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Designing without nature: unsewered residential development in rural Wisconsin

James A. LaGro [1], Jr.

Department of Landscape Architecture and Institute for Environmental Studies, 1450 Linden Drive, University of Wisconsin, Madison WI 53706-1522, USA

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Abstract

In the classic environmental planning book, *Design with Nature*, McHarg (1969) demonstrated a land use planning process that employed multiple layers of geocoded data. Computerized geographic information systems (GIS) have subsequently enhanced land use planners' abilities to identify the opportunities and constraints posed by a landscape's biophysical systems. Nevertheless, improvements in transportation infrastructure, combined with an assortment of technological advances, have greatly diminished the constraining effects of distance and physiography on land use spatial patterns. In the United States, for example, advances in wastewater management technology have decreased the influence of soil permeability, depth to bedrock, and depth to water table on residential development locational decisions. The evolution of this technology has helped facilitate scattered, low-density residential development in rural landscapes across the nation. This paper examines the public health and rural growth management implications of unsewered residential development in the State of Wisconsin.

Keywords: Private sewage systems; Groundwater; Public health; Growth management; Land use policy

1. Introduction

Humans are integral components of the earth's ecosystems, now appropriating the products of photosynthesis from approximately 40% of the planet's terrestrial surface (Vitousek et al., 1986). Population growth and redistribution continue, however, to precipitate extensive landscape changes throughout the world. In highly industrialized nations, rural landscapes near existing cities are particularly desirable locations for residential development. Changes in labor-force composition, increased mobility, and a reduction in urban-rural differences are a few of the factors that facilitate population redistribution from urban to rural areas (Wardwell, 1980; Fuguitt et al., 1989). Two national surveys in the United States revealed that 35% of the nation's adults preferred to reside in rural and small town settings within 30 miles of medium-sized cities (Fuguitt and Brown, 1990). These residential preferences for non-urban areas help explain why migration alone accounted for 43% of the population growth that occurred during the early 1990s in non-metropolitan counties (Johnson and Beale, 1994).

[1] Tel.: (1-608) 263-6507; fax: (1-608) 265-6262; e-mail: jlagro@macc.wisc.edu

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Population growth and decentralization, combined with a steady decline in the size of the average household, have led during the past few decades to extensive conversions of rural land to urban uses in the United States (Zeimetz et al., 1976; Vesterby and Heimlich, 1991). Advances in telecommunications technologies and continued highway construction have made rural areas more amenable to commuting - either electronically or physically - by individuals employed in cities and suburbs. In rural areas without access to municipal sewer service, improvements in wastewater management technology have facilitated residential construction on sites that were once considered unsuitable for development. Residential development that is unsewered - or not served by a municipal sewage treatment facility - has therefore become a significant factor in the transformation of rural landscapes. Because the nation's population centers are generally located along river and lake shores, in coastal areas, and near other ecosystems of great value to society, unsewered residential development has potentially negative implications for public health, safety, and welfare.

2. Private sewage system installation in the State of Wisconsin

2.1. Study area

Municipal sewage treatment facilities remove chemical and biological impurities in wastewater collected from residential, commercial, and industrial buildings in both urban and suburban settings in the United States. In areas without access to public sewerage infrastructure, wastewater is piped to on-site private sewage systems that individually serve usually one, but sometimes, several buildings. This paper reports on private sewage system installation in Wisconsin, a state with a surface area of 14.5×10^6 ha in the upper Midwestern region of the United States (Fig. 1). Wisconsin is a land of relatively subtle topographic relief, with soils of glacial origin covering all but the southwestern part of the State. Although the State is bordered on the west by the Mississippi River, on the north by Lake Superior, and on the east by Lake Michigan, Wisconsin's large glaciated region is young, geologically, with moder-

