developed a sampling harness used to collect E. coli samples through his drone. The state plans to work on replicating this harness and determining the capacity of its current fleet to expand sampling capabilities.

Figure 2. Summary of Drone Use by State Environmental Agencies

No.	STATE	Year Began	Emergency Preparedness and Response	Water Monitoring (HABs, E.Coli, Cyanobacteria, Bathymetric, PFAS, etc.)	Mapping	Mining	Watershed & Groundwater Inspections	Dam Inspections	Volume & Construction Estimation	Drinking Water (DW), Coastline Inspection (CI), & Other Uses (O)
1	Alaska	2019	X			X	X			DW
2	Arizona	2016	X	X	X	X				
3	Arkansas	2019	X	X						
4	Connecticut	2018	X	X	X		X			
5	Delaware	2016-2017	X				X			CI
6	Kansas	2016-2017				X			X	O
7	Kentucky	2014	X	X		X		X		O
8	Louisiana	2017-2018	X							
9	Maryland	2019						X		
10	Michigan	2017		X	X		X	X	X	CI, O
11	Montana	2019				X				DW
12	New York	2015	X	X	X	X		X	X	
13	North Carolina	2016	X	X	X			X		
14	Oklahoma	2017-2018					X			DW
15	South Carolina	2016	X	X	X			X	X	CI
16	Texas	2020-beginning phases	X							
17	West Virginia	2016			X	X				
18	Wisconsin	2017 development / 2019 drone deployment	X				X			
19	Wyoming	2015			X	X			X	
	Total		**12**	**8**	**8**	**8**	**6**	**6**	**5**	**3 DW 3 CI 3 O**

Alaska
Department of Environmental Conservation (ADEC)

Program Summary

The Alaska Department of Environmental Conservation (ADEC) formed a Small Unmanned Aerial Systems (sUAS) Workgroup in Spring 2019, at the request of Commissioner Jason Brune. In Summer 2019, ADEC purchased its first pair of sUAS drones, and in early Fall 2019, the first six ADEC staff received their FAA Part 107 training and licenses. Staff completed initial practice flights and first inspection flights beginning shortly thereafter. In February 2020, ADEC received a Multi-Purpose Grant from U.S. EPA (#AA-01J69901) for $106,366, with the purpose of using these funds to further develop a department-wide sUAS program, to train and license additional ADEC staff, and to purchase addition sUAS equipment. As of October 2020, ADEC had 12 sUAS drones (including one advanced drone with a thermal camera), seven FAA Part 107 certified pilots, and 56 pilots in training status. The current sUAS drone fleet is made up entirely of DJI products.

In July 2020, ADEC initiated a State of Alaska (SOA) UAS Leadership Team. The purpose of the team is to bring together drone "leaders" from multiple SOA departments to collaborate and find efficiencies in drone operations.

ADEC has observed, or anticipates, the following benefits:

- More safely capturing a cost-effective aerial perspective of facilities and site areas for a more comprehensive inspection and compliance overview over less safe physical navigation of commonly wild, undeveloped terrain. Avoiding unwanted and potentially dangerous wildlife interactions, such as bear and moose encounters, while continuing to perform field investigations.
- Reduced costs for similar data compared to much more expensive chartered plane/helicopter flights.
- Reduced operating costs and increased operational efficiencies, along with enhanced staff development, regulatory decision-making, and environmental protection.

Current and Planned Activities

- The Drinking Water Program (under EPA's Public Water Supervision System grant) was better able to inspect a previously inaccessible portion of a watershed that contributes source water to a public water system to evaluate the system's continued compliance with the filtration avoidance watershed protection requirements.
- In Spring 2020, travel restrictions due to the COVID-19 pandemic limited ADEC's ability to further field test sUAS drone equipment, however, the agency plans to continue flights in the near future.
    - To maintain flight practice time, the workgroup purchased flight simulator software and controllers.
- Planned activities include:
    - Characterizing treacherous or otherwise inaccessible terrain.
    - Inspecting elevated portions of water tanks that cannot be evaluated without climbing ladders, walking on rooftops, or flying overhead in fixed wing or rotary aircraft.
    - Investigating waterborne contamination during shoulder seasons when ice quality is insufficient to support safe travel.
    - Evaluating remote watersheds where access is difficult or risky to access on foot or by all-terrain vehicles.
    - Detecting potential landslides or other natural hazards when evaluating watershed status.

- Evaluating potential sources of contamination within source water protection areas and minimum separation distances for public water system sources.
- Characterizing conditions over water, where personnel would normally have to charter a boat or aircraft to investigate.
- Measuring and tracking environmental changes over time since sUAS can take pre-programmed images from the same altitude, angle, and position on successive trips over a facility's lifespan.
- Creating a more complete and reproducible inspection record that can be further analyzed after onsite inspections conclude. This will help to minimize the number of missed issues and further reduce the number of follow-up inspections at the same facility, which saves on future travel expenses and staff time.
- Detecting unauthorized development when evaluating watershed status.
- Evaluating mine-tailing ponds at hard rock mines in support of the Alaska Pollutant Discharge Elimination System permitting decisions.
- Investigating turbid water quality exceedances and characterize settling ponds when inspecting placer mines (alluvial, glacier, or marine gold deposits).
- Characterizing the extent of permafrost damage during construction projects and determine new hydrology patterns.
- Aerial inspection of landfills to document site conditions and use the images to guide the facility towards increased compliance.
- Supporting regulatory compliance and enforcement complaint investigations, such as localized sources of wood smoke in areas with high particulate matter or other air advisory concerns.
- Investigating open burning in areas where terrain limits safe access by foot or vehicle.
- Using a more advanced sUAS with an infrared sensor to:
    - Detect and characterize the volume of liquid within a water tank, which sometimes cannot be determined otherwise.
    - Detect and characterize gas leaks from piping, valves, equipment, tanks, wellheads, landfills, and other sources when terrain or other safety considerations limit access.

Application Highlights

1) **Watershed Inspections:** In Fall 2019, ADEC staff were able to use a sUAS to obtain the first-ever image of an extremely rugged and remote portion of a watershed for a public water system. Routine watershed inspections are required for filtration avoidance drinking water treatment requirements; however, this portion of the watershed has remained inaccessible until now.

2) **Measurement of Flooding:** In January 2020, during two sequential site visits, sUAS allowed ADEC staff to evaluate the change in extent of a local aufeis (groundwater overflow) flooding event near a public water system. Aerial imagery was used to estimate the change in the extent of flooding over time. Without a sUAS drone, this would have only been possible with cost-prohibitive chartered fixed-wing aircraft.

3) **Permafrost degradation:** In July 2020, ADEC used the sUAS to collect photos and video footage of permafrost degradation before remediation activities started. Staff will continue to collect photos and video footage to determine if permafrost stabilization has been achieved.

4) **Placer Mine Development**: In August 2020, ADEC used the sUAS to collect photos and video footage of a new placer mine development. Footage will be used to measure and track environmental and hydrological changes over time.

Lessons Learned

- Coordinating and collaborating with other state agencies has been crucial in finding efficiencies as ADEC develops a cost-effective and sustainable sUAS program.
- Prior to being trained and certified for sUAS drones, the perception was that flying UAVs was easy, especially for recreational pilots, but it quickly became clear that using sUAS drones for department purposes added considerations and requirements that are taking time to sort out and understand in order to implement a department-wide program. For example:
    - Using sUAS drones for programs still often requires traditional travel mechanisms to get to field sites, and at least two people need to be on site to fly a drone under Part 107 requirements – a pilot-in-charge and a visual observer. Planning field trips for at least two staff was unanticipated.
        - Travel restrictions for various reasons, including budgetary constraints or a pandemic, leads to missed opportunities for drone use.
        - Flying in cold weather climates can affect the operation of drone equipment and understanding these limits is a learning process. To illustrate this, during the January 2020 flooding evaluation, the air temperature of each visit was 16F, then 2F, sequentially. We learned that even though the drone was able to operate in these temperatures (in this case), the camera gimbal appeared to struggle collecting clear video and imagery at 2F.
        - Object-avoidance capability is an important feature that allows for safer control of drones in environments with obstructions such as trees, or for flights that occur close to objects being evaluated. Object-avoidance capability may not be available for certain drones, especially smaller units like the DJI mini.

Contacts:

- Katrina Chambon, Environmental Program Specialist IV, Division of Water, katrina.chambon@alaska.gov, 907-269-7550

Links/Resources for drone use in ADEC:

Currently internal only.

Arizona
Department of Environmental Quality (ADEQ)

Program Summary

The Arizona Department of Environmental Quality (ADEQ) has employed drones since 2016. Currently, the Water Quality Division is using drones, the Air Division is considering the use of drones, and the Waste Programs Division began use of the technology in 2020.

ADEQ has observed the following benefits:

- Drones allow for more efficient field reconnaissance; they can cover a lot of ground quickly and allow suspected contamination to be confirmed before hiking to a site.
- Detailed, accurate topographic maps can be created quickly and support project planning and development.
- Internal drone program development has led to cross-program coordination and collaboration.
- Pre and post remediation aerial photos are effective communication tools

Current and Planned Activities

- Current: *Water Quality Division*
    - Comparing pre and post implementation of stock tank renovations (volume calculations).
    - Developing aerial imagery of pre and post implementation of mine remediation projects.
    - Determining the effectiveness of grassland restoration projects.
    - Creating/updating aerial site photos (greater detail than available imagery through Google Earth, for example).
    - Creating topographic maps for areas of interest (greater detail than U.S. Geological Survey topographic maps).
    - Conducting aerial reconnaissance for source identification, and to support Arizona Pollutant Discharge Elimination System inspections.

- Current: *Waste Programs*
    - Emergency Response Unit is looking to purchased drones to assist in chemical fires, as well as wildfires.
    - The drone that has air-monitoring capabilities that can be used to map hazardous constituents in a chemical fire plume, aiding in providing information to the local first responders regarding evacuations, etc.
    - The drones also assist during a wildfire to help monitor particulate matter 10 micrometers or less in diameter (PM-10) and particulate matter 2.5 micrometers or less in diameter (PM-2.5), and local wildland firefighters are interested in collaborating with the Ecological Response Unit during wildfires.

- Considering the use of drones: *Air Quality Division*
    - Monitoring and researching PM-2.5 and PM-10 before and after prescribed burns.
    - Monitoring for PM-2.5 and PM-10 during wildfires.
    - Monitoring and researching ozone and ozone precursors.
    - Monitoring and measuring opacity emissions at regulated facilities.

Application Highlights

1) **Water Quality Division:** One of Arizona's citizen scientists has developed a sampling harness used to collect E. coli samples through his drone/unmanned aerial vehicle; ADEQ plans to work on replicating this harness and determining the capacity of its current fleet to expand sampling capabilities.

Contacts:

- Trevor Baggiore, Director, Water Quality Division, baggiore.trevor@azdeq.gov, 602-771-2321

Links/Resources for drone use in ADEQ:

None.

Arkansas

Department of Energy and Environment (ADEE)

Program Summary

The Arkansas Department of Energy & Environment (ADEE) launched its Unmanned Aerial Vehicle (UAV) Program in Fall 2019. The State of Arkansas has consolidated various cabinet-level agencies as part of a statewide transformation. The ADEE includes the Division of Environmental Quality (DEQ), the Oil & Gas Commission (OGC), the State Geological Survey (AGS), and the Liquefied Petroleum Gas Board (LPGB). The UAV Program began as a shared service program to provide UAV flights for DEQ environmental programs to enhance data collection. The program has only conducted a few projects to date following the completion of the UAV training program because the COVID health emergency grounded the program. However, the pilots did maintain their Federal Aviation Administration Licensed proficiency with training flights during that time. The technical services program, although in its initial startup phase, has already proven to be a powerful tool for monitoring dynamic environmental processes.

