The additional gains when integrating drone technology as a business tool in New Zealand's district council structures

by

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ABSTRACT

Worldwide, drones are being employed by many industries vital to architectural and engineering practice, including territorial authorities (TAs) and councils. This is largely thanks to the breath-taking speed at which drone technology has developed and become more sophisticated. Drones are now equipped with precise sensors, are made from highly durable materials, and enjoy much longer battery life than they did only a few years ago. In combination with the latest software solution, drones allow TAs and councils to undertake projects which were previously unimaginable. Local authorities in New Zealand are slowly realising the potential of drones and are beginning to integrate them as a recognised tool.

This paper weighs the advantages and challenges incurred by New Zealand local authorities in employing drones. Industry data from Airways about drone usage were compared against statistical data. Drone deployment in district councils was mapped and three cases of drone use in councils were compared and analysed. A field study in Wainuiomata was carried out for final demonstration purposes. The findings confirmed the usability of drones as a business tool for TA and council tasks such as aerial mapping and asset inspection, but also indicated the need for an overarching organisational structure.

Keywords: Drone; Council; Aerial Mapping; New Zealand

1 INTRODUCTION

Worldwide, unmanned aerial vehicle (UAV) – or drone – technology is being increasingly used and researched. The combination of longer battery life, new sensors, and an ever-increasing payload in conjunction with industry-specific software opens up application areas that were uneconomical or even technically impossible until quite recently. The international Data Corporation forecasts that the investment in smart cities will reach 80 billion USD in 2018 [83] and will rise to 121 billion USD in 2021. Thus it is unsurprising that the potential uses of this key technology interest governments and local authorities.

The UK-based charity NESTA sees over 600,000 jobs in the drone economy by 2030 and a challenging competition worldwide for a leading position [1]. The "Flying High" project, a collaboration between the University of Southampton and five participating cities [2], explored the hypothesized economic potential of drones and their social benefit to the UK. It showed that smart Drones have been successfully used in urban case studies related to medical delivery, traffic incident response or the support of fire and rescue services, to mention a few. NESTA found there was a general lack of knowledge about the potential of drones including the detail of the governing policy environment and the usability for council needs [1] under the public and some city stakeholders.

New Zealand's many remote locations present ideal opportunities for the successful deployment of drones. For example, the University of Canterbury was sponsored by Defence Technology Agency to analyse volcanic distal ash clouds [72], which pose a risk to jet aircraft engines. The solution provided information about the ash location and helped define safe flying regions. But it is at the Territorial Authority (TA) level that this technology seems to be having impact.

In 2016, Peter Wimsett, GIS Manager at Tararua District Council, attempted to embed drone technology in council-related functions through bridge inspections [81]. Wimsett claimed, at the Autumn 2018 conference of the Association of Local Government Information Management (ALGIM), that drones are useful business tools for a variety of council-related tasks [81]. He concluded that investment is needed and reported he had the data to prove this.

The small regional district council Tararua is named as a leader in drone technology in Oceania and their GIS consultant, Roger Blair, believes that in a few years every engineer would use a drone as another day-to-day business tool [77]. The spectrum of UAV adoption in other districts ranges from professional use to cautious approach and outright rejection of this technology. In the face of these different approaches and the fact that an organizational framework is missing, the New Zealand Local Government UAV Interest Group was created under the initiative of the Ruapehu District Council (RDC) after the 2018 Association of Local Government Information Management (ALGIM) conference. The interest group was created to provide a channel for discussion regarding UAV operations. The importance of more research is highlighted by the attempts of individual councils to communicate their acquired knowledge to other authorities in order to help reduce the information deficit.

New Zealand's central government and local authorities are responsible for its citizens and are therefore required to identify and counter risks to its citizens with state of the art technology, particularly with a view to fostering global economic success and competitiveness. Councils should have data sovereignty [73] rather than relying on services outside the country. They are further required to work economically. It is claimed that drone technology has, in areas such as bridge inspections [38] [57], already proven to be more economic [1] when it comes to asset inspection. It has been proven safer and, as an out-of-the-box solution, faster than conventional methods in addressing some of the already-mentioned issues. Also, it provides a video record that is a strong evidence base for non-technical decision makers in the TA's.

It is important to further research the practical use of UAV technology and to explore the potential gains and limitations for New Zealand authorities.

This paper will initially give a broad overview of the current literature in the field and reflect unmanned aerial vehicle (UAV) applications that are in use worldwide and then proceed to represent the commercial drone industry in New Zealand. Subsequently, it will compare UAV abilities with potential council needs in New Zealand. It will further map the use of commercial drones being used to undertake district council activities and compare this use with publicly available data.

In the final step, the gathered case reports provided by 3 different District Councils were analysed and compared. The differences and similarities of the data are compared and presented in an overarching, new process framework, which maps the activities involved in drone imagery capture. This process framework can then be used by other researchers and users as a basis for Council departments intending to use UAV technology to follow more uniform methods and technical standards when using drones for council tasks.

Eventually the additional possibilities of obtaining information such as orthographic photos and digital surface models (DSMs) through the practical use are presented in an exemplary field test in Wainuiomata.

This paper hypothesises that drones, among their other useful capabilities, can in some cases replace or deliver complementary solutions to traditional data-gathering methods; and that drones could, in a competitive economic framework, be an effective professional business tool, especially for extremely high-resolution data acquisitions, such as aerial mapping, asset inspections in small or inaccessible areas where user-defined, up-to-date material is required.

The possible implications, such as the need for an organizational framework, infrastructure, and any legal implications for architectural use in New Zealand are beyond the scope of this paper and as such not discussed in depth.

If this paper confirms the information gain resulting from the use of drones to be worthwhile, it would provide enhanced independence from third party data for councils and providing a flexible and faster path for data gathering and therefore more economical and precise results.

1.1 Research Objectives

This paper examines the future of architectural and engineering practice for New Zealand Councils. Are drones changing the way councils gather information and to what extent should this be done?

Objectives:

- to gain extensive knowledge of the extent to which drones can deliver additional information for aerial mapping and imagery beyond that which conventional methods can offer
- to gain a knowledge of other relevant drone capabilities for the New Zealand built environment
- to create awareness of potential challenges for drone in-house operations in TAs and Councils
- to enable decision makers to access the most crucial knowledge fields in this domain for their judgement

2 LITERATURE REVIEW

The literature review for this paper was primarily concerned with potential use of drones for TA and Council needs. Some sources in the literature which named the main key application areas of drones as their usage in agriculture [48] and in disaster response [49] are not further treated in this paper. McKinsey sees the construction industry with increasing automatization and networking requirement as one of the key trends for the next decade [76], and smart cities [75] will play a big role. The following reviewed literature is focusing on these requirements.

2.1 OVERVIEW: DRONE TECHNOLOGY FOR TA'S AND COUNCILS

It seems likely that the implementation of enhanced information and communication tools in a smart city network will lead to more sustainability by lowering resource consumption and improve the quality of life of its residents [3]. [4] predicts that wireless sensors, cloud computing big data and networked unmanned systems will and that these advances will make it possible to use drones as flexible units to integrate them into the smart city infrastructure.

The use of drones is increasingly being reported in categories such as civil defence, asset monitoring, situational awareness, and inspection.

UAVs support **civil defence and safety** for the urban infrastructure by their capacity to deliver broadband wireless connectivity [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], establish wireless sensor network [15], [16], [17] and providing radio coverage during emergencies. When it comes to security they can [18], [19], [20], [21], [22], [4] enhance urban surveillance [3] with the ability of aerial observation [13] which brings them in the range of suitable border surveillance [23].

UAVs support with **monitoring** capabilities civil defence teams on the ground [24], [25], give assistance in cases of emergency [23] and search and rescue [25] as well as firefighting [26], locating victims [27], personal protection [28], hazardous material recovery [29]. evacuation assistance [30], [31], damage assessment [34], situational awareness such as heat source detection [24], [25], gas monitoring [31] and radiation detection [30], forest fire monitoring [13], [29], natural disasters (floods, fires, landslides) monitoring [35]and public safety on beaches [40] or ports [41]. They are observing and monitoring traffic movements [13], [29] when counting cars [32] and observing other traffic control systems [33]. Their abilities to map vegetation [34], monitor ecosystems [34], weather forecasts [4] and atmospheric forecasts [35] are also being proven. UAVs can provide **situational awareness** [24] when it comes to border patrol [13] [23], coast patrol [40]coastal management [34]. When surveying with their terrain-mapping [19] and data-collecting abilities [18], they can be generally used for **inspection and repair** in hazardous or difficult to reach environments [19]. Hence, UAV technology or drone use will increasingly be a data source for TA and Councils.

2.2 Practical use Areas: Aerial Mapping and Asset Inspection

Aerial mapping is the process of collecting airborne imagery using helicopters, planes, balloons or drones as a preliminary stage for the creation of map material. Visual imagery captured by drones [55] can accurately map larger areas in high detail via a process known as *image stitching* or merging PCD (Point Cloud Data) with photogrammetry data taken from UAVs or generate spatial data for extracting the amount of earthwork [56] for construction purposes or estimating landslips after natural disasters [85] .

Drones are being deployed more and more due to their ability to cover different height levels [38], unique viewing angles and, due to their imaging capabilities they are used to generate and provide 3D models and aerial mapping. Drone technology claims to provide enhanced image quality and damage identification for bridge inspections [86] at a lower cost compared to traditional methods.

2.3 Advantages for Drone Implementation in Local Councils

Drones have the given attribute to act mobile [6] [36], [37] and airborne [20] and hence could be preferably used for these reviewed application areas.

When it comes to sensing abilities such as surveillance, monitoring, or situational awareness based on real time, their mobility [20], their capability to fly in 3D spaces [6], relatively lightweight [20] and their potential to cover large areas [38], [13] [23] makes drones perfect for urban sensing platforms [3], [13]. Modern drones are, to an increasing extent, able to provide on-board decisions [25] paired with significant embedded processing power [20], so that tailored and complex surveys can be done, e.g. the assessment of urban structures such as bridges [38] or in creating 3D models within urban locations [39]. Especially within the context of critical operations, UAV technology has the massive advantage of being expendable [36] and have been deployed to support human operators on the ground [39] [24], [25].

2.4 CHALLENGES FOR DRONE IMPLEMENTATION IN LOCAL COUNCILS

Whenever a new technology is to be integrated into an existing structure, challenges arise in terms of costs, organizational conditions, knowledge and employees. Some of the most important areas of knowledge are explained in the following section.

2.4.1 HARDWARE REQUIREMENTS AND COST

The market for hardware in connection with a large number of sensors and accessories is not shown in detail here. DJI is the market leader for commercial drones, followed by 3DRobotics and the French based company Parrot [88].

Drone Type	**Pros**	**Cons**	**Applications**	**Price $ NZD**
Fixed Wing	Large area coverage	Price Launching and Landing	Area Survey Structural and asset inspection Aerial Mapping	$ 20k-$150k
Rotary Wing Helicopter	Large Payload, Hovering	Price	Inspection Supply Drops	$ 20k-$150k
Multicopter	Price Availability Hovering Small area Indoor use	Limited payload Short flight	Area Survey Structural and Asset Inspection Aerial Mapping	$ 3k-$50k

Table1: Comparison of different drone types

2.4.2 SOFTWARE REQUIREMENTS AND COST

The most widely soft used for post-processing found in the reviewed literature are the in Switzerland based company PIX4D S.A. [69] with PIX4DMapper [47], [57], [58], [59], [60], [61], [62], [63], and the in Russia based company Agisoft [70] with their software product Photoscan [42], [59], [61], [62], [64], [65], [66], [67] (since 2019 rebranded to Metashape).

Company	**Product**	**PROS/Cons**	**Outputs**	**Price**
PIX4D [69]	PIX4DMapper	Most expensive Solution but most also most used in professional area, extensive Knowledge needed	Colored Point Cloud, Classified Point Cloud, Orthomosaic, Digital Surface Model, Digital Terrain Model, 3D Textured Mesh, Contour Lines, Façade Digital Surface, Index Maps, Thermal Maps, Façade Orthomosaic	$ 4990 USD One time charge $ 292 USD Monthly subscription
Drone Deploy [87]	Large Payload, Hovering	More flexibility, Outsourcing for Post processing Less upfront cost, Works on IOS and Android devices	Professional Platform for specialized applications	$ 250 USD With annual commitment

AGISOFT [70]	Metashape	Less upfront cost, extensive Knowledge needed	Colored Point Cloud, Classified Point Cloud, Orthomosaic, Digital Surface Model, Digital Terrain Model, 3D Textured Mesh, Contour Lines, Façade Digital Surface, Index Maps, Thermal Maps, Façade Orthomosaic 4D Modelling,	$ 3499 USD Professional Version $ 179 USD Standard Version

Table2: Comparison of post-processing software

2.4.3 LEGAL REQUIREMENTS FOR THE OPERATORS

Operators who are flying in controlled airspaces (Figure 1) need to satisfy the Civil Aviation rules part 101 and 102 when operating in this area [53]. All airport operators included those ones for helicopters in an area of at least 4 km of any uncontrolled aerodrome, unless the operation is undertaken in accordance with an agreement with the aerodrome operator. Drone operators also require an air traffic control clearance issued by Airways when flying inside of controlled airspace. The time, location and all flight details need to be transmitted alongside and pilots are required to identify any risks and the associated plans they have in place to mitigate those risks. Professional drone operators are also required to hold a 102 certification for their company or organisation.

CAA [53] strictly defines that operating a drone according to its Part 101 regulations is only permitted if pilots:

referencing text

1. do not operate an aircraft that is 25 kg or larger and always ensure that it is safe to operate [53]
2. at all times take all practicable steps to minimize hazards to persons, property and other aircraft (ie. don't do anything hazardous) [53]
3. fly only in daylight [53]
4. give way to all crewed aircraft [53]
5. be able to see the aircraft with their own eyes (eg. not through binoculars, a monitor, or smartphone) to ensure separation from other aircraft (or use an observer to do this in certain cases) [53]
6. not fly their aircraft higher than 120 metres (400 feet) above ground level (unless certain conditions are met) [53]
7. have knowledge of airspace restrictions that apply in the area they want to operate
8. do not fly closer than four kilometres from any aerodrome (unless certain conditions are met) [53]
9. when flying in controlled airspace, obtain an air traffic control clearance issued by Airways [53]
10. do not fly in special use airspace without the permission of the administering authority of the area (eg. military operating areas or restricted areas) [53]
11. have consent from anyone they want to fly above [53]
12. have the consent of the property owner or person in charge of the area they are wanting to fly above. [53]

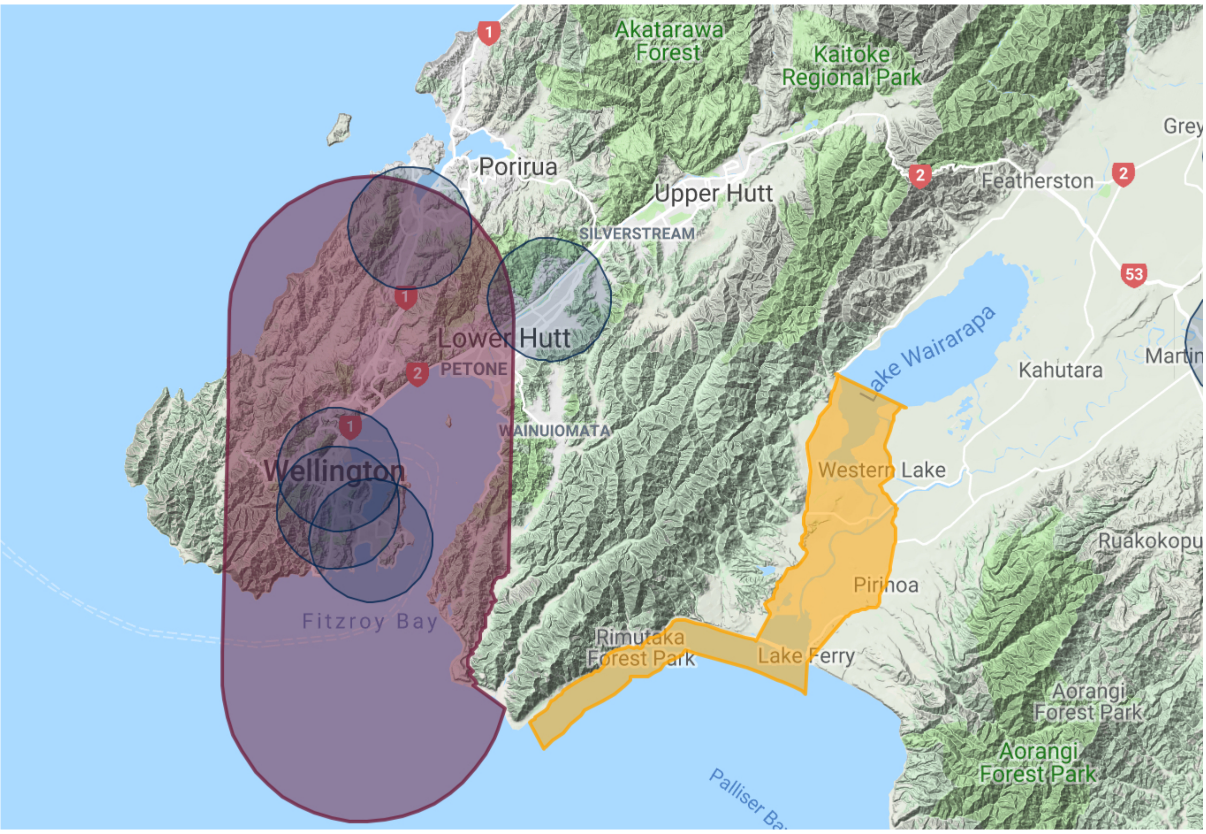

FIGURE 1 EXAMPLE FOR THE WELLINGTON AREA FROM AIRSHARE [71]

The red transparent areas in Image 1 indicate controlled zones and are managed by Air Traffic Control [71]. The blue circled areas indicate a radius of four kilometres around every airport. The orange areas are low flying zones. UAVs are not permitted in low flying zones.

2.4.4 DATA ACQUISITION

The sensor and drone type used for data acquisition depends the intended use.
In addition there is a requirement for the capture software which is used the definition of an automated flight process. This depends on inputs such as flight altitude [22], camera angle and model and other data. The environmental conditions such as rough obstacles, trees or the protection of the public and many other factors are influencing the strategy.

2.4.5 POST-PROCESSING OPERATION

In this phase, the images generated by drones and the GPS position data are loaded into photogrammetry software. In the first step, this software merges the images like a mosaic [43],[44]and uses SFM (Structure from Motion) algorithms to produce a spatial 3D structure [42]. Due to the strong overlapping of the images, a measuring point can be seen several times in other images and needs to be checked for possible errors. Photogrammetric algorithms [47] allow the software to measure the exact position of the drone, camera and ground geometry. The resulting large number of measuring points on the ground is also called 'point cloud' [48]. In this point cloud, the operator can manually select the ground control points and assign them to the measured GPS positions. Thus the whole 3D model can be georeferenced[45][46]. This means that after this step the surveyor can read the precise position at any point in the model.

2.4.6 SECURITY, PRIVACY, AND THE LEGAL FRAMEWORK

Drones have a kind of social stigma attached to them [50] and they are seen by many people as posing a potential risk to society because of concerns about privacy, data protection and unwanted surveillance [51].Deploying drones in dense urban areas where they have a potential to cause harm through collisions with planes or other aircraft in national airspaces [52] can produce a potential risk. In response to this, lawmakers in New Zealand have had to tighten the rules to protect the national airspace [54] and are trying to balance the advantages of drones with safety and privacy concerns on the ground. In order to receive clearance to use a drone in a controlled airspace, a pilot must request authorization from the Civil Aviation Authority [53] . The UK based government global innovation foundation NESTA [1] sees the need to develop a shared vision between convened key stakeholders and regulators.

FIGURE 2 ENGAGEMENT -STAKEHOLDERS AND REGULATORS NESTA (2019)

2.5 OVERVIEW: ACTIVITIES IN ARCHITECTURAL AND ENGINEERING PRACTICE

In recent times, two large New Zealand organizations have been conducting surveys on the usage patterns and operational backgrounds of commercial drone operators. The CAA government agency tasked in the survey from 2017 with establishing civil aviation safety and security and as such have rules in place that Remotely Piloted Aircraft Systems (RPAS) users must abide [80]. The second survey [79] from Airways in 2018 is focusing on similar views as the only air traffic service in New Zealand. They sent out 7000 questionnaires to their operators and received 1442 responses. 77.56 % have been using drones for filming and images and 70 % of business owners were expecting that the demand for drones will increase 2019. Only 4 % of all operators were women.

2.5.1 THE INTRODUCTION OF DRONE TECHNOLOGY INTO TAS AND COUNCILS

The American company Mulkey Media is concerned with the technological requirements placed on Smart Cities [77] in the areas where rapid data generation collection, analysing and delivering is required. The special position of the Tararua district is emphasized [77] at this point, which, due to the large service area, is able to handle some of its tasks with drone technology. Blair Rogers, a GIS consultant of Tararua District Council believes that drone technology will be most effectual [77] during and in and in respond to disasters such as floods or earthquakes. The ALGIM (Association of Local Government Information Management) is trying to provide professional development and thought leadership across local district councils and as such presenting on regular basis examples and future outlooks of drone technology on its regular annual conferences [78].

The following chapter deals with three different case studies on droning missions within district councils in New Zealand grouped each in categories as opportunities and challenges, execution, and Quality controlling. The content is only the restructured summary of the given reports and in full length available in the appendix of this paper.

2.5.2 DRONE TECHNOLOGY AS A DAILY INHOUSE BUSINESS TOOL AT TARARUA DISTRICT COUNCIL [CASE STUDY 1]

Opportunities and Challenges

In a May 2016 report titled Tararua District Council: Drone Acquisition Project Plan
Peter Wimsett reported that, because drone technology had at that point reached such an advanced stage in its development, opportunities for its more widespread use by councils could be said to be commercially justified.

