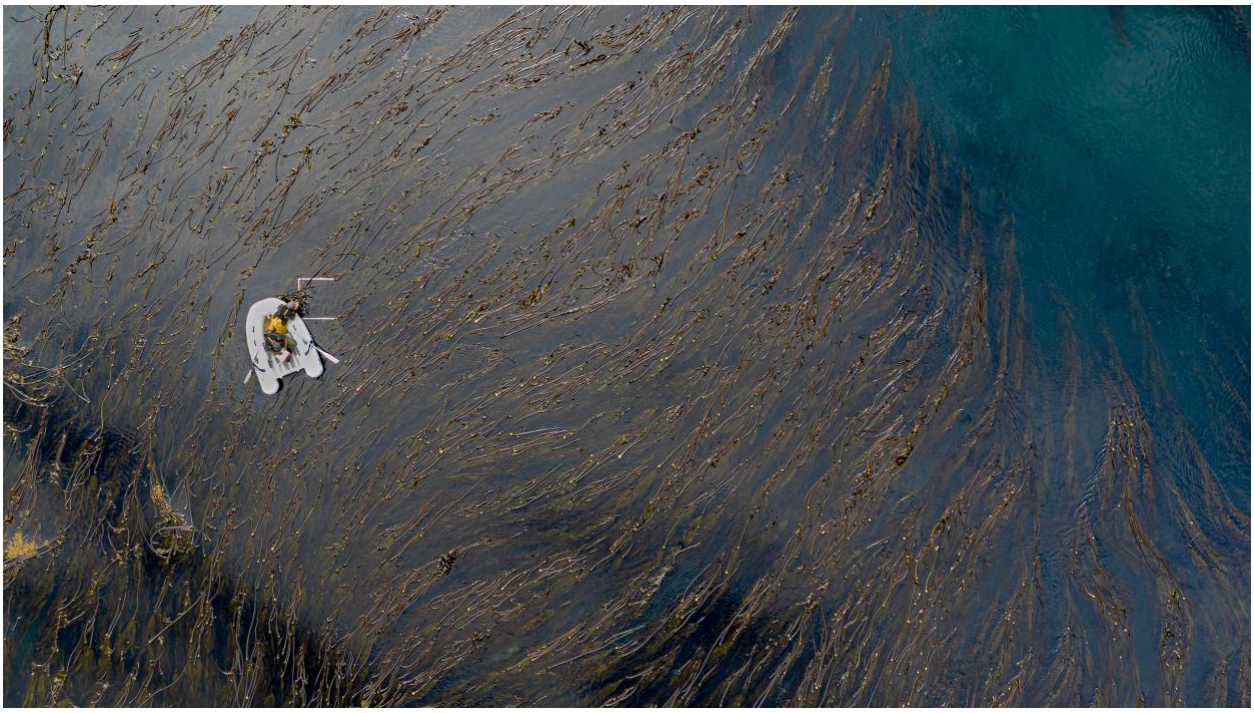

Marine Plan Partnership for the North Pacific Coast (MaPP)

DRONE MAPPING GUIDE FOR KELP MONITORING

Prepared by Markus Thompson for MaPP's Ecosystem Based Management Indicator Subcommittee
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Disclaimers:

The MaPP Partners and contractors or anyone else connected with MaPP, in any way whatsoever, are not responsible for use of the information contained in this document.

Please note that users of this document should review and implement their organizational safety protocols as required prior to conducting monitoring in the field.

The purpose of this document is to:

- support the MaPP Partners to conduct kelp monitoring training, field work and data collection
- provide guidance and examples for other organizations or practitioners wishing to conduct kelp monitoring

Introduction:

The following instructions are designed to guide field technicians through the process of planning, building, and flying a drone geospatial habitat mapping project. This is not a comprehensive guide covering drone flight software, hardware, or drone rules and regulations. Users should be familiar with their drone and drone manual, the Transport Canada rules for flying drones safely and legally, and have experience flying their drone before flying a drone geospatial mapping project.

Most consumer level camera drones – drones with stabilized high resolution cameras – can be used for geospatial mapping projects, but there are a number of drones that are designed specifically for this purpose. This guide covers twenty drones in four categories that can be used for mapping habitats:

1. DJI Enterprise and Matrice series drones using DJI Pilot 2 software.
2. DJI Consumer drones with no built in or third party mapping software.
3. DJI legacy drones (no longer supported by DJI) that can use third party mapping software.
4. Non-DJI Drones with proprietary mapping software.

DJI Enterprise and Matrice series drones are the most effective and easiest to use for mapping. DJI separates these drones into categories specialized for different industries. Thermal drones (the 3T, 30T, and 4T) are designed specifically for emergency response and industrial inspection work. Mapping drones (the 3E, 3M, 30, and 4E) are designed specifically for geospatial mapping and survey work. The primary visible light (RGB) camera sensor on the mapping drones is larger than the sensor on thermal drones, and uses a mechanical shutter – this allows the mapping drones to record images faster, sharper, and in lower light. The RGB camera on thermal drones can be used for mapping and will be adequate for most situations – but these camera sensors are not designed specifically for mapping tasks. All of the Enterprise and Matrice series drones use the same DJI Pilot 2 autonomous mapping software.