ADEE has observed the following benefits:

- The ability to perform inspections in areas not readily accessible, such as inspecting facilities during flooding.
- The ability to gather various remote sensing data not easily or economically gathered through ground access, such as aerial mapping and survey data for mine reclamation purposes, magnetometer data (locating abandoned wells), and infrared data to determine leaks and spill extent, as well as an overview perspective during an emergency response.

Current and Planned Activities

- Pipeline, oil, and gas production facility inspections for OGC.
- Geologic mapping and investigations for AGS.
- Mining survey and mapping for DEQ OLR.
- Emergency response flights to assist ADEE Emergency Management incident responses.
- Planned: topographical mapping, subsurface mapping, air monitoring, and continued emergency response capability.

Application Highlights

1) **Office of Water Quality:** In September 2020, the ADEE Office of Water Quality teamed with the ADEE UAV pilots to examine remotely the harmful algal blooms (HABs) in Lake Hamilton, one of the state's most popular recreational and residential lakes, located in Garland County, Arkansas. Images and videos collected from the flight were used to study the status of the HABs, including migration spread and distribution in the state's rivers and streams.

2) **Office of Land Resources:** In October 2020, the ADEE Office of Land Resources teamed with the ADEE UAV pilots to map and calculate volume of material to provide information for a mine reclamation project.

3) **Arkansas Geological Survey:** In October 2020, the ADEE Geological Survey and the ADEE UAV pilots flew a mission to record and document a landslide in a remote area of the U.S. Forestry property.

Lessons Learned

- Thoroughly understanding the importance of the pilot training.
- In the initial investigation during the development of the ADEE UAV program, it was evident that the growing UAV industry provided numerous drone platforms, but the training was generally surficial and provided by the manufacturer.
- It is important to utilize professional in-depth training programs in all aspects of development and management of a drone program.
- In addition, ADEE sought out specific skill sets for the pilots in the UAV program, selecting employees with previous flight experience as pilots and employees with GIS experience to manage the acquired data to better fulfill the agency's missions.

Contacts:

- Larry Bengal, Chief Technical Officer & Director, Oil and Gas Commission, ADEE, Larry.Bengal@aogc.state.ar.us, 501.683.5814

Links/Resources of drone use in ADEE

- Innovations in Environmental Programs, Arkansas Use of Technology in Conducting Monitoring & Assessing Compliance, September 2020, Minute 2:04 – 4:26.

Connecticut

Department of Energy & Environmental Protection (DEEP)

Program Summary

Since 2018, the Connecticut Department of Energy & Environmental Protection (DEEP) has operated an Unmanned Aircraft Systems (UAS) program. In these two years, DEEP has developed a program with four FAA certified pilots and purchased a DJI Inspire 1 drone, mainly for use in hazardous materials incidents. This drone has also been used for situational awareness at tanker truck spills, mill fires having the potential to release hazardous materials, and other emergency responses. Recently, DEEP has been working with other groups within the agency to use the drone for mapping and environmental monitoring. DEEP has purchased an Inspire 1 drone with emergency spill response funds, and currently, there is funding available through grants to purchase another drone that would be better suited to Long Island Sound embayment studies. DEEP has also used a federal U.S. Department of Transportation Hazardous Materials Emergency Preparedness grant for some key training.

DJI is the manufacturer of the drone that DEEP currently holds; however, the agency is aware of the issue of data sensitivity using non-domestic drone manufacturers. The state's UAS program, like many other public safety programs, is evaluating options for drones that allow the same level of quality that DJI delivers to its customers while maintaining appropriate data protections. DEEP notes that the most important features of the drone depend on its intended usage, but these features certainly include a reliable airframe platform and sensors that work properly (thus far for DEEP, this includes a high-quality visual and thermal camera).

DEEP has observed the following benefits:

- The technology allows for a greater ability to obtain critical information in real-time, especially in a spill response context.
- DEEP's drone has an optical and thermal camera that allows the team to obtain detailed visual and temperature readings at incidents where first responders' safety may be at risk.
- There has been a reduced cost of obtaining and processing aerial imagery.
- Costs aside, drone technology gives DEEP another effective tool in making informed decisions about environmental problems and significantly enhances situational awareness where safety is of the utmost importance.

Current and Planned Activities

- Spill response including hazardous spills on roadways, water bodies, and large fires where hazardous materials are involved.
- Forest fire imagery.
- Mapping of an unpermitted dumpsite.
- Infrastructure improvement in a state wildlife management area.
- Cyanobacteria breakouts in a water body.
- Eye-in-the-sky activities where situational awareness is desired.
- Planned: Enhancing the programs' mapping capabilities.
    - This may involve purchasing other drones and software.
    - DEEP is currently involved with planning coastal embayment studies (including eelgrass surveys) in support of the Long Island Sound Program.

Application Highlights

1) **Water Monitoring Program**: The DEEP UAS program recently provided visual support to the water-monitoring program, which was interested in photo documenting cyanobacteria plumes. The UAS program provided video imagery for the program's sampling protocol.

2) **Forestry Division**: The DEEP UAS program also provided visual and thermal imagery to the Forestry Division as it coordinated fire suppression efforts at a wildfire located in Thompson, Connecticut. This imagery taken from the drone enabled the division to visualize where the hotspots were and work to extinguish them in just the right areas.

3) **Oil Spill**: An oil tanker crash and spill in Derby, Connecticut caused fuel oil to flow into a catch basin, and then directly into a navigable river. The drone enabled the DEEP UAS program to see the oil that had become trapped among rocks on one bank of the river. Pinpointing the outfall location enabled DEEP's cleanup contractor to maximize efforts to recover oil.

Lessons Learned

- Depending how far a state agency wants to take it, a drone program could involve a significant commitment in the form of time, equipment investment, and logistical coordination. Management support and enthusiastic staff are important.
- It is also important to manage expectations with respect to outcomes. UASs can be a valuable addition to a state's toolbox, but like any tool, it has its limitations.
- With regard to deliverables, DEEP has found that it is better to under-promise while hoping to over-deliver, and to always learn from its mistakes.
- Privacy issues are a big concern. When members of the public are given information about what DEEP is doing and why they are doing it, they seem supportive of the efforts, though this could be unpredictable depending on the situation.

Contacts:

- Gilbert Richards, Environmental Analyst II, Site Assessment and Technical Support Unit, Emergency, Response, & Spill Prevention Division, Bureau of Materials Management & Compliance Assurance, Gilbert.Richards@ct.gov, 860-424-3523

Links/Resources for drone use in DEEP:

- DEEP Divisions Share New Technology to Identify Hotspots in Fire Response, August 2020
- Gil Richards, a member of DEEP's Emergency Response and Spill Prevention Division (and one of 4 certified drone pilots on staff), Demonstrates Flying DEEP's Drone, August 2020

Delaware

Department of Natural Resources & Environmental Control (DNREC)

Program Summary

The State of Delaware as a whole began using drones in late 2016 or early 2017. State agencies that were using these technologies at the time were doing so prior to receiving Federal Aviation Administration (FAA) licenses, and the activity was not prevalent within Delaware Department of Natural Resources & Environmental Control (DNREC). However, once the FAA began the implementation of license requirements, a drone program and training began throughout various divisions within DNREC including Climate, Coastal, & Energy, Fish and Wildlife, Community Affairs, Watershed Stewardship, and the State of Delaware Unmanned Aircraft System Training & Certification Steering Committee and Fire School. DNREC also works in collaboration with other agencies including the Delaware Department of Emergency & Management Agency (DEMA) on various drone work. All divisions within DNREC agree that drones are an effective tool to advance environmental monitoring, even though each division uses the technology differently.

DNREC has observed the following benefits:

- Improved efficiency – ability to quickly respond and observe.
- Ability to monitor certain environments more easily (e.g. wetlands).
- Cost savings – previously had to pay for a helicopter to complete permit required pre and post photos of marsh management projects, now a drone can be used.
- Improved safety for staff.
- Aerial perspective vs. ground-level perspective increases impact when working with citizens.

Current and Planned Activities

- Studies of effluent outflow.
- Establishment of baseline conditions.
    - When a major natural disaster event (e.g., hurricane, storm) is predicted, use the drones for difficult-to-reach areas to take pre-photos of the baselines and assess what areas should be monitored.
- Inspections of infrastructure.
- Emergency preparedness.
    - Survey work for channel markers to ensure they were placed in the correct locations.
- Photo imagery in wetland areas.
- Damage assessment in cooperation with DEMA.
- Vegetation monitoring.
- Creation of Digital Elevation Models using aerial photos and ground surveillance.
- Planned floodplain and high-water event management.

Application Highlights

1) **Division of Fish & Wildlife**: The Mosquito Control Section began using drones in June 2017 and has seen great benefits. The program is seasonal, as it addresses mosquito population and is heavily active throughout the months of March through November. Drones are especially useful in analyzing and monitoring Open Marsh Water Management projects that the program installs to eliminate areas of mosquito-breeding habitat along Delaware's coastal salt marshes. The program uses drones to collect before and after photos of the sites and to oversee the history of the project.

2) **Division of Watershed Stewardship:** The 234 Tax Ditch organizations across Delaware are collectively responsible for managing more than 2,000 miles of channel. Tax Ditch organizations are governmental subdivisions of the state managed by elected landowners within each Tax Ditch watershed. The DNREC Division of Watershed Stewardship's Drainage Program provides administrative and technical assistance to the state's Tax Ditch organizations. The program responds to drainage concerns raised by citizens and provides technical assistance or guidance toward a solution when possible. Tax Ditch officers use unmanned aerial vehicles to improve efficiencies.

3) **The Fire School within DEMA:** In Laurel, Delaware, drone technology was used to help with emergency response following storms. The team found it more efficient to use drones due to the ability to quickly respond and observe, in comparison to the work that would have been required on the ground and the time it would have taken. Drones allowed the team to get the resources in the right place, figure out what the needs were, assess the damage, and work with the Sussex County geographic information system (GIS) mapping team by using the photos to help with property owners in the community with their insurance and damage assessment. The drones also helped in determining what category storm it was and how it affected the community.

4) **Delaware Natural Resources Police:** The Delaware Natural Resources Police (DNRP) has multiple FAA certified drone pilots that cover the entire state of Delaware. These drones are typically used in a law enforcement capacity to assist with police investigations and public safety operations. The DNRP Environmental Crimes Unit (ECU) has also used their drone to assist the DNREC Emergency Response Team with multiple oil spills throughout the state. DNRP-ECU utilized the drone to take photos and track the spread of the oil across the waterways. The drone helped the teams prevent the oil from spreading further.

5) **Delaware Coastal Programs:** The Delaware National Estuarine Research Reserve (DNERR) created a Digital Elevation Model using varying heights of drone imagery. The DNERR also plans to use the drone to capture aerial images of vegetation for vegetation community mapping. Doing so will help limit the impact from doing the survey on the ground.

