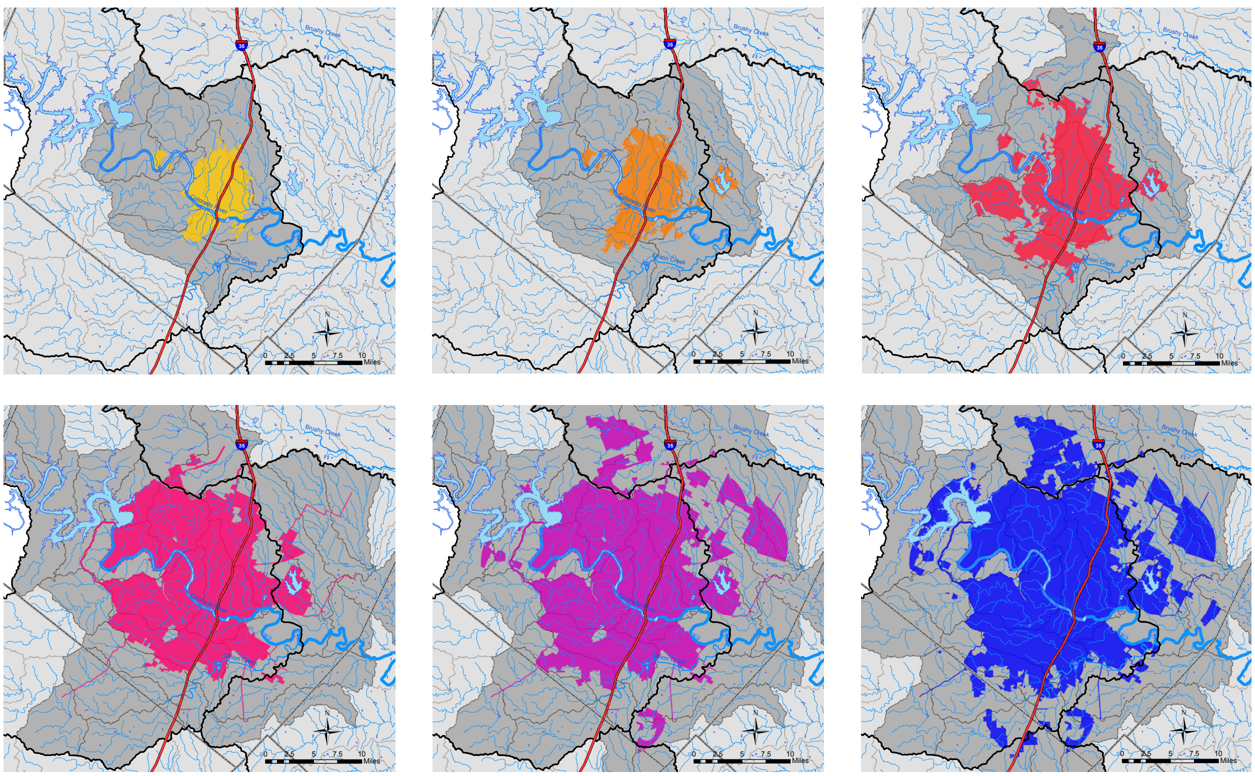
GROWTH TRENDS AND ENVIRONMENTAL INTEGRITY IN AUSTIN, TEXAS



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SUMMARY

This report investigates recent conditions and trends in environmental integrity in Austin, Texas. This is done in tandem with an analysis of population growth in the watershed context.

The City of Austin's Environmental Integrity Index (EII), a program that measures ecological health in the city, is examined and discussed as a planning resource. GIS analysis is then used to determine recent population change in the city's watersheds. EII data over the same period of time is examined to determine current levels of watershed health and trends of deterioration, and correlations with recent population growth are discussed. It is determined which watersheds may be more sensitive to population growth and related factors, and areas where future effort is needed to preserve environmental integrity are identified.

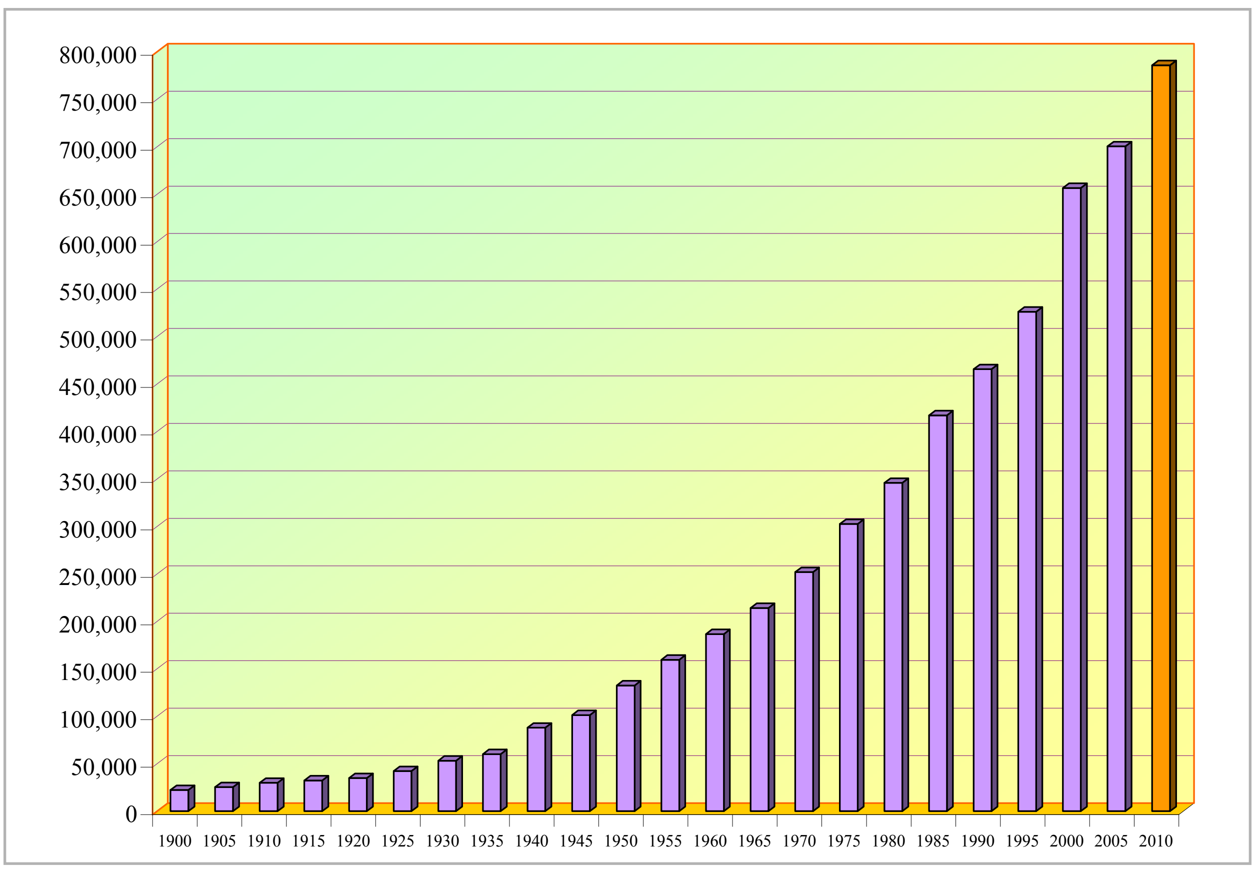
It is concluded that while the urban core watersheds display the lowest levels of environmental integrity, the majority of the city's watersheds are experiencing trends of degradation. The highest levels of recent population growth are seen in suburban and peripheral watersheds, signifying greenfield development. While many of these watersheds have seen decreased ecological health, some have seen improvements, indicating the various and interrelated factors that determine watershed sensitivity to development. Detailed data from the EII reports can be utilized to help understand these subtleties.

INTRODUCTION

Austin, Texas, has seen nearly exponential population growth since the 1960's (see Figure 1). According to Ryan Robinson, the city's demographer, this can be attributed to a high quality of life, creating a "physical and cultural oasis where talented, entrepreneurial, hard-working people are drawn from all over the world."[1] While this is certainly a good thing, there are consequences in how the city grows.

Robinson identifies "intensifying urban sprawl" in his top ten demographic trends for Austin.[2] Even while residential development is happening in the urban core and downtown, these new units are only "a drop in the bucket" of the total residential units being created in the region. Most new development is happening in greenfield areas on the fringe of the city's jurisdictional boundaries and beyond. As this expansion progresses, adding population and infrastructure to previously untouched areas, it serves to impact more land area and occupy more watersheds with each passing year of growth.

