Site Selection For Post-Facto Water Quality Protection Works: Targeting the "Dirtiest Dozen"

Ian A Allan, and James A Peterson,
E Mail: Ian.Allan@arts.monash.edu.au, Jim.Peterson@arts.monash.edu.au
Department of Geography and Environmental Science, Monash University, Clayton, Victoria, 3168 Australia.
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Abstract

The legacy of settlement that pre-dates implementation of land use planning schemes and stream water-quality protection rules in rural Australia includes inappropriately sited septic tanks. For water harvesting corporations relying on runoff from private land (as opposed to closed catchments) this can be a problem. Spatial modelling using readily-available spatial data bases is shown to offer information relevant to decision makers needing to know if post-facto mitigation measures offer an effective approach to the problem of protecting water quality. In particular it indicates the scope to implement measures that are an alternative to the installation of (expensive) trunk sewerage and treatment, and/or water purification plants.

Introduction

The evolution and diffusion of infra-structure for city and town water supplies in Australia reflects environmental constraints such as climatic seasonality (as reflected in the regime of surface streams; eg see Ceplecha 1971), and the changing nature of industrial and public health needs. Where possible, closed catchments have been set aside (eg see, Dingle and Rasmussen, 1991; Griffith 1992**)** but this has not been possible to any significant extent in areas that were destined for settlement by farmers, horticulturalists and graziers. Here, water corporations must collect water that has come to streams from private land. Small wonder that water authorities have an interest in being part of the land use planning process.

The use of private land in Australia is now governed by local government planning schemes. These can be amended to allow closer settlement either land parcel by land parcel, or sub-division by sub-division. Water corporations have an interest in monitoring and predicting land use changes so that catchment management expenses can be planned. Outside closed catchments they are not the prime land planning authority and so they must exert influence indirectly. In such cases, five approaches to water quality maintenance emerge:

a) achieving and/or retaining status as a planning scheme referral authority

b) exploring and using opportunities to influence decision-making during appraisal of planning policy and practice in general and of planning scheme amendment proposals in particular,

c) directly challenging (eg through the Administrative Appeals Tribunal (AAT) or by negotiation) planning decisions that would result in land use changes detrimental to water quality maintenance

d) building (expensive) trunk sewerage networks and sewerage treatment/constructed wetlands works and/or water purification plants

e) mitigating the detrimental effects of inappropriate land uses that are in place.

Implementing the last of these options is attractive in that it does not involve challenging the power of other land management agencies, nor the building and maintenance of large- scale infra-structure. Because many planning permits pre-date the implementation of planning schemes and related measures that now support water quality maintenance policies, there is some scope for improving water quality by adopting the mitigation approach. It is contingent upon identifying an effective mitigation site-selection process so that best value for expenditure may be gained.

Site selection processes vary with the nature of the mitigation works. In this study we explore the utility of spatial modelling techniques for identifying the septic tank installations that are most at variance with the water quality protection rules. The data handling necessary was carried out using a Geographical Information System (GIS) in a study of the type known among GIS scientists as a "search for the dirty dozen" (eg see Huxhold 1991, p.99.) on the assumption that often mitigation is achieved incrementally; say, a dozen at a time. It is a popular approach because the outcome identifies a few sites among very many, all of which are easily "groundtruthed" as a routine step in the application of results. Thus any errors that accumulate grossly enough to cause misidentification of sites are uncovered easily.

The Study Area

In the Lal Lal water catchment, water quality maintenance problems mentioned above began to emerge during the 1970s. The catchment is within commuting distance of Ballarat, Melbourne and Geelong (see Figure 1). Closer settlement in such areas is typically in the form of hobby farms, and so it is septic tank rather than trunk sewerage installations that increase in number. Water quality protection measures have been part of the local planning scheme since 1988 (Shire of Buninyong, 1988). Pressure to add septic tank installations to the catchment comes from:

a) farming families wanting to add extra houses to their farms,

b) those planning sub-division, and

c) those perceiving a "right" to build for owners of small land parcels that date from township surveys (eg see Bate, 1978) made under the impetus of the 1850s-60s gold rush, but now hidden within the fence-lines of farms made up of many titles.