Lessons Learned

- It is critical to invest and dedicate time to training pilots under FAA Part 107.
- Be sure that each flight meets the line of sight requirements, and learning how to leverage current GIS data is important.
- If practical, consider waiting for leaf-off time in wooded areas to facilitate line of sight and picture quality.
- When looking into purchasing drones and getting introduced to drone technology, agencies may not want to start with a $30,000 drone, and instead, they might get something less expensive in order to gain confidence and skills when going out to complete missions.
- If the drone will be used for fires, include thermal imaging abilities.
- For use in agriculture, flat range cameras are helpful (but not for fires).

Contacts:

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- Kenneth Conaway, Kenneth.Conaway@delaware.gov Environmental Program Manager, Delaware Division of Fish and Wildlife, Mosquito Control Section
- Drexel Siok, Environmental Scientist, Division of Climate, Coastal, & Energy, 302-739-6377, Drexel.Siok@delaware.gov

Links/Resources for drone use in DNREC:

- Nanticoke Stream Restoration Review with a 3D model Generated from UAV Photography
- Lewes Beach Replenishment Efforts for Shoreline and Waterway
- Drone Deployment for Delaware Drainage , Division of Watershed Stewardship – Drainage Program, 2019

Kansas

Department of Health & Environment (KDHE)

Program Summary

The Kansas Department of Health & Environment (KDHE) has had a drone technology program since 2016-2017. Drones are used throughout the agency through an environmental services contract. The environmental services contracts covers multiple programs, with 21 environmental consultants on contract to assist with assessment, sampling, and remediation monitoring.

With its contracts, in case of an emergency KDHE has the ability to respond with drones and provide any other needed response. Drones are most often used on a site-by-site or case-by-case basis. In addition, a good deal of work is done for the Superfund program, inspections of abandoned mine lands, and at coal strip mining sites. As the use of drone technology continues to advance for environmental monitoring and site inspections, KDHE plans to explore further use of the technology. The existing contracts will expire in 2021, and the state will start a rebidding process.

KDHE has observed the following benefits:

- Ability to conduct high resolution surveys.
- Calculation of volume estimates of construction materials more quickly; processes that would take weeks now may generate data in hours.
- High-resolution images result in better inspections of sites in rural areas where current aerial imagery is poor.
    - KDHE has sites where commercially available aerial imagery is poor quality or insufficient for agency needs (e.g., 2m resolution, outdated). The agency then will contract with a consultant to obtain new high-resolution imagery.
    - KDHE also uses real-time drone flights to conduct inspections of repository cells to identify potential erosional features or areas that need vegetative management of the evapo-transparative cover or control of invasive species.
- Monitoring of sites and data collection in real time.
- Use on sites with limited access, limited line of sight.

Current and Planned Activities

- Superfund Program sites.
- Inspections of abandoned mine lands, extent of former mining areas and smelters.
- Mining site elevation surveys.
- Inspections of erosion on landfill caps and repositories.
- Strip mining for coal sites.
- Real-time monitoring of tall grass prairie pasture burning areas for nitrogen oxides (NOx) and particulate matter (PM) (e.g. Flint Hills).
- Fire damage/potential contamination review.
- Subsidence inspections.
- Planned: Emergency response, specifically in response to flooding.

Application Highlights

1) **Construction Estimation:**

   a) Lead Smelting Site: KDHE used drones to inspect an abandoned lead smelting site in order to conduct a construction estimate. The drones were used to calculate the estimate of material present at the site. KDHE found it useful to be able to properly size the repository quickly. The drones were beneficial in collecting accurate current data.

   b) Bruce Mining and Smelting Site: KDHE used drone technology to conduct a construction estimate on the materials that were present at the Bruce and Mining and Smelting Site. The drone helped with quick data collection, making it easier to properly and accurately size the repository.

2) **Tall Grass Prairies:** The State of Kansas has many tall grass prairies, and there is a critical need to burn off warm season grasses. Due to timing of vegetative growth and weather, this annual burn-off typically occurs during a short time window. The Bureau of Air within KDHE has found that when this occurs, it results in exceedances of air quality standards. Drones have helped the Bureau of Air conduct real-time monitoring of these burning areas in order to identify NOx concentration and PM in real time.

3) **Cherokee County Superfund Site:** Construction repairs were completed under a cooperative agreement with U.S. EPA. Drones allowed for improved environmental monitoring. The cooperative agreement with EPA allows KDHE to complete construction repair activities to address erosional features and other issues prior to transfer to the state for operation & maintenance. KDHE contracted with consultants to fly high-resolution LIDAR imagery to accurately map the completed grade of the repositories and adjacent properties. Engineers then used the high-resolution LIDAR data to re-contour drainages and letdown structures.

Lessons Learned

- Drones make it possible to keep staff away from flooded areas while receiving real-time imagery with high-resolution images to allow for quick assessment of site conditions and increased staff safety.

Contacts:

- Joseph Dom, Chief, Assessment and Restoration Section, Joseph.Dom@ks.gov, 785-296-1914

Links/Resources for drone use in KDHE:

- Environmental Services Contract KDHE, 2020
- Drones Playing Key Role in Kansas Flint Hills Smoke Management Plan, September 2018
- Use of Unmanned Aerial Vehicles (drones), August 2018, Kansas Environmental Conference, 2018.
- Request for Proposal, 2016

Kentucky
Department for Environmental Protection (DEP) and Department for Natural Resources (DNR)

Program Summary

The Kentucky Department for Environmental Protection (DEP) and the Kentucky Department for Natural Resources (DNR) Energy and Environment Cabinet (EEC) has been using drone technology since 2014. Initially, the drone technology aided first responders during flooding events and served as an effective tool in assisting incident commanders with real-time data and imagery. As the program has evolved, several divisions within EEC have used drone technology, including the Divisions of Water (DOW), Waste Management (DWM) Forestry (DOF), Abandoned Mine Lands (AML), and Mine Reclamation & Enforcement (DMRE).

DNR uses 11 drones in AML and 5 in DMRE. AML has two DJI Phantom 4 Pros, two DJI Matrice 200s, two DJI Mavic2 Pros, one DJI Mavic 2, one Yuneec H520, and two retired training drones all purchased through federal grants. Each drone is able to provide 3D modeling and video and execute a more thorough investigation of sites. DMRE uses 5 DJI Mavic 2 Pro drones.

DEP uses one drone in DWM, which is a DJI Mavic Pro that retails around $1,700, similarly purchased through a federal grant, and has one certified pilot. DOW has a DJI Mavic Pro 2 and one certified pilot.

The EEC drone team has grown to 14 certified pilots, and the AML has 12 certified pilots who maintain an equal number of drones with differing capabilities. The state also built in-house a high-altitude performance drone equipped with air monitoring equipment. This was built on the Ardupilot platform within DWM in coordination with the Kentucky Division of Aviation (DA). To share lessons learned and provide team support, the state hosts a monthly multi-agency unmanned aerial vehicle (UAV) users group.

KY AML hosted a UAV user group at Kentucky State University in 2018 and 2019 to bring all of the states under the Office of Surface Mining (OSM) together to compare UAV programs. Over the two years of three-day sessions, KY AML hosted pilots from 12 states. It has also worked closely with the DA to develop procedures and policies for preflight checklists, flight operations, and training requirements for all of its pilots. KY AML hosted a UAV Working Group Conference in Frankfort at Kansas State University in 2018 and 2019. This invitation only event and state participation was funded by the Technical Innovation and Professional Services (TIPS), which is housed in OSM. The event sought to guide emerging UAV programs and to share knowledge and experience including software, hardware, and program needs and status. Further, KY AML worked with its Department of Aviation, an invaluable resource.

The state has pursued use of software like DroneDeploy, and Pix4D capture for flight missions. Global Mapper, Pix4D, ArcGis and Autocad are used for processing to improve the quality of data gathered by drones, which in turn allows for more informed decision-making.

Kentucky has also worked closely with its Department of Transportation to develop procedures and policies for preflight checklists, flight operations, and training requirements for all pilots. The agency keeps all of its data processing in-house and has developed many different workflows shared amongst all divisions. The agency is currently training on the Ardupilot platform with the potential to build its own UAVs for air and water applications. The agency also develops orthorectified stitched imagery of their sites as an integral part of AMLs project design process. AML also utilizes drones to monitor changes over time on various sites and has begun to work with bathymetric techniques to generate water volumes.

The state is considering investing in a drone equipped with infrared sensors or thermal cameras (KY AML purchased a Flir thermal camera in 2019 to monitor mine seam fires) to assist in detecting harmful algal blooms, identifying leachate outbreaks at landfills, delineating wetlands, monitoring vegetative health, and identifying plants that may be stressed from drought or other factors. This technology may also better identify springs and seeps into water bodies and karst environments, monitor leaks in dams, and watch for drought conditions.

DEP has observed the following benefits:

- Provides real-time data and imagery.
- Eliminates the need to send personnel into potentially hazardous environments.
- Enhances environmental protection and management of Kentucky's natural resources.
- Provides ability to monitor a site and project overtime.
- Makes it easy to periodically assess large sites with a high level of accuracy with lower costs. AML indicates the drones provide a much more accurate estimate of how much it will cost to reclaim areas at a lower cost than using a helicopter costing approximately $600 an hour.
- Allows for more informed decision-making.

Current and Planned Activities

- Emergency response.
- Inspections.
- Monitoring sites, facilities, natural resources.
- Inspection and observation of landfills.
- Planned: Using thermal and multispectral data to conduct vegetation assessments and more in-depth monitoring activities.
- Planned: Monitoring harmful algal blooms and other issues in Kentucky's streams and lakes.

Application Highlights

1) **DOW:**

- **Monitor Dam Conditions** – Inspect state owned dams to establish baseline imagery using a Mavic Pro 2.

- **Distillery Spills and Fires** – Drones were used to monitor a number of distillery spills and fires, which resulted in releases to Kentucky waterways, a number of fish kills, and drinking water supply concerns. The drones were used to identify "hot spots" during the fire and to identify potential water and bourbon runoff during and after the event.

- **Bathymetric Pilot Study** – In March 2020, the Division of Water used an unmanned surface catamaran, or drone boat, to perform its first bathymetric pilot study, and has gone on to conduct similar evaluations. In the pilot on a reservoir built in 1969, an aerial drone was used to map the ridgeline and the elevation of the water surface, and the drone boat equipped with an echo sounder measured the depth of the reservoir and mapped underwater features. Information such as this helps provide a more accurate picture of available water supply.

2) **DWM:**

- **Emergency response** – In February 2020, heavy rains led to a mudslide in Pike County that derailed a CSX train, partially plunging it into the Big Sandy River. The drone was used to quickly obtain a good view and provide video to decision-makers as the river was flowing so fast it would have potentially endangered staff to monitor conditions by boat.

- **Maxey Flats Superfund Site:** As of Fall 2019, the Division of Waste Management had four drones on hand. One of the existing off-the-shelf drones is used by the Superfund Branch and dedicated to the Maxey Flats nuclear disposal Superfund site. Agency personnel and staff use the custom-built drone to carry a hazardous air pollutant sampler that records contaminate levels where it may be unsafe or impractical to deploy samplers.

- **Landfills:** The division's other drones are used to survey, photograph, and take video of landfills, by capturing images to investigate citizen complaints, to investigate open dump investigations, and to augment facility inspections. DWM is in the process of having drones document every landfill in the state.

- **Superfund sites and UST:** Drones are also used to document pre and post activities for Superfund sites as well as underground storage tank installations. The drone allows for collecting a large amount of data in a short period and keeps workers out of potentially dangerous terrain and circumstances. In addition, drones are used in emergencies like tracking smoke plumes or hazardous waste releases and documenting the before and after of construction and cleanups.

