

LAND ACQUISITION FOR WATER QUALITY PROTECTION: NEW YORK CITY AND THE CATSKILLS WATERSHED SYSTEM

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INTRODUCTION

New York City water's supply is derived from almost 2000 square miles of watershed located primarily in the rural Catskills Mountains, approximately 150 miles north of the City. Water collected in upstate reservoirs is delivered to the City via a complex network of aqueducts, tunnels and pipes.

As a surface water system, the City would ordinarily be required to filter its entire water supply pursuant to the Surface Water Treatment Rule promulgated under the Safe Drinking Water Act Amendments of 1986. However, due to the generally high quality of the water supply and a comprehensive watershed protection program, the US Environmental Protection Agency has granted the City a filtration waiver until at least 1996, when the program will be re-evaluated.

Land acquisition from voluntary sellers is an important component of the City's watershed protection program. The voluntary nature of the program, the size of the watershed, fiscal constraints and sensitivity to watershed communities' social and economic concerns require the City to develop and apply criteria that maximizes the water quality benefits of voluntary acquisitions.

This paper discusses the development of tools through a "partnership" with a University to facilitate the prioritization of land for acquisition by merging Geographic Information Systems (GIS) and multi-objective decision making tools to incorporate environmental, social and management concerns. A flexible prototype system and graphical user interface was designed that may enable decision makers with diverse backgrounds to easily access and utilize sophisticated technology and complex and evolving data resources.

BACKGROUND

The New York City Department of Environmental Protection (DEP) operates and maintains the world's largest water supply system, providing pure drinking water for more than eight million residents of New York City, commuters tourists, and about one million people living in upstate communities. Water is derived from 1.2 million acres of watershed land feeding approximately 6500 kilometers of tributary streams. Water is collected in upstate reservoirs and distributed through a vast network of tunnels, aqueducts and pipes.

Rules promulgated by the United States Environmental Protection Agency under the Safe Drinking Water Act Amendments of 1986 require filtration of most public water systems supplied by surface water (40 CFR Sec 141). The purpose of this rule, commonly referred to as the Surface Water Treatment Rule (SWTR) is to protect against contamination of drinking water by microbial pathogens. The SWTR permits a waiver of the filtration requirement if the water supplier can demonstrate adherence to strict operational and water quality standards.

Due to increasing suburban development, New York City is constructing a filtration plant to service its Croton system, located east of the Hudson River. The Croton system ordinarily supplies about 10% of the City's water supply. West of the Hudson the River, in the Catskill Mountains, the Catskill and Delaware systems account for 90% of the City's water supply. The cost of constructing a filtration plant for the Catskill and Delaware system has been estimated at 6 billion dollars, with annual operating costs of 150 million dollars. Because of the high cost of filtration and the extraordinarily high quality of the water supply, New York City applied for a waiver of the filtration requirement of the SWTR. Based upon a multi-faceted watershed protection program, the U.S. EPA granted a temporary waiver until 1996, at which time a more permanent waiver will be considered. The City's watershed protection program includes enactment of regulations governing activities in the watershed, (especially septic system siting and sewage treatment plant, siting and design), innovative planning initiatives, development and funding of best management practices for farms, and land acquisition .

Land acquisition is a particularly important component of the filtration avoidance and watershed protection programs. U.S. EPA's filtration avoidance determination, required the City to spend not less than 201 million dollars to acquire not less than 80,000 acres of watershed land. This represents about 7% of the watershed, and would roughly double the City's current holdings. New York State owns 276 thousand acres, approximately 23% of the watershed. While the amount of land to be acquired is substantial, it is nevertheless a relatively small percentage of the vast watershed land area. Thus, while ownership and maintenance of an entirely undeveloped watershed might be preferred, financial, political and practical considerations require the City to focus its

acquisition efforts on those lands most sensitive to development or other alteration.