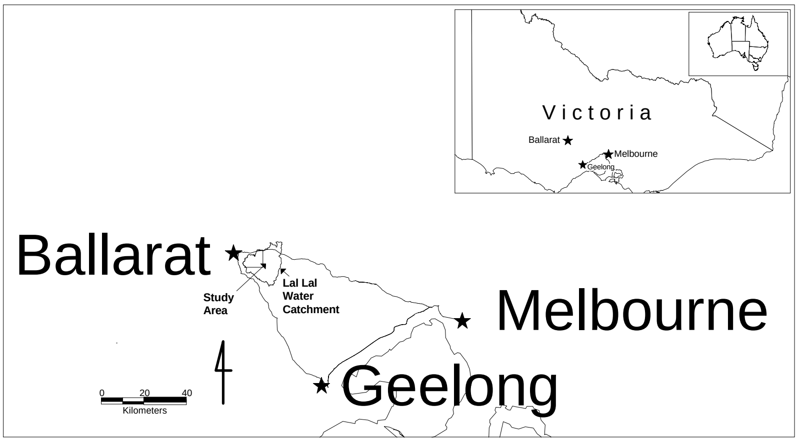

Figure 1: The Lal Lal Catchment is within commuting distance from the three major employment centres of Melbourne, Ballarat and Geelong. It was declared in 1973 (Victorian Government 1973) and over 220,000 people in Geelong and Ballarat rely on water harvested from it. (West Moorabool Water Board, 1986)

Pressure from the first group has been steady since water quality rules were implemented. Local government approval of applications for extra installations has been consistently opposed by the water harvester (originally the West Moorabool Water Board (WMWB) now the Central Highlands Water (CHW) corporation). CHW, like the WMWB was before it, is a Referral Authority (Victorian Government, 1987) which means that it must be notified of all development permit applications within the catchment (eg see Morris 1987, [21,036]). If there is disagreement between the Shire and the referral authority, negotiation or appeal must take place.

The community has become aware that land-parcel based water quality protection provisions in the planning scheme do not satisfy the CHW's whole-of-catchment management strategies because there have been many Administrative Appeal Tribunal (AAT) hearings and hard fought negotiations (eg see Allan and Peterson, 1993) since 1987. Despite land use conflicts between LGA and water authority, there can be no doubt that, in general terms, both the LGA (now the Shire of Ballan) and CHW can claim to be supporting official water quality protection policies.

Sub-division without trunk sewerage/with septic tank waste water disposal, is permitted in Victoria, if, as a result, no more than 500 people are to live in the township so formed or so added to (Victorian Government 1988) Thus, closely settled communities of less than 500 persons are, ostensibly, saved the expense of installing trunk sewerage. However, inappropriate septic tank siting can be a common feature of whole sub-division projects if land resources are not appraised with waste water disposal capability in mind during the planning stages. For instance, at Westland estate, near Ballarat (but outside the Lal Lal catchment), a subdivision was established (against the advice of the water authority relevant at the time) that left the local population short of the 500 persons threshold. However the terrain chosen was such that the septic tanks needed for waste water disposal were installed in unsuitable sites. Water quality and amenity were so affected that trunk sewerage had to be installed in 1997 by CHW at a cost of ~A$3million (Ford R, March 1998, CHW Chief Engineer, Personal communication).

The potential for such problems to develop has been recognised for some decades. The Victorian Government has supported a number of land capability studies designed to document information upon which planners and LGA Councillors could call for decision support when amending planning schemes. The studies were carried out by officers of the (now defunct) Victorian Soil Conservation Authority. The Lal Lal catchment features in one of them (see Jeffrey, 1980; Jeffrey and Costello, 1979; Costello and King, 1979). Because what amounts to land capability had to be referred to during appraisal of applications for amendments of the Buninyong Shire Planning Scheme (now superceded during planning scheme reformulation following LGA amalgamation) Jeffrey's (1980), land system/land capability maps have been referred to often (eg see Allan and Peterson, 1993). They have also been reproduced in a spatial data base (Alan 1996) so that scenario mapping can be carried out for CHW catchment planning experiments in aid of adding to the water quality protection offered by the LGA planning scheme.

Parcel-based water quality protection

The present planning scheme imposes three simple water quality protection rules (Shire of Buninyong, 1988), all of which are mappable.

