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Introduction
Clean water, distributed and collected through centralized infrastructure, is a driving force in modern urban growth. Our goal is to measure the development of water infrastructure measures the location, timing, and spatial extent of urban fringe infrastructure. Ideally, the expansion of these utility conduits network can be used to evaluate the relationship between urban growth and the distribution of water services and their impact upon specific urban ecological processes, including habitat fragmentation. Multiple societal forces, including economic cycles, shape variations in local urban development. These forces are summarized empirically in local building permits that describe the number and location of building permits. Timing of water service provision may precede, be coincident with, or lag the development of road networks providing access to urban fringe building sites.

Objective
The objective of this paper is to identify the magnitude of urban fringe infrastructure within measured time periods for the City of Phoenix. The City of Phoenix, under the Ruristate of Arizona annexation laws, now includes about 500 square miles. Its water infrastructure of over 600,000 physical components serves both residential and non-residential users.

Methodology
We use GIS to identify local building cycles that shape the expansion of public water infrastructure into the growing urban fringe. Periodic trends in the number of Maricopa County and City of Phoenix building permits occur at decades since 1930. These local economic cycles reflect local availability of public and private funding; the impact of national legislative changes in lending and loan requirements; and state and national economic conditions. We analyze total water infrastructure investments over time for the City of Phoenix between 1954 and 2003. The database is a proprietary City of Phoenix, Water Services Department file made available to the authors as part of the Arizona State University-Center for Business Research, and Center for Real Estate Research (Specrifically, we use GIS procedures to develop two sequential analyses of urban fringe expansion for the City of Phoenix, Arizona, 1954 – 2003). The database is a proprietary City of Phoenix, Water Services Department file made available to the authors as part of the Arizona State University-City of Phoenix GIS Data Collection Pilot Project. Our current analysis examines the location of underground water pipeline segments by use of construction multiple entries for the same water segment in different time periods reflect routine maintenance and operations as well as building rehabilitation requiring expanded infrastructure capacity. The existence of water infrastructure is an early spatial indicator in the development process. Once a building permit is issued, construction is required within a year.

Table 1: Change in fringe water services by period

<table>
<thead>
<tr>
<th>Year</th>
<th>Year</th>
<th>Change</th>
<th>Value</th>
</tr>
</thead>
<tbody>
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<td>1960</td>
<td>1961</td>
<td>1965</td>
</tr>
<tr>
<td>1965</td>
<td>1970</td>
<td>1971</td>
<td>1975</td>
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Extended Findings

Urban Fringe Development Periods
Figure 4: Initial expansion occurred from 1960 through the early 1980's. This period was the fastest growth experienced in Phoenix, and the total population served was less than half of the current average.

Figure 6: Water infrastructure expanded by 36% in this period building permit and was primarily located in the central core.

Figure 8: Elevation expansion moves the central core, from the Mountains of South Mountain to the east, and Tempe to the west.

Figure 11: Ahwatulala Community

Figure 13: (Left) The number of water segments per year in the Light Rail Corridor reflects rapid construction through the mid-1990s and redevelopment, especially in the Central Business District in the late 1990s.

Figure 13: (Right) The number of water segments per year in Ahwatulala describes a classic building cycle for new urban development with a peak in the mid-1980s and later decline.

Figure 16: Logistic curve of the rate of water infrastructure for both Ahwatulala and Light Rail corridor.

Implications for Urban Fringe Research
This study offers an additional approach for urban fringe identification that can be expanded locally and used for future comparative studies. Additional analysis of data on urban infrastructure may readily incorporate location and extent. The location of Phoenix is segmented through urban expansion evaluation.

Special Thanks: