Evaluation of Environmental and Economic Impacts of Revised Water Quality Standards and Criteria on a Subbasin Basis

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Mission

The Missouri Department of Natural Resources protects our air, land, water, and mineral resources; preserves our unique natural and historic places; and provides recreational and learning opportunities, while promoting the environmentally sound operations of businesses, communities, agriculture, and industry for the benefit of all Missourians.

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Executive Summary

Missouri's Water Quality Standards (WQS) regulation at 10 CSR 20-7.031 is reviewed and modified at least once every three years. Termed the triennial review process, coordinators with the Missouri Department of Natural Resources' Water Protection Program meet with the U.S. Environmental Protection Agency (EPA), other state agencies, interested stakeholders, and concerned citizens to evaluate the effectiveness of state standards. Issues for discussion are identified during a solicitation of items to be included in the triennial review and further refined through the Department's Water Protection Forum.

This report documents the promulgation of revised WQS and the evaluation of environmental and economic impacts in implementing those revised WQS and criteria. The evaluation of environmental and economic impacts is required by Section 644.058 Missouri Revised Statutes (RSMo), which states –

Notwithstanding the provisions of section 644.026 to the contrary, in promulgating water quality standards, the commission shall only revise water quality standards upon the completion of an assessment by the department finding that there is an environmental need for such revision. As part of the implementation of any revised water quality standards modifications of twenty-five percent or more, the department shall conduct an evaluation which shall include the environmental and economic impacts of the revised water quality standards and criteria on a subbasin basis. This evaluation shall be conducted at the eight-digit hydrologic unit code level. The department shall document these evaluations and use them in making individual site-specific permit decisions.

The Missouri WQS revisions covered by this report became effective in state regulation on April 30, 2018. EPA approved Missouri's numeric nutrient criteria (NNC) for lakes on December 14, 2018, and the Department is implementing these criteria. As of the date of this report, however, EPA has not approved the remainder of WQS revisions submitted. As a result of their pending approval, Missouri may not implement these unapproved revisions per federal regulation at 40 CFR 131.21. However, estimates of environmental and economic impacts of WQS implementation can be evaluated and have been included in this report.

Upon completion of the analysis required by statute, the Department has determined that the most significant near term economic impact will be from the implementation of NNC for lakes. However, the longer term economic benefit of improved lake water quality outweighs the near term impacts to communities within those watersheds. The evaluation also revealed that changes to aquatic life protection criteria for selected 304(a) federal criteria will not be impactful to permittees or the economy.

Introduction

The Department conducted the following evaluation to fulfill the requirements contained in Section 644.058 RSMo and to better understand the impacts and economics associated with revised WQS and criteria. This report's purpose is twofold:

- Document the Department's assessment and finding that there is an environmental need for revised WQS and criteria; and
- Document the Department's evaluation of the environmental and economic impacts of the revised WQS and criteria on a subbasin basis at the eight-digit hydrologic unit (HUC-8)[1] code level.

Scope

This report presents readily-available information on the environmental need for revised water quality standards and criteria and:

- Evaluates the environmental impact of the revised water quality standards and criteria.
- Evaluates the economic impact of the revised water quality standards and criteria.
- Analyzes and documents the environmental and economic impacts of the revised water quality standards and criteria on a subbasin watershed basis.
- Relies on readily-available environmental, economic, and social activity data and information through state fiscal year 2018.

Method

Department staff in the Water Protection Program researched and acquired environmental, economic, and social data and information from which to conduct environmental and economic analyses and evaluations consistent with 644.058 RSMo. Staff from the Watershed Protection and Operating Permits Sections met periodically in 2018 to discuss data and evaluation methodology, as well as to establish report timelines and to resolve issues as they arose.

The overall method was to:

- Define the scope of revised water quality standards (WQS) and criteria and evaluation
- Review economic and environmental literature to support quantitative economic models
- Obtain environmental and economic data and information relevant to the revised WQS
- Obtain social, economic, and demographic information for the state of Missouri
- Obtain information on industries and activities impacted by the revised WQS
- Develop socio-economic models for each WQS revision to determine impacts
- Document the results of the socio-economic models for revised WQS by watershed

[1] Eight digit hydrologic units, or 8-digit HUCs, are a structured and standardized method of identifying individual watersheds using the hierarchical classification system developed by the U.S Geological Survey (https://water.usgs.gov/GIS/huc.html)

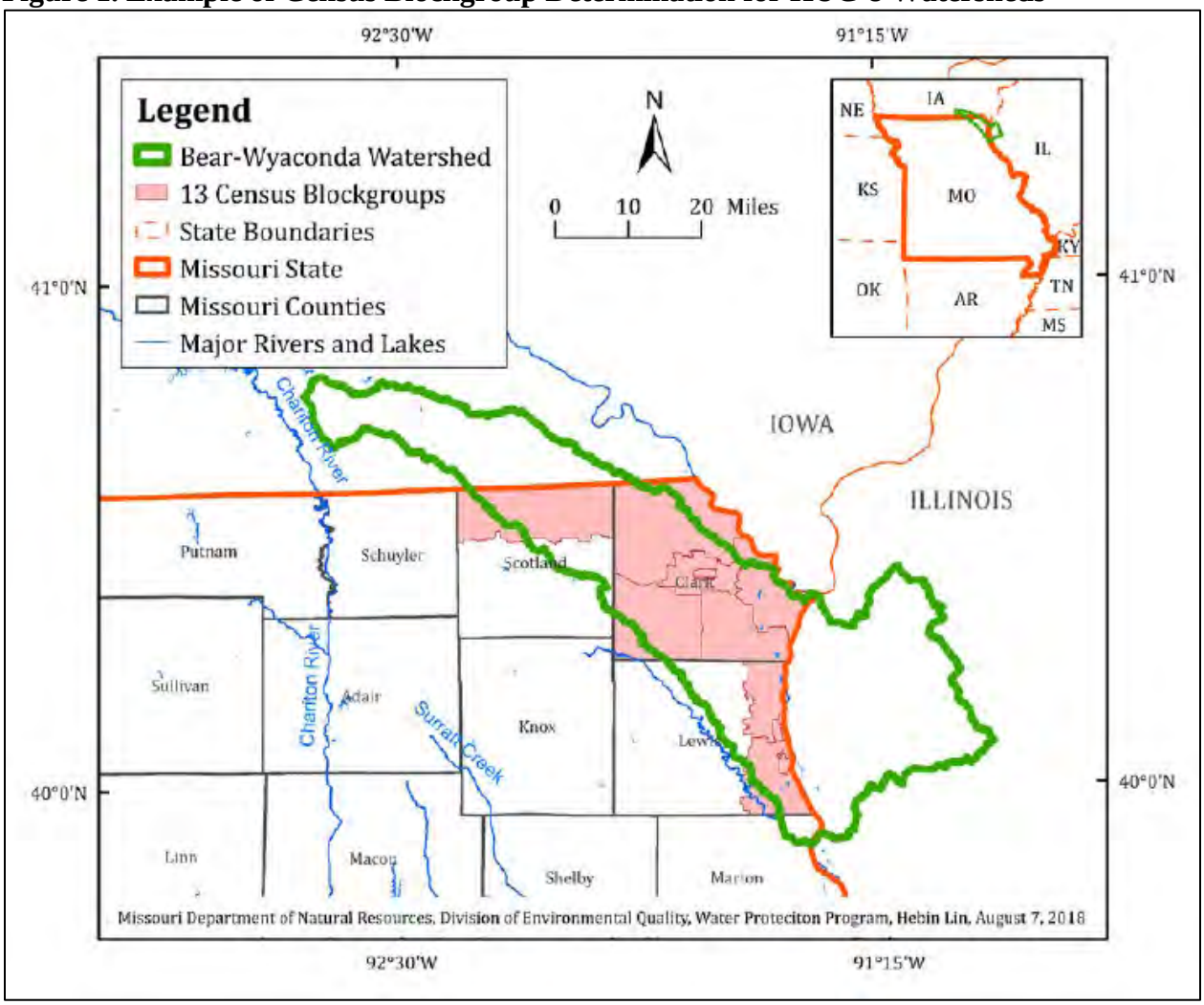
Data Sources and Adjustments

Data and information collected by the Department include statewide social, economic, and environmental data and well as data for specific communities, industries, and watersheds. These data and information include water quality data; regulated entity and permit information; state economic and census data; county and watershed level median household income; low-income and small business impacts; environmental and economic cost benefit; environmental justice concerns; alternative strategies for compliance; and integrated resource plans.

The environmental, economic, and social data were then used to develop economic models and scenarios to determine watershed-based environmental and economic impacts of new or revised WQS and criteria. These evaluations and analyses were compiled in report format by HUC-8 to be used by Department staff, the regulated community, and the public as reference on the environmental and economic impacts of the rulemaking and in making individual site-specific permit decisions.

Because most social and economic data are not collected using a hydrologic unit framework, these data required adjustments and decisions for how the data were to be treated on a watershed basis. For example, state and county population estimates are readily available from the U.S. Census Bureau as census blocks. In order to capture accurate watershed population information for economic analyses, census block data needed to be converted and assigned to a specific hydrologic unit (i.e., watershed). The conversion and assignment process is typically most challenging near watershed boundaries, where a decision must be made on where to assign the population data. To ensure consistency of process and best practice, population estimates for hydrologic units were derived using Geographic Information System (GIS) software and superimposing the watershed boundary over a map of census blocks (Figure 1). Wherever the centroid of a census block fell within a watershed boundary, the entire population of the census block was included in the total. If the centroid of the census block was outside the boundary, then the population of the entire block was excluded. Using a similar method, the municipal population was estimated by superimposing municipal areas over the map of census blocks. The rural population of a watershed was calculated as the difference of the municipal population from the total population. This type of adjustment was also used for other statewide datasets where data needed to be converted and assigned by watershed. Complete methods for this process can be found in “Estimations of Population Growth Rates and Median Household Incomes for 66 Watersheds at the Eight-digit Hydrological Unit Level in the State of Missouri,” August 28, 2018.

Figure 1. Example of Census Blockgroup Determination for HUC-8 Watersheds



The data used in the evaluations and this report are the most current and readily available as of state fiscal year 2018. Department staff acquired or requested the data used in the evaluation from primary sources through internet searches and direct requests. Data and information from secondary sources were also collected and noted as secondary in the analyses that used those data. Where available, metadata was also requested to ensure data quality and quantity met Department standards where such standards are available. Department staff excluded data and information that was not relevant or pertinent to the WQS revisions evaluated by this report. For example, those industries or activities not impacted by a WQS revision where not examined or evaluated. As noted previously, Appendix C documents the data sources, specific adjustments and assumptions, and quantitative methods for future replication.

Description of Water Quality Standards Revisions

Rulemaking Process and Timeline

The WQS rulemaking covered by this report was initiated by the Department on May 2, 2014, by a public notice of intent to initiate a triennial review. This public notice period to receive input from the public and interested stakeholders was from May 2 through June 15, 2014. Several of the revisions for the rulemaking were a result of stakeholder input gathered during the public notice and subsequent Water Protection Forum and WQS Workgroup meetings.

Priorities established as a result of this process included addressing EPA disapproved items (specifically, NNC for lakes), updating water quality criteria for pH and other pollutants, and changes to sections describing mixing zones, general criteria, and existing definitions. The proposed rule amendment was published in the Missouri Register on October 16, 2017 (MoReg Vol.42, No. 20, pages 1424 – 1551). A public hearing for the proposed rule was held before the Missouri Clean Water Commission on November 21, 2017. The commission adopted the order of rulemaking for the proposed rule at its January 4, 2018, meeting and the order was published in the Missouri Register on March 15, 2018 (MoReg Vol. 43, No. 6, pages 590 – 616). The rule became effective in state regulation on April 30, 2018, and is the focus of this report. As of the date of this report, EPA has approved the WQS revisions regarding NNC for lakes, but has taken no action on the remaining revisions. As a result, Missouri may not implement the unapproved revisions per federal regulation at 40 CFR 131.21. However, estimates of environmental and economic impacts of WQS implementation can be evaluated and have been included in this report.

Portions of the rule required a Regulatory Impact Report (RIR) pursuant to RSMo, Chapter 536, the public notices for which were from July 24 through September 22, 2017, and September 25 through November 24, 2017. The cost estimates from the two RIR public comment periods were used to inform the public and private fiscal notes for the rule and subsequent estimates of impact used in this report. The public and private fiscal notes for the revised WQS have been included in Appendices B and C, respectively.

Water Quality Standards Revisions

Under Governor Parson’s leadership, all state agencies are working to reduce regulations or other government rules or processes that unnecessarily burden individuals and businesses while doing little to protect or improve public health, safety, and our natural resources. The Department is committed to limiting regulation to only what is necessary to protect Missouri's environment, implement statutory mandates and maintain state control of programs. The recent revisions to Missouri's WQS, the RIR and fiscal notes for those revisions, and these environmental and economic impact evaluations have been guided with these goals in mind.

Most WQS revisions can be grouped into one of two broad categories:

- Revisions that apply minimum criteria, conditions, or methods that provide for the protection and propagation of fish, shellfish, and wildlife and for recreation in and on the water (i.e., environmental need); and
- Revisions that provide clarity, flexibility, and consistency within the rule without additional regulatory burden (i.e., administrative need).

While both categories of revisions can directly or indirectly have an environmental need, revisions that apply minimum criteria to protect human health and the environment have the most direct connection. Examples of these types of revisions include revisions to minimum criteria that protect aquatic life against toxicity from heavy metals, protection of human health from increased levels of mercury in fish tissue, and protection of lakes and reservoirs from excessive nutrients that could cause harmful algal blooms. The following WQS revisions apply minimum criteria, conditions, or methods to protect human health and the environment and were found by the Department and Missouri Clean Water Commission to be environmentally necessary:

- pH criteria – clarify the specific criteria for pH and how they apply;
- Hardness – clarify the method to derive hardness for WQS and permit calculations;
- Section 304(a) criteria – adopt certain national criteria developed by EPA to ensure the criteria in Missouri's WQS conform to the most recent scientific data regarding the effect of these pollutants on human health and the environment; and
- NNC – adopt revised NNC for Missouri lakes to address recent litigation against the EPA regarding these disapproved criteria.

Revisions contained in the most recent rulemaking that provide clarity, flexibility, and consistency within the rule also protect human health and the environment through administrative means. While these changes in rule do not require additional regulatory burden, the flexibility that may result from the changes could allow changes in facilities or activities that promote better water quality. These types of revisions are also environmentally necessary. Examples of these types of revisions include expanding mixing zone requirements, removing outdated or disapproved rule language, and incorporating by reference methods and data to increase the Department's operational efficiency. The following WQS revisions provide clarity, flexibility, and consistency in rule and were found by the Department and Missouri Clean Water Commission to be environmentally necessary:

- Waters of the State – amends the definition to match statutory changes enacted in 2015;
- Mixing Zone Requirements – allows greater latitude for mixing zone considerations for permittees;
- Variances – incorporates by reference "Missouri's Multiple Discharger Variance Framework from the Water Quality Standards of Total Ammonia Nitrogen" and updates other variance provisions previously disapproved by EPA;
- Antidegradation – incorporates by reference an updated Antidegradation Implementation Procedure that addresses concerns by EPA regarding *de minimis* provisions;

- Dissolved Oxygen Criteria – removes site-specific dissolved oxygen criteria that were previously disapproved by EPA;
- Losing Streams/Table J – removes an outdated table of losing streams and replaces it with a geospatial dataset; and
- Missouri Use Designation Dataset – updates the data set used to implement Missouri's use classification system.

Regulatory Impact of Revised WQS

The Department published a RIR for the revisions to 10 CSR 20-7.031, Water Quality Standards covered by the last rulemaking. A RIR is required at the beginning of the rulemaking process by Section 640.015 RSMo for rules prescribing environmental standards or conditions. The report documents the environmental and economic costs and benefits associated with the proposed changes.

The report originally was filed on July 24, 2017, and the 60-day public comment period concluded on September 22, 2017. The report was then revised to reflect key changes to the proposed rule, including the removal of nutrient criteria associated with the drinking water supply designated use and the reassignment of Truman Lake to the plains ecoregion. The revised report was filed on September 25, 2017, and another 60-day public comment period was held until November 24, 2017. The Department received comments from six groups and individuals during the second public notice period and responded to those comments on December 21, 2017.

None of the comments received by the Department modified or changed the estimates of cost or extent of regulated activities contained in the RIR. As a result, the cost estimates and regulated facilities contained in the RIR were used to develop the public and private fiscal notes required for the rule. The public and private fiscal notes for the rule, and information associated with their development, serve as the basis for the evaluations contained in this report.

The most significant component of the recent WQS rule is the revision of NNC for lakes and reservoirs. The Department developed cost estimates to public and private permittees discharging domestic wastewater within the watersheds impacted by the revised NNC for lakes. The Department estimated the rule would require upgrades to remove nutrients at approximately 166 public and private wastewater treatment facilities (WWTF) following assessment of their receiving lakes as impaired. EPA approved this portion of the last rulemaking on December 14, 2018, and the Department is currently implementing these approved criteria.

The second most significant component of the recent WQS rule is the revision of Section 304(a) criteria to reflect national criteria developed by EPA. These criteria revisions ensure the criteria in Missouri's WQS conform to the most recent scientific data regarding the effect of these pollutants on human health and the environment. During the RIR process, the Department originally estimated that these changes would create increased (less stringent) limits for 1,376 permits, and decreased (more stringent) limits for 477 permits. No change was expected for 4,839 permits. However, due to stakeholder concerns with the Section 304(a) human health protection criteria being proposed, the Department withdrew these criteria from the rule. As a

result, estimates of cost and permits impacted by changes to Section 304(a) criteria were revised to include only those for the protection of aquatic life designated use. These changes create increased (less stringent) limits for 606 permits, and decreased (more stringent) limits for 80 permits. No change was expected for the remaining 6,006 permits.

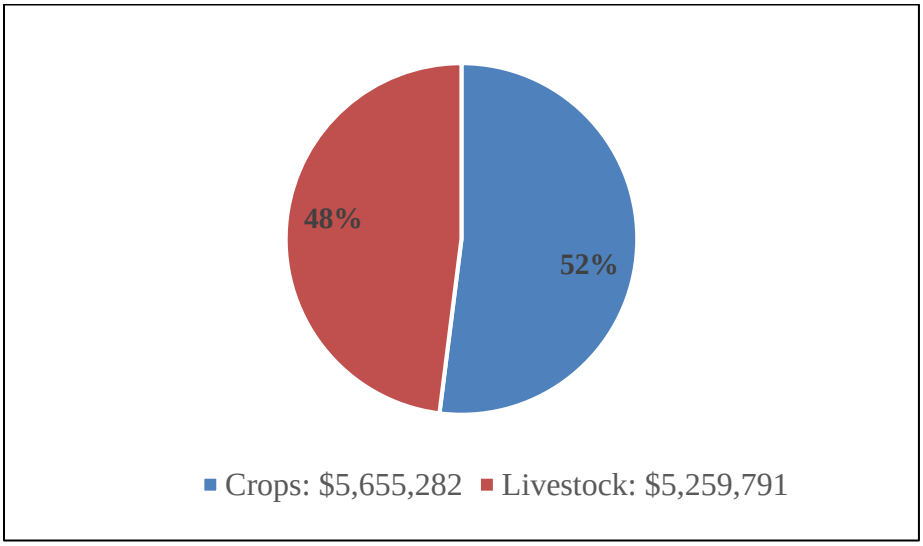
The remaining WQS revisions provide clarity, flexibility, and consistency in rule and were considered in the RIR as neutral with regard to cost impacts. Additionally, administrative changes made to the standards are not criteria and it is difficult to estimate or calculate the required 25 percent change for these revisions. Because of these factors, administrative revisions to the water quality standards rule could not be evaluated under 644.058 RSMo and are not contained in this report.

Description of Missouri's Economy

Missouri's economy is diverse and varies by geography, population, and local natural resources. Missouri's economy is dominated to a large extent by industry and agriculture. Aerospace and transportation equipment are the main manufacturers; food products, chemicals, printing and publishing, machinery, fabricated metals, and electrical equipment are also important. Kansas City Region has been the fastest growing economy in the state from 2011 to 2016, where the regional employment grew 2.8 percent from 2015 to 2016. The Ozark Region has also had strong employment growth relative to the rest of Missouri, with employment gains of more than 2 percent in three of the past five years. St. Louis continues to be an important center for the manufacture of metals and chemicals and employment in the region grew 1.3 percent from 2015 to 2016, adding 13,690 new jobs (US Census Bureau, 3rd Quarter 2016). The St. Louis Region workforce has over 1,054,000 employees, making up 38 percent of Missouri employment.

Missouri has a strong natural resources-based economy built on an abundance of iron ore, zinc, barite, limestone, and timber. The state's top agricultural products include grain, sorghum, hay, corn, soybeans, and rice. Missouri also ranks high among states in the production of cattle and calves, hogs, and turkeys and broilers. A vibrant wine industry also contributes to Missouri's agricultural economy. Agriculture's (crops and livestock) economic impact in Missouri is $9.1 billion per year on average. Figure 1 represents crop and livestock sector's production value in the state. A Missouri Department of Agriculture study using 2012 USDA Census of Agriculture and Economic Impact Analysis for Planning (IMPLAN) economic modeling found that agriculture, forestry, fisheries and related industries in Missouri contributes $33 billion (9.3 percent of Missouri total) value added to the economy, sustains 378,232 (10.5 percent) of total Missouri jobs, and provides $2.2 billion in state taxes and $4 billion in federal taxes. Sectors wise changes in Missouri gross state product in 10 years (2007-2017) are presented in Table 1.

Figure 2. Crop vs. Livestock Production Value in 2017



Source: www.mo-agriculture.com//2016-17

Table 1. Missouri Gross Domestic Product: 10 years Change by Industry

Private Industries	2007	2017	Change
Agriculture	1.4%	1.6%	0.3%
Mining	0.6%	0.3%	-0.3%
Utilities	1.4%	1.7%	0.3%
Construction	4.6%	3.3%	-1.4%
Durable Mfg	6.3%	6.6%	0.2%
Nondurable Mfg	7.7%	5.8%	-1.9%
Wholesale	7.0%	7.1%	0.1%
Retail	6.3%	6.4%	0.1%
Transport & Warehouse	3.6%	3.3%	-0.3%
Information	4.3%	4.7%	0.5%
Finance & Insur	7.2%	6.5%	-0.8%
Real Estate	9.7%	11.2%	1.5%
Professional, Science, Tech	5.7%	7.4%	1.7%
Management of Companies	3.2%	3.3%	0.1%
Admin Suport and Waste Mng	2.8%	3.0%	0.2%
Education Services	1.2%	1.2%	0.0%
Healthcare & Social Assistance	7.9%	9.1%	1.2%
Arts, Entertainment, & Rec	1.2%	1.1%	-0.1%
Accomo & Food Service	2.8%	2.7%	-0.1%
Other	2.7%	2.2%	-0.5%
Government	12.6%	11.7%	-0.9%

Source: www.missoureconomy.org

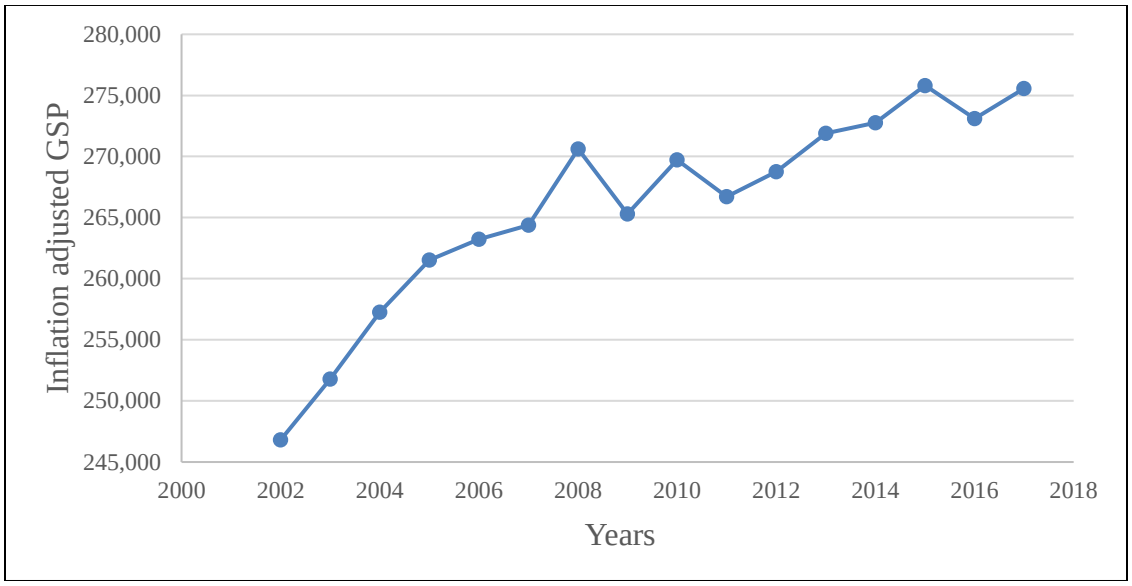
Because of Missouri's rich natural resources, the state's recreational industry is increasing by 2.65 percent per year. Based on a 2016 study conducted by the Missouri Department of Conservation, Missouri recreational activities generate $14.9 billion in consumer spending and support 133,000 direct jobs and $889 million in local and state tax revenue (ORA, 2017).

Over the five year period ending in 2016, the Missouri economy grew in *real* terms by 5.56 percent at a compound annual growth rate of 1.09 percent per year. Missouri Economic Research and Information Center (MERIC) estimates Missouri's Gross Domestic Product (GDP) grew by 1.1 percent from 2016 to 2017. Nationally inflation-adjusted GDP increased 2.1 percent over the same period. Real Missouri GDP was $263.9 billion in 2017. According to U. S. Bureau of Economic analysis, Missouri GDP constitutes 1.61 percent of U.S. GDP which made it the 22nd largest state economy in the nation in 2016. Missouri per-capita GDP was $43,317 in 2016 which is $7,260 lower than the US per-capita GDP. Real Missouri per-capita GDP is 4.13 percent higher today than five years prior in 2011. In that time the population in Missouri grew by 82,283 (1.37 percent) people. Missouri's Unemployment Rate (Seasonally Adjusted) as of October 2018 is 3.1 percent.

As of November 2018, Missouri's Gross State Product (GSP) is $321 Billion (Forbes, 2018) and preserves sustained growth over the years 2002-2017 (Figure 3). The state's median household income is $53,567 with a 1.2 percent job growth rate. However, Missouri ranks below the national average in the cost of doing business (2.6 percent). Missouri stands number 22 in

business cost; 37 in labor supply; 14 in regulatory environment; 24 in Economic Climate and 20 in future growth prospects. According to a U.S. News study conducted in 2017 Missouri ranks 30th in overall economic ranking in the U.S. (U.S. News, 2017).

Figure 3. Missouri Gross State Product in Millions dollar



Source: https://www.missourieconomy.org/indicators/gsp/index.stm

In 2017, Missouri's private sector grew by 1.3 percent and contributed over $232.5 billion to the state economy while the public sector's contribution declined 0.9 percent to $30.6 billion. Looking over the past 10 years, Missouri industry's contribution to Missouri's GSP is 88.4 percent while the government/public sector contributes 12.7 percent on average. Among private sector industries, Manufacturing represents the largest share of GSP in the state at 13.2 percent, followed by Real Estate (11.7 percent), Health Care and Social Assistance (8.7 percent), Professional, Science, and Technology (6.8 percent), and Finance and Insurance (6.6 percent). Minor downturns have been recorded in chemical manufacturing, paper manufacturing, and uneven fluctuations in food, beverage, and tobacco product manufacturing (MERIC/DED, 2018).

Manufacturing exports totaled nearly $12.3 billion dollars, up slightly from $12.2 billion in 2016. Missouri's highest valued industry exports were Transportation Equipment and Chemicals. Missouri's Manufacturing sector accounts for 11.2 percent of the state's private sector employment, 265,863 employees, with a recorded average wage of $57,139 (MERIC, 2018). Industrial manufacturing has added 17,324 jobs since 2012, growing 1.4 percent per year over five years compared to the nation's 0.8 percent growth rate over the same period. About 62.6 percent (72 counties), have a Location Quotient (LQ[2]) over one, which demonstrates a greater specialization in manufacturing compared to the nation.

[2]The Location Quotient describes the concentration of an industry in a geographical region, in relation to the nation, with 1.0 being the national average.

The Missouri regional economic structure shows that the major metropolitan areas are economic engines. The St. Louis Region accounts for 36.58 percent of the economic share with 19.35 percent of that activity coming from St. Louis County. The Kansas City Region represents 19.39 percent of the economic share with 11.42 percent of that activity from Jackson County. Missouri's Ozark Region contributes 8.45 percent to total economic share with about half of that from the Greene County. In Central Missouri, Boone County contributes 3 percent of the state GDP.

Given manufacturing jobs increased by 1.4 percent per year (in the most recent five years), along with increased average wages in the private sector, it is not difficult to envision the potential for environmental pressure due to industrial construction and development in the short-run. Noble laureate economist Simon Kuznets suggests that periods of rapid economic growth witness environmental degradation and income inequality until the average income reaches a certain point over the course of development (Costantiny and Monni, 2008; Grossman and Krueger, 1991). However, the incremental and steady growth of Missouri's manufacturing economy is not anticipated to create such deleterious impacts. In fact, microeconomic studies of water quality suggest that economic welfare is increased because good quality water reduces the marginal cost of production. The producers will be benefited when water quality is good and the consumer will also benefit because of not increasing (i.e., stable) product price. In fact, improved education (both formal and informal), social corporate responsibility, and real income to their communities have the potential to maintain a healthy environment in the long-run. With more demand for outdoor and recreational activities, small business at local levels both in peri-urban and rural areas create employment and provide direct services to the public.

A study from MIT (Meyer, 1995) compared two period time-series analysis to establish the association between environmental regulation and state economic growth. Those two periods were normal economic conditions (1982-1989) and a national economic recession (1990-1992). The MIT study shows that GSP growth *increased* on average about 0.2 percent for every unit *increase* in environmental regulatory requirements. The relationship between the two appears to be positive and there is no evidence that GSP growth was depressed by strong environmental policy. Each unit increased in environmental control is associated with an approximately 0.3 percent increase in non-farm employment. Jorgenson and Wilcoxen (1990) finds that the added operating costs due to pollution abatement plays a minor role in economic growth slow down, if any. Most econometric-based studies found relatively small or no effect on sector-specific productivity and employment, although firms were less likely to open plants in locations subject to more stringent regulation compared to other U.S. locations (EPA, 2017). While price increases due to regulatory requirements outweighed the simulative effect of investments in pollution abatement, they nearly offset one another.

As found in the statement of policy for the Missouri Clean Water Commission at 644.011 RSMo, it is the policy of the state to "strive to meet these objectives while maintaining maximum employment and full industrial development of the state." The rulemaking that is the subject of this report achieves this policy by providing mechanisms to comply with new requirements, such as compliance schedules, variances, etc., in a manner that is affordable and economically efficient. This will ensure that maximum employment and full industrial development are maintained while ensuring economic growth and environmental protection.

Environmental and Economic Impacts of Water Quality Standards Revisions

The evaluation of environmental and economic impacts of revised WQS and criteria is required by Section 644.058 RSMo, which states –

As part of the implementation of any revised water quality standards modifications of twenty-five percent or more, the department shall conduct an evaluation which shall include the environmental and economic impacts of the revised water quality standards and criteria on a subbasin basis. This evaluation shall be conducted at the eight-digit hydrologic unit code level. The department shall document these evaluations and use them in making individual site-specific permit decisions.

For the WQS rulemaking effective April 30, 2018, the evaluation focused on implementation of new or revised WQS and criteria that were estimated by the September 25, 2017, RIR to produce costs, namely NNC for lakes and Section 304(a) national recommended criteria. All other revisions were not anticipated to have costs or impacts that required evaluation under the statute.

Numeric Nutrient Criteria for Lakes

In August 2011, EPA disapproved the majority of Missouri's NNC for lakes in rule at 10 CSR 20-7.031(3)(N), citing concerns in regard to scientific rigor, reproducibility, and connection to designated uses. The Department and Missouri Clean Water Commission, with input from stakeholders, promulgated revised NNC for lakes that provide protection for aquatic life designated uses in the state. The NNC include numeric chlorophyll-a (Chl-a) criteria by ecoregion as well as screening and eutrophication thresholds that protect aquatic life. These criteria apply to all lakes assigned designated uses in the Missouri Use Designation Dataset (MUDD), with the exception of lakes located in the big river floodplains. Because NNC for lakes are new criteria, their environmental and economic impacts have been evaluated.

The public fiscal note developed for NNC estimates the rule will cost seven public entities up to $35,930,000 in the aggregate for the construction of wastewater treatment system upgrades to meet new requirements due to lake impairments. In addition, these public entities will pay up to $2,984,000 in the aggregate annually for system operation, maintenance, monitoring, and reporting. The private fiscal note estimates the rule will cost 23 private entities up to $40,090,000 in the aggregate for the construction of wastewater treatment system upgrades to meet new requirements due to lake impairments. In addition, private entities will pay up to $4,117,000 in the aggregate annually for system operation, maintenance, monitoring, and reporting. It is anticipated that the operation, maintenance, and reporting costs will recur over the life of the rule and will vary with inflation. These fiscal notes were developed at the time of rule promulgation and subject to change as new lake water quality information is collected and assessed. In accordance with 644.058 RSMo, the facilities impacted by initial implementation of the NNC rule can be found in Tables 2 and 3 below by HUC-8.

Table 2. South Grand River Watershed (HUC-8: 10290108) Permits Impacted by NNC

Permit ID	Facility Name	WBID	Name	Public
MO0129321	Ballard R-II School WWTF	7208	Montrose Lake	
MO0112461	Country Creek Estates WWTP	7214	Harrisonville, Lake	

Table 3. Upper St. Francis Watershed (HUC-8: 08020202) Permits Impacted by NNC

Permit ID	Facility Name	WBID	Name	Public
MO0125750	Nelson's Music City	7328	Fredericktown City Lake	
MO0131890	BSA, Astronaut Hall WWTF	7328	Fredericktown City Lake	
MO0123340	Oak Ridge Mobile Home Park	7328	Fredericktown City Lake	
MO0122009	Cedar Rock MHP	7328	Fredericktown City Lake	
MO0116475	Deer Run Estates Lagoon	7328	Fredericktown City Lake	
MO0080667	Arcadia East WWTF	7332	Killarney, Lake	Y
MO0051217	The Baptist Home WWTF	7332	Killarney, Lake	
MO0050687	Arcadia West WWTF	7332	Killarney, Lake	Y
MO0132195	D and S Resources WWTP	7336	Lake Wappapello	
MO0123293	Cinco de Mayo Campground WWTF	7336	Lake Wappapello	
MO0055956	Corral Motel, Cherokee Pass and RC	7336	Lake Wappapello	
MO0120171	Anna Dodson Home LLC	7336	Lake Wappapello	
MO0055034	DeGuire Subdivision	7336	Lake Wappapello	
MO0126772	Open Door House Prayer Church	7336	Lake Wappapello	
MO0056065	Longhorn Motel and Restaurant	7336	Lake Wappapello	
MO0132985	MILL CREEK MHP WWTF	7336	Lake Wappapello	
MO0124991	Black River Electric Coop WWTP	7336	Lake Wappapello	
MO0056553	Farmington Manor	7336	Lake Wappapello	
MO0127574	Blue Mountain Methodist	7336	Lake Wappapello	
MO0127591	Pinecrest Camp WWTF	7336	Lake Wappapello	
MO0124796	Walnut Grove Park	7336	Lake Wappapello	
MO0132080	Wolf Creek Crossing Subdivision WWTP	7336	Lake Wappapello	
MO0093432	Greenville WWTF	7336	Lake Wappapello	Y
MO0122581	Iron Mountain Lake WWTF	7336	Lake Wappapello	Y
MO0135658	Eagle Sky of the Ozarks	7336	Lake Wappapello	
MO0028690	Fredericktown WWTP	7336	Lake Wappapello	Y
MO0028860	Farmington East WWTP	7336	Lake Wappapello	Y
MO0040312	Farmington West WWTP	7336	Lake Wappapello	Y

Additional facilities may be impacted in the future as additional water quality data and assessment are conducted. Evaluations for these watersheds will be conducted and included in future reports.