FIGURE 1: CITY OF AUSTIN POPULATION HISTORY



Source: Ryan Robinson, City of Austin Demographer

1 Ryan Robinson, *The Top Ten Big Demographic Trends in Austin, Texas* (2010), 4.
2 Ibid.

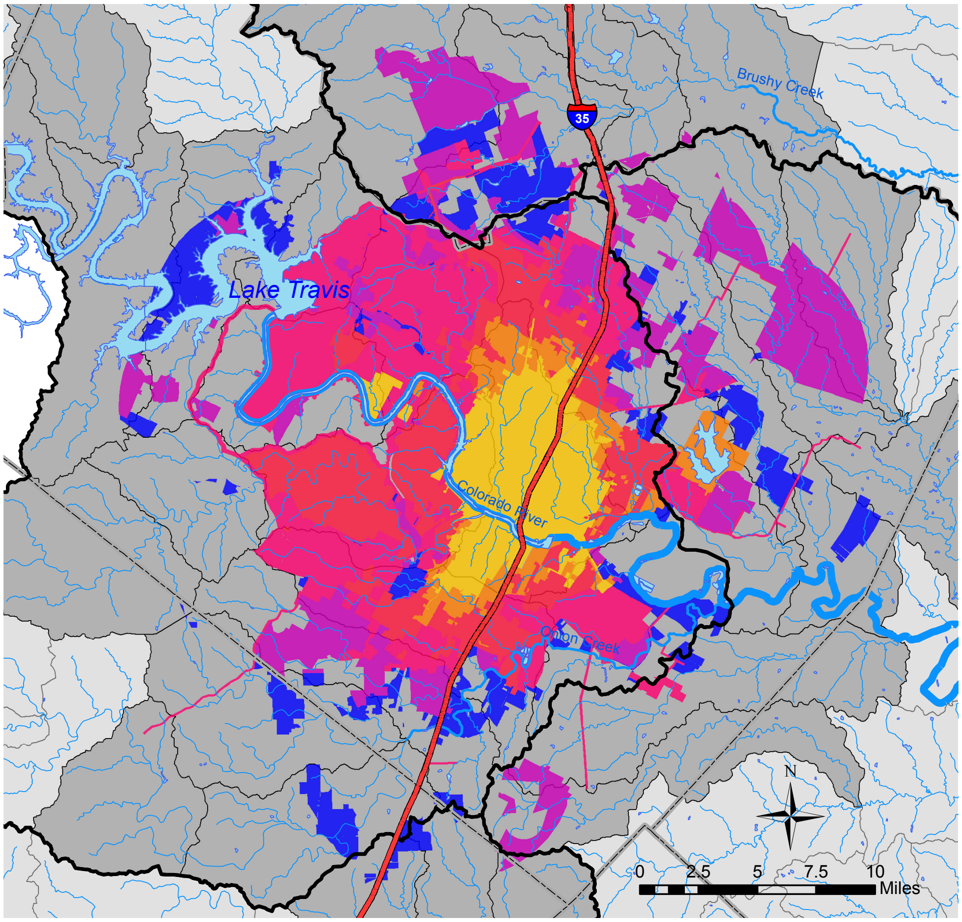


FIGURE 2: JURISDICTION HISTORY OF AUSTIN

GIS Methodology:

- *Obtained "Jurisdiction History" spatial data from City of Austin*
- *Added attribute field to reclassify each annexation date by decade*
- *Symbolized using this new classification.*

Data Sources: CAPCOG, City of Austin GIS, NHDPlus, USDA

As the population of Austin grows, the city expands its jurisdiction. As the city expands its boundaries, municipal services such as wastewater and new roads are delivered to these areas. This provides incentive for further development, and usually results in more rapid greenfield growth in these areas. Figure 2 shows the city's explosive expansion since 1960. As a result, Austin's combined full-purpose, limited-purpose, and extra-terrestrial jurisdictions now occupy 578 square miles and 33 HUC12 subwatersheds. The growth seems to take little regard for water systems; as development expands in this scattered and undirected manner, more watersheds are feeling the impacts of human settlement.

When thinking about recent impacts of development on environmental integrity, special attention should be paid to the areas that have been annexed since 1990, as these are the areas that have seen the most aggressive recent development (see Figure 3). The large number of subwatersheds occupied by these areas should be noted, as well as the countless streamlines that intersect these areas.

Thankfully, the City of Austin has taken action in monitoring the environmental changes associated with the city's growth. The Environmental Integrity Index (EII) is a program that

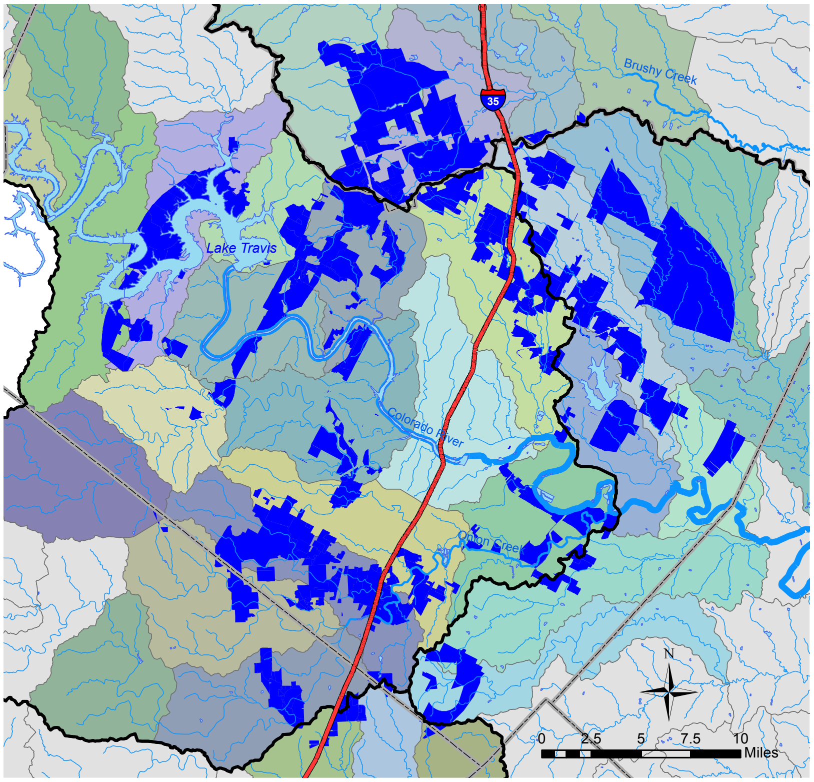


FIGURE 3:
ANNEXATIONS SINCE 1990

GIS Methodology:
- *Used "Select By Attribute" to select annexations since 1990*
- *Exported selected data to create new feature class*

Data sources:
CAPCOG
City of Austin GIS
NHDPlus
USDA

was created by the city's Environmental Resources Management Division in 1999 to monitor and assess the ecological integrity of Austin watersheds. Monitoring occurs both in urban core watersheds as well as suburban and fringe area watersheds that are experiencing new development. The reports offer a valuable planning tool to guide future development, identify areas negatively impacted by growth, as well as determine sensitive watersheds where effort is needed to preserve environmental health.

OBJECTIVES

Considering the areas of recent growth and the available resource offered by the EII reports, the objectives of this study are as follows:

1. Discuss the purpose and methods of the EII program.
2. Use GIS spatial analysis to understand recent population growth in Austin, in the context of subwatersheds.
3. Use GIS analysis to map the current levels and trends of environmental integrity over the past decade in Austin, and discuss how areas of recent environmental degradation are related to areas of recent population growth.
4. Explore areas where effort is needed to preserve ecological integrity in Austin, considering areas that may be more sensitive to development.

AUSTIN ENVIRONMENTAL INTEGRITY INDEX (EII)

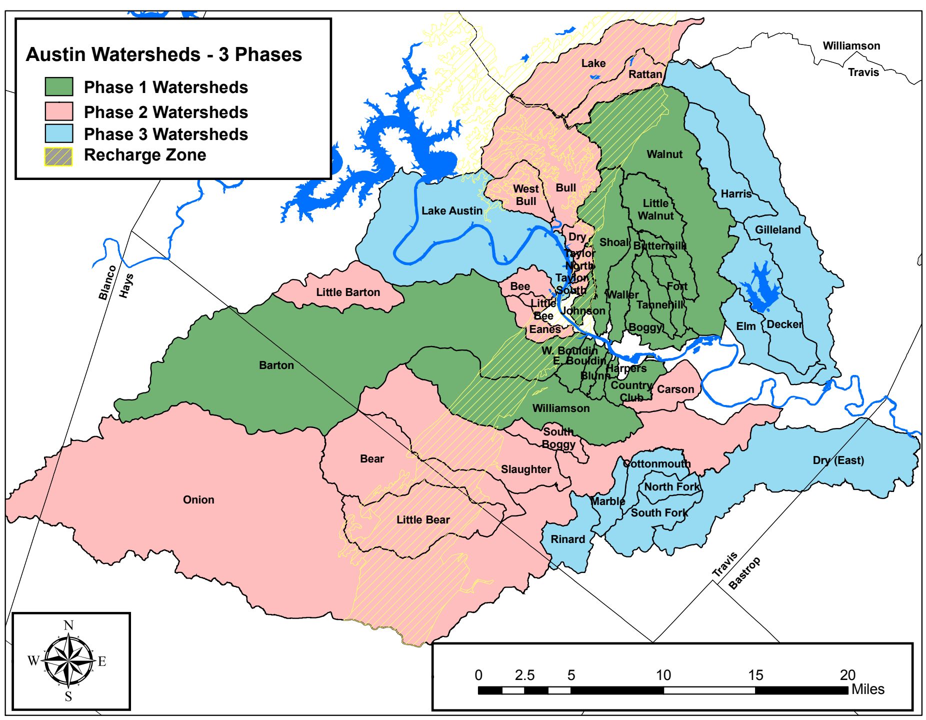
The City of Austin has been conducting water quality monitoring for the creeks and streams around the Austin area since 1990, originally through a volunteer-based program called Water Watchdogs.[3] For practical and quality control reasons, the program was shifted to city staff in 1999, as well as expanded to contribute to the technical assessments used in the citywide Watershed Protection and Development Review Department.[4] In this role, the EII program works to prioritize certain watersheds to address through capital improvement projects, new regulations, and educational programs.[5]

The EII monitors all 46 watersheds in the city's planning area at over 161 sample sites. The watersheds were organized into three phases for monitoring in 1996, and one phase is sampled per year (see Figure 4). This means that each watershed is only monitored once every three years, a drawback in a rapidly changing environment. Nonetheless, with the latest round of reports released from 2006 to 2008, the program had obtained data from all of the city's watersheds over a ten year time span, a suitable length of time to investigate long term changes in environmental quality.