DJI camera drones (the Mavic 3, Mavic 3 Classic, Mavic 3 Pro, Air 3S, and Mavic 4 Pro) are designed for photography and videography. These drones have fast, sharp camera lenses but do not have built in software to autonomously run mapping surveys. Surveys must be completed manually. This requires some skill and experience, but if completed properly can provide high quality results. DJI legacy drones – no longer supported by DJI – and some non-DJI drones can be used with third party software (*DroneDeploy* and *DroneLink*) to conduct autonomous mapping surveys. The software however can often be unreliable, and it is advisable to know how to conduct manual surveys if using legacy DJI drones. Non-DJI drones often have their own proprietary software that can be used for geospatial mapping projects.

The ideal drone and mapping software will depend on the users' primary needs and their budget. The following list provides a breakdown of the most popular drones used for habitat mapping.

1. Habitat mapping with no budget limitations (both options include DJI Pilot 2 mapping software):
    - *DJI Matrice 4E*: built for habitat mapping with a large visible light sensor and mechanical shutter. Includes a medium range (70mm) camera that can be used manually by skilled pilots to conduct high resolution surveys. The *Matrice 4E* provides some incremental upgrades over the *Mavic 3E*, including the medium range camera, 0.5s image capture (vs. 0.7s) and 49min battery life (vs. 45min).
    - *DJI Mavic 3M*: built with the same large visible light sensor and mechanical shutter as the *Matrice 4E*. Includes multispectral lenses for advanced mapping projects. Multispectral sensors capture image data within specific wavelength ranges to extract

information that visible sensors (and the human eye) cannot see. There are many applications for multispectral photogrammetry, including monitoring and mapping forest health and density. Marine researchers use multispectral sensors to see further into the water column and to separate water from vegetation, including kelp and seagrass.

2. Dual use: habitat mapping + search and rescue:
    - *DJI Matrice 4T*: built for emergency services / search and rescue operations. Includes a thermal camera that can be used for to find people or wildlife under certain conditions. The visible light camera sensor is smaller on the 4T to create space for the thermal lens and it does not have a mechanical shutter. It can be used for mapping and will be adequate in most situations – but the drone will need to fly slower (i.e. cover less area per flight) and the images in low light will be lower quality when compared with the Matrice 4E. The Matrice 4T includes DJI Pilot 2 mapping software.
        - The *DJI Mavic 3T* provides similar capabilities at a slightly lower cost.
3. Habitat mapping on a budget:
    - *DJI Mavic 4 Pro*: built for professional photography and videography. Can be used manually by experienced pilots for habitat mapping. When completed properly can provide high quality results.
    - *DJI Air 2S*: can be used with third-party software (*DroneDeploy* and *DroneLink*) to fly automated habitat mapping surveys. The *DJI Air 2S* is no longer sold or supported by DJI (i.e. must be purchased used). The third-party software will not be as reliable as *DJI Pilot 2*.

DJI Pilot 2 – Build a Drone Survey:

- For the DJI Mavic 3 Enterprise series (3E, 3T, 3M) and DJI Matrice series (30, 30T, 4E, 4T).

Create a new flight route:

1. On the DJI Controller open DJI Pilot 2 and click *Flight Route* to access the *Flight Route Library*.
    - Here you will find all of the previously saved flight routes (a.k.a. surveys). You can organize these (top right menu option) by *Name*, *Date*, or *Distance*.
2. Click the + icon in the top right corner of the *Flight Route Library* to create a new flight route.
3. Select *Create a Route* from the drop down menu, then select *Area Route* from the list of options.
4. Move to the location on the map you want to survey using the controller touchscreen.
    - Change the map between standard and satellite view with the layers button on the right.
5. Follow the directions on the map to draw a polygon covering the area you want to survey (Figure 1).
    - Keep the polygon as simple as possible. Complex shapes will not stitch together effectively.
        - Make the polygon larger than the area you want to survey (~20% larger or more). It is very important to be sure the entire kelp bed is surveyed. If time and battery power allow, fly an area large enough to include adjacent kelp habitat, including kelp outside of the area that will be surveyed on the water with transects.
    - Inspect the survey map area for obstacles to your flight:

- Physical features (geographic or man-made) that may be within the altitude range of your survey (i.e. how high are the trees in the survey area).
- Areas where wildlife, human activity, airports, private property, or Provincial and Federal Parks may prohibit you from flying (refer to Transport Canada drone safety for drone flight regulations).

- Click and drag the polygon nodes as needed. Delete individual nodes with the garbage can button or delete all nodes to start again with the x button.
- Note the mapping info located top left, including *Mapping Area* and *Estimated Duration*.