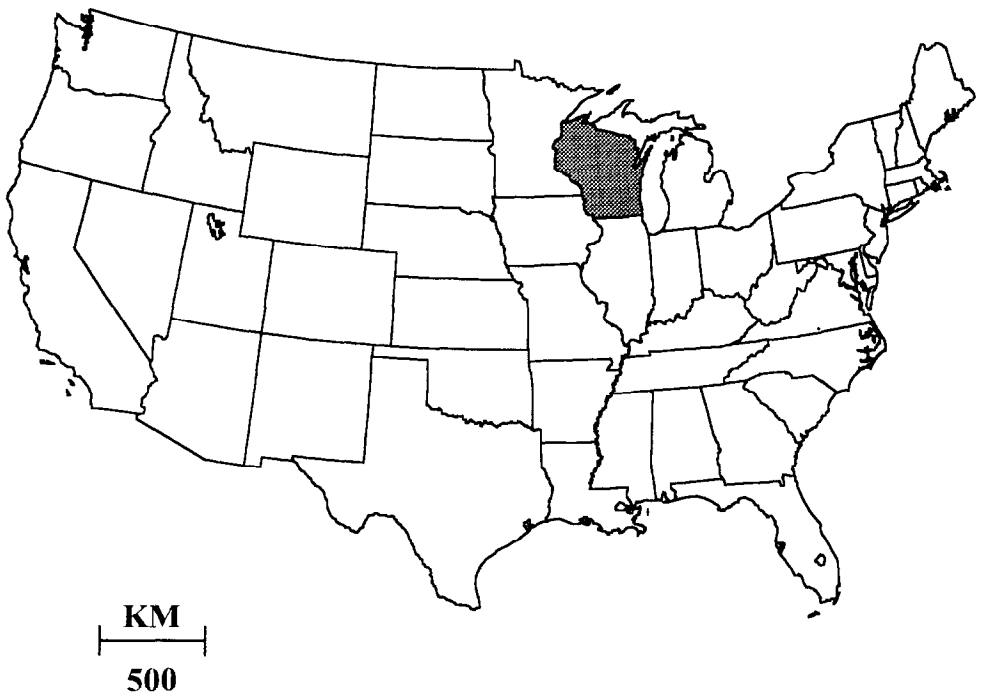

Fig. 1. Location of Wisconsin in the upper Midwestern region of the United States.

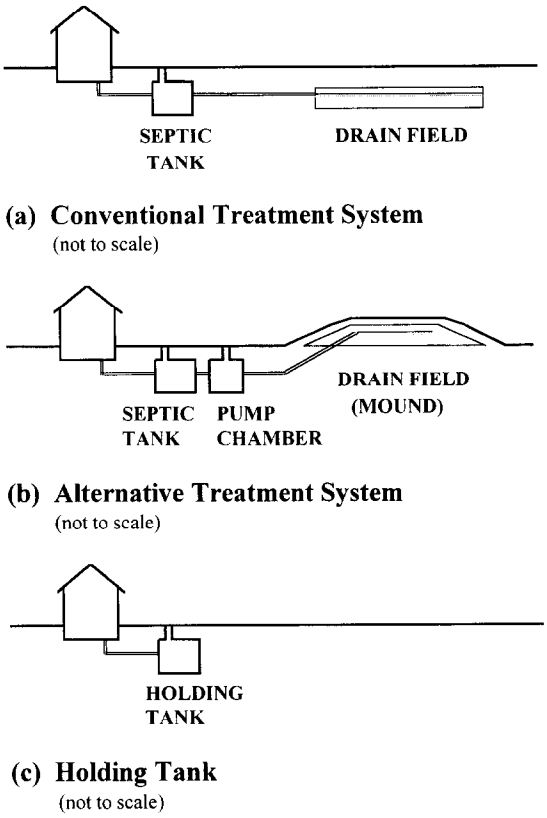

Fig. 2. Schematic diagrams of three private sewage systems installed in Wisconsin: (a) conventional sewage treatment system; (b) alternative sewage treatment system (mound); (c) holding tank.

ately dissected landscapes and imperfect surface drainage. Consequently, many marshes and small lakes are scattered throughout most of the State. Considerable site-scale variation in soil permeability within these landscapes has had a significant influence on State wastewater management policy.