Tararua District Council's *Drone Acquisition Plan* described how a business case could be made for the Council to use a drone and the necessary drone-supporting software and services in order to reduce the cost as well as improve the safety involved in a range of its services and activities. It also pointed out that using drones could offer an opportunity to integrate drone-gathered data with traditionally-gathered data and compare observations with computer models currently used. This could be done by:

- integrating drone-gathered data such as high-resolution aerial images into the council's asset database;

- incorporating geo-referenced information into the Council's geographic information system;
- incorporating high-resolution orthomosaics into its urban planning process.

Moreover, it was noted that the rules and regulations necessary for the safe and socially acceptable use of drone technology already lies within New Zealand's aviation legislation.

A review showed that drone technology available in 2016 could viably deliver the anticipated benefits identified in the Council's project plan and would be an improvement on methods currently used.

To underscore the desire proposed in its plan to take up the opportunities that drone technology offers, the identified and listed a range of councils and authorities in Australia and New Zealand that are already successfully deploying drones to fulfill crucial functions.

The Council identified a number of challenges where the deployment of drone technology could improve efficiencies and reduce costs associated with gathering the aerial imagery data needed to fulfill resource management functions and other roles. These challenges included a need to:

- improve the timeliness of bridge inspections, as well as improve council personnel and public safety around these inspections, which would free up Council resources;
- improve the council's ability to more cost-effectively gather high-quality images while surveying steep or marshy terrain and mass vegetation, or gathering aerial images while flying over water – which, in turn, would result from not having to hire expensive site access equipment or additional safety equipment;
- gather high-quality aerial images of small areas in order to produce terrain models for planning and consent approvals as using helicopters or aircraft is more expensive;
- reduce the use of aircraft and helicopters overall in gathering aerial imagery as these are expensive to hire, gather less clear images, and cannot be deployed at short notice or in windy conditions;
- improve the council's ability to more rapidly and more safely inspect the results of seismic or weather events;
- more accurately measure the volume of storage areas such as storm water, sewerage and aggregate reserves;
- deploy solutions, aid or assistance more effectively where differences between the models and reality are noted;

- capture aerial imagery of the effects of coastal erosion over the long term, which has already proven effective in Australia, in order to take timely actions to address problems;
- provide aerial imagery of public events, which could be of benefit to the public.

Execution

The Council plan then outlined items it needed to scope/actions to take in order to execute its proposed drone project. These included:

- identifiying, selecting and acquiring drone and camera equipment as well as manufacturer-recommended spares.
- identifying, selecting and acquiring image processing software.
- identifying any additional technologies that could be appropriate to the Council's future requirements.
- identifying what competencies needed to be covered in operator training.

Unmanned Aircraft Operator Certification also needed to be addressed. The Council's project plan listed these as:

- the creation of a Part 102 exposition for application to the CAA
- the creation of processes to support Part 102 certification
- the issuance of a Part 102 certification.

The Council's Project plan included a detailed timeline for the execution of all actions associated with this plan and reported that the project was finally delivered by October 2016.

Costs for the project were calculated and included in the project plan. The initial outlay for acquiring a high-quality drone and its associated technology, such as a camera, pilot handset and monitor, camera operator handset and monitor, transport case, batteries and charger, spare parts and software was calculated to be $44,000.

Operator training, regulatory compliance, as well as the costs associated with the certification of unmanned aircraft operators were calculated to be $20,000.

The Council's project plan also outlined costs of operator training, regulatory compliance, as well as the costs associated with the certification of unmanned aircraft operators. This amounted to $20,000.

The project concluded too that the need for key non-technical skills to replace and/or maintain drone equipment would reduce over time, and that drone technology would improve too, thus reducing outlay and maintenance costs.

Not within the scope of the project were: adapting existing Council systems to include drone-gathered data, or assessing the staff resources required to use drone imagery and analysis tools.

2.5.3 Cemetery as 3D Environment for the Public at Ruapehu District Council [Case study 2]

Opportunities and challenges

In its report, *4D Cemeteries Project: A collaboration between RDC, Hawkeye Systems and 4DMapper*, Ruapehu District Council (RDC) described how it began to spot opportunities for using drones to address other Council functions.

In particular, there was a growing public need to gain access to higher-definition, 3D aerial images of council-owned cemeteries in the Ruapehu district. Previously, RDC had relied on cemetery images obtained by the New Zealand Company Hawkeye Systems, which were gathered only every five years from a height of 15,000 feet, resulting in much less distinct images. This meant RDC could not easily identify individual graves or cemetery plots and, at best, could only give members of the public paper maps when requested.

However, RDC was already building its experience at using technologies that could deliver more accurate, clearer aerial images. It had developed a working relationship with Hawkeye Systems to gain high-quality 3D imagery of streets in Ohakune and Raetihi in a street revitalization project. In addition, GIS staff at RDC had already purchased and successfully used drone technology to carry out an aerial survey of the Taumarunui landfill site.

In the Taumarunui project, the accuracy of results was far greater than could be gained using traditional survey methods and the cost of surveying the site had been reduced by thousands of dollars. This accuracy and clarity of images combined with the lower surveying costs, helped to justify the Council in choosing to use a drone to survey its cemeteries in order to produce clearer images that the public could access.

In addition, Hawkeye Systems had also enabled RDC to start using 4DMapper, which offers RDC a flexible and cost-effective way to process and store high-quality 2D autho-rectified imagery, digital elevation models (DEMs) and 3D models on the cloud.

Having established that a seamless way of capturing clear images of cemeteries was becoming more possible, based on RDC's previous use of drones, the Council also needed to solve several challenges particular to the cemetery project. It had to find a software platform that would need to:

- be web-browser based;
- support annotated data as well as imagery and hyperlinks (ie be capable of supporting and storing information that is drawn from other sources such as historical and ancestral links;
- offer end users a way to feel as if they are actually walking through the cemetery, looking at the headstones;
- be capable of delivering the annotated data on headstones in an accessible manner (via an icon next to each headstone, which users would be able to click on and find more information about a grave and the person buried there);
- be compatible across most common computer systems (ie be 'device agnostic');
- be capable of refreshing the 3D models annually so that end users would be able to refer to imagery and data chronologically.

Execution

- **Assessing user needs:** The planning stage involved assessing who the various end users were to be as well as what their needs were.
- **Choosing a delivery platform:** It was determined that this needed to provide imagery, notations and links within a web browser, which supported the WebGL. During planning, RDC also needed to decide what type of data needed to be captured so that they could be processed quickly.
- **Acquisition of tools for the project:** This had already been done via other RDC drone projects.
- **Image acquisition:** Although other RDC drone projects had determined what type of images should be captured in order to render clear, detailed 3D models, in the cemetery project, decisions had to be made about the best kind of images to collect that were specific to cemetery aerial surveys. Also, the best environmental conditions and preparations for image acquisition needed to be determined. For example, the optimal weather conditions for cemetery image capture were deemed to be overcast conditions in order to avoid shadows and too much contrast; grass around headstones was considered to be mowed to avoid small flowers confusing the image processing. It was also thought best to avoid interference from too much close-range movement by cars or people in the cemetery. The complexity of the capture methodology such as

having to fly at low levels, avoid trees and operate sensitively in relation to members of the public using the cemeteries meant that it was decided to capture the images manually using the DJI Go software application. This could be used on both Apple and Android devices, and offers flexibility and a range of options during image capture. To ensure it was important to capture aerial imagery from different heights and perspectives, to ensure that 3D processing was able to work effectively.

- **Aerial imagery capture:** This was done using a DJI Inspire 1 UAV drone.
- **Ground imagery capture – choosing software:** This was done using the same camera that RDC had used for UAV Aerial capture. A mini iPad was used to offer better viewing on a larger screen.
- **Particular considerations in relation to ground capture:** The complexity of the capture methodology such as having to fly at low levels, avoid trees and operate sensitively in relation to members of the public using the cemeteries meant that it was decided to capture the images manually using the DJI Go software application. This could be used on both Apple and Android devices, and offers flexibility and a range of options during image capture.

Reporting and quality control

Throughout the image acquisition process (both aerial and ground) there were several attempts to gather imagery by refining and improving the way it was being done.

In order to capture ground-based imagery that would be useful, RDC decided it needed to first capture the detail on each headstone; second, it had to capture images of the headstones showing their geometry. However, the first attempt was not successful due to a malfunction on the SLR Digital camera being used. This meant that the context capturing software being used could not link with the images that the drone had captured. To solve this, it was decided to use the DJI Osmo with a Xenmuse X5 camera attached, and an iPad loaded with the DJI Go application.

The Zenmuse X5 camera produced clean, clear 16 Megapixel imagery without having to use custom settings, which simplified the job for members of the RDC capture team who had little photography skills. However, the iPad provided poor GPS location, which meant that context capture could not successfully generate the necessary tie points to tie the images to the image sets. Therefore, considering the time frame and constraints within which the Council was working, it was decided that the drone would also be used to capture the ground images. The drone used was the DJI Inspire 1, which proved to be responsive and reliable for the task.

This led RDC to conclude that, for further imagery capture operations at cemeteries, it would be useful to have a second remote control for the photographer, so that the pilot could focus on just piloting the UAV.

In addition, some low-level flights took place at 6.0m in order to capture side and front views of headstones and even though the weather conditions were different on the day this was done, the processing handled the resulting imagery well.

RDC reported that, although its imagery capture methods seemed ‘cumbersome’ (capturing 3 images of each headstone), the approach had some advantages. These included: being able to use a minimum of 12 GPS satellite for geo-referencing; being able to use the same camera and settings that the drone capture used; being able to control the camera more easily; and longer battery life due to no flight taking place (no flight logs are therefore available).

Captured images (800 aerial images plus 1400 ground images equating to 15.4 gigabytes) were loaded onto a OneDrive folder so that Hawkeye Systems could download and process these. This was done using Bentley Context Capture processing software on a platform situated on a render farm comprising 4-highpowered servers, which shared the processing.

Hawkeye Systems processed the images into a range of outputs, which included:

- a 2D autho-rectified Geotiff – which was to be incorporated into RDC’s Intramaps GIS system;
- a 3D 3mx model, which could be viewed in Bently’s Acute 3D viewer software;
- a WebGL version, which could be viewed online using Bently’s Acute 3D viewer software;
- the ‘Cesium’ model, uploaded to 4DMapper’s 3D online application.

RDC reported some challenges around using the DJI Inspire for aerial imagery capture without GCP (Ground Control Points). Standard ‘drone’ GPS was reported to be undesirable and post-processed kinematic/real-time kinematic (PPK/RTK) positioning – permanent ground control points – recommended instead in order to benchmark image accuracy during initial capture, thus avoiding the necessity to manually pinpoint tie points.

It was decided that in future QR Codes can be placed on specific assets or landmarks in order to pinpoint GCPs accurately and also provide Context Capture with specific information about the point and thus tie in aerial and ground capture imagery. RDC used a 5m x 5m ‘tiling schema’ to enable the model to be updated quickly when new plots needed to be shown on the 3D model.

At what sort of intervals new burial plots should be inserted into the model is still being discussed. The intention is to capture imagery of the cemeteries annually in order to discern changes, including additional headstones, burial plots and headstones that may have been cleaned, and so on.

Opportunities and Challenges

The Ruapehu District Council (RDC) reported in their document, Drone Deployment 30 of May 2016, that it had been exploring the use of off-the-shelf, relatively low-cost drones and software which were becoming increasingly advanced and far less expensive than traditional methods used to gather aerial data. The Council reported that in its view this technology could start to be used more frequently and integrated with its present aerial data-gathering methods.

An opportunity to enlist the use of a drone presented itself when the RDC Waste Management team needed to gather more profile data from the Taumarunui landfill site. The Council stated that a traditional survey had already been commissioned by the Waste Management team in order to assess the current and potential heights of the refuse mound, as these data were required to gain resource consents. However, RDC reported that fresh additional data were required to establish exactly how high the refuse mound was and by how much material it would need to be capped.

The RDC reported that traditional methods of gathering aerial data in the Ruapehu district posed a number of challenges in general, and to the waste management case. One of these challenges was stated to be the fact that aerial photographs were only being taken every three years and the most recent ones in the Council's possession dated back to 2011. It was reported too, that unsuitable weather conditions were delaying the gathering of further data needed to assess the landfill site. In addition, the RDC report pointed out that aircraft or helicopters could only gather aerial images during short time frames, which allowed for the elimination of shadows that could cause inferior images to be gathered.

Execution

The Council reported that it opted to use the reasonably low-cost DJI Phantom Professional 3 drone to gather the aerial data it needed for the Taumarunui landfill project.

In addition, RDC reported that this choice of drone enabled it to use the subscription drone-control software, dronedeploy, which could be installed on iOS or Android devices – phones or iPads – and would allow collected data to be uploaded to the cloud and processed quickly. This capability further endorsed the case for using a drone to carry out the RDC's aerial data-gathering functions.

Here is the step-by-step process, which RDC reported was followed to carry out an aerial survey of the Taumarunui landfill site.

- First, RDC obtained permission from the Council's Environmental manager to deploy the drone. Also, since the operation was to take place within only 4Kms of the RDC aerodrome, permission from the aerodrome operator had to be obtained.
- Next, a drone flight plan was generated on the DroneDeploy website.
- The flight plan was synchronised to the DroneDeploy mobile software.
- The drone pilot also ensured that all CAA drone deployment requirements had been satisfied and then travelled to within 500 metres of the survey site.
- The drone was then set up, ready for launching.
- The drone pilot opened the DroneDeploy application on the mobile device and selected the already listed flight plan or 'mission', which had been generated at the RDC desktop.
- The DroneDeploy software automatically set the flight height to about 80 metres. It also checked for any barriers or obstacles that could interfere with the drone's flight path, eg high trees or hills. However, the pilot also carried out extra manual/visual checks, just to be sure, so that any necessary adjustments could be made on site.
- The drone took off and the aerial survey was completed.
- 305 captured images were loaded to the cloud.
- Post-flight data processing was then undertaken, which took five hours.

To aid the post-flight processing of images, RDC explained it its document that DroneDeploy features a range of useful tools, which helped it to prepare the images for integration with existing systems. These are:

A location tool, which displays the co-ordinates of an image (In WGS84 Projection) and the height of the pin placed on the map, which can then be transposed to a GIS system such as Intramaps or Google Earth.

A distance tool, which provides a cumulative distance; or, as a single line, provides a cross-section showing an elevation profile.

An area tool, which shows the area of the marque drawn under it.

A volume tool, which enables the volume based on two properties to be calculated. The 'best fit' solution calculates the volume of the area requiring to be levelled in cubic metres – particularly relevant to the Taumarunui exercise.

Quality control and reporting

In its report, the RDC outlined the full capabilities of this drone, which it considered to be highly suitable for its intended purposes
The report stated that, apart from reducing the cost of gathering aerial data using traditional methods, the drone solution was chosen as it was considered able to gather localised data more immediately, accurately and more regularly than every three years (eg gathering data from ERP and Asset management systems). This could be done efficiently, notwithstanding strict adherence to New Zealand's current and detailed CAA regulations governing drone use.

Part of the process which RDC reported it undertook before it could integrate the drone-gathered data with existing data systems was the 'orthorectification' of the captured map layers. This had to be done so that images with a constant scale could be created. These would then show features where they actually stood on the landfill site – ie in their true positions.

The DroneDeploy system is able to generate four types of map layers:
A 2D map: this provides high-resolution images, processed and ready to be downloaded as Geotiffs;
A 3D map model: this allows easy visualisation;
Plant health layer: this shows vegetation in the area being surveyed, a feature that would be applicable in agricultural/horticultural exercises;
Elevation map layer: this shows elevation heights calculated from the collected images.

Once the map layers had been 'orthorectified', the required 3D maps were generated and made available to download. The DroneDeploy software allows 2D and 3D maps to be exported in various formats and then imported into GIS systems as Geotiff files. The Geotiff files were opened in the GlobalMapper application, exported as enhanced compression wavelets (ECWs) and then imported into Intramaps as raster layers.

RDC reported that using the drone saved considerable time in assessing the landfill site. Compared to traditional data-gathering methods, often hampered by adverse weather in the Ruapehu area as well as other restrictions previously mentioned in this case study, it took just 20 minutes to plan the drone flight and 10 minutes to deploy the drone.

The post-processing activities took 35 minutes. These included: uploading imagery (15 minutes), exporting Global Mapper Enhanced Compression Wavelets (ECWs) (10 minutes), and importing the 3D and 4D maps into Intramaps as Geotiff files(10 minutes)

The cost of gathering data, reported by RDC to be high when using traditional methods, were considerably reduced in this project. Here is an short outline of the basic costs, which RDC reported were incurred using drone technology for the Taumarunui landfill site project:

One-time purchase of the DJI Phantom 4 Professional Drone	$2,700
A monthly DroneDeploy subscription	$249
GlobalMapper software	$450

3 METHODOLOGY

The research question was how potential benefits of drone technology can be integrated into TA and Council structures and the outcome in this research should enable decision makers to access the most crucial knowledge fields in this domain for their judgement. It was answered with a mixed method approach from quantitative and qualitative sources. Three case studies were compared as a reflective piece on the ease of uptake of UAV/drone technology and data from surveys were analysed.

- Due to the time available, it was not possible to set up my own qualitative data such as surveys and interviews. On the other hand existing interviews and a recent 2018 survey were sourced which would have made only been duplicated by any surveys of my own. Thus the case study material is based on these public domain materials that were verified by discussing them with the authors involved.

- The methods and technologies applied in the individual studies were developed and applied by different individuals and are probably contextually based. There they are probably not generalist but specific to that TA or Council. Nonetheless, they do outline and address the research question.

- Due to the different descriptions of drone use, the varied amount and types of information they covered, as well as varying objectives in the individual studies, these reports were processed by methodically adapting and shortening them in order to compare their approaches according to uniform criteria.

- The literature review is focused on the practical day-to-day use of UAVs by Ta's and Councils and may not fully reflect their use in agricultural or disaster management. These were 'aspirational' areas that they hoped to move into but there is an interesting picture of UAV/drones that emerges.

- With regard to the challenges around their use, only introductory references to problem areas can be reproduced due to the extensive amount of information provided

The literature was researched for the technical capabilities of unmanned aerial vehicle (UAV) and applications areas that are related to the needs of TAs and councils. This information was then systematically compared with the typical tasks that New Zealand authorities have to perform, taking into account social, legal and economic needs. The operational areas now identified for a possible use have been extended by additional information fields such as costs, knowledge about work processes and legal considerations which would be necessary for an embedding into the working structure of councils.

In the following step, research methods have been applied as data from publicly accessible databases were used to evaluate drone activities and to illustrate the application of this technology in a New Zealand context. Data on drone activity was compared with demographic data. The aim was to find out how this technology was distributed and whether factors such as the employment of drones in rural areas, with their lower population density and possibly greater acceptance of drone use by their populations, leads to greater application and dissemination of the technology.

An in-house application requires a higher degree of organizational and technical structure. the spatial distribution of district councils that use drone technology themselves or purchase services from a third party was depicted on a map. For this purpose, the receptions of all 54 district councils were contacted by telephone. From this, conclusions could be drawn about distribution and knowledge transfer between the councils.

The main focus of this research was on the comparison of received internal Council papers reporting on three different applications of drone technology in two councils. The documents received were relatively extensive and, due to their common characteristics, easily comparable. They were regarded as particularly valuable sources of information with regard to the nationwide distribution that had already been identified in the field. Comparisons between the case studies was regarded as powerful sources of causal inferences. A comparison framework was created:

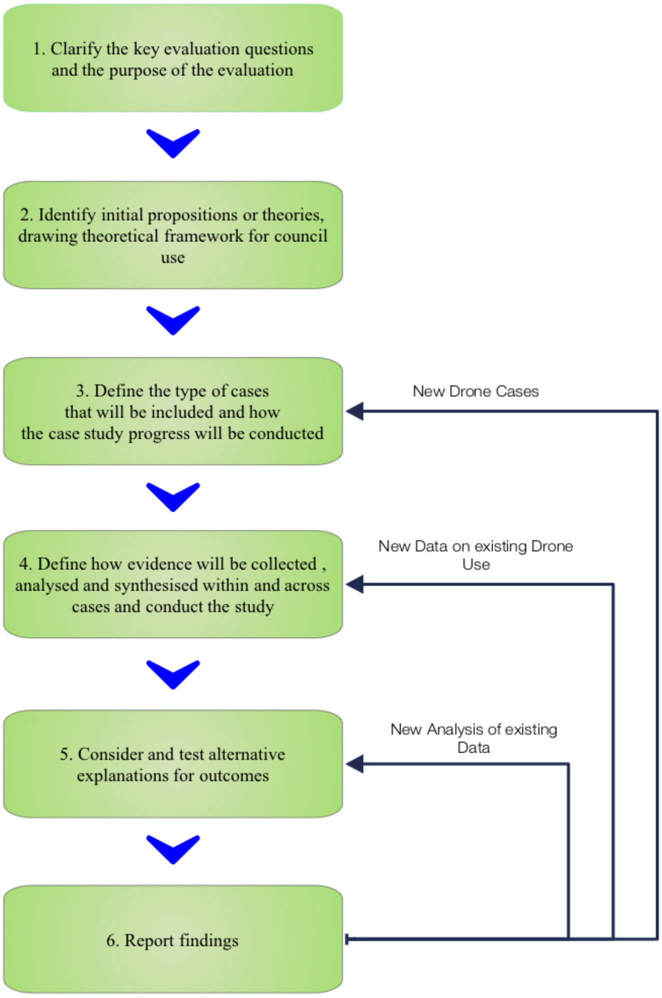

FIGURE 3 BASED ON THE DISCUSSIONS ON CASE STUDY [82] DESIGNS IN YIN, ROBERT K., CASE STUDY RESEARCH, DESIGN AND METHODS, FIFHT EDITION, SAGE, LOS ANGELES, 2014

The initial focus was to identify similarities and differences between cases in order to develop a holistic view and evaluate the measures taken with regard to their outcomes. On the basis of what was included as well as what was omitted from the Council reports, a process framework for drone deployment is developed. A simplified assumption was made that there are four basic conditions for achieving a strategic goal and its sustainable quality control.

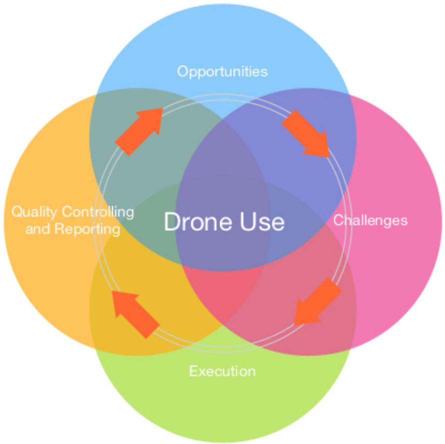

FIGURE 4 BASIS FOR PROCESS MINDMAPPING

Based on this construct, a scheme was outlined and used to compare the case studies that had the greatest strategic commonalities. A comparison table was created. The relevant data was analyzed, synthesized across the case studies.

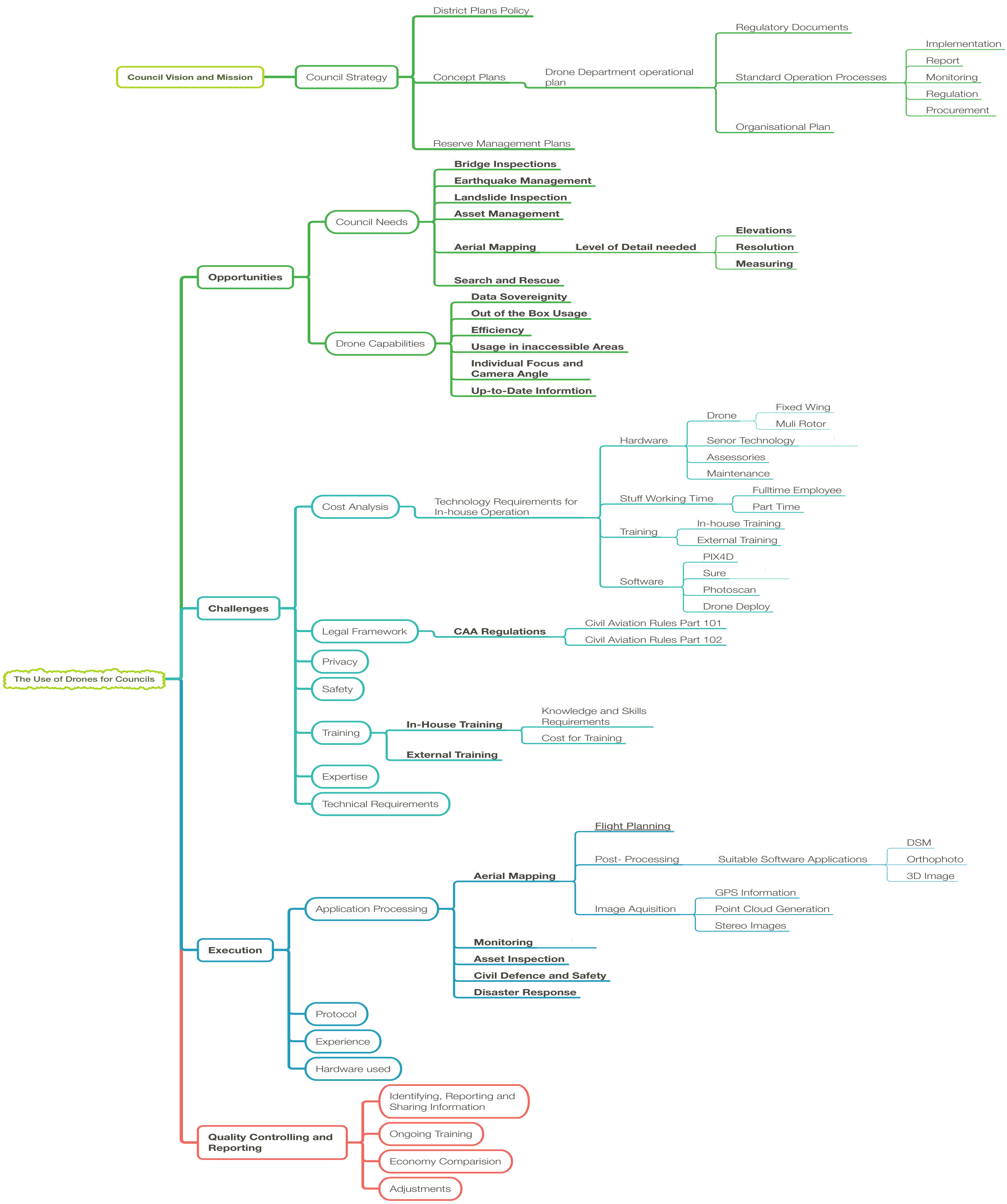

FIGURE 5 DEVELOPED PROCESS MINDMAPPING STRUCTURE

Eventually a field study was carried out in Wainuiomata in order to demonstrate the practical technology use of drones . The DJI Mavic 2 Zoom was used in conjunction with the mapping software PIX4d to create an orthophoto and a digital surface model (DSM). This data were then compared and evaluated with image material gathered using conventional methods and the user handling experience descript.

4 RESULTS AND DISCUSSION

4.1 DATA COMPARISION

Survey data from Airways [79] about the commercial use of drones from 2018 with 1442 responses out of 7000 in regions of New Zealand were compared with demographic data from Statistics New Zealand. 40.66 % of these were commercial operators.

The results are for the use of drones in relation to the population in regions:

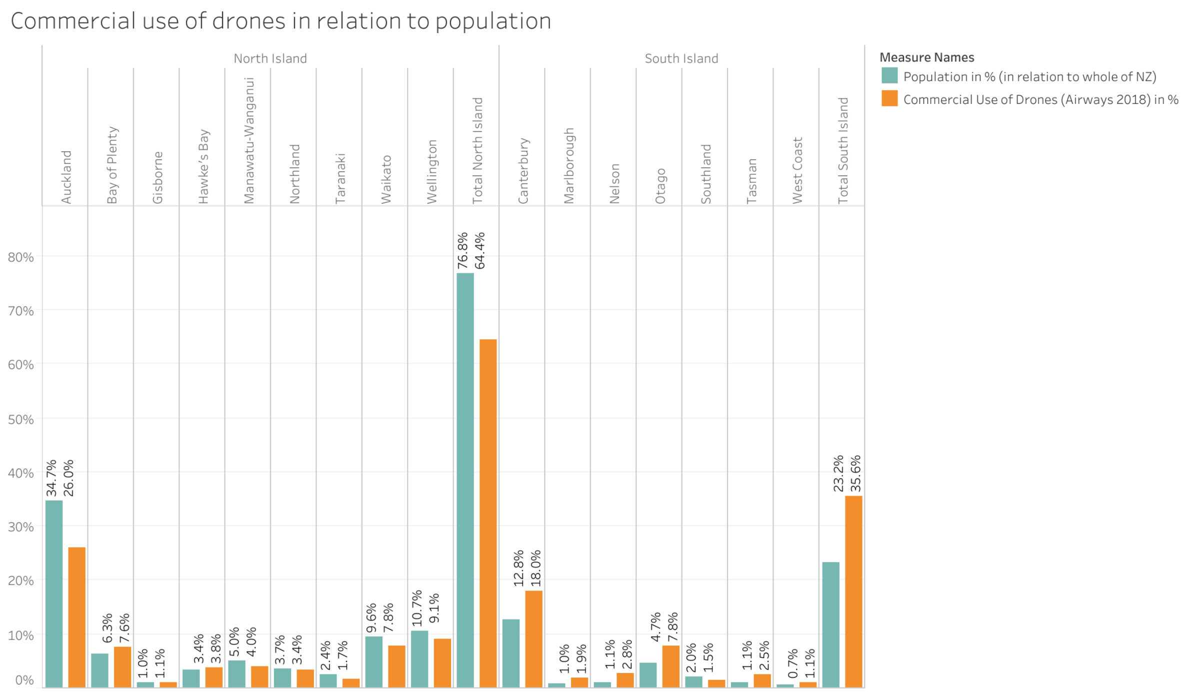

TABLE 3 COMMERCIAL USE OF DRONES IN RELATION TO POPULATION

As expected, the use of industrially operated drones is different from the population density in individual regions of New Zealand. In urban areas such as Auckland or Wellington, the rate of deployment is well below the average at -25.3 % respectively -14.8 %, while in Nelson and Tasman regions the rate is higher than the average at 167.9% and 129% respectively.

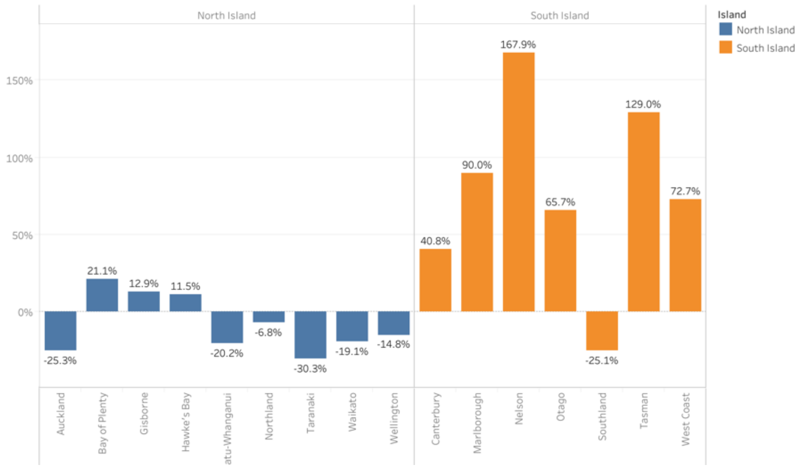

TABLE 4 OVER AND UNDERREPRESENTATION OF DRONE MISSIONS IN THE REGIONS

These figures must be understood as a trend, as no differentiation was made according to type of use. The reasons for this might be related to the greater risk in urban areas and the additional use of drones in agricultural areas.

The results reflect the commercial use of drones in relation to the geographical size of each region:

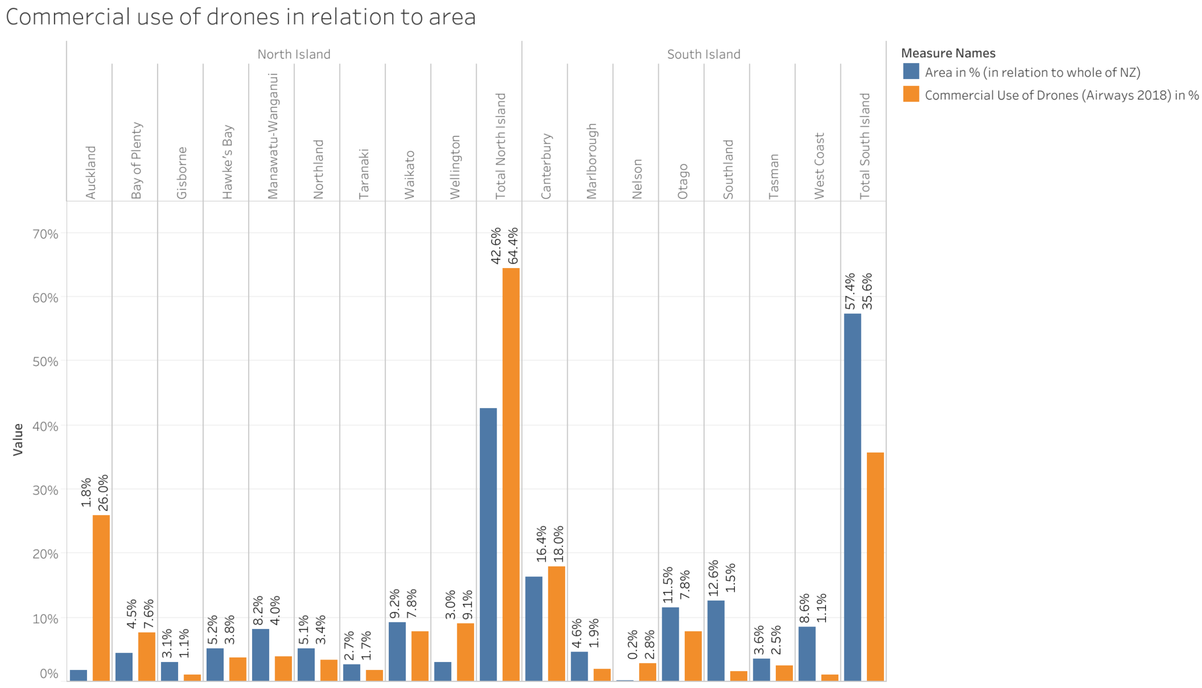

TABLE 5 COMMERCIAL USE OF DRONES COMPARED TO AREA

The data show that the use of drones is expected to have a greater impact on the airspace above it. For example, the volume of all drone flights in the Auckland district with +1675 % is taken as a basis, with a high population density and comparatively low land mass. The drone activity here is significantly higher than in the West Coast with a deviation of -86.7 % from the mean.

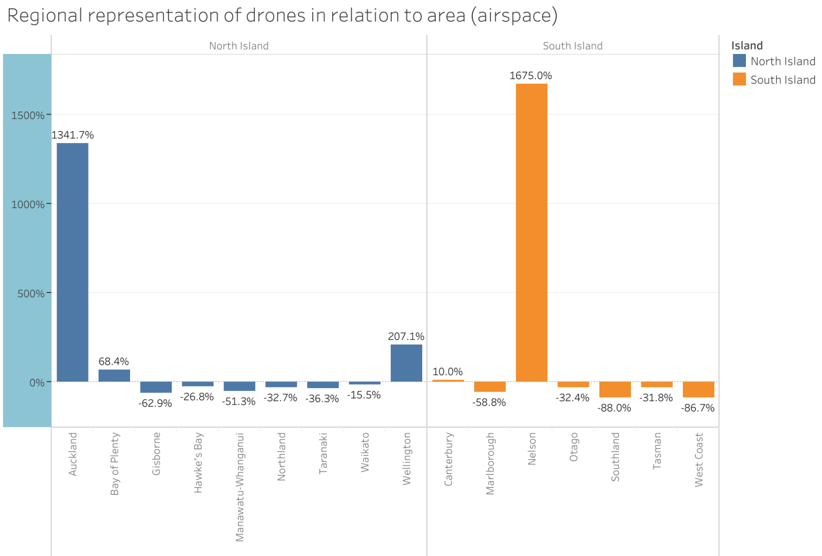

TABLE 6 DEVIATION COMPARED TO TABLE 5

The figures show, in a simplified representation, the extent to which the risk for air traffic depends on the airspace and the number of flights. This data may be useful for more detailed future risk assessments in regions.

Section Summary and Discussion :

With its rural structures, the South Island exhibits an above-average amount of drone operations. In particular the regions Tasman and Nelson stand out. In Wellington, knowledge and technology would have to be brought over from other regions in the case of an emergency that required drone usage. The different representation of the drone industry cannot be conclusively clarified as there are no usable figures for the application areas in the regions.

4.2 Findings: Mapping of Drone Implementation in New Zealand District Councils

All 54 district councils in New Zealand were contacted and asked whether they were using drone technology in their daily work, whether they were using a company to do so, or whether they were not using this technology at all. The results are presented below:

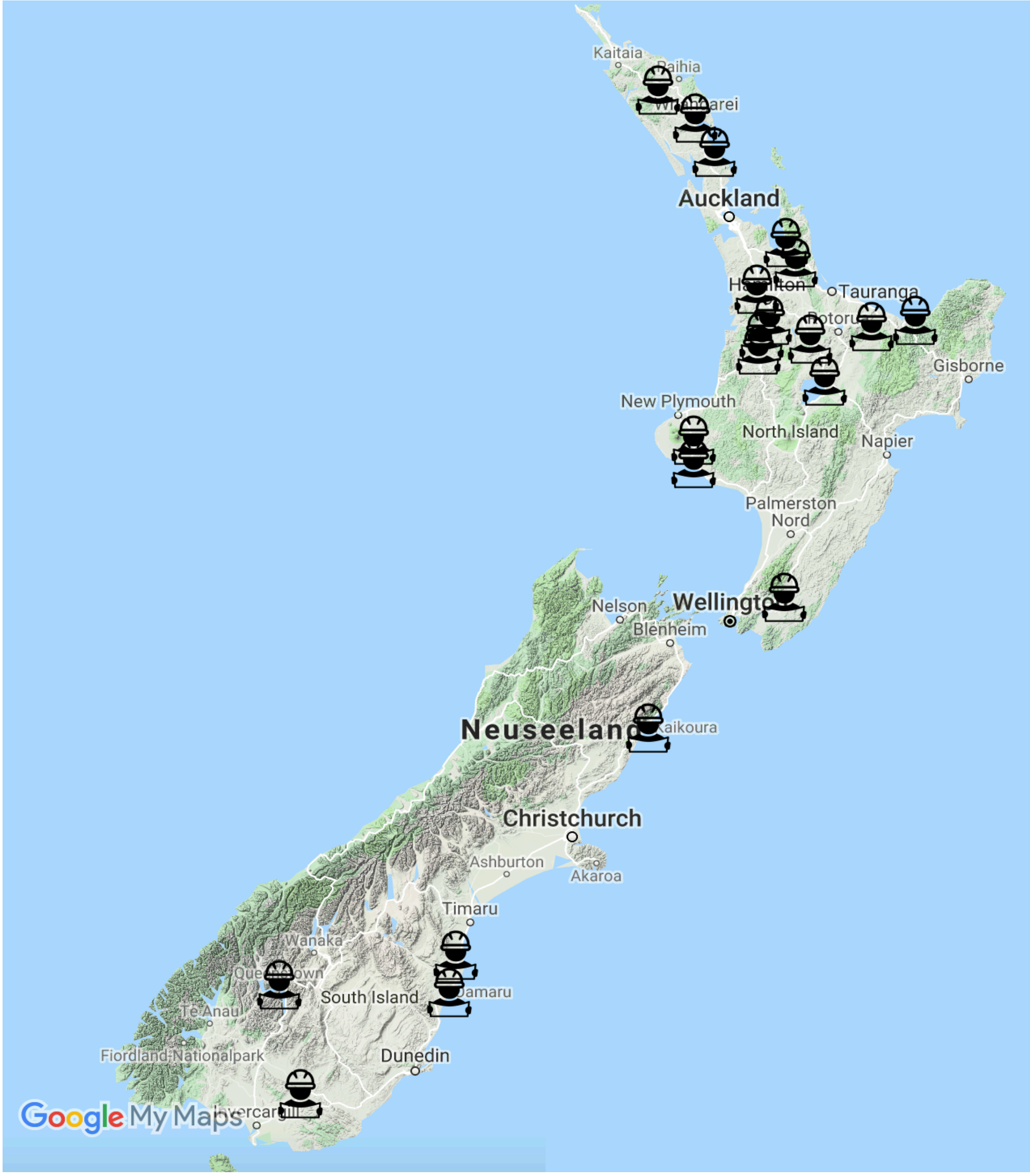

FIGURE 6 DISTRIBUTION OF DISTRICT COUNCIL WITHOUT THE USE OF DRONES

North Island-No Drones

Carterton District Council
Far North District Council
Hauraki District Council
Kaipara District Council
Kawerau District Council
Opotiki District Council
Otorohanga District Council
South Taranaki District Council
South Waikato District Council
Stratford District Council
Taupo District Council
Thames-Coromandel DC
Waikato District Council
Waipa District Council
Waitomo District Council
Whangarei District Council

South Island- No Drones

Gore District Council
Kaikoura District Council
Queenstown District Council
Waimate District Council
Waitaki District Council

