ARCHAEOLOGY IN NEW ZEALAND

Metal Detectors for Archaeological Prospection: A Subsurface Survey at Vinegar Hill, Otago

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Introduction

Geophysical survey serves as a nonintrusive means of site selection that can provide information only otherwise retrieved through the most comprehensive of archaeological excavations. While there are a variety of different methods of subsurface survey available to archaeologists, each of these has a price tag, a required level of operational competence, and is more or less suited to selected tasks. Although using metal detectors for geophysical survey may be less conventional than ground penetrating radar, electronic resistivity, or electromagnetic conductivity, detectors are advantageously cheap, portable, and easy to use (Stine & Shumate 2015: 290). A novice operator can rapidly sweep a large surface area and guide archaeologists to areas of amplified metal deposits after just a single morning of hands-on training. Metal detectors can also be used for systematic surveys by identifying clusters of metal artefacts that may be indicative of subsurface features. Through these methods detectors have been employed across a range of archaeological applications from the underwater survey of shipwrecks to reconstructing skirmishes on battlefields (Marmor 1997: 12; Connor & Scott 1998: 79; Hanna 2010: 12). In New Zealand they are well-suited for post-colonial sites where there are abundant metal artefacts less than a metre from the surface. Such site types are found across much of New Zealand, but are particularly prevalent across Central Otago's goldfields. This paper explores some of the practical uses, benefits, and limitations of using metal detectors for an archaeological subsurface survey using a late-nineteenth century gold mining settlement near St Bathans Otago as a case study example.

Metal Detector Basics

Fundamentally a metal detector works by emitting an electromagnetic field through a coil at the end of a handle, which then relays to a control box. The larger the coil the deeper and wider the signal penetrates into the ground (Connor & Scott, 1998: 78). When these electromagnetic waves come into contact with a metal object a disruption occurs that is displayed either numerically or through audio feedback (Stine & Shumate, 2015: 295). These readings are based on the objects' ferrous (Fe) and conductivity (Co) levels. Ferrous levels relate to a metal's iron content, measured by its attraction to electromagnetic waves, whereas conductivity is a measure of how well an object conducts an electrical current (Davenport 2001: 90). The larger the object the longer a current takes to travel through it, so depending upon the type of metal a Co level can carry more or less weight. Iron, for example, produces a high Fe and typically a high Co reading, while lead results in a low Fe reading and a low Co reading (as lead is less conductive than iron) (Davenport 2001: 92). This is only a brief summary of detector physics and in reality there are more contributing factors to readings than size and metal type (Connor and Scott 1998: 80). It is therefore beneficial to test a few different known objects prior to a survey in order to gauge a detector's Fe and Co readings.

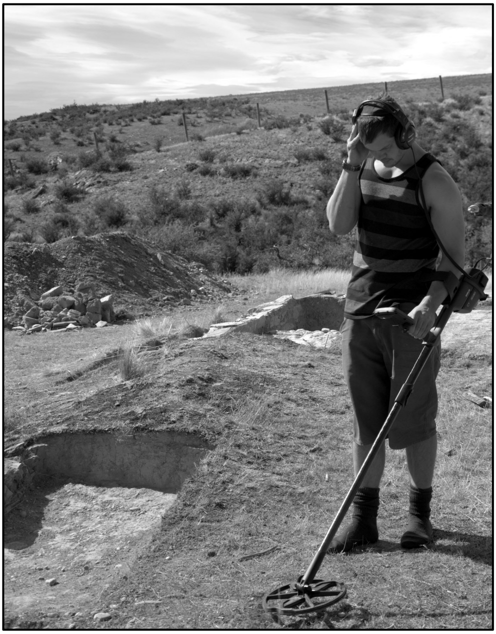

Figure 1. The author surveying adjacent to ongoing excavations near St Bathans in Central Otago.

Depending on the cost and quality of the metal detector, other additional features may also be available to the user. For example, the detector used for this paper's case study (the Minelab CTX 3030) is capable of discriminating against unwanted metal types, provides depth as well as GPS coordinates of discovered artefacts, and includes a pin-pointing feature that reveals, with increased accuracy, where a given artefact may lie. In addition to these faculties the CTX 3030 has a graphical user interface allowing the operator to view and record information for up to 100 find-spots before being uploaded to a computer. Once on a computer this data can be mapped, processed, and interpreted within a Geographic Information System (GIS) such as ArcGIS. While these supplementary features are not necessarily required for a systematic and productive subsurface survey they do greatly enhance the speed and degree of data collection.