3) **AML:**

- **Water monitoring:** Uses drone technology in monitoring impacts to the waters of the Commonwealth, evaluate the condition of water left in a mine pit, or track the extent of a mudslide. The division developed a technique for sampling pond impoundments for metals and measuring approximate depths of the pool. In one instance, the pH of the water at an impoundment was between two and three. This level presented an unacceptable risk to inspectors and had not allowed previous sampling to occur. The division has tracked the progress of black water along embankments and into area waterways, the result of a breach of a coal processing plant's refuse impoundment. Regular monitoring and inspection of those ponds, sometimes acres in size, can be a challenge and a health concern when content is unknown, but creative thinking and ingenious rigging of the drones have allowed water sampling and depth analysis to be carried out with little or no human contact with the water.

- **Mapping mine sites**: Utilizes drone technology in mapping mine sites. AML views drones as a valuable tool in reclaiming forfeited permit sites. Staff is using drones to assess site feasibility, and offer in-depth understanding of an area and provide granular information on environmental risks. This includes creating 3D maps from vertical shots of a mine to develop comprehensive design plans for stabilization or restoration.

- **Volumetric calculations**. Utilizes drones to collect elevation data used for volumetric calculations. The program sets up ground control and incorporates data into its processing workflows to supplement traditional surveying methods.

- **Underground seam fires.** Kentucky is beginning to use a thermal camera to find seeps and monitor underground seam fires.

4) **DOF:**

- Utilizes drone technology to monitor and spot fires, in addition to searching for insect damage and disease in forests across the Commonwealth.

5) **DMRE:**

- Utilizes drone technology to observe large coal impoundments, to track reclamation efforts, and to take aerial, 3D photos to show the entire scope of a reclamation area. The state's UAV is used onsite two to three times a month. While helicopter flights are still being used to track reclamation efforts, DMRE is identifying additional sites that could benefit from drone usage.

Lessons Learned

- Some of the drones acquired by DEP are commercially available off-the-shelf purchases while others are custom built in house to meet specific needs.
  - DEP hopes to expand its capabilities with additional drones and sensor capabilities.

Contacts:

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- Robert Cammack, AML Environmental Control Supervisor, Robert.Cammack@ky.gov, 502-782-6334
- Ben Enzweiler, AML Environmental Scientist, Ben.Enzweiler@ky.gov, 502-782-6602
- Wesley Turner, Geoprocessing Specialist with the Division of Water, Wesley.Turner@ky.gov, 502-782-6793

Links/Resources of drones use in DEP and DNR:

- "EEC's Innovative Drone Use Promoted Efficiency, Worker Safety," by Kentucky Energy & Environment Cabinet – Includes Video Footage of AML Estill County Water Sampling, July 8, 2020
- "New Technology is Changing the Energy and Environment Cabinet," — Drones Play an Integral Part in EEC, August 2018

For more information about the drones Kentucky is using, specs may be found at the following links:

- Mavic Pro specs (DOF)
- DJI Inspire 1 Pro specs (DMRE and AML)
- DJI Phantom 4 Pros specs (AML)
- DJI Mavic Pro specs (DWM and DOW)

Louisiana
Department of Environmental Quality (LDEQ)

Program Summary

The Louisiana Department of Environmental Quality (LDEQ) first purchased small drones in 2017. The department quickly realized it needed a trained drone operator as well, and LDEQ conducted its first mission in February 2018. LDEQ has an active drone program that is set up outside of all sections so there is the ability to support various divisions in whatever way is needed. LDEQ has focused on emergency response, inspections such as landfills and debris piles, and surveillance. The department has an average of one to two requests for drone usage per week with, with most requests from inspectors and emergency response. LDEQ has flown more than 290 flights since the start of the program in 2017, and as of July 1, 2019, there are five trained LDEQ pilots. As a public agency, LDEQ operates under Federal Aviation Administration Part 107 (unmanned aerial systems under 55 pounds).

The agency has collaborated with sister agencies within the state, particularly focused on oil spills and the appropriate coordinating office. In April and August of 2019, after two oil spills, the Louisiana Oil Spill Coordinator's Office (LOSCO) initiated a collaboration with the National Oceanic & Atmospheric Administration (NOAA). LDEQ then collaborated with LOSCO to help in this effort. NOAA took images using a multispectral camera of both oil spill sites and then worked with LOSCO and LDEQ to compare imagery taken by the state to see if the oil spill had an effect on plant life, ecosystems, and wildlife.

In October 019, LDEQ's drone program received its first fixed-wing drone. The fixed-wing drone is primarily used for mapping purposes and is anticipated to be highly requested due to its capabilities, including its ability to fly considerably longer, covering about 400-500 acres in an hour. In June 2020, LDEQ received a large drone, primarily to use for air and water sampling. The drone will also have the ability to carry out payloads, including ground-penetrating radar, optical gas imaging cameras, magnetometers, and any other sort of sensor.

LDEQ has observed the following benefits:

- Improved monitoring of sites.
- Reduced costs mainly in person-hours.
    - For example, instead of sending out multiple inspectors to conduct large inspections or manually measure debris/waste, the drone program manager can go out with one inspector and map the entire facility much faster. LDEQ also gets a lot more data by using a drone than just with taking notes and taking measurements by hand.
- Increased ability to ensure staff safety.

Current and Planned Activities

- Emergency response (e.g. oil spills).
- Facility Inspections (e.g., waste, landfill, and tire piles).
- Compliance verifications.
- Facility & Land Mapping.
- Criminal Investigations.
- Air and Water Sampling.

Application Highlights

1) **Cocodrie Oil Spill:** In April 2018, in Cocodrie, Louisiana, drones were a crucial tool in examining and inspecting an oil spill. Storage tanks had leaked into a marsh, which led the LDEQ drone team to gather staff to inspect the site on a boat. The further down the channel the team went, and the closer they got to the site, the more apparent it became that bins had leaked. With the use of drones, staff were able to more thoroughly grasp the magnitude of the oil spill and its severity.

2) **Storage Tank Spill:** In March 2018, an oil spill occurred at a storage tank site north of Baton Rouge toward the Mississippi border. This site was located in fields. Concurrent with the spill, there was a heavy rainfall and the fields began to experience flooding just high enough to make walking and driving difficult, yet the water was too shallow for boats. This is a prime example in which drones are an asset. The team was able to access and inspect the flood by using the drone without compromising the safety of the team. In addition, the drone provided quick observations of the extent of the spill, the location of the product, and the spill's impact.

Lessons Learned

- If drones are used for sampling, larger drones are needed.
- Drones have been used to compare imagery in areas following an oil spill to view effects on plant life, wildlife, etc. in periods prior to and following an event.
    - The drone imagery has been used as part of LDEQ's Natural Resource Damage Assessments, comparing imagery taken right after a spill to imagery taken months later. This allows LDEQ to see change over time in the environment.

Contacts:

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Links/Resources for drone use in LDEQ:

- LDEQ presentation at the EE2020 webinar, December 2020 Minute 27:00 – 32:59
- How is LDEQ Utilizing Drone Technology?, July 2019
- LDEQ Unmanned Aircraft Systems (UAS) Program, July 2018

Maryland
Department of the Environment

Program Summary

The Maryland Department of the Environment (MDE) uses drones mainly within its Dam Safety Program. The Dam Safety Program acquired a drone in Summer 2019 to increase the program's capabilities to conduct routine inspections of dams and to increase situational awareness during potential dam emergencies. After considering a number of drone platforms and capabilities, MDE determined that a relatively lower-cost option (DJI Mavic Pro Platinum) was preferred at the outset of the dam safety drone program. If successful, consideration would be given to acquiring additional drones, potentially with survey or thermal camera capabilities. As of Winter 2020, with the exception of training flights, the drone has been deployed at five dams during routine inspections, and one dam to inspect a non-emergency seepage and sloughing incident. In addition, the Water and Science Administration's Field Service Program has used a drone in a pilot effort to detect harmful pollution sources, harmful algae blooms, and identify indicator bacteria for shellfish sanitation.

MDE has observed the following benefits:

- The ability to capture aerial images of the dams during routine or emergency operations allows for the observation of defects or variations in the dam's surface that would be difficult to discern by a ground-based observer. For example, variations in the color of vegetation on a dam's embankment may point to an area of seepage.
- The drone has the added benefit of increased employee safety with its ability to prevent the need for direct access to observe damaged dam elements and the use of special equipment to inspect tall vertical concrete surfaces, such as gravity dams.

Current and Planned Activities

- Dam safety inspections.
- Detection of failing septic systems along the shoreline for the state's pollution source assessment program (shoreline surveys).
- Fish kill/algae bloom response program (to document severity and extent in inaccessible areas).

Application Highlights

1) **Dam Embankment and Concrete Spillway Chute**: The drone deployment was successful in capturing the spillway images, which were stitched together by the dam owners engineer to supplement a condition survey of the spillway and to assess the integrity of recent repairs. The drone operator found that the equipment was surprisingly easy to operate, even in the relatively high wind conditions experienced during the inspection. The drone deployment reduced the need for fall-protection equipment and other health and safety considerations when accessing the tall concrete spillway crest.

2) **Dam Seepage/Sloughing Investigation**: Upon report of new suspected seepage and surficial slope movements, the Dam Safety program deployed an engineer with a drone to inspect the high hazard dam. While surface observations were sufficient to determine that the observations by dam operators were a non-emergency, the drone was deployed to obtain high-resolution images of the area, with the intent of comparing photographs over time to detect smaller changes in the problem area.

3) **Harmful Algae Blooms and Septic System Pilot**: Two years ago, with a homeowner's permission, drones were used in a pilot study in the Bodkin Creek area (northern Anne Arundel County). This was a collaborative effort with the National Aeronautics and Space Administration, University of Maryland, and Anne Arundel Community College to develop remote sensing technology to detect harmful pollution sources, harmful algae blooms, and identify indicator bacteria for shellfish sanitation. The homeowner had a failing septic system and various remote sensing platforms in and around the property (satellite and drones) were used to develop proxies for bacteria in the water that have unique optical spectra. The results detected some unique signatures along the shoreline near the failing septic system, but funding ran out and the project ended.

Lessons Learned

- Thus far, MDE has not found battery life/flight time to be a limiting factor for deployment, but that DJI batteries tend to degrade rapidly if allowed to discharge without periodic use.
- Camera resolution is important to capture clear images.
- Software and licenses for flight tracking/planning and data storage/manipulation should be considered during the purchase planning process to ensure the drone can be used to the fullest extent of its capabilities.
- Based on the agency's research prior to purchasing the drone, smaller and lower cost recreational drones often have a narrower range of acceptable operating conditions (height, range, wind) that would limit usefulness.
- Where routine periodic inspections of structures are planned, capability to mimic flight paths and photographs is important to allow for detection of small changes over time.
- Staff have found it difficult to set aside the required time to observe training videos and to study for the exam, on top of normal duties. In addition, because the exams are conducted in-person, there is a reluctance to risk potential COVID exposure.

Contacts:

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Links/Resources for drone use in MDE:

None.