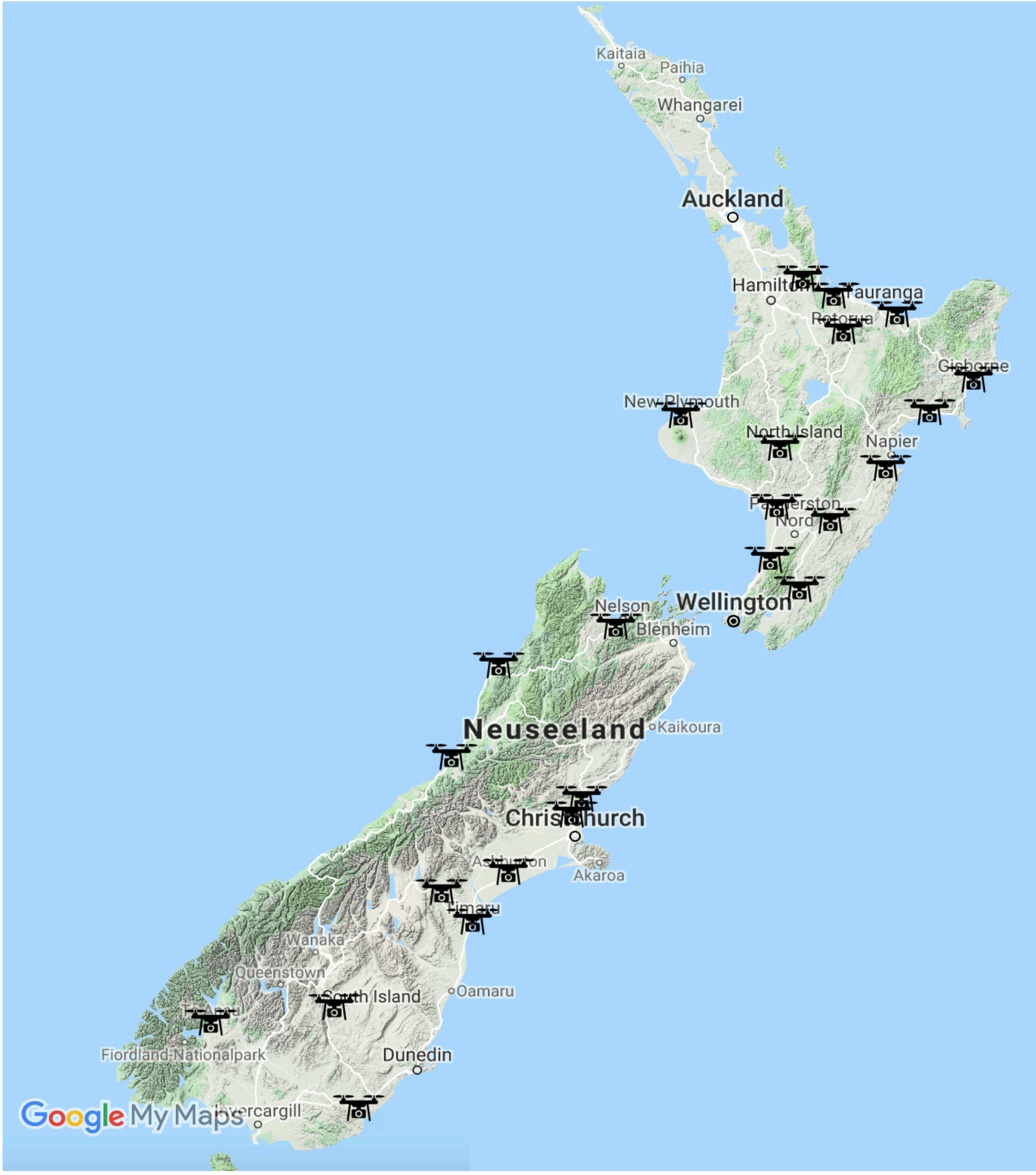

FIGURE 7 DISTRIBUTION OF DISTRICT COUNCILS USING DRONES IN-HOUSE

North Island-Inhouse Drones

Gisborne District Council
Hastings District Council
Howhenua District Council
Hurunui District Council
Masterton District Council
New Plymouth District Council
Rangitikei District Council
Ruapehu District Council
Tararua District Council
Wairoa District Council
Western Bay of Plenty DC
Whakatane District Council
Southland District Council

South Island-Inhouse Drones

Buller District Council
Central Otago District Council
Clutha District Council
Mackenzie District Council
Tasman District Council
Timaru District Council
Waimakariri District Council
Westland District Council

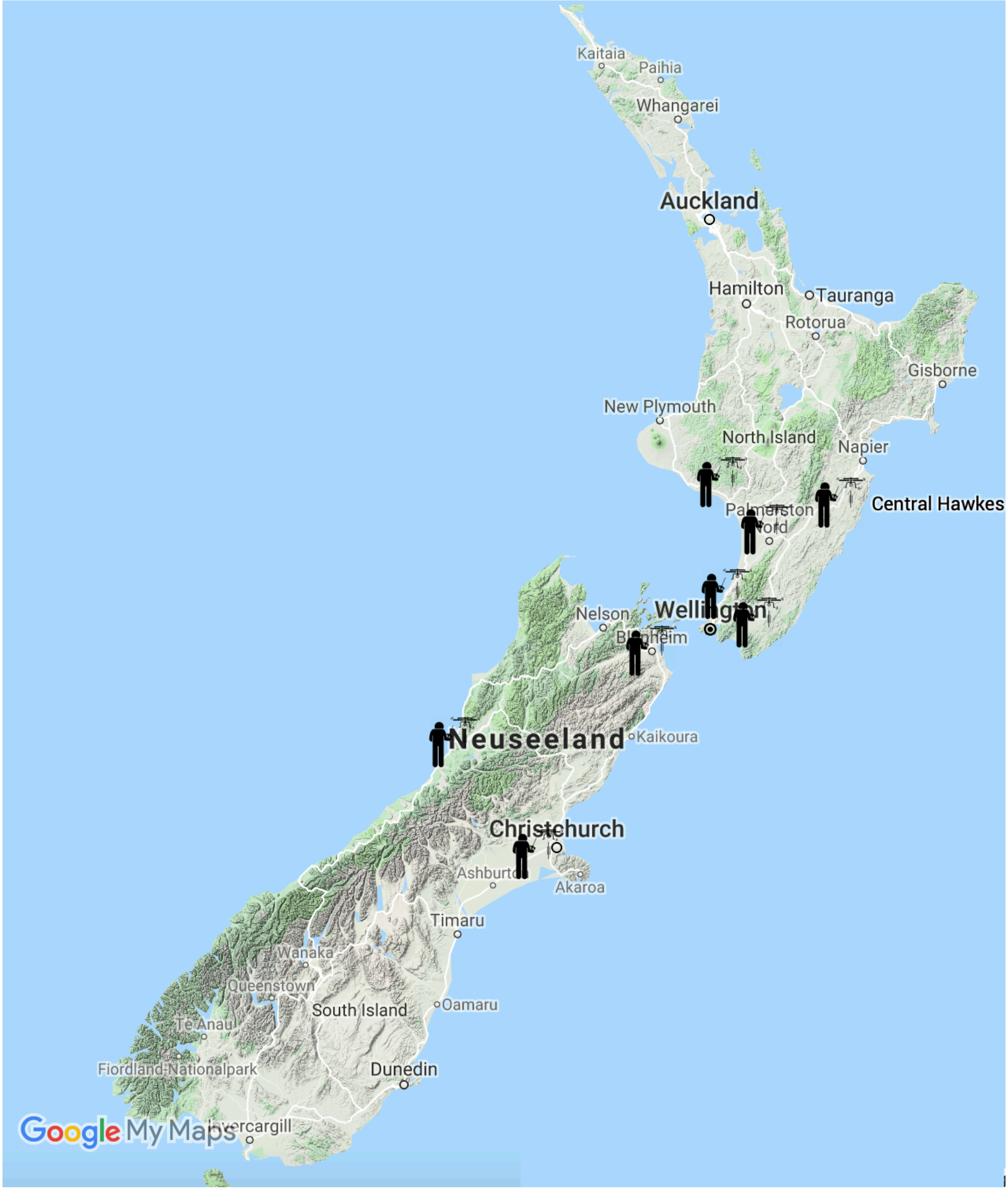

FIGURE 8 DISTRIBUTION OF COUNCILS USING CONSULTANTS FOR DRONE OPERATIONS

North Island-Drone use by Consultants

Central Hawkes Bay District Council
Kapiti District Council
Manawatu District Council
South Wairarapa District Council
Whanganui District Council

South Island-Drone use by Consultants

Grey District Council
Marlborough District Council
Selwyn District Council

Section Findings and Discussion:

The spatial representation of the use of drones by councils shows a relatively strong spread in the Canterbury region and on the southern North Island. Speculative reasons for this could be the acceptance of drones following their successful deployment after the Canterbury earthquakes of 2011. The geographical density of the practical use of drones by councils on the map could be due to an informal exchange of information in geographically neighbouring areas.

4.3 Findings: Comparison of three different drone Deployments

Based on the process framework developed for drone use in district councils, three cases were compared and discussed. The results are presented in the table below:

	C1 Tararua DC Business Tool for the Council	**C2 Ruapehu DC** Online visiting platform for council owned cemetery	**C3 Ruapehu DC** Implementation for aerial photography in GIS for landfill site
Opportunities			
Council Needs	**Case 1: Business Tool for the Council** Other potential use reported: Aerial images for asset management Georeferenced images for GIS System Geo-referenced ortho-mosaics for Urban Planning Improvements to the efficiency of bridge inspections Models for planning consent approvals in small areas such as creation of 3D point cloud images. Imagery for marshy terrain and mass vegetation or over water Inspection of Earthquake and other disaster scenarios Monitoring storm water, sewerage and aggregate reserves	**Case 2: Public Services** Other potential use reported: Aerial images to be renewed after less than 5 years Process and store high-quality 2D orthorectified imagery Refreshing 3D models annually Higher definition 3D aerial images required	**Case 3: Aerial Mapping** Other potential use reported: Aerial images to be renewed after less than 3 years

	Aid and assistance capabilities		
Drone Capabilities	Cost-effective images Images when flying over water Short notice deployment Safe inspection of seismic and weather events vs helicopters Ability to measure volumes for storm water or landslips Creation of georeferenced map images.	Updating out of the box Up-to-date information Accuracy of images 3D Models Digital Elevation Models Capture Software for Android and Apple Different height and perspectives	Updating out of the box
Challenges			
Cost Analysis	Commercially justified Less access or safety equipment Cheaper then helicopter or plane Camera, pilot handset, monitor, transport case, battery and charger for $44,000 NZD Operator Training and regulatory compliance for $20,000 NZD	Outsourced to Hawkeye Systems	DJI Phantom 4 pro for $2700 NZD monthly drone deploy description for $249 NZD Global Mapper Software for $450 NZD
Legal Framework	Existing CAA Regulations Planning for Part 102 exposition for application to the CAA Planning for creation of processes to support Civil Aviation Authority (CAA) Rules, Parts 71, 101 and 102	Not reported	Permission was required as within 4 km of an airport Permission of the council's environmental manager was needed
Privacy	Not reported	No issues	No Issues

Safety	Council will produce documented procedures for the operation of drone technology in order to meet its obligations under the Health and Safety Act	Risk during low level flights caused by trees and members of the public	
Expertise		GIS staff used before aerial survey for Taumarunui landfill site RDC capture team had little photography skills	
Technical Requirements	Easy exchange payload for future sensors	Compatible computer systems Web-browser based applications	
Training	Identifying and describing key competencies for staff training	No formal training reported	
Execution			
Application Processing		Postprocessing with 4DMapper Capturing manually with DJI Go 800 Aerial images and 1400 ground images were loaded to one drive using Bently Context capture 16 mb imagery without custom settings	Drone Deploy Height of 80 m 305 images loaded to the cloud Data processing took 5 hours Importing 3D and 4D maps into intramaps
Hardware used	Not specified	DJI Inspire Ipad mini for large screen Xenmuse X5 Camera SLR Digital camera	DJI Phantom 3
Protocol	Drone Acquisition Plan Supporting governance documents will be created	Not reported	Not reported
Experience	Complex bridge inspections with lower cost and risk involved	Complex operation at cemetery Staff need to decide what data are needed Who is the end user and what do they want	Weather conditions were unsuitable

		DJI Inspire classified as responsible and reliable for the task Need for good weather conditions Flowers are confused with headstones Need for Ground Control Points	
Quality Controlling and Reporting			
Identifying, Reporting and sharing data and information	Identifying competencies for operator training Identifying selecting and acquiring processing software Identifying future council needs Sharing information on ALGIM conference	Published online at nzherald Sharing information on ALGIM conference-Excellence in Innovation Award Finalist	It took 20 min to plan the flight and 10 min to deploy the drone Postprocessing took 35 min
Training	In-house operation and training	unknown	Not reported
Economy Comparison	Conclusion that non-technical skills to maintain drone equipment will reduce over time	Lower surveying costs	
Adjustment	Have described software needs based for applications	Continuous attempts to gather imagery by refining and improving Second remote control for photographer concluded best practise for further operations	

Table7: Comparison Table for Case Studies

Section Findings and Discussion:

- The drone was deployed and proved to be safer, more economical and time efficient for inspecting council-owned bridges
- By using them for inspecting bridges, the Tararua District Council has established drones as business tool
- Successful knowledge was contributed over the ALGIM and in articles
- Challenges because of risks, missing experience, technical issues or legal requirements observed
- Knowledge and experience transfer is crucial and should be enhanced
- Different protocols or no protocols
- Different hardware and software used
- Different levels of training or no training
- Different application areas
- Different Budget
- More Efficiency could be established when councils setting common organisational and strategic goals

There is no visible overarching organizational structure or planning measures in place. In addition, the evaluation and comparison of the three case studies showed that the individual personal involvement of council staff led to the in-house use of drone technology within a district. The organizational structure, the related processes and the use of hardware and software were designed differently.

Due to the complexity of the interlocking technical, economic, legal and ethical issues associated with each category of council, it seems advisable to form a dedicated department within the administration. Here, expert committees should develop strategic frameworks for the specific use of drones and an create an organizational structure within the organisation. Here, framework plans for use in task categories should be defined and the necessary hardware and software selected and made available. Employees should be prepared and trained according to uniform standards in an overall embedded organisational structure.

4.4 FINDINGS: AERIAL IMAGERY IN WAINUIOMATA

This section reports on the operator experience and the outcome of a field study outside of Wellington.

The local golf club in Wainuiomata is just outside the restricted airspace of the Wellington region. The operators kindly granted permission to fly a drone over the property for research purposes and to take aerial photographs. A DJI Mavic 2 Zoom drone was used. As PIX4DCapture software doesn't support this drone, the image editing software MAP Pilot was used instead. The flight plan was entered into the software in advance. At a flight altitude of 60 meters and 75 % image overlap, 457 images were compressed in 26 minutes. One additional battery was required. All data were calculated automatically based on the entered parameters. The area covered was 0.146 km2.

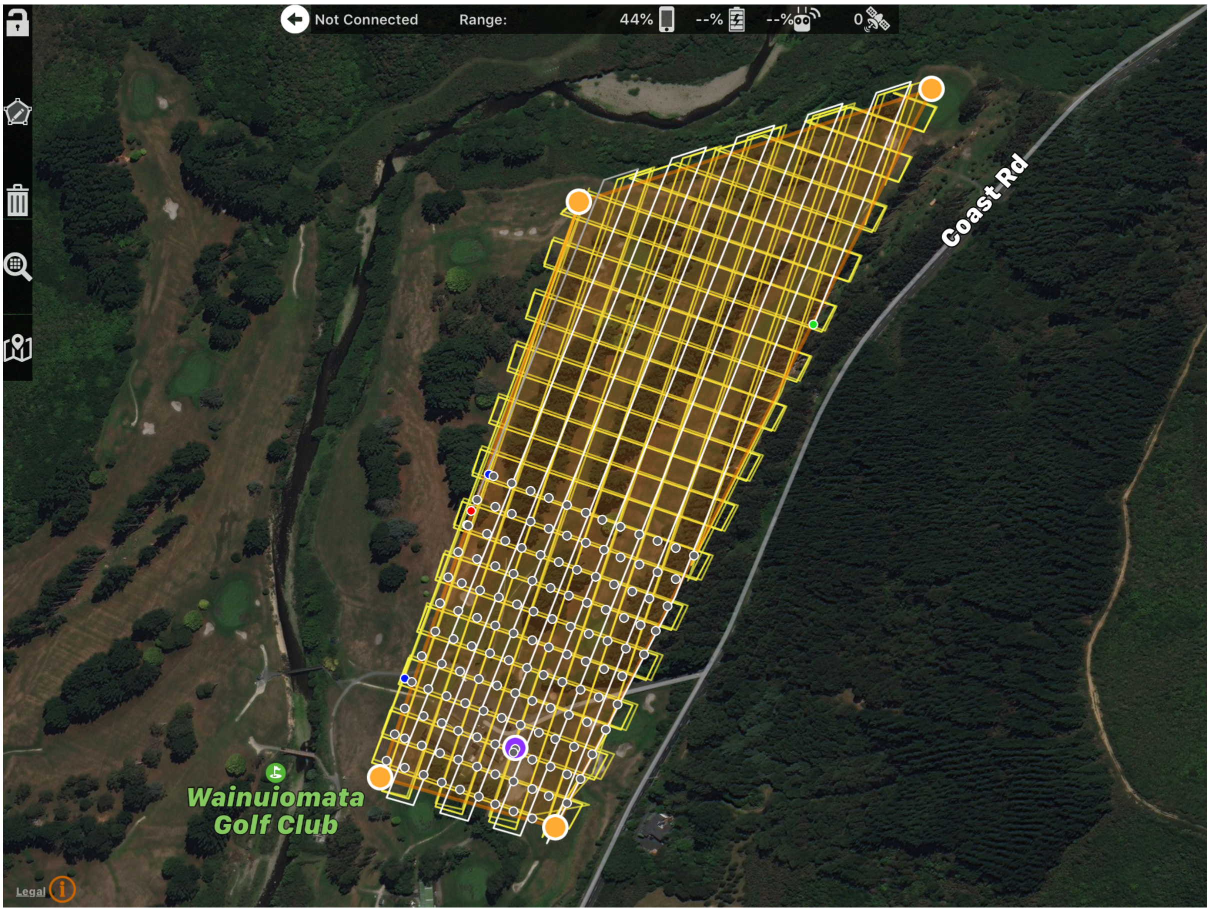

FIGURE 9 FLIGHT PLAN FOR WAINUIOMATA MISSION

The PIX4DMapper processing time for the point cloud densification was 01h:21m:01s, for the 3D textured mesh generation was 15m:52.s, for the DSM generation 43m:47s, and the orthomosaic generation 01h:26m:10s.

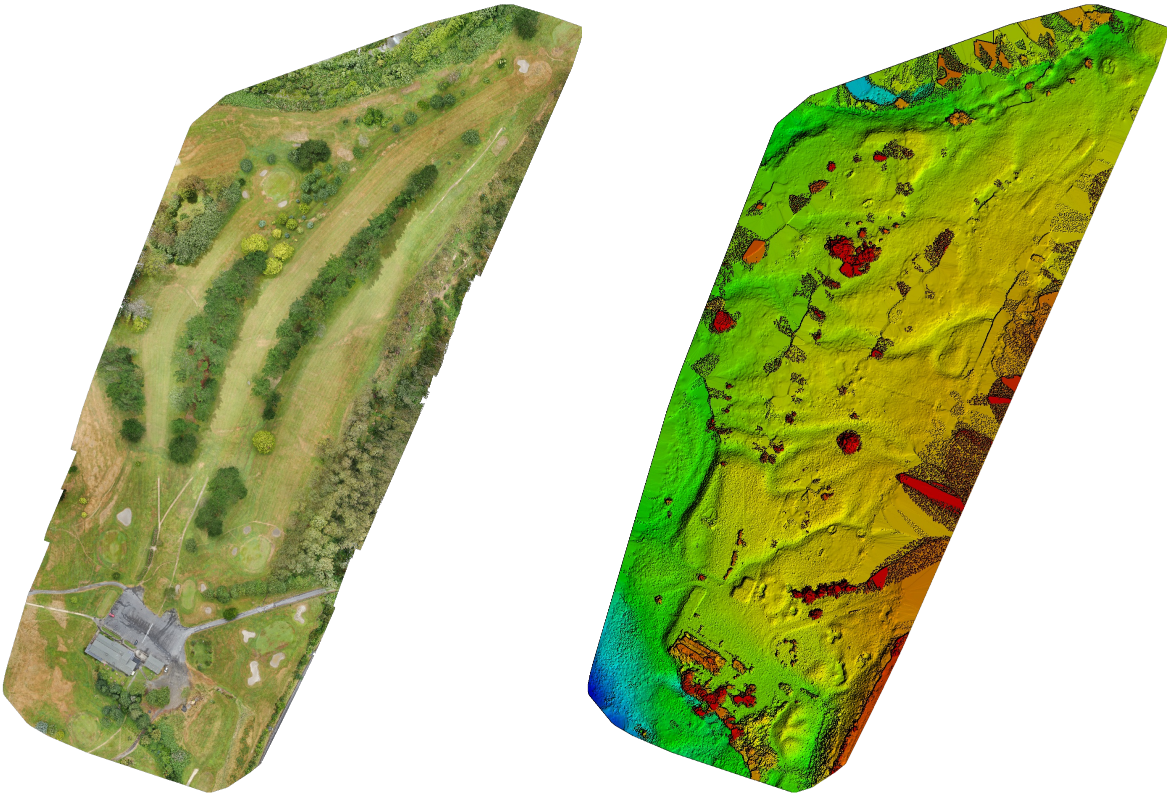

FIGURE 10 ORTHOMOSAIC AND CORRESPONDING DIGITAL SURFACE MODEL (DSM) BEFORE DENSIFICATION

FIGURE 11 SCREENSHOT FOR TEXTURED 3D MESH

Section Findings and Discussion:

The newly acquired DJI Mavic 2 Zoom was relatively simple to use after a short training period. Because it was not supported by PIX4D software due to its adjustable zoom, map pilot was used. Only one hour was needed for training and planning the route. From a subjective point of view, the test flight and the data processing was seamless and produced large amounts of useful data in a short time.

5 CONCLUSION

Drone have proven abilities such as surveillance, monitoring, or situational awareness based on real time, their mobility ,their capability to fly in 3D spaces , relatively lightweight and their potential to cover large areas makes drones perfect for urban sensing platforms. Modern drones are, to an increasing extent, able to provide on-board decisions paired with significant embedded processing power so that tailored and complex mission can deployed with reduced risk by council which have not been possible before.

Drones have proven that they are suitable as professional business tools within public administrations and should be integrated into their structure. Bridge inspections, for example, are less costly and have a minimal risk associated with them when performed by drones, due to their ability to fly over steep terrain, marshy ground, mass vegetation and over water and this has resulted in reduced inspection times and hence also a lower cost
Their additional advantages, such as observation and inspection from the air, make conventional methods redundant. No traffic had to be interrupted or scaffolding platforms had to be erected to inspect the lower bridge sections. And at the end of it they have a video record that is evidence based.

This paper has shown that crucial knowledge and experience has been built up in rural TA's and Councils rather than Urban ones. This was unexpected; but on the other hand the rural areas are where the distribution of drone technology per person was higher than in the more densely populated urban regions. There also appeared to be a more plausible business case for drones in the rural areas and the need to get permission from all of the people that a drone might flyover in an urban one is apparently the biggest hurdle for drone flight. However, urban regions threatened by sudden onset disasters such as earthquakes, tsunami and flooding (such as Wellington), will require access to this knowledge and associated hardware in case of such an event.