2.2. *Private sewage system types*

The three major types of private sewage systems currently permitted in Wisconsin are conventional sewage treatment systems, alternative sewage treatment systems, and holding tanks (Fig. 2). Conventional systems consist of two major components: a septic tank that separates liquids from solids and provides partial anaerobic treatment of the raw waste, and a below-grade drain field where liquid discharged from the septic tank is dispersed into the soil for absorption and aerobic treatment (Wilhelm et al., 1994). Soil microorganisms in the drain field break down microbial pathogens and decompose organic carbon and nitrogen contaminants in the sewage effluent. Conventional soil absorption systems operate properly on sites that are flat to gently sloping, that have relatively permeable soils containing a combination of sand, silt and clay, and that are not limited by shallow bedrock, flooding, or a high water table. If properly installed and maintained, conventional treatment systems can provide trouble-free operation for more than 20 years (Wisconsin Department of Health and Social Services, 1979).

More than half of Wisconsin's land area is poorly suited, however, for conventional soil absorption treatment systems (Wisconsin Department of Health and Social Services, 1979). Alternative sewage treatment systems are installed on sites with one or more of the physiographic constraints that preclude the use of conventional systems. Depending on the severity of the site conditions, the mounded drain fields of alternative systems are constructed either at or above existing grades with washed gravel and sand that are typically brought to the site. Installation of these mound systems has been recommended for locations that are as little as 25 cm above the water table (Converse and Tyler, 1987). Holding tanks, the third major type of private sewage system, are simply water-tight containers that store the solid and liquid wastes until they are pumped out and trucked to municipal sewage treatment facilities.

Soil conditions assessed on-site by certified soil testers determine the type of private sewage system installed at any given location in Wisconsin. The soil testers are required by law to file complete and accurate reports of their site and soil profile evaluations (Wisconsin Department of Industry, Labor and Human Relations, 1990). These reports typically document the depth to the water table, depth to bedrock, and site conditions such as slope, vegetative cover, and distance to surface waters. Percolation tests are usually performed to assess the soils' ability to receive sewage effluent, thereby helping soil testers determine the type of private sewage system that can be safely installed on the site. Soil testers specify conventional systems for sites with no substantial soil, bedrock, or water table constraints; alternative systems are specified for somewhat less suitable

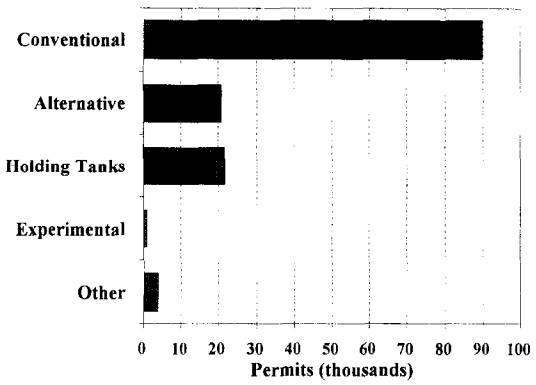

Fig. 3. Total private sewage system permits issued in Wisconsin over a ten-year period (1981–1990).

sites; and holding tanks are specified for sites with the most severe physiographic limitations (Wisconsin Department of Industry, Labor and Human Relations, 1990).

Table 1
Year-round housing units served by public or private sewage systems in Wisconsin

	Year		% Change
	1980	1990	
Public sewage systems	1262265	1440024	14.1
Private sewage systems	494046	615750	24.6
Totals	1756311	2055774	17.1
Public sewage systems (%)	71.9	70.0	−1.9
Private sewage systems (%)	28.1	30.0	1.9

Source: US Bureau of the Census (1983), US Bureau of the Census (1993).

2.3. Private sewage system installation trends

Private sewage systems served 28.1% of Wisconsin's year-round housing units in 1980 and 30.0% in 1990 (Table 1). The number of year-round housing units served by private sewage systems increased during the 1980s by 24.6%, or nearly double the rate

