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Characterizing Water-Related Land Uses Across Urban River Reaches

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Abstract

Boundaries dividing political authority rarely match natural water flow. Multiple agencies, often with competing agendas and policies, manage water within single watersheds. This discrepancy can render management efforts ineffective. Comparisons between natural watersheds and human political geography are therefore necessary. As part of a statewide, multidisciplinary water sustainability project titled iUtah, three series of environmental monitoring sites are planned. The sites run across reaches of the Logan, Red Butte Creek, and Provo Rivers in Utah. Here, water-related land use data acquired from Utah's Automated Geographic Resource Center are analyzed using ArcGIS geoproceessing tools. Land uses contributing to water quality in urban areas along each of the rivers are described. Spatial distributions of land use were examined using three different boundary sets, comparing the political geography of the river reaches to their physical geography, as depicted in United States Geologic Survey Hydrologic Unit Code (HUC) watersheds. Land use mixes using political infrastructure were contrasted with land use mixes derived from HUC boundaries. All land uses were classified in seven categories: residential, commercial/industrial, riparian/ water features, irrigated agriculture, non-irrigated agriculture, farmsteads, and parks/open spaces. A gradient from rural Heber, to urbanizing Logan, to fully urbanized Red Butte Creek is shown. Land use mixes vary between rivers and between boundary sets, primarily in percentages of residential land use and irrigated agriculture. Differing land use mixes emerge depending upon the boundary set used, with the nature of those differences varying from river to river. Irrigated agriculture, residential, and commercial/industrial land uses varied between natural and political watersheds. For example, while Red Butte Creek HUC boundaries showed 53.8 % residential land use, Red Butte Creek municipal boundaries and community providers totaled 26 % and 39 % residential use, respectively. The most striking differences emerged when irrigated agriculture was assessed using HUC boundaries. Irrigated agriculture totaled 0.2 % in in Red Butte Creek, with Logan showing 29. 7%, and Heber irrigated agriculture sitting at 41.1 %. Comparative data sets are now available to agencies from divided jurisdictions within Utah watersheds.

Keywords: GIS, iUTAH, Water-Related Land Use

1. Introduction

Land use is important to many investigators, including scientists, engineers, and urban planners. Shifts from agricultural to suburban land use have been shown to subtly alter stream sediment loads and taxonomic richness in Appalachian streams[1.] Mining related land uses are related to reduced macroinvertebrate diversity in the Susquehanna river[2]. Changes in land use have also been associated with increases in dissolved silicon in streams due to reductions in surrounding vegetation cover in Southern New England[3]. A modeling based study of an urban to rural gradient in the Southern Applachian watershed concluded that urban land use affects water quality at the edge of urban expansion[4]. Human infrastucture, both political and engineered, can complicate seemingly straightforward investigations into land use and its relationships with water quality and flow. Political boundaries rarely match the boundaries in natural systems[5]. Regulatory authority is often divided among a number of agencies, even within the same watershed. Differing

levels of government can often have competing interests and agendas. An integrated approach at the watershed scale had been offered as a solution to arising problems[6].

Geographic Information Systems have been used to categorize and analyze spatial data in land use studies. A study of the Ward Creek watershed in Baton Rouge, Louisianna used a GIS based approach to categorize land uses to determine their effects on urban water flow[7].GIS has has also been used to quantify land use statistics in the rapidly urbanizing Pearl River Delta in China[8].

From the available literature, conclusions can be drawn. First, land use represents an important contributor to water quality. Second, human political boundaries rarely match natural hydrology, and arising conflicts can complicate water management. Thus, comparisons and contrasts of differing ways of bounding a watershed are valuable.

1.1 iUTAH

A National Science Foundation funded project, iUTAH, has planned a series of sampling sites along Utah river reaches. The Gradients Along Mountain to Urban Transitions (GAMUT) sites combine to create ecohydrolic observatories measuring variables such as snow melt, evapotranspiration, and soil moisture, along with other variables[9]. These rivers include the Logan River in Northern Utah, Red Butte Creek in the Salt Lake City area, and the Provo River in the Heber City area of Southeastern Utah.

1.2 This Project

Here, ArcGIS is applied to urban Water-Related Land Use (WRLU) in three areas of interest to the iUTAH, a water sustainability research project funded by the National Science Foundation. Urban areas near sampling sites designated Gradients Along Urban to Rural Transitions (GAMUT) locations are examined. The three areas include the urban areas along three waterways. These waterways include the Logan River (GAMUT 1), the Red Butte Creek in Salt Lake City (GAMUT 2), and the Provo River in Southeastern Utah (GAMUT 3). WRLU in the three areas is characterized to draw contrasts in terms of three boundary classifications for WRLU in Utah: Community Water Provider (CWP) boundaries, municipal boundaries, and United States Geologic Survey Hydrologic Unit Code 12 (HUC) boundaries. An additional analysis of the human engineered watershed in the Logan River was performed.

This was primarily a descriptive study, and goals included: 1) To describe land uses contributing to water conditions along urban sections of the three GAMUTs, 2) investigate different approaches to studying contributing areas, and 3) define study areas contributing to water distribution and quality, and to illustrate disparities between natural watersheds and human political infrastructure accross the three urban GAMUTs. This work has been used to assist investigators in working toward conceptualizing multiple and overlapping definitions of a watershed in urbanized areas[10].

2. Methods

GIS data for municpal boundaries, HUC 12 boundaries, and WRLU were acquired from Utah's Automated Geographic Resource Center (AGRC). Community Water Provider (CWP) GIS boundary data were acquired from the Utah Division of Water Rights. HUC 12 watersheds were visually inspected using and ArcGIS display, and HUC watersheds directly intersecting the rivers were selected for analysis. CWP, and municpal boundaries were selected by visually analyzing maps of the area. Geographies with a GAMUT river flowing through them, or with major waterways connected to GAMUT rivers were selected.

All data were were loaded into ArcMap 10.1, and the Clip and Calculate Geometry tools were used to characterize WRLU using the varyng boundary types. Land use categories were combined into seven categories: Irrigated Agriculture, Non-Irrigated Agriculture, Commercial/Industrial, Residential, Riparian/Water Features, Parks/Open Spaces, or Farmsteads. Data were rounded to the nearest whole number, and summed for each GAMUT area. A Chi square test was performed for each geography to determine if the GAMUTs were statistically independent.

Table 1. Community Provider water-related land uses class totals rounded to integer values, in acres. A chi square test showed all areas to be statistically independent ($p < 0.001$).

	Irrigated Agriculture	Non-Irrigated Agriculture	Riparian/Water	Farmsteads	Residential	Commercial/Industrial	Parks/Open
Logan Community Suppliers	2026	1102	637	157	5477	2661	768
Red Butte Creek Community Suppliers	1820	6599	2024	49	24673	23537	2759
Heber Community Suppliers	1672	600	156	51	2251	801	106

Table 2. Totals, in acres obtained when municipal boundaries were used to calculate water-related land use, rounded to integer values. A chi square test showed all areas to be statistically independent ($p < 0.001$).

	Irrigated Agriculture	Non-Irrigated Agriculture	Riparian/Water	Farmsteads	Residential	Commercial/Industrial	Parks/Open
Logan Municipal Boundaries	4095	1660	864	280	6911	3053	809
Red Butte Municipal Boundaries	1811	6613	2094	35	11691	21305	2133
Heber Municipal Boundaries	3803	1003	290	126	3924	1271	297

Table 3. Totals, in acres, obtained when HUC 12 boundaries are used to calculate water-related land use totals, rounded to the nearest integer. A chi square test showed all areas were statistically independent ($p <0.001$).