Comparing the case studies showed that the organizational structure was the missing element once a business case had been established Where should such a drone capability be located? In the engineering department, or the communications and publicity or more on the operational side in Parks and reserves? What appears to be happening in rural TA's and Councils is that a separate Drone Department is set up around the business case but it appears that from there it is largely personality driven. Nonetheless, TA’s and Councils have to report to their communities in a clear and accountable way about the services and their impact on the community: and drone footage does appear to do that very neatly. In addition, there was feedback that those TA’s and Councils that were developing a drone capability were seen as positively ‘progressive’ by the public, by senior and line management and also by staff.

Moreover, the related operating and training processes, including the use of hardware and software, does need to be bundled within one department and its capabilities distributed throughout the organisation when and where needed.

Therefore the additional gains are firstly business case based in terms of doing the work of TA’s and Councils more efficiently and effectively and are quantitative; second are its ability to communicate across the various organisational levels and into the public accountability areas and third in terms of how TA’s and Councils are perceived both internally and externally to the organisation. These last two though qualitative must not be undervalued.

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7 Appendix

7.1 Tararua District Council, Drone Acquisition, Project Plan [A1]

7.2 Cemetery as 3D Environment for the Public at Ruapehu District Council [A2]

7.3 Ruapehu District Council, Capturing and Implementing Aerial Photography into RDCs GIS Application [A3]

Tararua District Council

Drone Acquisition

Project Plan

30th May 2016

Commercial in Confidence

Table of Contents

Version Control	Project name		
Date	Version #	Revision History	Author/Reviser

1. Executive Summary

It is often said in technology that there are "killer apps" – things that are overwhelmingly effective, economical and have quick payback.

Drones have now achieved this overall thresh-hold, with multiple potential high value benefits. These are now realised with carbon-fibre-robust, smart, extreme element designed drones. While these will only increase in capacity in the coming years, the justification for purchase has already been achieved.

2. Introduction

Project Name	Drone Acquisition
Project Description	This document establishes a business case for the Tararua District Council to aquire a drone and associated services in order for the efficiency of a number of Council services to be improved and to assist the Council investigate other areas where the use of drone technology may assist with increased efficiency or cost reduction.
Project Manager	
Project Sponsor	Peter Wimsett
Stage/Status	Draft
Time frame	Project delivered by October 2016

Background

Unmanned aerial vehicles, known in popular parlance as drones, are increasingly being used as a means of expanding techncial capabilities, reducing physical risk to personnel, and increasing operational efficiency in a number of sectors around the world.

At the forefront of their use are the fields of asset inspection and mapping where the technology and associated systems have now advanced to the point where they can be considered to be mature enough for general use.

New Zealand aviation legislation has identified this maturing of drone technology and rules and regulations have been introduced to enable organisations to be able to operate this technology in a safe manner while, at the same time, protecting the interests of others.

The Tararua District Council considers that drone technology has developed to a point where there are benefits to the Council to be achieved through its use.

A project review has confirmed that the identified benefits are achievable using currently available drone technology and are practical within the Council’s scope of operations.

Project Objectives

Project Benefits

Benefits include:

- Improvements to the efficiency of bridge inspections together with a reduction in inspection related risk to personnel and a reduction in public impact from road closures during bridge inspections.

  Challenges currently faced during the bridge inspection process include:

  1/ The requirement at times to close public roads in order to gain access.

  While the use of drone technology will not remove this requirement for all inspections, it is expected that there will be many cases where this requirement will be removed or the period of the road closure be significantly reduced.

  The removal of the requirement to close roads where possible, or reduce the length of time of the closure, would result in a reduction in public impact and a possible increase in public service perception.

  2/ Access restrictions due to terrain.

  There are locations within the Tararua District where access to assets, including bridges, is difficult with the result that the inspection period becomes extended, or requires the contracting in of site access equipment or additional safety services.

  The ability for a drone to fly over steep terrain, marshy ground, mass vegetation and over water, while at the same time obtaining high quality images, would result in a reduction in time for this type of inspection and may remove the requirement for the contracting in of site access equipment or additional safety services.

  3/ Cost of aerial imagery and flight operations

  The only means by which the Council can currently obtain aerial imagery of its assets is to overfly the asset using an airplane or helicopter equipped with imagery capture equipment.

  The Council incurs considerable cost per hour when utilising this type of service and is limited to high level imagery at moderate definition. These services require advance notification and the Council has limited ability to overfly at short notice.

  Planes and helicopters are restricted in their ability to cope in windy conditions. It is at windy times during and after storms, that drones may be most useful. It is also as a matter of convenience when people are available or there are deadlines and project dependencies that capturing imagery from drones is essential.

  Drones are ideally suited for the capture of aerial imagery, can be flown over a small area at short notice and delivery extremely high quality aerial imagery.

In addition to the benefit of being able to optain high quality aerial imagery there is the ability to use this imagery to create 3D image models at low cost in order to assist with site and volumetric analysis.

4/ Resource constraints

The bridge inspection team identify resource constraints as one of their major issues and this impacts on the timeliness of inspections.

It is expected that the use of drone technology will reduce the time to perform inspections in many cases with a resulting increased availability of resource.

5/ Inspection health and safety risk.

Bridge inspection frequently means that personnel are required to work at height or traverse difficult and, at times, steep terrain.

The use of drone technology would, in many cases, remove or minimise the requirement for personnel to subject themselves to these risks.

The health and safety of those undertaking manual inspections is paramount and ensuring their safety for manual bridge inspections requires this special equipment, training, support and additional time and effort to effect and deliver.

- A reduction in the time required to perform preliminary investigations of Council assets following weather or seismic events with the adidtional benefit of a reduction in risk to personnel during these asset inspections.

  The ability to rapidly deploy drone based image capture equipment into difficult and challenging situations such as slip and flooding events would give the Council an increased ability to determine appropriate actions to remediate the situation and return the asset to use. Examples may be the incorrect decision to leave a road open when a bridge, hillside or bank are in fact unsafe or the incorrect decision to close a road when it was in fact safe, but thereby trapping people or creating extensive re-routing and drive times. This might

  The use of drone technology to inspect areas which are difficult or dangerous to inspect manually will reduce the risk associated with such inspections.

- An ability to obtain high quality aerial mapping imagery and produce terrain models of small areas that would previously have required the use of costly helicopter or aircraft based services.

  The development of advanced terrain modelling techniques based solely on captured visual images introduces a new in house airborne imagery capability that may assist the Council with district planning and consent approvals.

- Improvements in the processes associated with volumetric measuring of storage areas including stormwater, sewerage and aggregate reserves.

The use of drone technology in association with readily available software will allow volumetric measurement to the performed based on a simply overflight and multiple image capture during the flight.

The information gathered would also be used to validate computing models currently used by the Council and will assist in amending these models if variances are observed between the model and reality.

- The introduction of a capability for long term imagery capture of coastal erosion effects.

  The use of drone based technology in association with high resolution image capture and extrapolated 3D imagery is already proven in the monitoring and management of coastal erosion in Australia.

  The ability to increase the frequency of obtaining aerial imagery combined with 3D modelling techniques will allow the Council to more closely study the effects of coast erosion and increase the timeliness of any corresponding actions.

- A potential for improvement in the process of stormwater and sewer leak detection.

  There exists a potential for the use of drone technology to assist with stormwater and sewer leak detection though this will require field trials to prove the efficacy of this usage.

- An ability to provide aerial imagery at local events for the public good.

  The use of drone technology can be used by the Council to demonstrate to its citizens that it is investing in modern technology for the public good. In addition to highlighting the increase in asset inspection efficiency there exists an opportunity for Council owned drone technology to be used at public events to capture aerial photographs to be subsequently made available online.

Outcomes

The use of drone technology is expected to:

Increase the efficiency of asset inspection services.

Reduce the risk level associated with asset inspection services.

Provide an additional inspection resource during weather and civil defence related events.

Provide an additional inspection resource for district planning, asset and environmental monitoring.

Increase the skill level of those staff members involved in the deployment, operation and processing of drone based technology and the information gathered from the use of the technology.

Integration

An opportunity exists to integrate the information gathered by drone technology into existing systems and processes operated by the Council.

These include:

- The incorporation of high resolution aerial images into the Council's asset database.
- The incorporation of georeferenced information into the Council's Geographic Informaton System.
- Incorporation of high resolution orthomosaics into the Council's urban planning process.

Existing Local Authority Uses

Local authorities in New Zealand and Australia are already seeing benefits from the use of drone technology.

Notable examples include:

Waitaki District Council
    This council has an ongoing programme in place to use drone technology for erosion monitoring where access to the location is limited.

Sutherland Shire Council NSW
    This council is using drone technology for inspection purposes where physical inspection would be considered hazardous.

West Kempsey Shire Council NSW
    This council is seeing benefits from using drones to survey landfill and calculate changes in volume with far greater accuracy then ground surveying techniques.

Central Otago District Council
    This council is using drone technology for structural assessment and is seeing cost and safety benefits when inspecting tall structures.

Logan City Council QLD
    This council has reported success with a number of drone related projects including volumetric reporting and compliance related matters.

2. Scope

In Scope

Items in scope for this project are:

Identification, selection and acquisition of a drone and associated technology:

- Drone
- Camera Mount Gimbal
- Camera
- Pilot handset and monitor
- Camera operator handset and monitor
- Transport case
- Batteries and charger
- Manufacturer recommended spares

Identification, selection and acquisition of image processing software.

Identification of additional technologies which may be appropriate to the Council's future requirements.

Operator training:

- Regulatory compliance
- Drone operator airmanship
- Health and safety
- Operator flight training
- Operator certification to fly within 4km of an aerodrome

Unmanned Aircraft Operator Certification

- Creation of a Part 102 exposition for application to the CAA
- Creation of processes to support Part 102 certification
- Issuance of a Part 102 certification

Out of scope

Customisation of existing Council systems to incorporate new information sources.

Staff resourcing to utilise imagery and analysis tools

3. Time Frames

Milestones	Key Milestone	Date
1	Completion of project plan.	30th June 2016
2	Approval of Project and budget.	15th July 2016
3	Issuing of RFP to drone equipment and systems providers	18th July 2016
4	Commencement of creation of CAA Part 102 Exposition	24th July 2016
4	Identification of selected training providers	24th July 2016
5	RFP submissions close	29th July 2016
6	Selection of drone equipment and systems provider	5th August 2016
7	Selection of initial drone operating team	5th August 2016
8	Placement of drone order	5th August 2016
9	Initial Training of operators completed	31st August 2016
10	Submission of Part 102 exposition to CAA	31st August 2016
11	Drone Delivery	31st August 2016
12	Operator familiarisation, test jobs under supervision	September 2016
13	CAA Part 102 liaison as required	September 2016
14	Flight proficiency and knowledge test for operators intending to work within 4km of an airfield under CAA Part 101 requirements	Last week September 2016
14	Operational capability under CAA Part 101 commences	October 1st 2016
15	CAA Part 102 Operator Certificate Issued	Unknown

4. Costs

Budget

Item Description	Budgetary Price
Capital Items	
Drone	$19,000
Gimbal & Zoom Still/Video Camera	$8,000
Batteries (2 Hour Airborne Capability)	$3,500
Pilot Controller	$3,000
Camera & Gimbal Controller Station	$10,000
Ballistic Recovery	$3,500
Total Capital Cost	**$44,000**
Operations: Initial one off	
Safety and operations training (2 persons)	$3,000
Flight training (2 persons)	$5,000
Flight certification (2 persons)	$2,500
CAA Part 102 Certification:	
CAA Application Fee	$2,000
Consultancy	$6,000
Operations: Ongoing	
Consumables, Per Annum	$1,500
Total Operational Cost	**$20,000**

Changes

Once the project plan has been signed off by the Executive Leadership Team, any changes to budget must be approved by the Project Sponsor.

5. Quality

The conditions of use and expect life will determine the extent of need for quality and the maintenance requirements of drone equipment.

The purpose of the drone is in high wind conditions and therefore access to replacement parts and ease of non-technical skills to replace key components such as blades and modulised components will reduce downtime for maintenance.

The life cycle of the equipment will be affected by rapid advances in technology and this will render the design and purchase equipment obsolete for Council purposes in four to five years.

6. Project Governance

The Chief Executive and Senior Management team will determine the viability of the project with final reference of the report to Council.

7. Communications

An external communications plan for affected land owners will be developed.

Internally, a booking system for Drone use will be established with a primary person assigned to make this available to internal customers and correspond with external customers.

8. Risks and Issues

There are many possible benefits resulting from the Council use of drones. There are also risks which will require mitigating or minimising in order to protect the Council's interests.

In exploration of risk areas, probabilities, and possible impacts, the following areas have been considered.

- Piloting error
- Inadequate training of personnel controlling drones, or overseeing drone use
- Mechanical or technical failure of the drone
- Mechanical or technical failure of associated drone software, hardware, or associated systems
- Maintenance and storage of data and information, including images, captured via drone use
- Inappropriate use of a drone by an employee
- Breach of privacy
- Unauthorized breach of drone technology systems, including data and information storage and control systems
- Drone accidents

Regulatory Compliance

Operators of drone technology in New Zealand are required to comply with Civil Aviation Authority (CAA) Rules, Parts 71, 101 and 102.

Part 71 covers the designation and classification of airpace.

Part 101 covers the general rules under which operators of Remotely Piloted Aircraft Systems (RPAS), generally referred to as drones, must operate. The rule does not differentiate between amateur and commercial operators.

Part 102 covers the rules under which RPAS operators wishing to operate outside of Part 101 controls must comply with.

CAA Part 101

CAA Part 101 requires that RPAS operators must:

- Not operate an aircraft that is 25 kg or larger and always ensure that it is safe to operate.

  The Council can meet this weight limitation requirement as commercially available drones together with full camera payload typically weigh less that 5 kg.

- At all times take all practicable steps to minimize hazards to persons, property and other aircraft.
- Fly only in the times designated by the CAA as being daylight hours.

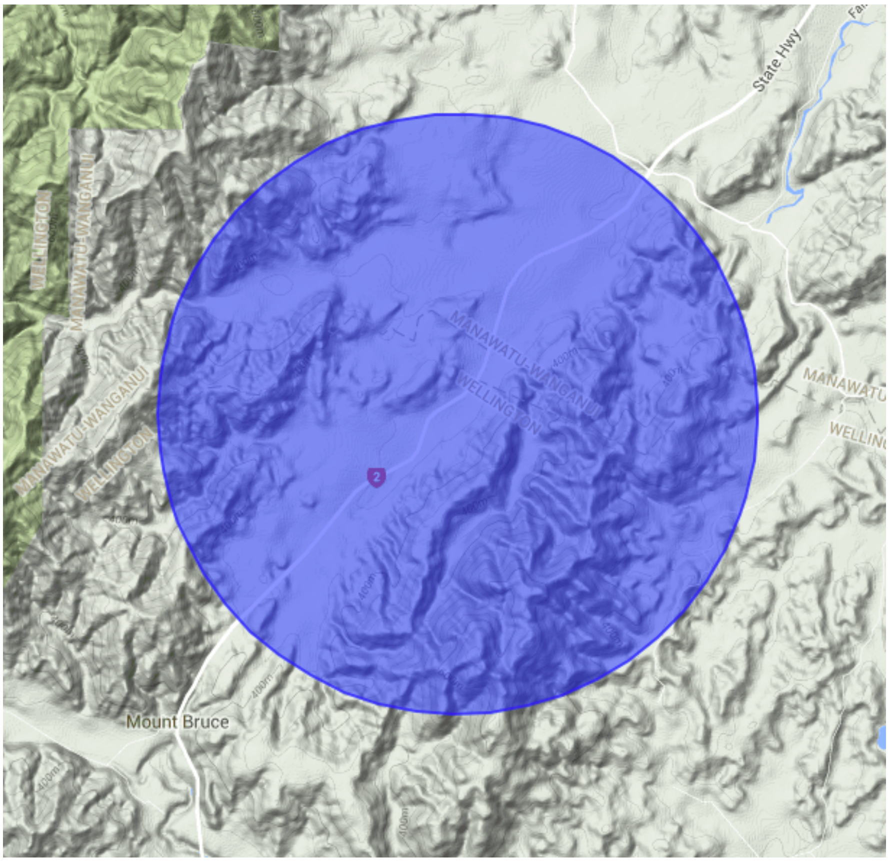
- Give way to all crewed aircraft
- Be able to see the aircraft with your own eyes (eg, not through binoculars, a monitor, or smartphone) to ensure separation from other aircraft (or use an observer to do this in certain cases)
- Have knowledge of airspace restrictions that apply in the area you want to operate.

  These requirements can be met through appropriate operator training.

- Not fly in special use airspace without the permission of the controlling authority of the area (eg, military operating areas or restricted areas).

  A designated restricted flight area, NZR501, exists in the vicinity of Mount Bruce. Part of this area encompasses the southern most part of the Tararua District. Any drone flights within the restricted flight area will require the prior permission of the Department of Conservation.

  A map of the restricted area is shown below



CAA Part 101 also requires that RPAS operators must:

- Not fly closer than four kilometres from any aerodrome (unless certain conditions are met).

  The only aerodrome within the Tararua District is the Dannevirke Aerodrome.

  The requirements for flying within four kilometres of the aerodrome are:

  1/ Permission to fly within 4km of the aerodrome must be granted by the aerodrome operator and the flight is less than 400 feet above ground level.

  As the operator of the aerodrome is Tararua District Council, it is felt that objections to operate will be unlikely.

  2/ The flight must be performed by an operator approved by the Director of Civil Aviation which includes a person trained by an approved training facility or holder of a pilots licence, or the flight must be under the supervision of a person trained by an approved training facility or holder of a pilots license.

  Appropriate operator training and certification or an arrangement to obtain the services of an approved person or private pilot will allow the Council to meet these requirements.

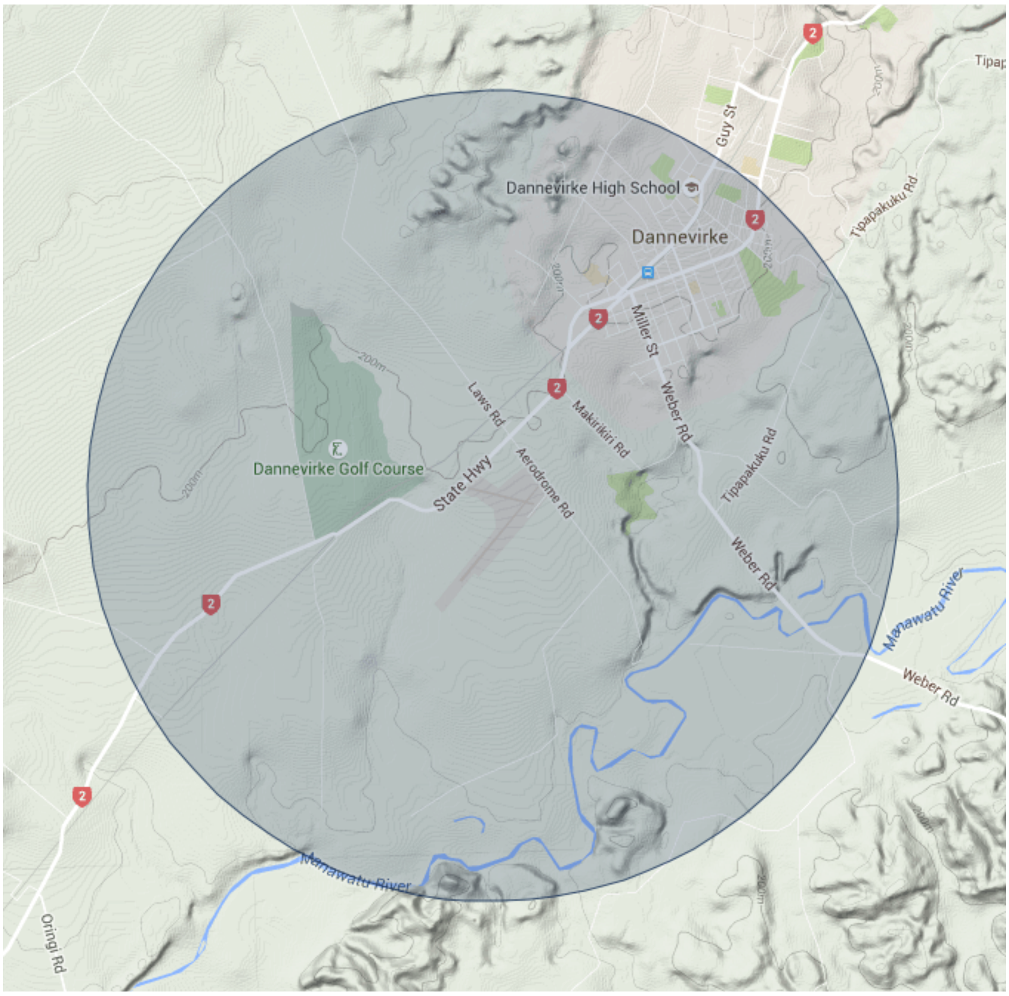
  3/ An observer is present.

  This requirement can be met through appropriate operating practice.

  An exemption to these requirements exists for flights outside of the boundary of the aerodrome where the flight is considered to be a shielded operation, and in airspace that is physically separated from the aerodrome by a barrier (such as a building or trees) that is capable of arresting the flight of the aircraft.

  A shielded operation is defined as: An operation of an aircraft that is within 100m of, and below the top of, a natural or man-made object.

The Dannevirke Aerodrome airspace 4km boundary is defined as:



Dannevirke Aerodrome and 4km Boundary

- When flying in controlled airspace, obtain an air traffic control clearance issued by Airways.

  There is no controlled airspace within the Tararua District though operators need to be aware of the Palmerston North Airspace boundary close to the town on Ashhurst.

- Not fly the aircraft higher than 120 metres (400 feet) above ground level

  This will be monitored via the control system of any commercial grade drone control system.

- Have consent from anyone you want to fly above

- Have the consent of the property owner or person in charge of the area you are wanting to fly above.