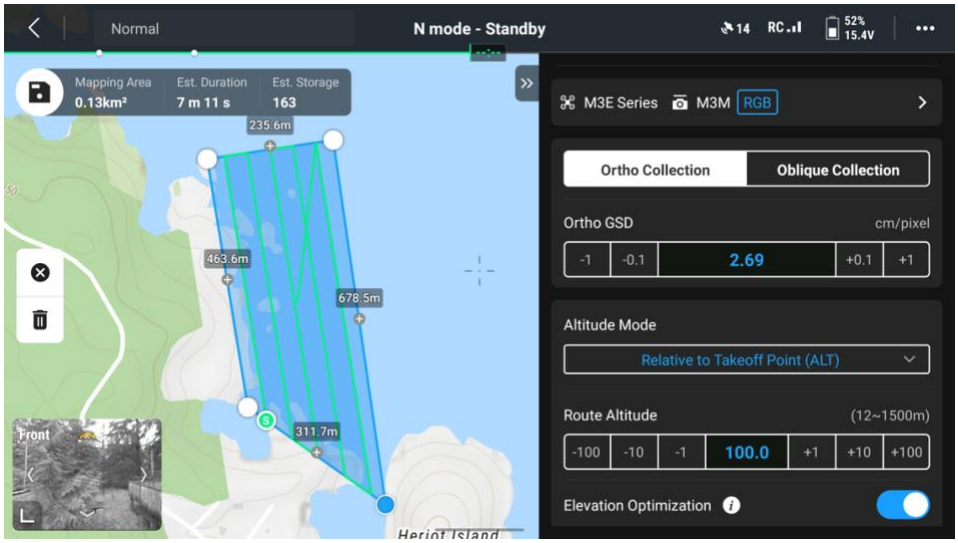

Figure 1: DJI Pilot 2 – Flight Route building tool.

6. Click the *Save Icon* (top left) to save the flight route area.
7. Click on the *Area Route* box to name your survey. Make sure the name is specific to the site and survey to ensure you and others working with the data can easily find and identify it.
    - Note: you cannot use the space or underscore characters. Use the dash or period.
8. Use the menu that opens on the right side of the screen to select the drone and camera you will use:
    - Select the *Aircraft*:
        - Select *M3E Series* for the Mavic 3E, 3T, and 3M
        - Select *Matrice 3D Series* for the Matrice 4E and 4T
        - Select *M30 Series* for the Matrice 30 and 30T
    - Select the *RGB Camera Model* for MaPP kelp and seagrass surveys.
        - RGB (visible light) images are used for analysis in the Kelp-o-Matic tool and for sharing images for communication purposes.
        - Select *Thermal* or *Multispectral* only when you are flying specifically for that data.
9. Adjust the altitude to 120m. Select a lower altitude if higher resolution is needed.
    - 120m will provide more than enough image resolution for standard photogrammetry surveys. Flying lower will increase the number of transects and the relative speed of the image sensor over the surface (i.e. you will need to lower the flight speed to keep images sharp).
10. Adjust the speed to 10m/s for bright skies (mid-day sun or bright clouds), 5m/s for dark skies (low sun or dark clouds). Full speed (15m/s) risks blurry images.

11. *Advanced Settings*: leave all advanced settings and settings not listed above in steps 1–8 in their default configuration for standard photogrammetry surveys.
12. Click the *Save* button (top left) to save the flight route to the DJI Pilot 2 library.
    - This flight route is now saved directly in your DJI Controller and can be accessed in your *Flight Route Library* (see Step 1 above) and selected to re-fly the same route (a.k.a. survey) consistently every year.
    - Review the flight route information by clicking on the down arrow next to the flight route name.
        - Note the *Duration*: will the flight require more than one battery?
        - Note the number of *Photos*: most processing services will not allow more than 1,000.
        - Click the pencil icon to edit the flight route settings.

NAV Canada – Preflight Planning:

1. Use the NAV Canada *NAV Drone* web portal or app to plan and verify your flight.
    - Create an account. Add your certification and drone registration details.
    - Plan your *Flight Operation* including the area you will fly, the pilot, drone, and category for the operation, and the planned flight time. *NAV Drone* will validate your plan and inform you of any warnings or restrictions, including airspace details and the weather forecast.
        - Use the NAV Drone map to see where nearby restricted (red and orange geozones) and warning (yellow geozones) flight areas are located.
        - Operations that follow the regulations in uncontrolled airspace will be allowed. Caution warnings will be provided if the flight operation overlaps airspace with uncontrolled air traffic (small airports, floatplanes, helicopters, and military airspace).
        - If your operation overlaps with an airspace that triggers a NAV Drone warning, click on the airspace geozone in the NAV Drone map and note the airspace details and contact info (typically a floatplane terminal or heliport). Call the listed flight operator(s) if you have any concerns about your drone interfering with air traffic or other operations. Fly with caution and be aware of flight times for uncontrolled air traffic in these areas.
        - Operations in controlled airspace will require you to obtain authorization from the air traffic controller or NAV Canada. Authorization can be requested via NAV Drone for airspace managed by NAV Canada (Class C, D, or E).
        - Save your flight in NAV Drone to register the flight with NAV Canada and create a flight log. You are required by law to register flights in controlled airspace. You are not required to register flights in uncontrolled airspace.