Among the private entities evaluated are operations that may qualify as small businesses. As required by state statute, the Department developed the rule in cooperation and consideration with stakeholders during advisory meetings with Clean Water Forum participants, some of which represent the interests of small businesses. Small businesses that may be impacted are restaurants, resorts, service stations, and other private businesses operating a permitted domestic sewage treatment system. Any small business that is required to obtain a permit for the discharge of wastewater from a domestic or industrial treatment system may be required to upgrade their system should it be a significant source of pollutants for which water quality criteria are being added or revised. The impacts to small businesses are addressed for each of the new or revised standards or criteria, as appropriate.

Direct costs to small businesses would include the design and construction of wastewater treatment facility (WWTF) upgrades, and the operation and maintenance of upgraded facilities. Indirect costs would include the cost of monitoring effluent for nutrients, specifically total nitrogen and total phosphorous. Small businesses may be any privately-owned facility discharging wastewater at a rate of 50,000 gallons per day or less. An estimated 22 facilities may be required to design, construct, operate, and maintain nutrient removal systems to comply with NNC imposed by this rule within impaired lake watersheds. The estimated cost for constructing the above treatment is $36,600,000. The estimated annual cost for operating and maintaining the above treatment is $3,802,000. The prevailing consensus is that domestic sewage treatment systems that discharge nutrients to impaired lakes will be required to upgrade their systems to remove these pollutants. Compliance schedules will be the primary method of deferring or reducing the impact of the proposed rule on small businesses.

In direct economic terms, the greatest beneficiaries from the proposed rule may be owners of lake front property. Several studies have indicated that increased water clarity associated with nutrient reduction is a significant factor in raising the value of such property. [3] One such study found an average increased value of $235 per lakeshore lot for each 1 meter increase in water transparency as measured with a Secchi disk. [4] Conversely, numerous studies have demonstrated that the reduced water clarity associated with excessive nutrient loading have resulted in a wide range of losses of home values.[5] Water clarity was a significant explanatory variable for lakeshore property prices. One study analyzed more than 1,200 lakeshore property sales in northern Minnesota that occurred between 1996 and 2001. A loss of 1 meter in Secchi depth could result in losses of up to $80,000 sales value in an individual lot.[6] Another study found a decrease of $128 to $402 in the value per shoreline foot in Wisconsin lakes that had high algae blooms, when compared with nearby lakes that did not have this problem.[7]

[3] Michael et al., 1996; Wilson and Carpenter 1999
[4] Steinnes 1992
[5] U.S. EPA, 2015
[6] Krysel et al. 2003
[7] Kashian and Kasper 2010

Other economic beneficiaries include businesses that are reliant on tourism-related lake recreation, such as restaurants, hotels, and marinas, as well as gas stations both near to and on the way to or from resort areas. Many of these businesses will likely be classified as small businesses as noted previously. Several studies demonstrated relationships between lake water clarity and levels of tourist recreation.[8] Protected and enhanced water clarity will maintain and improve opportunities for whole body contact recreation. And, while some sport fishing potential is enhanced with higher nutrient loading, the potential for greater aquatic biodiversity tends to increase with reduced nutrient loading.[9] Failure to protect a water body from excessive nutrient loading; however, can be economically devastating to a community. For example, in 2009 and 2010, Grand Lake St. Mary's, a 13,000 acre lake in Ohio, was the site of large algal blooms and fish kills. High concentrations of toxins produced by blue-green algae prompted Ohio EPA to post warning signs advising people to not contact the water. There were 23 cases of human illness, and several dog deaths that were associated with the blooms. The local tourism industry, which previously accounted for $150 million in annual economic activity, suffered losses of between 23 and 30 percent. Several boat dealers, marinas, and other small businesses closed.[10]

Two of the lakes included in this evaluation, Fredericktown City Lake and Harrisonville City Lake, are designated in Missouri's WQS as drinking water supply lakes (Class L1). Drinking water systems that use lakes as a source would experience fewer episodes of taste and odor problems that can occur as a consequence of excessive nutrient loading. Furthermore, improved water quality in drinking water reservoirs would lead to a reduction in the cost of treating the water by reducing organic matter and other pollutants that require additional treatment. For example, the city of Celina, OH, which draws its drinking water supply from Grand Lake St. Mary's, spent over $13 million in upgrades to control taste and odor problems in the treatment process.[11] In Waco, TX, the public water supply system, for which the source water supply is Lake Waco, had to spend an estimated $70.4 million between 2002 and 2012 to treat taste and odor problems that resulted from high nutrient loading and algal blooms. Additionally, they lost between $6.9 million and $10.3 million in revenue due to the withdrawal of neighboring communities from the utility.[12] For the two lakes in the evaluation, inaction would leave these source waters unprotected, negatively impacting the primary drinking water supply for many communities. Additionally, any secondary water systems that may utilize water from these public water supply systems would also be impacted. Reducing nutrients in source water will lead to concomitant improvements in finished water, more efficient and cost-effective water treatment, and a longer useful life of the source water supply.

Detailed descriptions of the two HUC-8 watersheds with permits impacted by lake NNC, South Grand River and Upper St. Francis River, follow and provide additional watershed based details to support the evaluation. A complete list of HUC-8 watersheds impacted by lake NNC, including those without permits, can be found in Appendix A.

South Grand River Watershed

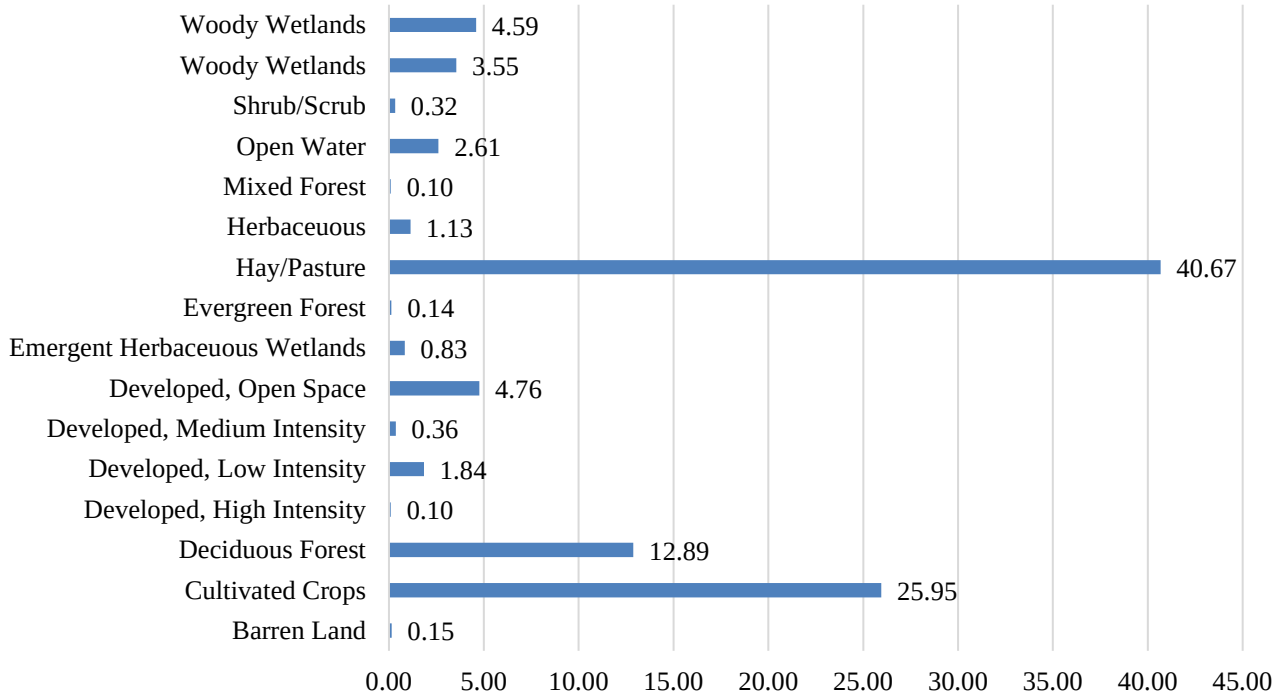
[8] Bouwes and Schneider, 1979; Ribaudo and Epp, 1984; Smith et al., 1986; Wilson and Carpenter, 1999
[9] Egertson and Downing, 2004
[10] Davenport and Drake, 2011
[11] Davenport and Drake, 2011
[12] Dunlap et al., 2015

The South Grand River watershed (HUC-8: 10290108) covers approximately 1,352,800 acres and contains Harry S Truman Reservoir and Harry S Truman State Park. Of the 55,600 acres of Harry S Truman Lake, 36.23 percent of the lake area is within the South Grand River HUC-8. This HUC-8 watershed also contains 36 lakes having unique water body IDs and 124 other lakes with presumed uses that were added to the MUDD in 2014. Total lake area for the HUC-8 watershed is 26,392.4 acres.

Population growth in the watershed is 1.7 percent, which is higher than the national average of 0.7 percent per year. The watershed enjoys a Medium Household Income (MHI) of $60,260; more than $10,000 higher than the national average of $49,683 (adjusted in 2016). The presence of good water quality and recreational opportunities within the watershed and Harry S Truman reservoir play an important part in these key indicators being higher than national averages.

Current land uses for the South Grand watershed are shown in Figure 4. Hay/Pasture is the most dominant land use (40.67 percent), followed by cultivated crops (25.95 percent). Total forest and wetland areas are a smaller percentage of the watershed area at 13.75 percent and 4.59 percent, respectively. Given the predominantly agricultural land uses of the watershed, nutrient pollution from nonpoint sources is anticipated to be of concern with regard to water quality in lakes and reservoirs. There are two domestic facilities in the South Grand watershed that are projected to be impacted by the rule (see Table 1 above).

Figure 4. Percentage of current land uses South Grand Watershed (HUC-8: 10290108)



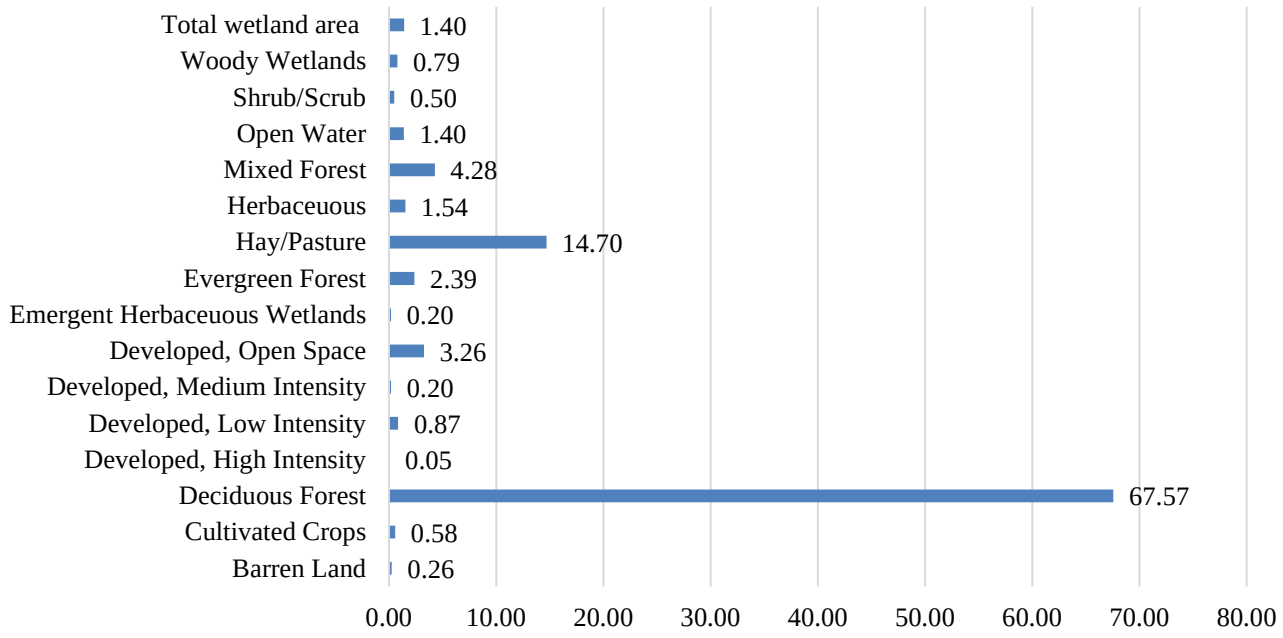
Upper St. Francis River Watershed

The Upper St. Francis River watershed (HUC-8: 08020202) covers approximately 842,927 acres and contains one State Historic Site and five state parks. Among them, three state parks (Elephant Rocks State Park, Lake Wappapello State Park, and Sam A. Baker State Park) are fully contained within the watershed, while the remaining two state parks (St. Joe State Park and Taum Sauk Mountain State Park) are only partially contained. This HUC-8 watershed contains 71 classified lakes with a total surface area of 9,934 acres. The biggest lake, Lake Wappapello, covers 8,200 acres and is an important recreational resource for the region.

Population growth in the watershed is 0.8 percent, which is a bit higher than the national average of 0.7 percent per annum. The watershed has a MHI of $38,465; about $11,000 lower than the national average of $49,683 (adjusted in 2016). The presence of good water quality and recreational opportunities within the watershed support tourism in the Upper St. Francis River watershed.

Current land uses for the Upper St. Francis River watershed are shown in Figure 5. Deciduous forest is the most dominant land use (66.57 percent), followed by Hay/Pasture (14.7 percent). Cultivated crops cover less than a percent of the total basin area. A largely forest dominated watershed, the upper St. Francis River HUC-8 is anticipated to have less nutrient pollution from nonpoint sources than the South Grand River HUC-8. There are two domestic facilities in the South Grand watershed that are projected to be impacted by the rule (see Table 2 above).

Figure 5. Percentage of current land uses Upper St. Francis Watershed (HUC-8: 08020202)



Section 304(a) Criteria

National recommended water quality criteria are developed and published by EPA pursuant to Section 304(a) of the Clean Water Act. These recommendations provide pollutant specific water quality criteria and conditions that will ensure protection and propagation of fish, shellfish, and wildlife and recreation in and on the water. Additions and/or revisions to specific ambient water quality criteria for the protection of aquatic life were promulgated in Missouri's WQS to ensure state standards are up-to-date with the latest EPA national criteria.

Facilities that treat wastewater containing the Section 304(a) numeric water quality criteria being added or revised may be affected by the proposed changes. Facility data were queried from the Missouri Clean Water Information System (MoCWIS) in support of the July 24 and September 25, 2017, RIRs. Facility permit information was reviewed and validated prior to this analysis. A summary of the number of facilities having permitted effluent limits for the pollutants being added or revised can be found in Table 4. The effect of the proposed rule on each facility depends on the type of treatment system, the levels of the pollutant in the wastewater and in the receiving stream, and the applicability of anti-backsliding requirements. Because these factors are unique to each facility, the Department is unable to determine from this list the precise extent of impact from the proposed changes. However, general impacts on these facilities, either positively through an increased limit or negatively through a decreased limit, can be estimated based on the available data and current effluent limitations.

Table 4. Facilities with monitoring requirements or effluent limits for parameters in which the numeric criteria changed more than 25 Percent.

More than 25% DECREASE in numeric criteria *(more stringent)**	
Permit type	**Number of facilities**
Site-specific	80
General Stormwater	0
General Other	0
TOTAL	80
More than 25% INCREASE in numeric criteria *(less stringent)*	
Permit type	**Number of facilities**
Site-specific	189
General Stormwater	411
General Other	6
TOTAL	606
More than 25% CHANGE in numeric criteria*	
Permit type	**Number of facilities**
Site-specific	198
General Stormwater	411
General Other	6
TOTAL	615

* This includes *new* numeric criteria except for NNC.

The proposed revisions to Section 304(a) criteria in rule are in response to changes in these criteria at the federal level to establish appropriate thresholds to prevent toxic effects on aquatic life and human health. An explanation of the basis for the changes in the federal criteria can be found in the supporting science and information referenced in the RIR for the rulemaking. Missouri is adopting these updated federal criteria without modification, and any environmental and economic costs and benefits are determined by the actions at the federal level, and not at the state level. However, for the purposes of 644.058 RSMo, the Department has evaluated the environmental and economic impacts to the 2,676 site-specific permits, 1,388 general permits, 774 storm water permits, and 3 underground injection permits might be affected by these revisions. Tables 5A and 5B show the number of permitted facilities having NPDES permits with limits or monitoring requirements for each federal 304(a) criteria revised by 25 percent or more.

Table 5A. Parameters with new numeric criteria or numeric criteria that decreased more than 25 percent *(more stringent)* and the number of facilities with monitoring requirements or effluent limits for that parameter. This table excludes new nutrient criteria.

Parameter	Acute	Chronic	Facilities
4-4'-Dichlorodiphenyltrichloroethane	*	*	0
Acrolein	*	*	0
Aldrin	*		1
Alkalinity (minimum CaCO3)		*	0
Carbaryl	*	*	0
Chlordane	*	*	1
Chlorpyrifos		*	0
Diazinon	*	*	1
Dieldrin	*	*	1
Endrin	*	*	1
Heptachlor	*		1
Heptachlor Epoxide	*	*	0
Lindane	*		1
Mercury	✓		67
Methylmercury	*	*	0
Nonylphenol	*	*	0
Parathion		✓	1
Phenol (Coldwater Aquatic Habitat)	✓	✓	0
Phenol (Warmwater Aquatic Habitat)	✓		19
Polychlorinated Biphenyls (PCBs)		*	3
Toxaphene	*	*	1
Tributylin (TBT)	*	*	0

✓ Numeric criteria decreased more than 25%.
* New numeric criteria.

Table 5B. Parameters with numeric criteria that increased more than 25 percent *(less stringent)* and the number of facilities with monitoring requirements or effluent limits for that parameter.

Parameter	Acute	Chronic	Facilities
Arsenic		✓	75
Cadmium*	✓	✓	111
Chlorpyrifos	✓		0
Chromium (III)*	✓	✓	91
Copper*	✓	✓	364
Endosulfan	✓		1
Lead*	✓	✓	329
Mercury		✓	67
Nickel*	✓	✓	87
Silver*	✓		66
Zinc*	✓	✓	379

✓ Numeric criteria increased more than 25%.

* The criteria for these parameters are dependent on the hardness of the receiving stream. Median hardness values by ecoregion were used for the above determination and are not applicable in every situation.

Table B1 in Appendix B shows the number and type of permitted facilities by HUC-8 having NPDES permits with limits for each of the federal 304(a) criteria that are proposed to be decreased (i.e., made more stringent) by 25 percent or more. Operations covered by general, stormwater, and underground injection site permits consist predominantly of facilities that are not allowed to discharge either wastewater or stormwater, and there should be no, or minimal, increased costs associated with the change in 304(a) criteria. To the extent that WWTF may need to upgrade to meet more stringent criteria, the data to estimate these costs are extremely site-specific in nature. However, the Department has included general estimates of increased costs for the purposes of this report, where required.

Table B2 in Appendix B shows the number and type of permitted facilities by HUC-8 having NPDES permits with limits for each of the federal 304(a) criteria that are proposed to be increased (i.e., made less stringent) by 25 percent or more. Where criteria have been proposed to increase, it is anticipated there will be either no impact to existing permittees or a cost savings. Cost savings to permittees can be spent on other environmental improvements at the plant or provide cost savings to rate payers.

Pesticides

The majority of parameters with new acute or chronic numeric criteria for the protection of aquatic life are classified as pesticides. Some of these pesticides, such as

Dichlorodiphenyltrichloroethane, Acrolein, Carbaryl, Chlorpyrifos, Heptachlor Epoxide, and Tributyltin, do not have Missouri State Operating Permit facilities associated with them. Reductions in these criteria will have an environmental and a human health benefit through reduced carcinogenic impacts, while having no economic impact or costs on the regulated community.

The remaining pesticides, including Aldrin, Chlordane, Diazinon, Dieldrin, Endrin, Heptachlor, Lindane, Parathion, and Toxaphene, have one regulated facility with either monitoring requirements or effluent limitations for the parameter. However, multiple pesticides are associated with a single facility and these parameters have already been included in state operating permits due to other designated uses requiring protection, such as drinking water supply. For example, the Conservation Chemical Company facility, (MO0108472), has monitoring only requirements for Aldrin, Dieldrin, Endrin, Heptachlor, Lindane, Parathion, and Toxaphene. These monitoring requirements will not need to be modified since reasonable potential to cause or contribute these pollutants to violations of the criteria in the Missouri River is unlikely given the large amounts of dilution available in the receiving water body. Similarly, monitoring requirements for chlordane at the Kansas City, Birmingham WWTF (MO0049531) and diazinon at the HPI Products, Inc. facility (MO0135747) are also not expected to change for these discharges to the Missouri River for the same reason. It is important to note, however, that the Missouri River has a Total Maximum Daily Load (TMDL) study for chlordane approved November 3, 2006. As detailed in the TMDL, the impairment and TMDL are for concentrations of chlordane in fish tissue and not chlordane levels in water. The reduction of chlordane criteria in water has no effect on the approved TMDL or requirements for the Kansas City, Birmingham WWTF. Given the above evaluation, no economic impacts are anticipated to permitted facilities that contain effluent limitations or monitoring requirements for pesticides.

Polychlorinated Biphenyls (PCBs)

New chronic aquatic life protection criteria for polychlorinated biphenyls (PCBs) required an evaluation of Missouri State Operating Permit requirements for three permitted facilities. The Conservation Chemical Company facility (MO0108472) contains a monitoring requirement for PCBs and addition of new chronic criteria should not result in a permit change due to the large amount of dilution available in the Missouri River. The Bannister Transformation & Development Company - Bannister facility (MO0004863) contains a monitoring requirement and a benchmark for PCBs in its operating permit. The monitoring requirement, benchmark, and special permit conditions for the Bannister facility ensure that discharge of PCBs in stormwater are in compliance with the water quality standards. No impact is anticipated to this facility as a result of the addition of a chronic PCB criterion. Lastly, the City of Columbia Municipal Power Plant (MO0004979) contains a permit requirement that there shall be no discharge of PCBs from the facility per federal effluent limitation guidelines for Steam Electric Power Generating Point Sources at 40 CFR 423.13. No impact is anticipated to this facility as a result of the PCB chronic criterion. Given the above evaluation, no economic impacts are anticipated to permitted facilities that contain effluent limitations or monitoring requirements for PCBs.

Phenol

The acute criterion for phenol decreased by twenty-five percent or more with the past rulemaking and was assigned to both cold water and warm water aquatic habitat protection. In addition, a

new chronic criterion for cold water aquatic habitat protection was promulgated. There was no change to the chronic criterion for warm water aquatic habitat protection.

The facilities impacted by the change in phenol criteria discharge to streams designated in rule as warm water aquatic habitat. These facilities are classified as sanitary landfills (i.e., refuse systems), municipal WWTF (i.e., sewerage systems), wood preserving or wood product industries, or other industrial categories. Table 6 contains facilities that hold current or expired Missouri State Operating permits that contain effluent limitations or monitoring requirements for phenol.

Table 6. State Operating Permits Evaluated for Phenol Criteria Changes

Permit Number	Facility Name	Facility Type	Monitoring Requirement	Effluent Limitation	HUC-8
MO0110833	BFI, Backridge Landfill	Refuse Systems	N	N	7110001
MO0108103	JZ Landfill (Expired)*	Refuse Systems	Y	N	7110008
MO0111805	Kiesel Marine Service	Petroleum Products	N	N	7140101
MO0108227	Chillicothe WWTP	Sewerage Systems	N	N	10280101
MO0089109	Nevada Municipal WWTF	Sewerage Systems	Y	Y	10290104
MO0106658	Springfield Sanitary Landfill	Refuse Systems	Y	N	10290106
MO0117331	Former Tronox Facility - Springfield MO	Wood Preserving	Y	N	10290106
MO0111325	International Paper Company*	Wood Preserving	Y	N	10290108
MO0099503	BFI, Missouri City Landfill	Refuse Systems	Y	Y	10300101
MO0115703	Kansas City Southern Railroad Repair Facility	Railroads, Line-Haul Operating	N	N	10300101
MO0104540	Central Missouri Landfill (Closed)	Refuse Systems	Y	N	10300103
MO0025810	Washington WWTP	Sewerage Systems	N	N	10300200
MO0114804	Laclede Gas Company – Underground Storage	Natural Gas Distribution	Y	Y	10300200
MO0122718	Mill Spring Wood Recovery (Closed) *	Wood Products	Y	Y	11010007
MO0127931	Missouri Tie, LLC	Wood Preserving	Y	N	11010007
MO0103349	Joplin – Turkey Creek WWTF	Sewerage Systems	Y	Y	11070207
MO0104906	Neosho WWTP	Sewerage Systems	Y	Y	11070207
MO0108731	Joplin Municipal Landfill (Closed) *	Refuse Systems	N	N	11070207
MO0110272	Lamar Closed Sanitary Landfill	Refuse Systems	Y	N	11070207

Phenol is a pollutant of concern at sanitary landfills and wood product/preserving facilities. As a result, effluent limitations and monitoring requirements are included in the effluent limitation guidelines (ELG) for these industrial categories (i.e., 40 CFR 445 for landfills, 40 CFR 429 for wood products). Four facilities listed in Table 6 have had their permits terminated since the

initial survey of impacts was conducted in late 2017; these facilities have been noted with an "*" in the table. Most of the remaining active and closed landfills have monitoring only requirements for phenol and changes in the phenol criteria are not anticipated to change these requirements. Therefore, the decrease and addition of criteria for phenol will not change the effluent limitations or monitoring requirements for facilities with active permits listed in Table 6. As a result, no economic impacts are anticipated to permitted landfills and wood products facilities that contain effluent limitations or monitoring requirements for phenol.

Municipal facilities with effluent limitations and monitoring requirements for phenol will have those requirements reviewed at next permit renewal. New reasonable potential analysis for phenol will be conducted for the Joplin, Neosho, and Nevada municipal WWTF using the new criteria at the next permit renewal following EPA approval. Reasonable potential analyses will determine whether new, and perhaps lower, effluent limitations are needed or if the effluent limitation can be removed and replaced with a monitoring only requirement. Preliminary reasonable potential analyses for these three facilities indicate no reasonable potential and the potential for reduction or removal of requirements at renewal. Prior to promulgation of the rule, the cities of Washington and Chillicothe had reasonable potential analyses conducted using recent discharge monitoring data and the analyses demonstrated no reasonable potential for the facilities to cause or contribute to an exceedance of the phenol water quality standard. As a result, effluent limitations and monitoring requirements were removed from the state operating permits for these municipal facilities.

Because phenol in municipal effluent is typically generated by industrial users connected to the municipal collection system, reductions in phenol in a city's influent should enable the WWTF to comply with any new requirement. Pretreatment programs under federal and state clean water law (40 CFR 403 and 10 CSR 20-6.100, respectively) provide cities and the Department the authority to regulate industrial pollutants in municipal influent[13]. Inspection of industrial users and establishment of local limits for phenol are mechanisms available to municipalities through pretreatment programs approved by the Department. The cities of Joplin, Neosho, and Nevada each have Department approved pretreatment programs which provide the ability to inspect and set local limits on industries contributing phenol to the city WWTF. These cities should be aware of any industrial users that may contribute phenol to municipal treatment plant influent and take reasonable actions to control those contributions. As a result, reduction in effluent limitations at these facilities due to reduced phenol criteria should not cause economic impacts for these communities.

Three private industrial facilities with either monitoring requirements or effluent limitations for phenol were captured by the RIR process and have been evaluated for this report. The Kiesel Company/Kiesel Marine Service facility (MO0111805) and Kansas City Southern Railway Company/KCSR One Spot Repair facility had monitoring only requirements included in their state operating permits at the time facilities were queried for the RIR. Since that time, the Department has removed phenol requirements from these operating permits due to no reasonable potential to exceed WQS. As a result, any potential impacts for phenol anticipated by the RIR for these facilities no longer apply and negative economic impacts are not anticipated. The third

[13] https://dnr.mo.gov/env/wpp/cpp/e1-pretreat.htm

industrial facility, Laclede Gas Company – Underground Storage (MO0114804), maintains a state operating permit with monitoring requirements and effluent limitations for phenol at the emergency discharge outfall from the facility's evaporation basin. As noted in the permit, the facility must operate as a "no-discharge facility" and wastewater must be stored and evaporated from the evaporation basin on-site. No discharge of phenol is anticipated during normal operational conditions and any emergency discharge during large precipitation or storm events is not anticipated to cause or contribute to exceedances of the phenol water quality standard in the Missouri River due to sufficient dilution in the receiving water. For these reasons, changes in the phenol criteria are not anticipated to have an economic impact on this facility.

Mercury

The acute criterion for total recoverable mercury decreased by 25 percent or more and the chronic criterion increased by 25 percent or more with the past rulemaking. In addition, new Section 304(a) criteria for methylmercury were promulgated at the same levels as total recoverable mercury.

The facilities impacted by the change in total recoverable mercury criteria are classified as sanitary landfills (i.e., refuse systems), municipal WWTF (i.e., sewerage systems), mining related industries (cement, iron, lead, zinc, and nonferrous metals), or other industrial categories. Table 7 contains facilities that hold current or expired Missouri State Operating permits that contain effluent limitations or monitoring requirements for mercury.

Table 7. State Operating Permits Evaluated for Mercury Criteria Changes

Permit	Name	Type	Monitoring	Effluent	HUC-8
MO0110833	BFI, Backridge Landfill	Refuse Systems	N	N	7110001
MO0136514	TNT General Contracting	Trucking, Except Local	N	N	7110001
MO0111686	Continental Cement Company	Cement, Hydraulic	Y	N	7110004
MO0111996	Eagle Ridge Landfill	Refuse Systems	Y	N	7110007
MO0112721	Hannibal Sanitary Landfill	Refuse Systems	N	N	7110007
MO0108103	JZ Landfill (Expired)*	Refuse Systems	Y	Y	7110008
MO0028720	City of O'Fallon WWTF	Sewerage Systems	N	N	7110009
MO0058343	St. Charles Mississippi River WWTF	Sewerage Systems	Y	N	7110009
MO0025151	MSD, Lemay WWTP	Sewerage Systems	N	N	7140101
MO0025178	MSD, Bissell Point WWTP	Sewerage Systems	N	N	7140101

MO0027111	Herculaneum WWTP	Sewerage Systems	Y	N	7140101
MO0000574	Pea Ridge Resources	Iron Ores	Y	Y	7140102
MO0000086	Doe Run, Viburnum Operations	Lead And Zinc Ores	Y	Y	7140102
MO0100226	Doe Run, Viburnum Mine #35 (Casteel)	Lead And Zinc Ores	Y	Y	7140102
MO0110779	Peerless Demolition Landfill	Refuse Systems	Y	N	7140102
MO0113000	Oak Ridge Landfill*	Refuse Systems	Y	Y	7140102
MO0110205	Interstate Disposal Systems	Refuse Systems	Y	N	7140102
MO0000337	Doe Run, Buick Resource Recycling Facility	Secondary Nonferrous Metals	Y	Y	7140102
MO0025283	Union West WWTP	Sewerage Systems	Y	N	7140103
MO0099465	St. Clair WWTF	Sewerage Systems	N	N	7140103
MO0104736	Sullivan WWTP	Sewerage Systems	Y	N	7140103
MO0108774	St. Francois County Environmental Corp	Refuse Systems	N	N	7140104
MO0115304	Perry County Landfill	Refuse Systems	N	N	7140105
MO0120081	Charleston WWTF	Sewerage Systems	N	N	8020201
MO0050326	Bloomfield WWTF	Sewerage Systems	Y	N	8020203
MO0000388	Leggett & Platt, Inc.	Fabricated Rubber Products	N	N	8020204
MO0113891	Lemons Landfill East	Refuse Systems	Y	N	8020204
MO0033286	Maryville WWTP	Sewerage Systems	N	N	10240013
MO0119741	Rye Creek Landfill*	Refuse Systems	Y	N	10280202
MO0108723	Moberly Sanitary Landfill*	Refuse Systems	Y	N	10280203
MO0117471	Maple Hill Landfill	Refuse Systems	Y	N	10280203
MO0111082	3M Commercial Graphics	Refuse Systems	N	N	10290104

MO0121045	BFI, Prairie View Regional Waste Facility	Refuse Systems	Y	N	10290104
MO0106658	Springfield Sanitary Landfill	Refuse Systems	Y	N	10290106
MO0108464	Ellis-Scott Sanitary Landfill*	Refuse Systems	Y	N	10290108
MO0110876	Lee's Summit Resource Recovery Park	Refuse Systems	Y	N	10290108
MO0107506	Black Oak Landfill	Refuse Systems	Y	N	10290201
MO0108472	Conservation Chemical Company	Nonclassifiable Establishments	Y	N	10300101
MO0099503	BFI, Missouri City LF	Refuse Systems	Y	N	10300101
MO0123790	Centropolis Sanitary Landfill	Refuse Systems	Y	N	10300101
MO0115801	Advantage Metals Recycling	Scrap And Waste Materials	Y	BM	10300101
MO0024911	KC, Blue River WWTF	Sewerage Systems	Y	N	10300101
MO0024929	KC, Westside WWTP	Sewerage Systems	Y	N	10300101
MO0089681	Independence, Rock Creek WWTP	Sewerage Systems	N	N	10300101
MO0101087	LBVSD, Atherton WWTP	Sewerage Systems	N	N	10300101
MO0004979	Columbia Municipal Power Plant	Electric Services	Y	N	10300102
MO0112640	Columbia Landfill & Yard Waste Compost	Refuse Systems	Y	N	10300102
MO0113352	Fulton Sanitary Landfill*	Refuse Systems	N	N	10300102
MO0114375	Republic Services, Jefferson City Landfill	Refuse Systems	Y	BM	10300102
MO0097837	Columbia Regional WWTP	Sewerage Systems	Y	Y	10300102
MO0136034	City of Columbia Water Treatment Plant	Water Supply	Y	N	10300102
MO0104540	Central Missouri Landfill	Refuse Systems	Y	N	10300103

MO0097543	IESI MO Champ Landfill	Refuse Systems	Y	Y	10300200
MO0112771	Bridgeton Landfill	Refuse Systems	Y	N	10300200
MO0121975	Washington Santiary Landfill Silt Pond	Refuse Systems	N	N	10300200
MO0045420	Gerald WWTF	Sewerage Systems	Y	N	10300200
MO0058351	St. Charles Missouri River WWTF	Sewerage Systems	Y	N	10300200
MO0049522	Springfield Southwest WWTP	Sewerage Systems	Y	N	11010002
MO0001848	Doe Run, Brushy Creek Mine/Mill	Lead And Zinc Ores	Y	Y	11010007
MO0001856	Doe Run, Fletcher Mine & Mill	Lead And Zinc Ores	Y	Y	11010007
MO0100218	Doe Run, West Fork	Lead And Zinc Ores	Y	Y	11010007
MO0001881	Doe Run, Sweetwater Mine/Mill Site	Lead And Zinc Ores	Y	Y	11010007
MO0108731	Joplin Municipal Landfill (Closed)*	Refuse Systems	Y	N	11070207
MO0110272	Lamar Closed Sanitary Landfill	Refuse Systems	Y	N	11070207
MO0023256	Joplin, Shoal Creek WWTF	Sewerage Systems	Y	N	11070207
MO0103349	Joplin – Turkey Creek WWTF	Sewerage Systems	Y	Y	11070207
MO0104906	Neosho WWTP	Sewerage Systems	Y	Y	11070207

Mercury is a pollutant of concern at sanitary landfills and facilities associated with mining of heavy metal ores. As a result, effluent limitations and monitoring requirements are included in the ELG for these industrial categories (i.e., 40 CFR 445 for landfills, 40 CFR 440 for metals ore mining and dressing). Seven facilities listed in Table 7 have had their permits terminated since the initial survey of impacts was conducted in late 2017; these facilities have been noted with an "*" in the table. Most of the remaining active and closed landfill facilities have monitoring only requirements for mercury and changes in the mercury criteria are not anticipated to change these requirements. Therefore, the decrease and addition of criteria for mercury and methyl mercury will not change the effluent limitations or monitoring requirements for facilities with active permits listed in Table 7. As a result, no economic impacts are anticipated to permitted landfills and ore mining related facilities that contain effluent limitations or monitoring requirements for mercury.

