

Ian Allan

10 PRACTICAL APPLICATIONS OF

Geographical Information Systems



GIS | UNIVERSITY

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Ian Allan

Visit my website at gis-university.com

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Geocode Mapping and Analysis pl

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Introduction

The typical definitions of Geographical Information Systems (GIS) that you find in text books and around the web are often too technical for beginners to understand. Such definitions were appropriate at a time when GIS had many technical obstacles to be overcome. For desktop GIS, few obstacles still exist and its time to focus once again on solving geographical problems. These days even brand and version of GIS software rarely matter.

We're now in a perfect storm - GIS maps, GIS software and computer hardware have all matured, and so much of what was previously impossible can now be done. The opportunities for newcomers are exciting. Society's social and environmental problems are better understood, and more and more by governments, corporates, and the press, the communication of these problems is being aided with maps. Google and others have put mapping into the hands of the masses and social media is giving the masses a greater say. A flow-on from this is that the expectations of map consumer have been raised. More sophisticated skills are required to analyse and present maps that can be easily understood by both stakeholders and decision makers.

Over the years I've become disappointed in the GIS industry because the great advances in GIS technology have not matched with advances in GIS applications. Experience tells me that this is because the people with geographical problems tend not to be interested in learning GIS, and people with GIS know-how tend not to be interested in learning about geographical problems. Herein lies the opportunity for newcomers – there is a great need for map users to learn the basics of how to use GIS, and a great need for GIS professionals to learn the basics of the geographical problems to which their mapping is being applied. Maps are so much more useful when those involved in their creation can explain the data inputs, the GIS processes used to create them, and what the resulting maps mean!

For the past two decades my work has involved solving a variety of geographical problems. The two major issues of GIS map quality and the need to understand the data that lies behind what's being mapped have not changed in this time. Most of the work I do just demonstrates a thoughtful understanding of a geographical problem and is deliberately simple so that both stakeholders and decision makers can understand it readily. I always try to get to the point where

few people would argue about a map I produce. When you can get your audience to that point, it comes down to how the decision makers weigh your map in their final decision.

There are two keys to creating useful GIS maps. The first is to make the effort to understand the data behind the theme you're mapping, and second is to make the effort to put yourself in the boots of your client – how will they use the information you present to them and how can you make the interpretation easy for them to digest? I always think of my maps as an executive summary because in a report they're usually what people look at first. Pay attention to these simple ideas and you'll quickly gain the attention of key people in your workplace as being someone who produces information that's useful for their decision making.

For me, GIS is so much easier to understand with the aid of examples. I am a generalist geographer and like to think of myself as a GIS analyst rather than a GIS technician. Over the years I've worked with engineers, archaeologists, demographers, soil scientists, economists, ecologists, and epidemiologists. In the examples that follow I'll talk you through some of the many GIS projects I've worked on.

Social Science Application: Housing Market Analysis

Housing markets are a fantastic application to show off the creative use of Geographical Information Systems (GIS). Once you have a house sale as a dot on a GIS map there are so many things you can do with it. You might want to map neighborhoods with similar investment potential, determine a real estate agents performance by mapping areas where they sell most of their properties and the fewest, or incorporate other datasets such as census information to determine whether or not housing is affordable for people to purchase. Following are a few examples of uses that I've been involved with over the years.

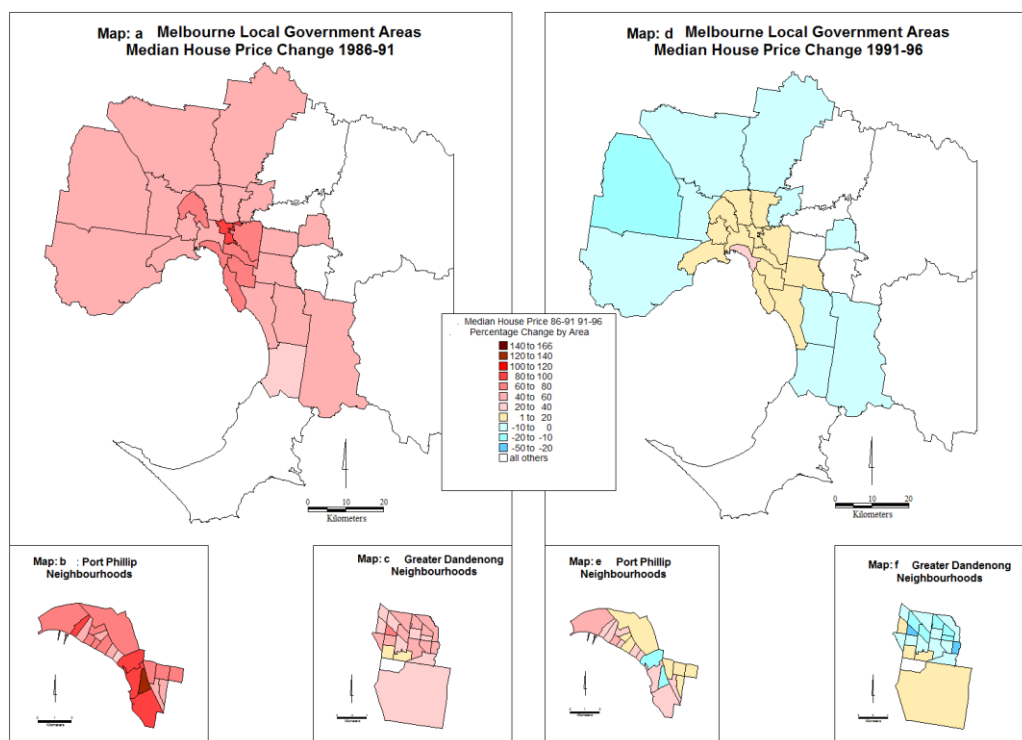
Mapping real estate sales neighborhoods

In the late 1990s I was involved with a group of housing researchers in Australia's first GIS housing study. The study confirmed their intuition that housing markets operate at the scale of local neighbourhoods rather than large regions. It also confirmed their suspicions that inner city housing markets were more resilient to financial crashes than outer suburban housing markets.

The group's aim was modest - to produce a few maps of housing themes and then interpret the results. We were unsure exactly what to expect and were delighted to discover that GIS would allow us to map the fine detail of Melbourne's housing market through time.

We began the project by enlisting two work experience students to "geocode" (turn the sale address to a dot on a GIS street map) around 150,000 house sales for 1986, 1991 and 1996. It was the sort of laborious work that was well suited to such a labour force. Next we related the dots to two GIS maps - one of local government areas and another of neighbourhoods. Up until then, housing researchers only knew intuitively that housing markets operated in small neighbourhoods rather than regions, but it had never been demonstrated. These maps show a level of detail in Melbourne's housing markets that had never been observed before.

Some of the resulting maps are shown as a series in Map 1. This map series is only one of many that we produced for the project. It shows that between 1986 and 1996 the greatest change in house prices was consistently in the inner city, and also that Melbourne's outer suburbs had the smallest price increases (and sometimes decreases).