Michigan
Department of Environment, Great Lakes, & Energy (EGLE)

Program Summary

The Michigan Department of Environment, Great Lakes, & Energy (EGLE) launched an extensive Unmanned Aircraft System (UAS)-Drone program in Spring 2017. As of spring 2020, EGLE has 17 certified FAA pilots with nine additional staff in training. EGLE currently owns 25 FAA registered UAS aircraft, with seven of its nine divisions flying drones, and seven of 10 regional districts with a pilot and an aircraft. All EGLE remote pilots in control are certified under FAA Part 107, and flights qualified by EGLE's "Demonstration/Evaluation Process" section of the EGLE Mission Plan. Michigan's EGLE provides remote pilots in training with a non-camera, stick control trainer drone to start with, ranging from $50-$100. Part of the evaluation and demonstration process is to run through various scenarios including geo-fencing, return to home altitude, maintenance propellers, etc. This is all in order to gauge how comfortable the pilot is with a range of maneuvers. Once staff graduate and pass the evaluation and demonstration process, they may lead a mission.

EGLE has observed the following benefits:

- Increased efficiencies when conducting field work.
- The ability to observe areas that are difficult or impossible to get to (e.g., wetland surveys, pollution response calls).
- Aerial perspective.
- Increased staff safety.
- Collection of better data.

Current and Planned Activities

- Developing current and accurate base maps for Redevelopment/Site Assessment.
- Site Inspections.
- Chemical and Radiation measurements in the field.
- Planned: GPS and mapping software combined with image.

Application Highlights

1) **Scrap Tire Program:** In Michigan, scrap tire recyclers are allowed to have a certain amount of tires on their site, but not enough that they become a nuisance. EGLE's scrap tile program now routinely flies and generates maps of tires on sites throughout Michigan. This method allows EGLE to generate an estimation of volume for tire piles without having to climb the piles. In the past, three to five inspectors would work together and climb several tire piles, manually measuring the volume, and providing the information for calculations. Tire piles are not always perfectly shaped, which complicates volume calculations. Drones are able to provide 3D imagery of map tire piles, significantly improving the volume determination. Prior to making any drone flight over regulated facilities, the EGLE team coordinates with the operator/owner of the site and establishes an agreement for the purpose of the drone flight.

2) **Eroding Shoreline on Lake Superior:** EGLE also used drone technology to monitor the eroding shoreline on Lake Superior. The drones allowed staff to access old mining tractor tire piles that were starting to show up on the shoreline of the lake. The drone allowed EGLE staff to identify where all the

tires were located along the shoreline. Without the use of drone technology, this would have been impossible, due to the inability of staff to physically access the site and various locations along the shore.

3) **PFAS over Van Etten Lake:** EGLE has deployed drones over Van Etten Lake, located in northeast Michigan, as part of its PFAS response. EGLE flew the drone from the Ken Ratliff Memorial Park along the shoreline of Van Etten Lake to determine the best location and height to mount an all-weather camera that will be linked wirelessly to EGLE staff. The drone's Forward Looking Infrared camera was also used to look for groundwater seeps entering the lake from the Wurtsmith Air Force Base. Following the creation of standards and procedures to protect public safety and address privacy concerns, EGLE also employed drone technologies to assist in PFAS responses and other environmental investigations throughout the state. In September 2018, EGLE flew a drone over Lake Margrethe to locate seeps that could be carrying PFAS contamination from past firefighting activities at the Camp Grayling military base. This was believed to be the first time any state or federal agency used a drone in a PFAS investigation. It proved to be extremely beneficial in identifying where the foam was located, and how best to move forward in taking the foam out.

Lessons Learned

- All drone purchases are approved through the Information Management Division within EGLE, which supports this innovation through centralized funding.
- Divisions should share drones, and purchase their own if they have extra funding.
    - Technology funding is directed into this effort.
    - Within each department, there is a small amount of discretionary money to put toward innovative projects and initiatives.

Contacts:

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- Arthur Ostaszewski, Environmental Quality Specialist & EGLE UAS Coordinator, Materials Management Divisions/Hazardous Waste Section, OSTASZEWSKIA@michigan.gov, 517-936-7991

Links/Resources for drone use in EGLE:

- MI EGLE presentation at the EE2020 webinar, December 2020 Minute 8:11 – 10:58
- Shoreline-mapping EGLE drone sent to watery Lake Michigan grave by U.P. bald eagle, August 2020
- MI EGLE Mission Plan, October 2019
- EGLE deliverables as part of the Landfill Cover Assessment, and Program overview, October 2019
- MI EGLE drone deployed over Van Etten Lake as part of Wurtsmith PFAS response, November 2018
- MI EGLE UAS Policy and Procedures, August 2018
- Michigan Senate Bill in reference to UAS, 2018
- UAS Act, State of Michigan, 2016

Montana
Department of Environmental Quality

Program Summary

The Montana Department of Environmental Quality (MDEQ) Opencut program has been using unmanned aerial vehicles (UAV) since December 2019. The Opencut Section reviews permit and amendment applications within its statutory timeframe to ensure opencut minerals (bentonite, clay, scoria, soil materials, peat, sand, or gravel) are extracted in accordance with the act and rules to ensure adequate protection of environmental resources and successful reclamation of the affected land back to a productive post-mining land use. The Opencut Section uses UAV technology to inspect sites and obtain clear and accurate data. These data allow the Opencut Section to measure stockpile quantities, disturbance, highwall heights, and much more.

Montana DEQ has observed the following benefits:

- Data obtained is very accurate.
- Flying a site reduces the time a scientist spends onsite and increases their safety, while also providing superior inspection data.
- Clear aerial photography allows a scientist to refer back to a clear and detailed aerial photo during the permit review in the office to address any questions that may have come up, and to avoid the need to revisit the site.
- Stockpiles, high-wall disturbance, and more can be quantified and measured.

Current and Planned Activities

- Inspect Opencut sites ranging in size from a few acres to several hundred acres.
- Inspect sites for hard rock minerals.

Application Highlights

1) **Groundwater:** The UAV has allowed MDEQ to determine ground water levels to better help the operator determine their proposed mining depth to avoid the water table.
2) **Land Reclamation:** The UAV allows MDEQ to view the land before it gets disturbed, during disturbance, and after it has been reclaimed. The UAV allows agency staff to see how the reclamation compares to pre-disturbance.
3) **Land Observation:** The UAV allows MDEQ to safely fly over very large sites in a timely manner to view current land health, in addition to finding any potential issues. The UAV also allows the Opencut section to create reclamation plans of historic bond forfeited sites.

Lessons Learned

- Create and follow protocols and checklists to ensure the site is safe to fly with an UAV.
- Look at other established UAV programs to help your own UAV program and prevent making similar mistakes.
- Wind plays a direct role in the ability of the UAV to perform, and it may be better to fly the site manually as opposed to auto-flights if the wind exceeds 10 mph.
- High and low, temperatures both affect battery life.

Contacts:

- Michelle Hauer, Information Services Section Supervisor, Michelle.Hauer@mt.gov, 406-594-1010

Links/Resources of drone use in MT DEQ:

- MDEQ Opencut Section
- Pix4D – Issues and Resolutions
- Phantom 4 Calibration Procedure
- Montana DEQ UAS Checklists

New York State
Department of Environmental Conservation (DEC)

Program Summary

The New York State Department of Environmental Conservation (DEC) began its pilot program Winter 2015. The program is now very diverse, with DEC managing land, water, and waste program drone activities at the DEC headquarters in Albany and many of its regional offices across the state. DEC pilots were trained under the guidance of the Northeast Unmanned Aircraft Systems Airspace Integration Research team at a federal drone test site. On average, DEC receives one drone mission request per week, primarily within New York, yet DEC's drones have also deployed to provide assistance during the Hurricane Harvey response in Texas and the Hurricane Maria response in Puerto Rico.

DEC has observed the following benefits:

- Cost savings.
- Force multiplier, enhancing ability of personnel to respond to emergencies.
- Safety.
- Accessibility.
- Rapid and efficient data collection.
    - Helps in making better-informed decisions.

Current and Planned Activities

- Emergency response.
- Remediation.
- Superfund.
- Brownfields.
- Mapping.
- Volume measurements.
- Materials management.
- Oil and gas well capping.
- Wildlife observation.
- Landfills.
- Underwater missions including (marine inspections and artificial reef progress).

Application Highlights

1) **Lake Ontario:** In 2017, at a particular area on Lake Ontario, there was extremely high water and heavy wind events that eroded dunes. DEC staff observed the east point of the lake, where miles of shoreline had been impacted. DEC-certified drone pilots spoke with engineers about steps forward and solutions to mitigate the issue. Prior to utilizing drones, this mission would have taken weeks in order to get a proper and accurate assessment. However, because of the drones, work was completed efficiently. The DEC team was able to fly the drone in one afternoon to observe the area of the shoreline, and it only needed to remain in the sky for half an hour for all necessary data to be acquired. The drone allowed for a photomap and accurate measurements of the map area. Using the drones saved a great deal of money and time as compared with what would have been a two-week survey/mission.

2) **Addressing climate change:** State-of-the art drone technology carrying a magnetometer will take flight in 2021 to detect orphaned oil and gas wells in four target areas of central and western New York State. These legacy wells, most of which pre-date DEC's regulatory program, may release climate-altering greenhouse gases such as methane, and DEC is working to identify and evaluate as many of them as possible by leveraging this promising technology. A recently announced partnership between DEC and the New York State Energy & Research Development Authority includes the investment of $400,000 in cutting edge drone equipment and instrumentation that will help state scientists from DEC's Division of Mineral Resources to locate hidden abandoned wells. Many of these wells, which are concentrated in areas of historic oil and gas production in New York State, have been found leaking oil and brine, and may release methane, a potent greenhouse gas, to the atmosphere. The airborne sensing equipment detects anomalies in Earth's magnetic field caused by the well's casing, allowing DEC staff to create relevant maps using GIS resources. These maps are compared to existing resources such as database records, historical lease maps, landowner information, and other sources to aid in locating wells during field surveys. Once located, the wells can be plugged to help mitigate fugitive methane releases to the environment. In 2019 and early 2020, DEC's staff teamed up with scientists from Binghamton University in a pilot program to test the technology. Initial test results indicate the technology will be useful in detecting difficult to locate, pre-regulatory orphaned and abandoned oil and gas wells.

3) **Remote observation in emergencies:** Using drones has helped ensure the safety of staff and other first responders. Most recently, DEC utilized drones equipped with sensory packages to monitor the temperature of a tanker at risk of explosion in Albany County, obtaining critical data while personnel remained at a safe distance during the emergency response. Drones were also used during the state's COVID-19 response to remotely monitor the temperatures of people coming into the Javits Center's field hospital. In 2019, drones were used to monitor several barges and boats that were removed from their moorings by ice jams on the Hudson River. The drones helped confirm there were no people on board the vessels and were used to conduct preliminary evaluations of potentially impacted infrastructure.

4) **Wildlife Rescue:** In October 2020, drones were used to assist in wildlife conservation after a wayward moose became trapped in a remote area on private land for more than a week. After assessing all options, wildlife staff determined that sedating and removing the moose was the best course of action, but the moose was elusive. DEC Wildlife staff requested help from drone pilots from DEC's Environmental Conservation Police to help locate the young bull in the 200-acre cow pen in the Adirondacks. The moose was located using thermal imaging footage taken by a drone, intercepted on the ground, tranquilized, and, with the assistance of DEC staff and members of the property owner's family, removed from the cow pasture and relocated to a nearby forest. Visit DEC's Facebook post for video and more details.