While the Phase 1 watersheds are mostly smaller, urban watersheds, Phases 2 watersheds consist of peripheral urban areas and Phase 3 watersheds were mostly suburban or rural at

FIGURE 4: EII PHASED MONITORING OF AUSTIN WATERSHEDS

Source: City of Austin EII

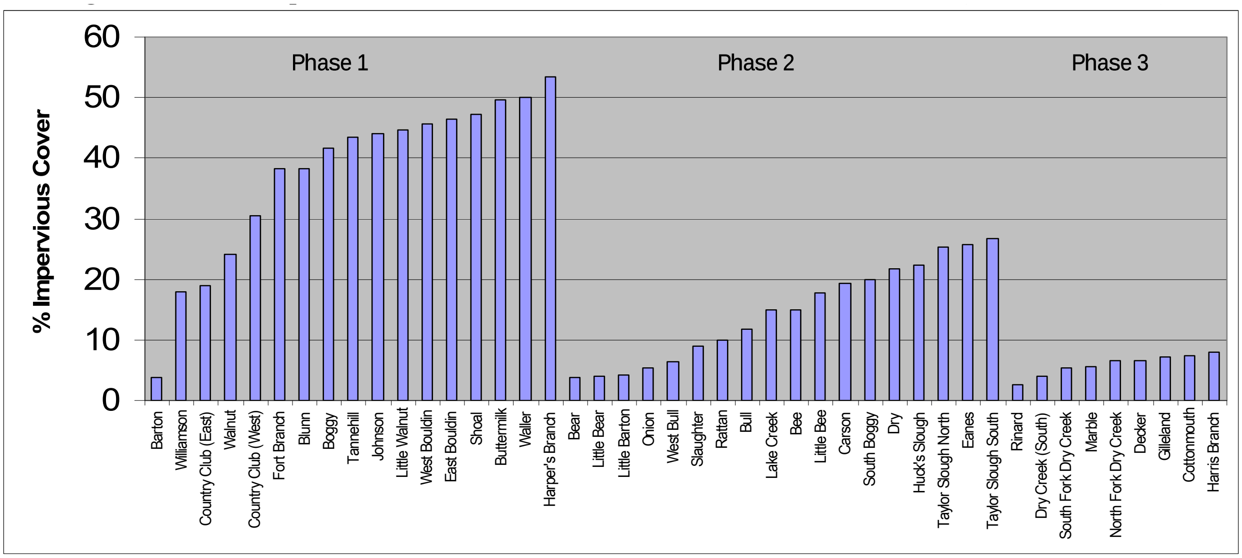


3 City of Austin, *Environmental Integrity Index Watershed Summary Reports* (2007-2009), 1.
4 Ibid.
5 Ibid.

the time of designation. When thinking about population growth, however, the Phase 2 and 3 watersheds have likely seen the most *new* development over the past decade. The program's distinction between urban and suburban watersheds offers a nice way to compare the impacts of differing stages of development on ecological health.

Corresponding to levels of development are the levels of impervious cover in each watershed. Estimates of impervious cover were calculated by the Center for Research in Water Resources in 1997, and can be seen in Figure 5. A clear distinction can be seen between the levels of development in each phase, however these estimates are likely outdated by this time, especially in the Phase 2 and 3 watersheds.

FIGURE 5: 1997 PERCENT IMPERVIOUS COVER ESTIMATES



Source: City of Austin EII

Data contributing to the EII reports includes water quality, habitat and biological data, and is collected during quarterly water quality sampling events and an annual biological sampling event.[6] Collection of a sample at any site is dependent upon baseflow conditions, which reduces the influence of recent stormwater or drought conditions.[7] Field parameter measurements include dissolved oxygen, specific conductivity, pH, and water temperature.[8] Water samples are analyzed in labs for ammonia, sulfate, turbidity, nitrate, orthophosphorus, suspended solids and E. coli bacteria.[9] The annual biological sampling event includes a benthic macroinvertebrate and diatom survey, stream and reach stability assessment, non-contact recreational assessment, habitat assessment, flow measurement, and conventional field parameters.[10] While the raw data

6 City of Austin, *Environmental Integrity Index Watershed Summary Reports* (2007-2009), 3-4.
7 Ibid, 4.
8 Ibid.
9 Ibid.
10 Ibid.

from these sampling events is included in the reports, data is also analyzed through the use of the following sub-index calculations for each watershed:

- Aquatic Life Use Score
- Benthic Macroinvertebrate Score
- Diatom Score
- Water Quality Score
- Contact Recreation Score
- Non-Contact Recreation Score
- Sediment Quality Score
- Physical Integrity Score
- Overall Watershed Score

FIGURE 6: EII SAMPLING EVENT

Source: City of Austin EII

The resulting "Overall Watershed Score" serves as a simple metric to represent the complex factors that define "environmental integrity," and allows comparisons to be made between watersheds.

The bulk of the EII reports is contained in the "Watershed Summaries," which are thorough reviews of each watershed. Each watershed section is six pages in length and includes a summary sheet, a land use map, an aerial photograph map, and data summary graphs.[11] The summary sheet for each watershed offers a wealth of information (see Figure 7): a fact list of physical, demographic and land use characteristics; an overview map; the flow regime for all monitoring sites in the watershed; a table with an overview of sampling data; a summary paragraph describing the salient aspects of the sampling results; and sub-index and total site scores for the current year and previous sampling years.

The land use maps and aerial photograph maps are valuable in that they display the locations of current and previous monitoring sites, as well as their surrounding context (see Figures 8 and 9). The land use maps include a discussion of land use, development and topography of the watershed, and the aerial photo maps identify the stream reach boundaries for each monitoring site. This information is valuable for analyzing a specific watershed. Monitoring site locations can be compared to get a better understanding of the changes taking place between upstream and downstream portions of a watershed. For specific monitoring sites, surrounding land uses and assumptions from aerial photography can help inform the factors impacting environmental health. A drawback is that both the land use maps and aerial photos are from 2003, and may be outdated depending on recent development. Nonetheless, the land use summary describes the recent changes in the watershed at the time of publication.

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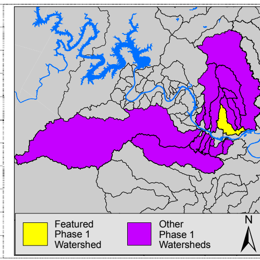
11 City of Austin, *Environmental Integrity Index Watershed Summary Reports* (2007-2009), 12.

Boggy Creek Watershed

Summary Sheet

Catchment	Total area	6 square miles
	Area in recharge	none
	Creek length	8 miles
	Receiving water	Colorado River
Demographics	2000 population	23,372
	2030 projected population	35,728
	30 year projected % increase	53 %
Land Use	Impervious cover ('97 crwr data)	41.7 %
Overall EII Scores	2000	56
	2003	58
	2006	57



Flow Regime* for Sample Sites on Boggy Creek Upstream to Downstream

		2003					2006				
		Feb 19 WQ	Mar 10-17 Bio	May 14 WQ	Sep 23 WQ	Dec 3 WQ	Feb 22 WQ	May 18 WQ	Jul 5-12 Bio	Aug 23 WQ	Nov 29 WQ
Site #	Site Name										
2754	North Boggy at Manor	B	B	B	B	B	B	B	B	n	B
837	North Boggy at Nile Street	B	B	B	B	B	B	B	B	n	B
493	North Boggy at Delwau Lane	B	B	B	B	n	n	n	B	n	n

* B = baseflow conditions n = no flow was present Storm = storm flow was present
Blue = Samples were taken Grey = Samples were not taken Blank = site not visited

	Parameter	Mean	Max	Min	Relative concentrations compared to other 2006 Phase 1 watersheds
Physicochemical	**D.O.** mg/l	6.7	10.0	2.7	Below average at Site 2754, average[1] at Site 837
	pH st.units	7.6	7.9	7.3	Average[1]
	Cond uS/cm	703	776	562	Average[1]
	SO_4 mg/l	51.2	62.4	43.7	Average[1]
Nutrients	**NH_3** mg/l	0.03	0.05	0.01	Average[1]
	NO_3 mg/l	0.15	0.61	0.02	Average[1]
	Ortho P mg/l	0.10	0.16	0.06	Above average concentrations at Sites 2754 and 837
Sediment Load	**TSS** mg/l	2.0	3.1	0.5	Average[1]
	Turbidity ntu	1.8	3.3	1.1	Average[1] at Site 2754, occasionally above average at Site 837
Biology	**E.Coli** /100ml	1,104	2,900	27	Above average at Site 2754, average[1] at 837
	Benthic Macs	Below average for most metrics. Site 2754 very low (1 EPT, 1 tolerant taxa, only 55 individuals in sample)			
	Diatoms	Although all sites showed excellent diversity, the *Cymbella* richness and % motile taxa were poor.			