Detectors for Subsurface Survey

Using a metal detector for a subsurface survey incorporates many of the same methods as a pedestrian survey. In such surveys volunteers walk along set transects, or within a gridded system, searching for and recording all visible surface artefacts (Shiffer et al. 1978: 4). Once these artefact locations have been plotted onto a map, clusters or other spatial patterning can be identified. Areas containing higher levels of above-ground cultural material may be indicative of subsurface features, thus this method can provide useful data for site prospection. Although pedestrian surveys have been shown to have merit across a number of site locations, they require an abundance of surface artefacts and rely on the assumption that a link can be made between surface artefacts and subsurface features. As a metal detector's electromagnetic waves can identify the presence of metal artefacts above and below ground they are less affected by a site's surface conditions, such as the presence or absence of surface artefacts, or poor visibility due to vegetation.

As with any method of geophysical survey, a metal detector's effectiveness depends upon not only the way it is used, but the environment within which it is used. Most modern detectors are capable of being auto-tuned to cancel out environmental interference such as soil moisture or naturally occurring concentrations of iron (Connor & Scott 1998: 80; Davenport 2001: 92). However, ground-truthing by means of a test pit (if permitted) can pay future dividends by preventing the needless recording of false-positives. After determining background noise, the operator can assess if any other natural or anthropogenic factors are present that may interfere with a survey. These include obvious metal articles found on or near the surface like fencing wire or other environmental issues such as preventatively thick vegetation or overburden.

After taking such considerations into account an operator can outline a strategy to survey an area based on the needs of their project. Depending on the size of the search area, measuring tapes, wooden stakes, or a pair of volunteers can be used to demarcate a search grid (Stine & Shumate 2015: 298). The operator can then systematically sweep the entirety of the area while placing stakes on find-spots or plotting points digitally using GPS. Decisions involving search perimeter and find recording must be made on a site by site basis and are crucial to conducting a subsurface survey that is both productive and systematic.

The remaining sections of this paper provide a case study example of a metal detector survey at an archaeological site in New Zealand. Following a presentation of the survey's methods and results is a discussion of the project's outcomes.

John Ewing's Gold Mining Settlement at Vinegar Hill

Vinegar Hill, located near St. Bathans in Central Otago Figure 2), was once home to a bustling gold mining settlement owned by influential entrepreneur John Ewing.

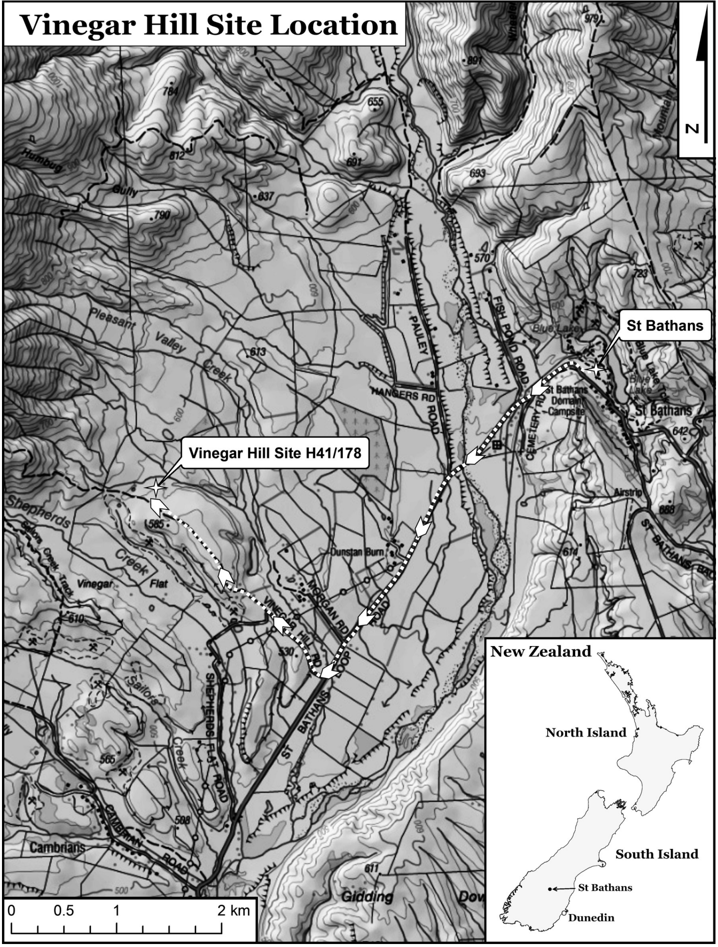

Figure 2. The St Bathans region of Central Otago, showing the location of the Vinegar Hill site (H41/178).