Map 1: This series of maps shows that between 1986 and 1996 Melbourne's inner city housing market experienced the greatest value change, and was also more resilient to economic downturn than the outer suburban housing market. The map insets show that local government areas contain neighborhoods with differing rates of change. Following the 1989 financial crisis, local government areas that seem to be resilient (map d) had neighborhoods with negative growth (blue in map e), and local government areas that were dominantly in decline had neighborhoods that were resilient (yellow in map f).

The way the maps look depends on the time period being mapped. The 1986-91 maps (a thru c) show everything increasing in value, while the 1991-96 maps (d thru f) show almost everything decreasing in value.

The blue shaded areas in maps d, e and f, show that Melbourne's housing markets responded to the 1989 financial crisis with a slow-down. In contrast to the boom period of universal price increase that is the backdrop to maps a thru c, map d shows that during the 1989 financial crisis, inner city areas still increased in value while outer suburban areas declined in value. However, both inner and outer areas, when mapped at the neighbourhood scale (maps e and f), reveal pockets of investment resilience (red areas) that could not be seen when mapped at local government area scale.

Some of these patterns can be explained by looking at the demographics that lie behind the data. Inner city areas tend to be largely populated by white collar

workers who's job security (and purchasing confidence) in an economic downturn is better than the dominantly blue collar workers that live in the outer suburbs.

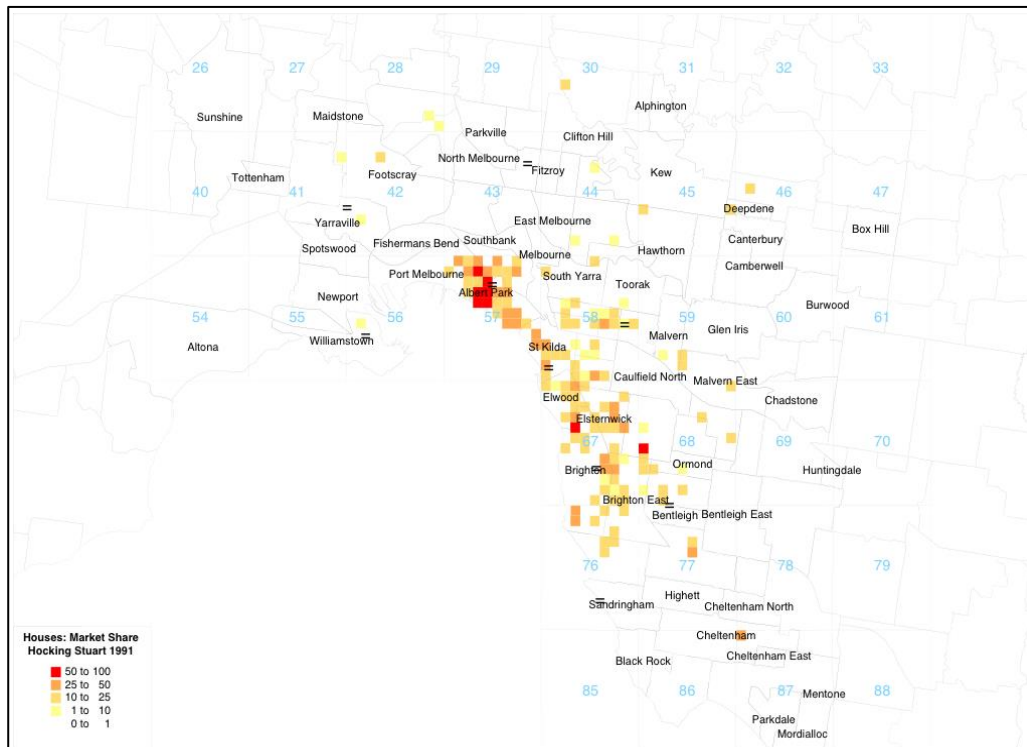
Mapping Change In A Real Estate Agent's Market Share

Real estate agents like to understand how their business is performing in each of their sales areas. Are they selling more homes in some areas than others and what is the value of all homes they've sold in an area? How are they performing compared to their competitors – are they selling every home in an area? Every second home? Every fifth home? And are any of these figures changing over time? Let's look at a GIS project that addresses these questions.

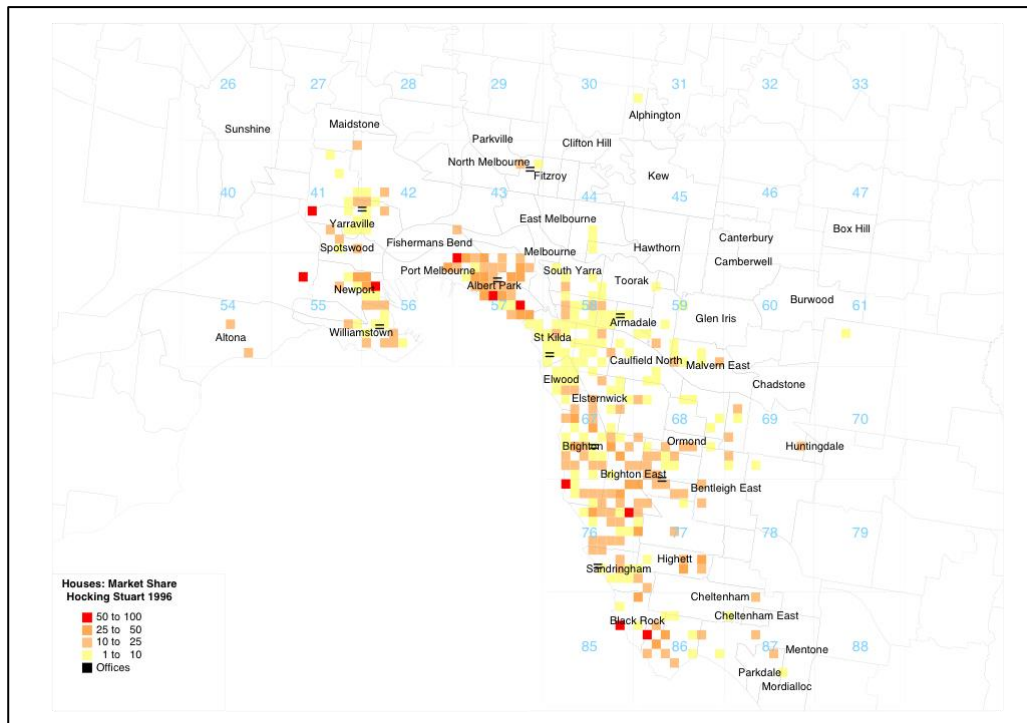
Still in the 1990s, I teamed up with a housing researcher and developed some GIS software to analyse housing markets. The software was simple. It automated the large number of mouse clicks required to produce the GIS maps manually. It turned a list of house sales into dots on a GIS map and then annotated each dot with the sale date, value and agent details. The next step was to relate each dot to a grid square from a GIS street directory. For each real-estate agent we shaded the grid-squares according to the total value of house sales, the number of sales, the market share of each agent, and change in the themes over time.

For me, market share was one of the most interesting series of maps. Market share is the ratio of all the sales in an area compared to the sales made by an individual agent - so if 10 homes were to be sold and one agent sold 5 of them, then that agent would have a 50% market share.