[1] values for this parameter are similar to the median scores for the other 2006 Phase 1 watersheds

Discussion: Despite reliable baseflow at the upstream sites, the mouth site (493) is typically dry, due in part, to subsurface flow in significant alluvial deposition. Although several of the individual sub-index scores have improved since 2000, overall watershed scores have consistently remained in the "fair" category. Bacteria levels at Site 2754 are chronically elevated resulting in poor contact recreation scores.

Sub-index scores for Boggy Creek Sites (upstream to downstream) 2000, 2003, 2006

Site Number	Site 2754			Site 837			Site 493		
Year of Sampling	2000	2003	2006	2000	2003	2006	2000	2003	2006
Water Quality		51	52	62	52	57	67	67	
Sediment		88	85	88	88	85	88	88	85
Contact Recreation		45	25	78	62	65	82	82	
Non-Contact Rec.		56	63	62	75	66	79	58	71
Physical Integrity		54	48	20	47	51	23	47	36
Aquatic Life		26	38	23	26	52	30	37	50
Benthic Mac.		23	25	33	30	43	29	42	37
Diatom		28	51	13	22	61	31	31	62
Total EII Score		53	52	56	58	63	62	63	61

* sediment samples only collected at the downstream site, blank cells indicate parameter was not collected, blank columns indicate site was dropped

100-87.5 Excellent 87.5-75 V. Good 75-62.5 Good 62.5-50 Fair 50-37.5 Marginal 37.5-25 Poor 25-12.5 Bad 12.5-0 V. Bad

FIGURE 7: EXAMPLE EII SUMMARY SHEET

Fact List and Overview Map

Flow Regime

Sampling Data Overview

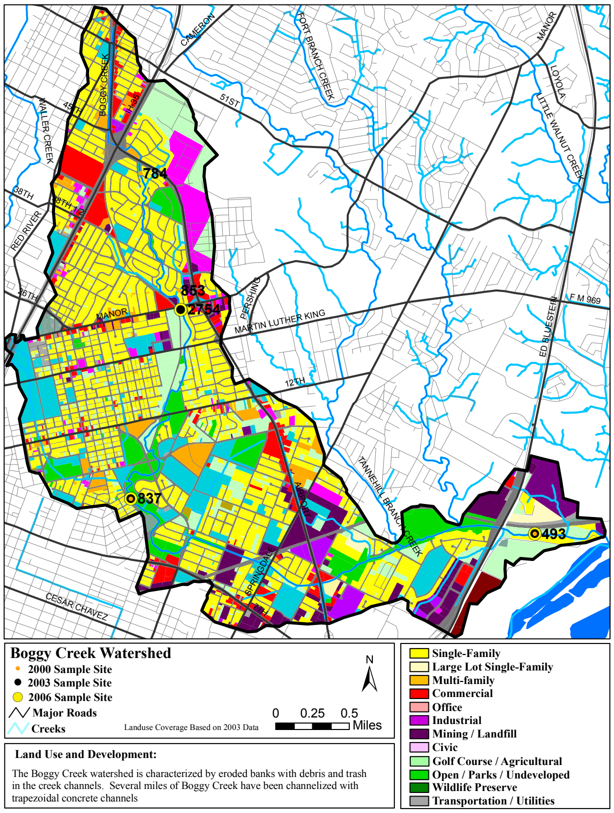
Summary Paragraph

Sub-Index and Total Site Scores

Source: City of Austin

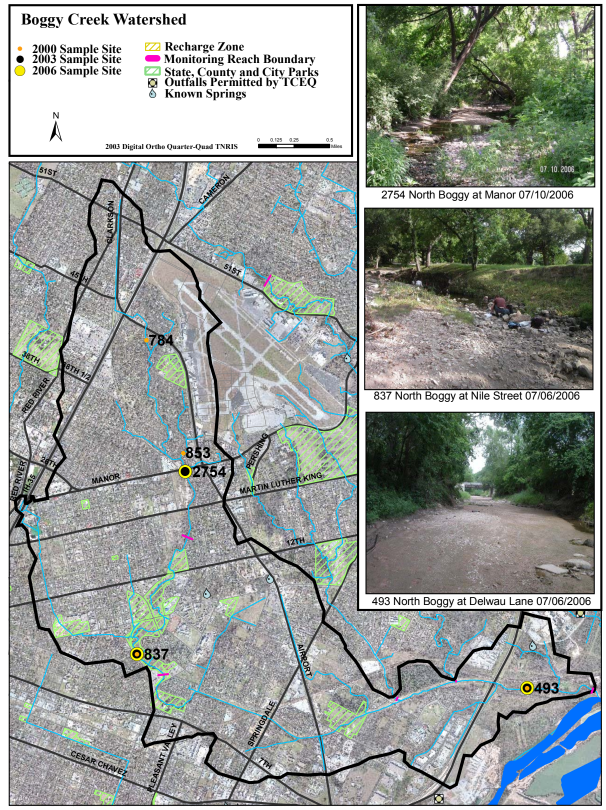
In summary, the data that is presented in the EII reports is both comprehensive and informative, whether the reader is a trained scientist or an interested resident. The reports certainly succeed as a tool to guide policy decisions, providing an overview of environmental conditions that can be understood by planners, city council members, neighborhood groups, and other decision-makers. For the purposes of this study, the reports provide temporal data that can be used to identify trends in ecological integrity. After estimating recent population changes in each watershed, the results can be compared to changes in overall EII scores over the same time period to identify areas that have been most impacted by recent growth.

FIGURE 8: EII LAND USE MAP



Source: City of Austin EII

FIGURE 9: EII AERIAL PHOTO MAP



Source: City of Austin EII

WATERSHED POPULATION CHANGE

Despite the thorough nature of the EII reports, one element that is lacking is updated population figures for each watershed. While year 2000 watershed populations are given in the reports, Austin has seen substantial growth since that time. Considering the most recent reports were published in 2006-2008, it is important to develop a better understanding of which watersheds have seen the most population growth (and corresponding development) since 2000. In addition, if changes in overall EII scores are determined for the time frame of 1996-2008, estimates of population change from a similar time frame would provide a good basis for comparing changes in environmental integrity with changes in population. Therefore, 2010 Census population data was used in conjunction with GIS analysis to estimate watershed population change between 2000-2010.

The first step in estimating watershed population change was to obtain watershed boundary geospatial data that corresponded to the watersheds analyzed in the EII reports. After obtaining HUC12 watershed boundaries from the USDA Geospatial Gateway, it quickly became apparent that the 12-digit hydrologic units did not correspond with the watersheds defined by the City of Austin. Watershed boundaries consistent with the EII watersheds were obtained from