  It is believed that these two requirements of CAA Part 101 will have an impact on the operation of drone technology by the council.

Given an scenario where an inspection is to be performed of a road bridge over a stream, with the stream and road forming property boundaries this may result in the permission of four property owners being required to provide consent prior to the bridge inspection by a drone being undertaken.

For drone operations within more densly populated areas where a drone is being used for mapping or aerial photography purposes there may be situations where overflight of a person cannot be avoided it the task is to be performed efficiently.

In order for the Council to be able to meet its objectives and operate in compliance with CAA regulations a Part 102 Unmanned Aircraft Operator Certificate will be sought.

A Part 102 Unmanned Aircraft Operator Certificate grants rights to operate outside of the conditions imposed by CAA Part 101 providing specific requirements are met.

These requirements include the submission of an exposition to the CAA detailing:

- The aircraft to be used.
- The control systems to be used.
- The personnel to be involved in flight operations.
- The details of the physical locations to be used in the operation.
  In the case of the Council's operations this would be the entire Tararua District.
- A hazard register and risk assessment detailing what measures are to be used to mitigate or manage risk.
- Procedures for the maintenance of the aircraft and measures to ensure continued airworthiness.
- Inflight procedures including minimum distances from persons and property.

  For Council operations it would be proposed that:

  > A drone may fly over property without owner consent for the puposes of asset inspection, aerial photography or mapping where that flight does not overfly a residential building.
  >
  > A drone may fly over persons for the purposes of asset inspection, aerial photography or mapping where the vertical distance from a person is not less than 20 metres.

- Initial airworthiness standards.
- Procedures for controlling, amending and distributing the exposition.

The costs associated with the creation and submission of a Part 102 exposition have been included as part of the investment budget.

Health and Safety

In order to meet its obligations under the Health and Safety Act the Council will introduce documented procedures for the operation of drone technology that:

- Identify risks to the wellbeing of Council employees associated with the operation of drone technology.
- Identify risks to the wellbeing of other parties when Council employees are operating drone technology.
- Identify the risks to the wellbeing of Council employees and other parties when the Council contracts for services associated with drone technology.
- Implement processes that minimises the opportunity for these risks to eventuate.

9. Drone Specification

Research has been undertaken to establish the base specification for a drone that is capable of meeting the Council's base requirements in that it requires a drone and associated systems to assist with:

- Improvements to the efficiency of bridge inspections together with a reduction in inspection related risk to personnel and a reduction in public impact from road closures during bridge inspections.
- Improved ability to inspect bridges where terrain currently restricts the ability to inspect.
- A reduction in cost of aerial imagery and associated flight operations
- Introduction of the ability to obtain high quality small area aerial maps and terrain models.
- Improvements in the ability to assess the state of Council assets following weather, seismic or other civil defence related events.
- Improvements in the processes associated with volumetric measurement of council resources.
- The ability to capture imagery over a long term to assist with the monitoring of coastal erosion.
- Image capture, mapping and terrain modeling as part of the Council's planning and approvals process.

It was determined that these requirements can be met with drone technology technology that:

- Has an effective flight time.

  Given current battery technology, task definition and expected payload, a minimum effective flight time under nominal conditions is considered to be fifteen minutes plus a two minute reserve to return to the home landing spot.

- Has operational ability in high wind conditions.

  An analysis of wind conditions at Dannevirke for the 2015 year obtained from the NIWA climate database shows average wind speed frequently exceeding 20 km/h and on occasions exceeding 30km/h. The ability for a drone to operate in high wind conditions is considered to be important if the number of useful days is to be optimised. The analysis also shows that the indicated speed of wind gusts in the area is usually in excess of 15 km/h over the average wind speed.

There are operational risks to be taken into consideration when operating is higher wind conditions and it is expected that operators will need to gain experience at flying in lower speed wind conditions before proceeding to operate in higher winds.

Good operating practice places the maximum take off wind speed for safe operations at 75% of the stated maximum forward speed of a drone and it is expected that any selected drone technology would be able to operate at average wind speeds up to 25km/h and handle gusts of up to 55km/h. This will give sufficient safety margin to allow the drone to remain in position when operating in windy conditions.

It is noted that operations at higher wind speeds will result in a reduction of airborne time due to the additional power expended in keeping the drone in position while overcoming the effect of wind.

- Is capable of being operated by a two person team with one person operating the drone and one person operating the payload.

  Safe operation of a drone requires the full attention of the pilot. In order to use drone technology in an effective manner for inspection purposes it is expected that a two person team will be required with one person flying the drone and the other person operating the camera positioning system, checking the asset under inspection and photographing as required.

  Where the drone is being used for aerial mapping, terrain information capturing or with autonomous or semi-autonomous flights then single person operation is practical.

  Operation within a 4km radius of Dannevirke airport, where the flight is not considered to be shielded, then a two person team will be required at all times with one person designated as pilot and the other person designated as an observer.

- Has an ability to carry appropriate payloads.

  It is expected that any drone technology acquired by the Council will have sufficient power to be able to support a range of payloads.

  It is noted that flight endurance is affected by payload and nominal flight time has taken into consideration the largest expected payload, being a digital camera with a motorised positioning gimbal.

- Has an ability to easily exchange payloads (future use may include Infrared, telemetry, Normalised Different Vegetation Index (NDVI) camera and other as yet unidentified technologies).

  As it is expected that drone use within the Council will extend to other areas beyond inspection, the ability to easily swap payload types is considered to be an important feature of any selected drone as this will reduce the technical skill level required to support the drone.

- Maximises the opportunity for recoverability in the event of system failure.

  The Council does not assume that the systems used to control a drone or the operators involved in operating a drone are going to operate perfectly in all flight situations.

  When a flight is less than nominal and is affected by either on board system failure or by operator error, the Council is seeking systems that will allow the drone to safely land or, in the case of loss of control, allow the drone to be easily located for subsequent recovery.

- Has onboard systems to protect property and persons in the event of system failure.

  The Council considers the protection of property and persons being overflown to be of the highest importance.

  Any drone technology acquired by the Council must incorporate protections systems that can demonstrably reduce the impact on property and persons in the event of a system failure.

  The use of fall protection technology in the form of a ballistic recovery parachute to slow the descent of a failed drone will also assist the Council with demonstrating safety of operations under Part 102 of the Civil Aviation Act.

- Has a declared expected lifetime for the motors, propellers and structure.

  Drone technology, like all airborne systems have certain components that are determined to have a limited lifetime based on hours of operation.

  The expected lifetime of major components such as the motors and propellers is reflected in the operating cost of the drone and will be taken into consideration during the technology selection process.

- Has a declared capability to repair the drone structure in the event of crash.

  Whilst it is expected that every care will be taken when operating any drone technology acquired by the Council, there may be situations where landings are less than satisfactory and this may result in damage to the drone.

  The ability to repair the drone by technically competent Council staff, nominated contractor, or the drone manufacturer will be taken into consideration in order to ensure that operational time is maximised and cost of repair is reduced.

- Demonstrates conformance with New Zealand standards and regulations.

  There are currently no quality or production control standards affecting the manufacture of drones either in New Zealand or internationally though there are requirements that the control and monitoring systems conform with the Radiocommunications Act 1989 and the Radiocommunications Regulations 2001.

  Any supplier of drone technology to the Council will be required to demonstrate compliance with both the Act and the Regulations.

Any mains powered electrical charging equipment is required to comply with the Electricity Act 1992 and with the Electricity (Safety) Regulations 2010.

It is expected that any drone technology purchased by the Council will fall under the 15kg limit imposed under Part 101.215 of the Civil Aviation Act.

In order to obtain imagery and geographical information suitable for use by the Council it has been determined that a camera based payload with the following specification will be required:

- The camera will have the ability to capture high quality still images.

  The quality of the camera payload will have a bearing on the level of information obtained for inspection, mapping, terrain modeling and 3D modeling.

  It is expected that, based on currently available technology, a minimum resolution of 20 megapixels will be required.

- The camera system will include a three dimension motorised gimbal and the ability to stabilise the camera in high wind conditions.

  The purpose of the three dimension motorised gimbal is to provide a stabilized platform for the camera to counter movement within the drone platform while capturing still or video images.

  Gimbal technology has advanced dramatically in the past two years and has seen a near fivefold reduction in cost associated with the delivery of highly stabilised camera platforms.
  The market now appears to have established a pricing level and it unlikely that, unless there is a massive reduction in the cost of the motors used to stabilise the platform, further price reductions of this scale are unlikely.

- It is desirable that the camera has a remote controlled zoom.

  The ability for the remote camera operator to zoom in on an object independent of the position of the drone will reduce the workload of both the pilot and the camera operator.

  There are a number of technical limitations that currently affect the ability to remotely control zoom on drone mounted cameras and this capability has been classed as a nice to have rather than a specific requirement.

- The ability for the images to be georeferenced.

  The tagging of photographs taken by drone mounted cameras with geographical location references is an essential feature if the images are to be subsequently used for mapping, terrain modeling or 3D image creation.

- Ability to capture video at HD (1080/30fps) quality or greater.

  Whilst it is expected that the majority of imagery work undertaken by Council owned drone technology would be still images, there is an expectation that, on occasion, the ability to produce high quality video is desirable.

  The majority of high quality digital cameras supported by drone manufacturers have the ability to capture video.

- The ability to remotely position the gimbal and remotely monitor the camera images by the operator.

  As a primary purpose of the proposed Council owned drone is for asset inspection work the ability to remotely position the camera and view the images in high quality while the drone is still in flight is considered essential to the effective use of this technology.

  There are a number of approaches taken by various drone manufacturers to meet this common requirement and, from information available from the manufacturers, image quality at ground stations would be of sufficient quality to be able to be used for inspection purposes.

In order to support the expected operational model the drone system will need to support two operator controls and displays with one set being used by the pilot and one set by the camera/gimbal operator.

It is expected that the drone will become part of the standard field equipment set for an asset inspection team and should be capable of being taken out to the field with requiring special protection to be taken into consideration.

The provision of transport cases to ensure that the drone and supporting systems are not damaged when used to support daily operations is consider to be an essential requirement.

Until the use of drone technology by the Council has commenced the exact flight time per day is difficult to establish. An initial estimate of up to two airborne hours per day has been used to determine the number of batteries that will be required to support operations.

The ability to easily swap batteries in the field and the ability to charge batteries from a vehicle power source are considered to be essential requirements for effective use of a drone as this will maximise the available airborne time.

It is expected that the Council will need to purchase spares and accessories as required in order to support drone operations and to meet its obligations with regard to maintenance.

When used for mapping, terrain modeling and 3D mesh creation, the ability of an operator to correctly fly a drone over the required image capture flight path is limited and there will be a requirement to support autonomous operation.

The Council will acquire flight management software to includes provision for:

- The creation of flight plans for automated image capture.
- Automated flight operations.
- The ability to capture map images based on area bounds.
- Support for managed image overlap.
- The ability to revert to manual flight control if necessary.

In addition to the downloading of captured images for the purpose of keeping asset inspection images the Council will purchase, or select a service provider for, image processing software to include:

- Photo stitching.
- Creation of georeferenced map images.
- Orthomosaic correction of map images.
- Creation of digital surface models.
- Creation of 3D point cloud images.

10. Operator Training

As with the use of any advanced technology, the effective and safe use of drone technology requires that operators and support personnel receive adequate training in order to ensure that the Council is able to meet its legislative requirements and minimise the opportunity for loss or damage.

It is expected that operators of any selected drone technology will receive training that:

- Ensures that the operators are aware of any human, technical and environmental factors that affect operation.
- Ensures that the operators are aware of their requirements with regard to legislation and regulations and are able to comply with these requirements.
- Ensures that the operators minimise the risk of loss, damage or injury.
- Ensures that the drone is operated according to manufacturer's specifications.

11. Operational Controls

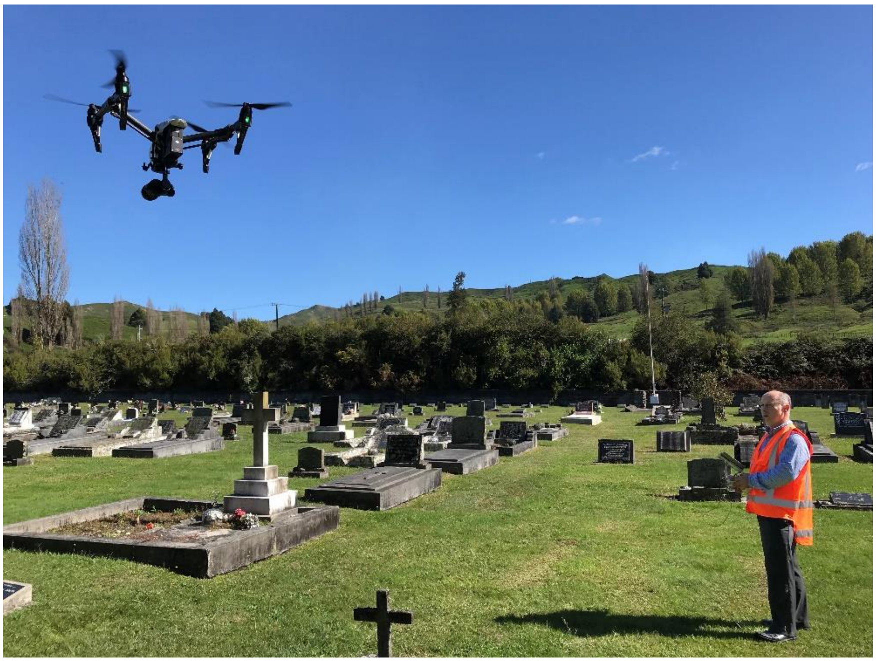
In order to meet its obligations under CAA Part 102 and to ensure that drone technology is operated in accordance with the Council's expectations a set of supporting governance documents will be created. These will include:

- Procedures for reporting information to the Civil Aviation Authority
- Operating requirements for personnel
- Procedures covering the use of drone technology.
- A maintenance schedule.
- Procedures for the recording of flights.
- Inflight procedures and operating limitations.
- Procedures for obtaining permission to overfly land and people.

Ruapehu District Council

4D Cemeteries Project

A collaboration between RDC, Hawkeye Systems and 4DMapper



Objective

To provide a rich 3D environment for the public to visit local cemeteries and include supplementary information on the specific subject matter.

Challenges

There were many challenges associated with this project including;

- Little historic or current projects that have been undertaken by others
- Formulating a effective and reliable capture methodology that could be replicated
- Seamless blending of ground capture and UAV (Unmanned Aerial Vehicle) technology to provide clear and crisp imagery that provides orthographic, 3D imagery and accurate geometric models
- A software platform that supports the entry of annotation data, including imagery and hyperlinks
- A delivery mechanism that is device agnostic, easy to use and supports the display of annotation data-this has to be web browser based

Project Background

All innovations start with a need, which in this case was the ever-increasing demand for requests for information pertaining to Council owned and managed cemeteries. Also the push for open and consolidated data and the increasing demand for site imagery in a 3D context.

RDC had embarked earlier on purchasing and deploying their UAV to undertake photogrammetry flights to enhance their GIS capability and delivery.

Initially this was carried out as a proof of concept via the online service “DroneDeploy”. This involved utilising one of the GIS staff’s semi-commercial DJI Phantom 3 UAV. It didn’t take too long to prove the value of aerial photogrammetry in the areas of low level, high definition imagery, especially in the area of cemeteries. That up until then had been reliant on high altitude aerial photography at up to 15,000 feet.

Prior to this, Hawkeye Systems, a New Zealand company had provided autho-rectified UAV imagery from 400 feet of Ohakune, the level of detail in this project far surpassed anything that had previously been provided by conventional methods such as previous aerial capture programs.

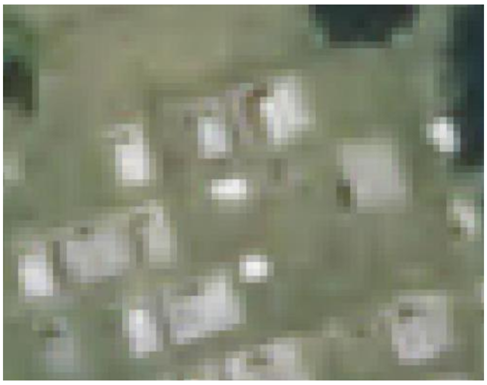
Further to this, the GIS staff used the data captured and processed via DroneDeploy, to report not only on the current state of their landfill in Taumarunui, but also to provide accurate volumetric measurements of the landfill extent, saving thousands of dollars on survey fees. This saving resulted in the cost justification for RDC to purchase its own commercial UAV.

Since the acquisition of the UAV, IT has become an essential tool in the GIS toolbox. RDC has also fostered a strong working relationship with Hawkeye Systems. This has provided cost effective, high quality image processing, delivering rich 2D Autho-rectified imagery, DEM and 3D models.

Hawkeye Systems has also been involved in a major Street re-vitalisation project, which involved the 3D modelling of the Raetihi and Ohakune townships to provide a basis for the design of new alterations. With the success of this project, it has been a natural progression to harness the capabilities of the capability available to RDC and Hawkeye Systems.

Hawkeye Systems has introduced RDC to 4DMapper, an Australian based technology company that provides a cloud-based geospatial data management and visualisation platform for enterprise. 4DMapper agility and flexibility of its platform allowed RDC quickly create a cost-effective solution for visualising 2D/3D geospatial data, including 4D Cemeteries project, and bring the benefits to general public.

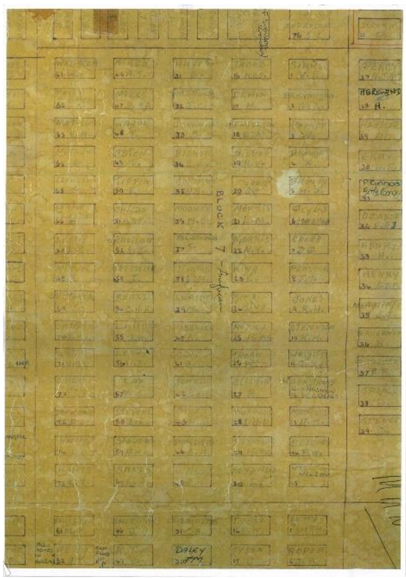
The evolution of GIS Raster imagery around cemeteries was driven from a need for greater visibility and resolution. Prior to the implementation of UAV technology the resolution of Cemetery imagery was only available with the regular Aerial Imagery capture conducted every 5 years.



Aerial Imagery taken at 15,00ft

Aerial Imagery taken by UAV at 75m

Without the ability to easily identify individual plots both individually and multiple, the best RDC could do was to maintain paper maps of the cemetery and include these in what was handed out to the public on request.



Paper map of Manunui Cemetery

With the establishment of a relationship with Hawkeye Systems, RDC was able to ascertain high definition 2D Raster imagery and as a consequence of the processing via Context Capture, a 3D model of the cemetery.

3D model from Context Capture processing

The above is the output from Context Capture from a Nadir flight only without any Oblique capture. This model was the impetus to drive towards higher resolution 3D models that could provide a higher enough resolution to enable headstone inscriptions to be read.

Why 4D not 3D?

The 4th dimension is time. The project platform is published as a 3D model, but with the inclusion of extended information that draws information from other timely aspects such as historical and ancestral links, it is more than just the presentation of a 3D model. The intention is also to refresh the models on an annual basis, thereby providing the ability to reference imagery and data chronologically.

Project outline

The outline of the project involved several key stages.

Planning and Scope

This phase was about planning and designing a system to meet the needs of the end users. Another consideration was, who are the end users and what would be the best delivery platform to serve that user.

The main factors were;

Internal RDC Users-this was primarily Customer Services Frontline staff and the property management team. The former would use this as a tool to walk through public who engaged counter staff with the requirement to understand the location of people interned in any of our RDC cemeteries. In regards to the property team, this was to provide a visual reference for the management of their cemeteries.

External Users: – primarily this would be the general public, including relatives, friends and those engaged in the research of ancestry.

Delivery platform: the following was set as a criteria for access and navigation of the end users.

Access: It was desirable to provide the imagery, notations and links within a web browser that supported the WebGL application.

Navigation: This needed to be simple for the end user and similar to other systems on the Internet, such as Google Earth and Google Street view.

Google Earth and several other mechanisms were investigated. However, due to limitation and licensing of Google Earth, this was not a viable option at this time.

Image Acquisition

Through working with Hawkeye Systems on several previous 3D projects, RDC had developed an understanding of what imagery needed to be captured to provide accurate and highly detailed 3D models. Also the tools that had been purchased for ongoing Photogrammetry work proved of high enough quality to proceed with the imagery required for the project.

Acquisition Tools

The Acquisition exercise requires two different capture methodologies to not only work together, but to mesh seamlessly to produce the final product. These were, Aerial and Ground based Capture respectively.

It was identified early on in the planning and with the experience of other work that RDC already possessed suitable tools to achieve this task.

Aerial Imagery Capture - DJI Inspire 1 UAV

As an aerial platform for photography and photogrammetry the DJI Inspire 1 proved to be fit for the purpose. Its responsiveness in flight, GPS accuracy and reliability provided a good mechanism to carry out the required tasks.

Camera – Xenmuse X5

The Inspire was fitted with a Xenmuse X5 camera. This provided clean and clear 16 Megapixel imagery from its standard photographic settings and lenses, without any custom settings whatsoever. This was well suited to our capture team, who have very little photography knowledge or experience.

Ground Capture – DJI Osmo with Xenmuse X5 Camera

To ensure consistency with the image acquisition for initial processing, we employed the same camera and settings for the ground as we did for the UAV Aerial capture. This was done with the assistance of a DJI hand held capture device and the Xenmuse X5 camera, via a mounting kit. Also we used a Mini iPad to provide a larger screen for better viewing.