The settlement (archaeological site H41/178), which operated from 1884 until 1904, had a homestead, smithy, stables, power station, and boarding house for Ewing's 60 workers (Nicolson-Garrett 1977: 24; McCraw 2009: 64). Over the past five years, the site has received increased attention from archaeologists interested in the region's rich goldmining heritage. In 2011, Angela Middleton surveyed and recorded the site producing an assessment that detailed its history and current condition (Middleton, 2011). During her investigation Middleton noted a lack of any substantial surface features, but highlighted the site's archaeological value due to its relationship to John Ewing (Middleton 2011: 28).

In February, 2016, Otago University conducted a three-week-long field school at the settlement with the aim of producing a clearer understanding of the remaining surface and subsurface features. The group's excavation focused primarily on the Vinegar Hill site's north-eastern area, revealing the location and make up of Ewing's power station. As surface features were markedly limited, a metal detector was used to conduct a subsurface survey across additional areas of the site. The aim of the project was to identify areas of substantial metal deposits that might indicate the location of Ewing's other buildings. The survey was carried out over three days in two grids covering a combined area of 750m^2.

Survey Areas

The search grids chosen for this survey were within a large stand of macrocarpas, approximately 50 metres southwest of Otago University's excavation of Ewing's power station (Figure 3). These areas were selected as they were mostly unobstructed by trees and a quick and unsystematic detector survey had previously shown these areas to contain significant metal deposits. Although the historical record indicates these areas were likely to have contained some of Ewing's buildings, as was found throughout the rest of the site complex, there were few remaining surface features (McCraw 2009: 64). The first search area, labelled as 1, was 30m by 15m and had a fallen tree and a row of wilding garden trees along its southern extent, with a second fallen tree along its northern. The area's interior was mostly clear of any obstacles, with the exception of a small patch of thistles and some protruding chicken wire mesh (probably from a rabbit-proof fence) along its northern side. The second search grid was 20m by 15m and was positioned diagonally from the northwestern corner of Area 1 under the cover of a large macrocarpa. Its surface had a few unorganised protruding schist slabs adjacent to the tree, but was otherwise clear of any surface features.

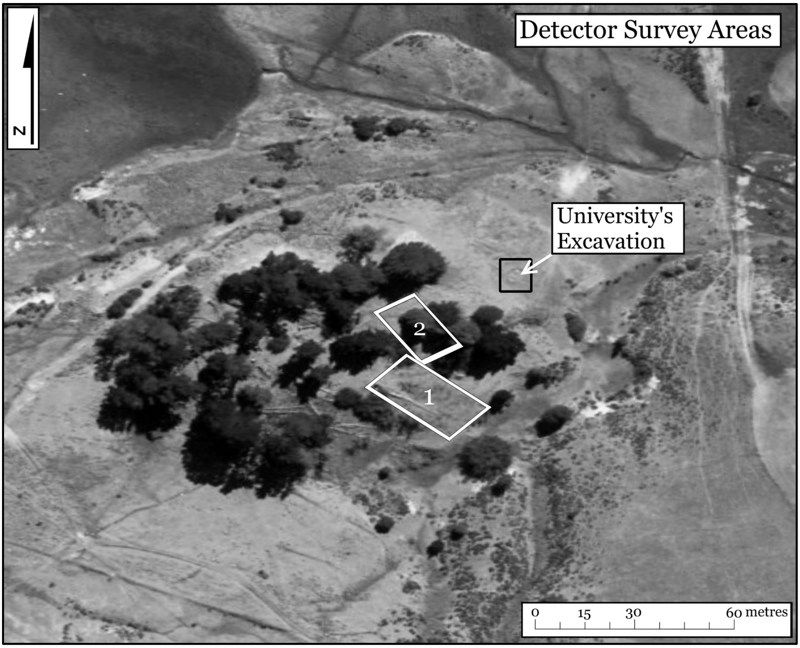

Figure 3. Search areas 1 and 2 in relation to the university's excavation of the power station site.