Municipal facilities with effluent limitations and monitoring requirements for mercury will have those requirements reviewed at next permit renewal. New reasonable potential analysis for

mercury will be conducted for the St. Charles – Mississippi River, St. Charles – Missouri River, Gerald, Herculaneum, Union West, Sullivan, Bloomfield, Kansas City – Blue River, Kansas City – Westside, Columbia Regional, Springfield Southwest, Joplin – Turkey Creek, Joplin – Shoal Creek, and Neosho municipal WWTF using the new criteria at the next permit renewal following EPA approval. Reasonable potential analyses will determine whether new, and perhaps lower, effluent limitations are needed or if the effluent limitation can be removed and replaced with a monitoring only requirement. Preliminary reasonable potential analyses for most of these facilities indicate no reasonable potential and the potential for reduction or removal of requirements at renewal. Prior to promulgation of the rule, cities listed in Table 7 with no monitoring or effluent requirements had reasonable potential analyses conducted using recent discharge monitoring data. These analyses demonstrated no reasonable potential for the facilities to cause or contribute to an exceedance of the mercury water quality standard. As a result, effluent limitations and monitoring requirements were removed from the state operating permits for these municipal facilities.

Because mercury in municipal effluent is typically generated by industrial users connected to the municipal collection system, reductions in mercury in a city's influent should enable the WWTP to comply with any new requirement. Pretreatment programs under federal and state clean water law (40 CFR 403 and 10 CSR 20-6.100, respectively) provide cities and the Department the authority to regulate industrial pollutants in municipal influent[14]. Inspection of industrial users and establishment of local limits for phenol are mechanisms available to municipalities through pretreatment programs approved by the Department. The cities of Joplin, Neosho, and Columbia each have Department approved pretreatment programs which provide the ability to inspect and set local limits on industries contributing mercury to the city WWTF. These cities should be aware of any industrial users that may contribute mercury to municipal treatment plant influent and take reasonable actions to control those contributions. As a result, reduction in effluent limitations at these facilities due to reduced mercury criteria should not cause economic impacts for these communities.

Three private industrial facilities, and two public non-domestic WWTF, with either monitoring requirements or effluent limitations for mercury were captured by the RIR process and have been evaluated for this report. The TNT General Contracting (MO0136514) and Leggett & Platt, Inc. (MO0000388) facilities had monitoring only requirements included in their state operating permits at the time facilities were queried for the RIR. Since that time, the Department has removed mercury requirements from these operating permits due to no reasonable potential to exceed WQS. As a result, any potential impacts for mercury anticipated by the RIR for these facilities no longer apply and negative economic impacts are not anticipated. The third industrial facility, Conservation Chemical Company (MO0108472) contains a monitoring requirement for mercury and the change in criteria should not result in a permit change due to the large amount of dilution available in the Missouri River.

The two public non-domestic WWTF captured by the RIR process are both owned and operated by the city of Columbia: the city of Columbia Water Treatment Plant (MO0136034) and Columbia Municipal Power Plant (MO0004979). The city of Columbia Water Treatment Plant

[14] https://dnr.mo.gov/env/wpp/cpp/e1-pretreat.htm

has a monitoring only requirement of once per year in order to collect data to conduct a reasonable potential analysis upon permit renewal. However, this plant has been permitted as a no-discharge facility and should not cause or contribute to an exceedance of applicable WQS for mercury. The city of Columbia Municipal Power Plant (MO0004979) also contains a monitoring only requirement for mercury in order to calculate reasonable potential for wastewater discharges upon next permit renewal. For both of these facilities, the change in mercury criteria should not result in a permit change and no impact is anticipated to these facilities.

Conclusions

Upon completion of the analysis required by statute, the Department has determined that the most significant near term economic impact will be from the implementation of NNC for lakes. However, the longer term economic benefit of improved lake water quality outweighs the near term impacts to communities within those watersheds. The evaluation also revealed that changes to aquatic life protection criteria for selected 304(a) federal criteria will not be impactful to permittees or the economy.

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Appendix A.

Permitted facilities impacted by Numeric Nutrient Criteria changes per 644.058, RSMo

Public and private estimated total capital costs and total annual operation and maintenance (O&M) costs by impaired watershed using HUC-8. Facilities that treat wastewater containing nutrients may be affected by the proposed changes. Facility data were queried from the MoCWIS in support of the July 24 and September 25, 2017, RIRs. Facility permit information was reviewed and validated prior to this analysis.

Note - Watersheds not represented in the tables below do not have facilities discharging to lake watersheds affected by the proposed rule nor in a Chl-a impaired water body.

Table A1. Public Facilities

HUC8	Design Flow (DF) in MGD	Number of Facilities		Capital Costs	Annual O&M	Total
All	DF≤0.05	1	Low	$1,160,000	$117,000	$1,277,000
			High	$2,020,000	$199,000	$2,219,000
	0.05<DF≤1	4	Low	$6,730,000	$592,000	$7,322,000
			High	$12,590,000	$1,161,000	$13,751,000
	1<DF≤20	2	Low	$10,470,000	$815,000	$11,285,000
			High	$21,320,000	$1,624,000	$22,944,000
	DF>20	0	Low	$0	$0	$0
			High	$0	$0	$0
	Totals	**7**	**Low**	**$18,360,000**	**$1,524,000**	**$19,884,000**
			High	**$35,930,000**	**$2,984,000**	**$38,914,000**

HUC8	Design Flow (DF) in MGD	Number of Facilities		Capital Costs	Annual O&M	Total
08020202 Upper St Francis	DF≤0.05	1	Low	$1,160,000	$117,000	$1,277,000
			High	$2,020,000	$199,000	$2,219,000
	0.05<DF≤1	4	Low	$6,730,000	$592,000	$7,322,000
			High	$12,590,000	$1,161,000	$13,751,000
	1<DF≤20	2	Low	$10,470,000	$815,000	$11,285,000
			High	$21,320,000	$1,624,000	$22,944,000
	DF>20	0	Low	$0	$0	$0
			High	$0	$0	$0
	Totals	**7**	**Low**	**$18,360,000**	**$1,524,000**	**$19,884,000**
			High	**$35,930,000**	**$2,984,000**	**$38,914,000**

Table A2. Private Facilities

HUC8	Design Flow (DF) in MGD	Number of Facilities		Capital Costs	Annual O&M	Total
All	DF≤0.05	22	Low	$24,400,000	$2,574,000	$26,974,000
			High	$36,600,000	$3,802,000	$40,402,000
	0.05<DF≤1	1	Low	$1,720,000	$149,000	$1,869,000
			High	$3,490,000	$315,000	$3,805,000
	1<DF≤20	0	Low	$0	$0	$0
			High	$0	$0	$0
	DF>20	0	Low	$0	$0	$0
			High	$0	$0	$0
	Totals	**23**	**Low**	**$26,120,000**	**$2,723,000**	**$28,843,000**
			High	**$40,090,000**	**$4,117,000**	**$44,207,000**

HUC8	Design Flow (DF) in MGD	Number of Facilities		Capital Costs	Annual O&M	Total
08020202 Upper St Francis	DF≤0.05	20	Low	$22,150,000	$2,340,000	$24,490,000
			High	$33,050,000	$3,440,000	$36,490,000
	0.05<DF≤1	1	Low	$1,720,000	$149,000	$1,869,000
			High	$3,490,000	$315,000	$3,805,000
	1<DF≤20	0	Low	$0	$0	$0
			High	$0	$0	$0
	DF>20	0	Low	$0	$0	$0
			High	$0	$0	$0
	Totals	**21**	**Low**	**$23,870,000**	**$2,489,000**	**$26,359,000**
			High	**$36,540,000**	**$3,755,000**	**$40,295,000**

HUC8	Design Flow (DF) in MGD	Number of Facilities		Capital Costs	Annual O&M	Total
10290108 South Grand	DF≤0.05	2	Low	$2,250,000	$234,000	$2,484,000
			High	$3,550,000	$362,000	$3,912,000
	0.05<DF≤1	0	Low	$0	$0	$0
			High	$0	$0	$0
	1<DF≤20	0	Low	$0	$0	$0
			High	$0	$0	$0
	DF>20	0	Low	$0	$0	$0
			High	$0	$0	$0
	Totals	**2**	**Low**	**$2,250,000**	**$234,000**	**$2,484,000**
			High	**$3,550,000**	**$362,000**	**$3,912,000**

Table A3. Full List of Impaired Lakes (projected) by HUC-8

HUC8	WBID	Water Body	Size (acres)
07110002	7015	Deer Ridge Community Lake	39.0
07110002	7011	Ella Ewing Community Lake	15.0
07110003	7026	Edina Reservoir	51.0
07110007	7031	Monroe City Lake	94.0
07110007	7034	Monroe City Lake B	55.0
07110008	7051	Vandalia Community Lake	35.0
07110009	7056	Busch W.A.- Kraut Run Lake	164.0
07140103	7288	Indian Lake	279.0
07140105	7273	Perry County Community Lake	89.0
08020202	7331	DiSalvo Lake	210.0
08020202	7332	Lake Killarney	61.0
08020202	7336	Lake Wappapello	8200.0
08020202	7328	Fredricktown City Lake	80.0
08020204	7341	Lake Tywappity	43.0
10240013	7076	Nodaway Lake	73.0
10280101	7386	Harrison County Lake	280.0
10280101	7105	Jamesport Community Lake	27.0
10280101	7438	Willow Brook Lake	53.0
10280202	7149	Sterling Price Community Lake	23.0
10290105	7234	Atkinson Lake	434.0
10290108	7208	Montrose Lake	1444.0
10290108	7218	North Lake	19.0
10290108	7213	Raintree Lake	248.1
10290108	7215	Garden City Lake	26.0
10290108	7214	Harrisonville City Lake	419.0
10290203	7241	Peaceful Valley Lake	158.0
10300101	7083	Ray County Community Lake	23.0
10300101	7086	Rocky Hollow Lake	20.0
10300102	7186	Ben Branch Lake	37.0
10300103	7187	Spring Fork Lake	178.0
10300104	7189	Blind Pony Lake	96.0
10300104	7192	Edwin A Pape Lake	272.5
10300104	7190	Higginsville Reservoir (South)	147.1
11070207	7356	Lamar Lake	148.0

Appendix B.

Permitted facilities impacted by Section 304(a) Criteria changes per 644.058, RSMo

Facilities that treat wastewater containing the Section 304(a) numeric water quality criteria being added or revised may be affected by the proposed changes. Facility data were queried from the MoCWIS in support of the July 24 and September 25, 2017, RIRs. Facility permit information was reviewed and validated prior to this analysis.

Table B1. Facilities with monitoring requirements or effluent limits for parameters in which the numeric criteria changed more than 25 percent by HUC-8. This includes *new* numeric criteria except for nutrients.

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
07110001	Landfills	Site-Specific	✓		1
	Motor Freight Transportation	Site-Specific	✓		1
	Motor Freight Transportation	Site-Specific		✓	1
	Landfills	Site-Specific		✓	1
	Farm Supplies	Site-Specific		✓	1
	Heavy Construction	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	3
07110002	Motor Vehicle Parts	MOR60A		✓	1
07110003	Lumber and Wood Products	MOR22A		✓	1
07110004	Concrete Products	Site-Specific	✓		1
	Concrete Products	Site-Specific		✓	1
	Municipal	Site-Specific		✓	1
	Heavy Construction	MOR203		✓	1
	Lumber and Wood Products	MOR22A		✓	1
	Primary Metal Industries	MOR203		✓	3
	Electrical Equipment	MOR203		✓	1
	Transportation Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	5
	Scrap and Recycling	MOR203		✓	1
07110005	Municipal	Site-Specific		✓	1
	Lumber and Wood Products	MOR22A		✓	1
	Motor Vehicle Parts	MOR60A		✓	1

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
07110006	Municipal	Site-Specific		✓	3
	Heavy Construction	MOR60A		✓	1
	Primary Metal Industries	MOR203		✓	1
	Fabricated Metal Products	MOR203		✓	2
	Electrical Equipment	MOR203		✓	3
	Motor Vehicle Parts	MOR60A		✓	4
07110007	Landfills	Site-Specific	✓		2
	Landfills	Site-Specific		✓	2
	Motor Vehicle Parts	MOR60A		✓	2
07110008	Landfills	Site-Specific	✓		1
	Concrete Products	Site-Specific		✓	1
	Municipal	Site-Specific		✓	4
	Landfills	Site-Specific		✓	1
	Primary Metal Industries	MOR203		✓	2
	Transportation Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	5
07110009	Municipal	Site-Specific	✓		2
	Electrical Equipment	Site-Specific		✓	1
	Municipal	Site-Specific		✓	2
	Primary Metal Industries	MOR203		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Industrial and Commercial Machinery	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	2

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
07140101	Municipal	Site-Specific	✓		3
	Petroleum Products	Site-Specific	✓		1
	Primary Metal Industries	Site-Specific		✓	1
	Railroad Transportations	Site-Specific		✓	1
	Water Transportation	Site-Specific		✓	1
	Municipal	Site-Specific		✓	4
	Scrap and Recycling	Site-Specific		✓	1
	Petroleum Products	Site-Specific		✓	1
	Primary Metal Industries	MOR203		✓	3
	Fabricated Metal Products	MOR203		✓	3
	Transportation Equipment	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	5
07140102	Metal Mining	Site-Specific	✓		3
	Primary Metal Industries	Site-Specific	✓		1
	Landfills	Site-Specific	✓		3
	Metal Mining	Site-Specific		✓	4
	Heavy Construction	Site-Specific		✓	1
	Primary Metal Industries	Site-Specific		✓	1
	Municipal	Site-Specific		✓	5
	Landfills	Site-Specific		✓	3
	Gasoline Service Stations	Site-Specific		✓	1
	Lumber and Wood Products	MOR22A		✓	3
	Primary Metal Industries	MOR203		✓	3
	Fabricated Metal Products	MOR203		✓	5
	Electrical Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	5
	Scrap and Recycling	MOR203		✓	1

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
07140103	Municipal	Site-Specific	✓		3
	Municipal	Site-Specific		✓	4
	Primary Metal Industries	MOR203		✓	1
	Industrial and Commercial Machinery	MOR203		✓	1
	Transportation Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	4
	Scrap and Recycling	MOR60A		✓	1
07140104	Landfills	Site-Specific	✓		1
	Drinking Water Supply	Site-Specific		✓	1
	Municipal	Site-Specific		✓	2
	Landfills	Site-Specific		✓	2
	Motor Vehicle Parts	MOR60A		✓	1
07140105	Landfills	Site-Specific	✓		1
	Municipal	Site-Specific		✓	1
	Landfills	Site-Specific		✓	1
	Gasoline Service Systems	Site-Specific		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Transportation Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	3
07140107	Municipal	Site-Specific		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Railroad Transportation	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	3
08010100	Transportation Equipment	MOR203		✓	1
08020201	Municipal	Site-Specific	✓		1
	Municipal	Site-Specific		✓	2
	Fabricated Metal Products	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	2
08020203	Municipal	Site-Specific	✓		1
	Municipal	Site-Specific		✓	2
	Transportation Equipment	MOR203		✓	1

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
08020204	Rubber and Plastic Products	Site-Specific	✓		1
	Landfills	Site-Specific	✓		1
	Rubber and Plastic Products	Site-Specific		✓	1
	Primary Metal Industries	Site-Specific		✓	1
	Fabricated Metal Products	Site-Specific		✓	1
	Municipal	Site-Specific		✓	3
	Landfills	Site-Specific		✓	1
	Primary Metal Industries	MOR203		✓	1
	Fabricated Metal Products	MOR203		✓	2
	Transportation Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	8
08020205	Primary Metal Industries	Site-Specific		✓	1
	Scrap and Recycling	MOR60A		✓	1
10240011	Farm Supplies	Site-Specific	✓		1
	Leather and Leather Products	Site-Specific		✓	1
	Air Transportation	Site-Specific		✓	1
	Municipal	Site-Specific		✓	3
	Gasoline Service Stations	Site-Specific		✓	1
	Fabricated Metal Products	MOR203		✓	2
	Electrical Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	2
	Scrap and Recycling	MOR203		✓	1
10240012	Municipal	Site-Specific		✓	1
	Landfills	Site-Specific		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Industrial and Commercial Machinery	MOR203		✓	3
	Electrical Equipment	MOR203		✓	1
	Transportation Equipment	MOR203		✓	1
10240013	Municipal	Site-Specific	✓		1
	Municipal	Site-Specific		✓	1
	Primary Metal Industries	MOR203		✓	2
	Fabricated Metal Products	MOR203		✓	1

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
10280101	Municipal	Site-Specific	✓		1
	Heavy Construction	MOR60A		✓	1
	Lumber and Wood Products	MOR22A		✓	1
	Primary Metal Industries	MOR203		✓	1
	Industrial and Commercial Machinery	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	2
10280102	Municipal	Site-Specific		✓	1
	Transportation Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	3
	Scrap and Recycling	MOR60A		✓	1
10280103	Heavy Construction	MOR203		✓	1
10280202	Landfills	Site-Specific	✓		1
	Landfills	Site-Specific		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	2
10280203	Landfills	Site-Specific	✓		2
	Landfills	Site-Specific		✓	2
	Fabricated Metal Products	MOR203		✓	1
	Transportation Equipment	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	4
10290102	Lumber and Wood Products	MOR22A		✓	1
10290104	Municipal	Site-Specific	✓		1
	Landfills	Site-Specific	✓		2
	Chemicals and Allied Products	Site-Specific		✓	1
	Municipal	Site-Specific		✓	1
	Landfills	Site-Specific		✓	2

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
10290106	Lumber and Wood Products	Site-Specific	✓		1
	Landfills	Site-Specific	✓		1
	Municipal	Site-Specific		✓	2
	Landfills	Site-Specific		✓	1
	Electronics	Site-Specific		✓	1
	Heavy Construction	MOR203		✓	3
	Fabricated Metal Products	MOR203		✓	1
	Industrial and Commercial Machinery	MOR203		✓	2
	Transportation Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	3
	Scrap and Waste Material	MOR60A		✓	1
10290107	Fabricated Metal Products	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	2
	Metals Service Centers	MOR203		✓	1
10290108	Lumber and Wood Products	Site-Specific	✓		1
	Landfills	Site-Specific	✓		2
	Lumber and Wood Products	Site-Specific		✓	1
	Municipal	Site-Specific		✓	2
	Landfills	Site-Specific		✓	2
	Heavy Construction	MOR22A		✓	1
	Lumber and Wood Products	MOR22B		✓	2
	Primary Metal Industries	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	6
	Scrap and Waste Material	MOR60A		✓	1
10290109	Municipal	Site-Specific		✓	1
	Furniture and Fixtures	MOR203		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Industrial and Commercial Machinery	MOR203		✓	1
	Transportation Equipment	MOR203		✓	4
	Motor Vehicle Parts	MOR60A		✓	3

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
10290110	Municipal	Site-Specific		✓	2
	Fish Hatcheries and Preserves	MOG13		✓	1
	Motor Vehicle Parts	MOR60A		✓	4
10290111	Municipal	Site-Specific		✓	1
	Carwashes	MOG75		✓	1
	Lumber and Wood Products	MOR22A		✓	1
	Chemicals and Allied Products	MOR22A		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	5
10290201	Landfills	Site-Specific	✓		1
	Municipal	Site-Specific		✓	3
	Landfills	Site-Specific		✓	1
	Carwashes	MOG75		✓	1
	Lumber and Wood Products	MOR22A		✓	1
	Electrical Equipment	MOR203		✓	1
	Transportation Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	2
10290202	Federal Sites	Site-Specific		✓	1
	Lumber and Wood Products	MOR22B		✓	1
	Motor Vehicle Parts	MOR60A		✓	1
10290203	Municipal	Site-Specific		✓	1

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
10300101	Railroad Transportations	Site-Specific	✓		1
	Municipal	Site-Specific	✓		5
	Landfills	Site-Specific	✓		2
	Scrap and Recycling	Site-Specific	✓		1
	Federal Sites	Site-Specific	✓		1
	Chemicals and Allied Products	Site-Specific	✓		1
	Chemicals and Allied Products	Site-Specific		✓	1
	Municipal	Site-Specific		✓	5
	Landfills	Site-Specific		✓	3
	Petroleum Products	Site-Specific		✓	1
	Real Estate	Site-Specific		✓	1
	Amusement Parks	Site-Specific		✓	1
	Federal Sites	Site-Specific		✓	1
	Chemicals	Site-Specific		✓	1
	Lumber and Wood Products	MOR22B		✓	1
	Primary Metal Industries	MOR203		✓	3
	Fabricated Metal Products	MOR203		✓	11
	Conveyors and Conveying	MOR203		✓	1
	Electrical Equipment	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	21
	Scrap and Waste Material	MOR60A		✓	5

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
10300102	Electric and Gas Services	Site-Specific	✓		1
	Drinking Water Supply	Site-Specific	✓		1
	Municipal	Site-Specific	✓		1
	Landfills	Site-Specific	✓		3
	Rubber and Plastic Products	Site-Specific		✓	
	Electric and Gas Services	Site-Specific		✓	1
	Drinking Water Supply	Site-Specific		✓	1
	Municipal	Site-Specific		✓	4
	Landfills	Site-Specific		✓	4
	Noncommercial Research	Site-Specific		✓	1
	Heavy Construction	MOR203		✓	1
	Concrete Products	MOR203		✓	1
	Fabricated Metal Products	MOR203		✓	4
	Electrical Equipment	MOR203		✓	2
	Transportation Equipment	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	31
10300103	Landfills	Site-Specific	✓		1
	Municipal	Site-Specific		✓	3
	Landfills	Site-Specific		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Transportation Equipment	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	3
10300104	Municipal	Site-Specific		✓	3
	Landfills	Site-Specific		✓	1
	Federal Sites	Site-Specific		✓	1
	Primary Metal Industries	MOR203		✓	1
	Fabricated Metal Products	MOR203		✓	2
	Electrical Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	6
	Scrap and Waste Material	MOR60A		✓	1

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
10300200	Electric and Gas Services	Site-Specific	✓		1
	Municipal	Site-Specific	✓		3
	Landfills	Site-Specific	✓		3
	Primary Metal Industries	Site-Specific		✓	1
	Transportation Equipment	Site-Specific		✓	1
	Air Transportation	Site-Specific		✓	1
	Municipal	Site-Specific		✓	6
	Landfills	Site-Specific		✓	3
	Gasoline Service Stations	Site-Specific		✓	1
	Real Estate	Site-Specific		✓	1
	Primary Metal Industries	MOR203		✓	2
	Fabricated Metal Products	MOR203		✓	4
	Industrial and Commercial Machinery	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	3
11010001	Heavy Construction	MOR203		✓	1
11010002	Municipal	Site-Specific	✓		1
	Fabricated Metal Products	Site-Specific		✓	1
	Electric and Gas Services	Site-Specific		✓	1
	Drinking Water Supply	Site-Specific		✓	1
	Municipal	Site-Specific		✓	2
	Lumber and Wood Products	MOR22A		✓	2
	Primary Metal Industries	MOR203		✓	1
	Fabricated Metal Products	MOR203		✓	5
	Industrial and Commercial Machinery	MOR203		✓	5
	Transportation Equipment	MOR203		✓	5
	Motor Vehicle Parts	MOR60A		✓	8
	Scrap and Waste Material	MOR60A		✓	1
11010003	Fish Hatcheries and Preserves	MOG13		✓	1
	Heavy Construction	MOR22B		✓	1
	Motor Vehicle Parts	MOR60A		✓	1

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
11010006	Fish Hatcheries and Preserves	MOG13		✓	1
	Motor Vehicle Parts	MOR60A		✓	1
11010007	Metal Mining	Site-Specific	✓		4
	Lumber and Wood Products	Site-Specific	✓		2
	Metal Mining	Site-Specific		✓	5
	Heavy Construction	MOR22B		✓	1
	Lumber and Wood Products	MOR22B		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Industrial and Commercial Machinery	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	6
11010008	Fish Hatcheries and Preserves	MOG13		✓	1
	Heavy Construction	MOR22A		✓	1
	Lumber and Wood Products	MOR22A		✓	1
	Fabricated Metal Products	MOR203		✓	1
	Industrial and Commercial Machinery	MOR203		✓	1
11010010	Chemicals and Allied Products	Site-Specific		✓	1
	Lumber and Wood Products	MOR22A		✓	1
	Electrical Equipment	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	2
11010011	Municipal	Site-Specific		✓	1
	Lumber and Wood Products	MOR22A		✓	2
	Lumber and Wood Products	MOR22B		✓	1
	Fabricated Metal Products	MOR203		✓	1
11070206	Food Products	Site-Specific		✓	1

HUC8	Facility type	Permit type	Decrease *more stringent*	Increase *less stringent*	Number of facilities
11070207	Municipal	Site-Specific	✓		3
	Landfills	Site-Specific	✓		2
	Food Products	Site-Specific		✓	1
	Electrical Equipment	Site-Specific		✓	1
	Municipal	Site-Specific		✓	10
	Landfills	Site-Specific		✓	2
	Heavy Construction	MOR203		✓	2
	Primary Metal Industries	MOR203		✓	3
	Fabricated Metal Products	MOR203		✓	9
	Industrial and Commercial Machinery	MOR203		✓	6
	Transportation Equipment	MOR203		✓	2
	Sporting and Athletic Goods	MOR203		✓	1
	Motor Vehicle Parts	MOR60A		✓	7
11070208	Lumber and Wood Products	MOR22A		✓	1
	Fabricated Metal Products	MOR203		✓	2
	Motor Vehicle Parts	MOR60A		✓	2

*Permits for facilities could contain parameters in which numeric criteria decreased more than 25 percent *and* parameters in which numeric criteria increased more than 25 percent. In these situations, the permit would be listed twice in the table above.
MOR = General Stormwater Permit.
MOG = General Other Permit.

Table B2. Site-specific permits that contain monitoring requirements or effluent limits for parameters in which the numeric criteria decreased more than 25 percent *(more stringent)* by HUC-8. This includes *new* numeric criteria except for nutrients.

HUC8	Permit number	Facility name	Facility type
07110001	MO0136514	TNT General Contracting, Inc.	Motor Freight Transportation
	MO0110833	Backridge Landfill	Landfills
07110004	MO0111686	Continental Cement Company	Concrete Products
07110007	MO0111996	Eagle Ridge Landfill	Landfills
	MO0112721	Hannibal Sanitary Landfill	Landfills
07110008	MO0108103	JZ Disposal Demo Landfill	Landfills
07110009	MO0028720	O'Fallon WWTP	Municipal
	MO0058343	St. Charles-Mississippi River WWTF	Municipal
07140101	MO0025151	MSD, Lemay WWTP	Municipal
	MO0025178	MSD, Bissell Point WWTP	Municipal
	MO0027111	Herculaneum WWTP	Municipal
	MO0111805	Kiesel Marine	Petroleum Products
07140102	MO0000574	Pea Ridge Resources	Metal Mining
	MO0000086	Doe Run, Viburnum Operations	Metal Mining
	MO0100226	Doe Run, Viburnum Mine #35 Casteel	Metal Mining
	MO0000337	Buick Resource Recycling Facility	Primary Metal Industries
	MO0110205	Interstate Disposal System	Landfills
	MO0110779	Peerless Demolition Landfill	Landfills
	MO0113000	Advanced Disposal Landfill	Landfills
07140103	MO0025283	Union West WWTF	Municipal
	MO0099465	St. Clair WWTF	Municipal
	MO0104736	Sullivan WWTP	Municipal
07140104	MO0108774	St. Francois County Environmental	Landfills
07140105	MO0115304	Perry County Landfill	Landfills
08020201	MO0120081	Charleston WWTF	Municipal
08020203	MO0050326	Bloomfield WWTF	Municipal
08020204	MO0000388	Leggett and Platt, Inc.	Rubber and Plastic Products
	MO0113891	Lemons Landfill East	Landfills

HUC8	Permit number	Facility name	Facility type
10240011	MO0135747	HPI Products, Inc.	Farm Supplies
10240013	MO0033286	Maryville WWTP	Municipal
10280101	MO0108227	Chillicothe WWTP	Municipal
10280202	MO0119741	Rye Creek Landfill	Landfills
10280203	MO0108723	Moberly Sanitary Landfill	Landfills
	MO0117471	Maple Hill Landfill	Landfills
10290104	MO0089109	Nevada WWTF	Municipal
	MO0111082	3M Commercial Graphics	Landfills
	MO0121045	Prairie View Regional Waste Facility	Landfills
10290106	MO0117331	Former Tronox Facility	Lumber and Wood Products
	MO0106658	Springfield Sanitary Landfill	Landfills
10290108	MO0111325	International Paper	Lumber and Wood Products
	MO0108464	Ellis – Scott Sanitary Landfill	Landfills
	MO0110876	Lee's Summit Resource Recovery Park	Landfills
10290201	MO0107506	Black Oak Landfill	Landfills
10300101	MO0115703	KCSR, One Spot Repair	Railroad Transportations
	MO0024911	KC, Blue River WWTF	Municipal
	MO0024929	KC, Westside WWTP	Municipal
	MO0049531	KC, Birmingham WWTF	Municipal
	MO0089681	Independence Rock Creek WWTF	Municipal
	MO0101087	LBVSD, Atherton WWTP	Municipal
	MO0099503	BFI Missouri City Landfill	Landfills
	MO0123790	Centropolis Landfill	Landfills
	MO0115801	Advantage Metals Recycling	Scrap and Recycling
	MO0004863	Bannister Facility	Federal Sites
	MO0108472	Conservation Chemical Company	Chemicals and Allied Products
10300102	MO0004979	Columbia Municipal Power Plant	Electric and Gas Services
	MO0136034	Columbia WTP	Drinking Water Supply
	MO0097837	Columbia WWTP	Municipal
	MO0112640	Columbia Landfill and Yard Waste	Landfills
	MO0113352	Fulton Sanitary Landfill	Landfills
	MO0114375	Jefferson City Landfill	Landfills

HUC8	Permit number	Facility name	Facility type
10300103	MO0104540	Central Missouri Landfill	Landfills
10300200	MO0114804	Laclede Gas Company	Electric and Gas Services
	MO0025810	Washington WWTP	Municipal
	MO0045420	Gerald WWTF	Municipal
	MO0058351	St. Charles Missouri River WWTP	Municipal
	MO0097543	IESI MO Champ Landfill	Landfills
	MO0112771	Bridgeton Landfill	Landfills
	MO0121975	Washington SLF Silt Pond	Landfills
11010002	MO0049522	Springfield SW WWTP	Municipal
11010007	MO0001848	Doe Run, Brushy Creek Mine and Mill	Metal Mining
	MO0001856	Doe Run, Fletcher Mine and Mill	Metal Mining
	MO0001881	Doe Run, Sweetwater	Metal Mining
	MO0100218	Doe Run, West Fork	Metal Mining
	MO0127931	Missouri Tie, LLC	Lumber and Wood Products
	MO0122718	Mill Spring Chip Plant	Lumber and Wood Products
11070207	MO0023256	Joplin Shoal Creek WWTP	Municipal
	MO0103349	Joplin Turkey Creek WWTF	Municipal
	MO0104906	Neosho WWTP	Municipal
	MO0108731	Joplin Municipal Landfill	Landfills
	MO0110272	Lamar Closed Sanitary Landfill	Landfills

Appendix C.

Estimations of Population Growth Rates and Median Household Incomes for 66 Watersheds at the Eight-digit Hydrological Unit Level in the State of Missouri

1. Introduction

Implementing more stringent water quality standards contributes to a more healthy and functional ecosystem which in turn supplies greater ecosystem benefits and natural resources to human societies residing in or visiting the watershed. On the other hand, implementing more stringent water quality standards potentially requires local industries to allocate additional funds from their profits to upgrade their wastewater treatment systems and requires local residents to allocate a greater portion of their expendable incomes to pay for the services of upgraded public wastewater treatment systems. It challenges local governments to channel financial capital and direct human capital more effectively in terms of taxation and public financing policies to support wastewater treatment infrastructure updates. It also requires regulatory agencies to consider potential financial assistance and flexible schedules of compliance for wastewater treatment infrastructure updates by the regulated communities.

From this perspective, in implementing water quality standards, it is important to consider the needs for upgrading wastewater treatment infrastructure and the financial capabilities of industries and local residents to finance these upgrades at the watershed scale. The watershed approach is appropriate since water quality of any given waterbody in Missouri is directly affected by water received from the upstream watershed. Therefore, it is an appropriate and applicable approach to analyze impacts of water quality standard implementation at a subbasin watershed scale.

Positively correlated to the need for upgrading wastewater treatment infrastructure, population growth is a key socioeconomic indicator reflecting the demographic change of a community over time. The indicator of population growth rate can be calculated based on time-series data for population. The indicator of population at the watershed scale is an average-based indicator and can be estimated through aggregating data in a statistical unit into a watershed unit.

Positively correlated to the financial capabilities of industries and local residents to finance the costs for upgrading wastewater treatment infrastructure, median household income (MHI) is a key socioeconomic indicator measuring the economic wealth of a community. MHI is represented by the "middle value" of the series of all household incomes in the community. MHI is not an average-based indicator but a distribution-based indicator. In other words, it is not feasible to estimate MHIs at the watershed scale through aggregating data in a statistical unit into a watershed unit but it requires a specific estimation approach to analyze the distributions of household incomes.

To support the analysis of the socioeconomic impacts of implementing water quality standards in Missouri per Section 644.058 of the Revised Statutes of Missouri (Box 1-1), this in-depth analysis develops a method of estimating population growth rates and MHIs for Missouri and the individual watersheds identified at the eight-digit hydrological unit level ("HUC-8 watersheds") in Missouri. This analysis elaborates the estimation methods which can be replicated, the socioeconomic data sources which are published by the U.S. Census Bureau, the results for both indicators for Missouri and for all individual HUC-8 watersheds in Missouri, and the implications for water quality standard implementation. The individual and trend results are presented in the forms of interconnected data tables, data charts, and geographic information system (GIS) maps.

Box 1-1. Statutory Requirement of Section 644.058 of the Revised Statutes of Missouri[1]

Chapter 644 Water Pollution

644.058. Water quality standards revised, when — evaluation to be conducted, when. — Notwithstanding the provisions of section 644.026 to the contrary, in promulgating water quality standards, the commission shall only revise water quality standards upon the completion of an assessment by the department finding that there is an environmental need for such revision. As part of the implementation of any revised water quality standards modifications of twenty-five percent or more, the department shall conduct an evaluation which shall include the environmental and economic impacts of the revised water quality standards and criteria on a subbasin basis. This evaluation shall be conducted at the eight-digit hydrologic unit code level. The department shall document these evaluations and use them in making individual site-specific permit decisions.

(L. 2014 S.B. 642 merged with S.B. 664)

The rest of the analysis is composed of the following components indexed with page numbers.