The City's program is complicated by several other factors. First, the program will be entirely voluntary. Second, the political landscape of the region is complex. Upstate communities have joined together to oppose the City's regulatory and acquisition efforts, while at the same time U.S. EPA and regional environmental organizations have urged even stricter controls and more aggressive acquisition purchases. Upstate residents are particularly concerned that the City may at some point decide to use condemnation. Additionally, watershed residents do not want increased regulation and acquisition to adversely affect the economic and social viability of their communities. As a consequence, DEP is under extreme pressure to implement an effective acquisition program clearly based upon water quality protection objectives.

DEVELOPMENT OF ACQUISITION CRITERIA

The DEP has devoted considerable personnel and equipment towards increasing understanding of the biophysical and anthropogenic forces affecting water quality. The Land Acquisition Program has drawn upon rapidly increasing and evolving understanding of the watershed region to develop criteria designed to identify natural features of relatively greater importance for protecting water quality. These criteria include general water quality concerns, system considerations, land use and socio-economic considerations, and managerial considerations. These four general concerns are summarized in Table 1.

The acquisition criteria outlined above enable DEP to identify a universe of parcels believed to be eligible for acquisition. These parcels must then be prioritized so that staff resources are focused on those properties of relatively greatest importance for protecting water quality. This tool must be sufficiently flexible to respond to changing scientific information and community input, yet provide sufficient support for the primary goals of the program.

A METHODOLOGY FOR ACQUIRING LANDS

In the fall of 1993, the authors formed a partnership to examine the problem of prioritizing from among a set of parcels, given the existence of multiple criteria and multiple objectives. This methodology relied on a coupling of Geographic Information Systems (GIS) with multi-objective decision making tools. The DEP provided GIS datasets and background material, while the University developed, applied and evaluated the methodology.

In order to identify parcels with key biophysical criteria, the DEP needed to be able to analyze geographically based data. GIS allow for the spatial referencing of tabular data, so that information such as soil types or landuses can be related in a geographical context. Large spatial databases can then be stored, manipulated and analyzed so as to provide new information. As part of its overall monitoring program, the

DEP has developed an extensive GIS software and digital data support system. Currently the DEP's workstations run Arc/Info, GRASS, and ERDAS on both workstations and PCs. Their database library includes:

- soils data that includes the complete data tables as found in the published Natural Resources Conservation Service's soil surveys,
- a digital elevation model to capture the watershed's complex topography,
- stream and reservoir hydrography,
- National Fish and Wildlife wetlands down to approximately 1 acre, and
- watershed basin delineation.

Remotely sensed imagery is in development to improve the land use coverages.

However, while a GIS allows the DEP to identify parcels with key biophysical and anthropogenic criteria, it lacks the tools necessary to then rank these parcels based on decision maker values. The answer seemed to lie in Multi-Objective Decision Making (MODM) theory. A considerable body of literature exists which focuses on methods of eliciting decision maker preferences and utilizing these values to determine optimum solutions. The authors' task was to couple the spatial information abilities of the GIS with the tools of MODM theory.

In the initial research study, a weighted linear combination approach was developed and tested using datasets for the Little Beaver Kill watershed, a small watershed in the Ashokan Reservoir. The approach adopted was loosely based on the Simple Multi-attribute Rating Technique or SMART. Questionnaires and interviews were used to determine preference weights for each of seven attributes, which were chosen based on DEP literature and personal conversations. These questionnaires were also used to determine constraints on the acquisition process. For example, early DEP literature stated that no property would be purchase which was under five acres in size. After the attribute values for all parcels were normalized, they were then multiplied by their respective preference weights and summed. The result was a single index value for each parcel which represented its acquisition value relative to other parcels within the watershed. In order to judge the reliability of the method, the results were compared to those produced using a decision support software package. A sensitivity analysis was performed to determine how changes in decision maker preferences would affect the overall results.

The methodology was shown to closely approximate the prioritization results of a rigorous preference software package. The sensitivity analysis demonstrated that while small shifts in values may cause minor fluctuations in rankings, no shift in values could cause a downgrading of those properties in the top 20 percent. Decision makers could therefore be secure in using this top percentage group as a starting point for an initial set of properties to begin the acquisition process.