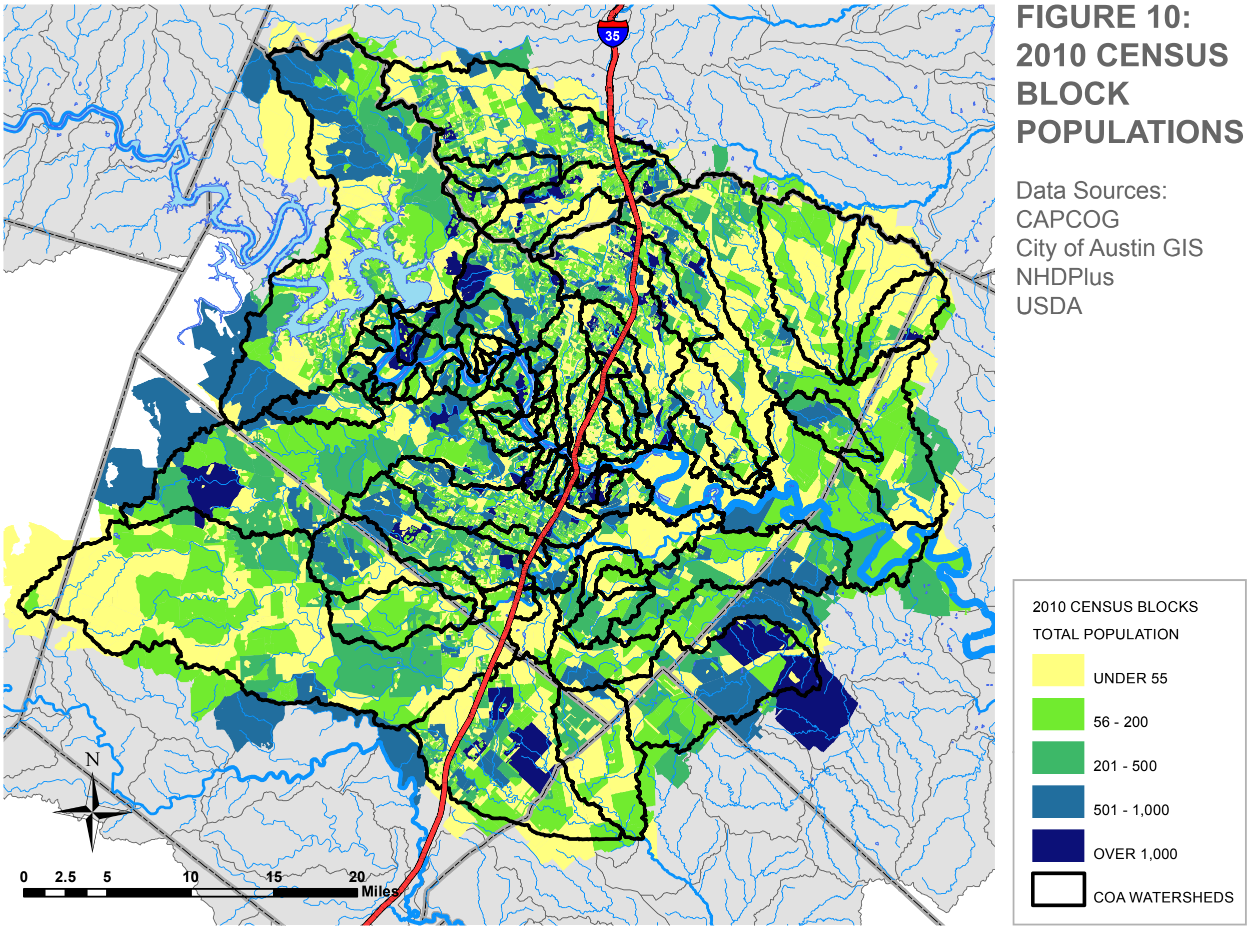


FIGURE 10: 2010 CENSUS BLOCK POPULATIONS

Data Sources:
CAPCOG
City of Austin GIS
NHDPlus
USDA

the City of Austin's GIS Data website and were used in place of the HUC12 watersheds for the remainder of the analysis.

2010 Census geography with selected demographic attributes (including total population) was available from the Capital Area Council of Governments (CAPCOG) for the Central Texas region. This data was obtained and the census block shapefile, the smallest census geographic unit, was added as a data layer. The reasoning behind using the smallest available geographic unit was to minimize the overlap of census geographies shared between watersheds. Using "Select By Location," the census blocks that intersected the City of Austin watersheds were selected, and this data was exported to a new feature class (see Figure 10).

The next step was to sum the populations of all the census blocks within each watershed. Looking at Figure 10, it is apparent that the geographic boundaries of water systems and human settlement often do not align. This makes it difficult to interpret most population data in a watershed frame of reference. By using GIS analysis, the population of each watershed can be better understood.

The *Union* tool was first used to create a geometric intersection of watershed boundaries and the 2010 Census blocks. This operation resulted in a new feature class that included attribute fields from both input features, including watershed codes and census block population data. In cases where a census block lied between two watersheds, the census block was split into two separate polygons in the new feature class, with population data for the entire census block being assigned to each new portion. This resulted in double counting of populations for all census blocks situated between watersheds, a drawback of this method.

Next, the *Dissolve* tool was used to sum the geographies and population data in each watershed. This was done by assigning the "Watershed Code" attribute as the dissolve field, and indicating "Population" as the statistics field with the statistic type set to "Sum." This operation created new watershed polygons based on the original watershed codes, while summing the populations of all the census blocks in each watershed. The result can be seen in Figure 11. As previously noted, the population counts are likely overestimates due to double counting. An alternative GIS analysis option is discussed in the conclusion of this paper.

Figure 11 is symbolized by total population, and serves to re-frame human settlement in the context of water systems. However, representing population this way does not effectively show the level of development in each watershed, due to the differing sizes of the watersheds. Population distribution amongst the watersheds can be better understood by symbolizing the watersheds by population density, shown in Figure 12. This offers a more lucid representation

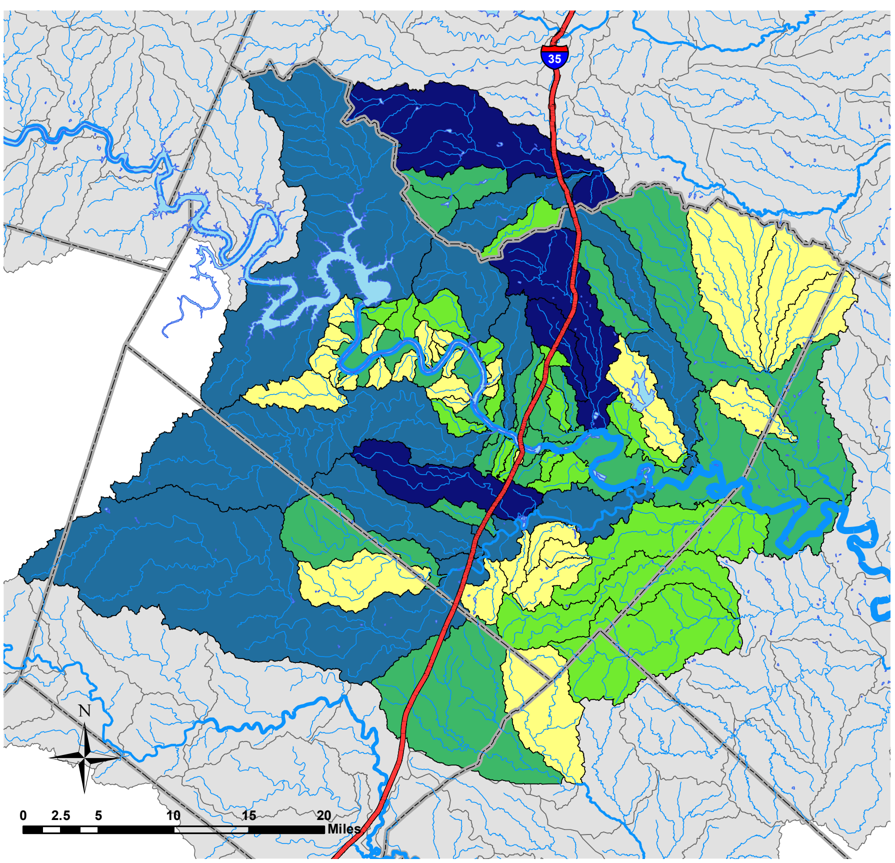


FIGURE 11: 2010 WATERSHED POPULATION

Data Sources:
CAPCOG
City of Austin GIS
NHDPlus
USDA

CITY OF AUSTIN WATERSHEDS
TOTAL POPULATION
LESS THAN 8,000
8,001 - 20,000
20,001 - 50,000
50,001 - 75,000
OVER 75,000

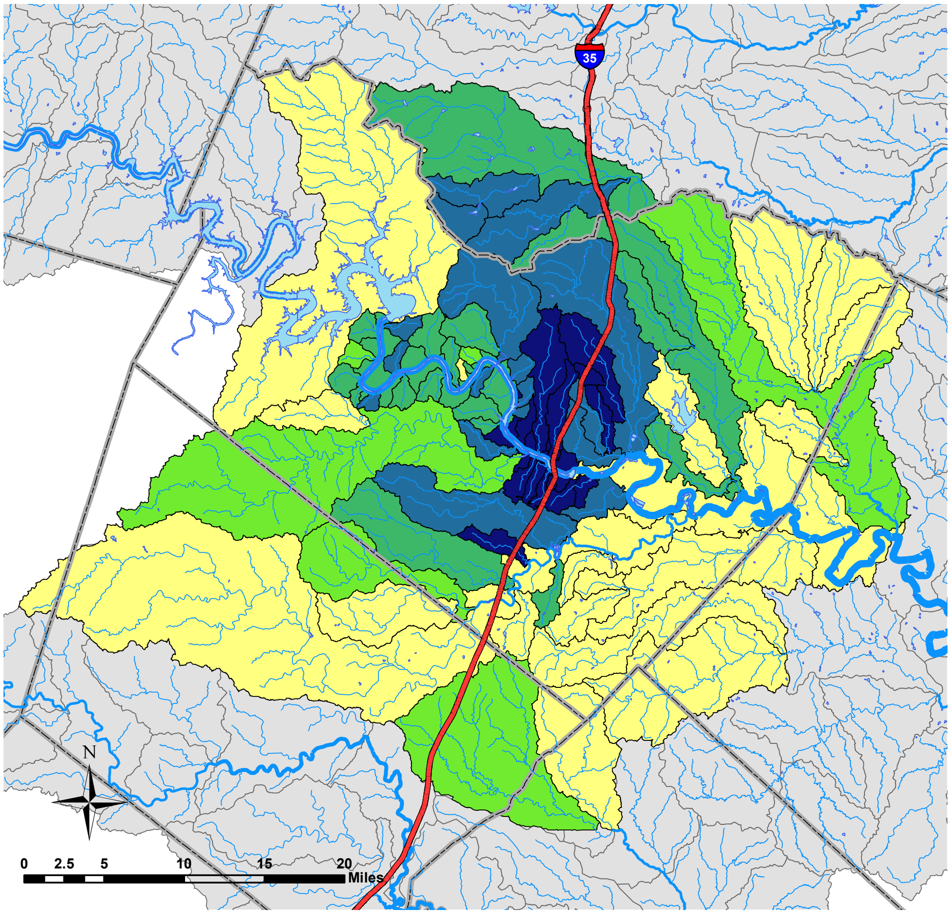


FIGURE 12: 2010 WATERSHED POPULATION DENSITY

GIS Methodology:
- *Add "Area" field*
- *Use 'Calculate Geometry' to find watershed areas*
- *Normalize watershed symbology by area*