	Irrigated Agriculture	Non-Irrigated Agriculture	Riparian/Water	Farmsteads	Residential	Commercial/Industrial	Parks/Open
Logan HUC 12 Boundaries	4777	2289	1381	365	5037	1708	550
Red Butte HUC 12 Boundaries	13	130	39	8	4201	2647	771
Heber HUC 12 Boundaries	10045	2265	2100	355	7573	1553	527

3. Results

All three GAMUTs were significantly independent ($p <.001$) for all three boundary types. Values for Chi Square tests are shown in Tables 1, 2, and 3. The chi square test demonstrates that no matter what ArcGIS shapefiles are used to delineate the watershed, Red Butte Creek, Logan, and Heber show significantly different levels of urbanization, and varying land use mixes. In addition, the same area appears differently depending on the boundary type used. For example, when Red Butte Creek is totaled using HUC 12 boundaries, 53.8% of the area has residential land use. If the region is analyzed using community provider boundaries, the same portion drops to 39%, and further down to 29% when municipal boundaries are used. Even within the HUC 12 boundaries, variation exists between Red Butte Creek, Heber, and Logan. When HUC 12 boundaries are used to calculate irrigated agriculture totals, proportions are 0.2%,

41.1%, and 29.7%, respectively. Full data sets are available, and can be obtained contacting Dusty Pilkington at pilkingtod@cwu.edu.

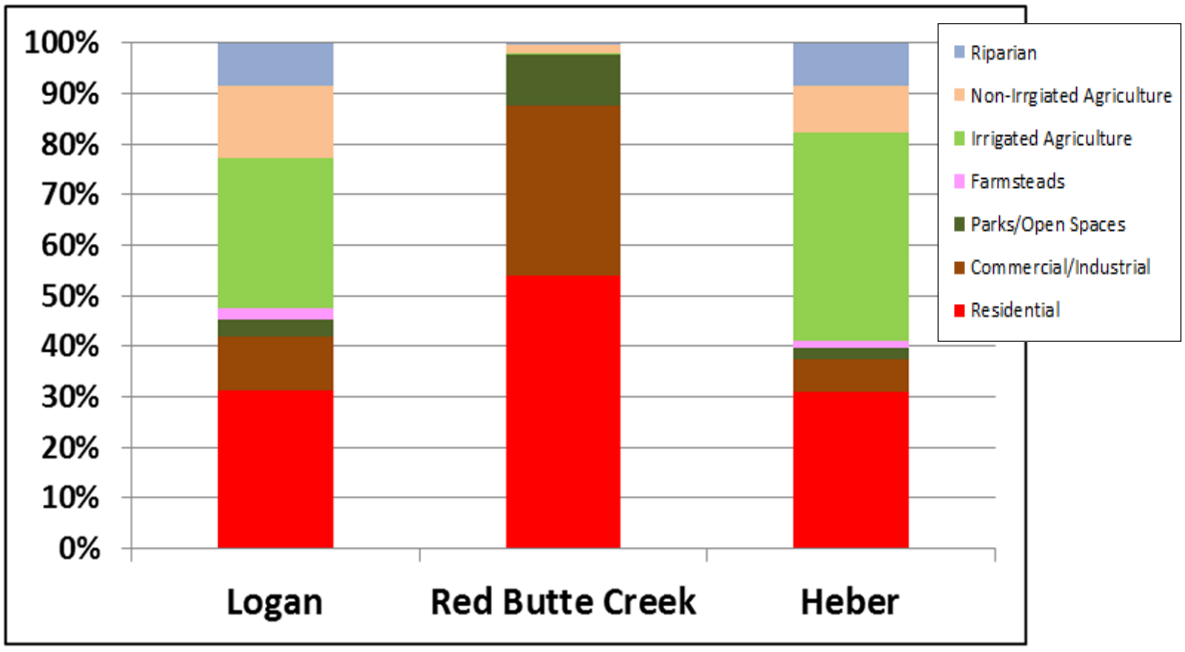

Figure 1: Hydrologic unit code 12 water-related land use.