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   2.1 Identifying HUC-8 Watersheds ..... Page 3
   2.2 Specifying Statistical Units ..... Page 4
   2.3 Assigning Statistical Units to HUC-8 Watersheds ..... Page 5
   2.4 Estimating MHI ..... Page 8
   2.5 Estimating Population Growth ..... Page 13
3. Results and Implications ..... Page 15
   3.1 Individual Data Charts and GIS Maps ..... Page 15
   3.2 Summary Table ..... Page 83
   3.3 Trends in GIS Maps ..... Page 85
   3.4 Implications for Water Quality Standard Implementation ..... Page 88
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Appendix: Communication of Requests Page 92

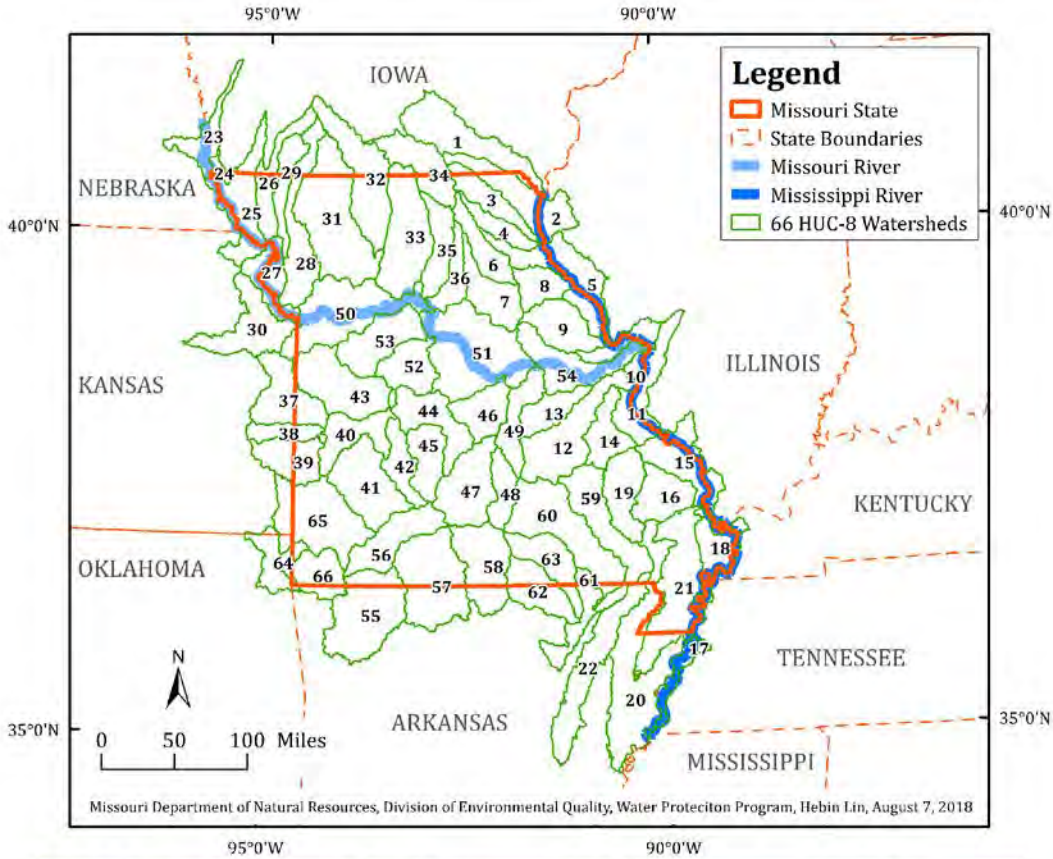
In this analysis, data tables and data charts are designed based on socioeconomic data sources footnoted throughout the analysis. GIS maps are designed based on the individual and trend results as well as the GIS database maintained by Missouri Department of Natural Resources ("the Department"). In this analysis, population growth rates refer to annual population growth rates between the years of 1990 and 2016. Household incomes refer to annual household incomes in the year 2016 and MHIs refer to annual MHIs in the year 2016, both in 2016 US dollars. HUC-8 watersheds refer to HUC-8 watersheds located completely or partially in Missouri.

[1] Source: http://revisor.mo.gov/main/OneSection.aspx?section=644.058&bid=31237&hl=, accessed on July 7, 2018.

2. Estimation Methods and Data Sources

2.1 Identifying HUC-8 Watersheds

Based on the GIS database maintained by the Department, 66 HUC-8 watersheds in Missouri are identified (Map 2-1). Each watershed is indexed with an ID number between 1 and 66. Their respective geographical boundaries and IDs are presented in the upper part of Map 2-1 whereas their respective names and IDs are listed in the table at the lower part of Map 2-1 in the ascending order of their HUC-8 codes. The HUC-8 codes are not included on Map 2-1 but will be presented in Section 3.



ID	HUC-8 Name	ID	HUC-8 Name	ID	HUC-8 Name	ID	HUC-8 Name
1	Lower Des Moines	18	New Madrid-St. Johns	34	Upper Chariton	51	Lower Missouri-Moreau
2	Bear-Wyaconda	19	Upper St. Francis	35	Lower Chariton	52	Lamine
3	North Fabius	20	Lower St. Francis	36	Little Chariton	53	Blackwater
4	South Fabius	21	Little River Ditches	37	Lower Marais Des Cygnes	54	Lower Missouri
5	The Sny	22	Cache	38	Little Osage	55	Beaver Reservoir
6	North Fork Salt	23	Keg-Weeping Water	39	Marmaton	56	James
7	South Fork Salt	24	Nishnabotna	40	Harry S. Truman Reservoir	57	Bull Shoals Lake
8	Salt	25	Tarkio-Wolf	41	Sac	58	North Fork White
9	Cuivre	26	Nodaway	42	Pomme De Terre	59	Upper Black
10	Peruque-Piasa	27	Independence-Sugar	43	South Grand	60	Current
11	Cahokia-Joachim	28	Platte	44	Lake of the Ozarks	61	Lower Black
12	Meramec	29	One Hundred and Two	45	Niangua	62	Upper White-Spring
13	Bourbeuse	30	Lower Kansas	46	Lower Osage	63	Eleven Point
14	Upper Mississippi-Big	31	Upper Grand	47	Upper Gasconade	64	Lake O' The Cherokees
15	Upper Mississippi-Cape Girardeau	32	Thompson	48	Big Piney	65	Neosho-Spring
16	Whitewater	33	Lower Grand	49	Lower Gasconade	66	Elk
17	Lower Mississippi-Memphis			50	Lower Missouri-Crooked		

Map 2-1. Geographic Locations and Names of 66 HUC-8 Watersheds in Missouri

2.2 Specifying Statistical Units

This analysis utilizes the following definitions published by the U.S. Census Bureau.

- *Household*[2]: A household includes all the people who occupy a housing unit (such as a house or apartment) as their usual place of residence. A household includes the related family members and all the unrelated people, if any, such as lodgers, foster children, wards, or employees who share the housing unit. A person living alone in a housing unit, or a group of unrelated people sharing a housing unit such as partners or roomers, is also counted as a household. The count of households excludes group quarters. There are two major categories of households, "family" and "nonfamily." Household is a standard item in Census Bureau population tables.
- *Household income*[3]: is the sum of the income of all people 15 years and older living in the household.
- *Median (household) income*[4]: is the amount which divides the (household) income distribution into two equal groups, one having (household) incomes above the median, and the other having (household) incomes below the median.

Two initial challenges exist in estimating MHI for a watershed. Firstly, data for MHI are generally calculated and published for statistical units, such as county and city, and not watershed units. Secondly, MHI is by definition not an average-based indicator but a distribution-based indicator. Hence, it is necessary to investigate the household income distribution data and to geographically assign statistical units to watershed units. Generally, the smaller the statistical unit, the more accurate the estimation for MHI.

In order to estimate a reasonably accurate and most recent value of MHI for each of the 66 HUC-8 watershed, the census block group is chosen as the primary statistical unit whereas the census block is chosen as a complementary statistical unit in this analysis. This is based on the data availability for census blocks and census block groups published by the U.S. Census Bureau, as described below.

- *Census block*[5]: A statistical area bounded by visible features, such as streets, roads, streams, and railroad tracks, and by nonvisible boundaries, such as selected property lines and city, township, school district, and county boundaries. A block is the smallest geographic unit for which the Census Bureau tabulates decennial census data.
- *Census block group*[6]: A statistical subdivision of a census tract, generally defined to contain between 600 and 3,000 people and 240 and 1,200 housing units, and the smallest geographic unit for which the Census Bureau tabulates sample data.

Specifically, data for population, described below, are available at both census block level and census block group level whereas data for household incomes are available at census block group level but not available at census block level.

- Population[7]: includes all people, male and female, child and adult, living in a given geographic area.

[2] Source: U.S Census Bureau, https://www.census.gov/glossary/#term_Household, accessed on July 7, 2018.
[3] Source: U.S Census Bureau, https://www.census.gov/glossary/#term_Householdincome, accessed on July 7, 2018.
[4] Source: U.S Census Bureau, https://www.census.gov/glossary/#term_Median, accessed on July 7, 2018.
[5] Source: U.S Census Bureau, https://www.census.gov/glossary/#term_Block, accessed on July 7, 2018.
[6] Source: U.S Census Bureau, https://www.census.gov/glossary/#term_BlockGroupBG, accessed on July 7, 2018.
[7] Source: U.S Census Bureau, https://www.census.gov/glossary/#term_Population, accessed on July 7, 2018.

2.3 Assigning Statistical Units to HUC-8 Watersheds

Based on the GIS database maintained by Missouri Department of Natural Resources, 4,506 census block groups are identified (Map 2-2). Each of the 4,506 census group IDs is assigned to one and only one of the 66 HUC-8 watersheds using the tool of Spatial Join in GIS based on the criteria that the geographical centroid of the census group is located within the boundary of the HUC8-watershed. In other words, the information contained in all the census block groups is completely and exclusively reflected at the watershed level. Except the following three very small HUC-8 watersheds, each of the rest 63 HUC-8 watersheds contains at least one census group.

- Lower Des Moines watershed (located in the northeast corner of Missouri; No. 1 on Map 1)
- Keg-Weeping Water watershed (located in the northwest corner of Missouri; No. 23 on Map 1)
- Nishnabotna watershed (located in the northwest corner of Missouri; No. 24 on Map 1)

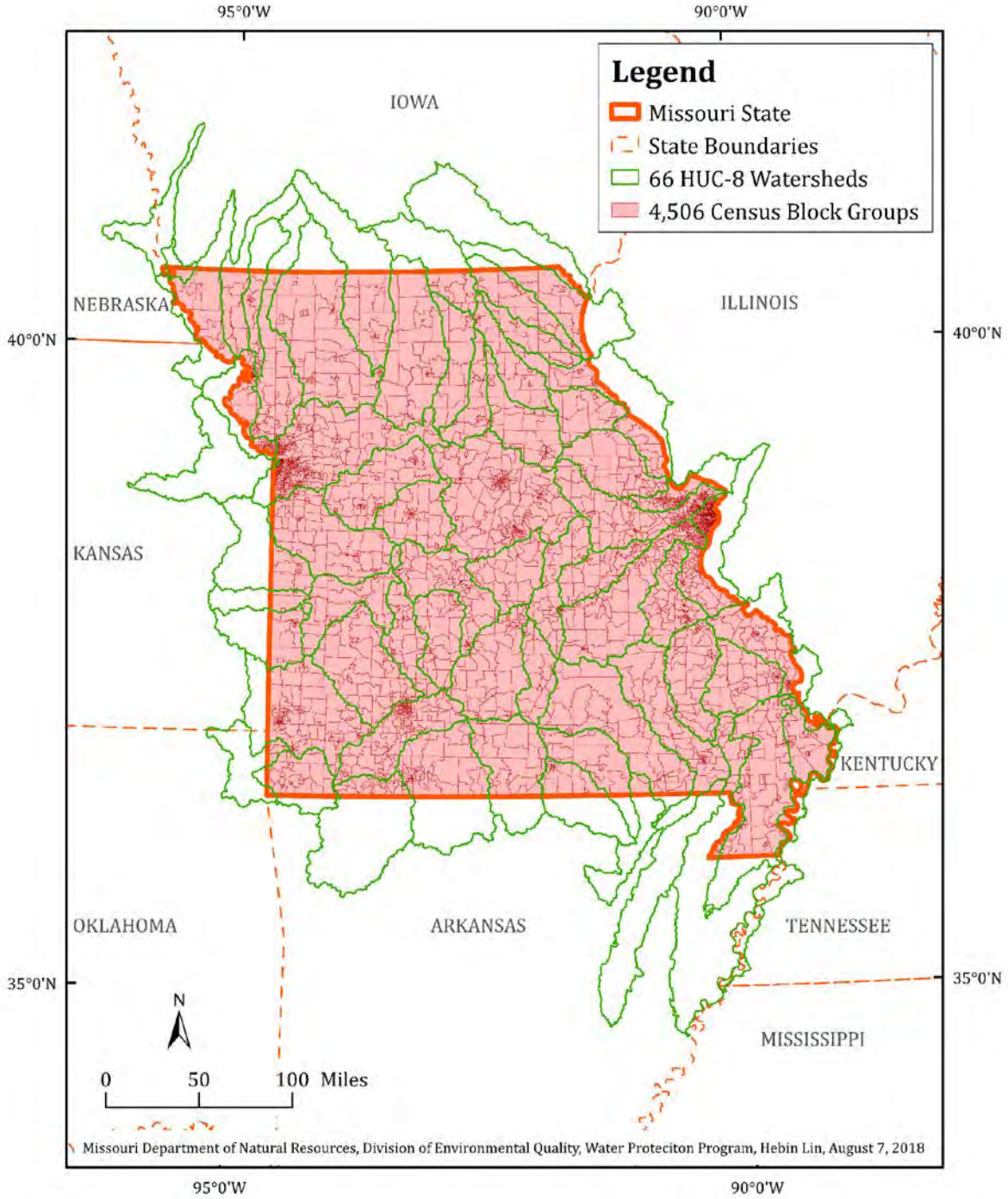
This generates another challenge. Namely, data for these three HUC-8 watersheds are not available based on the approach of choosing the statistical unit of census block group. This challenge is overcome through the following adjustments.

In terms of MHI, since the census block group with GEO ID 290459502002 covers the entirety of the Lower Des Moines watershed and part of the Bear-Wyaconda watershed (Map 2-3), the MHI for the Lower Des Moines watershed will be approximated by the MHI for the census block group 290459502002. MHI for Bear-Wyaconda watershed will be approximated by the MHI for the census block group 290459502002 as well as another 12 census block groups. Similarly, since the census block group with GEO ID 290059502002 covers the entirety of the Keg-Weeping Water watershed, the entirety of the Nishnabotna watershed, and part of Tarkio-Wolf watershed (Map 2-4), MHIs for both the Keg-Weeping Water watershed and the Nishnabotna watershed will be approximated by the MHI for the census block group with GEO ID 290059502002. The MHI for the Tarkio-Wolf watershed will be approximated by the MHI for the census block group with GEO ID 290059502002 as well as another 12 census block groups.

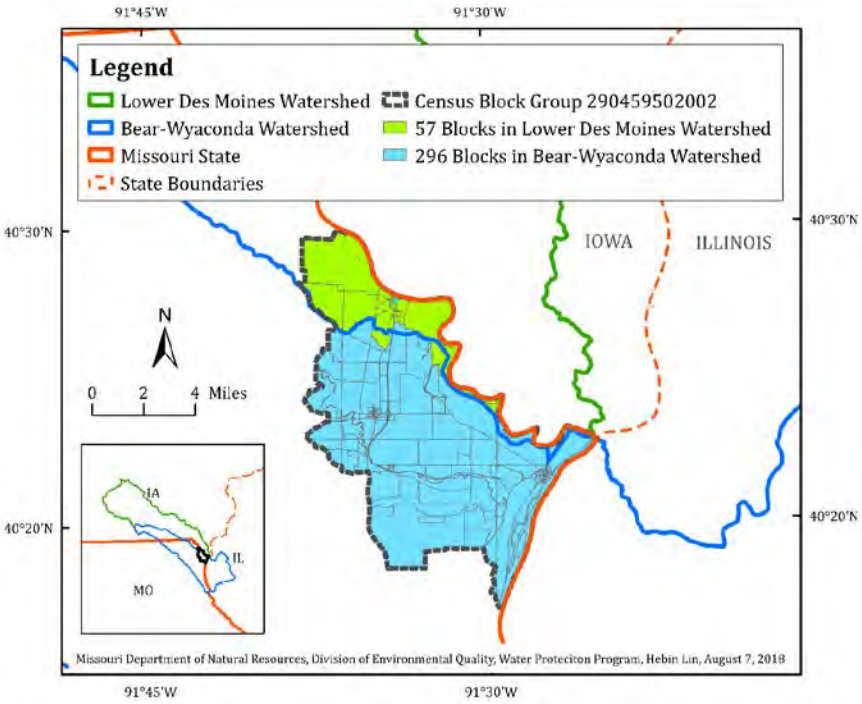
In terms of population, since population data are available on the census block level, population for these three small HUC-8 watersheds and the two related HUC-8 watersheds will be estimated based on data at the census block level. Based on the GIS database maintained by Missouri Department of Natural Resources, 353 census blocks in the census block group with GEO ID 290459502002 are identified (Map 2-3). Each of the 353 census block IDs is assigned to either Lower Des Moines watershed or Bear-Wyaconda watershed, using the tool of Spatial Join in GIS based on the criteria that the geographical centroid of the census group is located within the boundary of the HUC-8 watershed. This results in 57 census blocks containing a population of 283 in the year 2010 in the Lower Des Moines watershed and 296 census blocks containing a population of 1201 in the year 2010 in the Bear-Wyaconda watershed. In other words, the ratio of population within this census block between the two watersheds is 19%:81%. This ratio will be used to approximate population within this census block between the two watersheds for the years 1990, 2000 and 2016. In summary, population for Lower Des Moines watershed will be approximated by 19% of population for the census block group 290459502002. Population for Bear-Wyaconda watershed will be approximated by 81% of population for the census block group 290459502002 as well as population for another 12 census block groups.

Similarly, based on the GIS database maintained by the Department, 315 census blocks in the census block group with GEO ID 290059502002 are identified (Map 2-4). Each of the 315 census block IDs is assigned to the Keg-Weeping Water watershed, the Nishnabotna watershed or the Tarkio-Wolf watershed, using the tool of Spatial Join in GIS based on the criteria that the geographical centroid of the census group is located within the boundary of the HUC-8 watershed. This results in 14 census blocks containing a population of 6 in the year 2010 in the Keg-Weeping Water watershed, 157 census blocks containing a population of 200 in the year 2010 in the Nishnabotna watershed, and 144 census blocks containing a population of 328 in the year 2010 in the

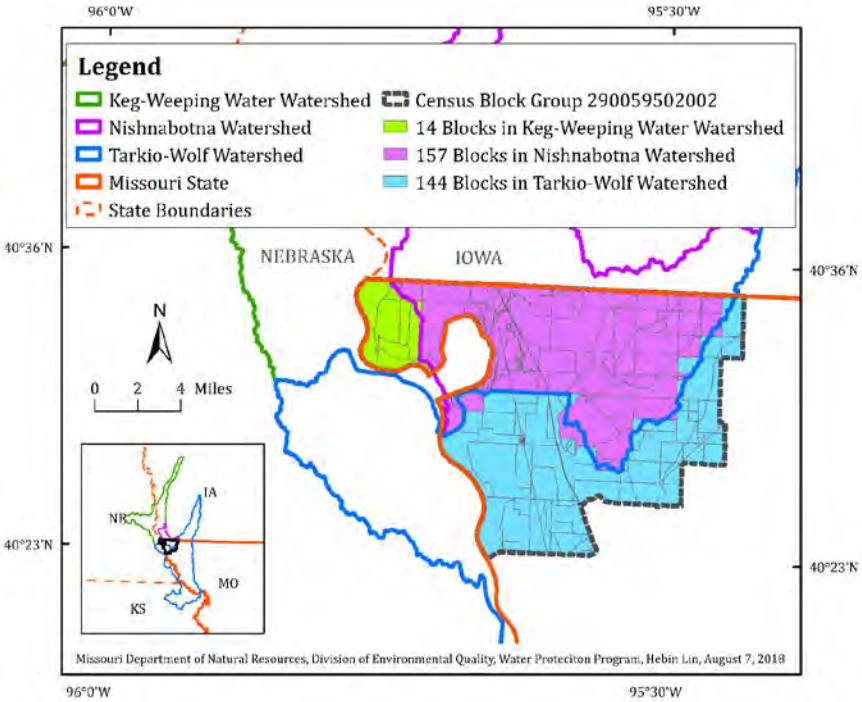
Tarkio-Wolf watershed. In other words, the ratio of population within this census block among the three watersheds is 1%:37%:61%. This ratio will be used to approximate the population within this census block among the three watersheds for the years 1990, 2000 and 2016. In summary, the population for the Keg-Weeping Water watershed will be approximated by 1% of population for the census block group 290059502002. The population for the Nishnabotna watershed will be approximated by 37% of population for the census block group 290059502002. The population for the Tarkio-Wolf watershed will be approximated by 61% of the population for the census block group 290059502002 as well as the population for another 12 census block groups.



Map 2-2. Geographic Locations of the 4,506 Census Block Groups in Missouri



Map 2-3. Census Block Group with GEO ID 290459502002



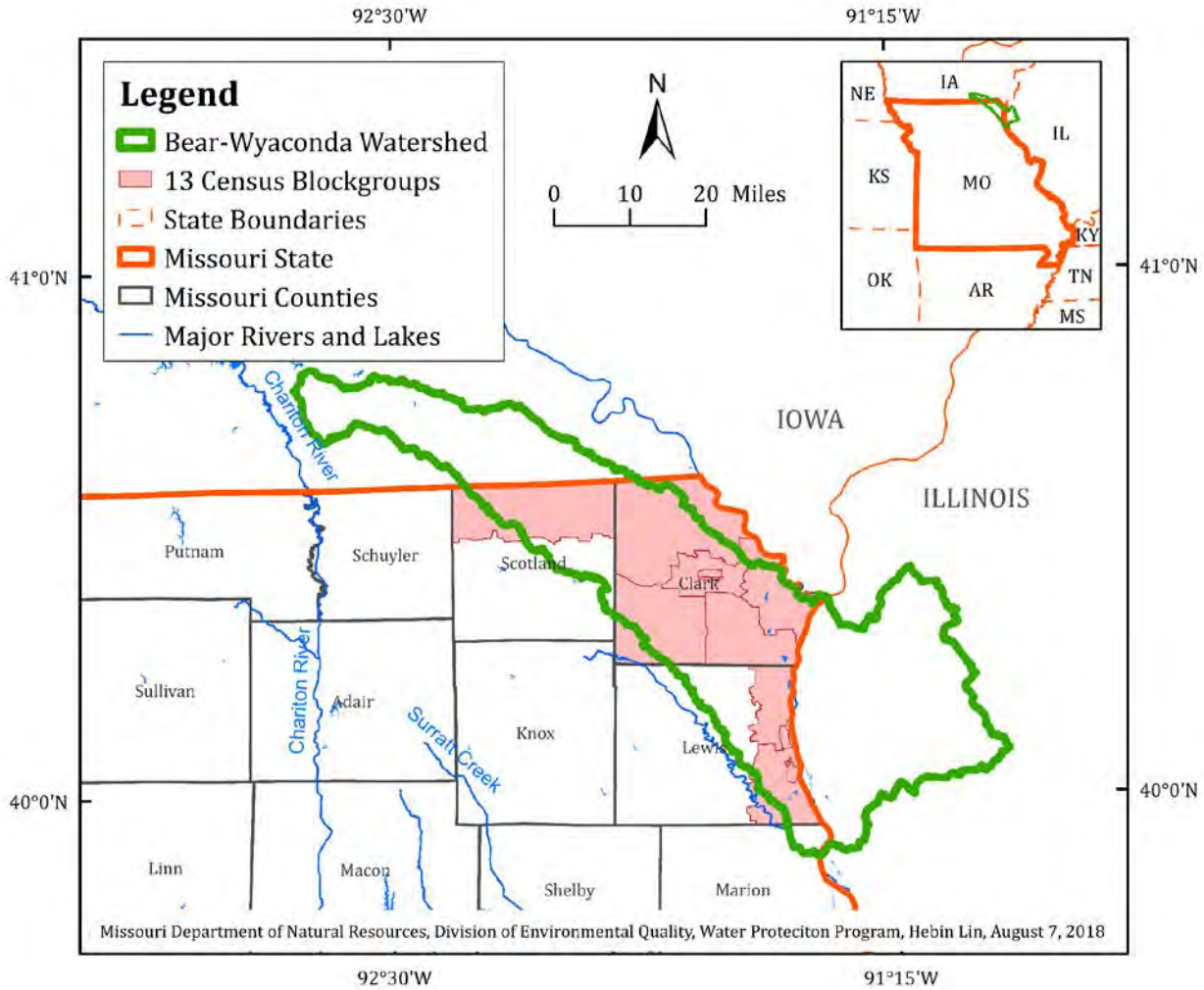
Map 2-4. Census Block Group with GEO ID 290059502002

2.4 Estimating MHI

The following four steps are taken to complete estimating the MHIs for each of the 66 HUC-8 watersheds.

- Step 1. Compiling data for distributions of household incomes at the census block group level
- Step 2. Aggregating data to form a sorted distribution of household incomes at the watershed level
- Step 3. Identifying the median income range
- Step 4. Estimating MHI using a linear function within the median income range

These steps will be illustrated using one of the HUC-8 watersheds – the Bear-Wyaconda watershed (No. 2 on Map 1). The Bear-Wyaconda watershed is located on the northeast corner of Missouri (Map 2-5). It contains 13 census block groups, the centroids of which are located within the boundary of the watershed, including 1, 7 and 5 census block groups within Scotland County, Clark County, and Lewis County, respectively.



Map 2-5. Locations of the 13 Census Block Groups in the Bear-Wyaconda Watershed

Step 1. Compiling data for distributions of household incomes at the census block group level

Data for distributions of household incomes in the latest year (2016) for all 4,506 census block groups were downloaded from the Missouri Census Data Center through the UEXPLORE electronic data archive[8] which extracts data from the U.S. Census Bureau's American Community Surveys. These data correspond to the data contained in Table B19001 "HOUSEHOLD INCOME IN THE PAST 12 MONTHS (IN 2016 INFLATION-ADJUSTED DOLLARS), 2012-2016 American Community Survey 5-Year Estimates" published at the U.S. Census Bureau's American Community Survey website. The data in Table B19001 present the numbers of households in each of 16 income ranges, with the lowest income range being "less than $10,000" and highest income range being "$200,000 or more." The household income data downloaded from the Missouri Census Data Center contain the same information in a more compact form such that the 14 income ranges in the middle of the distribution are presented as 8 income ranges.

An example of Table B19001 for Scotland County is provided in Figure 2-1. The first census block group in Figure 2-1, namely, "Block Group 1, Census Tract 4801, Scotland County, Missouri" corresponds to the census block group in the Bear-Wyaconda Watershed which is located within Scotland County (Map 2-5). In the U.S Census Bureau data system, this census block group is given a 12-digit GEO ID as "29-199-4801-001," representing the exact statistical unit of "state ID (29) - county ID (199) - census tract ID (4801) - block group ID (001)." In this census block group, among the 252 households, 39 households are in the lowest household income range and 23 households in the highest household income range, and so on.

https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_16_5YR_B19001&prodType=table

American FactFinder - Resu...

Versions of this table are available for the following years:
2016
2015
2014
2013

1 - 17 of 17

	Block Group 1, Census Tract 4801, Scotland County, Missouri Estimate	Block Group 2, Census Tract 4801, Scotland County, Missouri Estimate	Block Group 3, Census Tract 4801, Scotland County, Missouri Estimate	Block Group 4, Census Tract 4801, Scotland County, Missouri Estimate	Block Group 1, Census Tract 4802, Scotland County, Missouri Estimate	Block Group 2, Census Tract 4802, Scotland County, Missouri Estimate
Total	252	244	188	244	300	343
Less than $10,000	39	1	0	27	89	19
$10,000 to $14,999	0	35	0	18	17	19
$15,000 to $19,999	8	16	17	7	7	21
$20,000 to $24,999	0	3	12	29	35	44
$25,000 to $29,999	27	15	4	26	14	32
$30,000 to $34,999	8	6	0	16	11	0
$35,000 to $39,999	15	4	12	11	18	34
$40,000 to $44,999	0	44	32	23	11	4
$45,000 to $49,999	19	17	6	9	7	21
$50,000 to $59,999	21	2	5	6	17	30
$60,000 to $74,999	23	23	51	23	18	49
$75,000 to $99,999	44	5	24	9	39	30
$100,000 to $124,999	0	25	10	6	0	34
$125,000 to $149,999	16	17	0	0	6	6
$150,000 to $199,999	9	11	0	30	11	0
$200,000 or more	23	20	15	4	0	0

Figure 2-1. Data for Distribution of Household Incomes at the Census Block Group Level[9]

[8] Source: Missouri Census Data Center, http://mcdc.missouri.edu/cgi-bin/broker?_PROGRAM=websas.uex2dex.sas&_SERVICE=appdev&path=/pub/data/acs2016&dset=usmcdcprofiles5yr&view=0, accessed on July 7, 2018.

[9] Source: U.S Census Bureau, https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_16_5YR_B19001&prodType=table, accessed on July 7, 2018.

Step 2. Aggregating data to form a sorted distribution of household incomes at the watershed level

For the three very small HUC-8 watersheds specified in Section 2.3, the distributions of household incomes are based on a single census block group. For each of the rest 63 HUC-8 watersheds, the distributions of household incomes were aggregated using data from all the respective census block groups assigned to each watershed. Specifically, the numbers of households within each of the 10 income ranges for a HUC-8 watershed are aggregated using the numbers of households within each of the 10 income ranges from all the respective census block groups assigned to the watershed. When the aggregated distribution is sorted in the ascending order of income ranges, the income of the household at the exact middle point or the median location of the distribution (the "median household") becomes the MHI for the watershed, based on the definition of MHI. That is, MHI is the amount which divides the household income distribution into two equal groups, one having household incomes above the median, and the other having household incomes below the median.

In the case of the Bear-Wyaconda watershed, the distribution of household incomes is aggregated using distributions of household incomes from 13 census block groups. This results in 5,031 households in total (Table 2-1, Figure 2-2). After sorting the distribution of household incomes in ascending order of income ranges, each household is denoted by an integer from 1 to 5,031 which corresponds to its location in the distribution. Then each income range can be denoted by the "lower end location" and the "higher end location." For example, the second highest income range of "$150,000 to $199,999" has a "lower end location" of 4,815 and a "higher end location" of 4,952. In both Table 2-1 and Figure 2-2, "$150,000 to $199,999" is presented with zero decimal point and in the unit of thousand dollars, hence "$150-$199."

Table 2-1. Distribution of Household Incomes in the Bear-Wyaconda Watershed

Income Range (Thousand US$)	$0 -$9	$10 -$14	$15 -$24	$25 -$34	$35 -$49	$50 -$74	$75 -$99	$100 -$149	$150 -$199	$200 +
Number of Households	382	298	640	677	741	1,032	559	485	138	79
Accumulated Number of Households	382	680	1,320	1,997	2,738	3,770	4,329	4,814	4,952	5,031
Lower End Position	1	383	681	1,321	1,998	2,739	3,771	4,330	4,815	4,953
Higher End Position	382	680	1,320	1,997	2,738	3,770	4,329	4,814	4,952	5,031

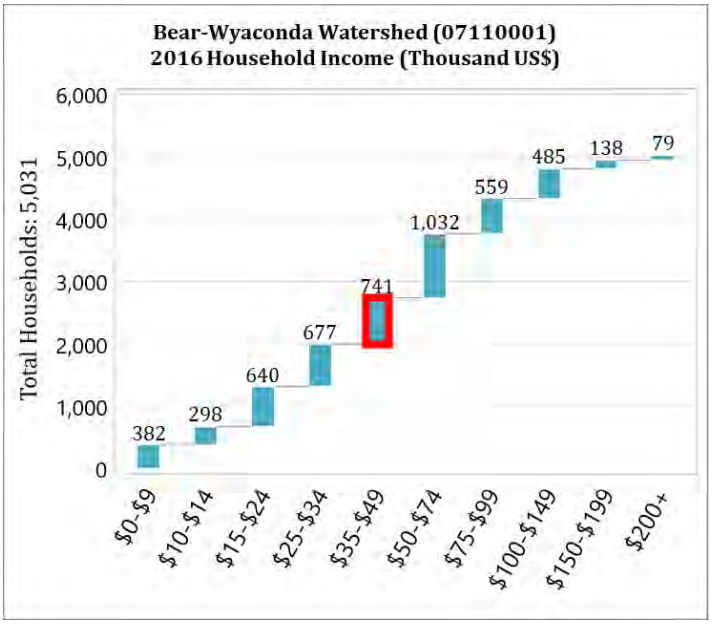


Figure 2-2. Distribution of Household Income in the Bear-Wyaconda Watershed

Step 3. Identifying the median income range

Since the household income data are available only in the form of income ranges and not individual incomes, in order to identify the income of the "median household," it is necessary to identify the income range which contains the "median household;" this income range is denoted as the "median income range." Therefore, the "lower end location" of the "median income range" should be less than the median location of the distribution; at the same time, the "higher end location" of the "median income range" should be greater than the median location of the distribution. This confinement is sufficient to identify the "median income range."

In the case of the Bear-Wyaconda watershed, the MHI for this watershed is the income of the "median household" in the median location of this distribution; that is, in location 2,516. The fifth income range "$35,000 - $49,999" which has a "lower end location" of 1,998 and a "higher end location" of 2,738 is the "median income range" because 2,516 is greater than 1,998 and less than 2,738. This "median income range" is highlighted with a red box in Figure 2-2.

Step 4. Estimating MHI using a linear function within the median income range

Within the "median income range," a linear correspondence between a household income and the household location in the distribution of household incomes is assumed. The MHI, or the income of the "median household" for the watershed can be pinpointed through the following linear projection.

$$y = \boldsymbol{\alpha} x + \boldsymbol{\beta}$$

$$x: household\ income$$

$$y: location\ of\ the\ household\ in\ the\ houseld\ income\ distribution$$

The coefficients $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are estimated using two correspondences; namely, the "lower end location" corresponding to the "lower end income" and the "higher end location" corresponding to the "higher end income" which are specified as follows.

$$(x_1, y_1) = (lower\ end\ income, lower\ end\ location)$$

$$(x_2, y_2) = (higher\ end\ income, higher\ end\ location)$$

Consequently, the MHI for the watershed is the value of x when y is the middle point of the distribution of the household incomes.

In the case of the Bear-Wyaconda watershed, the "median income range" highlighted in the red box in Figure 2-2 is enlarged into the red box in Figure 2-3. Given the end points of ($35.000, 1,998) and ($49.999, 2,738), the linear projection of distribution of household incomes within the "median income range" is estimated as follows.

$$y = \mathbf{49.337}x + \mathbf{271.22}$$

x: *household income*

y: *location of the household in the houseld income distribution*

In the projection, the unit for x is thousand US dollar. Consequently, corresponding to the middle point "y" of the distribution of household incomes (2,516), MHI "x" for the watershed is $45,499. Note that in Figure 2-3, the value of the median position (2,516) is half of the total number of households (5,031) as presented on the vertical axis.

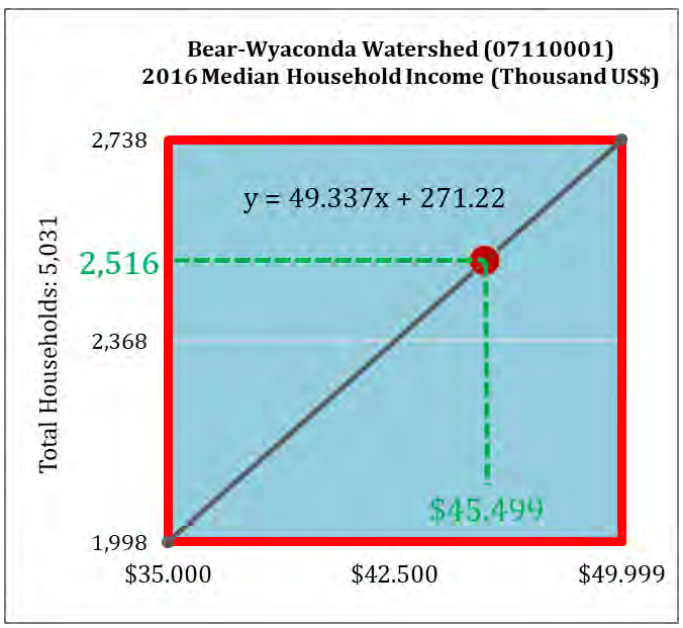


Figure 2-3. A Method of Estimating MHI for a HUC-8 Watershed

2.5 Estimating Population Growth

Similar to the estimation for MHI, the following two steps are taken to complete estimating the populations for each of the 66 HUC-8 watersheds.