Methods

This project's methods were carried in three parts consisting of preparation, survey, and data processing. Preparation and survey were carried out over three days while on site, while data processing occurred at a later date.

Preparation: Once location and dimensions of Area 1 were decided, a 30m by 15m grid was measured and laid out. As the survey was carried out by one person, measuring tapes were set up in order to keep the survey systematic and on course. Each corner of the grid was marked with fluorescent spray paint to ensure the tapes could be easily replaced if removed. Once the Area 1 survey was completed this same process was repeated to prepare Area 2.

Before commencing the survey, the CTX 3030's Fe and Co readings were tested on a collection of artefacts unearthed during the university's excavation (Table 1). The reason for this was twofold. Firstly, it was necessary to ensure the detector was adequately distinguishing between different types of metal artefacts and providing stable readings. Secondly, as the Vinegar Hill subsurface survey was to be largely nonintrusive, creating a Fe/Co reference guide of artefacts found in the vicinity improved the project's ability to link the data collected with potential artefact types. As indicated in Table 1, the CTX 3030 presents ferrous readings on a scale from 1-35 and conductivity from 1-50.

*Table 1. Showing the results of the CTX 3030's artefact readings (*readings fluctuated, but tended to return to these numbers).*

Artefact Type	**Ferrous 1-35**	**Conductivity 1-50**	**Artefact Length (mm)**	**Metal Type**
Roofing nail lead-head	12	32	10	Lead
Iron nail #1	33	45	20	Iron
Iron nail #2	34	46	20	Iron
Lead-head + iron nail	26	49	30	Iron/Lead
Large iron stake	32	46	300	Iron
Small piece of cast iron	34*	40*	60	Iron
Large piece of cast iron	24*	20*	200	Iron
Thin iron sheet (rusty)	10	41	400	Iron
Key hole plate	12	25	50	Brass
Bucket with lead paint	18	32	200	Iron/Lead

The CTX 3030's test showed that although iron objects had a tendency towards Fe levels of 30+, some of the larger iron items gave more confused signals. When lead and iron were found on the same artefact the numbers tended to produce an average Fe reading between the two metals. Brass and tin produced much lower Fe levels than iron. Although this sample size was too small to draw unequivocal conclusions, it provided an indication that the detector did indeed differentiate between metals and it presented a rough estimate of Fe and Co levels of generic artefact types.

Survey: The survey began at the northeast corner of Area 1 and was carried out by sweeping the detector uniformly while walking in transects from the southern to northern sides of the grid. At the end of each transect a metre-long-step was made west along the tape. Whenever an artefact was discovered, its GPS location, Fe/Co levels, and depth were stored within CTX 3030's on-board memory by pressing a save button. As this on-board memory has a 100 find-point limit, the survey was carried out over intervals in order to upload the data to a laptop computer. After the first survey area was completed the survey of Area 2 was carried out using the same methods.

To determine whether the detector's depth readings were accurate two test pits were conducted on two find-spots in Area 1 (Figure 5). Each find-spot was assessed by the detector five times before being excavated to ensure the readings were truly representative of the detector's capabilities (Tables 2 and 3).

Table 2. Test pit one assessments and results for chicken wire: actual depth of wire 140mm.

TP1 Assessments:	**Ferrous (Fe)**	**Conductivity (Co)**	**Depth (mm)**
1	12	30	120
2	19	31	160
3	15	30	110
4	16	32	160
5	14	31	140

Table 3. Test pit two assessments and results: actual depth of 100mm x 100mm scrap of thin iron sheet 60mm.

TP2 Assessments:	**Ferrous (Fe)**	**Conductivity (Co)**	**Depth (mm)**
1	9	41	50
2	10	35	50
3	9	40	20
4	10	39	30
5	9	40	30

The test pits indicated the detector was reasonably accurate in determining the depth of artefacts. An additional unexpected outcome of the assessment was the discovery that the chicken wire fencing continued 140mm below the surface beneath the northern extent of Area 1. The first assessment of the chicken wire fencing gave a similar reading to the roofing nail's lead-head tested in Table 1.

After the completion of Area 2 the detector was additionally used to track a large iron drainpipe that had been discovered during the university's excavations. The pipe was uncovered 500mm below the surface in a small excavation square. Although the CTX 3030's maximum recordable depth is

300mm, after its sensitivity settings were set to high, it was able to follow the pipes direction as it led away from the site ending at a water race. The outcome of this separate survey is found in Figure 4 in the results section.

Data Processing: At the completion of the survey the data was transferred from the detector to a computer using Minelab's software named Xchange2 before being imported into ArcMap. Once the CTX 3030's find-spots were within GIS it was possible to utilise ArcMap's spatial analyst tool named 'Kernel Density' to transform the points (using a search radius of .00002) into the density gradient found in the results section. This additional analysis was used to turn the cloud of found artefacts into mathematically determined clusters. Although it would have been possible to interpret the data without this post-processing, doing so provided a quick and systematic means of density analysis. Lastly, to display the different types of metals found during the survey, the object's ferrous levels were split into three groups: 1-18, 19-27, and 28-35. These specific groups were chosen as they were generally representative of the different metal type readings assessed during the preparation phase.

Results

The subsurface survey at Vinegar Hill resulted in a total of 349 stored find-spots. Of this total, 41 of these were from the iron drainpipe that led 60m away from the university's excavations, the remaining 308 were from the two search areas. Figures 4 and 6 show the result of the kernel density analysis, with clusters of metal finds displayed in white against a black background.

The Area 1 find-spot density increased as the survey moved west from its south-eastern corner before dropping off at its north-western end. There was a pocket of sparse activity found near its centre that contrasted substantially with the areas immediately adjacent to it. The chicken wire fencing that was discovered 140mm below the ground in test pit one (TP1) was near Area 1's highest area of metal activity (Figure 5). Although this may call into question whether any of the find-spots were nineteenth century, only a small amount of the ferrous readings found in this region were similar to the repeated assessments of the chicken wire found in the methods section. Until the area is excavated it will not be possible to truly discern the extent of the chicken wire's influence on this region of high density.

The Area 2 densest area of metal activity occurred within and surrounding its few protruding schist slabs (Figure 5). The region immediately north of this area of density was the location of the macrocarpa, thus no readings were capable of being taken where it stood. However, there was much less activity found on the northern side of the tree. As seen in Figure 5, there was a range of different metal types found throughout the site. Based on the project's reference collection tests, detailed in Table 1, find-spots with a Fe reading of 28-35 were likely to be iron, whereas 1-18 as lead, aluminium, or brass, with 19-27 representing either an object comprised of a combination of these or a confused detector reading.

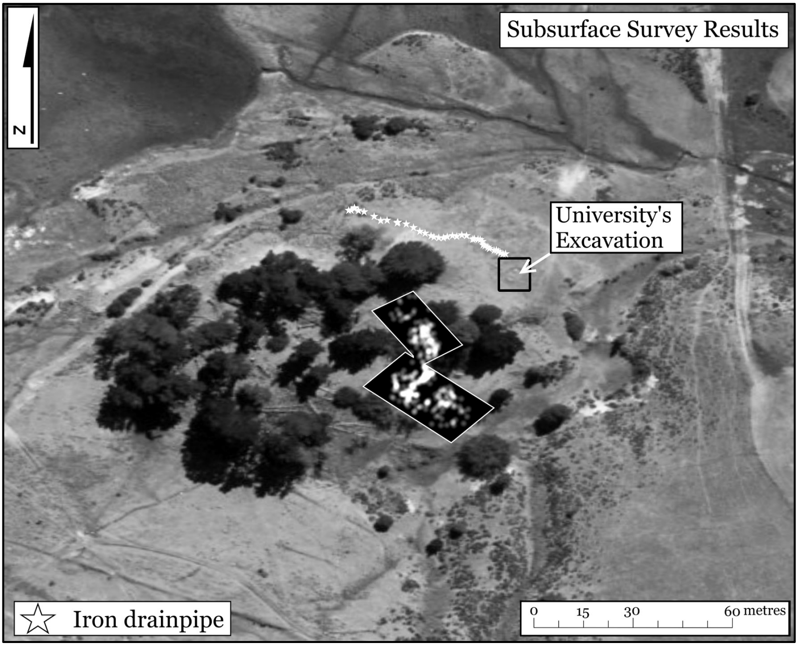

Figure 4. Densities of find-spots within Areas 1 and 2. Also showing is the large iron drainpipe, tracked by detector as it led away from the university's excavation area.