5) **Underwater/Marine Use:** DEC owns a drone with underwater capabilities to conduct marine research on issues such as surveying fish and invertebrates, surveying fish and invertebrate communities around proposed wind turbines, surveying oyster reefs, viewing whales from under the water to assess entanglements, monitoring tagged sharks and other fish post tagging, viewing various underwater habitats such as sea grasses and other marine life, enhancing stakeholder outreach and web development, searching or surveying for law enforcement, and inspecting underwater structures such as docks and bulkheads. In addition, as part of the largest artificial reef expansion in state history, drones are used to monitor and analyze how the reef has been changing over time.

Lessons Learned

- Work with various divisions within your agency.
    - Develop protocols for use, be aware that relying on one person is not going to work; one must create a strong team.
- Be sure to have a diverse team.
    - Assign a program coordinator, and have a lawyer in the room, in addition to natural resource and engineering professionals.
- Before you scale the program, be sure to have a standard operating procedures manual, which will serve as the foundation for all activities.
- Federal regulations should be followed as well.

Contacts:

- Sean Mahar, Chief of Staff, Sean.Mahar@dec.ny.gov, 518-402-8549
- Scott McDonnell, Aviation Coordinator, scott.mcdonnell@dec.ny.gov

Links/Resources for drone use in DEC:

- DEC and NYSERDA Announce New Drone-Based Initiative to Fight Climate Change by Finding and Plugging Orphan Oil and Gas Wells, December 14, 2020
- Wildlife Rescue, October 19, 2020
- New York Dept. of Environmental Conservation Launches 22-Drone Fleet, September 26, 2017 and related YouTube video, DEC's Drone Program Takes Off, September 25, 2017

North Carolina
Department of Environmental Quality (NCDEQ)

Program Summary

The North Carolina Department of Environmental Quality (NCDEQ) launched its drone program in 2016. The regulatory, air, waste, and coastal management divisions all share the same drones. As of December 2019, NCDEQ had 36 staff members in the process of taking the Federal Aviation Administration drone training courses through a community college system, for which funding was made possible through a grant for emergency responders given to the state. The Division of Coastal Management was the first division to use drone technology, focusing on hurricane impact surveys, wetland restoration, and coastal site surveys. Within the Fisheries & Coastal Management Division, there are two drones in use. Fourteen drones are now in place in DEQ and distributed across 7 to 8 remote locations. Mine and dam inspections are streamlined with the use of the Mavic 2 Pro fleet. NCDEQ has been able to increase the accuracy of tracking the dispersion, timing, and extent of Rhodamine dye studies and expects to reduce internal costs by 50%. The state uses KittyHawk software to manage the entire drone fleet and can track serial numbers, pilot assignments, and pilot hours, drone location, and hours flown per drone. Drone2Map is used to map and process drone data. In a pilot with UNC-Wilmington, the state notes it took 30 years to map the first 90% of the state's estuaries and 12.5 days to map the final 10%.

NCDEQ has observed the following benefits:

- More staff time available for analyzing collected data as less time is spent in the field collecting information.
- Improved site access to locations that are not as easily reached.
- Reduced staff and funding resources (e.g. travel time to sites/facilities).
- Enhanced staff safety from reduced exposure to potential harmful toxins and safer terrain.
- Ability to provide better and more accurate data. For example, following a 2020 earthquake, a drone was use to map fault lines that showed a 6-inch trench. This impressive detail would not be seen from photos taken on ground.
- Reduced salary, gas, and supply costs with smaller teams performing work manually.
- Elimination of shellfish and submerged aquatic vegetation (SAV) disturbance during inspections related to shellfish leasing.

Current and Planned Activities

- Coastal Site Surveys.
- Mapping.
- Emergency Response.
- Monitoring of Project Performance.
- Site Surveillance.
- Shellfish and SAV inspections.
- HAB monitoring.
- Rhodamine dye studies.
- Farmland inspections.
- Mine, dam, and dock inspections.
- Cold stun events to document the extent and number of fish affected.
- Create 3D models to estimate volumes of material for artificial reef program.

- Create 3D models for construction projects with 15-30 minute flights compared to more expensive and time-consuming terrestrial laser scanning.
- Planned: global positional system (GPS) and mapping software combined with image, live feed function with real-time coordination during emergency events.

Application Highlights

1) **Monitoring Project Performance & Verification:** NCDEQ uses drones frequently in order to monitor the process of a project and to ensure that everything is going as planned. The Division of Mitigation Services uses drones to confirm that streams and wetlands are functioning as designed. During Hurricanes Florence in 2018 and Dorian in 2019, NCDEQ was able to get a drone in the sky over a coal ash facility soon after the storms, permitting staff to see how severe the situation was and what had been impacted. In this instance, staff were able to observe a flooded cooling pond that then flooded into an adjacent lake, resulting in a dam breach in multiple places and ultimately a large breach in the dike.

2) **Emergency Response to Landslides:** The western part of North Carolina is vulnerable and subject to landslides due to its topography. Drones have been useful in mapping and responding to landslide emergencies, as they can map in minutes what took days with traditional land survey methods. Drone imagery can also be revisited as needed.

Lessons Learned

- It is important to stress from the beginning that the drone is not a toy.
- The state started with developing standard operating procedures (SOPs) and exercises purchasing discipline by having all drone requests funnel to a single point of contact.
- If new sensors are needed, an agency workgroup discusses the need first so resources are invested wisely and technology is interoperable and based on a common platform.
- Due to security concerns, the state does not use the drone manufacturer software.
- State staff note that each program/division will want to add to SOPs and policies. However, creating a uniform system for all divisions to utilize, rather than having separate systems for each division, is recommended.
- NCDEQ notes that tablets with built-in GPS were a great improvement over paper, and that drones were a real game-changer. For instance, with the Estuarine Benthic Habitat Mapping program, a two-person team using a DJI Phantom 4 Pro drone can produce data for 600 acres per day compared to traditional methods of 10 acres per day, saving approximately $400,000, an increase of 5,900% performance. The state collaborated with UNC-Wilmington in this mapping effort.
- NCDEQ has shared ideas and technical assistance with the North Carolina Department of Transportation and North Carolina Department of Public Safety sister agencies.

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- Tim Baumgartner, Director, Division of Mitigation Services, tim.baumgartner@ncdenr.gov
- Toby Vinson, Section Chief, Division of Energy, Mineral, and Land Resources/Land Quality Section, toby.vinson@ncdenr.gov
- Mike Griffin, DEQ Division of Marine Fisheries (252-808-8069), Michael.Griffin@ncdenr.gov
- Mike Ware, CIO, Department of Information Technology/ Environmental Quality, mike.ware@nc.gov, 919-707-8917

Links/Resources for drone use in NCDEQ:

- NCDEQ presentation at the EE2020 webinar, December 2020 Minute 13:55 – 22:44
- "Mapping with Drones in North Carolina", NASCIO Voices, October 21, 2020
- "North Carolina Landslide Mapping Program," September 2020, ECOS Innovation Videos, see 28:30 - 30:14 mark
- "UAV Benthic Habitat Mapping Overview: Hope Pole Creek Project," Michael Griffin, NC DEQ, March 31, 2020
- NCDOT Building a Statewide Drone Program, August 2019
- NCDEQ Standard Operating Procedure, January 2019
- NCDEQ Unmanned Aircraft System Policy, January 2019
- Mapping NC's Estuarine Benthic Habitat with Unmanned Aerial Systems, July 2018

Oklahoma
Department of Environmental Quality (DEQ)

Program Summary

The Oklahoma Department of Environmental Quality (DEQ) has been using drone technology since 2017-2018 in its drinking water and wastewater programs. The DEQ Criminal Investigation Unit has used them as well, and drone utilization is likely to expand within the agency. The DEQ Water Quality Division Director notes that the state's use of drones has paid immediate dividends not only in cost reductions but also by making once-dangerous tasks, like water tower inspections, safer. DEQ operates drones under the "Part 107" rules. DEQ drone pilots obtain a small UAS pilots license that is good for two years. DEQ has two models of drones, the Phantom 4 and the Matrice 210, which are both manufactured by DJI. The Phantom 4s are small drones, and Matrice 210s are large drones with multiple camera/payload options.

DEQ has observed the following benefits:

- Safe access to high-risk sites.
- Inspection of water towers from the ground.
    - Inspectors no longer need to climb towers or other tall equipment or rely on tower inspection reports provided by the water system.
- Inspection of drinking water intakes on lakes from the shore.
    - Inspectors no longer must travel to the intake on a boat, which increases water safety and allows for social distancing.
- Inspection of facilities that are temporarily inaccessible due to washed out roads, floods, or other impediments.
- Rapid surveys of large areas or water bodies to locate potential sources of pollution, such as in the event of a fish kill.
- Excellent imagery with enhanced optical zoom and infrared temperature reading capabilities.

Current and Planned Activities

- Inspections.
- Sanitary Surveys.
- Monitoring of waterways.
- Evaluation of thermal stratification in finished water storage facilities.
- Planned: expanded use in more routine wastewater inspections and complaint investigations.

Application Highlights

1) **Drinking Water**: DEQ's drones have been primarily deployed during sanitary surveys. There have been several instances where drones have identified finished water storage facilities with open hatches and/or damaged or missing vents and screens. These deficiencies pose a potential pathway for contaminants to enter finished water and would have gone uncorrected, as they were not observable from the ground.

2) **Wells:** DEQ has also used drones to investigate the potential impact of a UIC disposal well "purge" on the surrounding surface water bodies.

3) **Water Storage Facilities:** While still in the validation stage, DEQ is attempting to determine whether infrared cameras can be used to evaluate thermal stratification in finished water storage facilities. This would prove beneficial in assisting water systems in identifying potentially high disinfection byproduct formation in water tanks and towers and would help direct limited funding available to address these types of violations.

Lessons Learned

- The Phantom 4s (small drones) were acquired during staff training; the Matrice 210s (large drones) were acquired through a competitive bidding process. The training center where DEQ staff received the small UAS pilot training included the Phantom 4 drones as part of the training cost. DEQ subsequently purchased the Matrice 210s and multiple cameras. The purchase outside of the training class required DEQ to use the state bidding and purchasing process.
- Drones can be temperamental. A pre-mission check at the office might show that the drone is ready to fly (e.g., firmware up-to-date, good connection) but turns out not to be mission capable when in the field. Always bring a second drone, battery, and equipment, if possible.
- A great deal can be accomplished with a medium-tier drone, such as the Phantom 4.
- The rules regarding use, including such requirements as obtaining waivers, are constantly changing.
- The Public Water Supply Group of DEQ has assigned a Drone Coordinator to help develop new standard operating procedures for using and maintaining the drones.
- Considering that most drone users have limited experience as pilots, drone stability and ease of control are the most important features drones should have.
- Drinking water inspectors have found that when inspecting storage facility appurtenances, camera quality and capability, especially optical zoom, is very important.
- For long-term sustainability, it is beneficial to have secured storage facilities as well as dedicated electrical outlets, ethernet connections, and counterspace for performing routine maintenance activities.

Contacts:

- Shellie Chard, Director, Water Quality Division, Shellie.Chard@deq.ok.gov, 405-702-8157

Links/Resources for drone use in DEQ:

- UAS Flight Log Checklist, 2020
- Drone Bid Packet, 2020

South Carolina
Department of Health & Environmental Control (SCDHEC)

Program Summary

The South Carolina Department of Health & Environmental Control (SCDHEC) Environmental Affairs (EA) drone project was sparked by a recognition of the potential value of the unique view provided by (in the first instance, staff-owned and operated) unmanned aircraft. SCDHEC first used drones operationally in the response to Hurricane Matthew in 2016. As of June 2020, EA has five small Unmanned Aerial Vehicles (sUAVs or drones) available to support routine data collection or respond to events. The initial use of the technology during the Matthew response was in coordination with a contractor and SCDHEC staff to evaluate impoundment conditions that were not otherwise safely accessible. Since the 2016 response, EA has developed additional capability through acquisition of aircraft, development of standard procedures and processes by interested staff, and the attainment of Federal Aviation Administration Part 107 (FAA/107) Remote Pilot certification by five staff. These five pilots are instrumental in conducting safe field operations and are prepared to respond to requests from all five SCDHEC EA Bureaus. All staff participating in the project (pilots, crew, and support) do so in addition to their normal job duties.