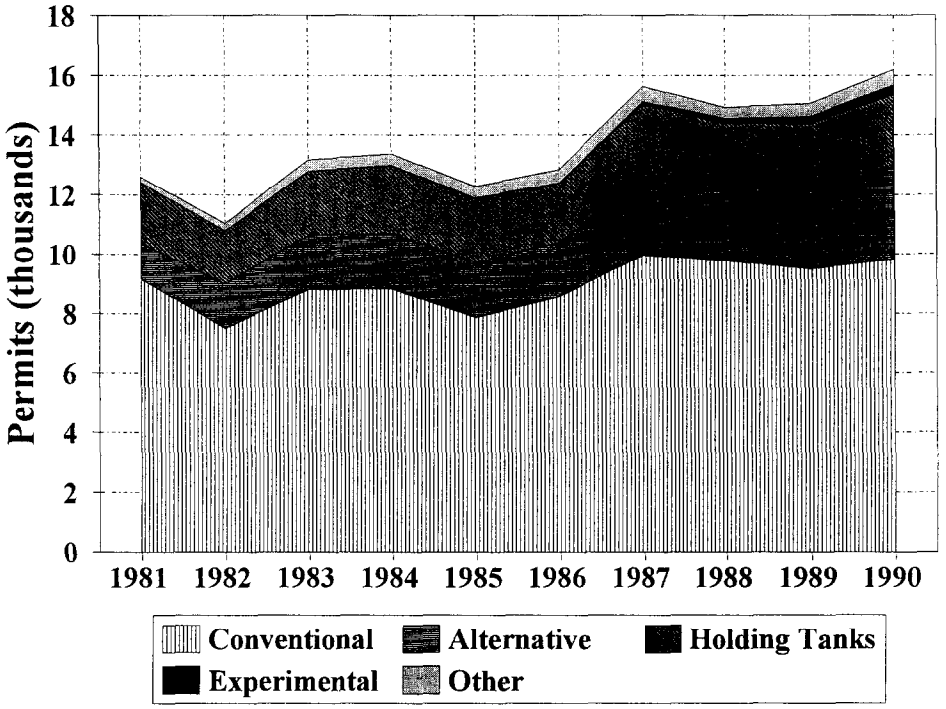

Fig. 4. Private sewage system permits issued annually in Wisconsin (1981–1990).

of increase in the number of housing units served by public, or municipal, sewage treatment facilities. To gain a better understanding of the types of private sewage systems installed in the State, computerized records of all private sewage system permits issued from 1980 through 1990 were acquired from the Wisconsin Department of Industry, Labor, and Human Relations. Because the State's electronic database of private sewage system permits was first implemented in 1980, relatively little permit data were available for that year. During the 10 year period from 1981 through 1990, however, a total of approximately 137 000 private sewage system permits were issued for conventional systems, alternative systems, holding tanks, experimental systems, and other minor private sewage systems (Fig. 3).

Alternative systems and holding tanks comprise increasingly large percentages of the State's private sewage systems (Fig. 4). Conventional private sewage systems dropped from 72.6% of the total permits issued in 1981 to 60.8% in 1990. Alternative systems steadily increased over this 10 year period from 9.8% to 18.8% of the total permitted systems, although a little more than one-half (52.8%) of these alternative systems were replacements for failed conventional sewage treatment systems. Holding tank percentages declined only slightly from 16.2% of the total systems permitted in 1981 to 15.2% in 1990. Collectively, experimental systems and other minor systems, including privies, increased from 1.3% to 5.2% of the total systems permitted.

3. Impacts of unsewered residential development

3.1. Landscape change

An administrative code revision adopted in 1980 allowed the installation of alternative sewage treatment systems throughout Wisconsin. The environmental impact statement (EIS) completed for the proposed code revision suggested that alternative systems might facilitate in-fill development on poorly drained soils near cities and villages, and thereby slow the conversion of prime farmland to urban uses (Wisconsin Department of Health and Social Services, 1979).

Hanson and Jacobs (1989) assessed the land use impacts of private sewage systems installed from

Fig. 5. Sign advertising building lots for sale in an unsewered residential subdivision located among scattered wetlands in southeastern Wisconsin.

1981 through 1985 in two metropolitan and six non-metropolitan Wisconsin counties. They found that conventional systems were somewhat more clustered than alternative systems and holding tanks, but there was little difference between these three system types in the rates at which agricultural and forested land were converted to residential uses. Subsequent research in Ozaukee County, a metropolitan fringe county in the Milwaukee Metropolitan Statistical Area (MSA), compared pre- and post-development site attributes for a stratified random sample of conventional systems, alternative systems, and holding tanks installed in the 1980s (LaGro, 1994a). All three private sewage systems facilitated scattered residential development, but they were not significantly different in either median distance to the nearest village or city, median parcel size, or median farming suitability of soils converted to development.