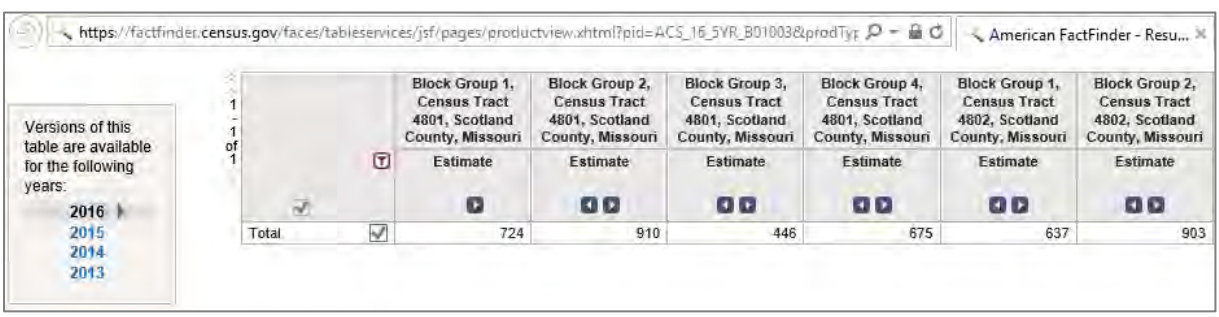
- Step 1. Compiling and aggregating data for population at the census block group and census block levels
- Step 2. Presenting population and population growth at the HUC-8 watershed level

These steps also will be illustrated using one of the HUC-8 watersheds – the Bear-Wyaconda watershed (No. 2 on Map 2-1).

Step 1. Compiling and aggregating data for population at the census block group and census block levels

Data for population in the recent decennial years of 1990, 2000 and 2010 for all 4,506 census block groups were extracted from the GIS database maintained by Missouri Department of Natural Resources. Data for population in the latest year 2016 for all 4,506 census block groups were downloaded from the Missouri Census Data Center through the UEXPLORE electronic data archive[10] which extracts data from the U.S. Census Bureau's American Community Surveys.

For year 2016, these data correspond to the data contained in Table B01003 "TOTAL POPULATION, 2012-2016 American Community Survey 5-Year Estimates" published at the U.S. Census Bureau's American Community Survey website. The data in Table B01003 present the numbers of persons in the census block groups. An example of Table B01003 for Scotland County is provided in Figure 2-4. For example, there are 724 persons in the census block group of "Block Group 1, Census Tract 4801, Scotland County, Missouri" which has the GEO ID of "29-199-4801-001."



	Block Group 1, Census Tract 4801, Scotland County, Missouri	Block Group 2, Census Tract 4801, Scotland County, Missouri	Block Group 3, Census Tract 4801, Scotland County, Missouri	Block Group 4, Census Tract 4801, Scotland County, Missouri	Block Group 1, Census Tract 4802, Scotland County, Missouri	Block Group 2, Census Tract 4802, Scotland County, Missouri
	Estimate	Estimate	Estimate	Estimate	Estimate	Estimate
Total	724	910	446	675	637	903

Figure 2-4. Population at the Census Block Group Level[11]

For the three very small HUC-8 watersheds and two relative HUC-8 watersheds, populations were estimated based on the ratios specified in Section 2.3. For each of the rest 61 HUC-8 watershed, the population was aggregated using data from all the respective census block groups assigned to each watershed.

[10] Source: Missouri Census Data Center, http://mcdc.missouri.edu/cgi-bin/broker?_PROGRAM=websas.uex2dex.sas&_SERVICE=appdev&path=/pub/data/acs2016&dset=usmcdcprofiles5yr&view=0, accessed on July 7, 2018.
[11] Source: U.S Census Bureau, https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_16_5YR_B01003&prodType=table, accessed on July 7, 2018.

Step 2. Presenting population and population growth at the HUC-8 watershed level

In the case of the State of Missouri, the population was aggregated using population data from 4,506 census block groups. This results in 5,118 thousand persons, 5,597 thousand persons, 5,992 thousand persons and 6,060 thousand persons in the years of 1990, 2000, 2010 and 2016, respectively (Figure 2-5) as presented using the solid green line. This also results in an average annual growth rate of 0.7%; that is, $5{,}118 \times (1 + 0.7\%)^{(2016-1990)} = 6{,}060$ as presented using the dotted grey line. This means, if every year the annual growth rate is 0.7%, the given population of 5,118 thousand persons in the year 1990 would become 5,462 thousand persons, 5,828 thousand persons and 6,060 thousand persons in the years of 2000, 2010 and 2016, respectively. Note that the dotted grey line is slightly bent downward for the last interval between 2010 and 2016. This is because the last interval represents the distance of 6 years whereas the first two decennial intervals represent the distances of a decade. If the population for the 26 years between 1990 and 2016 is plotted with equal intervals of years in the horizontal axis, the dotted grey line would become a straight line. This average annual growth rate of 0.7% will be used as a baseline to compare the population growth rates among the 66 HUC-8 watersheds.

In the case of the Bear-Wyaconda watershed, the population is aggregated using 81% of the population for the census block group 290459502002 as well as population for another 12 census block groups. This results in 13,410 persons, 13,460 persons, 12,916 persons and 12,460 persons in the years of 1990, 2000, 2010 and 2016, respectively (Figure 2-6) as presented using the solid red line. The average annual growth rate is -0.3%. By comparison, the population growth in this watershed is lower than that of Missouri which is 0.7%. For a more intuitive interpretation, the scenario of an average annual growth rate of 0.7% with the same initial population of 13,410 persons in the year 1990 is created and presented using the grey dotted line. This means, if every year the annual growth rate is 0.7%, the given population of 13,410 persons in the year 1990 would become 14,310 persons, 15,270 persons and 15,877 persons in the years of 2000, 2010 and 2016, respectively. In other words, if this watershed has the same average annual growth rate in population as that of the State of Missouri, there would have been around 3,000 more persons residing in this watershed in the year of 2016.

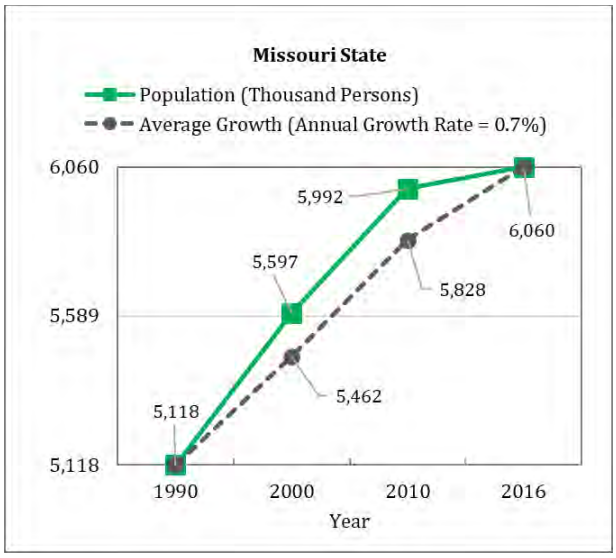


Figure 2-5. Populations and Population Growth in Missouri

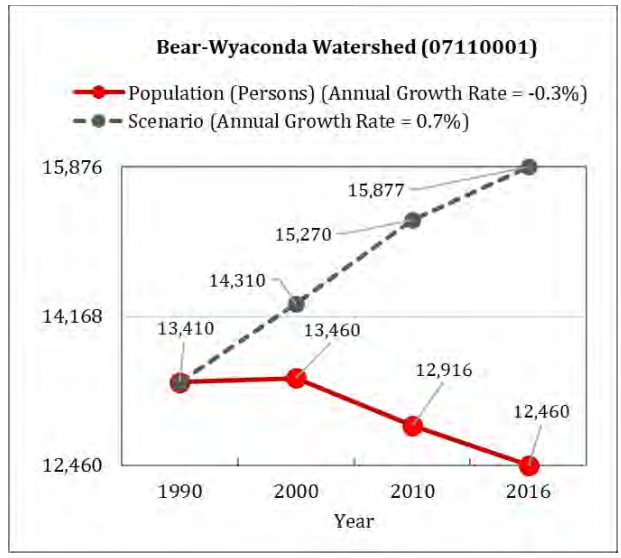


Figure 2-6. Populations and Population Growth in the Bear-Wyaconda Watershed

3. Results and Implications

3.1 Individual Data Charts and GIS Maps

The methods for estimating population growth and MHI as specified in Section 2 were applied to the State of Missouri as a whole and to each of the 66 individual HUC-8 watersheds. The key results are presented in the form of data charts and GIS maps in this Subsection. For the State of Missouri, the results include the following one map and three figures, grouped with one figure caption for the effect of compact presentation.

- On the first row and first column, a GIS map presenting the locations and boundaries of all 66 HUC-8 watersheds, the census block groups within Missouri, and the states bordering Missouri.
- On the first row and second column, a figure presenting the population and population growth during 1990-2016 for Missouri.
- On the second row and first column, a figure presenting the distribution of household incomes in 2016 for Missouri.
- On the second row and second column, a figure presenting the estimated MHI in 2016 for Missouri.

Similarly, for each HUC-8 watershed, the results include the following one map and three figures, grouped with one figure caption for the effect of compact presentation.

- On the first row and first column, a GIS map presenting the location and boundary of the HUC-8 watershed, the census block groups (shaded areas in orange color) within the HUC-8 watershed, the counties, major rivers and lakes, and bordering states around the HUC-8 watershed.
- On the first row and second column, a figure presenting population and population growth during 1990-2016 for the HUC-8 watershed in comparison with the scenario of an average annual growth rate of 0.7% with the same initial populations in the year 1990.
- On the second row and first column, a figure presenting the distribution of household incomes in 2016 for the HUC-8 watershed.
- On the second row and second column, a figure presenting the estimated MHI in 2016 for the HUC-8 watershed.

3.1.1 State of Missouri

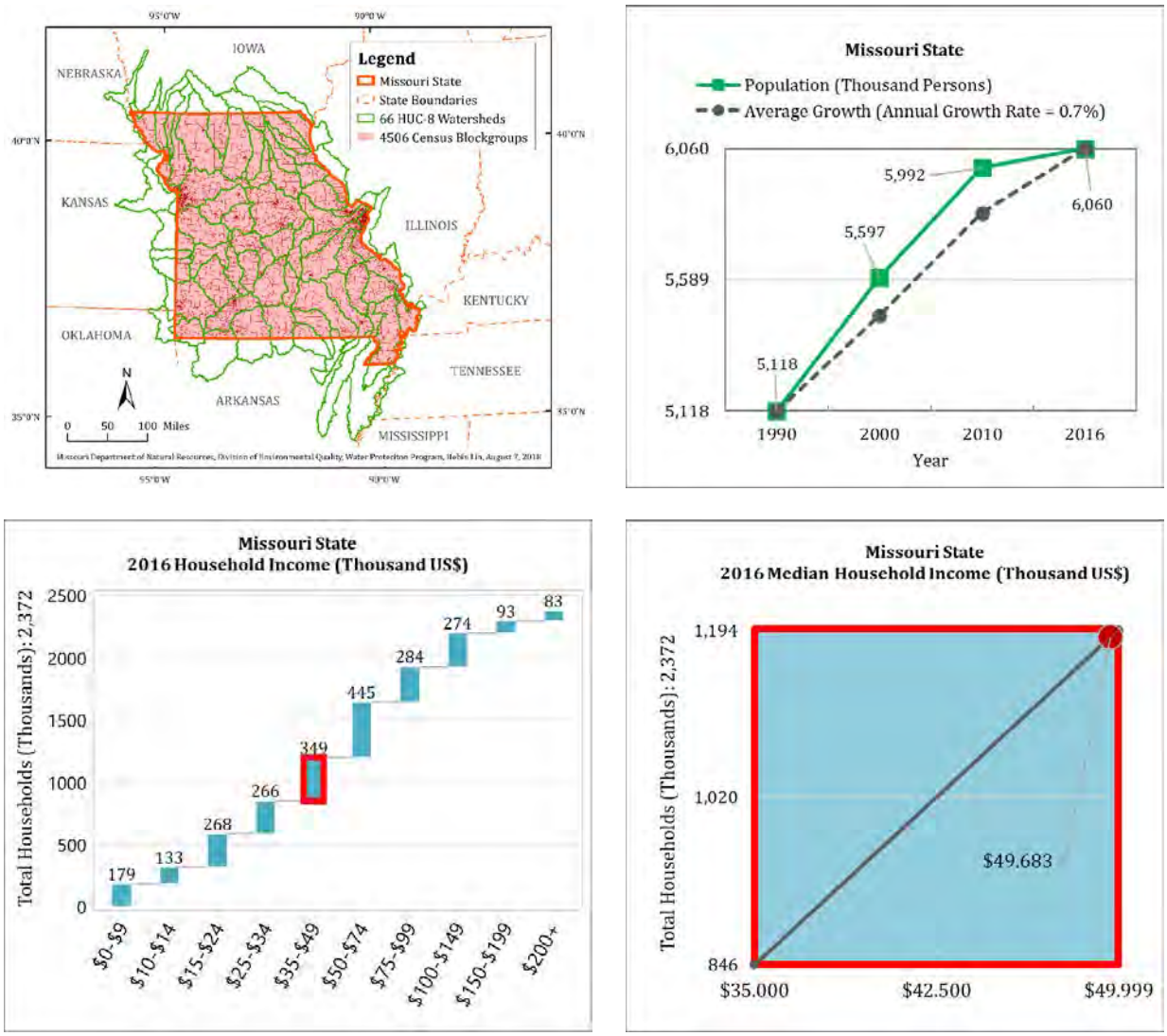


Figure 3-1. State of Missouri: Population Growth and Median Household Income

3.1.2 Lower Des Moines Watershed (HUC 07100009)

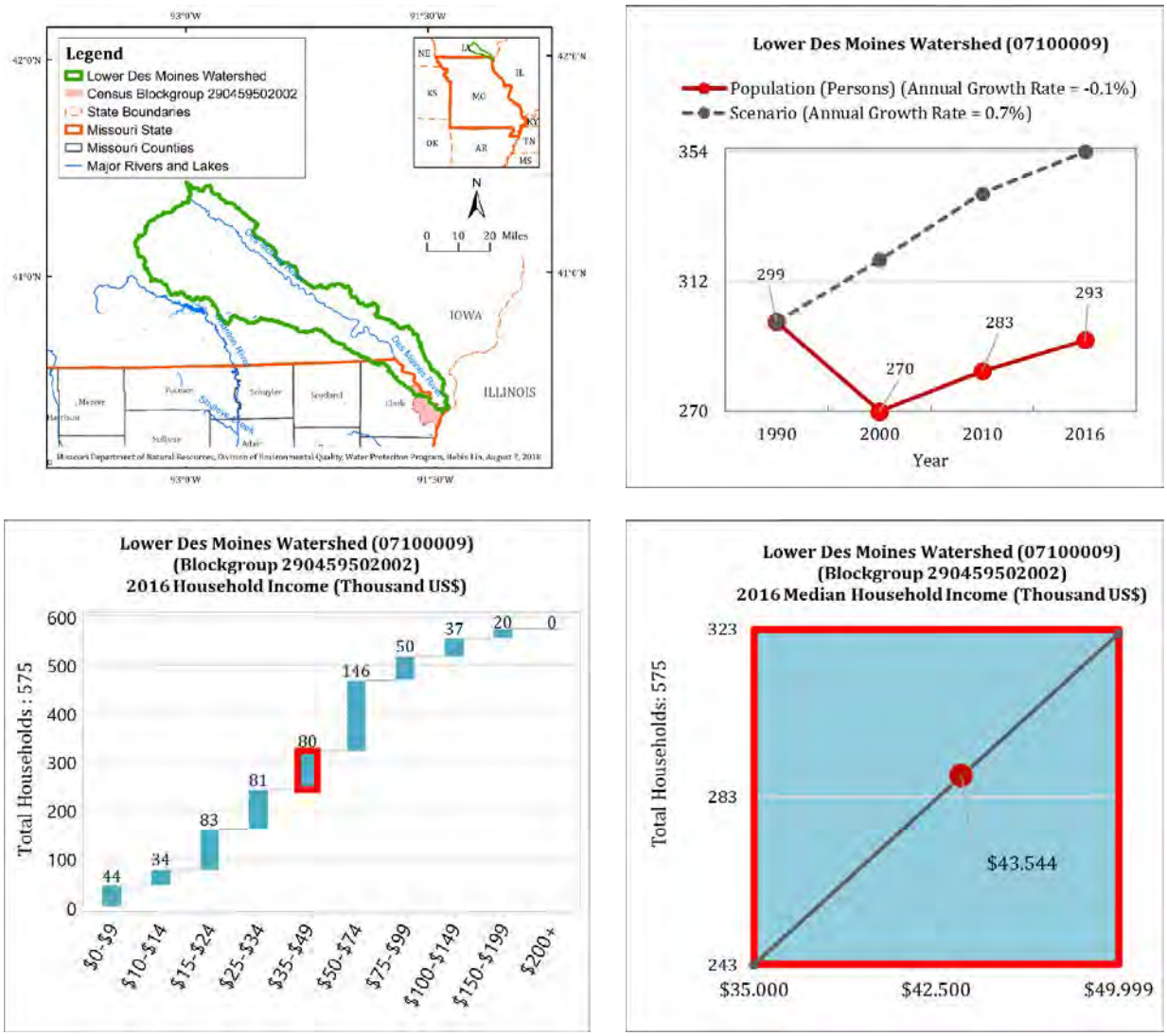


Figure 3-2. Lower Des Moines Watershed: Population Growth and Median Household Income

3.1.3 Bear-Wyaconda Watershed (HUC 07110001)

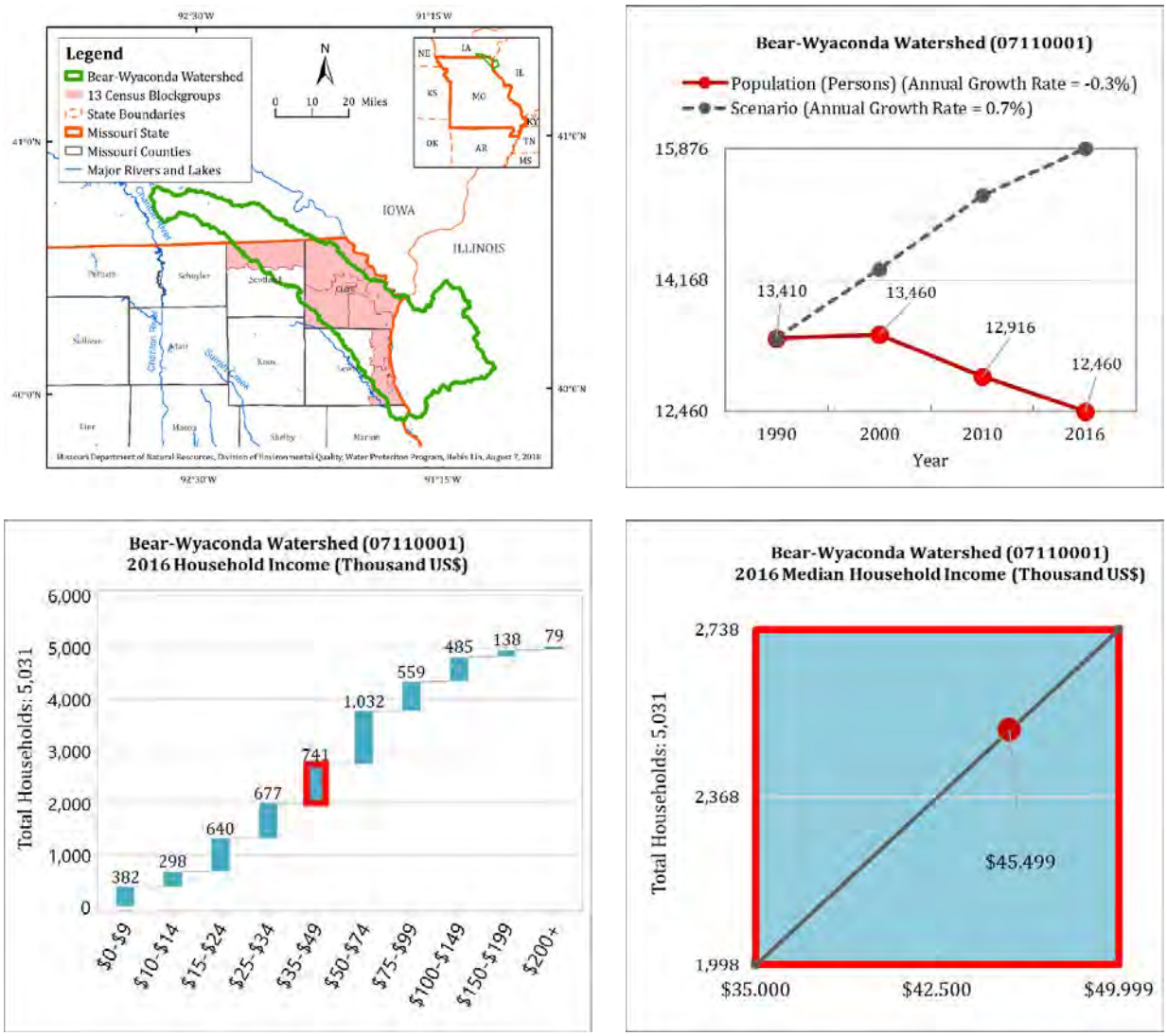


Figure 3-3. Bear-Wyaconda Watershed: Population Growth and Median Household Income

3.1.4 North Fabius Watershed (HUC 07110002)

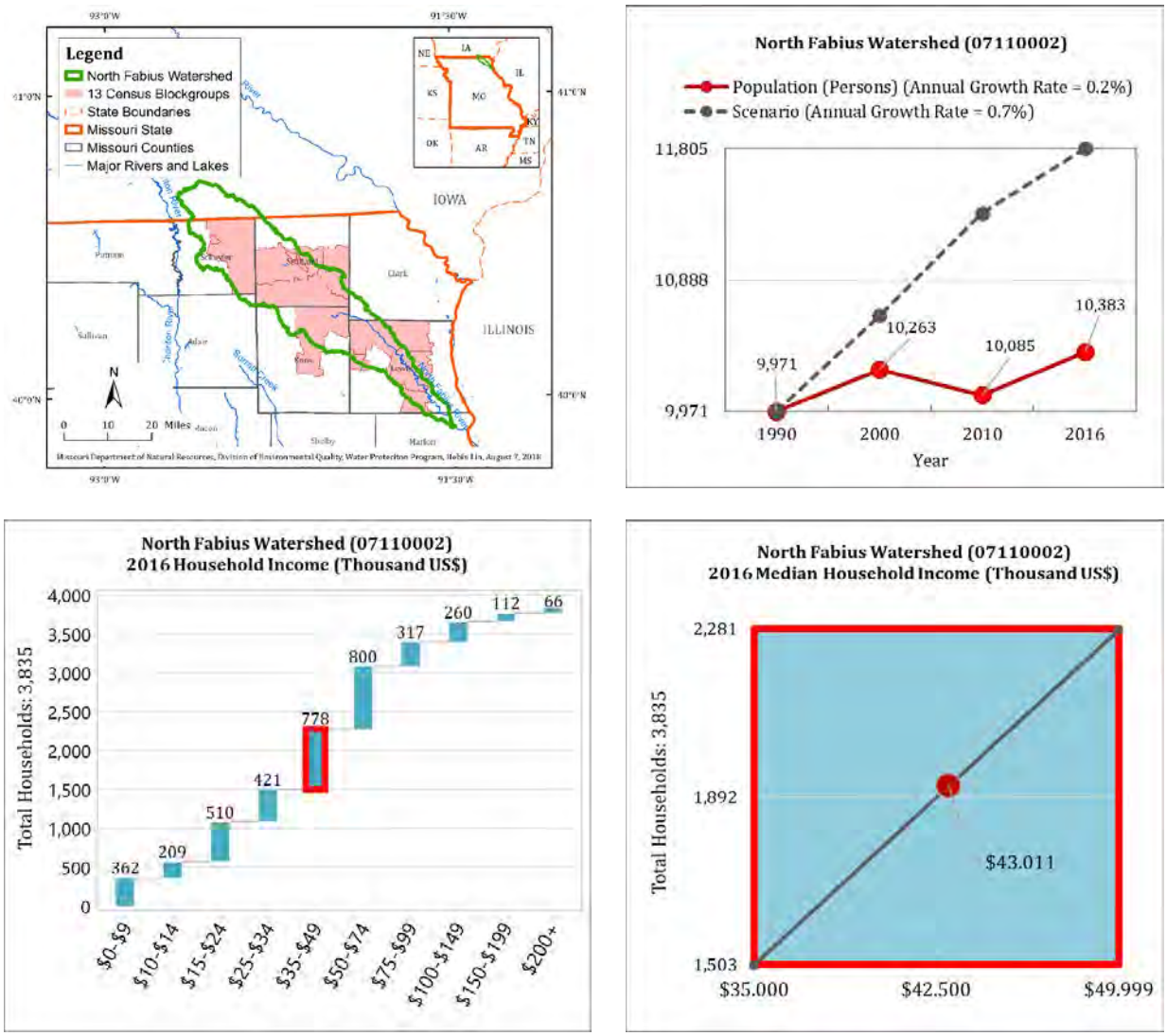


Figure 3-4. North Fabius Watershed: Population Growth and Median Household Income

3.1.5 South Fabius Watershed (HUC 07110003)

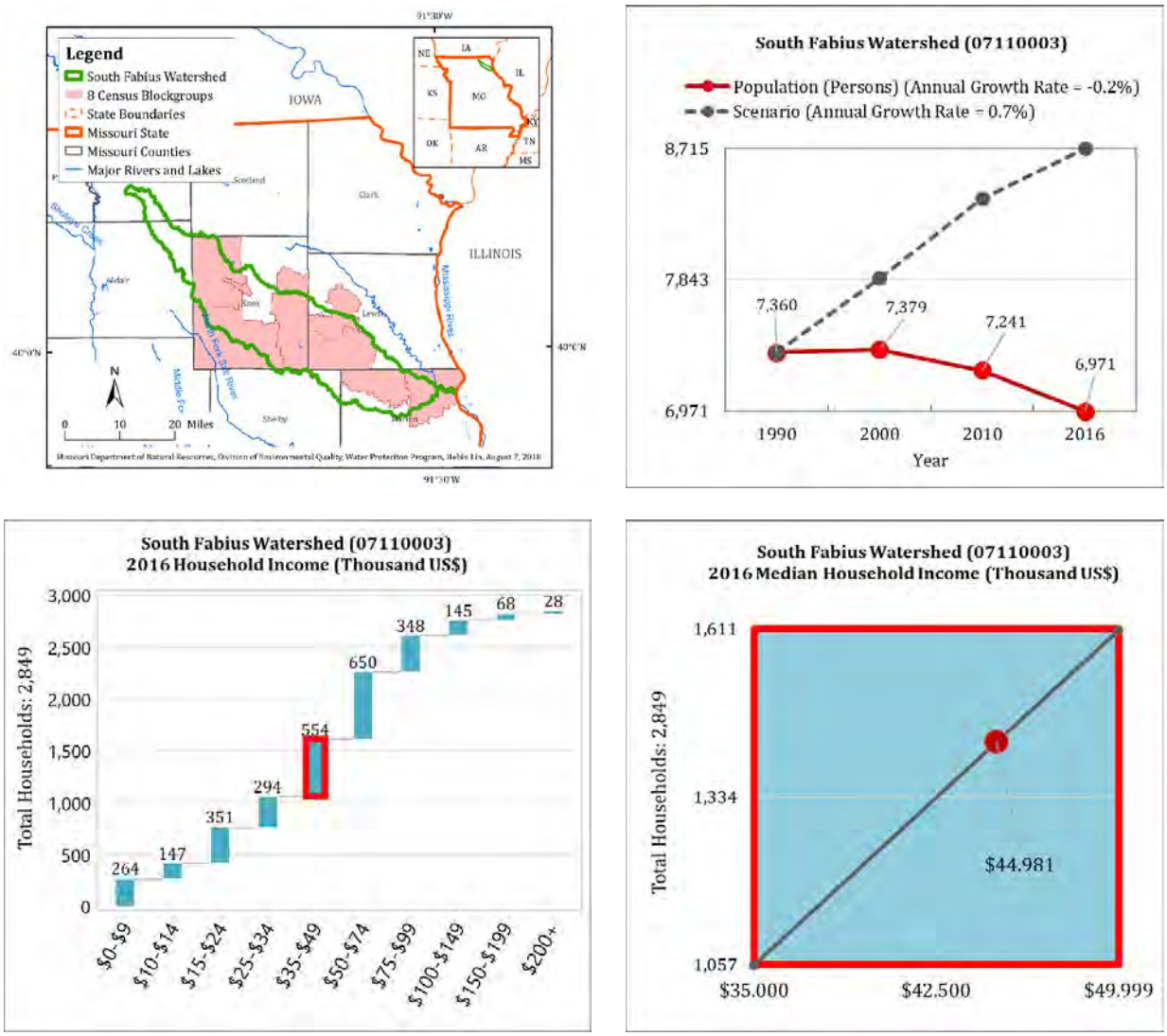


Figure 3-5. South Fabius Watershed: Population Growth and Median Household Income

3.1.6 The Sny Watershed (HUC 07110004)

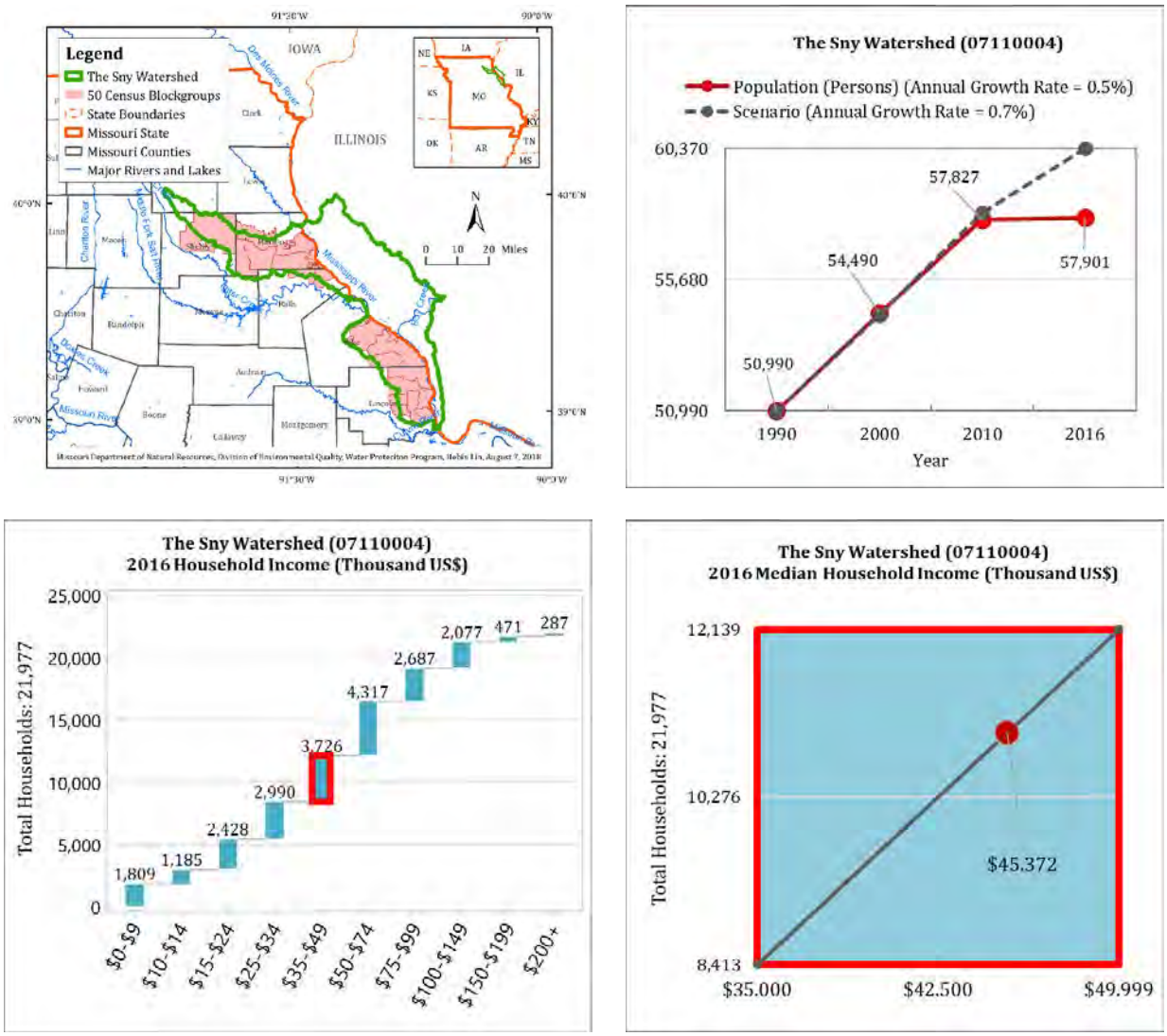


Figure 3-6. The Sny Watershed: Population Growth and Median Household Income

3.1.7 North Fork Salt Watershed (HUC 07110005)

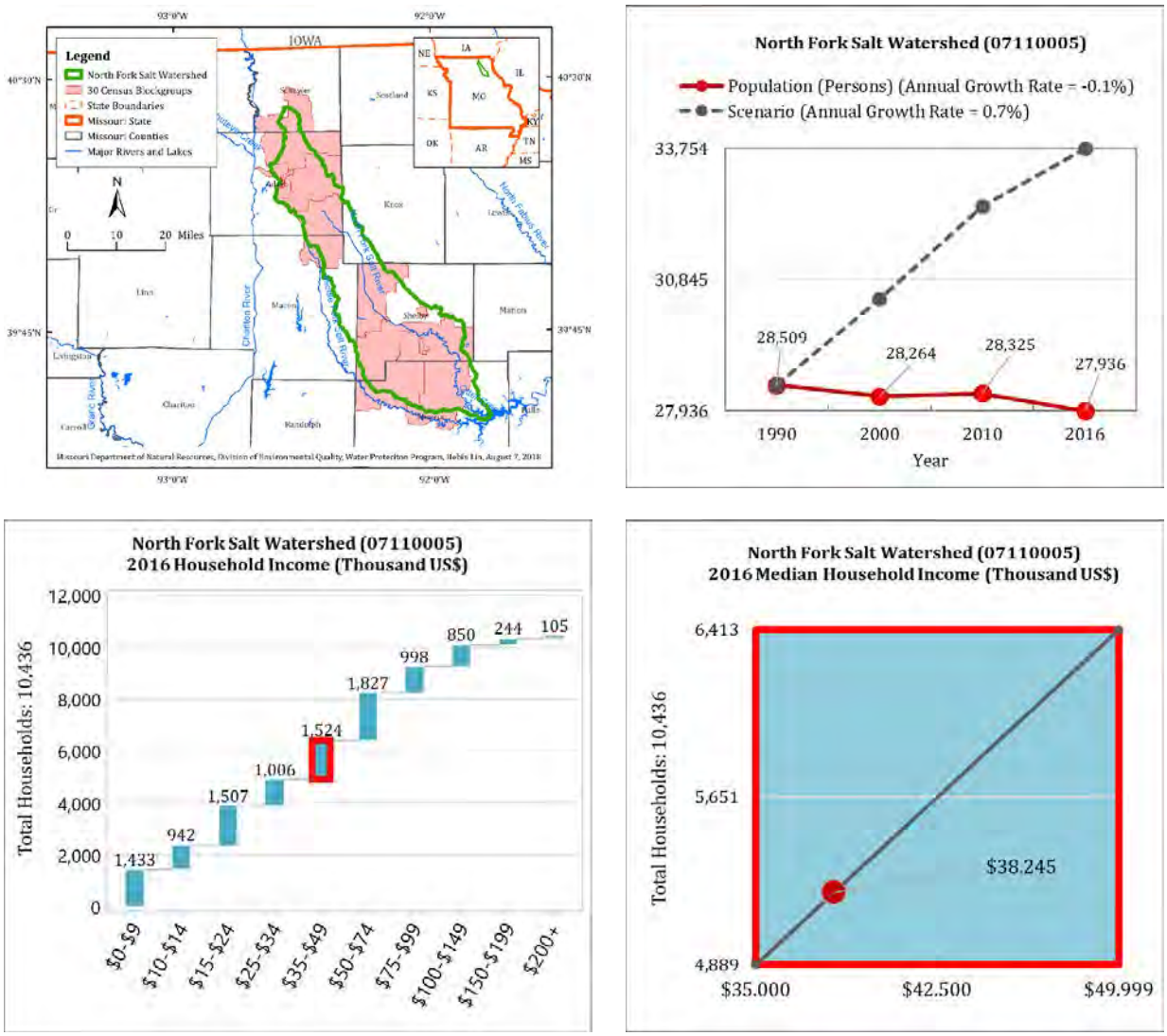


Figure 3-7. North Fork Salt Watershed: Population Growth and Median Household Income