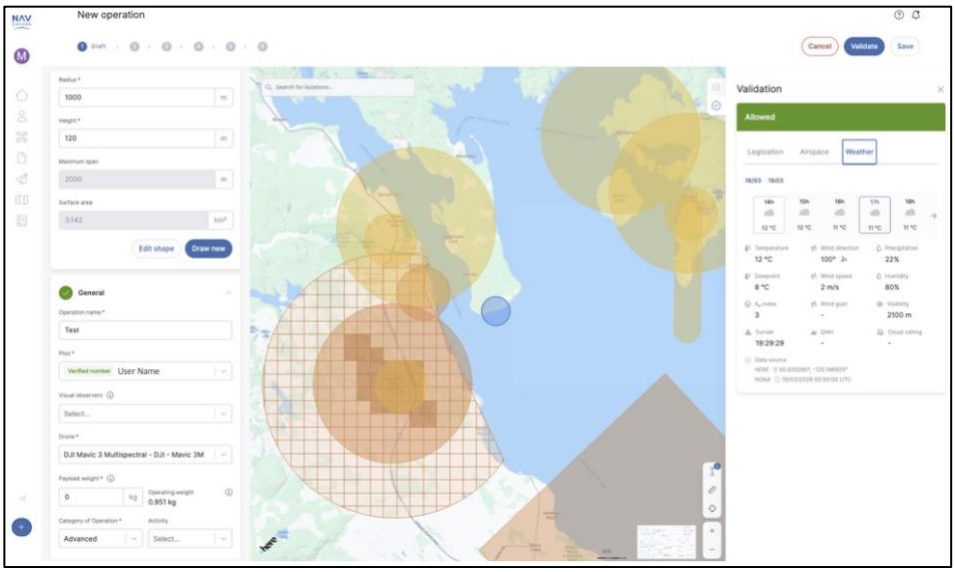

Figure 2: NAV Drone – flight operation validation web portal.

2. Check that the Transport Canada drone registration number is clearly marked on the drone.
3. Check that the controller and drone batteries are charged and the SD card is installed.
4. Check the drone frame, props, and gimbal for any signs of damage.
5. Turn the drone and controller on and connect to wifi to check for firmware updates.
    - Check that you are signed in to a DJI account if using a DJI drone. If you are not signed in to an account, DJI software will prevent users from flying more than 30m from the controller.
6. Check that you have packed a digital or paper copy of your flight plan, flight certificate, and drone registration.
7. Check weather, light, and tide elevation to ensure you have suitable conditions for your operation.

DJI Pilot 2 – Drone Flight Instructions:

1. Power on both the controller and the drone: tap the power button, then tap again and hold the button until you hear a series of beeps (time the taps like a double mouse click).
    - The power button for the drone is on the battery. Tap once to see the four light power indicator.
2. Click the Enter Camera View button on the controller touchscreen. This will take you to the Preflight Check.

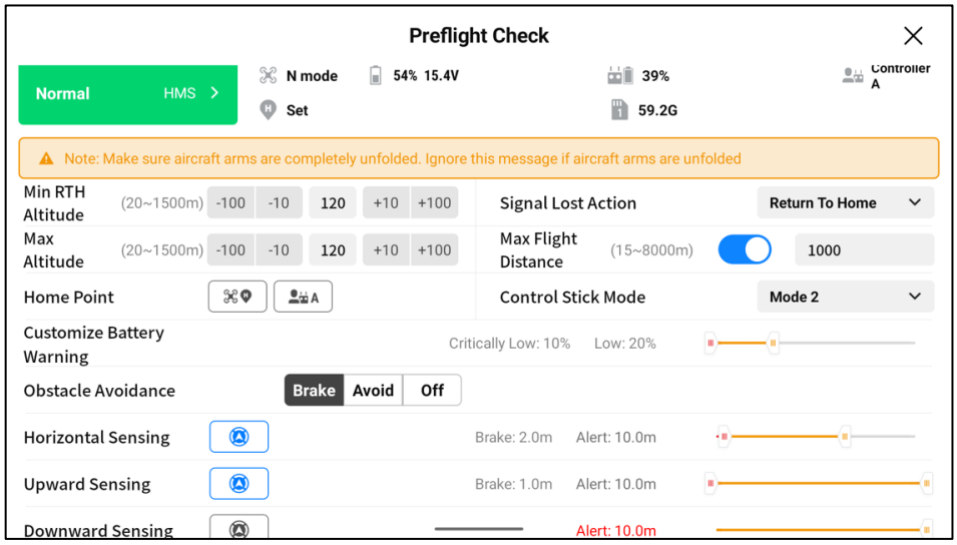

Figure 3: DJI Pilot 2 – Preflight Check screen.