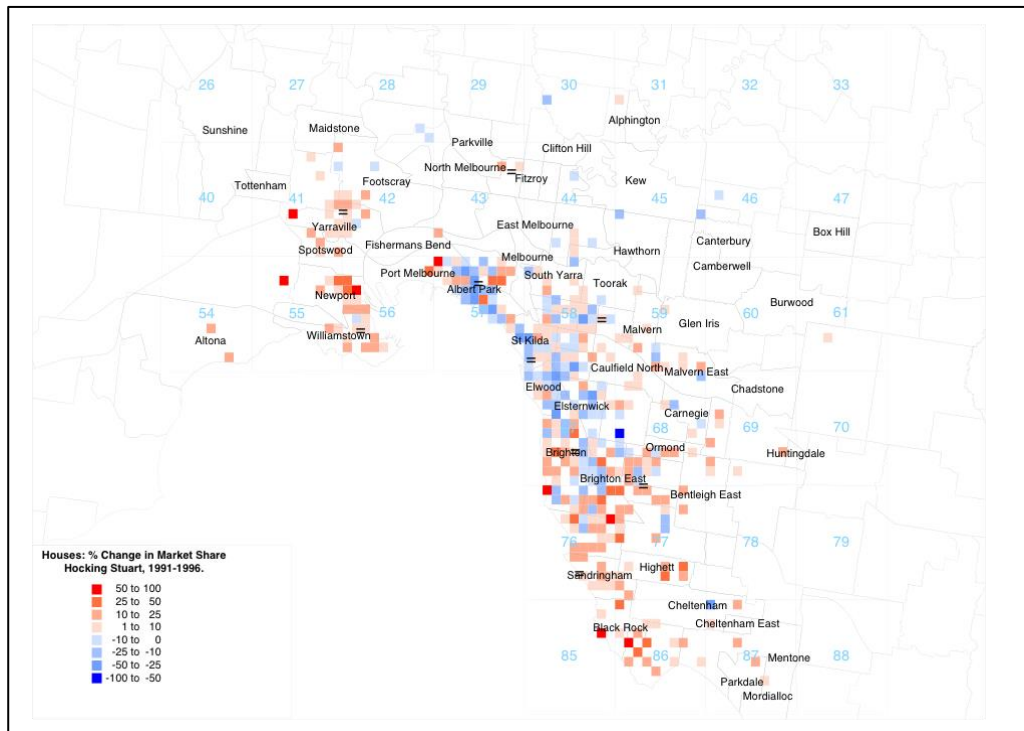
The Hocking Stuart series of maps are typical of the sort of maps we produced. In 1991 Hocking Stuart dominated all other agents in Albert Park (Map 2), but no longer dominated that area in 1996 (Map 3). We met with the agent's marketing manager and he explained that they had expanded into new geographical areas between these years. Map 4 shows that during their expansion phase, while increasing the overall value and number of sales, Hocking Stuart lost their home-turf dominance that they had in 1991. Perhaps they were distracted with their expansion?



Map 2: Albert Park is Hocking Stuart's head office and the area where it dominates (red). Satellite offices such as Williamstown and Sandringham were not opened until after 1991. The light blue numbers are street directory map numbers.



Map 3: By 1996 there are a bunch of new offices and Hocking Stuart are making an impact on Melbourne's south-east suburbs. However, the grids around Albert Park that were red in 1991 are now pink, indicating a loss of market share. The light blue numbers are street directory map numbers.



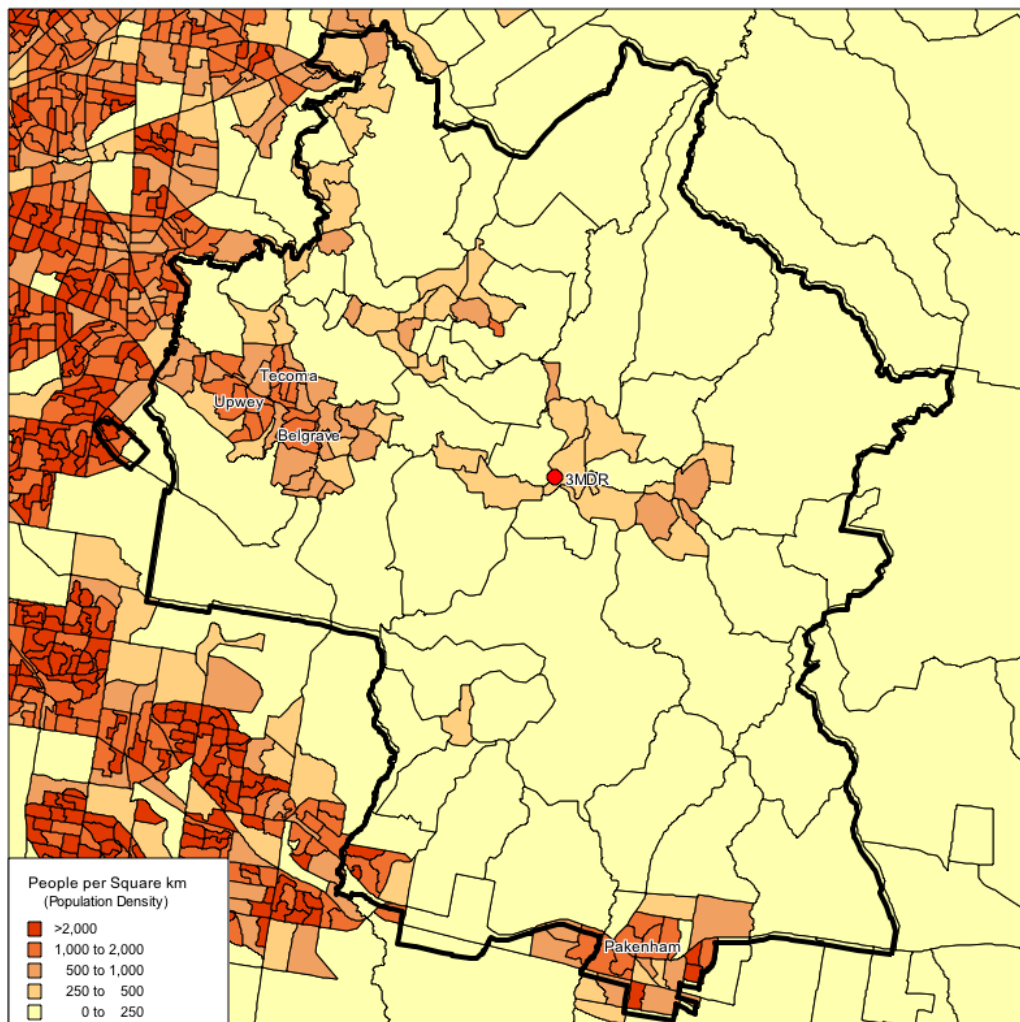
Map 4: Comparing the previous two maps to each other, this map shows that while expanding into Melbourne's south-east, Hocking Stuart lost focus around head office in Albert Park. The red squares show areas of market share gain and the blue areas of market share loss. The light blue numbers are street directory map numbers.