Acquisition Capture Software

It was important to use the best capture software for the project. Although there are many applications out there where the task of capture could be automated, in this case, due to complexity of the capture methodology, including; flying at low levels, avoiding obstacles such as trees and sensitivity to the public, it was deemed best to fly and capture the imagery manually.

DJI Go Application

The DJI Go application was used for the capture. As this can be deployed on different devices, such as Apple IOS and Android, it provides a degree of flexibility and options when performing the imagery capture.

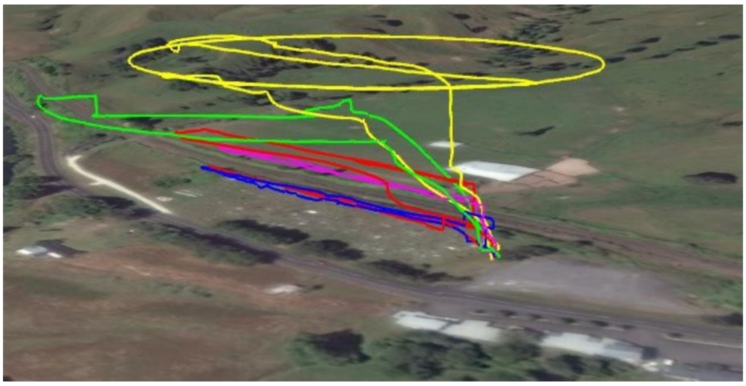
As mentioned above, it also provided us with a consistent camera setup, which we knew would assist with the subsequent image processing later on. And in respect to the aerial capture, the camera settings also provided an image capture every 2 seconds, ensuring that that the Pilot had one less task to focus on. Saying that, for the ongoing imagery capture, a second remote control specifically for the photographer would be of some assistance, leaving the pilot to focus on piloting the UAV.

Image Acquisition Methodology

Part of the initial planning was establishing what was required to deliver to the image processing, a complete set of imagery that could be easily and relatively quickly processed. With such a project, there is a lot to consider, including at least a rudimentary understanding of how the image processing works. Essentially, it requires the imagery to provide;

- Accurate GPS coordinates of each image – in the case of the DJI Inspire, there were a minimum of 12 GPS satellites visible at any time, however, ground control points were not required for this particular level of accuracy
- Substantial images of each plot and headstone from various angles. This included NADIR, Oblique Aerial and Ground Capture techniques
- Environmental conditions – this included;
    - Weather – ideal conditions were overcast, to minimise fluctuations in the contrast caused by shadows from trees etc.
    - Ground conditions – the cemetery was better mowed, so that small flowers in the grass did not confuse the image processing
    - Trees and other obstacles – an awareness of these was essential for low level flying of the UAV
    - No movement – avoiding cars or people moving with an image at close range, as this confuses the processing

Aerial Image Acquisition



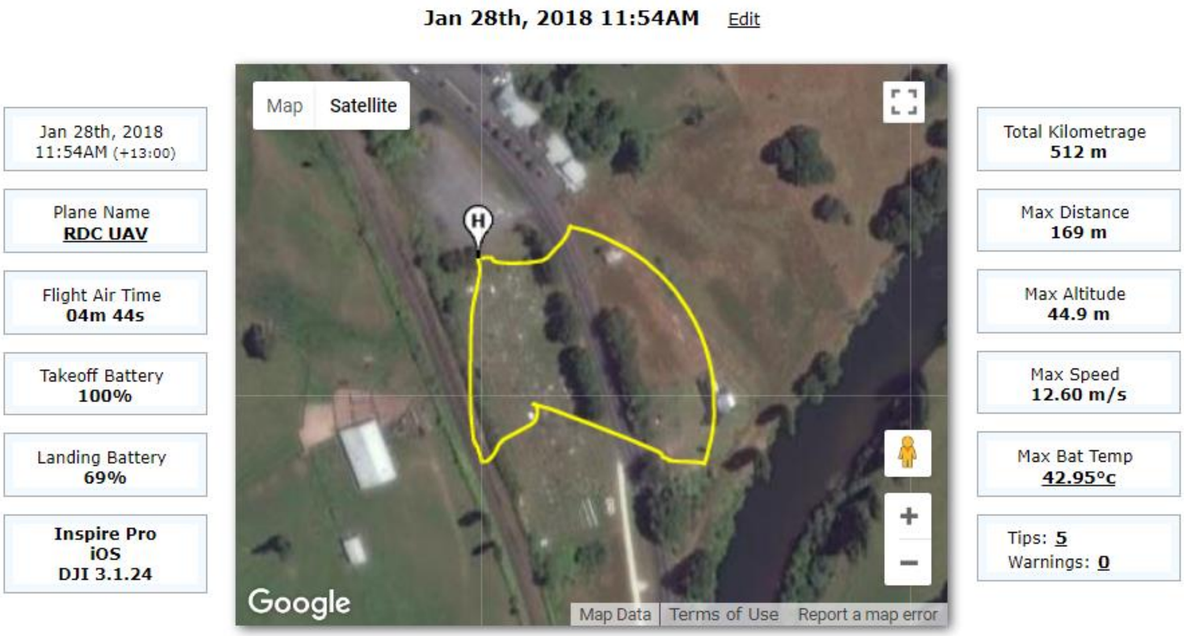
It was important to capture aerial imagery from different heights and perspectives, to ensure that 3D processing was able to work effectively. As part of the pilot study for this project, several iterations of employing trial and error were undertaken to refine the ultimate capture methodology.

This consisted of the following;

High level NADIR and POI flight

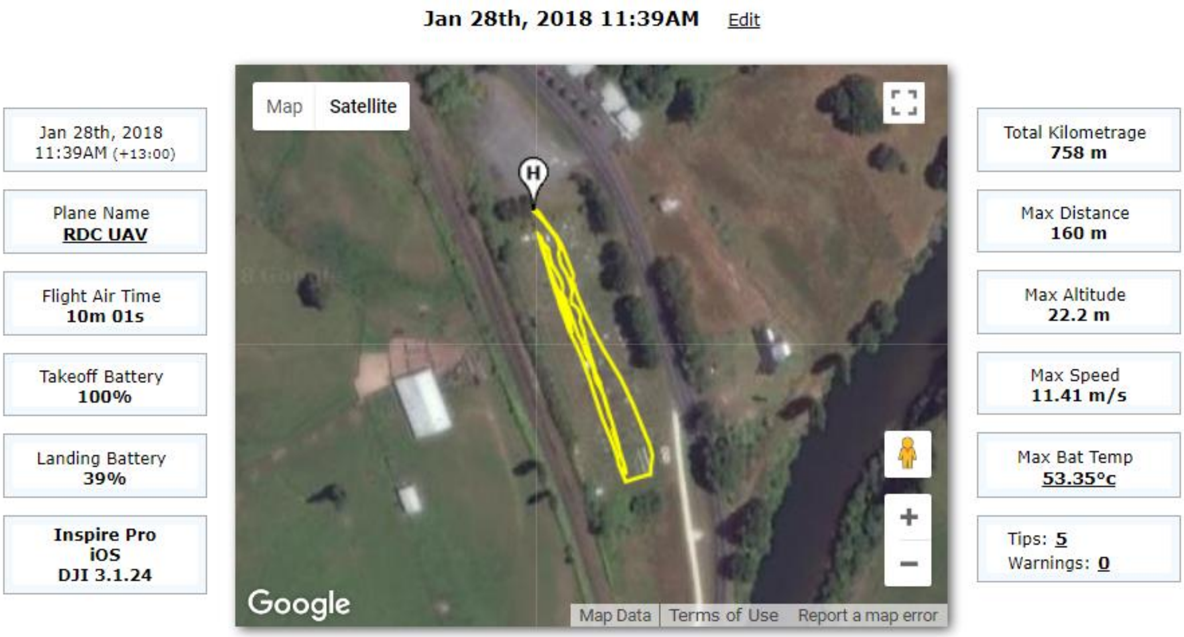
This was conducted at a maximum of 62.5m and consisted of 2 NADIR runs north to south and a POI (Point Of Interest) orbital flight to capture the surrounding area such as the main road, trees and railway lines at oblique angles.

Mid-Level Oblique's

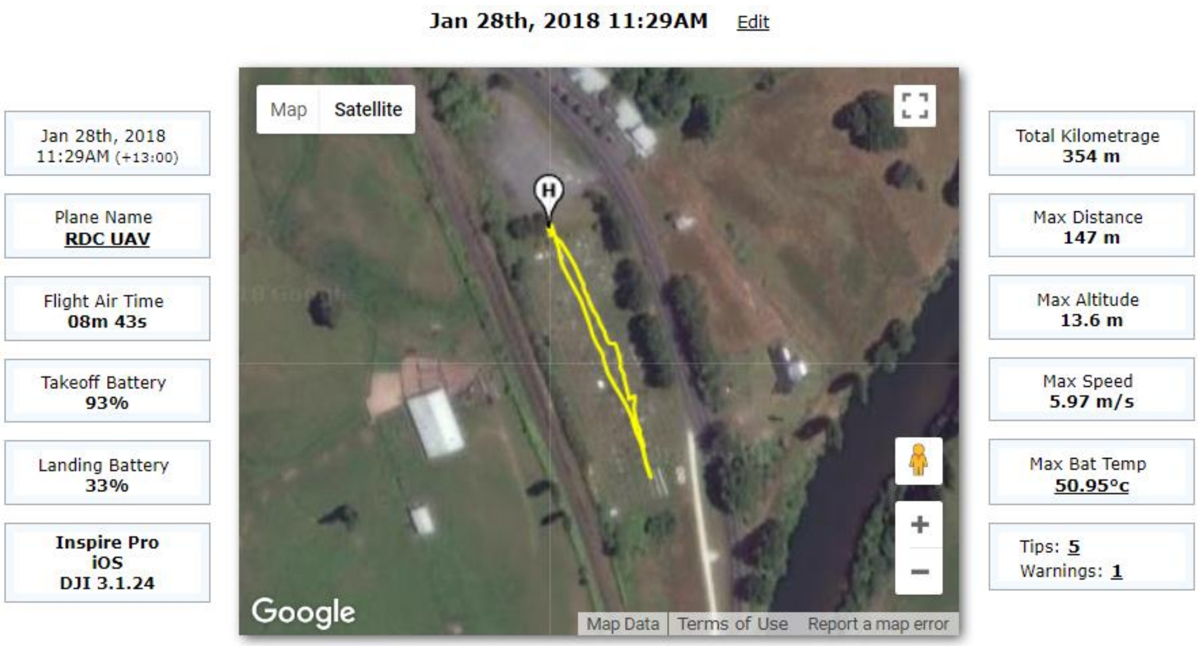


These were carried out to provide a lower level of detail, again focussing on capturing the higher level trees and background details.

Lower Level Oblique's

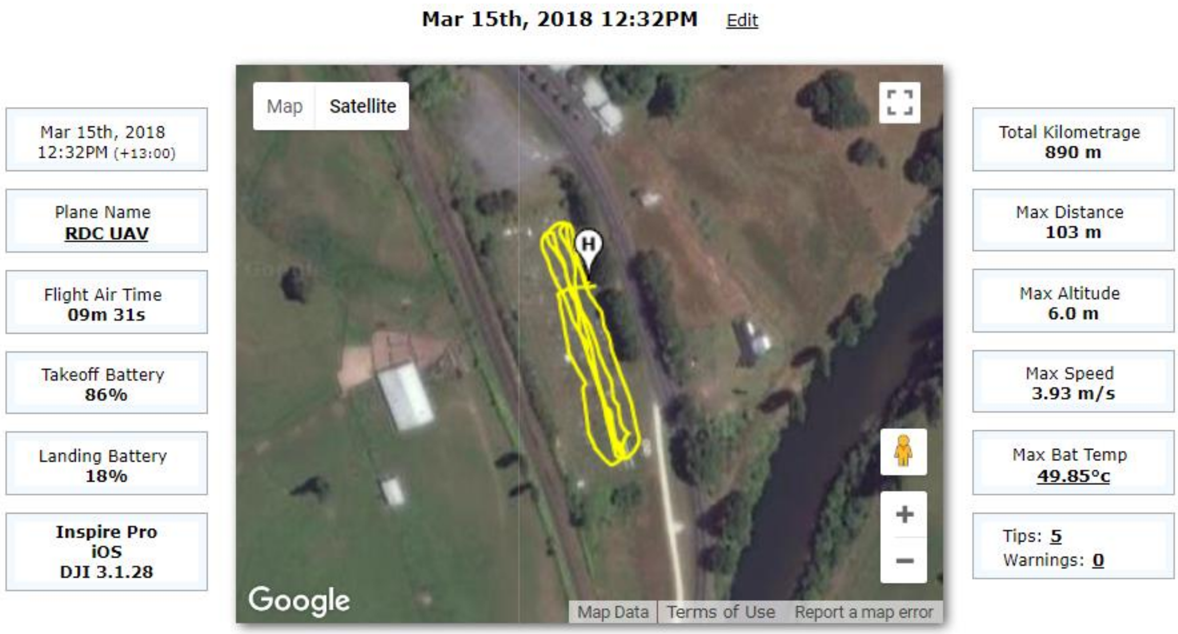


These were carried out to capture oblique's at lower level again especially focusing on capturing imagery from under trees etc.



Supported by even lower level oblique capture at 13.6m, again to support production of plots under the trees to the East.

Headstone Geometry Capture



On another day, some very low level flights were conducted at a maximum height of 6.0m. These were taken specifically to capture side-on obliques of the headstones and front as well as the front and back of these. Although the weather on this day was different from the imagery taken on the 28th of January, the processing handled this well.

Ground Imagery Capture

The approach to capturing good ground based imagery, was twofold; One, to capture the detail of each headstone; two, to capture the geometry of each headstone to tie into the other levels already captured.

The initial capture was unsuccessful due to a malfunction with the GPS unit on the SLR Digital Camera that we were using. Consequently the context capture processing software was unable to tie these into the images we had captured with the UAV.

Subsequently, we used the DJI Osmo with the Xenmuse X5 camera attached to it and an iPad with the DJI Go application. However, due to the poor GPS location provided by the iPad, this was not good enough to enable Context Capture to successfully generate tie points to tie these images into the image sets.

With time constraints and an understanding of the required processing time, we decided to use the UAV to capture the ground imagery as well.

Although this method seemed to appear cumbersome, it did provide several benefits, such as;

- Used a minimum 12 GPS satellites for geo-referencing
- Utilised the same camera and settings as the UAV capture
- Easy to control the camera position
- Sustained battery life due to no flight time

Unfortunately, as no flight as such took place, no flight logs are available.

This provided a set of ground imagery that included;

- Front on imagery of headstones
- Angular capture of each headstone to capture corner tie points for the geometric model

This was not a matter of stopping at each headstone to capture the different angles and perspectives, but more a matter of ensuring that we captured each headstone with 3 images, walking up each row at a speed that enabled this with the automatic 2 seconds per image capture from the DJI software.

As a consequence of this capture methodology, we also captured oblique perspectives of the background headstones as well as the one directly in the front.

Processing Methodology

Once the imagery was captured, it was placed in a shared OneDrive repository and made available to Hawkeye Systems for downloading. These were large image sets containing Geotagged JPEG files around 7 Megabytes each.

For the aerials, there were around 800 images and for the ground capture just over 1400, however we will still need about the same again in ground capture imagery to complete the photo sets. In total this equates to approximately 15.4 Gigabytes of imagery required to be downloaded and processed.

Hawkeye Systems use Multi-ray Photogrammetry using Bentley's Context Capture processing software. This is supported by a platform setup in a render farm of 4 high powered servers, sharing the load of the image processing and subsequent 3D output. Because of the complexity of processing a large amount of images to produce a high definition 3D model, the process takes over 3 days to complete. There was also the need at this early stage of the establishing a sound capture methodology and time constraints, the need to manually add some tie points and to clean up some of the 3D model.

Out of the processing the following outputs were made available;

- A 2D Autho-rectified Geotiff, that can be easily inserted into RDCs Intramaps GIS system
- A 3D 3mx model, that can be viewed in Bently's Acute 3D viewer software
- A WebGL version, that can also be viewed with Bently's Acute 3D viewer software online
- The "Cesium" model, that is uploaded to 4DMapper's 3D online application

There were some challenges with using the DJI Inspire for the aerial capture without GCP (Ground Control Points). Standard "Drone" GPS is not desirable – PPK/RTK positioning is recommended or permanent ground control points. Especially for initial capture which benchmarks accuracy. This ensures that any further capture for the site can easily be processed and embedded, rather than the possibility of having to manually pinpoint tie points.

In future the placement of QR Codes on specific assets or landmarks can be used not only to accurately pinpoint GCPs but also provide specific information about the point to Context Capture and tie in aerial and ground capture imagery.

A 5m X 5m tiling schema was implemented to allow for fast updates to the model in the updating, replacement and insertion of new plots etc. This will assist in the minimal and timely capture of imagery for this purpose.

Multiple lighting conditions can be handled but there will be limits. Capture during 10am – 2 pm even on cloudy days is acceptable. Although some of the imagery was capture on different days and in differing lighting conditions, the Context Capture software still handled these differences and produced a seamless 3D model.

Ongoing Plot Maintenance

RDC registers on average 3 burials per month over its 10 Cemeteries and district. In respect of when and how these new burials should be captured and recorded within the 3D model has been the subject of some discussion.

The request for a burial triggers an action point to the GIS team within its Ozone RFS system. This is easily setup and automated. However, the discussion has been around at what point is the capture of a new burial required and updated in the model for public viewing. There are several stages to a burial, from the burial itself after the funeral, sometimes accompanied by a temporary cross, to the settling in of the site, to the installation of the headstone at an unveiling ceremony.

As the system should reflect what is on the ground after a burial, you should see an accurate representation of this. However, this would entail at least 2 visits back to the cemetery to capture each iteration and change. At this point, this is still up for discussion.

However, to capture and slot in a new burial plot to the 3D model only requires a maximum of 10 ground capture images and 2 subsequent aerial images at low and higher levels, approximately 10 minutes work.

Also, it is intended to re-shoot each cemetery on an annual basis to pick up any changes, including additional headstones, burial plots and headstones that have been cleaned etc.

Presentation Platform

4DMapper Pty Ltd, an Australia geospatial technology company, have been very helpful in providing a customised application admin and user interface to assist in posting and displaying information. Their cloud-based geospatial platform provided most of the functionality required for implementing the project. 4DMapper's unmatched agility, willingness to work in partnership with RDC and their flexibility of their geospatial data management and visualisation platform allowed to develop a customised user interface to create an application that closely met RDC requirements specified for 4D Cemeteries.

Map Administration

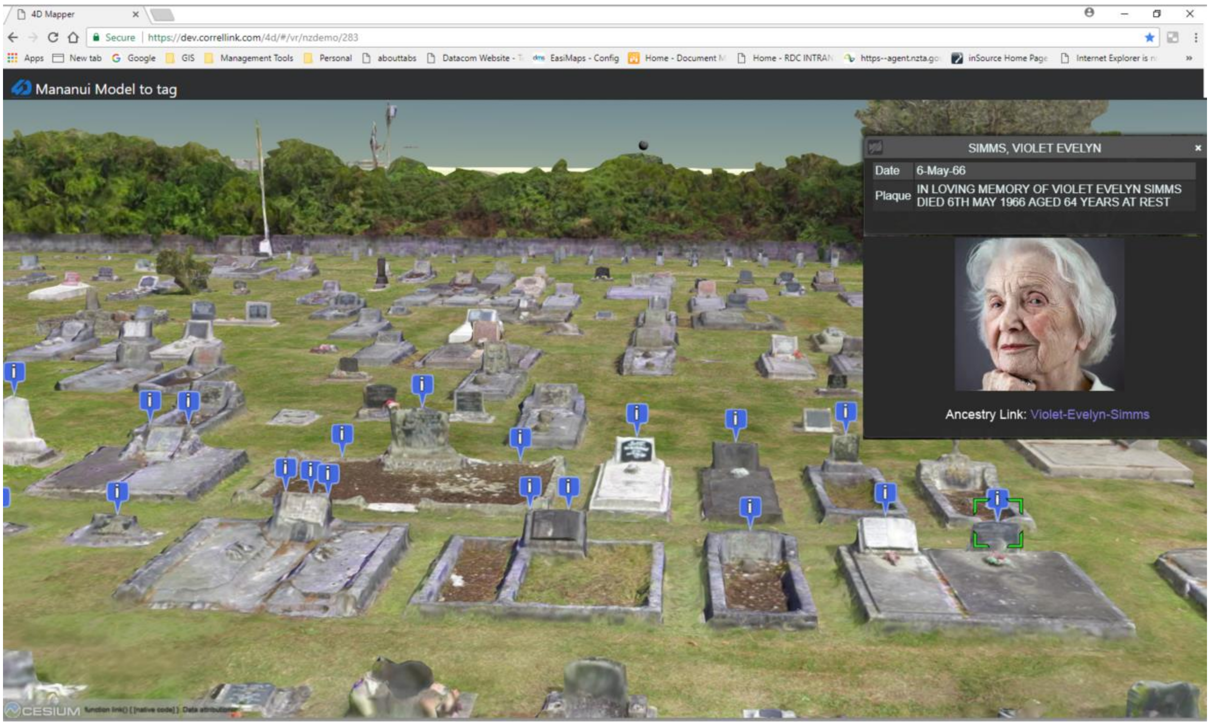
This module enables GIS staff to create points on the cemetery plots within the 3D environment and add specific field references that link directly to the underlying metadata in the cemetery database. To facilitate this, 4DMapper built a simple file upload function that enables RDC to upload a CSV file containing Metadata, including URLs to Images and sites that reference ancestry links and information.

This is a simple matter of right clicking and entering the same field reference number against the newly added point. Once the record has been saved, an icon indicates that it has been successfully linked to a record in the metadata table that has been previously uploaded. Such interface supports a streamlined and effective workflow for initial plot tagging and on-going maintenance.