DEVELOPMENT OF USER INTERFACE FOR LAND ACQUISITION

Based on the encouraging results of this initial research, the authors moved towards the development of a user-interface to provide decision support for the Land Acquisition Office. The goals of this interface prototype were to: 1) allow acquisition staff access to GIS datasets; and 2) provide tools for the prioritization of properties for acquisition. In order to meet these goals, two separate modules were created in the Arc-View AML environment. The first module allows the user to display basic biophysical and socioeconomic maps and to identify parcels which meet specified biophysical criteria. The second module allows the user to input preference weight values for several attributes and to apply constraints. Using the weighted linear combination approach described above, the module would then produce a ranking of the parcels in both digital and hardcopy format. By providing an iterative learning environment, staff can see how changes in the attribute weight values and constraints chosen affects the ranking process.

While the interface is still in the development stage, some conclusions have already become apparent. First, the quality of the results will be influenced by the accuracy and availability of geographical databases. The DEP currently lacks digitized tax maps and instead must rely on centroid points. As a result, while the DEP is able to locate sections of the landscape which met certain biophysical criteria with an acceptable degree of accuracy, associating these land areas with specific parcels is considerably more problematic. Second, despite considerable improvements in the analysis speed of the system, the processing time required for each iteration is still sufficiently high so as to detract from the overall learning value of the tool. Finally, the development of the interface has also been shown to be an evolutionary process. Although considerable time was dedicated to the development stage of the interface, each demonstration of the interface to new potential users brought requests for new analytical tools. These requests invariably added to the complexity of the analysis and therefore further increased the processing time required.

CONCLUSIONS

The development of a GIS based MODM tool has implications for other space initiatives. Conservation groups, land trusts and other organizations interested in the acquisition of land for environmental or open space protection could utilize such a tool in their programs. While these groups may not be under the same level of scrutiny and outside interest that the New York City DEP's program enjoys, they will want to be able to justify their purchases to their leaders and sponsors. However, the use of such a tool will be predicated on the existence of spatial databases, which can be costly to acquire.

One of the most positive aspects of this research has been the mutually beneficial relationship between the City and the

University. Given staff constraints and limited resources, the DEP has found that the use of outside resources has greatly enhanced its research program. The University is provided with an applied research problem, with all inherent complications that come with trying to operate in a real world scenario. The University was also granted access to databases that would have been cost-prohibitive to produce on its own. In addition, the interplay between the authors has often been invaluable in terms of gaining a new perspective on the land acquisition process and the philosophy of watershed management as a whole.

It is difficult to study watershed management without the use of empirical examples. Due to complex forces both within and without the watersheds of concern, New York City has been forced to develop a watershed management strategy and specifically a land acquisition program which is both environmentally defensible and managerially efficient. This process has been complicated by imperfect environmental information and shifting political landscapes. The result has been an evolving land acquisition program which should serve as a model for other municipalities and conservation programs.

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Table 1: Acquisition Criteria Considerations

1. General water quality concerns: finding sensitive lands that will generally protect surface water quality. This includes land that abate pollution such as wetlands, floodplains and riparian buffers, and lands relatively more sensitive to pollution generation. The later lands include parcels with moderate to steep slopes near streams, and land where the subsurface transport to surface water is relatively swift.
2. System considerations: how to apply water quality based criteria throughout the system to reflect the characteristics and functions of different reservoir and tributary basins. Considerations include 60 day travel time to City distribution system; terminal reservoirs (reservoirs that collect water from other parts of the supply system and then can feed directly into the distribution system; tributary basins with existing water quality problems.
3. Land use and socio-economic considerations: This includes development pressure, land use patterns and trends, community needs and concerns.
4. Managerial Considerations: Include issues relating to monitoring properties and maximizing staff resources. Such considerations include parcel size, and proximity to other City or publicly owned land.