Although hurricane response and recovery was the initial impetus for the drone program, early uses also included documenting issues at solid waste sites (tire and waste piles), impoundments (dams), and brownfields. Over the past 3 years, SCDHEC has recognized various benefits of using drone technology and shared that pilots and crew feel they learn something every time they fly a mission.

FAA/107 sets limits that are a challenge but help ensure safety. EA's internal operational procedures ensure that UAV operations are consistent with program policy and needs.

SCDHEC has observed the following benefits:

- Ability to perform safe and rapid documentation supporting site assessment.
- Ability to see an entire area and detail of sub areas in context during activities that are potentially unsafe or in areas that are inaccessible. For example, in the brownfields program, the upper structure of a partially demolished building.
- Aerial perspective allows for better presentation of before, during, and after cleanup documentation and review.

Current and Planned Activities

- Integration of RTK high precision data collection to support Bureau of Land & Waste Management, dam, and groundwater protection activities.
- Encouragement of vendors to improve image post processing capabilities.
- Dam assessment and mapping to support evaluations.
- Decision support for Coastal Zone Management.
- Improve and maintain capability to support emergency response and recovery with integration into the Incident Command System.
- Significant involvement in an organization of South Carolina public agencies (state, local, and federal) to promote communication, consistency, collaboration, and development of the tool.
- Exploration of the capability to detect, characterize, and track algal blooms with current sensors.
- Incorporation of skill training and proficiency standards for pilots and crew.

Application Highlights

1) **Waste Piles:** The ability to quickly and safely document the scope and scale of a problem with a detailed orthophoto of the complete site, estimate the volume of the material with 3D mapping and volume calculation, and document the progress of cleanup with regular, repeatable documentation has enabled reductions of scrap tire and waste piles.

Lessons Learned

- Start small. Fully featured aircraft can be very costly, but better quality consumer aircraft are very capable and are an affordable path to develop skills, capacity, and applications that support the environmental programs.
- Have staff familiar with the site involved both in planning and in operations to inform the pilot of the data needs, provide onsite direction, and engage the curious and interested on site so the pilot can focus on operations.
- Livestreaming of video from the drone has potential to inform offsite decisions and allow direction of the view and data collection by remote participants.
- There is no substitute for stick time. Although many mapping missions can be flown automatically, hands on experience with the tool has proven to be critical for data collection in difficult conditions and areas with a variety of obstacles and potential hazards.
- Prepare and follow up. The flight is a small portion of the task. Have a process and checklist that helps assure a safe and successful flight, from confirming airspace and potential flight restrictions through equipment checks to delivery of the data.
- Sensors more sophisticated than RGB cameras used for 2D and 3D photogrammetry (thermal, Lidar, sampling, etc.) increase the cost of the platform by at least an order of magnitude.
- The ability to post process and manage the large amount of data generated is critical. Pilots, data processors, and data users must coordinate throughout.
- Always have extra batteries on hand.

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- Uwe Klauck, Project Lead, Greenwood Environmental Affairs Office, KLAUCKUW@dhec.sc.gov, 864-227-5915

Links/Resources for drone use in SCDHEC:

- Waste Pile Removal Progress, July 2019-January 6, 2020
- NIST UAV Equipment Functionality and Maneuvering Proficiency, December 2019
- SCDHEC UAV Standard Operating Procedure, October 2019

Texas

Commission on Environmental Quality (TCEQ)

Program Summary

As of December 2020, the Texas Commission on Environmental Quality (TCEQ) was developing an Unmanned Aerial Systems (UAS) program to provide aerial support to TCEQ personnel during field activities. The development of the program includes the creation of standard operating procedures to define the program mission, pilot training requirements, equipment standards, and flight operation safety guidelines. The program is being structured to comply with 14 Code of Federal Regulations (CFR) Part 107 and/or an applicable Certificate of Authorization, plus applicable portions of 14 CFR Part 61 and 91; as well as Texas Government Code 423 and 2205. Pilot training for the program includes: 32 hours of classroom instruction through the Texas A&M Engineering Extension Service (TEEX) UAS course for Public Safety officials; 10 hours of flight training with a licensed pilot; and passing the Federal Aviation Administration (FAA) licensing exam to become a licensed UAS commercial pilot. The TCEQ UAS Program also receives mentoring from the City of Austin's Drone Unit. Currently, the agency has 23 emergency management staff that have completed the TEEX training course in preparation to become pilots. The program already has one FAA licensed pilot, with many others nearing completion of their flight training requirements.

This year TCEQ purchased its first twenty-five drones, including:

- 1 DJI Mavic 2 Pro (with smart controller) –includes a 20 MP Hasselblad camera, 4k video, 3-axis stabilized camera gimbal, active tracking, obstacle sensing, and a 31-minute flight time.
- 8 DJI Mavic 2 Zoom –includes a 12 MP Hasselblad camera, 4k video with 24-48mm optical zoom, 3-axis stabilized camera gimbal, active tracking, obstacle sensing, and a 31-minute flight time.
- 2 DJI Phantom 4 Pro + V2.0 Drones –include a 20 MP camera, 4k video, 3-axis stabilized camera gimbal, active tracking, obstacle sensing, and, a 30-minute flight time.
- 13 DJI Mini 2 -includes a 12 MP camera, 4k video, 3-axis stabilized camera gimbal and a 31-minute flight time.
- 1 Autel EVO II Duel 640 -includes a 48 MP camera, 8k video, 3-axis stabilized camera gimbal, FLIR Boson thermal camera, 1.9 lbs. payload capacity, active tracking, obstacle sensing, and a 38-minute flight time.

TCEQ has observed the following benefits:

- Drones with remote imaging capabilities allow staff to survey large areas in a short amount of time.
- Remote imaging also enables staff to assess a hazardous materials situation and plan an emergency response while remaining at a safe distance.
- Real-time images and video provided by the drones can also provide agency leadership with a current operational picture.

Planned Activities

- To secure flight operations and allow for live streaming video during disaster events, the agency also purchased the DroneSense Platform, which is third-party encrypted software (U.S./Austin-based Company) that will allow for the control of all drone flight operations and remote imaging capture within a secure environment.
- The agency will use the new DJI Mini 2 (<249 g) for staff flight training and smaller emergency response events.

- For the first year of flight operations, TCEQ is planning to deploy its UAS fleet to 8 of the agency's 16 regional offices. Eventually the agency plans to have several of these drones deployed to each of its 16 regional offices across the state.
- The agency will equip the drones with thermal cameras, optical gas-imaging cameras, multi-gas monitors (air monitoring) or Geiger-Mueller detectors (for radiation), enabling staff to monitor unknown site conditions from a safe distance.

Contacts:

- Jim Rizk, Senior Advisor to Chairman, Jim.Rizk@Tceq.Texas.Gov, 512-239-5500

Links/Resources for drone use in TCEQ:

- TCEQ Unveils New and Improved Emergency Response Assets, November 10, 2020

West Virginia
Department of Environmental Protection (WVDEP)

Program Summary

The West Virginia Department of Environmental Protection (WVDEP) started its drone program in 2016. As of Winter 2019, WVDEP had eight Federal Aviation Administration-certified unmanned aerial vehicle operators spread across the Geographic Information System Unit, the Division of Land Restoration, and the Active Mining Program. Initially, most of the unmanned aircraft system projects were associated with abandoned or forfeited mining sites where WVDEP has assumed responsibility for reclamation. More recently, the drone program has expanded to include activities within other WVDEP divisions. The agency has an in-house drone program that makes it much easier to respond to requests from the entire agency, and this has proven to avoid delays in data collection and results. WVDEP purchased a thermal camera in 2019 to evaluate its use to identify sources of ground water and for inspecting impoundment embankments. One of DEP's drone pilots has begun operating a bathymetric platform for mapping the contours of water bodies with the primary use is for monitoring sediment deposition in larger drainage control and treatment ponds.

WVDEP has observed the following benefits:

- Mapping costs have been reduced through avoidance of a contract with a staffed aircraft company. There is a fixed cost of using regular airplane, and using drones will be cheaper than doing traditional data collection.
- The in-house program responds more quickly to agency requests.
- Drones can fly on cloudy days, whereas regular planes cannot. Cloudy weather is common in West Virginia.
- The program has allowed for identification of abandoned sites where there were previous activities with potential environmental impacts.
- Use of a drone during coal refuse impoundment application reduced staff time onsite and resulted in high-quality images.

Current and Planned Activities

- Division of Land & Restoration activities.
- Mapping.
- Abandoned or forfeited mining sites.

Application Highlights

1) **Reclamation Design:** Within the Division of Land & Restoration, WVDEP has used drone technology to conduct reclamation design. One project required the agency to remove a drainage control pond that had been damaged during a flood. The drone was an effective tool in mapping the modified current conditions and collecting elevation data. Collected data were then utilized by an engineer, who was able to design a permanent solution.

2) **Coal Refuse Impoundment:** Under the guidance of WVDEP Department of Site Reclamation, a coal refuse impoundment was being reclaimed. With the help of drone technology, the state's project manager is able to confirm cut, fill volumes reported by the contractor, and verify that the post-reclamation elevation profiles match the approved engineering plans. This site was flown again in 2019 after reclamation was complete to document as "built" conditions on the site.

3) **Oil-tank Farm:** In the early 20th century, there was an oil tank farm in the state of West Virginia that is now heavily wooded. With the use of drones, even during leaf-on conditions, the agency was able to extract detailed elevation data from the site that revealed tank locations and associated earthworks, and to obtain high-resolution aerial photography.

Lessons Learned

- As important as drone technology is for the advancement of environmental monitoring within WVDEP, the agency does not solely concentrate on the actual drone itself. Instead, what is most important is the results and quick access to data that the agency receives from the technology.

Contacts:

- Michael Shank, Manager, Technical Applications and Geographical Information Systems, Michael.C.Shank@wv.gov, 304-926-0499 x1620

Links/Resources of drones use in WVDEP:

- WV DEP Drone Program slides
- West Virginia DJI Phantom 4 RTK Request for Quotes

Wisconsin
Department of Natural Resources (WDNR)

Program Summary

WDNR first worked on a drone policy for about three years beginning in 2017 and has owned a fleet of drones for about one year, since 2019. The WDNR purchases its drones through competitive bidding as a package, and all of the drones have come from the same source under one purchase order.

Policy was approved in late 2019 allowing the Division of Forestry/Aeronautics Team and the Bureau of Law Enforcement to establish drone programs. The Aeronautics Team provides services department-wide, while the Law Enforcement Team focuses on enforcement and public safety related missions.

The DNR Aeronautics Team has five DJI Mavic 2 Pro drones (one at each hangar), and all of the Aircraft Pilots hold Federal Aviation Administration Remote Pilot certificates. Using these new tools along with fixed-wing aircraft allows WDNR to offer the entire agency and its partners the ability to quickly access a variety of equipment to gather the information they require, both efficiently and effectively.