Data Sources:
CAPCOG
City of Austin GIS
NHDPlus
USDA

CITY OF AUSTIN WATERSHEDS
POPULATION PER SQ. MILE
UNDER 500
501 - 1,000
1,001 - 2,500
2,501 - 5,000
OVER 5,000

of which watersheds are more densely populated and developed. Not surprising, the watersheds inhabited by the urban core have the highest population densities.

The most important piece of information from this analysis is the change in population that each watershed has seen from 2000-2010. This was done by utilizing the year 2000 populations estimates for each watershed in the EII reports, and simply subtracting this amount from the 2010 estimates generated by this analysis. Population change estimates can be seen in Figure 13. Once again, it should be noted that these are overestimates due to double counting of census blocks. However, the *relative* changes in population between watersheds should be reasonably accurate. The number of watersheds under study was also reduced at this point, reflecting the availability of data from the EII reports.

Considering the city's expansion discussed in this paper's introduction, it should be no surprise that the peripheral and suburban watersheds have seen the most growth since 2000, while the urban core watersheds have seen less growth. Figure 14 displays watershed population change overlaid by areas of recent annexation. There is a strong correlation between recent municipal expansion and population growth over the past decade. The next question is whether these areas of recent growth have seen negative impacts to environmental integrity.

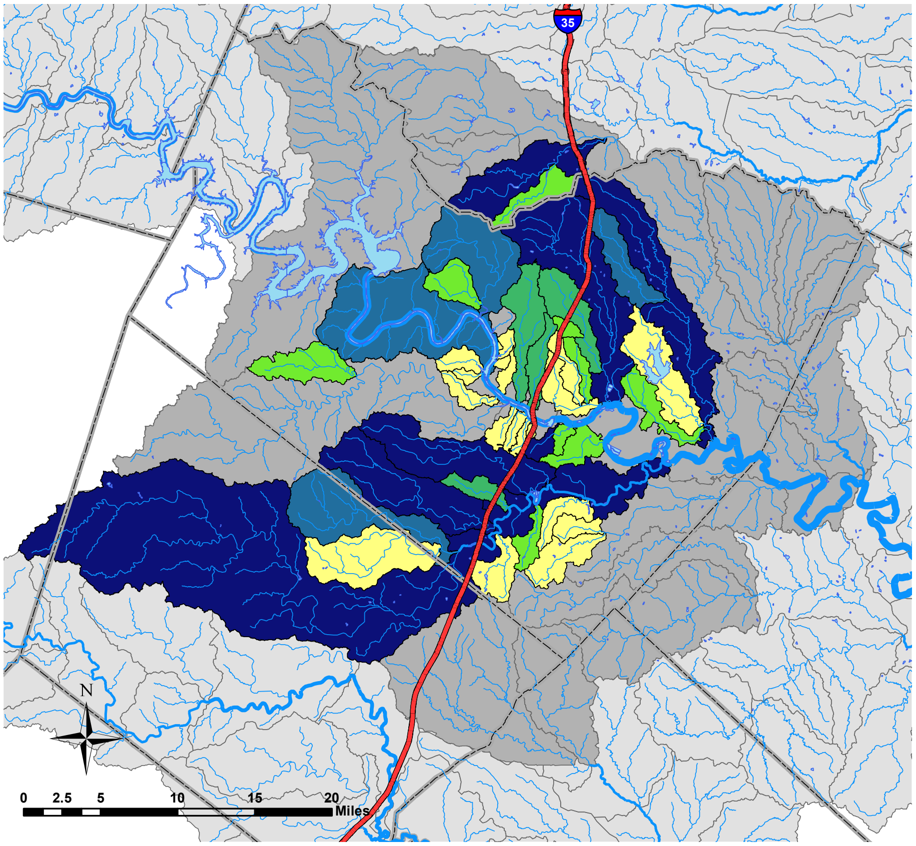


FIGURE 13: 2000-2010 WATERSHED POPULATION CHANGE

GIS Methodology:

- *Use 'Join' to add EII 2000 population data*
- *Use field calculator to find population change from 2000*