These rules are:

a) a development must be more than 100m from a watercourse.

In practice, this is defined by the streams on the 1:25 000 Victorian Survey and Mapping topographic map series.

b) a development must be on a suitable soil for disposing of septic tank effluent by soil absorption

In practice, this is taken as being defined by Jeffrey's Soil Absorption Land Capability Map (Map 4, 1980) which comes with the recommendation that those soils imposing high to very high levels of septic tank maintenance on users be excluded from closer unsewered settlement plans.

c) one acre (0.4ha) must be present down-slope between the septic tank and the land parcel boundary

This attribute cannot be mapped directly unless septic tanks/dwelling locations are geocoded, but surrogate locations can be generated using parcel centroids.

Clearly GIS offers scope to map, on a catchment-wide basis, the unsewered houses/land parcels that could be said to break the rules. Because development permits cannot be revoked retrospectively, some interest attaches to the results of analysis of the "rule-breaking population" so that the "worst offenders" can be identified in ways that point to the best approach to mitigation.

Mapping a "dirty dozen"

The experiment reported here was conducted with digital mapping referring to a 56 km^2 north-west portion of the 228 km^2 catchment (calculated using digital mapping of the area). The input maps required for the mapping are described in Table 1

Table 1: The data sets used in the study

Data Set	Scale	Form	Layer Status	Comments
Contours	1:25,000	Vector	Primary	Survey and Mapping Victoria. Used to create a digital elevation model (DEM) for use in orthophoto creation, and to assist in site analysis.
Watercourse and In Stream Dams	1:25,000	Grid & Vector	Primary	Survey and Mapping Victoria.
Dynamic Distance from Water Features	1:25,000	Grid	Derived	Derived from the Watercourse and In Stream Dams map, and created within the IDRISI GIS (Clark Labs for Cartographic Technology and Geographic Analysis, V.1), this was used to position the distance of a development from a water feature.
100m Stream Buffer	1:25,000	Grid	Derived	Created within the IDRISI GIS(Clark Labs for Cartographic Technology and Geographic Analysis, V.1), this was derived from the Dynamic Distance from Water Features map.
Orthophoto Mosaic	1:15,000	Grid	Primary	Fourteen photos (Qasco, October, 1993) were corrected for photogrammetric distortion, and joined to be a single photo using Orthophotogis (Salamanca Software) under Arc Info (Environmental Systems Research Institute, V.7).
Existing Development	1:15,000	Grid & Vector	Primary	One development per title was on-screen digitised within ArcView (Environmental Systems Research Institute, V.3) from the 1993 orthophoto mosaic.
Land Systems	1:15,000	Grid	Primary	Reinterpreted, scanned, vectorised using Provec vectorising software & photogrametrically corrected using Photogis (Salamanca Software) under Arc Info (Environmental Systems Research Institute, V.7).
Effluent Disposal by Soil Absorption	1:15,000	Grid	Derived	Derived reclassifying the Land Systems map to represent the system attributes important in the disposal of septic tank effluent by soil absorption.
Titles	1:10,000	Vector	Primary	Survey and Mapping Victoria.

Land parcel status with regard to the first two water quality protection rules can be assigned by deriving a combined status map in terms of :

a) position inside or outside the 100m stream buffer, and

b) soil absorption status.

Five classes emerged from this analysis (Table 2).

Table 2: The five class hierarchy used in this study segregates land according to the comparative amount of waste water management required by virtue of soil capability in waste water absorption.

Class	Description
Class 1 (Very Slight):	Outside 100 metre buffer and on that portion of the effluent disposal by soil absorption map ranked as having a "High" management requirement.
Class 2 (Slight):	Outside 100 metre buffer and on that portion of the effluent disposal by soil absorption map ranked as having a "Very High" management requirement.
Class 3 (Moderate):	Within 100 metre stream buffer and on those portions of the effluent disposal by soil absorption map ranked as having a "Very Low", "Low" and "Moderate" management requirement.
Class 4 (High):	Within 100 metre stream buffer and on that portion of the effluent disposal by soil absorption map ranked as having a "High" management requirement.
Class 5 (Very High):	Within 100 metre stream buffer and on that portion of the effluent disposal by soil absorption map ranked as having a "Very High" management requirement.