Social Science Application: Radio Station Demographics

I have a weekly radio show on a community radio station called 3MDR (webcast most Monday mornings on www.3mdr.com at 9am Australian eastern standard time - GMT +10). As a component of the station's strategic overview I prepared a demographic overview of its license area using census and business datasets.

In the text that follows report I describe a census map of population density and a map of business density. Both of these maps would be useful to businesses other than a radio station.

Population density



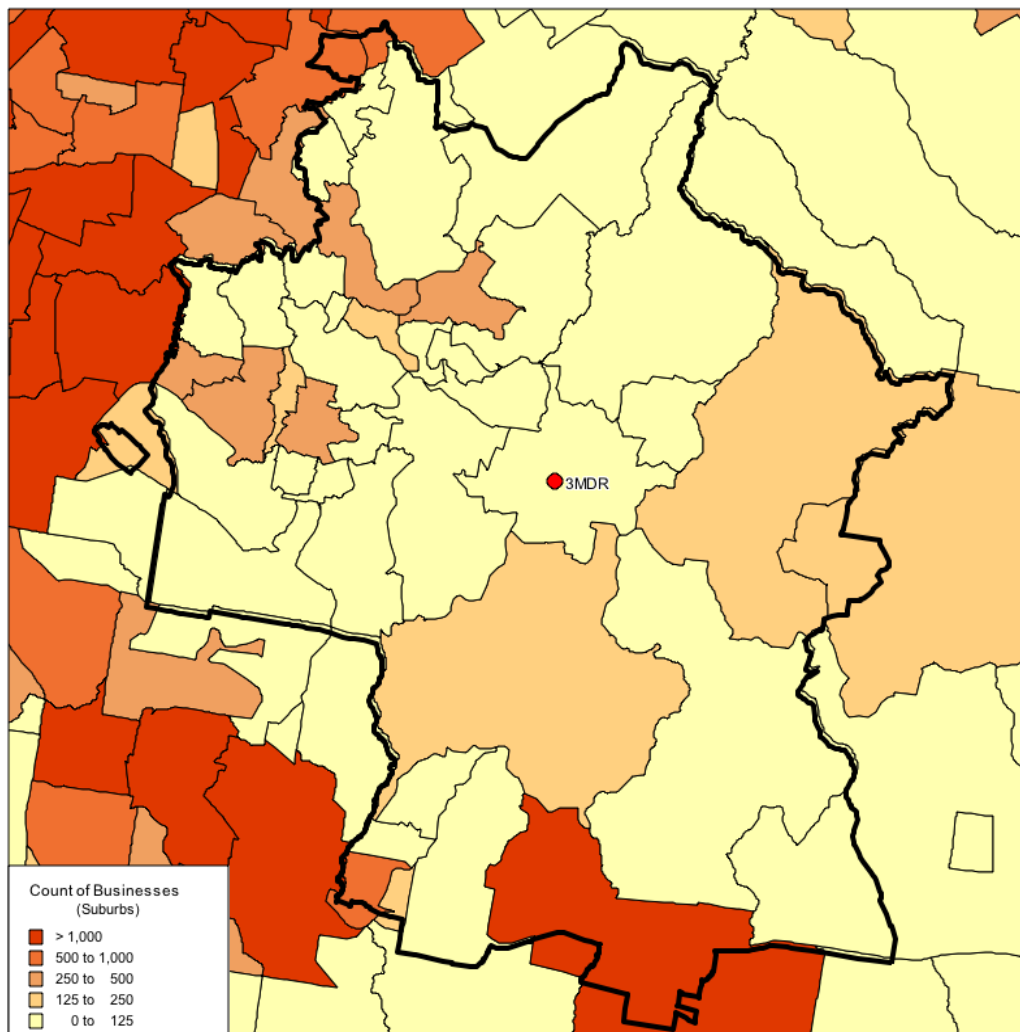
Map 5: In 2006 the population in 3MDR's license area was 72,190. This map shows that 3MDR's license area is dominantly rural with some densely populated urban areas within it and many densely populated urban areas surrounding

Beyond knowing that the population in 3MDR's license area is 72,190, what's more important is to understand the characteristics of the population distribution within it. Map 5 is a map of population density and it shows that 3MDR's license area is dominantly rural with some urban centres. Areas to the east are mostly rural and to the west mostly urban. The station started in response to severe bushfires in the 1980s so this map has important implications for the station's role as an emergency broadcaster. Table 1 shows that 85% of the licensed broadcast area are rural areas likely to have special emergency broadcasting requirements.

Table 1: Population density summary

Population density	Km²	Percentage of license area
0-250 per km ² (rural)	445 km ²	85%
> 250 per km ² (urban / semi-urban)	77 km ²	15%

Businesses within the 3MDR license area



Map 6: Counts of businesses in the 3MDR license area and surrounds

I related a business database to a GIS map of the station's license area to show that there are 6,351 businesses. No business can exist without customers and no community radio station could exist without sponsors. Therefore, quantifying how many businesses there were in the station's license area and where they were was an important task.

Map 6 shows that there is no shortage of potential sponsors in the area. This knowledge highlights the importance of having in place the human, procedural, equipment, programming and audience resources that would make 3MDR a logical sponsorship choice for many of these businesses.

Using GIS To Minimize Environmental Planning Conflict

In the early 1990s I observed a rural planning workshop that was, well, there's no other way to describe it, "constipated" by an entrenched conflict between elderly landowners that obviously dated back to the school yard. If the landowners couldn't agree with each other, how could they possibly reach agreement with planners? Fortunately, the tone of the workshop changed after a landscape architect took a wad of butcher's paper, hand-drew maps of the town on it, and then sticky-taped the maps around the walls of the venue. Almost immediately the interpersonal bickering ceased and all the workshop participants started to talk about what was right and what was wrong with the maps. This little episode captured my imagination and I wondered what difference it would make if accurate interactive GIS maps were used. It is the backdrop for both my personal career in GIS and the text that follows.

It is common for rural towns to have many vacant residential blocks. Increasingly there are pressures to build on these by people seeking tree change, sea change, or just affordable housing. Such pressures can trigger planning reviews that must refer to more rigorous environmental standards than were in place when the land was first subdivided. Often these blocks are not connected to town sewerage, so central to the planning conflict that follows these reviews is a block's ability to treat wastewater within its bounds. If a block is very small, has steep slopes, has inappropriate soils, or some combination of these, then planning regulations might prevent a landowner from building there. Planners have a responsibility to ensure public health and environmental health. Simply put, planners need to be sure that when someone flushes their toilet that the waste doesn't end up in their neighbour's yard, or in the local water supply.

Understandably, when planners revoke ratepayer's rights to develop their land it tends to make them angry! In the text that follows I'll use two examples to show you how GIS can be used to minimize small town planning conflict. The first uses GIS for conflict *resolution* and the second uses GIS for conflict *avoidance*.

The Lakefront Project

These days people's "BS" meters are fully operational. If someone's neighbor can develop their land but they can't, then they want to know why. The Lakefront project demonstrates that GIS has an important role to play here.