- Check the battery levels for the controller and the drone.
- Check that the SD card is installed with enough space to complete your survey.
- Check the RTH (return to home) altitude. Set the altitude higher than trees and other obstacles.
- Set the Control Stick Mode to the default 'Mode 2' (Left stick: vertical plane movement + turning. Right stick: horizontal plane movement).
    - Some pilots may prefer flying with Mode 3 (left and right sticks reversed).

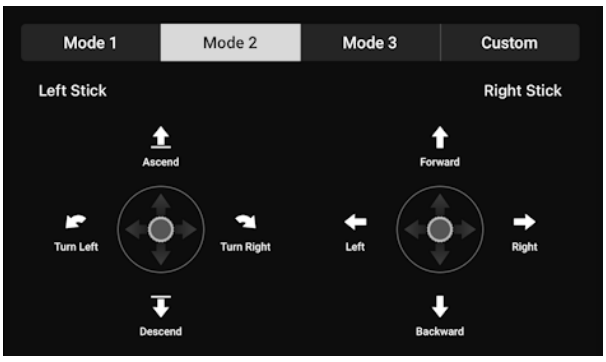

Figure 4: DJI Stick Mode 2.

- Set the Obstacle Avoidance to 'Brake'.
- Turn 'Downward Sensing' off if you will be landing the drone on a boat.
    - The downward sensors will cause the drone to hesitate before landing adding unnecessary risk when landing on a moving platform.

3. Check your flight area for wildlife, human activity, private property, or obstacles that may affect your flight.
4. If possible, take off and land the drone from a location on land where you can observe the drone flight path.
    - Flying from a boat increases the risk of losing the drone, particularly in wind and waves.
5. When flying from a boat use an assistant to hold the drone when taking off, and to catch the drone when landing.
    - Be aware of fishing poles, antennas, and other obstructions.
    - Keep clear communication with your assistant – communicate when you are powering the drone on, taking off, and the moment you are landing.
    - When taking off from the boat:
        - Fly up and away from the boat at a moderate speed to move clear of any obstructions.
    - When landing the drone:
        - The drone catching assistant should wear gloves and eye protection.
        - Face away from the sun so you and your assistant can see the drone.
        - Turn the drone around and fly the last 20m to the boat backwards. This allows your control inputs to match the drone movement (i.e. when you push left the drone moves left).
        - Keep your inputs slow and smooth. Rapid and/or inconsistent movement will make the drone difficult to catch.
6. The pilot should keep their eyes on the controller during the flight, while a designated visual observer keeps an eye on the drone and any potential hazards (wildlife, air traffic, and weather).
    - The controller screen gives the pilot access to information required for a safe and controlled flight, including speed, elevation, direction, battery power, and proximity to obstructions.
    - Maximum flight distance should not exceed 500m (roughly the distance where the visual observer can no longer see the drone). Maximum flight elevation should not exceed 120m.

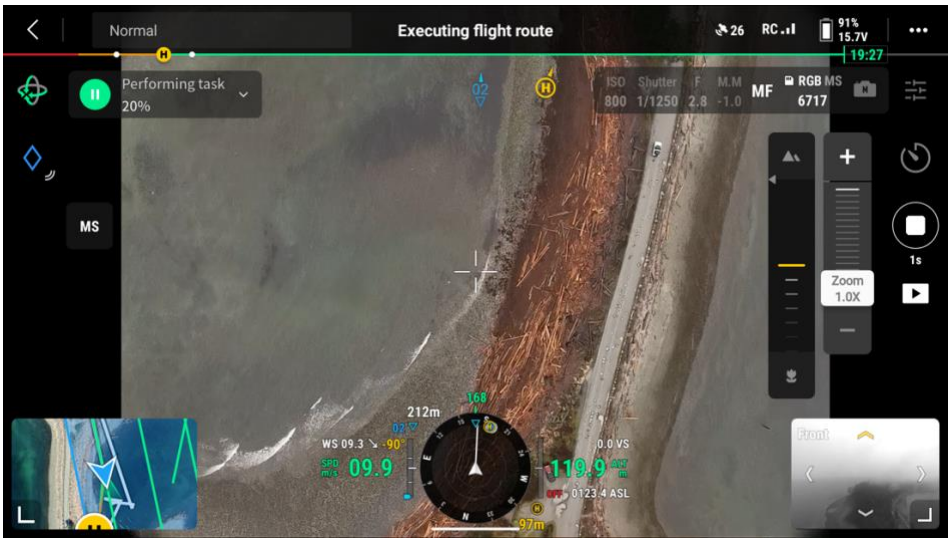

Figure 5: DJI Pilot on-screen display during flight.