The analysis involved modeling using grid/raster-based techniques and linking to the land parcel information for site identification and display. The sequence of tasks is summarised in Figure 2.

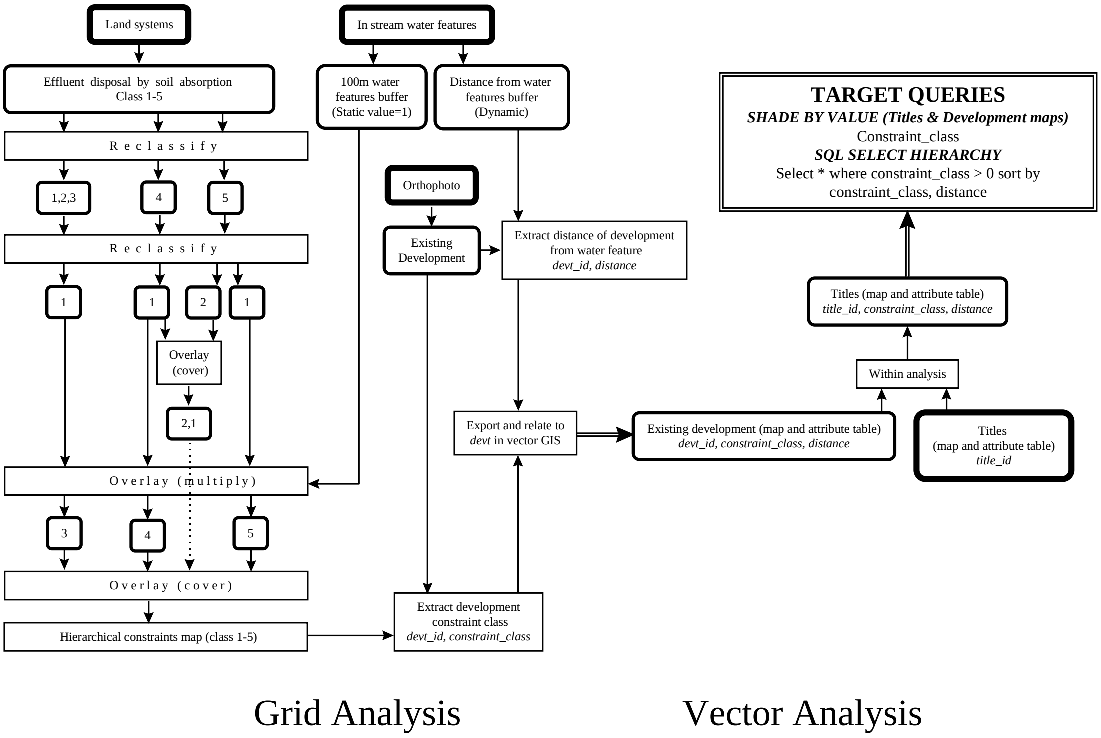

Figure 2: The processing steps undertaken. The land system map was reclassified into five classes to represent the capability of the soil to dispose of septic tank effluent by soil absorption. The five class risk hierarchy was then created by overlaying effluent disposal by soil absorption management requirement classes 5 (very high), 4 (high) and 1, 2, 3 (very low, low, and moderate) onto the stream buffer to create risk classes 5 (very high), 4 (high) and 3 (moderate) respectively. Management requirement for disposing of septic effluent by soil absorption classes 5 (very high) and 4 (high) that are outside the stream buffer were reclassified into constraint classes 2 (slight) and 1 (very slight) respectively. Grid cells representing houses were then overlayed onto the dynamic distance from water features map to add a further dimension to the prioritisation. Finally a tabular file was passed to the vector GIS with fields representing the Development Identifier, Constraint Class and the Distance from a Water Feature. Each title was given a constraint status that corresponded to the constraint class that the development was situated upon. This was then related to the titles so that the "dirtiest dozen" could be identified.