Data Sources:
CAPCOG
City of Austin GIS
NHDPlus
USDA

CITY OF AUSTIN EII WATERSHEDS
POPULATION CHANGE

- LESS THAN 5,000
- 5,001 - 10,000
- 10,001 - 15,000
- 15,001 - 20,000
- OVER 20,000
- NO EII DATA

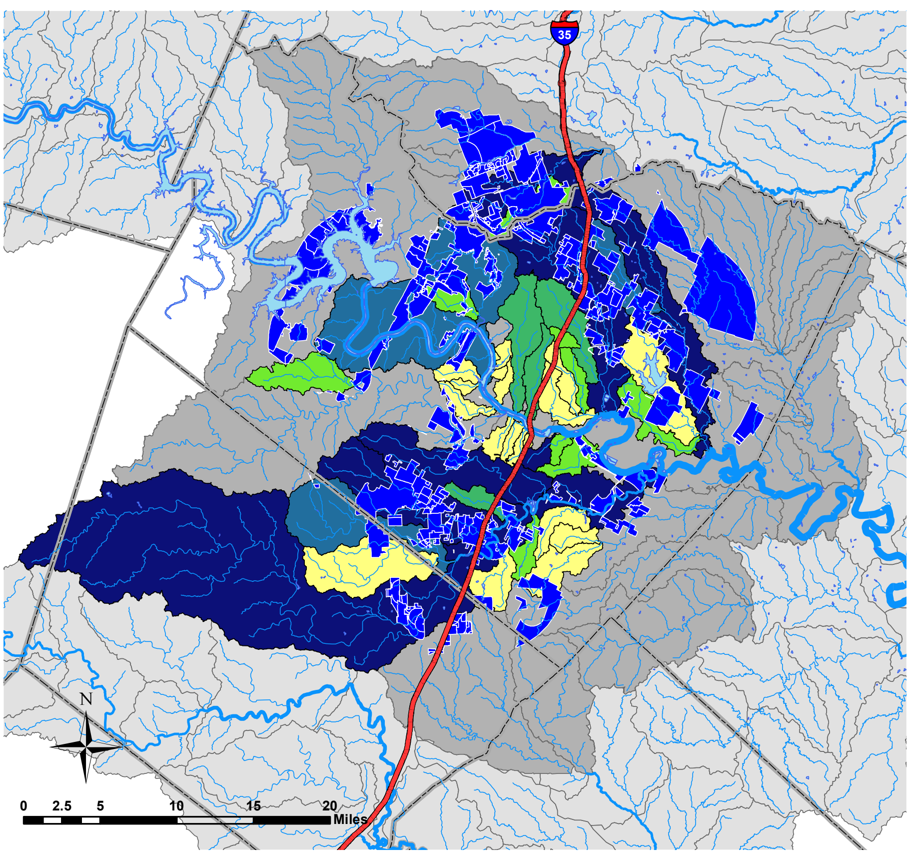


FIGURE 14: POPULATION CHANGE AND RECENT ANNEXATION

Data Sources:
CAPCOG
City of Austin GIS
NHDPlus
USDA

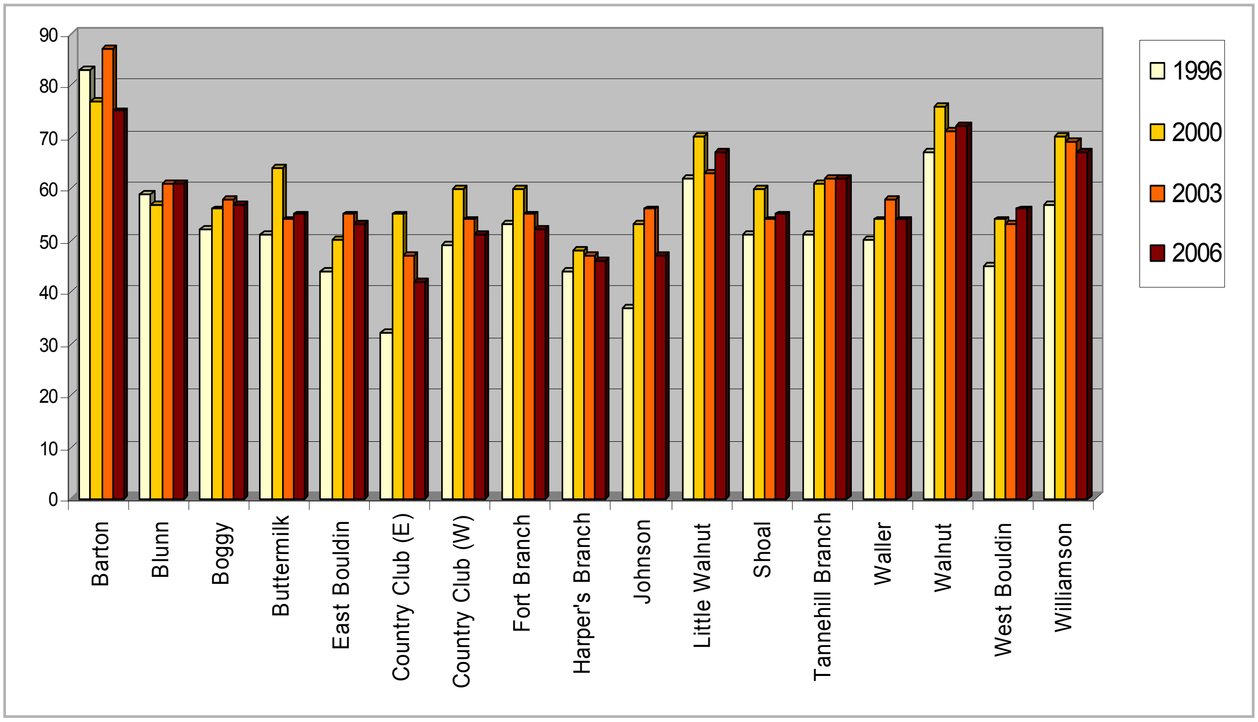
CITY OF AUSTIN EII WATERSHEDS
POPULATION CHANGE

- LESS THAN 5,000
- 5,001 - 10,000
- 10,001 - 15,000
- 15,001 - 20,000
- OVER 20,000
- NO EII DATA
- ANNEXATIONS SINCE 1990

ENVIRONMENTAL INTEGRITY TRENDS

While the EII reports provide past overall EII scores for comparison with the latest monitoring, both at the watershed and observation site levels, there is no spatial representation of this data at a citywide scope. The most comprehensive chart included in the reports is shown in Figure 15. The chart is helpful in that it provides scores from each monitoring year, which helps portray the sometimes erratic nature of environmental integrity, a reflection of the complex forces at play in determining the measures. However, the chart lends itself to make comparisons between watersheds rather than identify trends over time within watersheds.

FIGURE 15: CHANGE IN OVERALL EII RANKING BY MONITORING YEAR



Source: City of Austin EII

In order to represent this information spatially, for the entire city rather than just the watersheds being monitored in a given year, overall EII scores for all monitoring years were manually inputted into a table. Each watershed has been monitored at least three times since 1996, and most have had a fourth year of monitoring. Once the data had been inputted for all of the EII watersheds, the change in overall EII scores from the earliest observation year to the most recent were calculated for each watershed. This table was then added to ArcGIS and joined to the watershed layer's attribute table, allowing the data to be viewed on a map and symbolized according to improved or degraded environmental conditions over time. Most recent overall EII scores are displayed in Figure 16, and the change in overall EII scores are shown in Figure 17.

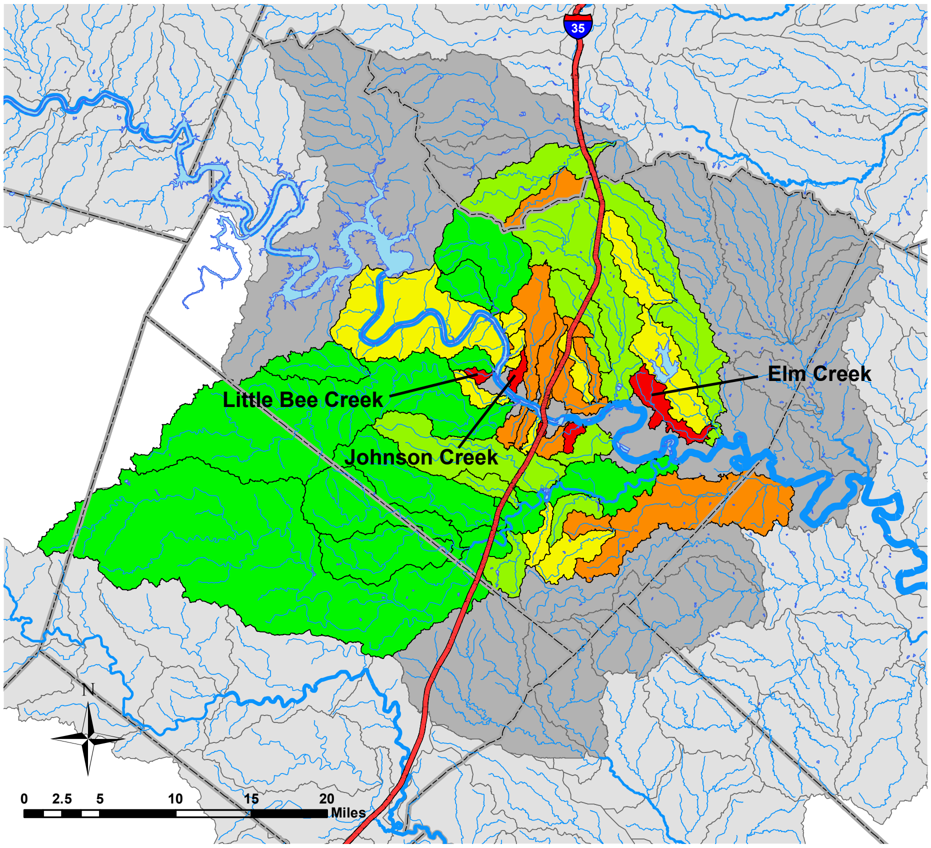


FIGURE 16: MOST RECENT ENVIRONMENTAL INTEGRITY SCORES

Data Sources:
CAPCOG
City of Austin EII
City of Austin GIS
NHDPlus
USDA

OVERAL INDEX SCORES
- 42 - 48
- 49 - 57
- 58 - 63
- 64 - 72
- 73 - 85
- NO EII DATA

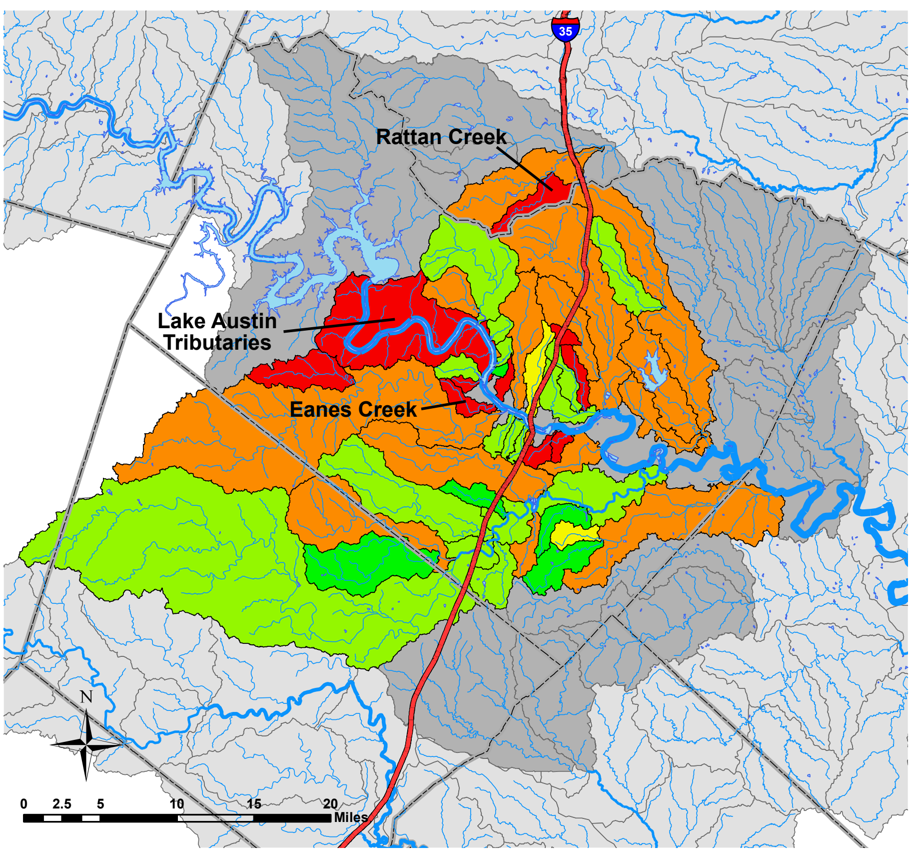


FIGURE 17: TEN-YEAR CHANGE IN ENVIRONMENTAL INTEGRITY

Data Sources:
CAPCOG
City of Austin EII
City of Austin GIS
NHDPlus
USDA

CHANGE IN OVERALL INDEX
- LOST 5 OR MORE POINTS
- LOST 0 - 5 POINTS
- NO CHANGE
- IMPROVED 0 - 5 POINTS
- IMPROVED MORE THAN 5 POINTS
- NO EII DATA

Figures 16 and 17 give a comprehensive summary of the current state and trends of ecological integrity in Austin. Looking at the spatial distribution of the most recent overall EII scores (Figure 16), it is clear that the environmental health of the urban core watersheds is more degraded than most of the peripheral and suburban watersheds, due to a greater density of impervious surfaces, human activity and pollution. At the same time, there are suburban watersheds that are considerably degraded, such as the Elm Creek watershed in East Austin and the Rattan Creek watershed in North Austin. Even while these watersheds have considerably less impervious surfaces, their environmental health is on par with the urban core watersheds, possibly due to increased sensitivity to development.