Map 7: When I related all the physical constraints (steep slopes and watercourse buffers) to the blocks, and then superimposed the soil's capability to dispose of domestic wastewater safely, the landowners could see which blocks could be developed, which could not, and why.

Some time ago I worked on a lakefront planning project. At a meeting before my group became involved tempers flared so much that security had to be called. In contrast, following the community meetings my group ran, residents shared tea and biscuits with Council staff. Why the difference? I think it's simple. The GIS approach promoted transparency in the planning process. These days, especially since social media has allowed community voice to be heard, people's "BS" meters are fully operational. If one resident gets an entitlement that another doesn't get, then the reason for the difference needs to be demonstrated. GIS can play a very important role here.

In the community meeting we began by talking about the environmental and planning constraints imposed by more senior levels of government and their link to water quality and community health. Then we overlaid the government regulated GIS constraint maps (steep slopes and watercourse buffers) on top of each other. After that we overlaid a soil map that we created, and finally a property map. Because, the community was able to see how the constraint maps built up and how each of the maps interacted, they could see that this planning process was scientific, repeatable and defensible. We demonstrated and explained to all stakeholders why the town could not sustain development at the density shown in the current plan. We also showed individual lots that could sustainably dispose of wastewater onsite, and which ones couldn't.

The Estuary Project

When wastewater flows into estuaries it can cause algal blooms and subsequent fish kills, wildlife kills, amenity loss and tourism loss. Such environmentally and economically important areas must be protected. The following project is an example of a planning authority trying to understand if a small town on the banks of an estuary has the potential to cause environmental harm.

In this project there was no community conflict but real concern by a planning authority that an unsewered small town was polluting its local estuary. Our role was to assess whether the low-tech domestic wastewater systems throughout the town were polluting the estuary. If they were then a multimillion dollar wastewater system would be required.

Normally we would look for evidence of wastewater problems in a town, but from the outset we knew this would be unlikely because the soils there were sandy and porous. Such soils tend to “dispose” of wastewater rather than “treat” it. Compounding this problem was our belief that there were likely to be very old, very basic (and highly polluting) domestic wastewater systems scattered throughout this town. Such systems would not be allowable under the present government domestic wastewater Code of Practice. However, often with GIS, some assumptions need to be made, and in this case I had to assume that all the systems in the town complied with the present Code.

I used GIS to model two scenarios of how sustainable the town would be over time, and color coded the resulting maps according to a traffic light principle. What if every block in the town was to be developed and each used...

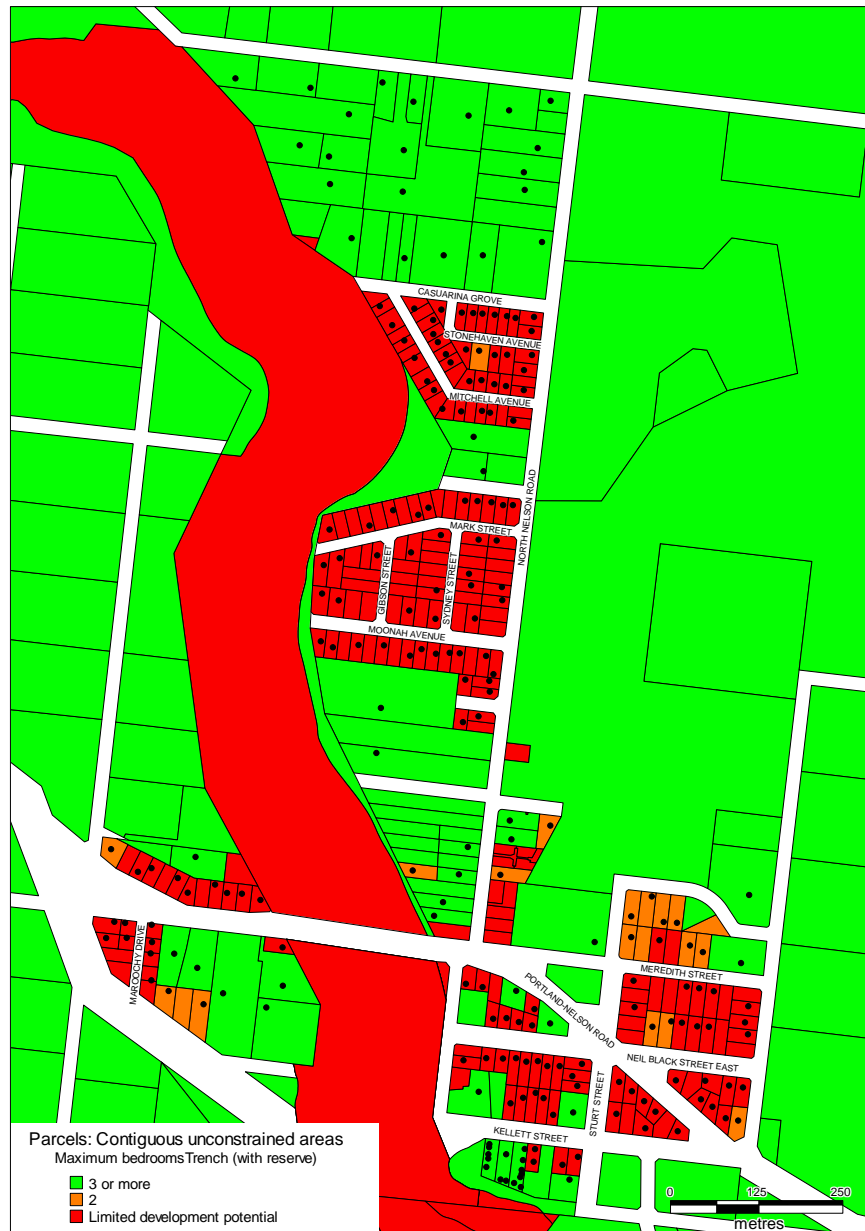
low-tech wastewater technology that required large blocks to be effective
(Map 8)

advanced wastewater technology that would be effective on small blocks
(Map 9)