3.1.8 South Fork Salt Watershed (HUC 07110006)

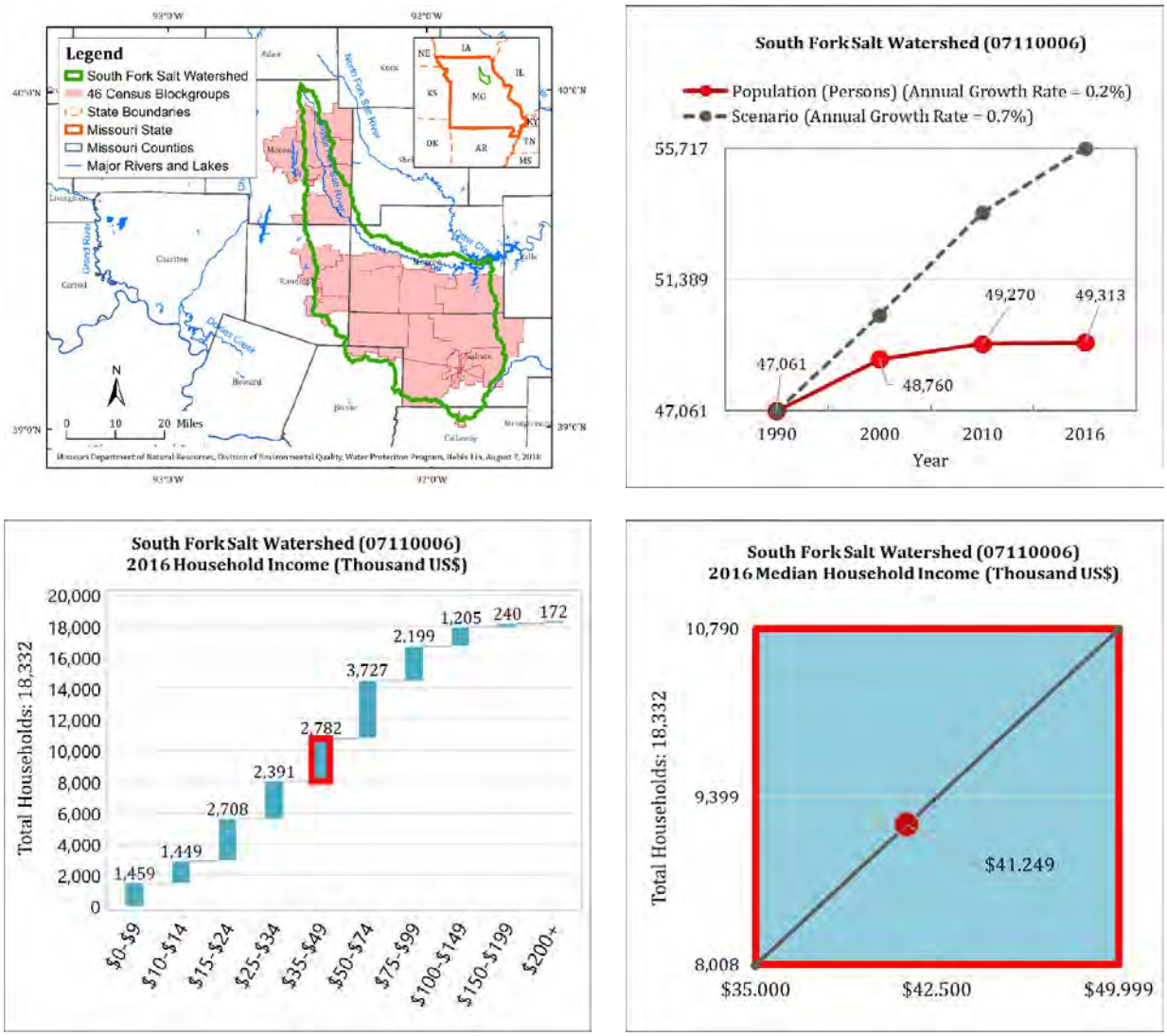


Figure 3-8. South Fork Salt Watershed: Population Growth and Median Household Income

3.1.9 Salt Watershed (HUC 07110007)

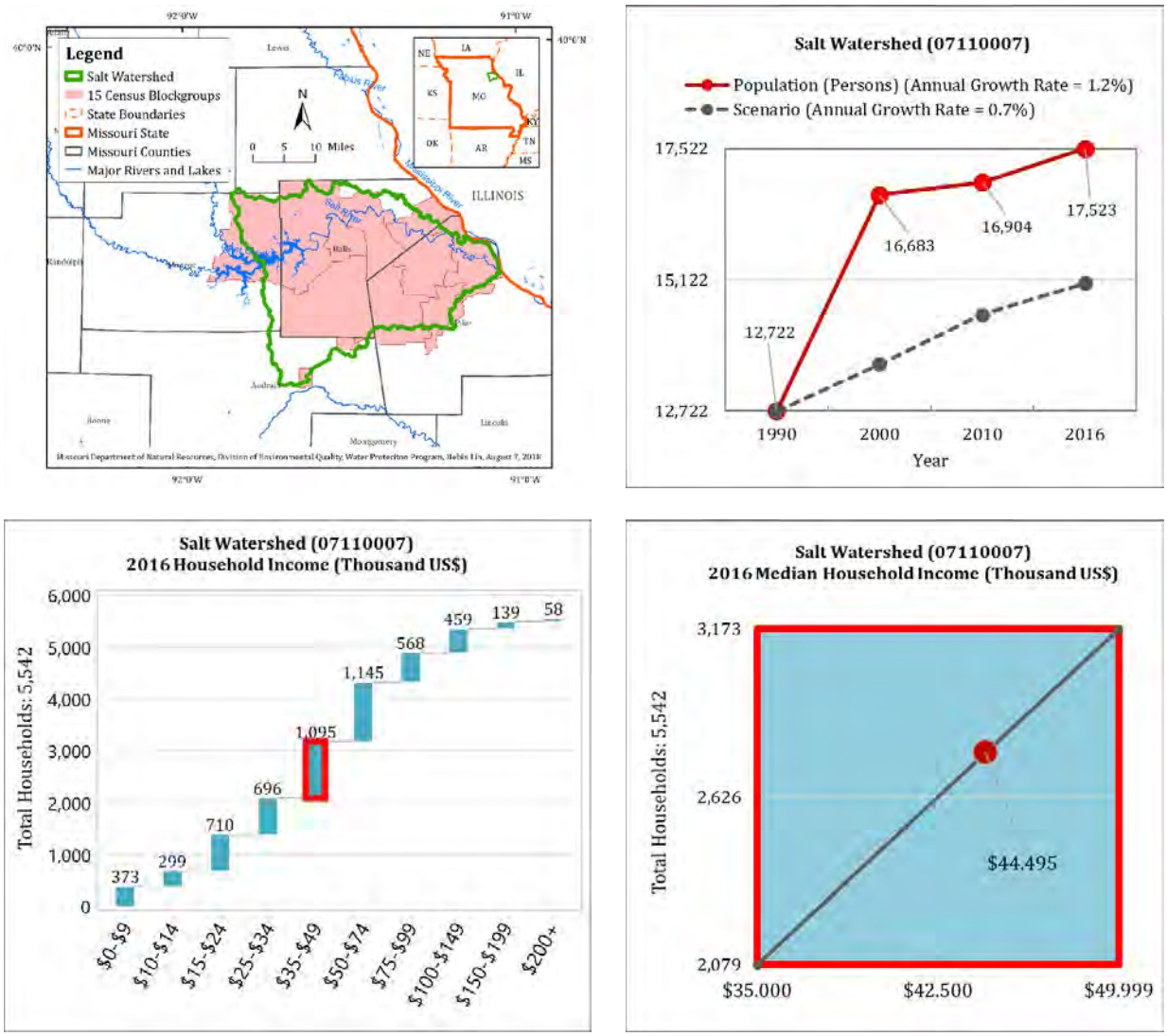


Figure 3-9. Salt Watershed: Population Growth and Median Household Income

3.1.10 Cuivre Watershed (HUC 07110008)

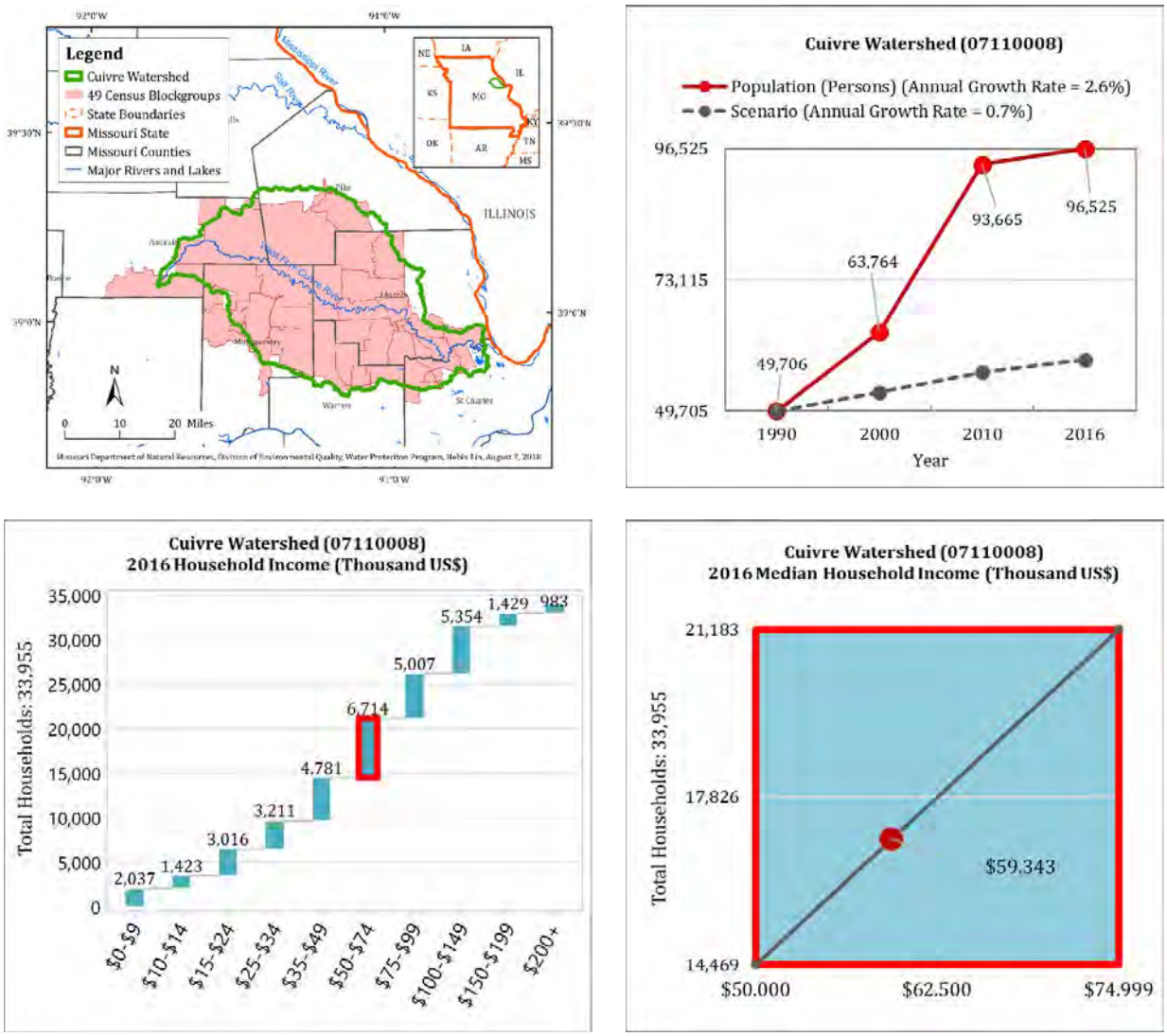


Figure 3-10. Cuivre Watershed: Population Growth and Median Household Income

3.1.11 Peruque-Piasa Watershed (HUC 07110009)

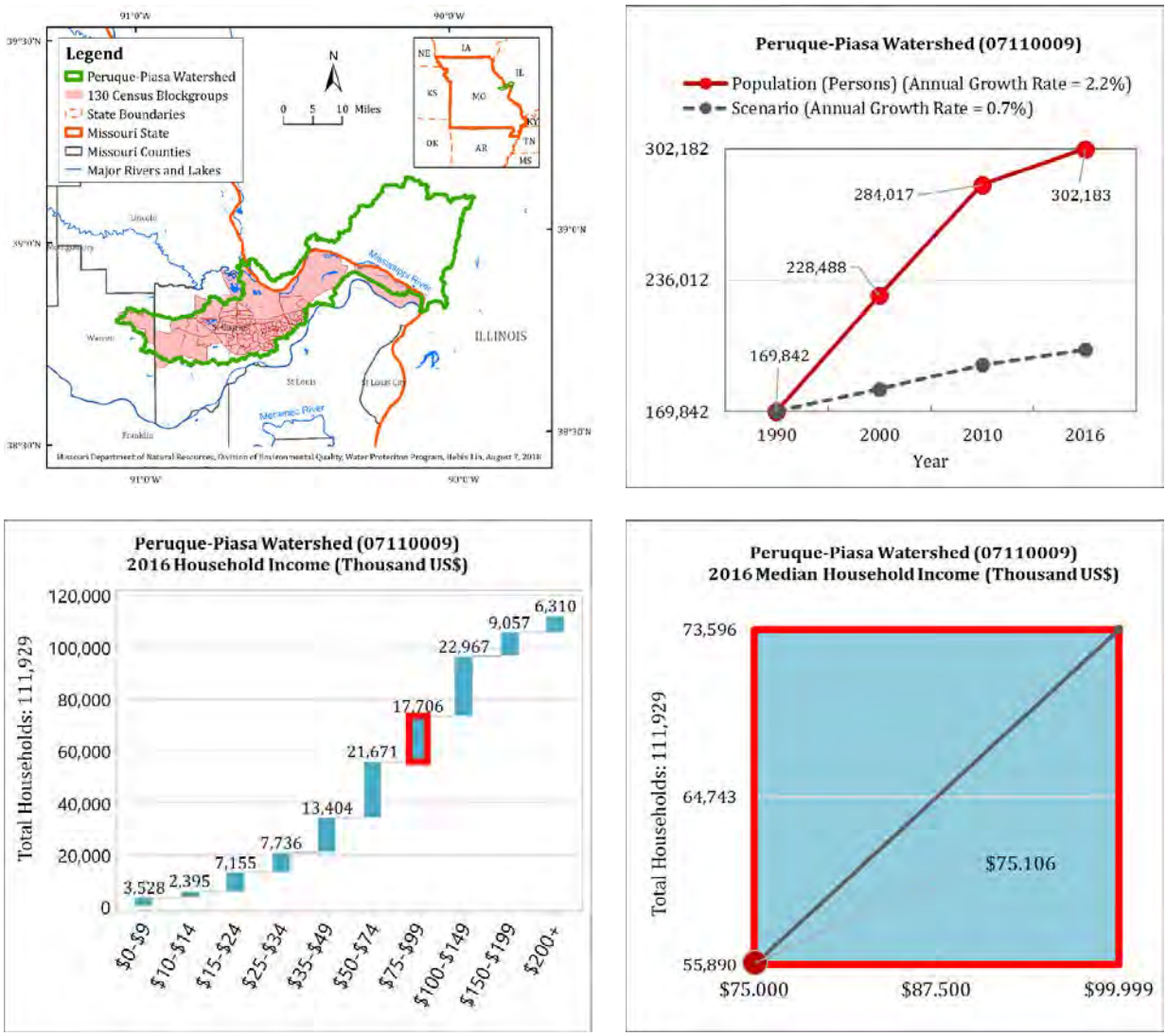


Figure 3-11. Peruque-Piasa Watershed: Population Growth and Median Household Income

3.1.12 Cahokia-Joachim Watershed (HUC 07140101)

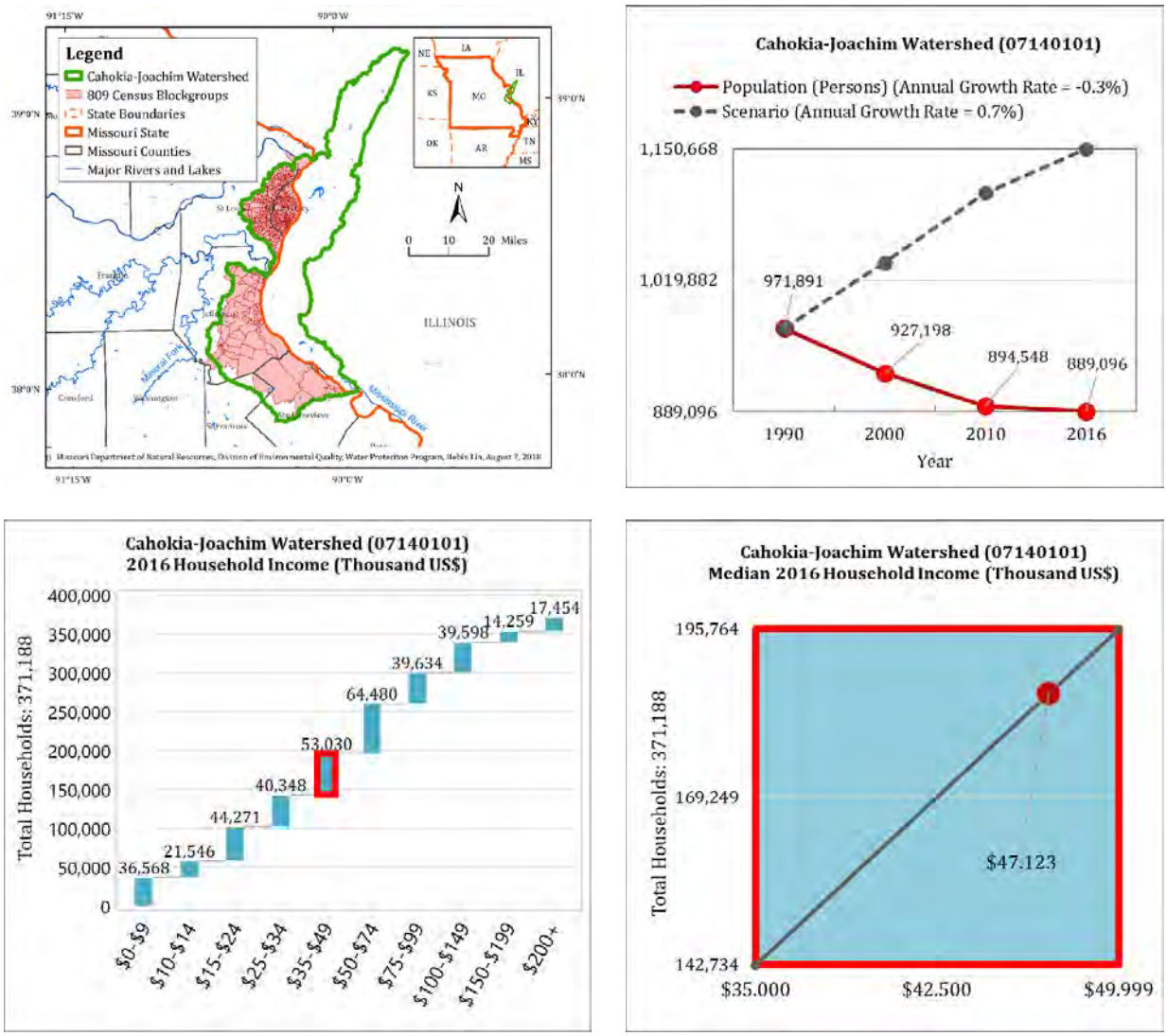


Figure 3-12. Cahokia-Joachim Watershed: Population Growth and Median Household Income

3.1.13 Meramec Watershed (HUC 07140102)

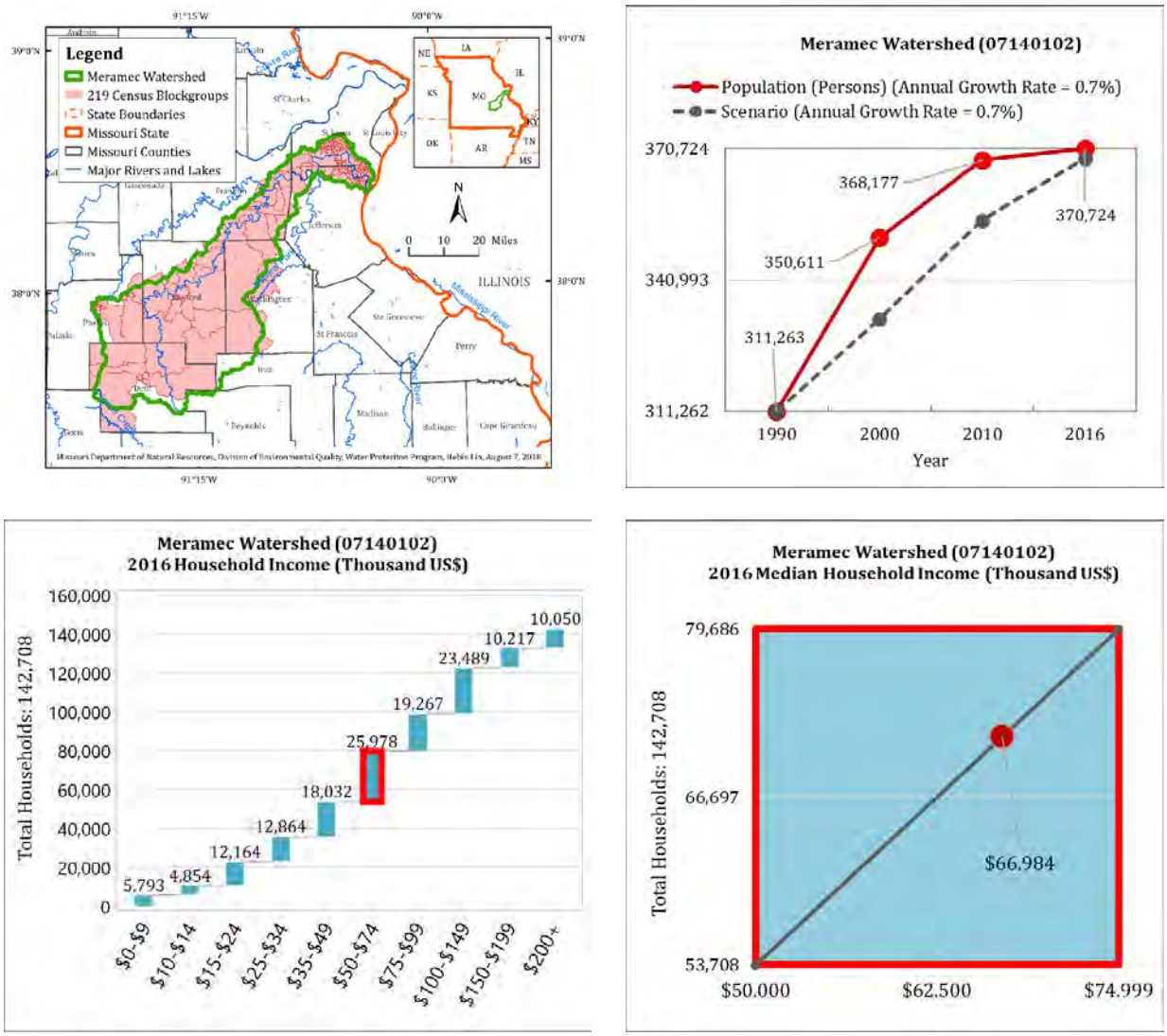


Figure 3-13. Meramec Watershed: Population Growth and Median Household Income

3.1.14 Bourbeuse Watershed (HUC 07140103)

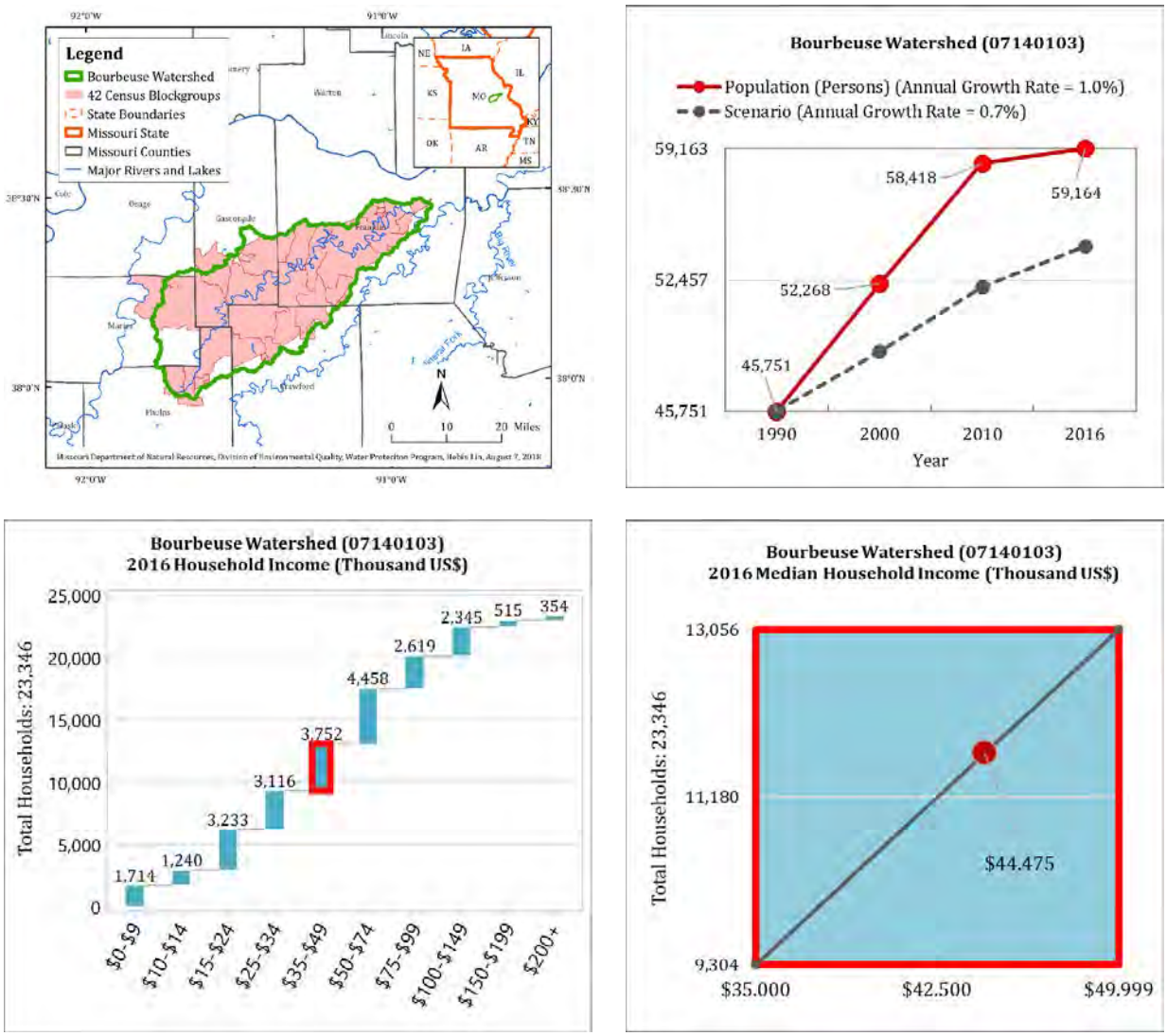


Figure 3-14. Bourbeuse Watershed: Population Growth and Median Household Income

3.1.15 Upper Mississippi-Big Watershed (HUC 07140104)

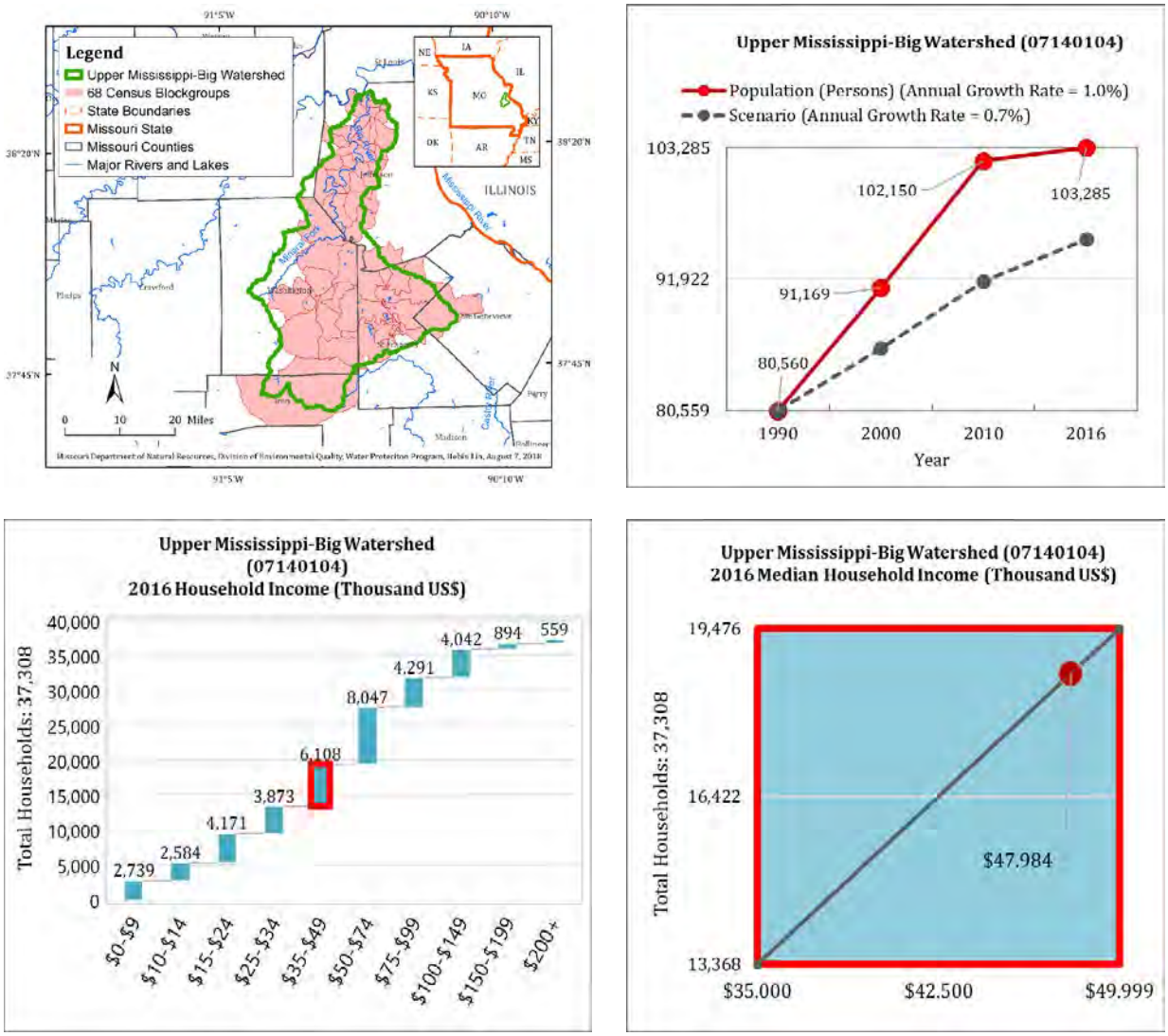


Figure 3-15. Upper Mississippi-Big Watershed: Population Growth and Median Household Income

3.1.16 Upper Mississippi-Cape Girardeau Watershed (HUC 07140105)

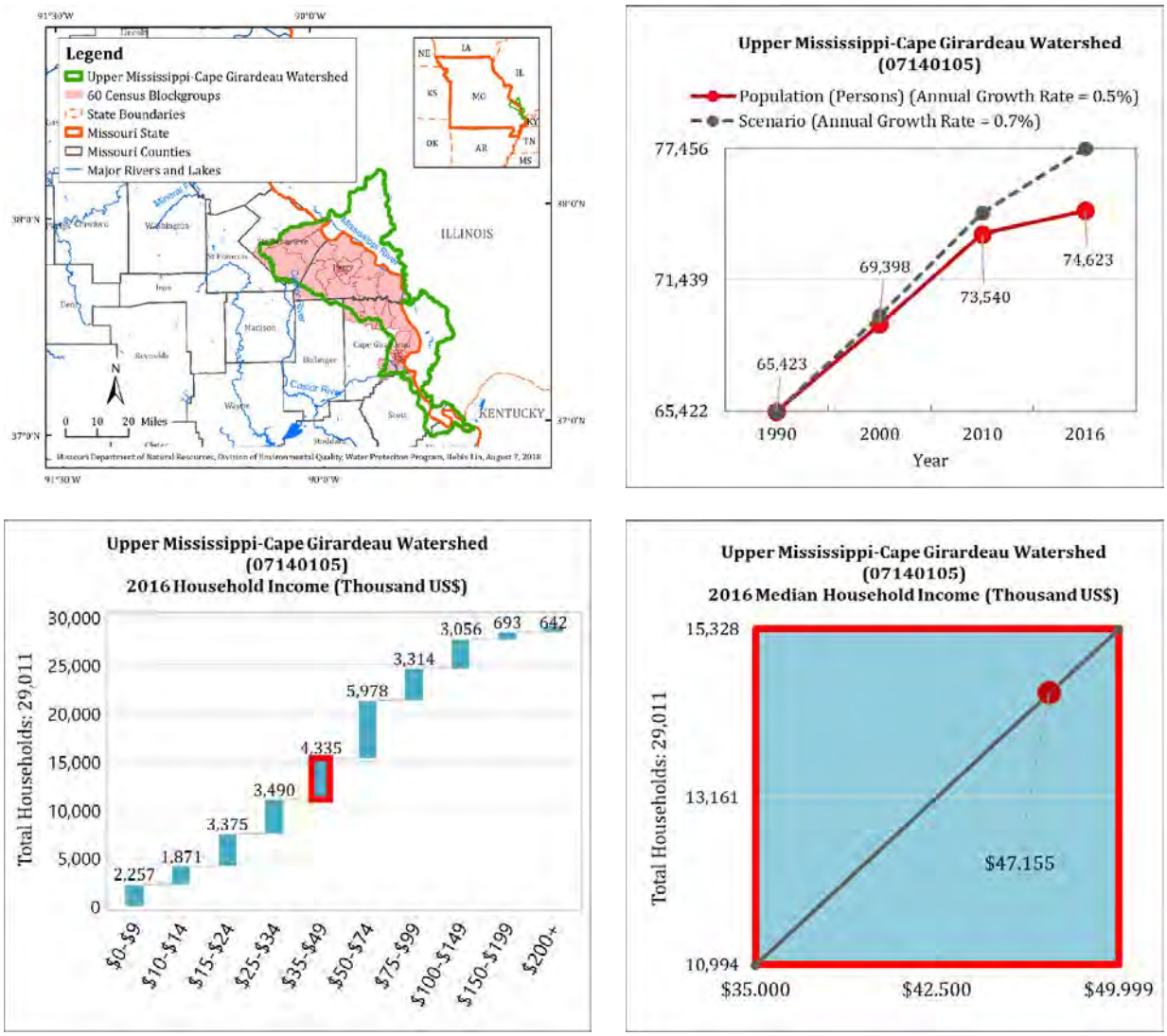


Figure 3-16. Upper Mississippi-Cape Girardeau Watershed: Population Growth and Median Household Income

3.1.17 Whitewater Watershed (HUC 07140107)

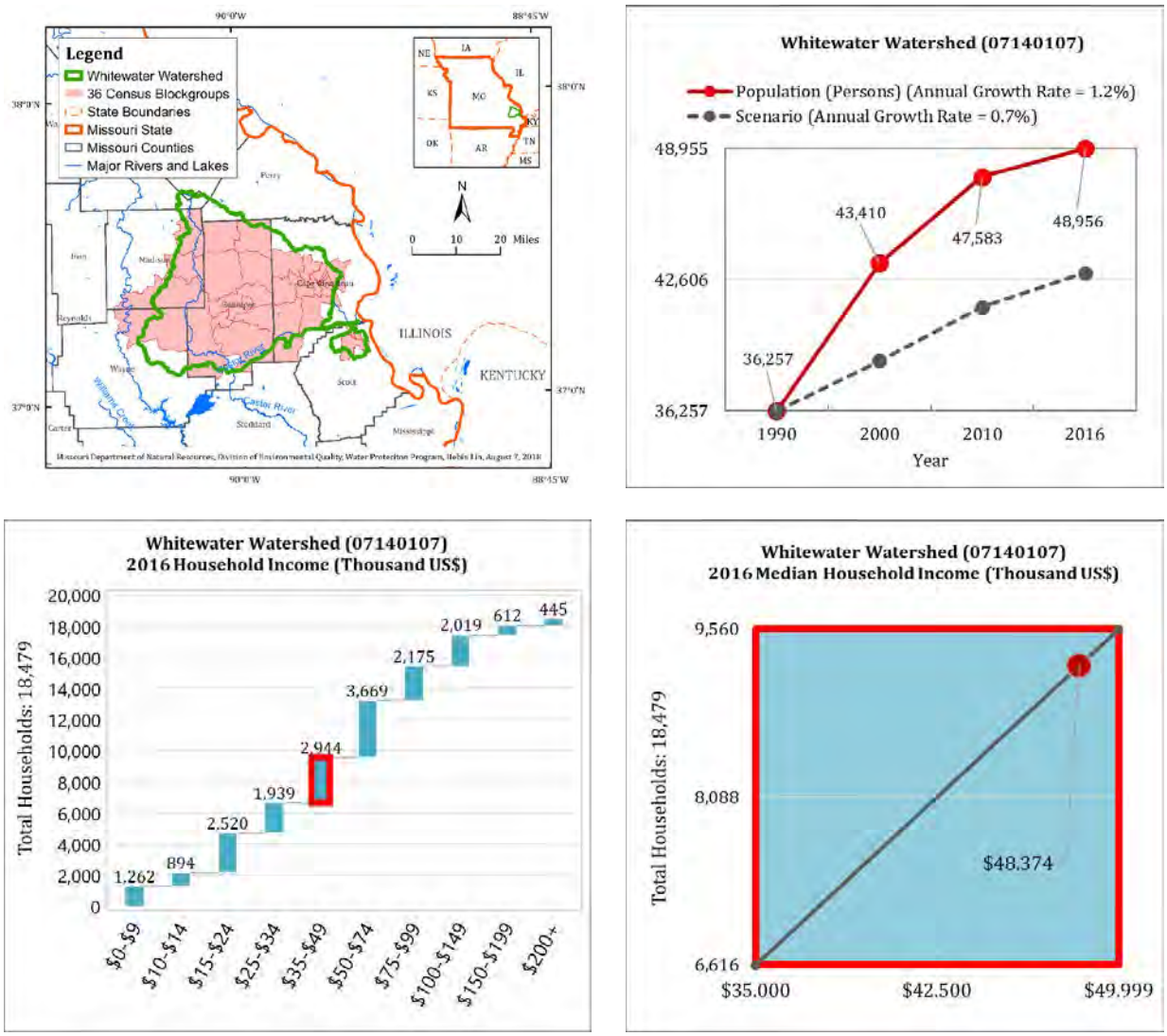


Figure 3-17. Whitewater Watershed: Population Growth and Median Household Income

3.1.18 Lower Mississippi-Memphis Watershed (HUC 08010100)

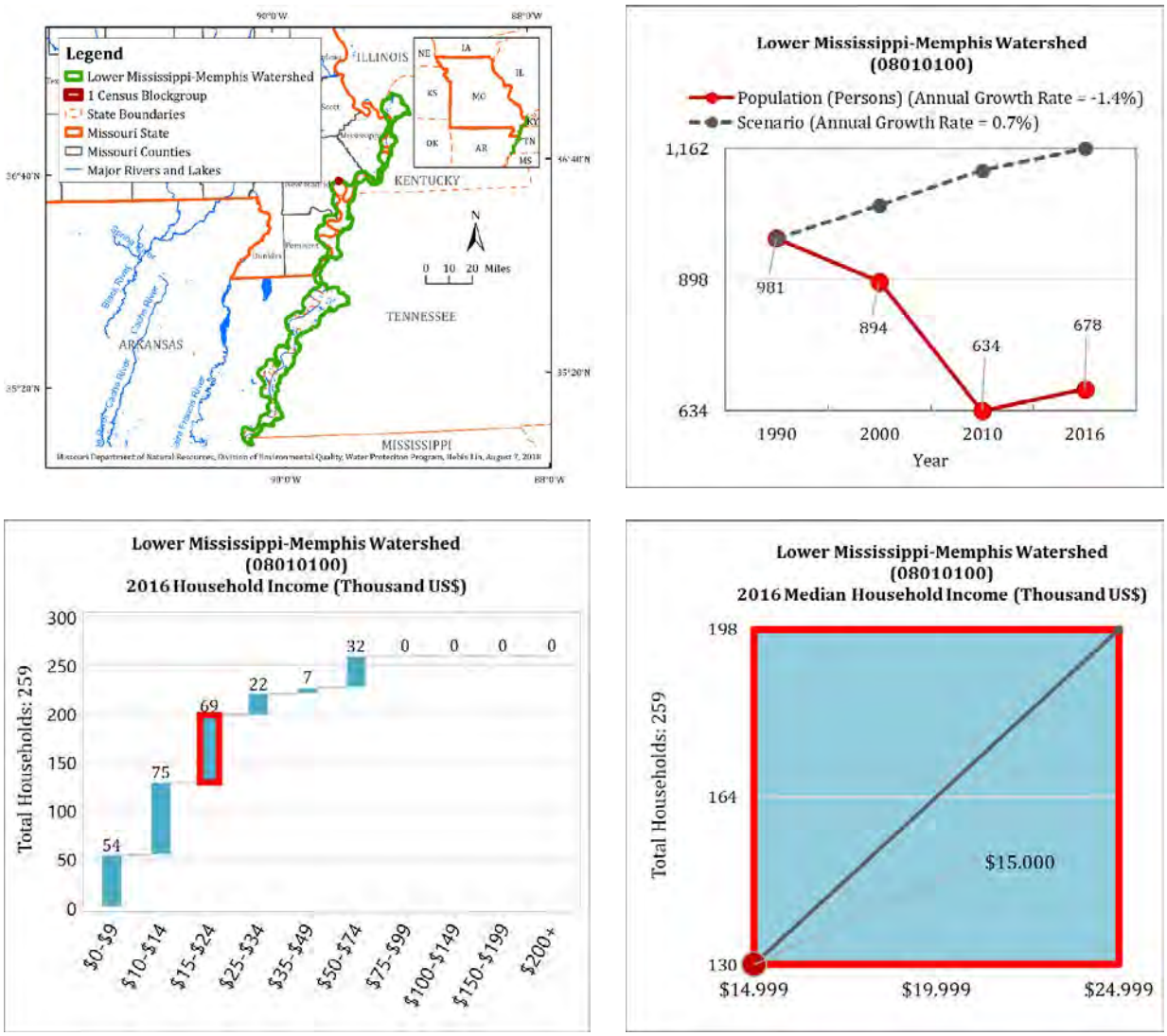


Figure 3-18. Lower Mississippi-Memphis Watershed: Population Growth and Median Household Income

3.1.19 New Madrid-St. Johns Watershed (HUC 08020201)

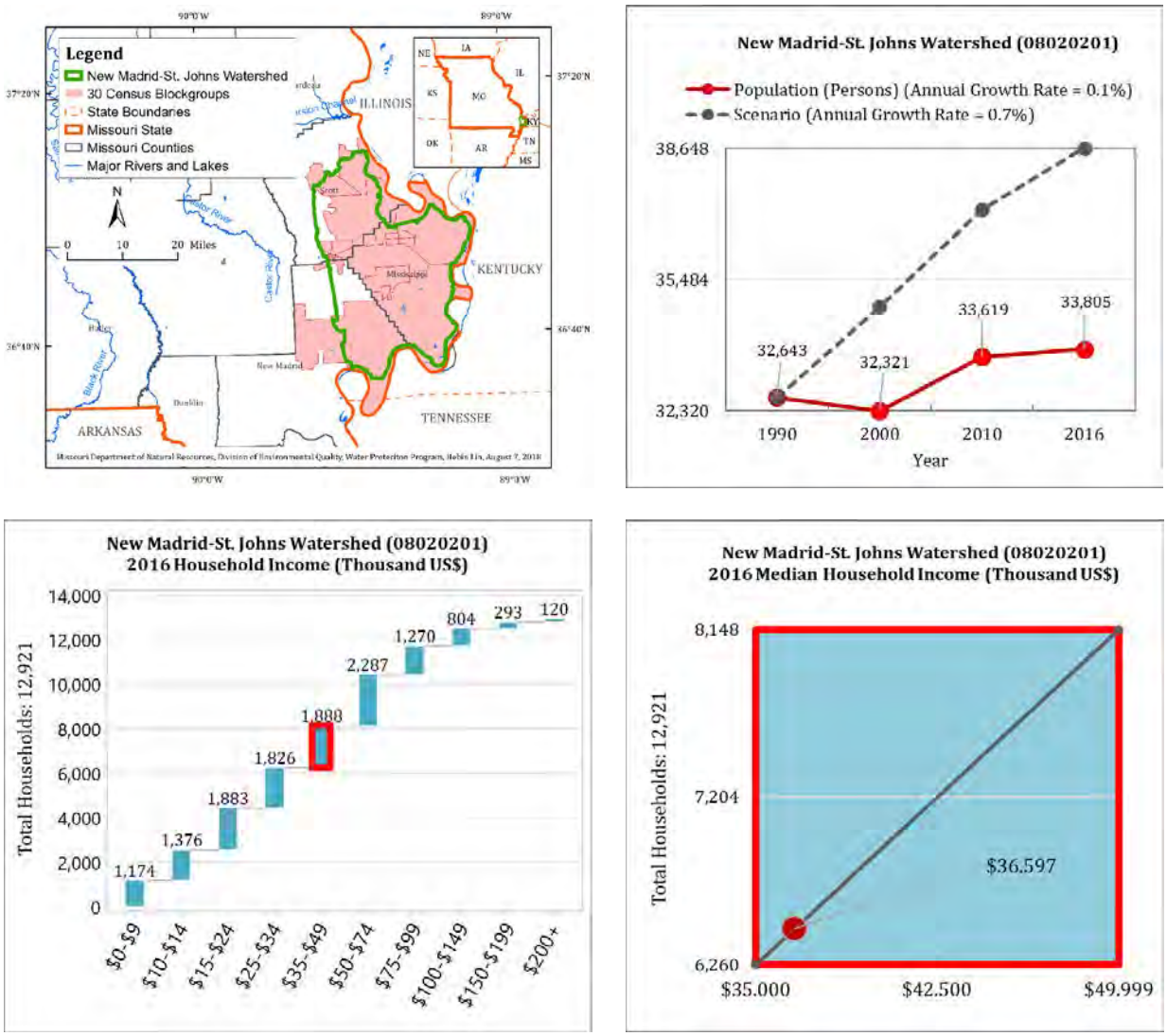


Figure 3-19. New Madrid-St. Johns Watershed: Population Growth and Median Household Income

3.1.20 Upper St. Francis Watershed (HUC 08020202)

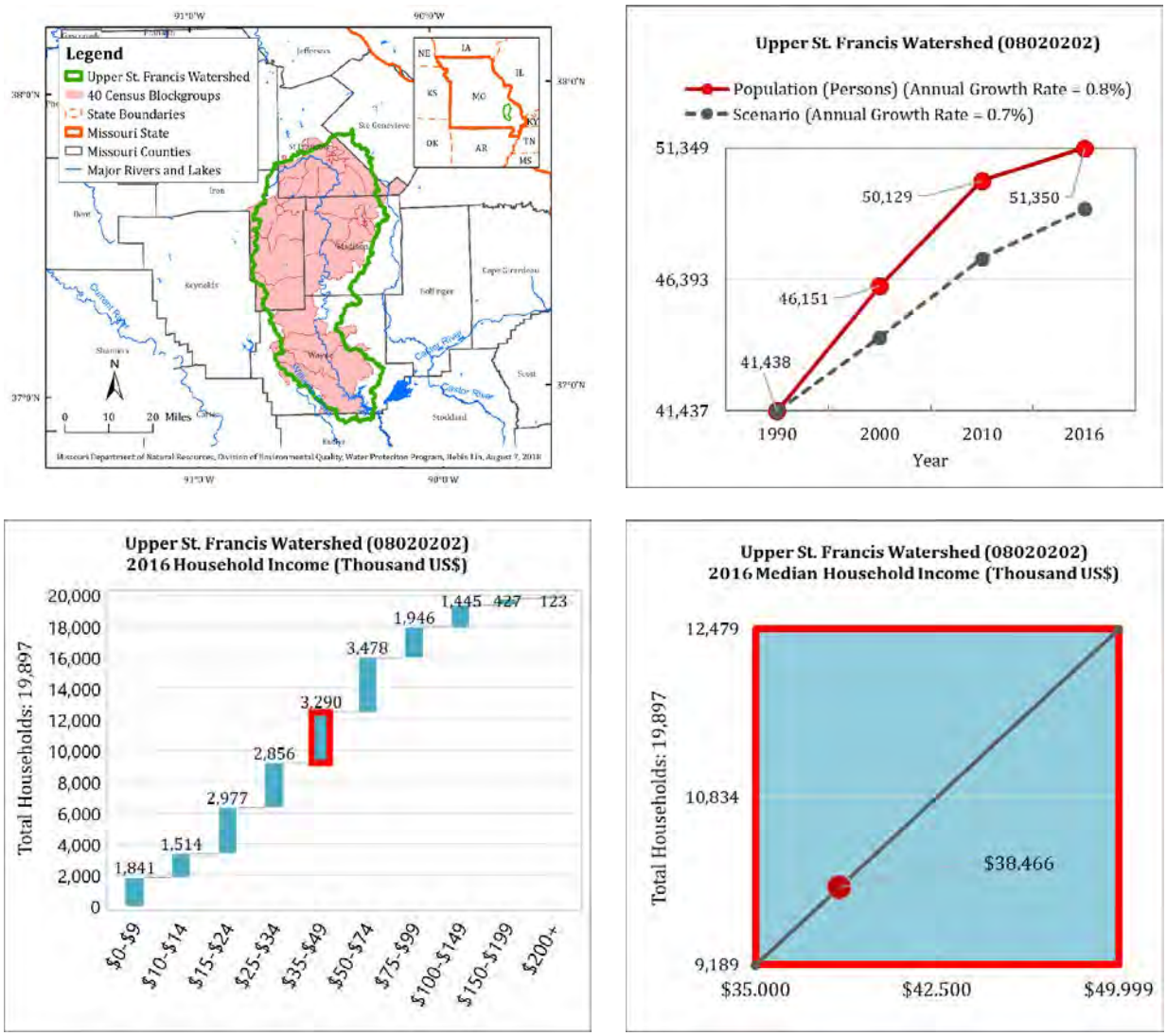


Figure 3-20. Upper St. Francis Watershed: Population Growth and Median Household Income

3.1.21 Lower St. Francis Watershed (HUC 08020203)

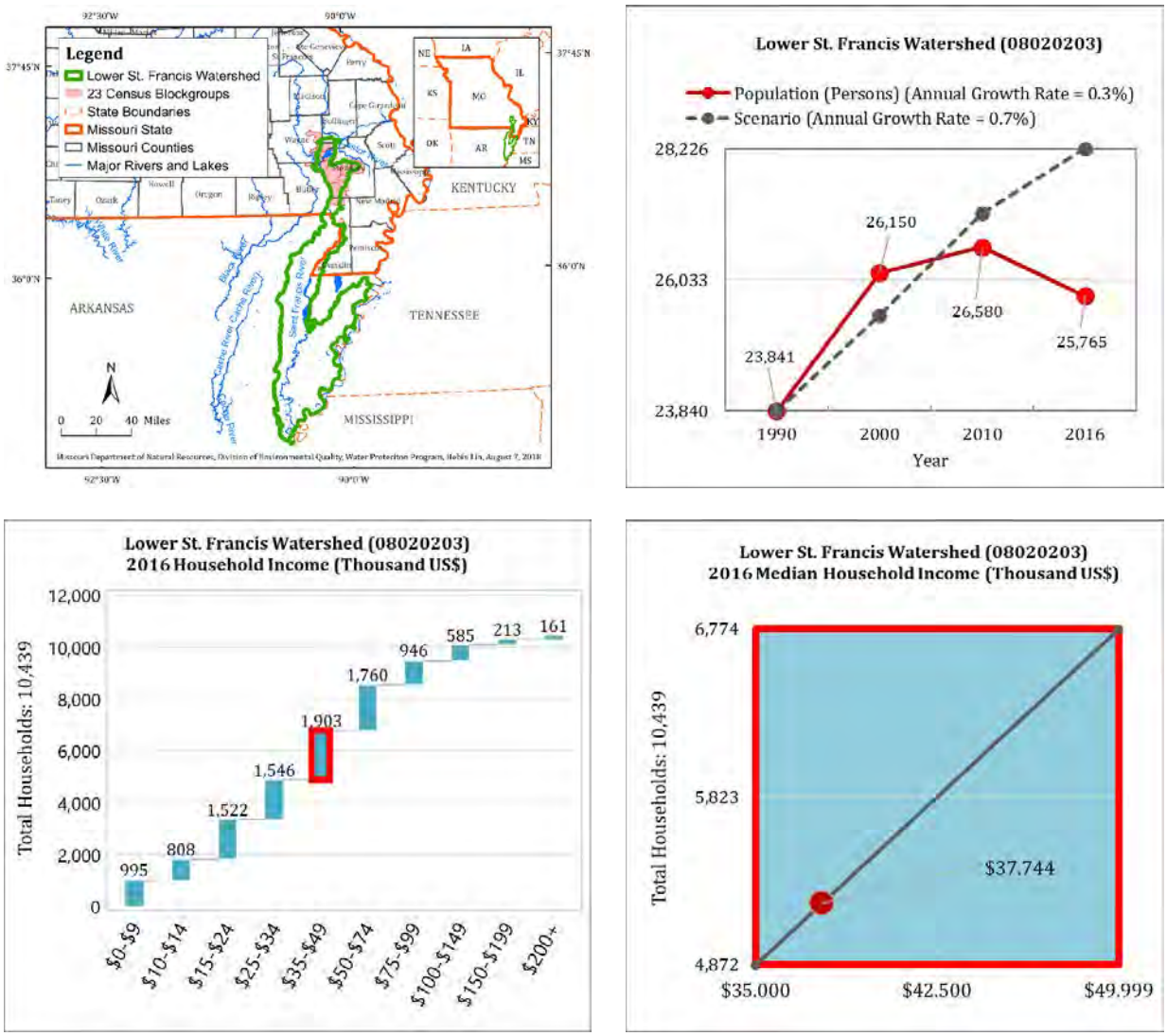


Figure 3-21. Lower St. Francis Watershed: Population Growth and Median Household Income

3.1.22 Little River Ditches Watershed (HUC 08020204)

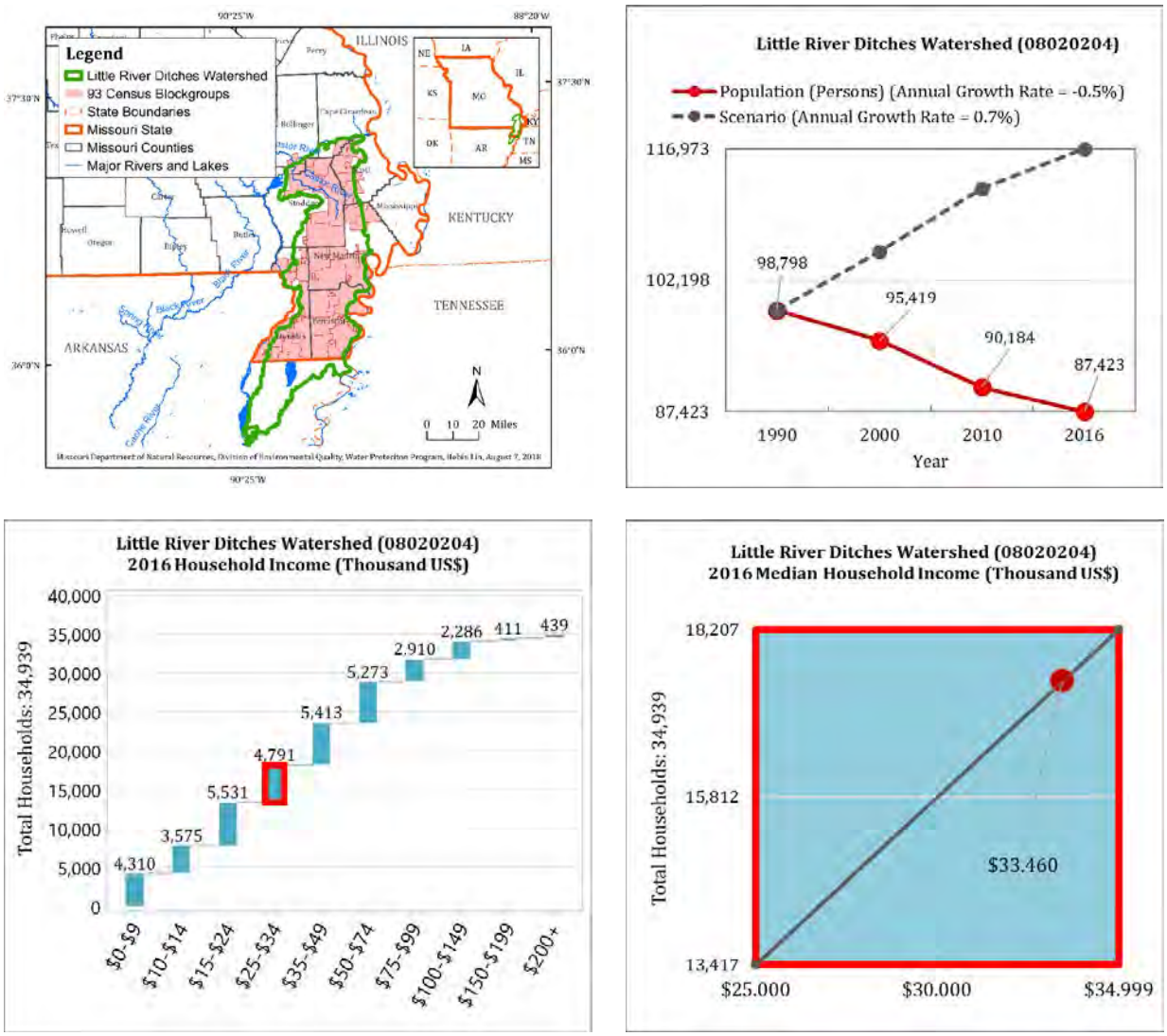


Figure 3-22. Little River Ditches Watershed: Population Growth and Median Household Income

3.1.23 Cache Watershed (HUC 08020302)

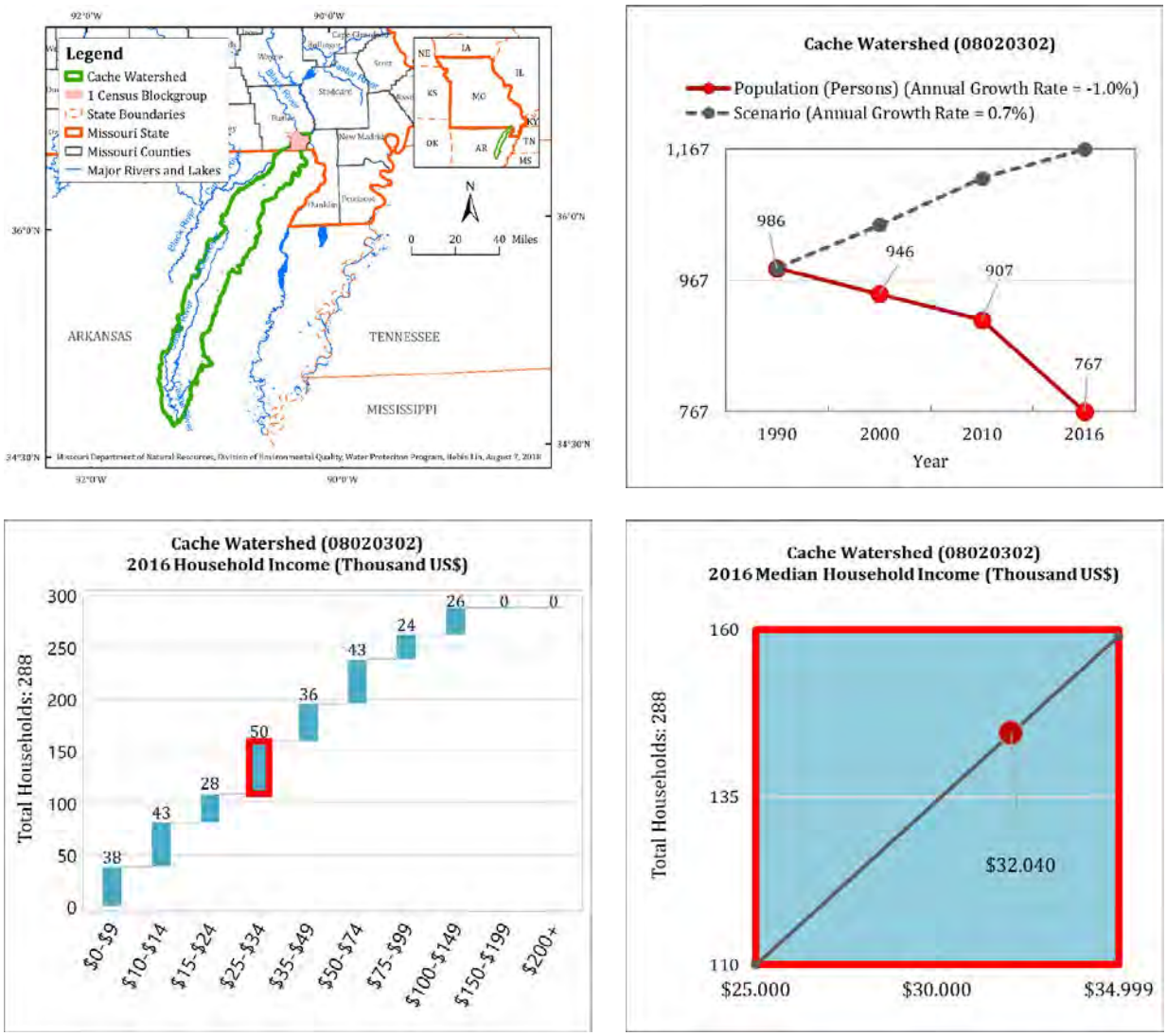


Figure 3-23. Cache Watershed: Population Growth and Median Household Income

3.1.24 Keg-Weeping Water Watershed (HUC 10240001)

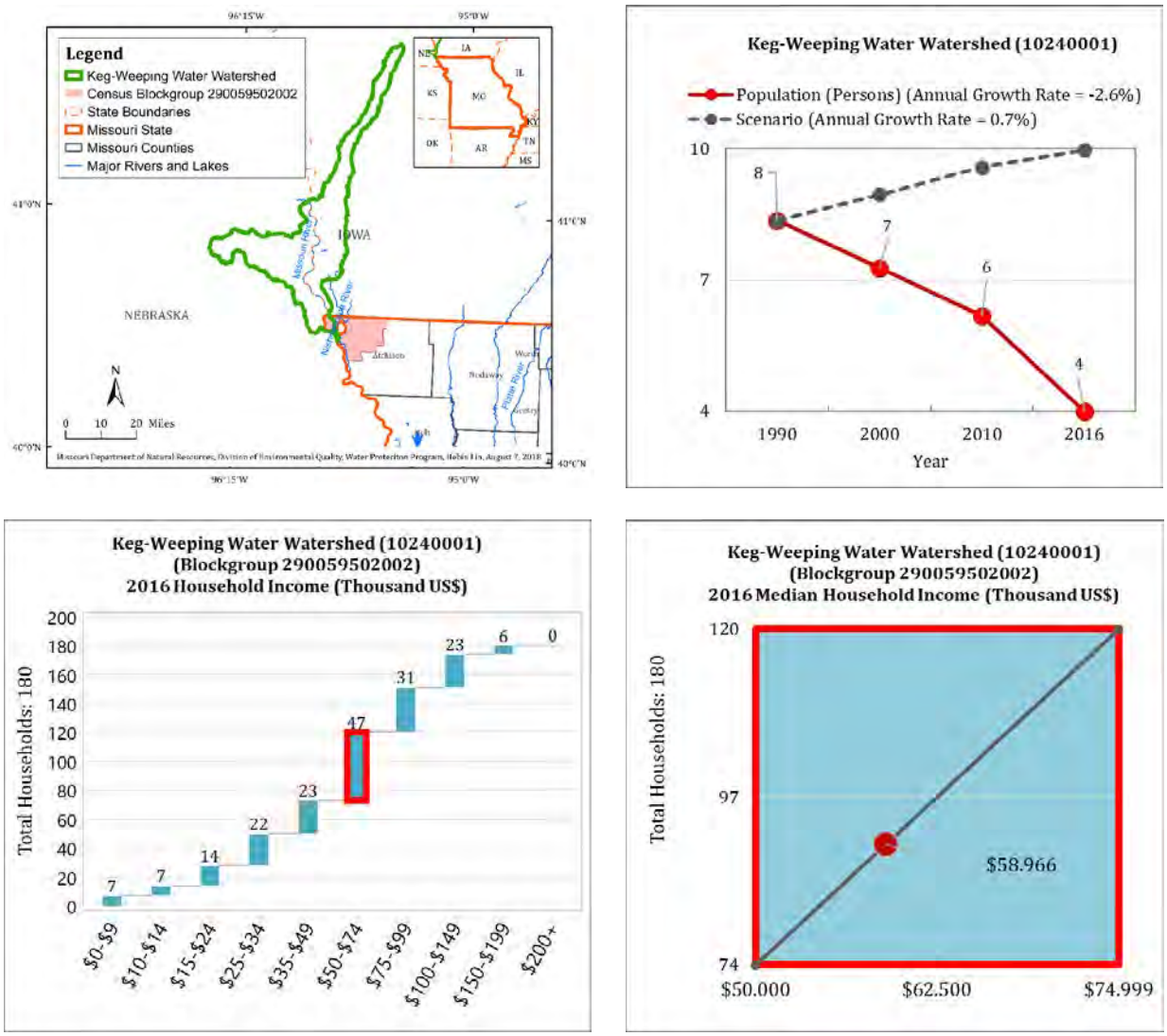


Figure 3-24. Keg-Weeping Water Watershed: Population Growth and Median Household Income

3.1.25 Nishnabotna Watershed (HUC 10240004)

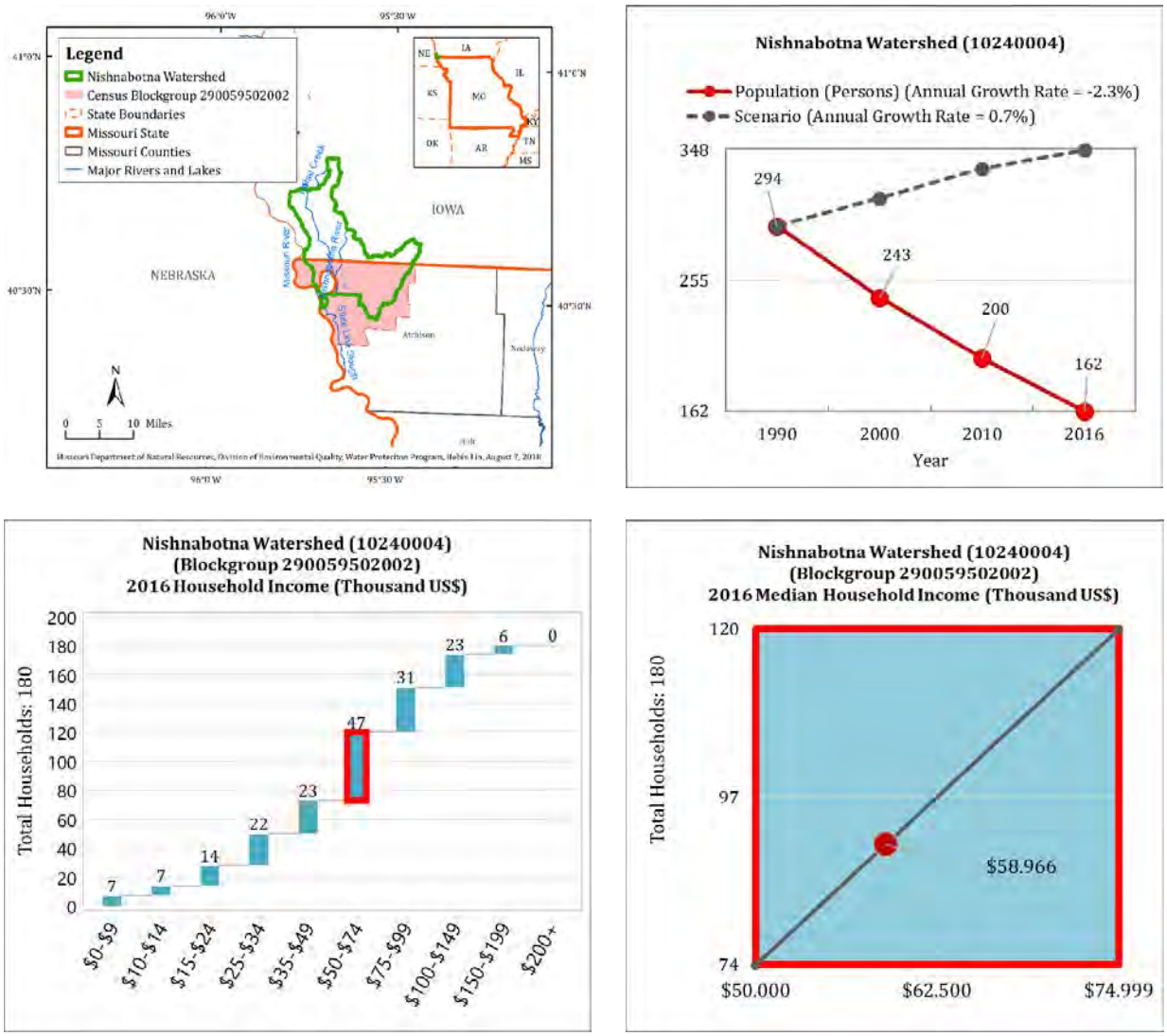


Figure 3-25. Nishnabotna Watershed: Population Growth and Median Household Income