Equally as substantive as the current state of environmental integrity is the trends of these conditions, shown in Figure 17. A cause for concern is that the majority of Austin watersheds have seen a decrease in their EII scores since the program implemented phased monitoring in 1996. Many of the West Austin watersheds near Lake Austin seem to be experiencing degradation, as well as most of the watersheds in North Austin. Considerable attention should be given to watersheds that are both scoring low and experiencing trends in degradation. In addition to the Elm and Rattan Creek watersheds, the Lake Austin tributaries and a few urban watersheds should be prioritized for improvements.

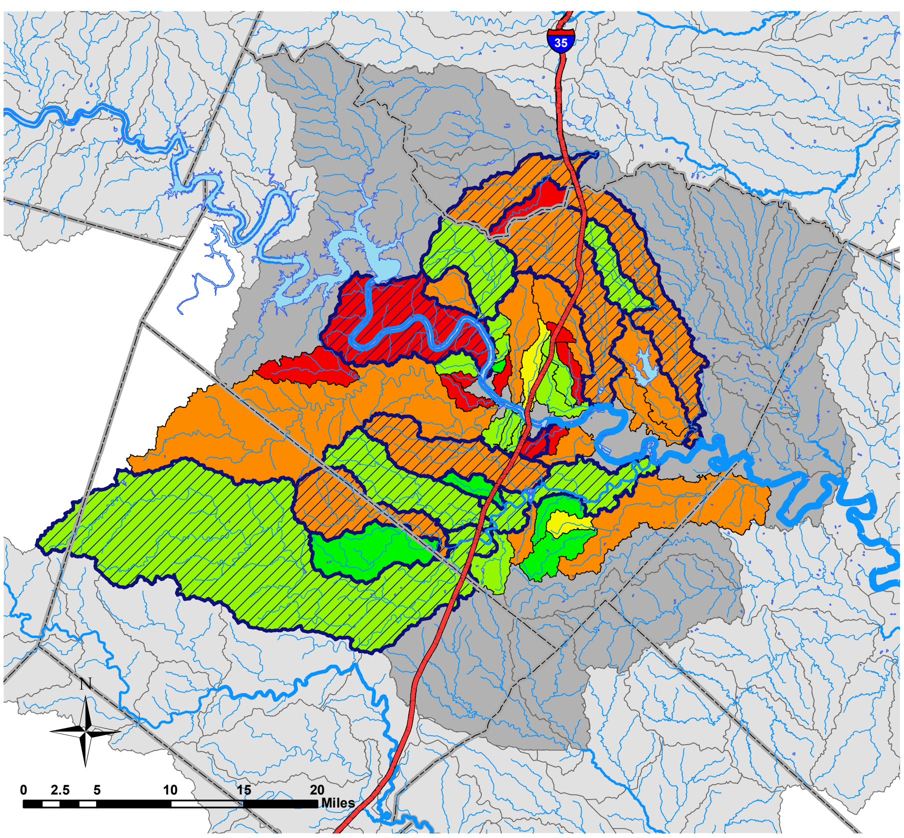


FIGURE 17: POPULATION GROWTH AND CHANGE IN ENVIRONMENTAL INTEGRITY

Data Sources:
CAPCOG
City of Austin EII
City of Austin GIS
NHDPlus
USDA

Next comes the question of whether recent changes in EII scores can be attributed to population growth. Figure 18 shows the changes in environmental integrity, with watersheds that have experienced the greatest amount of recent growth indicated by hatching. Again, these watersheds correspond to suburban and recently developed greenfield areas. While there are certainly cases in which growing watersheds are experiencing environmental degradation, there are nearly as many growing watersheds that have seen improvements over the same period of time. This can be attributed to the complex nature of environmental systems, and the various factors that determine ecological sensitivity. In the case of the Lake Austin tributaries in West Austin, as well as several watersheds in North Austin, recent development has come with consequences to ecological health. These watersheds are likely more sensitive to development, and should be monitored more closely in the future, as well as prioritized for mitigation.

Now that this report offers a comprehensive spatial analysis of population growth, watershed health and trends in environmental integrity, the EII reports can be revisited to learn more about the watersheds that seem to need attention. Notes in the summary sheet provide details about specific sub-index phenomenons, while the land use map provides notes on development trends and land use patterns. Figure 19 gives a summary of some of the degrading watersheds, with notes from the EII reports.

FIGURE 19: LOW EII SCORES AND TRENDS OF ECOLOGICAL DEGRADATION

Watershed	EII Notes
Eanes Creek	Has been heavily developed for single-family housing and commercial purposes; Second-highest percentage of impervious cover compared to other Phase 2 watersheds.
Elm Creek	Minimal baseflow over the past seven years; Low aquatic life scores; Turbidity and suspended solids have been primarily high; Relatively narrow riparian corridors due to historic agricultural use.
Lake Austin Tributaries	Sediment scores, bacteria concentrations and non-contact recreation scores have been noticeably decreasing over the past decade; Differing land uses in the subwatersheds; A wastewater plant is located in the lower reaches of Panther Hollow; Primary concern for the aquatic environment is the increase in sediment load to creeks due to development on steep slopes.
Little Bee Creek	Percent impervious cover is above average; Second-highest percentage of single-family land use of Phase 2 watersheds.
Johnson Creek	Majority of watershed is within the Edward's Aquifer recharge zone; Dense development near creek banks has resulted in poor riparian buffers; One-third of land use is classified as roadways, including Loop 1; Chronically high total suspended solids and turbidity levels; High bacteria levels; Investigation of suspected leaking sewer line revealed that a residential wastewater line had been connected to a storm drain for several years.
Rattan Creek	Within the Edward's Aquifer recharge zone; Of all Phase 2 watersheds, second-highest percentage (25.2) of transportation/utilities land use designation; Poor physical integrity and aquatic life sub-index scores.

Source: City of Austin EII

CONCLUSIONS AND RECOMMENDATIONS

The review of the EII reports and investigation of population growth in the watershed context makes it clear that Austin's expansive development is impacting environmental integrity in the region. While urban core watersheds continue to have low overall EII ratings, several suburban and peripheral watersheds are seeing trends of degradation, likely a result of greenfield development. Although some watersheds are experiencing improvements, the majority of the city's watersheds are depreciating in ecological integrity. The extent of degradation is likely the result of several factors that determine sensitivity to development. Some watersheds, including those highlighted in this study, are showing both poor environmental health and trends of further degradation. These areas should be prioritized by the city for improvement.

These findings highlight the value of the City of Austin's EII program in monitoring watershed health and prioritizing improvements and mitigation responses. Now with over a decade of data, the EII reports are a valuable resource for identifying trends in addition to monitoring current conditions. Serving as a planning tool, the program's findings can be used to inform future development as well as teach lessons from past decisions. While certainly serving their purpose, the reports could be improved in the future. More consistent formatting between reports and better communication of past data could more clearly identify trends in environmental health. In addition, more emphasis should be placed on the spatial distribution of conditions and trends. Maps such as those found in this report help paint the "big picture" for readers. Finally, data such as land use designations, watershed populations and percent impervious cover should be updated for future reports.

This study was limited in its scope, choosing to focus on population growth as an indicator of development. Other measures worth exploring would be land use designations, land cover including impervious surfaces, and specific areas of recent commercial or intensified development. The 2010 population estimates could also be made more sophisticated with further GIS analysis. Rather than intersecting population and watershed geographies, census data could be converted to a raster of population density. Raster cells could then be assigned to their corresponding watersheds. In doing this, double-counting of census blocks would be avoided.

Regardless of its simplicity, this study's re-framing of population in the watershed context is valuable in that it enables a better understanding of the complex interactions between human and natural systems. By looking at growth through the lens of natural systems rather than the built environment (streams rather than roads, watersheds rather than census tracts), human influence on environmental quality becomes more clear.

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