Contrary to the optimistic scenario posed in the EIS, empirical evidence has shown that recent unsewered residential development in rural Wisconsin is largely scattered and spatially separated - in many cases by several km - from the nearest cities or villages. In Ozaukee County's unincorporated townships, for example, unsewered residential development consists primarily of single-family houses that are either isolated or in small but scattered enclaves arranged around cul-de-sacs. These unsewered subdivisions of typically 5–15 houses are built on relatively small lots, and are interspersed among the rural landscape's farms, forests, and wetlands (Figs. 5 and 6). Although this could be characterized as an exurban growth pattern (Davis et al., 1994), this development is essentially a spatially dispersed yet more land-consumptive form of post-World War II suburban sprawl.

3.2. Public health

Rural groundwater quality in Wisconsin is affected by the timing and rates of agricultural pesticide and fertilizer applications, and by the spacing, installation, and maintenance of private sewage sys-

Fig. 6. A horse pasture and an afforesting field provide scenic amenities for the distant unsewered subdivision of single-family houses in southeastern Wisconsin.

tems. Safe densities of private sewage systems vary with local geological, hydrological, and soil conditions. In the coastal plain of the State of Delaware, for example, densities of between two and four conventional sewage treatment systems per acre (0.405 ha) resulted in nitrogen contaminated groundwater (Miller, 1975). The public health effects of nitrate-nitrogen concentrations greater than 10 mg/l can be serious when local groundwater serves as the domestic water supply (Sayre, 1988). Drinking water that is contaminated by nitrogen can cause methemoglobinemia or blue baby syndrome.

The accumulation of nitrate-nitrogen in groundwater is a potentially significant long-term consequence of on-site sewage treatment, even when the private sewage systems are properly designed and constructed (Wilhelm et al., 1994). In Wisconsin, improperly maintained holding tanks are also a threat to groundwater quality. In a study of 395 holding tank permits on record from 1987 through 1991 in four townships of Wood County, 126 (32%) homeowners only sporadically reported the proper disposal of holding tank waste and another 144 (36%) homeowners filed no reports or reported zero pumpage (Schwab et al., 1993). Anecdotal evidence from local officials further suggests that at least some of the unaccounted holding tank wastewater is being disposed of improperly, either by owners who purposely create leaks in their holding tanks or by wastewater haulers who discharge their tank trucks into roadside drainage ditches or other illegal locations.

Although efforts to educate homeowners may help reduce groundwater contamination from improperly disposed wastewater, rural groundwater quality cannot be reliably protected without the enforcement of private sewage system installation and maintenance regulations. As the number of unsewered homes increases, however, the enforcement problem burdening county and local governments also increases. This threat to groundwater quality could be mitigated by closer monitoring of pumpage records filed with the State regulatory agency. The Wisconsin Department of Industry, Labor and Human Relations (1995) has in fact recently proposed a computerized tracking scheme to facilitate monitoring of holding tank maintenance and service activities. An even more effective policy option, that has been implemented by some townships in the State, is simply to ban the use of holding tanks.

4. Rural growth management implications

Before installations of holding tanks and alternative private sewage systems were allowed in Wisconsin, health codes tended to preclude unsewered housing development on sites with shallow bedrock, a shallow water table, or slowly permeable soils. Alternative sewage treatment systems and holding tanks now facilitate rural development on these sites that were once considered undevelopable. Because approximately 50–60% of all Wisconsin land is unsuited for conventional sewage treatment systems (Wisconsin Department of Health and Social Services, 1979), holding tanks and alternative systems have collectively doubled the State's land area that could receive unsewered residential development.