7. Flight time: the pilot should start flying the drone home before the battery reaches 30% power.

- Monitor the weather, including wind direction and strength. Fly the drone home early if you will be flying against the wind (the estimated time remaining may not be accurate).
    - Note that the wind above the trees will often be stronger than the wind at ground level.

DJI Pilot 2 – Complete the Drone Survey:

1. Observe the area around you for obstacles to your flight.
    - Note tree heights, wildlife and human activity, private property, and any other activity, boundaries, or obstacles that could affect your flight.
    - Edit the flight route on the controller if needed.
2. Follow the *Drone Flight Instructions* above to start your drone flight.
3. Fly the drone manually to a location and altitude close to your survey starting point.
4. Click the *Flight Route* button (top left: S-curved arrow) and select the correct flight route from the list that opens on the right. The *Flight Route* button will change to a blue *Play / Start* icon and the flight route name.
    - Review the flight route information by clicking on the down arrow next to the flight route name.
        - Click the pencil icon to edit the flight route settings if needed.
    - Press the blue *Play / Start* button. Two checklist screens will pop up: *Preflight* and *Mapping*.
    - Review the *Preflight Checklist*, scroll down and click *Next*.
    - Review the *Mapping Checklist*, then click *Upload Flight Mission*.
        - Note the estimated duration. For large flight routes you may need to use more than one battery.
        - Leave all settings on default for standard surveys.
        - Advanced users: check and adjust the White Balance and Camera Modes.

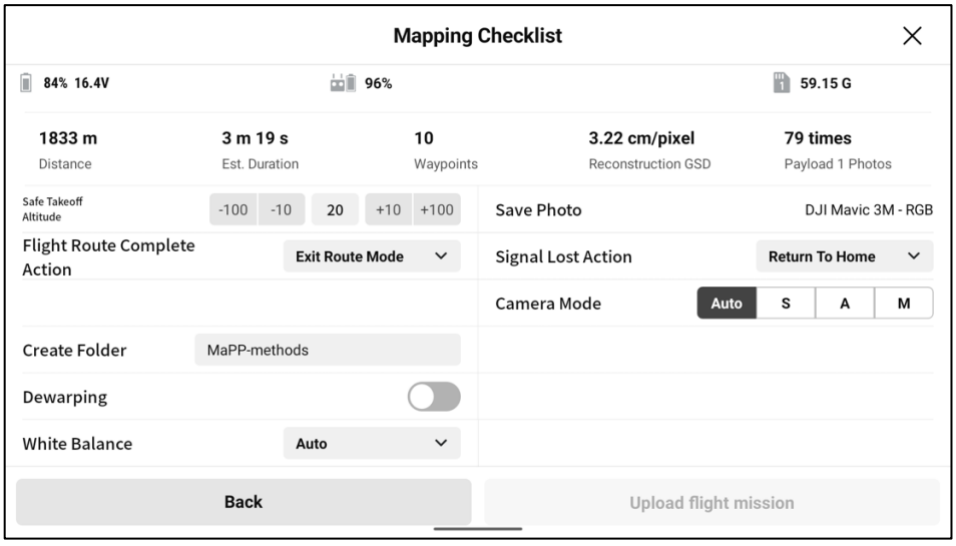

Figure 6: DJI Pilot 2 – Mapping Checklist

5. Monitor the automated survey progress.
    - Note the camera focus setting in the top right (MF, AF, or AFC). If it is set to *MF* (manual focus) click it to change the setting to *AF* (auto focus).

- Note the progress percentage (top left) in relation to the remaining battery time (red / yellow / green bar across the top). This time may adjust when the drone changes direction in relation to the wind.
- Click on the inset map screen (lower left) to view the map in full. Zoom in with the touchscreen as needed.
    - Click on the lower left screen again to return to camera view.

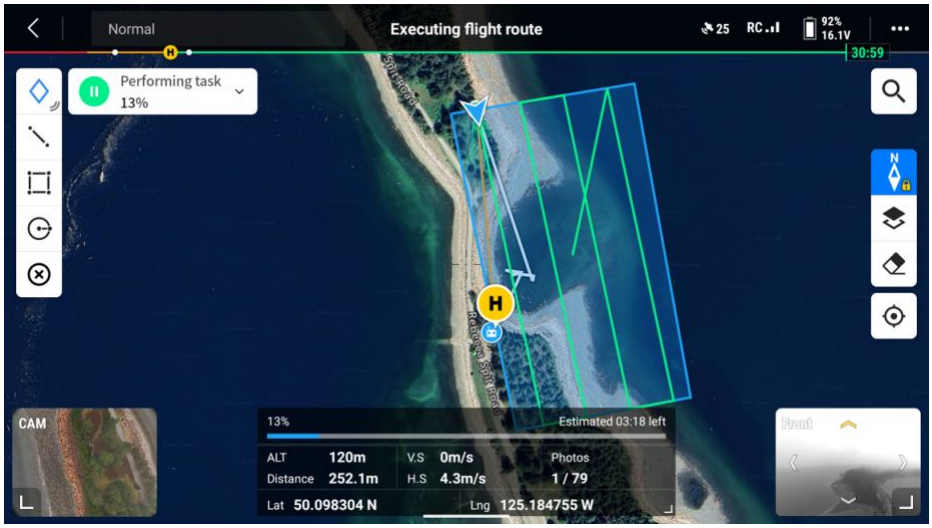

Figure 7: DJI Pilot 2 – Flight Route progress.