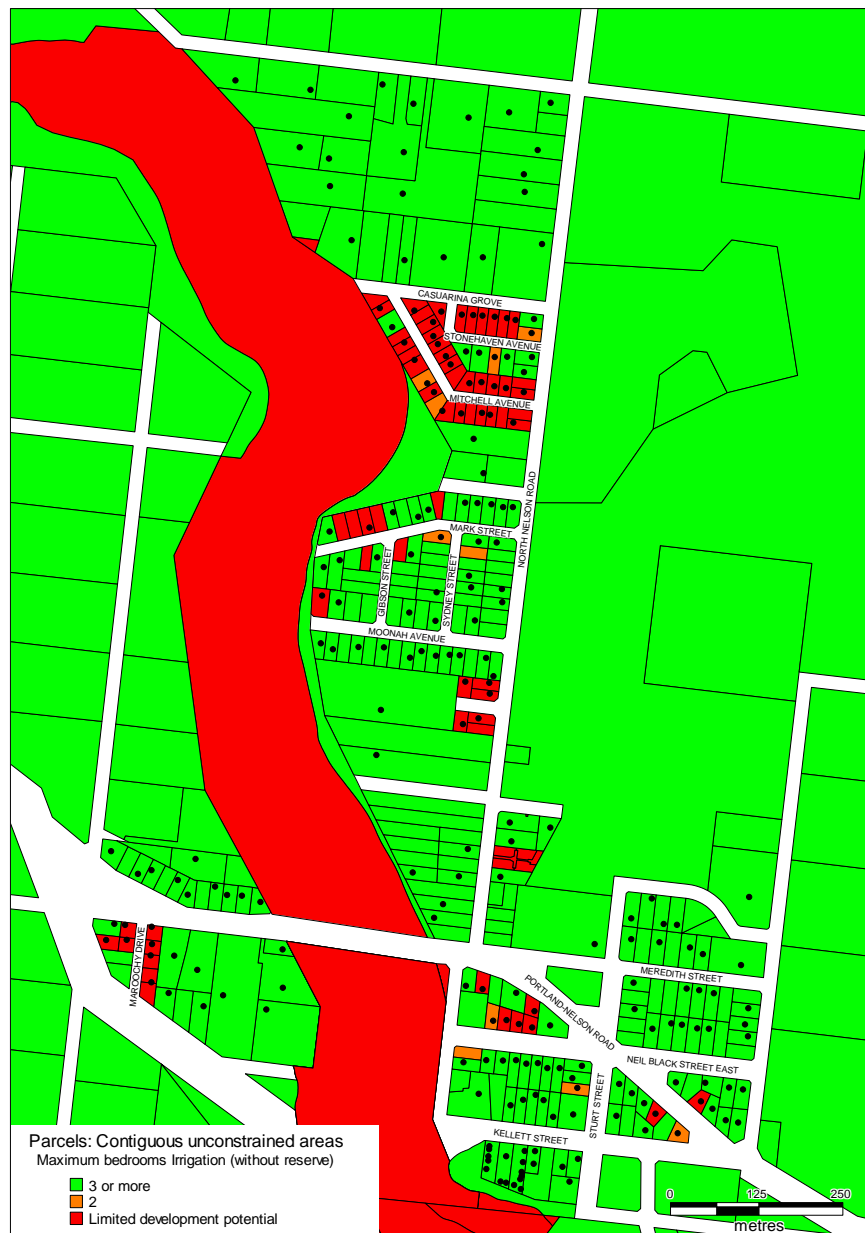
My GIS base maps incorporated constraints such as steep slopes, proximity to water, and soil suitability. Then I applied a formula that calculated the largest development that would be sustainable on each block, and expressed that in terms of the maximum number of bedrooms that would be allowable according to the Environment Protection Authority code of wastewater practice.

It's clear that the business-as-usual approach (Map 8) would not be sustainable in the long term. In this map the majority of the blocks in the town are shaded red indicating that they have limited development potential. It seems that the local government's concern for the estuary was justified.

In contrast, Map 9 shows that if the technology in all household wastewater systems were to be upgraded to advanced wastewater technology over time then only a section in the town's north would remain a concern. Although this area may need to be sewered, the project, and therefore cost, would be substantially less than sewerage the entire town.

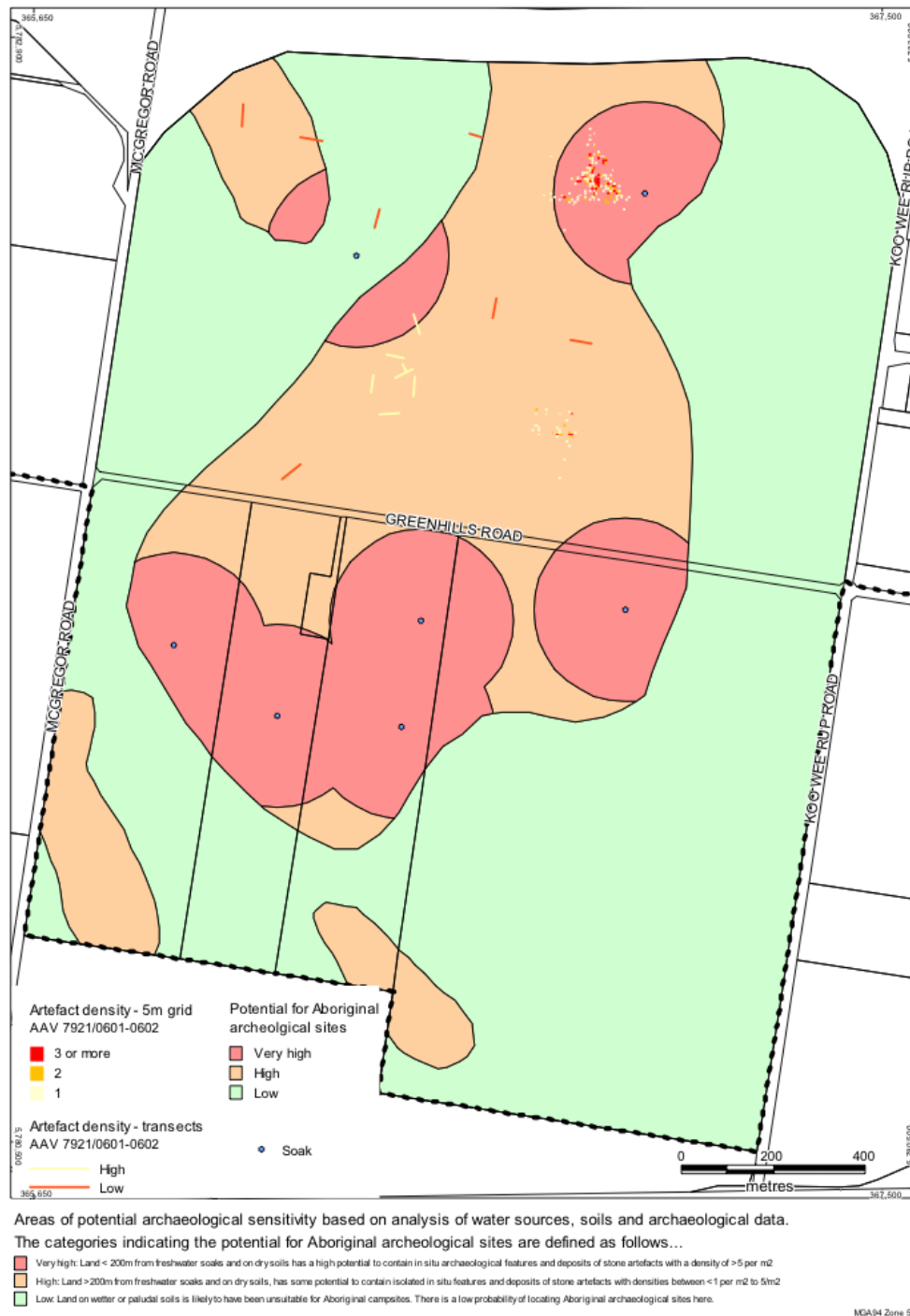


Map 8: This is a GIS map of the sustainability of the town if council continued to approve current wastewater technologies. This GIS map illustrates that the continued use of these systems is not a sustainable option for town growth. There are a significant number of properties with limited development potential. Many of these are already developed (dots), and many are clustered suggesting that there are probably already wastewater problems in the area. Such clusters represent areas where point sources are most concentrated, and by inference are the areas of most pressing concern. Severe problems could emerge if all parcels were to be developed under this scenario.