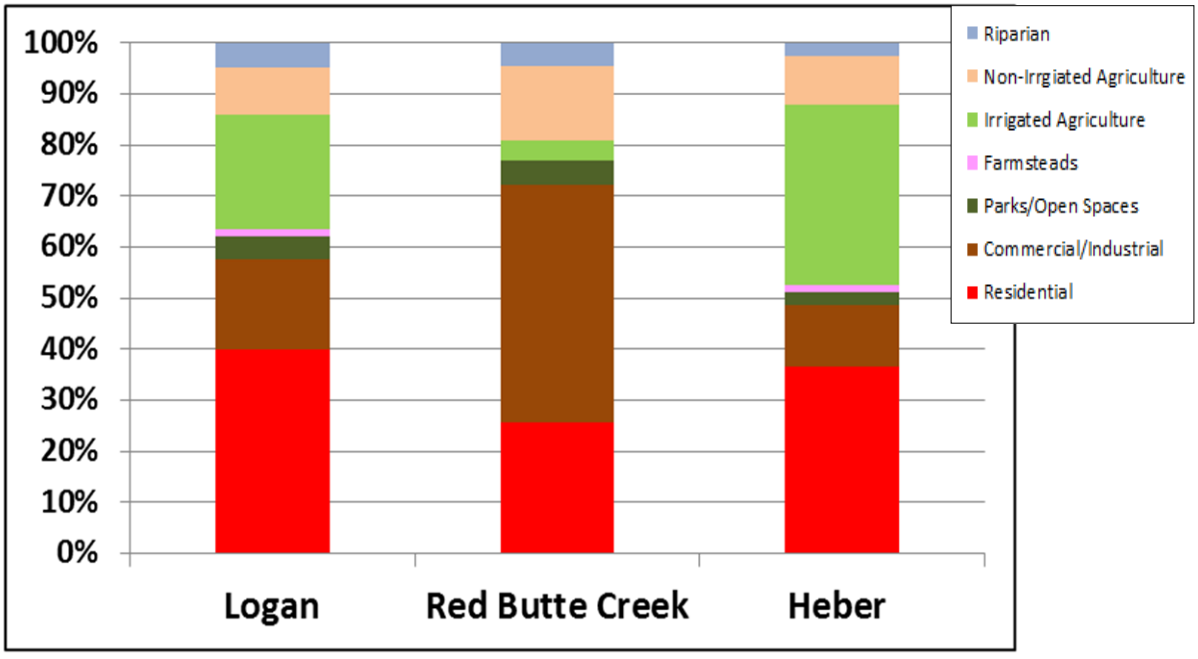

Figure 2: Municipal boundary water-related land use

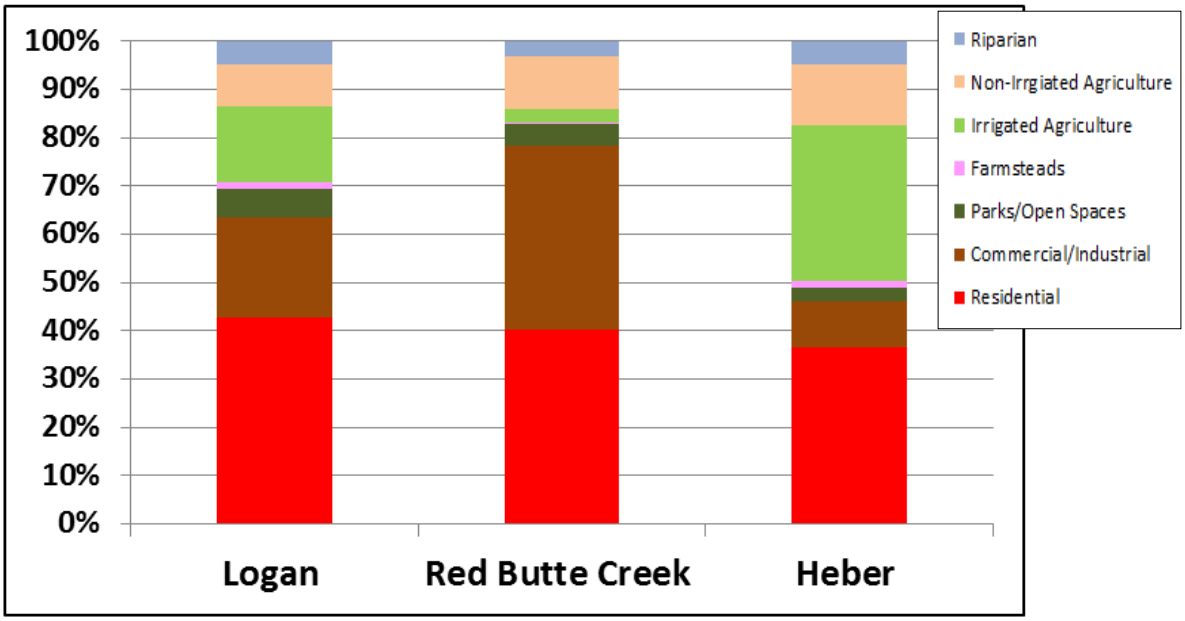

Figure 3: Community water provider water-related land use

4. Conclusions

Calculations performed in ArcGIS using municipal boundaries, United States Geological Survey HUC 12 boundaries, and community water provider boundaries have been performed, in order to describe varying water-related land use mixes in three Utah urban areas. Natural watersheds have been compared to human political boundaries to determine relative mixes of water-related land use.

Though the results show a clear gradient between Utah watersheds in terms of urbanization, these levels of urbanization vary depending on the type of boundary file used in ArcGIS. Considering the impacts that urbanization can have for water quality and flow, approaches to watershed delineation that integrate HUC 12 watersheds with political boundaries are needed. A multitude of study area definitions for future investigations into Utah water sustainability are now defined between HUC 12, community provider, and municipal boundary types.

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6. Endnotes

1. Burcher, C. L., & Benfield, E. F. (2009). Physical and biological responses of streams to suburbanization of historically agricultural watersheds. Retrieved from http://www.jnabs.org/jnabsonline/?request=get-abstract&issn=0887-3593&volume=025&issue=02&page=0356

2. Bruns, D. A. (2005). Macroinvertebrate response to land cover, habitat, and water chemistry in a mining-impacted river ecosystem: A GIS watershed analysis. *Aquatic Sciences*, *67*(4), 403–423. doi:10.1007/s00027-005-0792-3