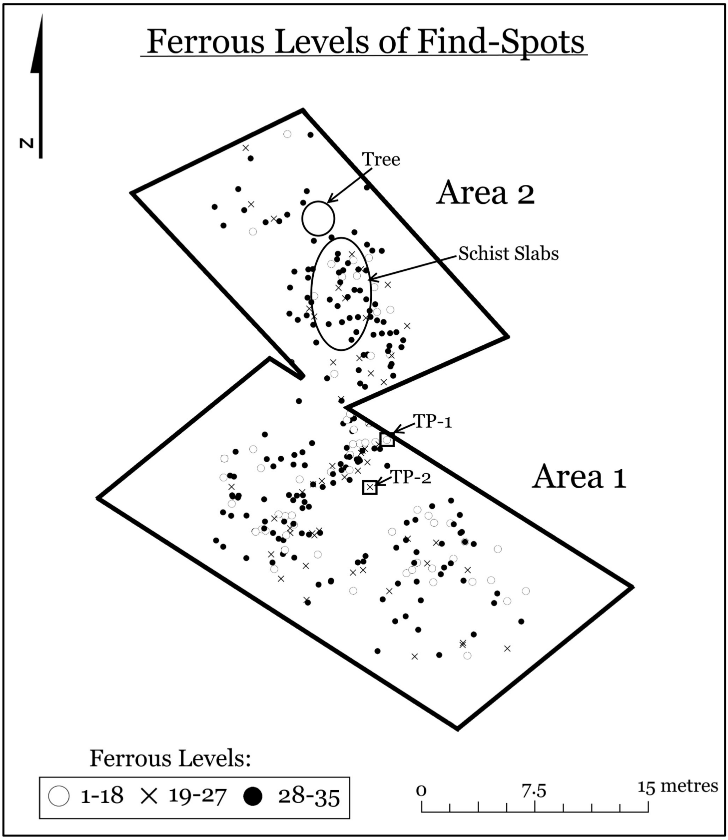

Figure 5. Ferrous levels of find-spots found in the two survey areas.

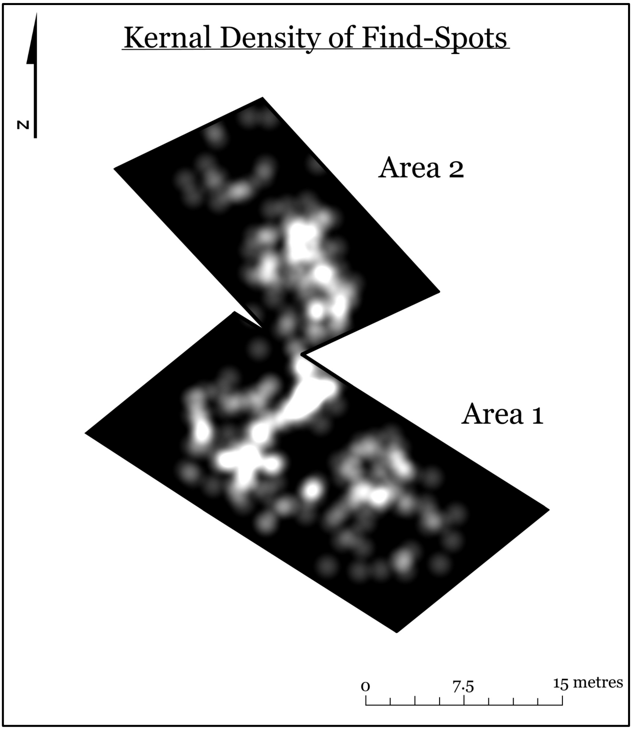

Figure 6. Results of the ArcGIS kernel density analysis of find-spots.

Figures 7 and 8 display the association between the depth of artefacts and ferrous/conductivity levels. The bell-shaped curve the data manifested indicates that 150-190mm represents the greatest amount of activity discovered between the two search areas. The CTX 3030 is only capable of recording depths up to 300mm, but as found when tracking the large iron pipe known to be 500mm in depth, the detector may still be capable of detecting further, but does not define find-spots as such. As the levels of overburden present at this area of the Vinegar Hill site are unknown, one must be careful in assuming no metal activity occurs at even greater depths. Caution should also be applied when attempting to relate ferrous and conductivity levels to known metal artefacts of similar readings. A long piece of iron barbed wire detected multiple times over a large area may produce the same result as a dozen scattered iron nails.