Public User Access

A pilot version of the presentation of the cemetery is available via a hosted URL. The navigation is via keyboard and had to be simple for the end user, so the same keys as Google Earth have been added

This via the URL: https://dev.correllink.com/4d/#/vr/nzdemo/demo



The challenge is to give the end user a real sense of walking through the cemetery to browse the headstones and via the information icon, view more information on the interred.

Project Management Summary

The project management was headed by Stuart Campbell, GIS officer of RDC and executed as an agile iterative initiative with a series of time-boxed stages, each providing working prototype of the end-to-end solution and valuable learnings that were fed back into the delivery process. This involved the cooperation of several different companies, including;

- Hawkeye Systems – Processing of imagery
- 4DMapper – supplier of the cloud based presentation tools and customisations

In respect of RDCs role, the RDC GIS team supplied the UAV and staff to capture Aerial and Ground based imagery.

As this project will provide subsequent interest in the area of online cemeteries and is very new in terms of its application, both Hawkeye Systems and 4DMapper have provided their time and effort for nominal fees and charges.

Moving into full production with a tried and proven capture, processing and presentation methodology and applications, it is estimated that the following costs would be incurred for each subsequent cemetery, based on the size of Manunui and the 1450 plots involved.

Planning

Flight planning, including any permissions required and flight planning.

0.5 hours per cemetery – RDC

Image Capture

Not including travel time to each location based on RDC average cemetery of 4,000 plots.

1.0-1.5 hours per cemetery - RDC

Image processing

This does not include image transfer times, just the actual time to process and associated costs based on RDC average cemetery of 4,000 plots.

In negotiation at this stage

Content Hosting

This is the ongoing cost of the hosting fees from 4DMapper

In negotiation at this stage

Content Admin

This is the time to set up a new site for the first time and the time to administer and existing site, based on RDC average cemetery of 4,000 plots..

8.0 hours to stand up a new cemetery site - RDC
2.0 – 3.0 hours per month on maintenance

Change Management

This is the time required to capture, process and administer a new plot to the system.

Approx. 1.0 hours per change – RDC

Project Budget = $5,000

Project Actuals to date = $1,500

Projected costs of additional cemeteries (7) total = Under Negotiation

Project Benefits

The overall benefit to RDC and the wider public community is yet to be fully realised, as this is using cutting edge and more importantly, cost-effective solutions. But with the demand of more cemeteries being available online and the subsequent emergence of Ancestry sites, there is a very real appetite for this next evolution how cemeteries are presented, accessed and interacted with.

This project also supports the vision of the organisation to provide more online services and present "Open Data" to the public, at the same time, keeping the costs to the organisation and ultimately the ratepayer to a minimum. Off-setting the setup and on-going costs of a cemetery database, is a very traditional and time consuming system, which has up until now relied solely on paper copies of plots that in no way represents what is actually on the ground. This leads to confusion and a poor customer experience.

Using cost effective UAV technology also enables the user to have a view on the ground of what was once just a blur, from traditional aerial capture carried out at around 15,000 feet. The process also provides very clear, autho-rectified 2D imagery that can easily be imported into any GIS viewer. This eliminates the need for GIS staff to manually with a "best guess", pinpoint actual plots, down to the nearest centimetre, therefore further enhancing the traditional 2D GIS viewer capabilities.

Consequently, another by-product of this process, is the accurate mapping of individual cemetery blocks and plots, via the use of the customised annotation tools provided as part of this project and having these outputted to a Shape file or other types of vector data. As the 2D Autho has been generated through the same process, this ensures that wherever we place the marker, will align exactly as plotted within the admin module.

Points plotted via the 4D Mapper Admin Module

Shape file exported and imported into GIS system

RDC Drone Implementation

This document outlines the impetus and steps required to capture and implement aerial photography into RDCs GIS application, Intramaps.

As part of progressing technology application towards a better understanding of the “Lay of the land”, the old adage that a picture paints a thousand words.

Using drones to gain a perspective of what is in a district, with the addition of data sourced from ERP and Asset management systems is not that new to most Local and regional Government organisations, this is surfaced through their GIS (Geospatial Information System) and supplemented with the usual Aerial layers.

These layers are usually sourced through joint collaborative ventures with other organisations such as LASS (Local Authority Shared Services), but due to the expense of the exercise, in most cases Tri-Annually.

However, with the advances in technology and the reduction in costs, organisations are now able to purchase and implement solutions at a fraction of the cost and with better localised results and data.

RDC have been exploring this technology using off the shelf hardware, in this case a DJI Phantom 3 Professional

At the lower range of the drone market, priced around $1,800, the DJI Phantom Professional 3 still boasts some impressive technology. In fact, it is more of a camera platform, than something you would fly for fun. It has a gimbal stabilised HD camera, that takes 12Megapixel images and 4K video and is capable of safe flying limits ranges of up to 2 Kilometres, however there are CAA regulations around the use of this equipment that restricts these ranges to maximum height of 400ft and not to fly as FPV (First person View), in other words, not to fly out of sight, which is easily done.

The clever thing about the controller for this machine is that the software or brains can be downloaded to an Android or IOS device such as a phone or IPad, which then connects to the remote control. This provides a FPV camera footage as well as aircraft and advanced camera controls.

More and more software developers are getting on board and creating feature rich applications not just for the DJI models specifically, but all manner of drones.

One of these applications is the cloud based DroneDeploy Photogrammetry software. This is a subscription service that has a device application as well that syncs with the cloud. This enables the user to setup tasking from the desktop, sync with the control software and then implement the mission in the field.

In the following example, we will look at the steps and output requested by RDCs waste management team, to aerial survey the Taumarunui Landfill. They had engaged a traditional surveyor to ascertain profile data, to get an idea of the current and potential heights of the refuse mound prior to capping. This is needed for resource consents.

Although there are aerial photographs of this site, as RDC works in a 3-year cycle in refreshing these, the latest RDC has are from 2011, delayed due to unsatisfactory weather conditions and timing. Essentially being part of a LASS arrangement and only having a small window in which to fly, to eliminate shadows, the image below is from 2011 and no longer accurately portrays the rapidly changing landfill.

With rapid and localised deployment, RDC is able to plan and carry out a mission, excluding travel to the site in under 20 minutes. Once complete, the imagery is then uploaded to the cloud for DroneDeploy to work their magic.

Mission Tasking

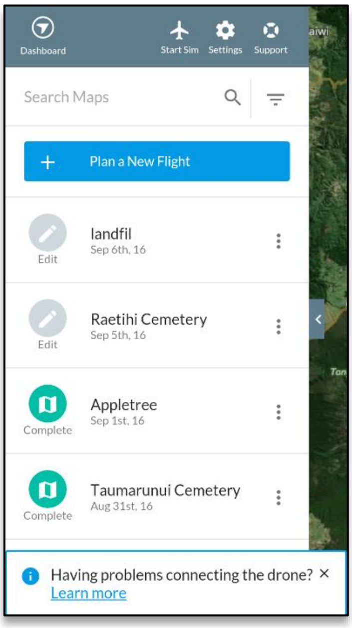
The first step in the process is to log onto the DroneDeploy web site and generate a flight plan.

Finding the site and plotting the area, the software calculates a base flight plan and height, which can be fine-tuned for things such as altitude and photo overlap. The flight plan is sync'd to the mobile application.

Flying the mission

Once the pilot has travelled to within 500 meters of the survey site and has satisfied all of the CAA requirements, they setup the Drone and connect the controller etc.

Then they open the DroneDeploy application on their device and select the mission.



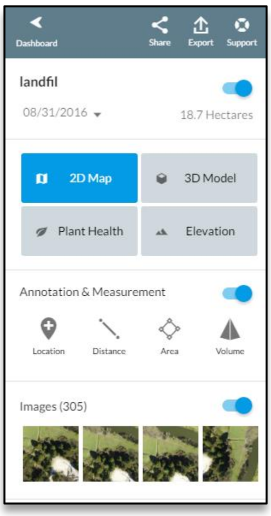
This shows the tasked mission and gives the pilot the opportunity to make any on-site adjustments, being particularly mindful of anything that could cause a crash, such as high trees or hills.

Although, the software does this automatically and sets the flight height to around 80 meters, it is always good to check.

After the pre-flight checks and it is clear to take off.

In this example the drone took 305 images.

After around 5 hours of post processing the maps are made available to view and download. The system provides 4 views.



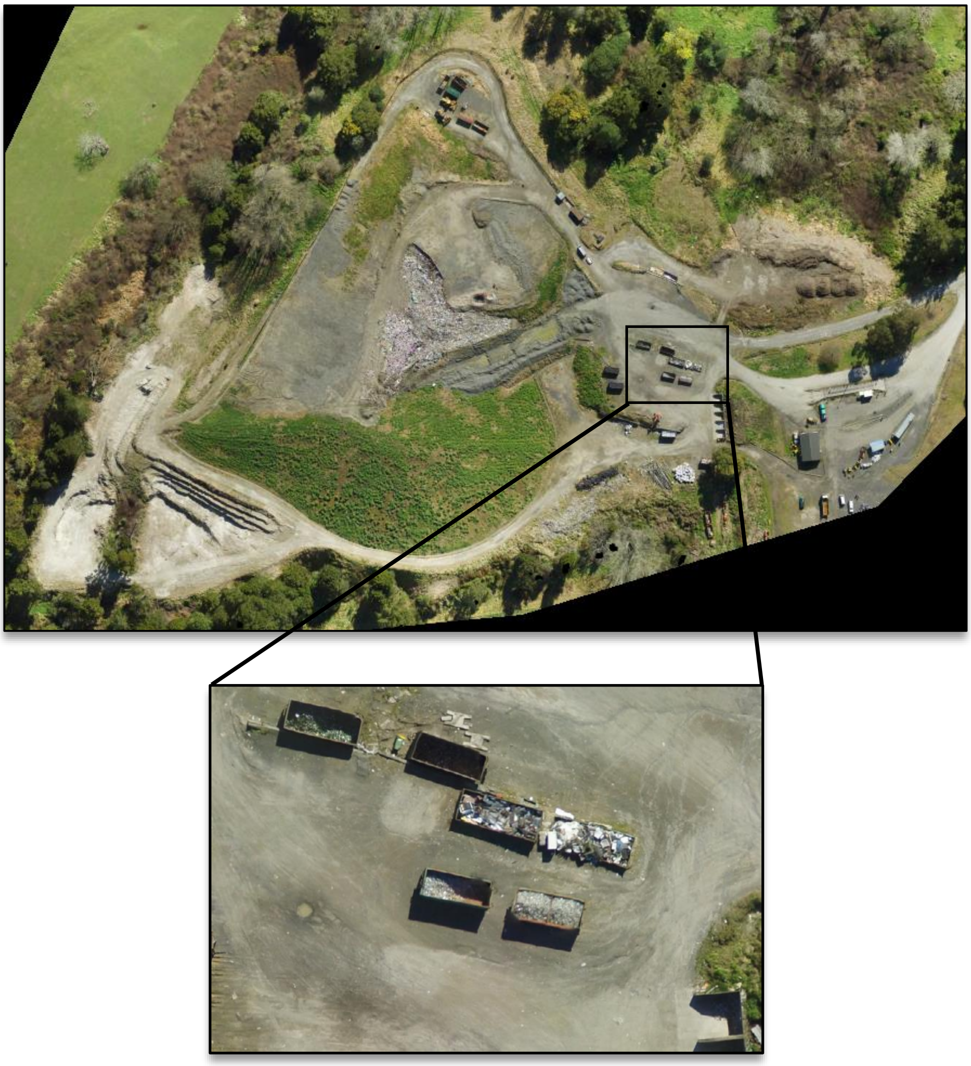
Post Processing

These maps are orthorectified and 3D maps generated.

***Orthorectification** is the process of removing the effects of image perspective (tilt) and relief (terrain) effects for the purpose of creating a planimetrically correct image. The resultant **orthorectified** image has a constant scale wherein features are represented in their 'true' positions.*

2D Map Layer

The 2D map provides high resolution image that is already geo-aligned, stitched and available for download as a Geotiff (Tiff file with X & Y co-ordinates)

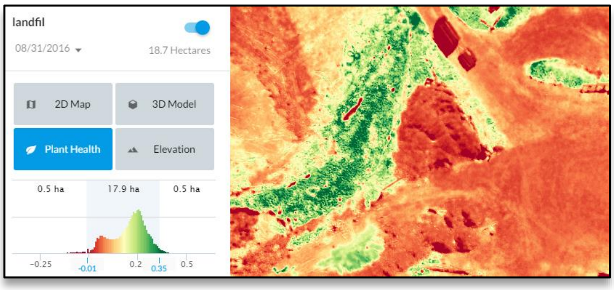


3D Model layer

A 3D model is generated of the area; this allows a view for easy visualisation.

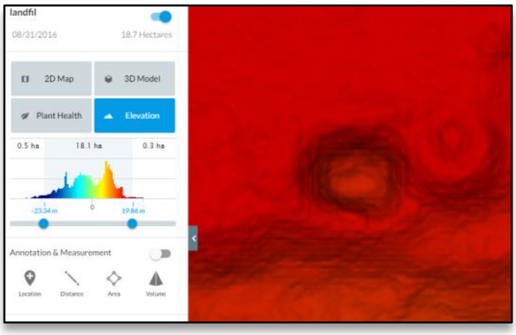
Plant Health layer

This view shows the organic material in the image. Good for agriculture applications.



Elevation Layer

This map shows the elevation heights calculated from the imagery.



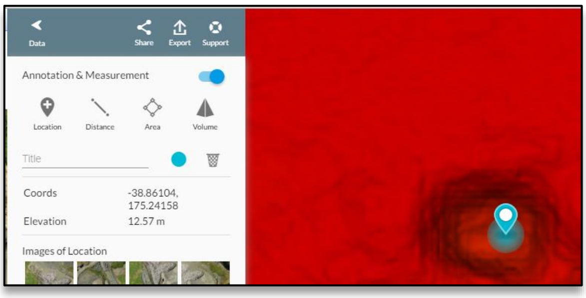
The Elevation Layer also allows for the export of contour data in the form of Esri Shape files. This provides accurate contour data of the survey area. This can be imported to Intramaps.

Tools

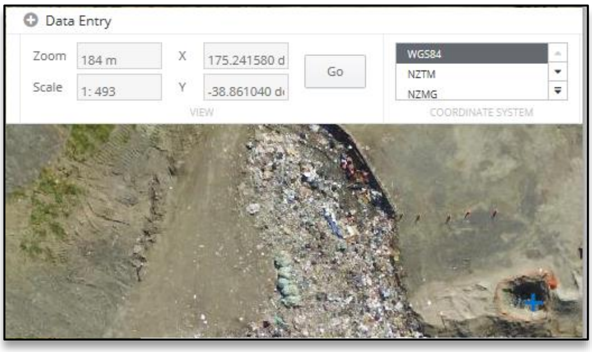
DroneDeploy has several built in tools, that assist with the information captured.

Location Tool

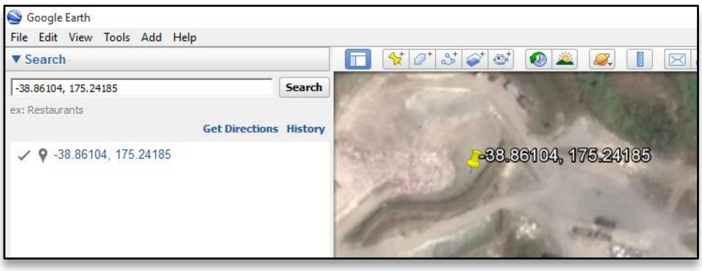
This tool displays the co-ordinates (In WGS84 Projection) and height of the pin placed on the map.



This can be transposed to a GIS system such as Intramaps to locate the point.



Also in Google Earth.



Distance Tool

This can provide a cumulative distance.

Or as a single line a cross section that shows an elevation profile.

To compare the accuracy of the data provided by the survey and what the actual depth on site, we compared the depth.

Actual depth was 2.0 metres, this provided a measurement of 110mm difference, a variance of 5%.

Area Tool

This shows the area of the Marque drawn under it.

Volume Tool

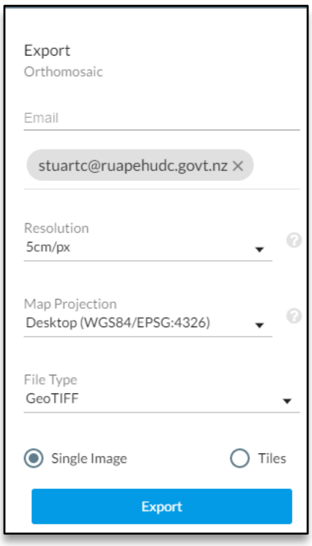
This is used to calculate the volume based on two properties;

Best fit-this shows the volume if the area based on the idea of filling it and how much cubic meters would be needed to level it up.

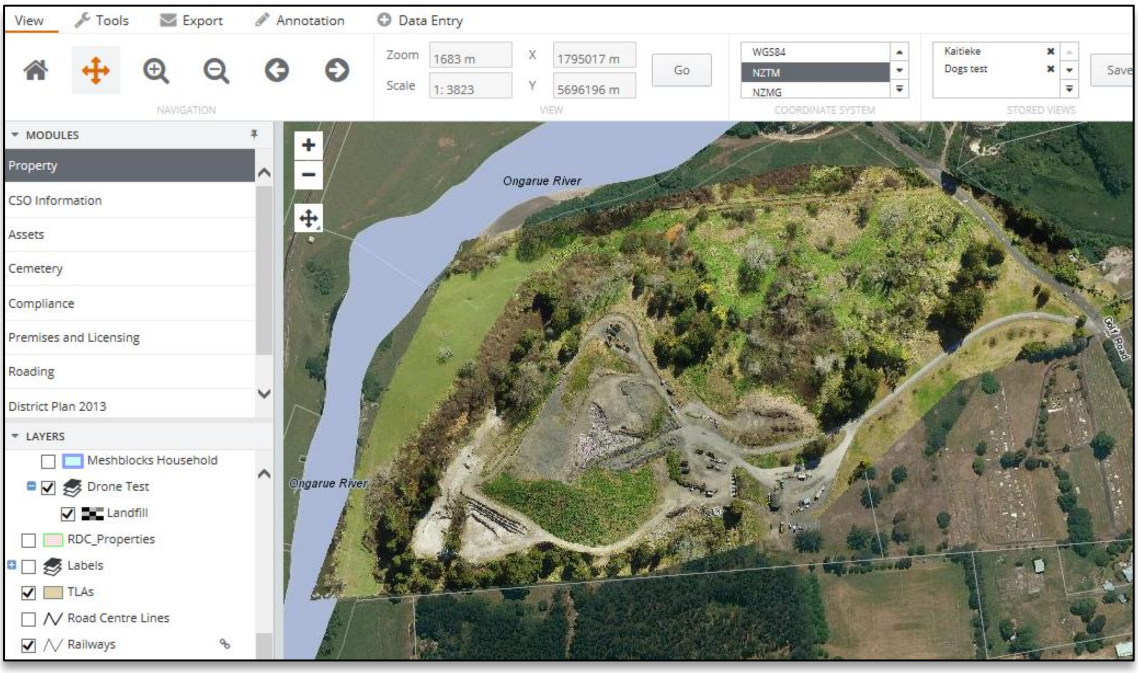
Lowest Point-this shows the amount of Cubic Meters required to excavate the area to the lowest point.

Export and Importing Data

2D and 3D maps can be exported in various formats, that can be imported into various GIS systems as Geotiff files.



After opening in the GlobalMapper application, this can be exported as an ECW (Enhanced Compression Wavelet) and imported as a Raster layer into Intramaps.



Once imported, it instantly provides cross referencing to all the local data in Intramaps and the available tools in the application.

Drone Operation

The operation of the drone is relatively simple but still requires a working knowledge of operation and flight in case manual intervention is required. Also an understanding of the CAA requirements and limitations of the drone being used.

The CAA regulations for operating a drone are;

New Zealand Civil Aviation Rules Top Tips:

There are 12 key things that are required under Part 101 - you must:

1. not operate an aircraft that is 25 kg or larger and always ensure that it is safe to operate
2. at all times take all practicable steps to minimize hazards to persons, property and other aircraft (ie, don’t do anything hazardous)
3. fly only in daylight
4. give way to all crewed aircraft
5. be able to see the aircraft with your own eyes (eg, not through binoculars, a monitor, or smartphone) to ensure separation from other aircraft (or use an observer to do this in certain cases)
6. not fly your aircraft higher than 120 metres (400 feet) above ground level (unless certain conditions are met)
7. have knowledge of airspace restrictions that apply in the area you want to operate
8. not fly closer than four kilometres from any aerodrome (unless certain conditions are met)
9. when flying in controlled airspace, obtain an air traffic control clearance issued by Airways (via airshare My Flights)

10. not fly in special use airspace without the permission of the controlling authority of the area (e.g. military operating areas or restricted areas)
11. have consent from anyone you want to fly above
12. have the consent of the property owner or person in charge of the area you are wanting to fly above.

As this was a RDC owned facility, permission was obtained from the Environmental Manager and as it was also within 4Kms of an aerodrome, permission was gained from the operator, also an RDC facility.

All other rules were observed before and during flight.

Once the tasking has been setup and sync'd with the application on the mobile controller, the operation of the drone to complete the task is completely automated, although there may be a requirement to adjust the actual landing operation to account for any wind shift etc.

Investment Profile

The investment to produce these maps and data would be approximately;

- DJI Phantom 4 Professional Drone - $2,700
- DroneDeploy Subscription - $249/month
- GlobalMapper software- $450
- Time
    - Flight planning – 20 mins
    - Flight deployment – 10 Mins
    - Post Processing – Per Layer
        - Uploading imagery - 15 Mins
        - Global Mapper ECW Export – 10 Mins
        - Intramaps import – 10 Mins

Investment

Item	Cost Type	Cost
Drone	One Off	$2,700.00
Global Mapper Software	One off	$450.00
Drone Deploy	Monthly	$249.00