Between 1982 and 1992, 100 845 ha of new development increased the total developed land area in Wisconsin by 11.8% (US Department of Agriculture, 1992). The extensive land use changes facilitated by expanded highway networks, advanced telecommunications technologies, and recent improvements in private sewage system technology expose the futility of piecemeal approaches to urban growth management. Even though local sovereignty or home rule gives minor civil divisions in Wisconsin adequate police powers to control land use change, rural local governments throughout the United States typically lack the personnel needed to administer comprehensive growth management programs (Doherty, 1991). With increasing numbers of individuals living in unincorporated townships, but working in distant cities or suburbs, these rural minor civil divisions may be simply too small to effectively manage the physical growth of communities that, in fact, transcend minor civil division boundaries.

Although the county is an imperfect planning unit - because commuting also occurs across county boundaries - counties more closely match the spatial scale of current rural-urban commuting patterns. Counties in Wisconsin, for example, generally range from ten to thirty times larger than the typical rural township. County-level planning is not without problems, however, as demonstrated by a study of rezon-

ing petitions considered by four county zoning committees in the State (Last, 1995). The committee members - all part-time public servants of whom most were farmers - approved more than 90% of the 127 rezoning petitions submitted over a 3 month period. By repeatedly granting variances to the adopted comprehensive land use plans of four counties, these lay committees allowed scattered, unplanned residential development in productive agricultural landscapes (Last, 1995).

Wisconsin has a farmland preservation program that provides State income tax relief to farmers as an incentive to keep prime farmland in agricultural uses (Wisconsin Legislative Fiscal Bureau, 1993). However, the current program's modest financial incentives are relatively ineffective in urbanizing landscapes where development pressures and land values steadily escalate. An annual average of 2390 ha of prime farmland were rezoned out of exclusive agricultural zoning (EAZ) districts in the State from 1987 through 1993, for example, and about 75% of this land was converted to residential uses (Wisconsin Department of Agriculture, Trade and Consumer Protection, 1993). Even if modifications to the program were effective in slowing the development of prime farmland, this would not necessarily ensure that urbanizing landscapes will remain desirable places to work, reside, or enjoy the outdoors. Scattered residential and commercial development can eliminate rural landmarks, alter historic land use patterns, and blur the boundaries of villages and cities. These landscape changes incrementally degrade the natural and cultural resources that not only sustain the State's agriculture and tourism industries, but also enhance local residents' quality of life.

5. Conclusion

Physiographic constraints now play a diminished role in the land use decisions that collectively shape rural development patterns in the United States (Popper, 1981). If private sewage system installation and maintenance regulations are consistently enforced, the threat of groundwater contamination from unsewered residential development can be minimized. Careful monitoring of alternative sewage treatment systems and holding tanks, in particular, is essential because these systems are specifically installed in areas where natural site conditions are unsuitable for soil absorption sewage treatment. Even if the potential threat to public health is effectively eliminated, however, private sewage system regulations will remain inadequate surrogates for explicit growth management policies designed to protect environmental quality, conserve prime farmland, and promote the development of safe and attractive communities.

Although substantial political and legal challenges can be expected to greet future growth management efforts in Wisconsin, statewide growth management programs have already been adopted in Florida, Oregon, Vermont, and six other states with nationally significant natural resources (Gale, 1992). Without the implementation of effective growth management policies in Wisconsin, unsewered residential development is likely to continue to transform rural landscapes and diminish both the quantity and quality of the State's natural and cultural resources. This threat to rural environmental quality could be diminished by directing new residential construction away from critical resources and to areas better suited for development (LaGro, 1994b). Transferable development rights (TDR) programs hold considerable promise for this purpose in Wisconsin and in other states, where private property rights pose a formidable legal obstacle to coordinated rural growth management.

Unsewered residential development occurs on some of Wisconsin's - and the nation's - most fertile soils. A reasonable rural planning objective would be to assure the adoption of land use policies that protect environmental quality and conserve prime farmland, yet allow for the accommodation of residential preferences for less urban areas. The transformation of rural landscapes by spatially dispersed residential development should make planners and policy makers reflect, however, upon the reasons for this phenomenon. As long as cities are perceived - rightly or wrongly - as places of crime, congestion, high taxes, and inferior public schools, families will continue to flee from urban areas into the countryside. A prudent strategy, therefore, would be to couple rural growth management programs with efforts to improve the quality of life in existing urban

communities, thereby reducing the push factors that stimulate migration from urban to rural areas.

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