6. If the flight route cannot be completed before reaching 30% battery power, click the green *Pause* button (top left) to pause the survey.
    - Fly the drone back manually to swap out the battery.
    - Fly the drone manually back to a location and altitude close to where you paused the survey. Click the blue *Play* button (top left) to resume the survey.
7. When the flight route has completed fly the done back manually. You may need to exit or pause the survey if it was set to return home and / or land when complete.

Survey Methods for DJI Consumer Drones:

- DJI Mavic 3, Mavic 3 Classic, Mavic 3 Pro, Air 3S, and Mavic 4 Pro.
    - Automated survey software is not available from DJI or third party developers for DJI consumer drones. Surveys must be completed manually. See instructions below.

1. Use a mapping app on your tablet or smart phone to visualize a plan for your survey.
2. Set the *Photo Mode* (above the touchscreen shutter button) to *Timed Shot – 3 seconds*.
3. Set the *Flight Mode* (toggle switch labeled 'C N S') to C (*Cine Mode*).
    - *Cine Mode* is set to 5m/s by default. You can adjust this speed if needed in the controller main menu (Control – Gain and Expo – Cine – Horizontal Speed).
4. Launch the drone and observe the survey area to visualize your flight plan. Note the space and geographic features where you will fly a series of parallel transects to complete the survey.
    - Find a straight section of coastline along the edge of your survey area to fly the first transect.
    - Visualize the space where you will fly a series of parallel transects to complete the survey.
    - Note geographic features that can give you a cue to stop and move to the next transect.
2. Fly to the starting point of your first transect (it should be directly below the drone). Turn the drone to align the center of the camera view with the direction of the transect.
3. Use the camera gimbal dial (top right on the controller) to set the camera angle straight down at 90 degrees.
    - The camera will stay in this position for the remainder of the survey.

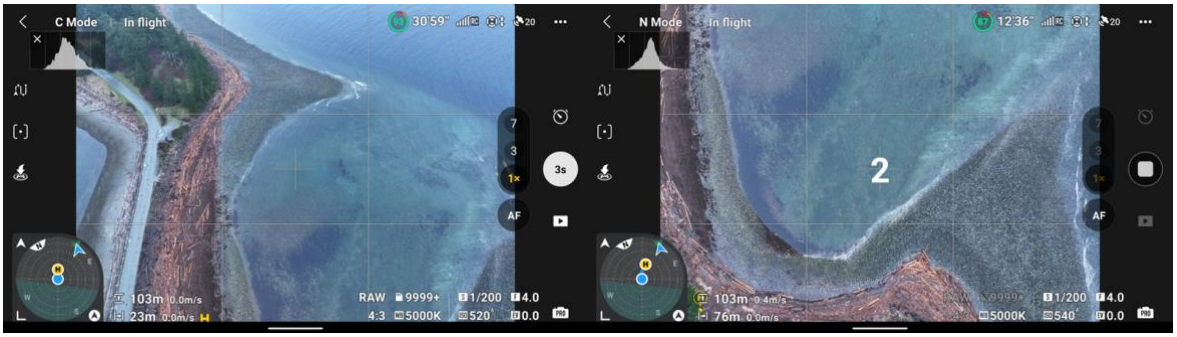

Figure 8: 1. Align the camera view with your first transect. 2. Set the camera to 90 degrees (down).

4. Tap the camera shutter button on the controller touch screen.
    - The drone will now take a photo every 3 seconds until the end of the survey.
5. Move the right stick all the way forward. Hold it in this position.
    - The drone will now fly down the transect at a constant 5m/s.
6. For the remainder of the survey only use the right stick and only fly in straight lines (forward, back, left, right).
    - Using the left stick will change the altitude and/or direction of the drone. Do not use the left stick.
    - Watch for the geographic features that cue the end of the transect.
    - Stop at the end and note an object in the middle of your camera view (a rock, log, or other object).

- Keep an eye on the object and move the drone sideways until the object is located at the edge of your camera view (far left or right). You are now on the next transect and your images will overlap by ~50%.
- Do not turn the drone around. Fly backwards down the new transect to the end.
- Use the map – tap the inset compass or map in the lower left corner of the screen – to see your flight path. It should show straight lines covering the survey area you have competed (Figure 9). In this screen you can follow your progress and make small direction adjustments if needed to ensure that the lines are equally spaced and straight.
    - Your flight paths don't need to be perfect – you just need 50% or more overlap between images.
    - Note: the red arrow in Figure 9 shows the drone moving backwards.