Map 9: This is a GIS map of the sustainability of domestic wastewater systems if all the existing systems were to be upgraded to a more sophisticated technology. The dots are houses. Blocks that were unsustainable with their existing systems become sustainable when the technology is upgraded. Slope and stream buffer constraints have less impact on developability due to smaller disposal area requirements. There is only one section of the town that seems to be a problem. When we last dealt with Council they were unsure whether a small localized sewerage plant would be installed there or whether residents would be forced to treat their wastewater to a higher standard by upgrading their systems to a better technology.

Aboriginal Heritage



Map 10: This map was accepted as a starting point for survey and site preservation by traditional owners, regulators and developers.

Government often frustrates developers by forcing them to undertake expensive and time consuming archaeological investigations on proposed development sites. GIS can speed things up by helping archaeologists focus on areas

where they're most likely to find artefacts. Read on for an account of one such project.

These days when someone is developing a large tract of land, all sorts of government bodies have a say. In Australia, as in many parts of the world, the documentation of traditional ownership and sometimes the recovery of significant items is important. Developers dread the government prescribed archeological surveys because they can be time consuming, expensive and often lack focus. Commonly the prescribed survey methodology involves site sampling on the basis of grid squares. For developers, mostly it's the delay-to-market that concerns them because nowadays their contracts tend to adjust the final purchase price to account for land lost to heritage issues.

Over the years I have participated in numerous Aboriginal heritage projects. My team's job is to give the archaeological investigation focus. The team includes an archaeologist who understands the cultural behaviours that might lead Aboriginals to favour some places in the landscape over others, a geomorphologist to interpret how the landscape would have looked at the time of occupation, and myself - I have a general understanding of landscape and archaeology, and tend to ask searching questions that usually result in better project outcomes.

In contrast to the grid square approach often prescribed by government, we begin each project with a hypothesis to test. For this study the hypothesis was that Aboriginal camp sites and workshop sites would be selected on the basis of physical advantages, such as dry sheltered sites, and proximity to food and drinking water. The key to these sorts of studies is to match the likely site characteristics to an understanding of how the landscape would have looked at the time of likely occupation (ie. an ideal campsite at one point in geological time might be under water at a different point in geological time).

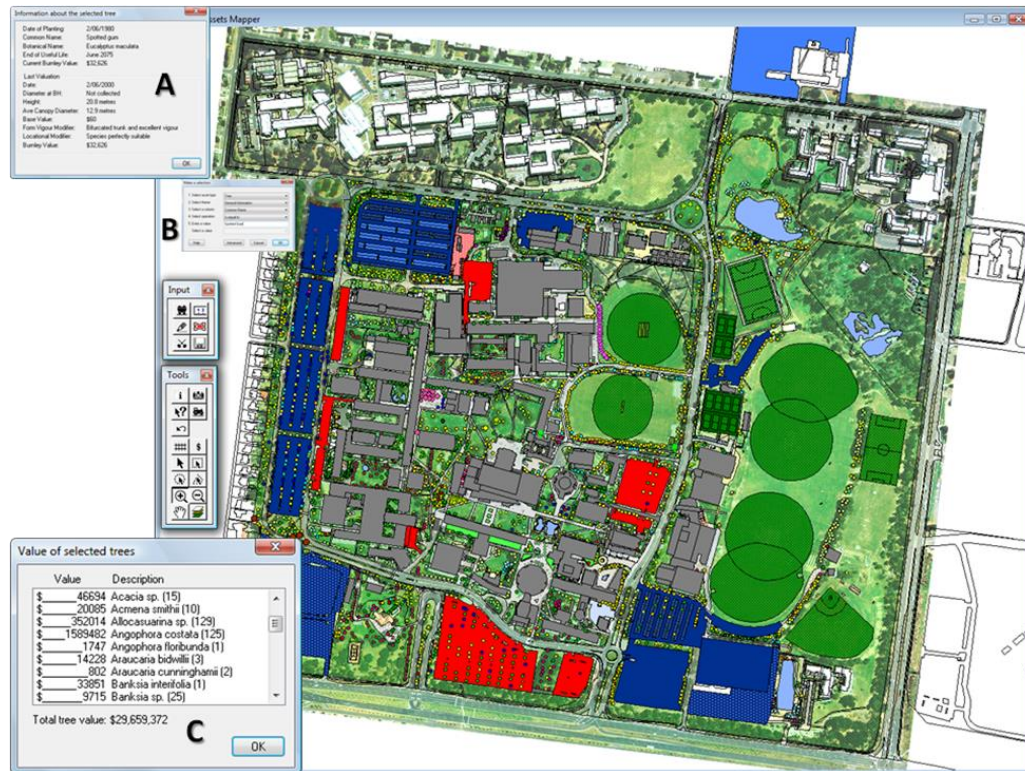
In this study, the archaeologist told us that Aboriginals preferred to get their drinking water from springs rather than streams, and chose to camp on cooler south and east facing slopes in summer, and the warmer north and west facing slopes in winter. Our report contained much science about why the local landscape was stable during the period of archaeological enquiry and then used this understanding to extrapolate some likely sites.

Map 10 shows water springs that we identified in the field and from air photos, and areas where the probability of finding aboriginal artifacts in certain areas was greater than in others. Often overlooked, another important facet of this map is that it also shows areas where the probability of finding artifacts is low. The map allowed archaeologists to focus their labor intensive efforts and gave planners and developers early warning about the likely pattern of estate development. Our methodology was acceptable traditional owners, regulators and developers.

Natural Assets

These days it is common accounting practice to include plants and gardens on government and corporate asset registers. GIS is an ideal stocktake tool for this. For some parks it is important to document assets such as garden seats and picnic tables. In other parks natural assets such as trees and habitat are important. Once documented, assets can be valued and management regimes determined. The flow on from this is that park managers have a better ability to report on the condition of their assets, and a much sounder basis for funding applications to support works. Park managers also tend to gain an improved status in the decision making loop. Following are two examples of vegetation surveys of quite different types. In the first we place a dollar value on park trees and in the second we document roadside vegetation for its habitat potential.

Living Assets Inventory



Map 10: Grounds staff could... A: click on an individual tree and find out information about it, B: look for a particular species of tree on campus (near box B all Spotted Gums are circled), or C: query the value of trees in a selection.

By the end of this project a humble grounds curator was the custodian of a \$30 million living asset inventory. Suddenly, decisions concerning his portfolio took on greater importance for his organization.