A typical project mission includes:

- Flight software used to both control the drone autonomously as well as create geographic information system importable JPG and Geo TIFF images, among other products.
- Ability to stitch together thousands of individual pictures to create a single georeferenced map
- Extremely high level of detail.
- Pay as you use system for map production ($0.022 per acre).
- Roughly one minute per acre to capture images.
- No charge for pilot and drone use for WDNR missions.
- Shared expenses with partner agencies and groups.

The following product formats are available: Geo TIFF, Full Resolution Image JPG, DEM TIF, Colorized DEM, Colorized DEM JPG, 3D Google Earth KMZ, Point Cloud LAS and TXT files, and 3D Model, Material, and Texture files.

WDNR has observed the following benefits:

- The ability to further support individual natural resource programs and their specific needs with high-resolution photographs and videos of individual sites.
- More efficient and effective use of staff hours.

Current and Planned Activities

- Forest health monitoring.
- Emergency mapping of natural disasters.
- Routine monitoring of infrastructure.
- Storm damage assessments and sales.
- Tracking changes in forest composition.
- Detection of changes in water quality.
- Monitoring of compliance on conservation easements.

- Monitoring of ecological changes.
- Detection and monitoring of invasive species.
- Reduced costs and time, and improved accuracy of assessment work (in real time).
- Improved access to remote resource management areas.
- Production of aerial videos and photos for outreach and promotion materials.

Application Highlights

1) **Forest Storm Damage***:* Drones were used to map storm damage in Summer 2019 so that Wisconsin and federal agencies could quickly and efficiently prioritize relief efforts and clean up.

2) **Invasive Water Species:** Drones have been used to map invasive water species and pre-identify its location before sending employees out to physically look at it. This has helped reduce time spent searching for the plants.

3) **Water Quality Program:** The program is piloting drone usage for characterizing stream bank erosion and habitat assessment by video.

Lessons Learned

- Drones are mainly used for missions that are small, specific, and not time-sensitive, whereas fixed wing aircraft are typically used for all other requests.
- The line of sight limitations of drones makes them challenging to efficiently use in forested areas.
    - The idea that one can just launch a drone and survey an area sounds simple to the person sitting in the office, but in the field, many hours are spent hiking and physically positioning the pilot in a location so that he/she can maintain line-of-sight with the drone.
- Many hours are spent preparing and setting up for a mission, and very few hours are spent actually flying.
- If your agency has multiple drones, the most important thing is to have one software program and operating system that is compatible with all equipment. The software is constantly evolving, and operating multiple drones with different software would be almost impossible to keep up with.

Contacts:

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- Timothy Lizotte, Bureau Director/Forestry Business Services, Division of Forestry, timothy.lizotte@wisconsin.gov, 608-333-2540
- John A Jorgensen, DNR Aeronautics Team Leader, johna.jorgensen@wi.gov, 608-219-3194

Links/Resources for drone use in WNDR:

- Drone flyover related to the Sediment Clean-up at the Portage Canal, April 2019 Footage
- WDNR Remote Sensing of Water

Wyoming
Department of Environmental Quality (WYDEQ)

Program Summary

The Wyoming Department of Environmental Quality began using and testing drones in 2015. At WYDEQ, while neither the Land Quality Division (LQD) nor the Abandoned Mine Land Division (AML) own a drone for state usage, WYDEQ has consultants and operators that fly drones for a myriad of uses on their behalf.

WYDEQ has observed the following benefits:

- Cost savings due to data that are more accurate, along with increased staff efficiency and timesavings.
- Higher level of safety due to personnel on the ground being able to collect data from a safe location.
- More accurate vegetation maps and data collection.
- Ability to monitor remote or hard-to-reach sites.
- Specifically for LQD, more accurate volumetric reporting has resulted in bonds that are more accurately calculated.

Current and Planned Activities

- Safety evaluations that captured imagery where mine fires, dangerous subsidence, or other unsafe conditions were known or suspected to exist (i.e., subsidence features are hard to identify from the ground but aerial views can reveal previously undetected openings).
- Pre-design identification and evaluation of abandoned mine features.
- Vegetation mapping and identification of weed infestations as well as pre-design evaluation of existing desirable and undesirable vegetation.

Application Highlights

1) **AML:**

    - Large site surveys including for pre-design, interim, and post construction topography as-built mapping, which were previously time consuming are now performed regularly.
    - LiDAR surveys to detect unknown cultural features that lay beneath soil and/or vegetation.
    - Large site surveys for vegetation mapping and identification of weed infestations as well as pre-design evaluation of existing desirable and undesirable vegetation.
    - Verification for dirt haulage and load counts to add certainty to construction management and billing.
    - The majority of the construction contracts are competitively bid by contractors before WYDEQ can award the job to a company/contractor. This process entails conducting pre-bid tours, which are onsite visits that allow the contractors to submit bids based on the construction site. However, due to COVID-19 and the inability to send out groups of people together to the sites, these pre-bid tours are now being conducted using drone footage.
    - Discovery and mapping of previously unknown or hidden adits and shafts, and underground mine subsidence features that have opened up to the ground surface.
    - Tracking the progress and extents of underground coal mine fires using IR technology.

2) **LQD:**

- Baseline surveys for pre-mined land surface conditions (vegetation, hydrology, and soils) are utilized for permitting.
- Surveys of current mined surface areas and volumes provide more accurate information for annual reports.
- Surveys to evaluate current mined surface areas and volumes to update reclamation bond estimates.

Lessons Learned

- Drone surveys result in more reliable land quality permitting data.
- It would be almost impossible for a human on foot to capture the same amount of data as the aerial imagery captured by a drone.

Contacts:

- Luke Esch, Deputy Director, Acting Administrator, Abandoned Mine Lands, luke.esch1@wyo.gov, 307-777-7062
- Lindsey French, Project Manager, Abandoned Mine Land Division, lindsey.french@wyo.gov, 307-335-6959
- David C. Pendleton, P.E., Program Manager, Abandoned Mine Lands, david.pendleton@wyo.gov, 307-335-6945

Links/Resources for drone use in WYDEQ:

None.

Further Information

1. The E-Enterprise for the Environment EE2020 Webinar on Drones
E-Enterprise for the Environment hosted a EE2020 webinar series in lieu of an in-person meeting, with the December 2020 webinar topic focusing on deploying drones for improved environmental results. States, tribes, and U.S. EPA discussed how they are improving results and worker safety by deploying drones in emergency response, compliance monitoring, mapping, sampling, and other activities. This webinar presented activity overviews, techniques for managing all the new data, and lessons learned on the ground and in the sky.

Panelists from the following agencies participated:

- **Michigan Environment, Great Lakes, and Energy (EGLE)**
  Arthur Ostaszewski
- **Shakopee Mdewakanton Sioux Community**
  Ryan Bonney
- **North Carolina Department of Environmental Quality**
  Toby Vinson, Michael Griffin, Michael Ware
- **Fort Sill Apache Tribe**
  Josh Worcester, Monte Scammahorn
- **Louisiana Department of Environmental Quality**
  Jason Smith
- **U.S. EPA Region 9**
  Pete Guria

View the webinar slides, and listen to the recording in its entirety here.

2. Interstate Technology and Regulatory Council (ITRC) Report Including Remote Sensing
ITRC is a state-led coalition working to reduce barriers to the use of innovative air, water, waste, and remediation environmental technologies and processes. ITRC produces documents and training that broaden and deepen technical knowledge and expedite quality regulatory decision making while protecting human health and the environment. ITRC is a program of the Environmental Research Institute of the States, a 501(c)(3) organization incorporated in Washington, DC, and managed by ECOS.

In December 2019, ITRC produced the Advanced Site Characterization Tool document. The document is organized as follows: Section 3 – Direct Sensing, Section 4 – Borehole Geophysical, Section 5 – Surface Geophysical, and Section 6 – Remote Sensing. In particular, Section 6 – Remote Sensing provides detailed information on data collection by remote sensing devices such as drones, types of drones, flight considerations and best operational practices, camera selection considerations, and water sampling devices, and provides the following case studies:

- Water Sampling in Montana
  - Remote Piloted Aircraft System collects water samples to avoid safety concerns at a tunnels mine in the state of Montana
- Mine in Colorado
  - High-resolution and thermal aerial images identify mine openings at an abandoned mine in the state of Colorado
- Golf Course in Missouri
  - Drone technology expedites and streamlines site characterization at a former golf course in the state of Missouri.

3. Federal Aviation Administration (FAA)

- This Drone Webinar Series on YouTube is a webinar series hosted by the FAA to help drone operators understand how to operate in the National Airspace System and successfully apply for an airspace authorization.

4. U.S. Environmental Protection Agency (U.S. EPA)

- U.S. EPA presentation at the EE2020 webinar, December 2020 Minute 33:04 – 38:38
- U.S. EPA UAS Policy, December 2020
- Unmanned Aircraft Systems Presentation Asbestos Removal Site — U.S. EPA Region 2, Edison, New Jersey 08837, Paul Kahn, OSC, kahn.paul@epa.gov
- The Role of Unmanned Aerial Systems/Sensors in Air Quality Research, 2015 — U.S. EPA, Science Inventory
- Use of Small Unmanned Aerial Vehicles for Air Quality and Meteorological Measurements — U.S. EPA, Robert A. Baxter and David H. Bush, 2014 National Ambient Air Monitoring Conference

5. George Washington Journal of Energy & Environmental Law

The article "Navigating the Legal Landscape for Environmental Monitoring by Unmanned Aerial Vehicles (UAVs)" **published in Spring 2016** in Volume 7 No. 2 of the George Washington Journal of Energy & Environmental Law, discusses the technological advancements in UAVs, particularly how UAVs could enable government regulators to achieve more efficient monitoring options than the already existing environmental enforcement programs. The article focuses on how different state legal frameworks will affect agencies' ability to use drones and other approaches to remote monitoring. As of January 2016, 18 states had enacted legislation on UAVs that define how this technology is used by both law enforcement agencies and other state agencies. The following are a few key overarching points in response to the key question of the article—whether or not environmental monitoring using UAVs is tenable.

- As compact data collection platforms, UAVs can offer a number of unique services including:
    - On demand data through detectors;
    - Environmental sampling in difficult-to-reach locations;
    - High-resolution aerial surveys; and
    - Mapping of pollutants across a landscape, including subsurface contamination.
- UAV technology is attractive in light of its relative ease and low cost of deployment with the possibility of collecting and processing large amounts of data quickly.
- Agencies serious about pursuing any monitoring and enforcement programs that use UAVs should closely follow certain legal developments with specific implications.
    - First, an agency should develop awareness of the risk associated with deploying UAVs and carry appropriate levels of insurance to protect against potential injuries to property or persons caused by either a malfunctioning UAV or a negligently operated UAV.
    - Second, environmental enforcement agencies should ask state legislatures to be more explicit about the application of UAV legislation to routine environmental monitoring programs that are otherwise conducted by inspectors.
    - Third, environmental enforcement agencies should also request that state legislatures be explicit in their legislation about the extent of airspace rights for private entities and any public exceptions that might exist to that right.
    - Fourth, it is currently unclear to what degree the federal government intends to occupy the field in terms of UAV regulation. Environmental agencies should request that both federal and state lawmakers be as clear as possible about the relationship between federal and state laws.
- Finally, environmental agencies that are designing UAV-based environmental programs should be explicit about how they will be protecting constitutionally derived privacy interests.