Results

There are 213 dwellings in the study area, ninety of which can be said to be on "constrained land". Selection of the first "dirty dozen" yields the twelve listed in Table 3 as the twelve probably contributing the most to water pollution. Thus, by application of a modern version of a time-honoured method (eg McHarg 1969) of spatial analysis the target land parcels among many have been identified. As Berry (1993, p.24.) has pointed out;

> *…in the absence of spatial guidance, there is a tendency to assume that every square inch […] is in conflict.……*

Table 3: Constraint hierarchy of the dirtiest dozen sorted by constraint class and then distance from a water feature. Note that within the constraint hierarchy, only 4 developments are very highly constrained and 6 developments are highly constrained. The table allows for the prioritisation of remedial works within the constraint hierarchy. The distribution of the "dirtiest dozen" is depicted in map 2 and the "dirtiest" parcel (ID 141) is depicted in some detail in map 3.

Parcel ID	Dirty Dozen Rank	Constraint Class	Constraint Description	Distance from Water (metres)
141	1	5	Very High	30
180	2	5	Very High	42
147	3	5	Very High	60
203	4	5	Very High	67
185	5	4	High	30
197	6	4	High	30
208	7	4	High	42
188	8	4	High	60
207	9	4	High	84
186	10	4	High	90
139	11	3	Moderate	30
199	12	3	Moderate	30

The distribution of the "dirty dozen" (see Figure 3) constrains choice of mitigation measure. Clusters of problem parcels might be such that investment in a small sewerage treatment plant is warranted. In other cases the mitigation measure will be best chosen from further analysis as illustrated in Figure 4.

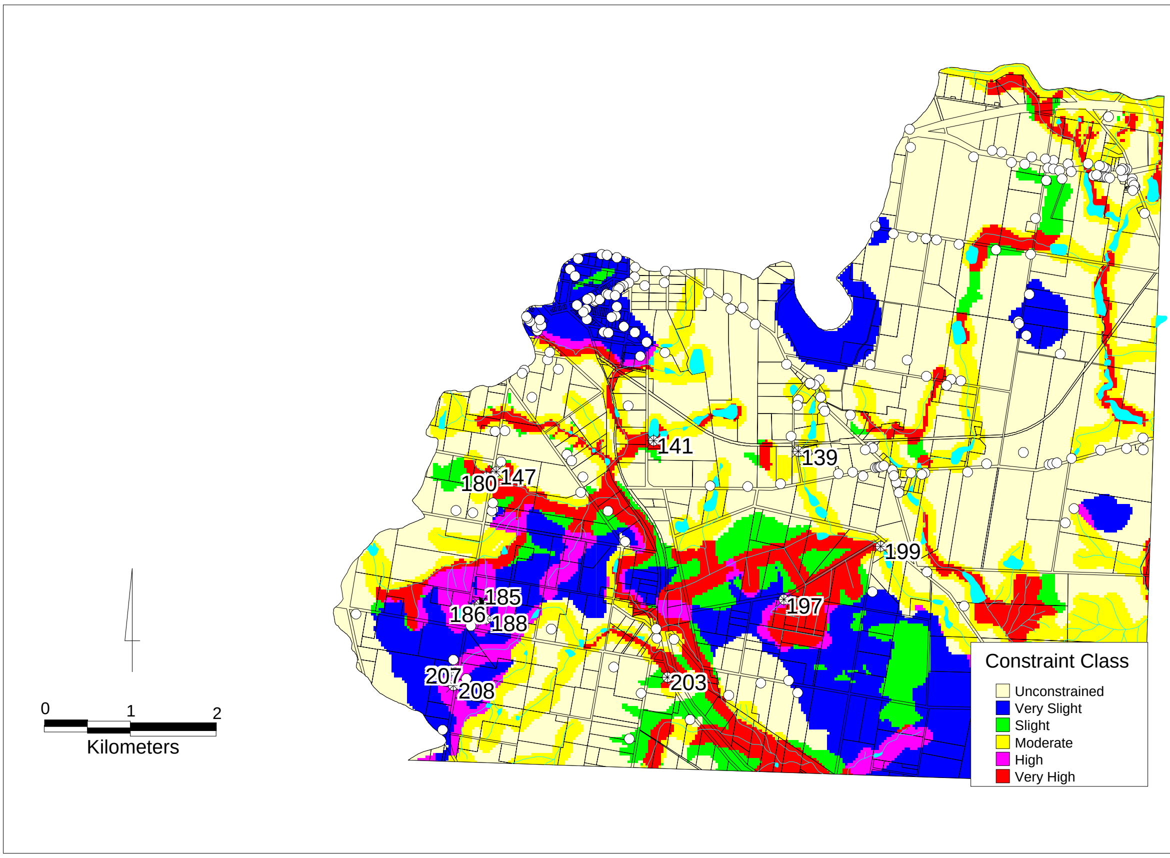

Figure 3: Distribution of the constraint hierarchy for the study area. The dots represent existing developments (as at October 1993). Identifiers of the "dirtiest dozen" (Table 3) are also shown.