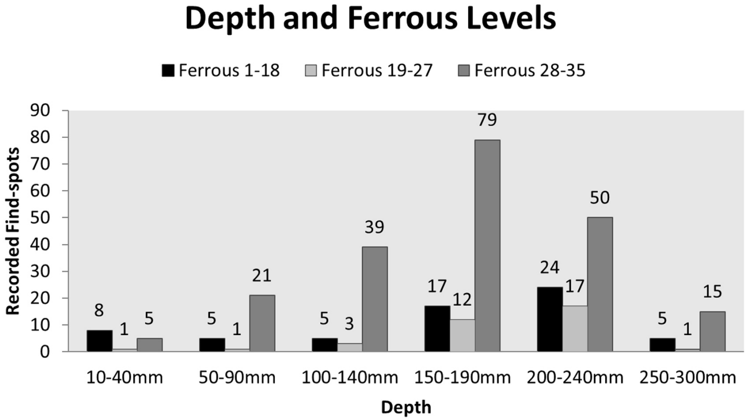

Figure 7. Graph showing the relationship between depth and ferrous levels.

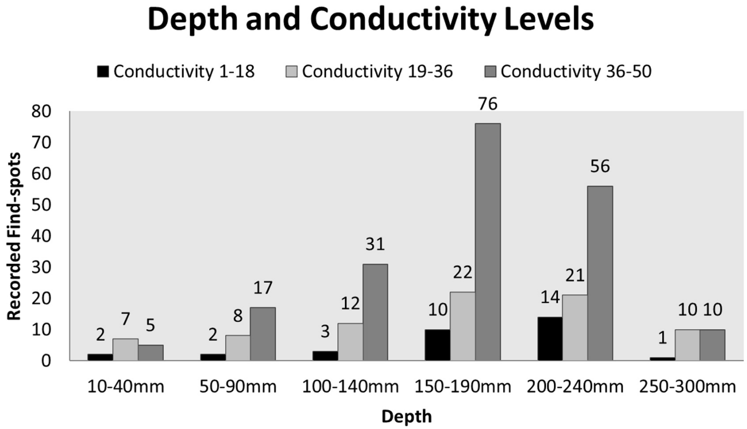

Figure 8. Graph showing the relationship between depth and conductivity levels.

Discussion

The survey at Vinegar Hill demonstrated some of the practical benefits and limitations of using a metal detector for a geophysical survey. In terms of benefits the detector provided a swift means of survey that differentiated between locations of abundant and sparse metal deposits. Clusters of metal readings surrounding the protruding schist slabs in Area 2 and the centre of

Area 1 may likely relate to subsurface features. These findings could potentially contribute to future site selection. If this survey's methods were expanded across the entirety of the Vinegar Hill site complex its usefulness would increase further still. Such a large-scale survey could distinguish the locations of Ewing's blacksmith and stables from other areas as these are likely to possess the greatest clustering of metal deposits. The detector was also able to provide an approximation of artefact depth and metal composition. Although the ultimate value of this gathered information might be disputable, the nonintrusive survey was neither labour nor time intensive.

In addition to these outlined benefits are a number of limitations. These are mostly derived from the interpretation of data, but practicality-wise, clusters of metal objects underground are hard to differentiate between, particularly when attempting to systematically sweep an area occupied by thistles. These confused readings are further complicated by the fact that metal objects laying closer to the surface may cause the detector to misinterpret or entirely miss any objects found below. As only one find-spot was taken for each given location, data must be interpreted cautiously. Furthermore, the presence of modern metals can easily influence a survey, shadowing results with uncertainty. While modern deposits might be less prevalent in sparsely populated areas such as Vinegar Hill in urban landscapes this could greatly limit a detector's ability to produce meaningful results. Lastly, one must acknowledge the methodological biases introduced by basing site selection solely on the presence or absence of metal deposits. Archaeologists typically have a limit on the amount of area they can excavate, so unreflective use of a detector might influence more sound modes of site selection.

With these limitations in mind, metal detectors are a worthwhile addition to an historical archaeologist's toolkit. When used systematically in conjunction with mapping software they have the ability to provide a straightforward and nonintrusive means of locating cultural activity across a large area. Vinegar Hill was an ideal location to test this survey's methods due to its remoteness, limited surface features, and time period of occupation. The detector showcased its usefulness by tracking a buried drainpipe to a neighbouring water race and by shedding light on a previously unexplored region of the Ewing site complex. A future large-scale detector survey could work to broadly identify the settlement's occupation areas, whereas future excavation could provide necessary ground truthing and information about this interesting period of Otago's history.

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