3. Carey, J. C., & Fulweiler, R. W. (2012). Watershed land use alters riverine silica cycling. *Biogeochemistry*, *113*(1-3), 525–544. doi:10.1007/s10533-012-9784-2

4. Wear, D. N., Turner, M. G., & Naiman, R. J. (1998). Land cover along and urban-rural gradient: implications for water quality. *Ecological Applications.*08(3), 619-630

5. Greve, A. I. (2012). Linking urban form, land cover pattern, and hydrologic flow regime in the Puget Sound Lowland. *Urban Ecosystems*, *15*(2), 437–450. doi:10.1007/s11252-012-0233-8

6. Roy, A. H., Wenger, S. J., Fletcher, T. D., Walsh, C. J., Ladson, A. R., Shuster, W. D., Brown, R. R. (2008). Impediments and Solutions to Sustainable, Watershed-Scale Urban Stormwater Management: Lessons from Australia and the United States. *Environmental Management*, *42*(2), 344–359. doi:10.1007/s00267-008-9119-1

7. Greene, R. G., & Cruise, J. F. (1995). Urban watershed modeling using geographic information system. *Journal of water resources planning and management*, *121*(4), 318–325.

8. Li, X., & Yeh, A. G.-O. (2004). Analyzing spatial restructuring of land use patterns in a fast growing region using remote sensing and GIS. *Landscape and Urban Planning*, *69*(4), 335–354. doi:10.1016/j.landurbplan.2003.10.033

9. Crowl, T. A., Ehleringer, J.A., Pataki, D., Baker, M., & Jackson-Smith, D. (2012). iUTAH_StrategicPlan_final_accepted_25Apr13.pdf. *http://iutahepscor.org/*. Retrieved August 26, 2013, from http://iutahepscor.org/resources/documents/iUTAH_StrategicPlan_final_accepted_25Apr13.pdf

10. Personal email communication, Douglas Jackson Smith, Utah State University