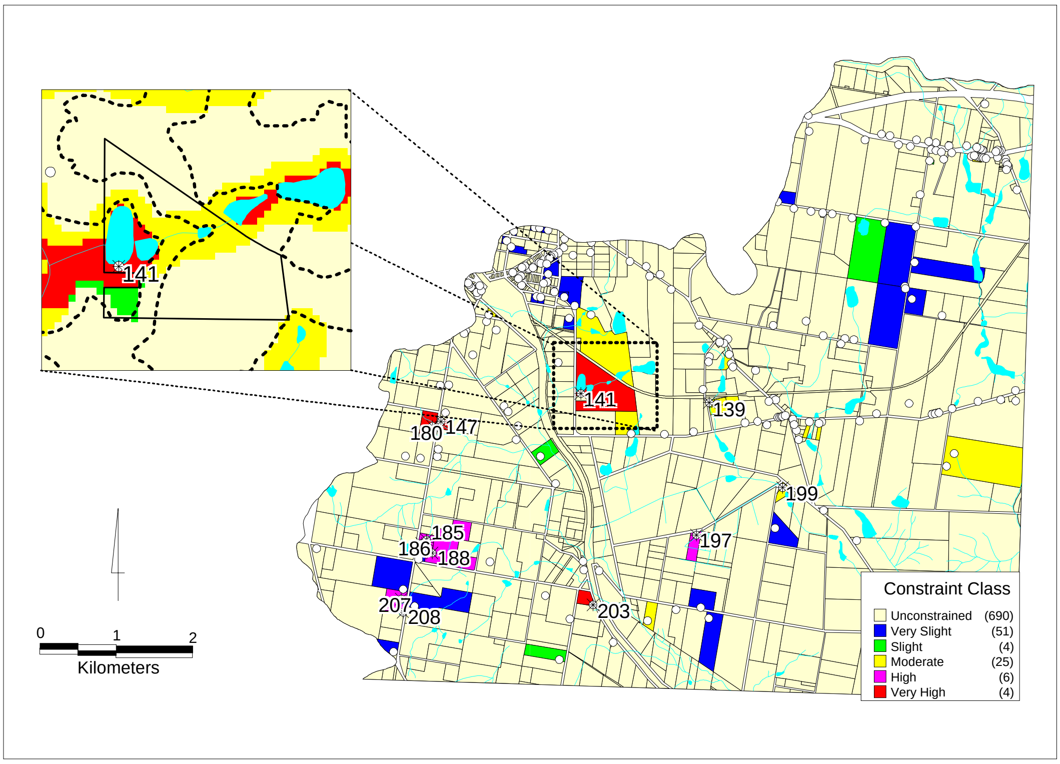

Figure 4: The land titles are shaded to represent the value of the "constraint class" of the development within it. Clearly, any monies to be spent on remedial works would be most effectively used if targeted to the greatest offenders. The map insert shows the grid version of the hierarchical constraint map surrounding the dirtiest of the "dirtiest dozen". The spatial data base can now be deployed immediately in aid of mitigation method selection This development is situated on the "Very High" constraint class and is surrounded by the "Moderate" and "Slight" constraint classes.. Perusal at the contours suggests that unless effluent can be pumped to an absorption field in an unconstrained area of the title, alternative methods for septic effluent disposal will need to be investigated. Clearly, parcel ID 141 is one that deserves priority in deployment of water quality protection funds.

Conclusions and future work

Our experiment indicates that a hierarchy of degree of post-facto non-conformity to water quality protection regulations can be derived through digital spatial data handling. Application to this study area revealed a “terrible ten” or a “dirty dozen”, depending upon how much mitigation might be contemplated. In that the assembly of high quality data for digital spatial data handling allows spatial modelling, it is clear that there is scope to experiment with any distribution patterns available and relevant to a site selection task.

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