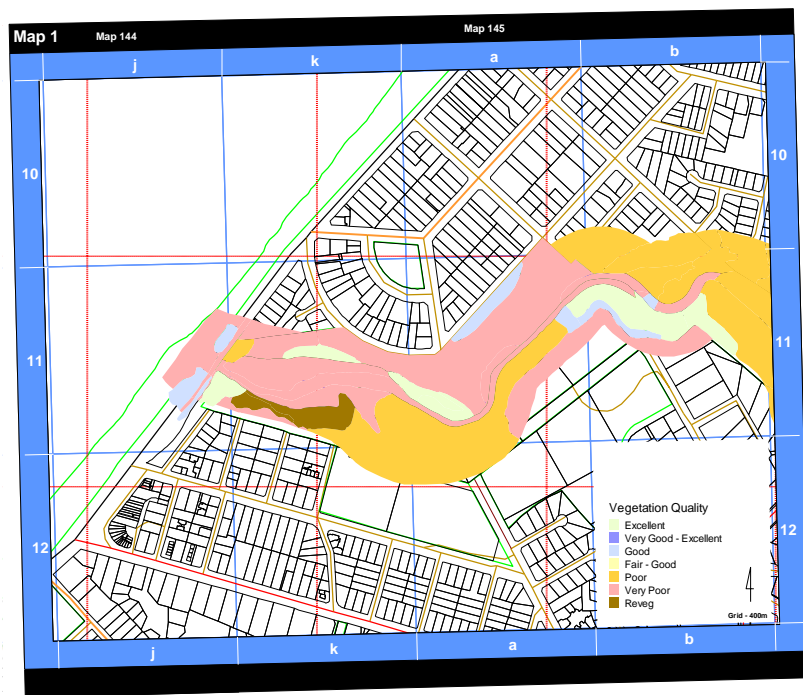
One of my first projects was to create a Living Assets Inventory for a university. The project involved surveying all the University's trees and writing GIS software to allow the grounds staff to query information about them.

Typically in an organization's circle of decision makers, the grounds curator does not wield the level of influence that other players do. It must be frustrating to nurture trees till maturity only to see them die because a different department has cut their roots while laying computer cables between buildings.

Using surveying quality GPS we surveyed around 3500 trees and then used a valuation formula developed by a local horticultural college to place a dollar value on each tree. The formula used attributes such as tree age, height and

general health. When finished, the trees, now redefined to be “living assets”, were valued at almost \$30 million. Although trees would be unlikely to compete with new building plans, on many occasions the grounds department had power around the decision making table that it had not previously had.

Vegetation Condition Assessment

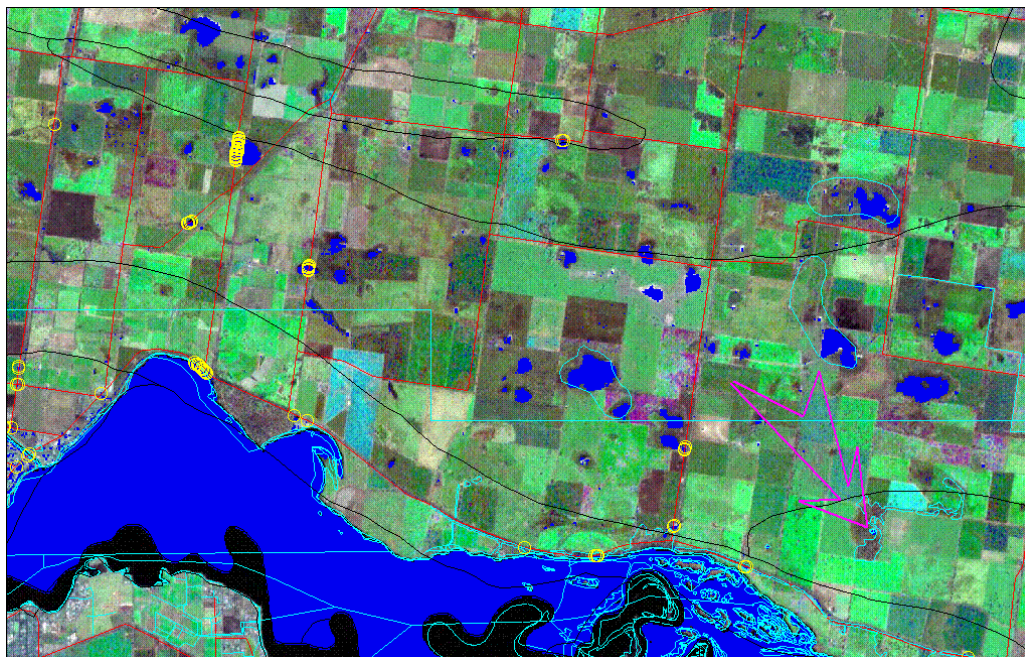


Map 11: This is one map of around 30 that were produced for our client. This map deals with vegetation quality at the mouth of the estuary. We used the grid system from a local street atlas so that casual users could relate the vegetation quality to the street map

Environmental departments are notoriously low priority at funding time. When nature parks are surveyed into areas representing vegetation types, habitat areas and quality, they can be managed in ways that make it more likely they will meet financial controller's funding criteria.

In this project I worked with an ecologist to map native vegetation conditions in public land surrounding an estuary. We used air photos, GPS coordinates, and street map coordinates to visually orient the interpretation. The resulting maps gave the environmental department a clear overview of the vegetation conditions and allowed them to target areas for better protection and improved maintenance, as well as helping budget for new works.

Using Satellite Imagery for Land and Water management planning



Map 12: This is a mixture of multiple GIS maps - roads, irrigation channels, and satellite derived "themes". A LandSat satellite image was "classified" to show ponded water as dark blue. Ponded water indicates that the soil has very poor drainage, and consequently low agricultural productivity. The pink arrow points to an area known to be poorly drained on one side of a fence and not the other, suggesting that at least some of the areas poor drainage problems could be overcome by different land management. The yellow circles were derived from a satellite image collected during drought. These are channel sides with vigorous plant growth and so possibly indicate channel leaks.

In low rainfall New South Wales, farms are square kilometres in size and their driveways are kilometres long. These large farms are a mix of irrigated and dry-land farming. Both water management and land management are important if soil salinity, a major factor affecting agricultural productivity, is to be managed. In this study I combined satellite imagery analysis with GIS maps to highlight areas where land management could be improved.

I have been involved in numerous regional agricultural studies over the years and this study is one that stands out in my mind. The farms here are large and annual rainfall is low (around 450mm or 17 3/4 inches), and so the area is very dry. The area was so large that we used satellite imagery because it was impractical to use conventional air photography.

Satellite images are not just large photos. They can be "trained" to detect features such as ponded water sitting on the ground, a very important theme for this study. I recall writing a paragraph in the project proposal that "ideally we would use one satellite image from drought times and then a second image following a large rain event. That way we could detect ponded water sitting on the ground." In a once-in-a-lifetime coincidence, the week we signed the project contract, the skies opened up to the largest rain event in more than a decade. Immediately following that the skies cleared in time for the Landsat satellite to collect a cloudless image on its one-in-every-16-days passover. It was pure luck!

Map 12 is one of many maps produced for the final report. It shows irrigation channels with potential leaks, and areas with surface water ponding where altered management practices would improve soils and return retired land to high productivity.