7. When you have reached the end of the last transect tap the shutter button to stop taking photos, raise the camera back up to see the horizon, switch the drone back into N (Normal) flight mode and fly home.

Figure 9: Map view showing the flight path during the survey.

Survey Methods for Legacy DJI Drones:

- DJI Mavic 2 series, DJI Air series, DJI Mini series, and DJI Phantom series.

Use *DroneLink* or *DroneDeploy* (third party software apps) on your smart phone or tablet to fly an automated survey.

- Automated survey apps typically follow similar protocols and can be set up using the instructions below.
- Check the software developer compatibility lists and instructions for full details.
- Note: the *Pix4D Capture* app is no longer available or supported by Pix4D.

1. Open the app and select the polygon option to build your survey.
2. Navigate to your site on the map using your smartphone touchscreen.
3. Place and move nodes as needed to build your survey area.
    a. Set the elevation to 120m.
    b. Set front and side overlap to 70%.
    c. Adjust the survey size and transect direction to manage the estimated survey time.
    d. Set the drone speed to a low or medium speed (5-10m/s).
4. Save the survey and note the survey name or number for future reference, so you can re-fly the same survey consistently every year.

5. If the survey plan does not connect or load properly try restarting the app.
    a. Third party apps may not always work as intended. Test the app before using for fieldwork. If the app fails, follow the instructions in the DJI consumer drones section to complete a manual survey.

Survey Methods for non-DJI Drones:

DJI competitors – Autel, Skydio, and Parrot – build their own autonomous geospatial mapping software. Notes on software utility and ease of use in comparison to *DJI Pilot 2* for non-DJI drones are provided below.

- Autel Robotics EVO II:
    - *Autel Explorer* – geospatial mapping software built into the flight controller. *Autel Explorer* is similar to *DJI Pilot 2* in terms of workflow and user interface. It is simple to learn and generally produces reliable results. The user interface however is not as robust or refined as *DJI Pilot 2*.
- Skydio X10 series:
    - *Skydio Flight Deck* – AI driven geospatial mapping software built into the flight controller. *Skydio Flight Deck* is an effective mapping tool, but the user interface is not intuitively simple to use.
- Skydio 2 series:
    - *Skydio 3D Scan* – AI driven 3D mapping tools built into the flight controller can be used for automated 2D surveys, but the software is not designed specifically for geospatial mapping.
- Parrot ANAFI:
    - *FreeFlight 6* app – waypoint flight plans can be used for automated surveys, but the software is not designed specifically for geospatial mapping.

Geospatial Map Processing Options:

Images captured using *DJI Pilot 2*, non-DJI software, third party mapping options, and manual surveys all have georeferenced positioning information embedded in the image EXIF (Exchangeable Image File Format) data. This allows any mapping software designed to process georeferenced orthomosaics to work with your images. DJI offers a native desktop processing software – *DJI Terra* – designed as the direct counterpart to *DJI Pilot 2*. For advanced users requiring more control over processing parameters, options include *Pix4D Mapper* and *Agisoft Metashape*. *WebODM OpenDroneMap* is an affordable desktop based alternative. User friendly cloud-based options are also available from *DroneDeploy* and *ArcGIS Site Scan*. Notes on cost and utility are provided below:

- *DJI Terra*: mapping and modeling software designed to work with *DJI Pilot 2*.
    - Utility: seamless integration, efficient workflow, user friendly. Designed to work with images from DJI Enterprise and Matrice series drones.
    - Purchase of Enterprise and Matrice series drones includes a 6 month to 1 year *DJI Terra* trail licence.
    - Cost: US $1,850/yr.
- *Pix4D Mapper*: US based desktop photogrammetry software often used by professionals requiring advanced processing for industry based projects.

    - Cost US $4,000/yr.
- *Agisoft Metashape*: Russia based desktop photogrammetry software for academics and professionals requiring customizable automation. Requires a computer with sufficient processing power.
    - Utility: interface complexity and processing power built for complex 3D mapping and modelling. Map parameters and output quality can be customized with user input Python scripting.
    - Cost: US $3,500 for a perpetual licence.
- *DroneDeploy*: cloud-based user friendly photogrammetry processing with built-in measurement tools.
    - Utility: the most user-friendly option.
    - Cost: US $1,900/yr.
- *ArcGIS Site Scan*: cloud-based photogrammetry software designed for organizations already invested and embedded in the ArcGIS ecosystem.
    - Utility: processed maps feed directly into ArcGIS databases.
    - Cost: US $5,000/yr.
- *WebODM OpenDroneMap*: open-source web-interface photogrammetry software.
    - Utility: provides comparable results to commercial software. Requires some expertise to install and run using a virtual environment (Docker container). Requires a computer with sufficient processing power.
    - Cost: US $60 (for Windows installer).