3.1.26 Tarkio-Wolf Watershed (HUC 10240005)

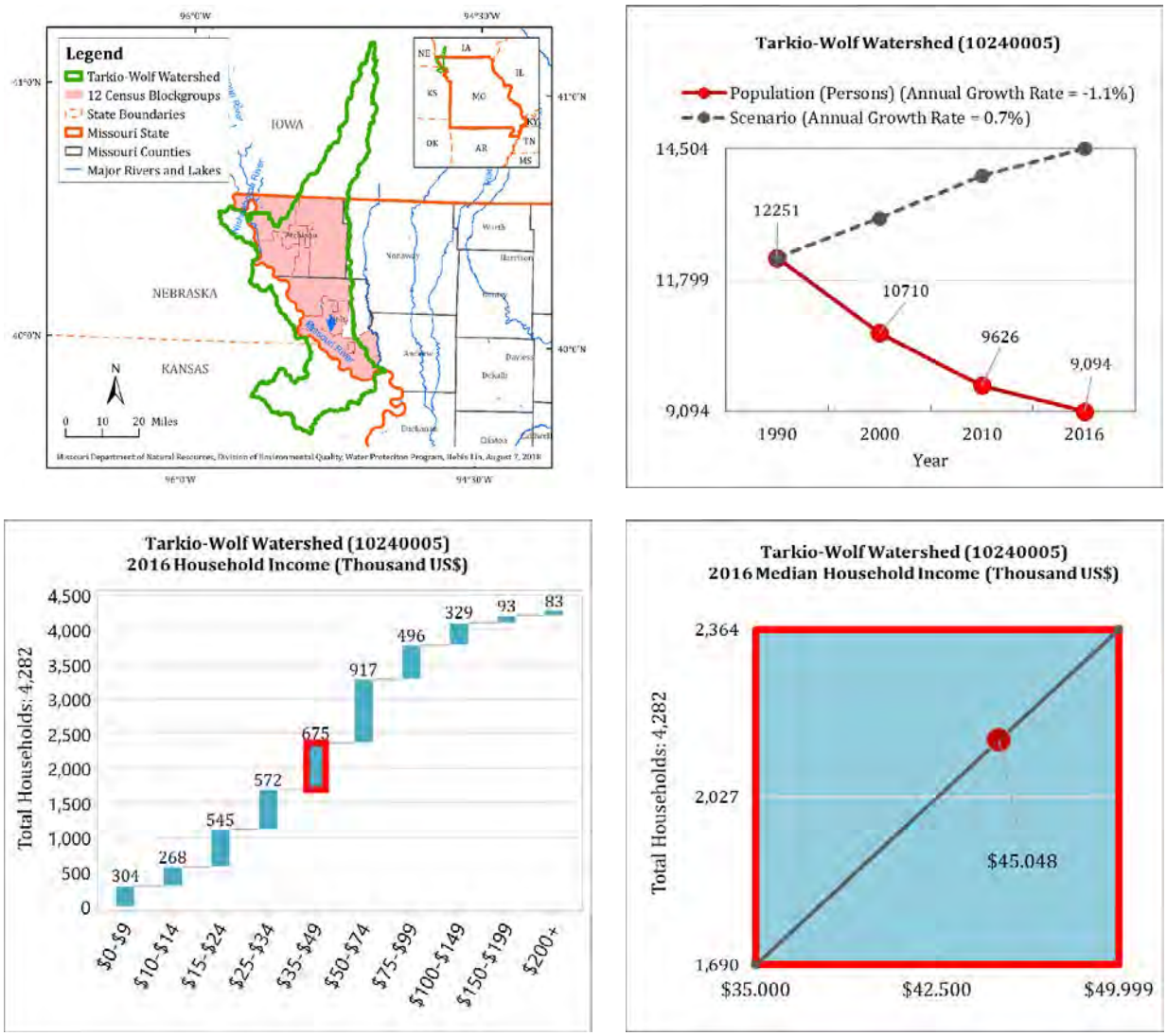


Figure 3-26. Tarkio-Wolf Watershed: Population Growth and Median Household Income

3.1.27 Nodaway Watershed (HUC 10240010)

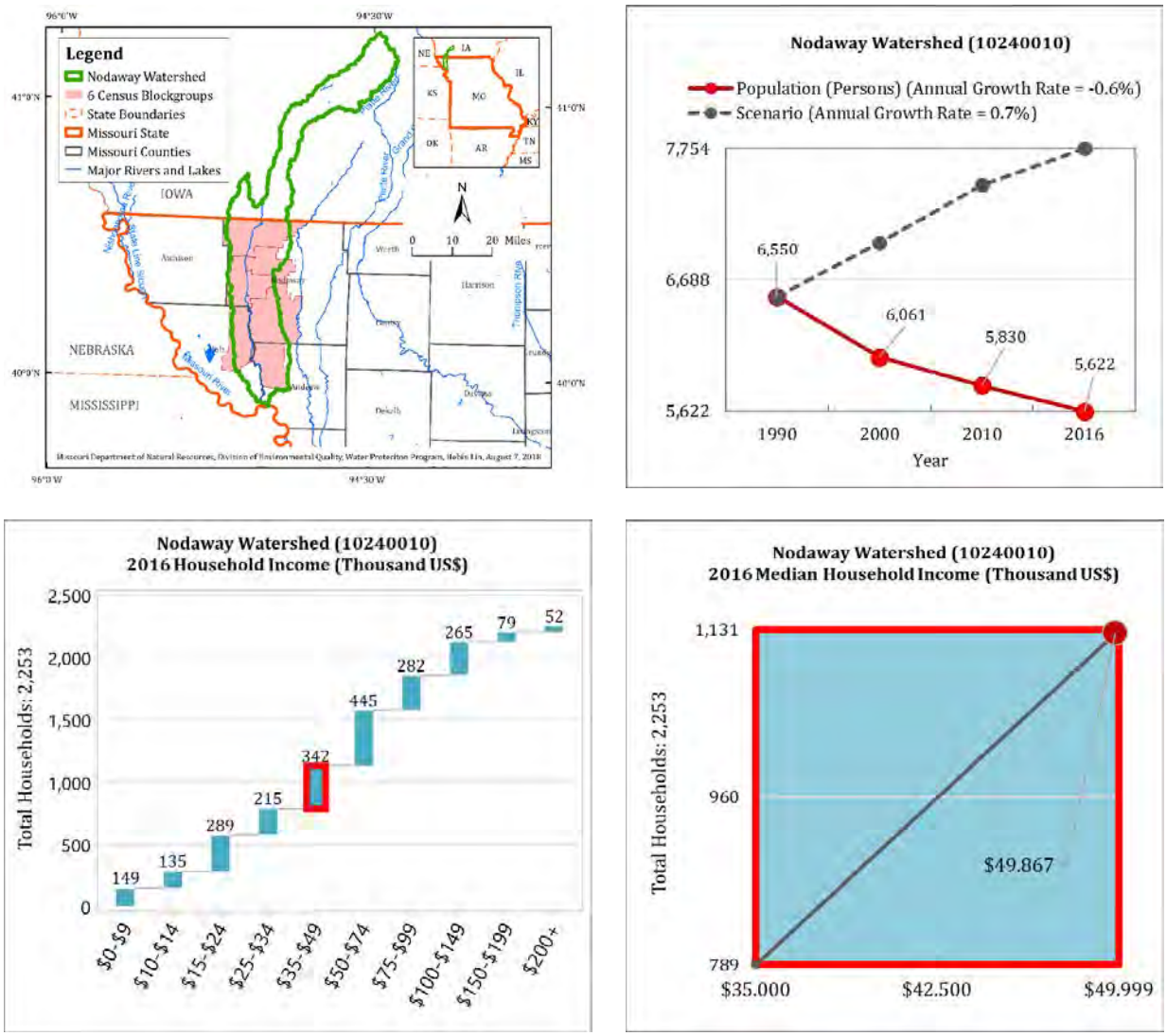


Figure 3-27. Nodaway Watershed: Population Growth and Median Household Income

3.1.28 Independence-Sugar Watershed (HUC 10240011)

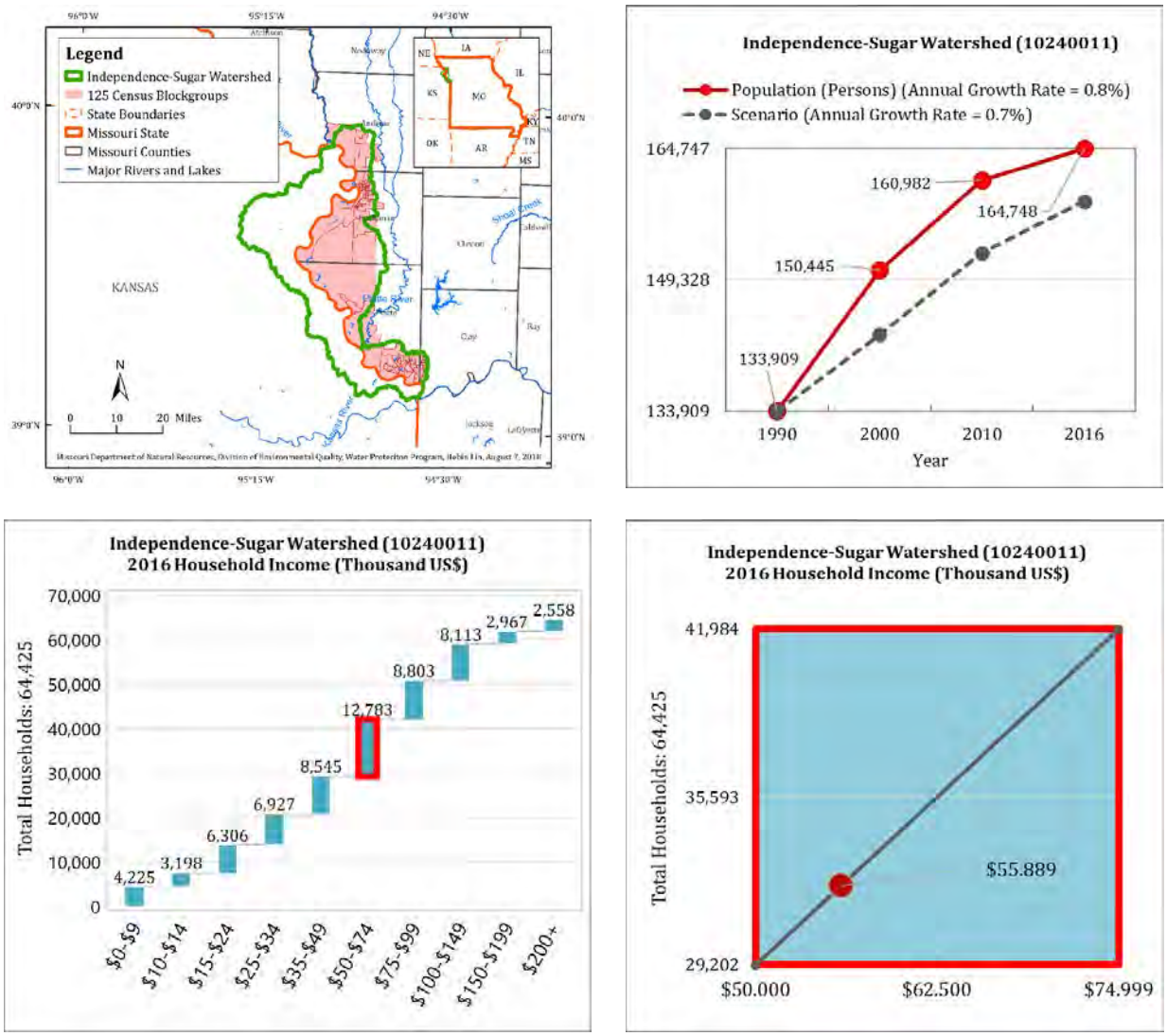


Figure 3-28. Independence-Sugar Watershed: Population Growth and Median Household Income

3.1.29 Platte Watershed (HUC 10240012)

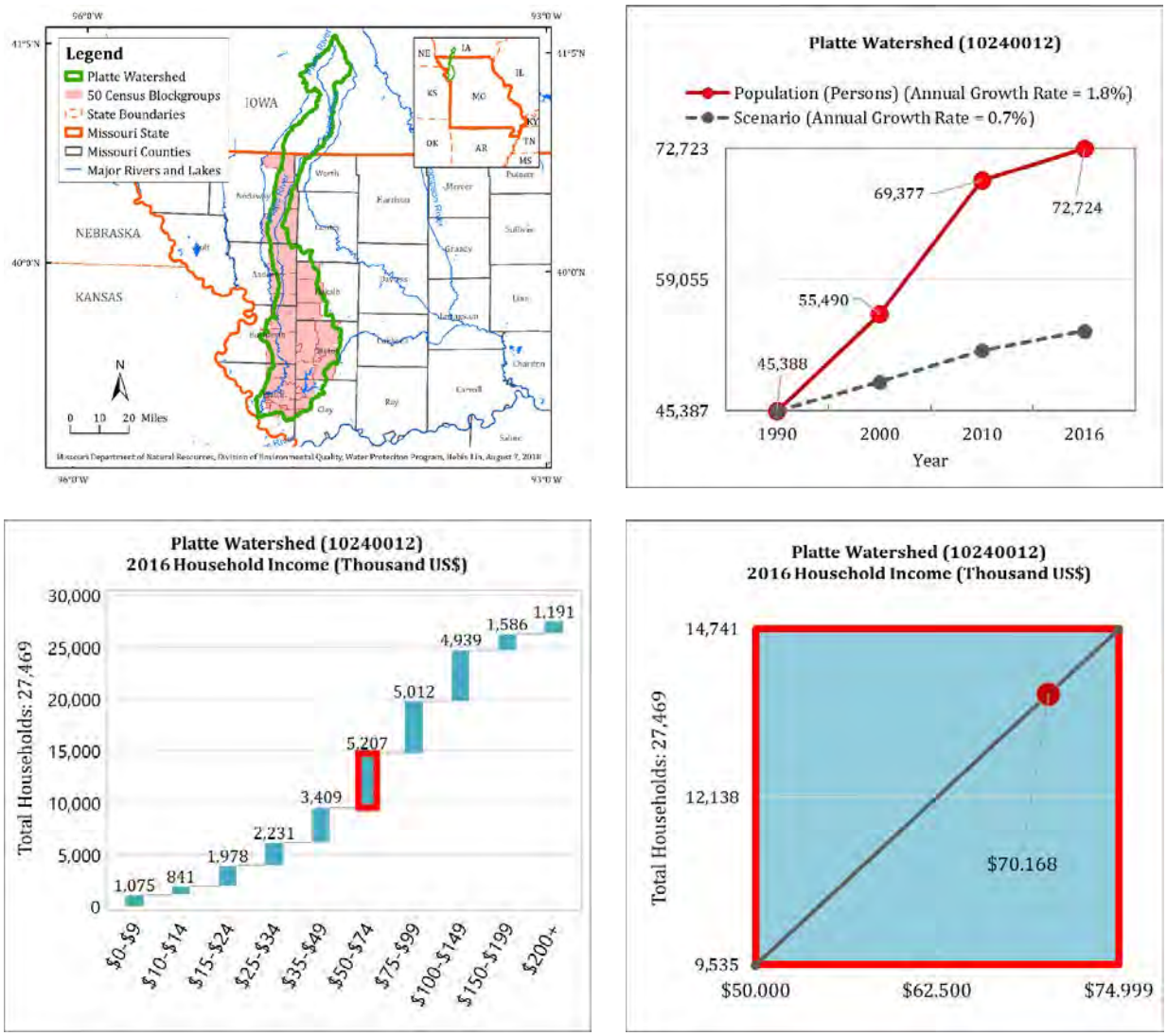


Figure 3-29. Platte Watershed: Population Growth and Median Household Income

3.1.30 One Hundred and Two Watershed (HUC 10240013)

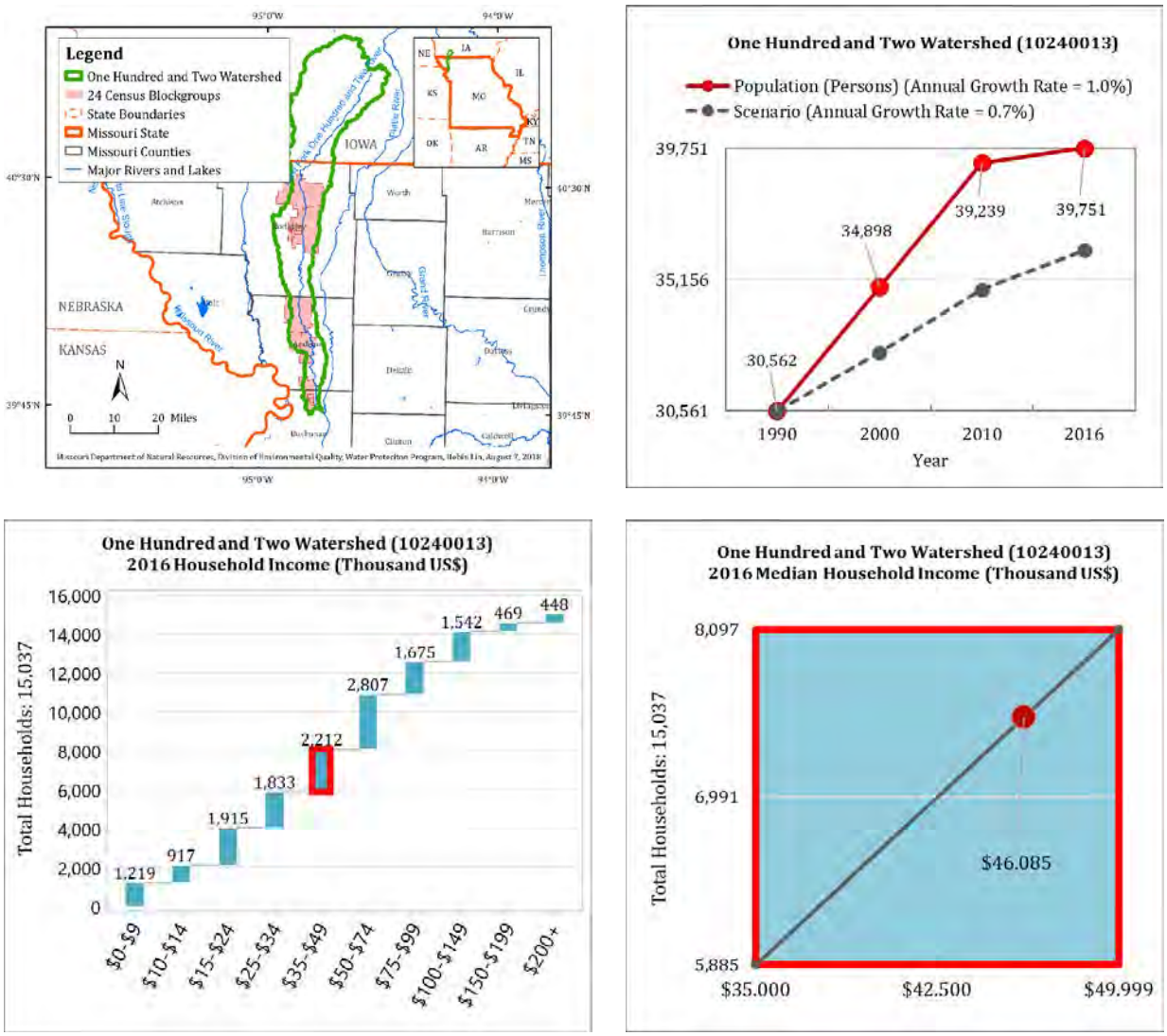


Figure 3-30. One Hundred and Two Watershed: Population Growth and Median Household Income

3.1.31 Lower Kansas Watershed (HUC 10270104)

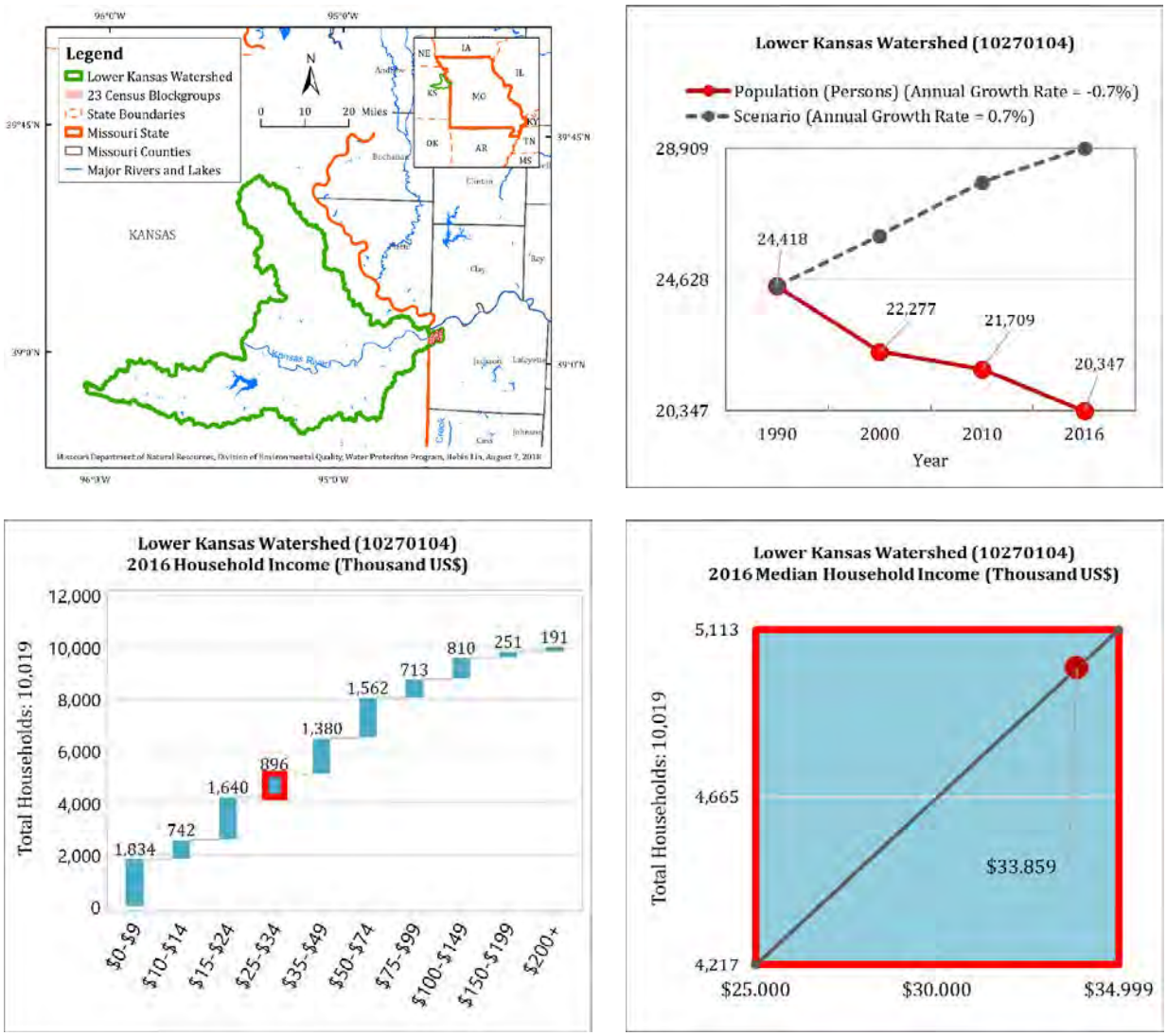


Figure 3-31. Lower Kansas Watershed: Population Growth and Median Household Income

3.1.32 Upper Grand Watershed (HUC 10280101)

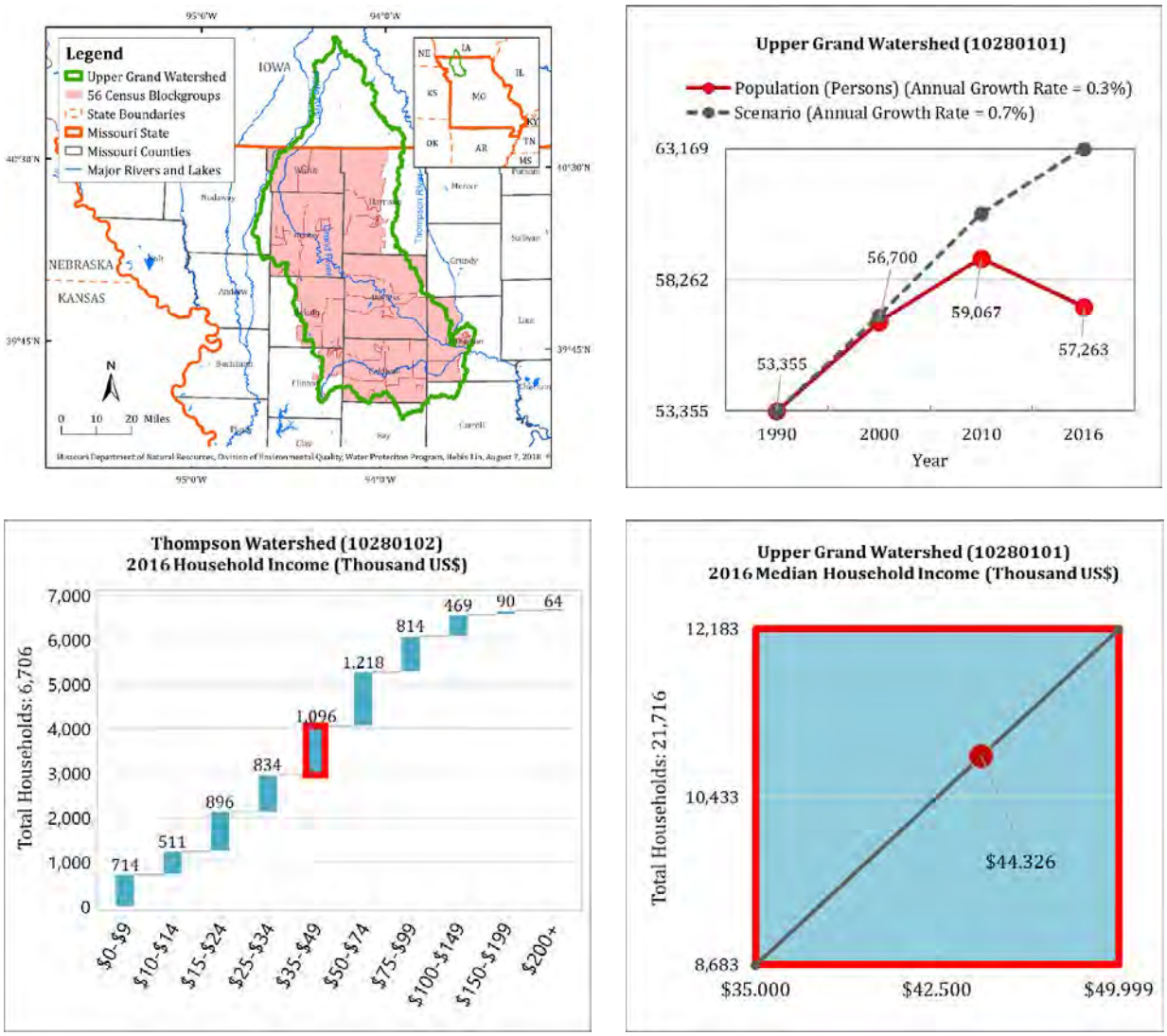


Figure 3-32. Upper Grand Watershed: Population Growth and Median Household Income

3.1.33 Thompson Watershed (HUC 10280102)

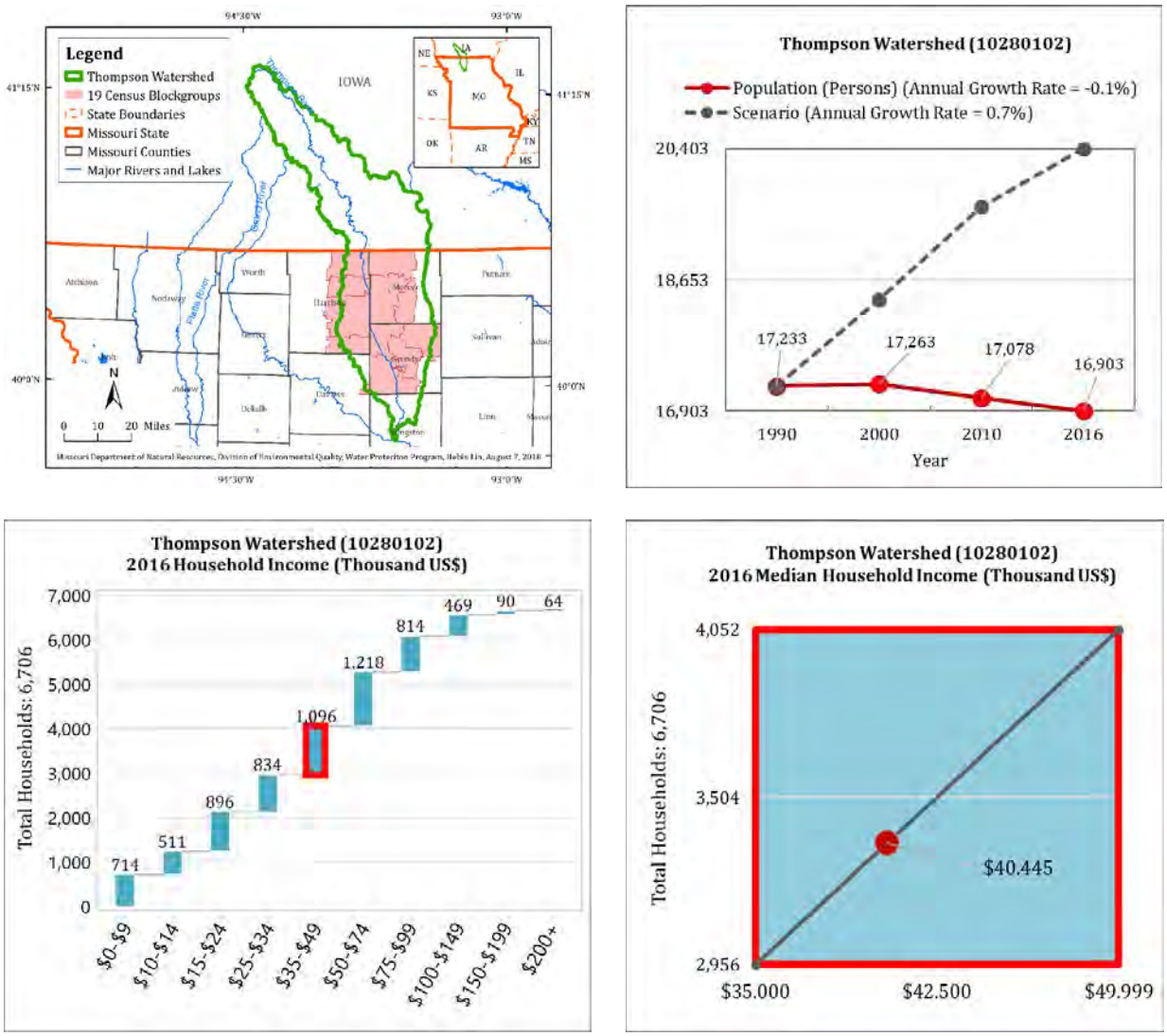


Figure 3-33. Thompson Watershed: Population Growth and Median Household Income

3.1.34 Lower Grand Watershed (HUC 10280103)

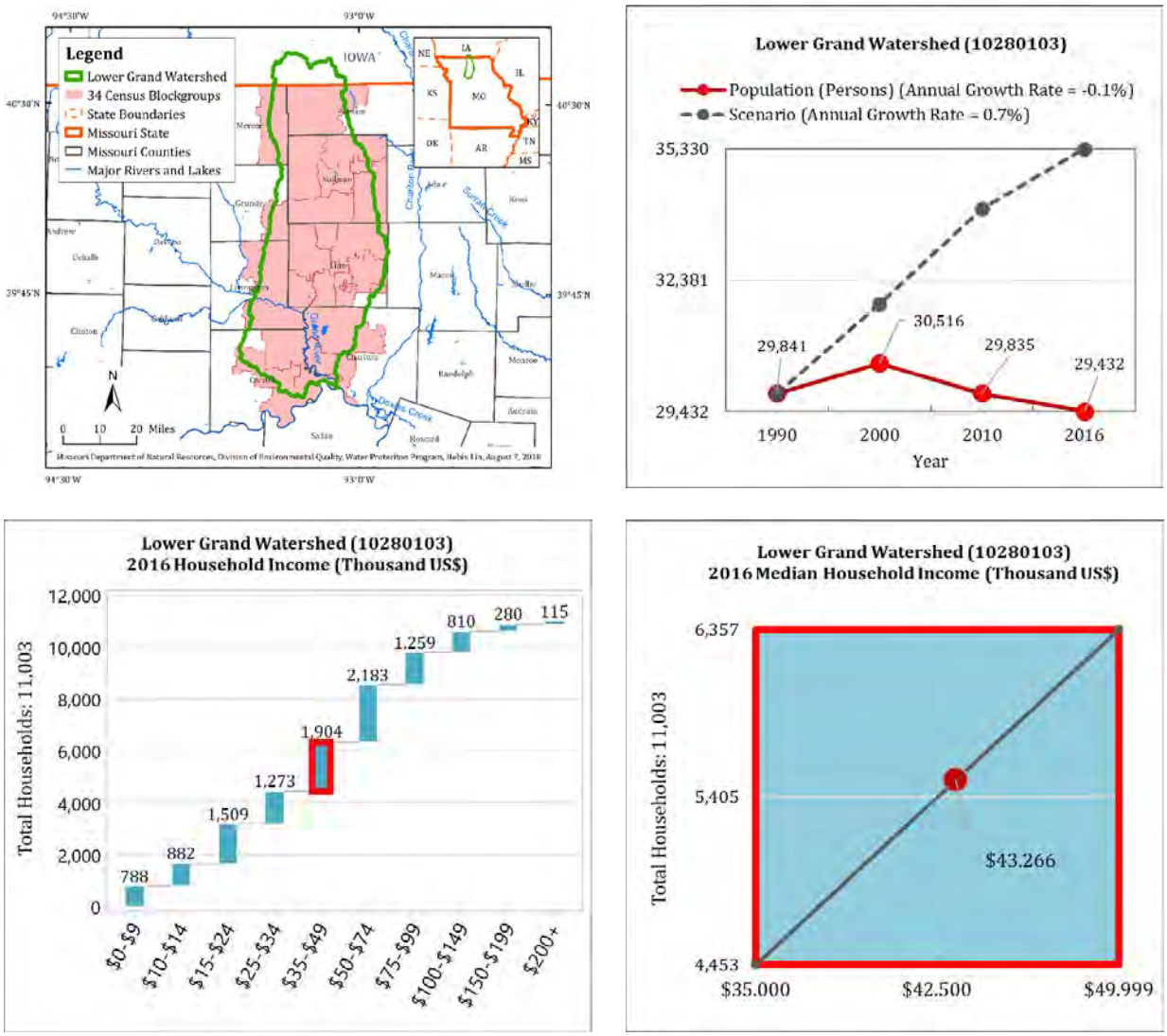


Figure 3-34. Lower Grand Watershed: Population Growth and Median Household Income

3.1.35 Upper Chariton Watershed (HUC 10280201)

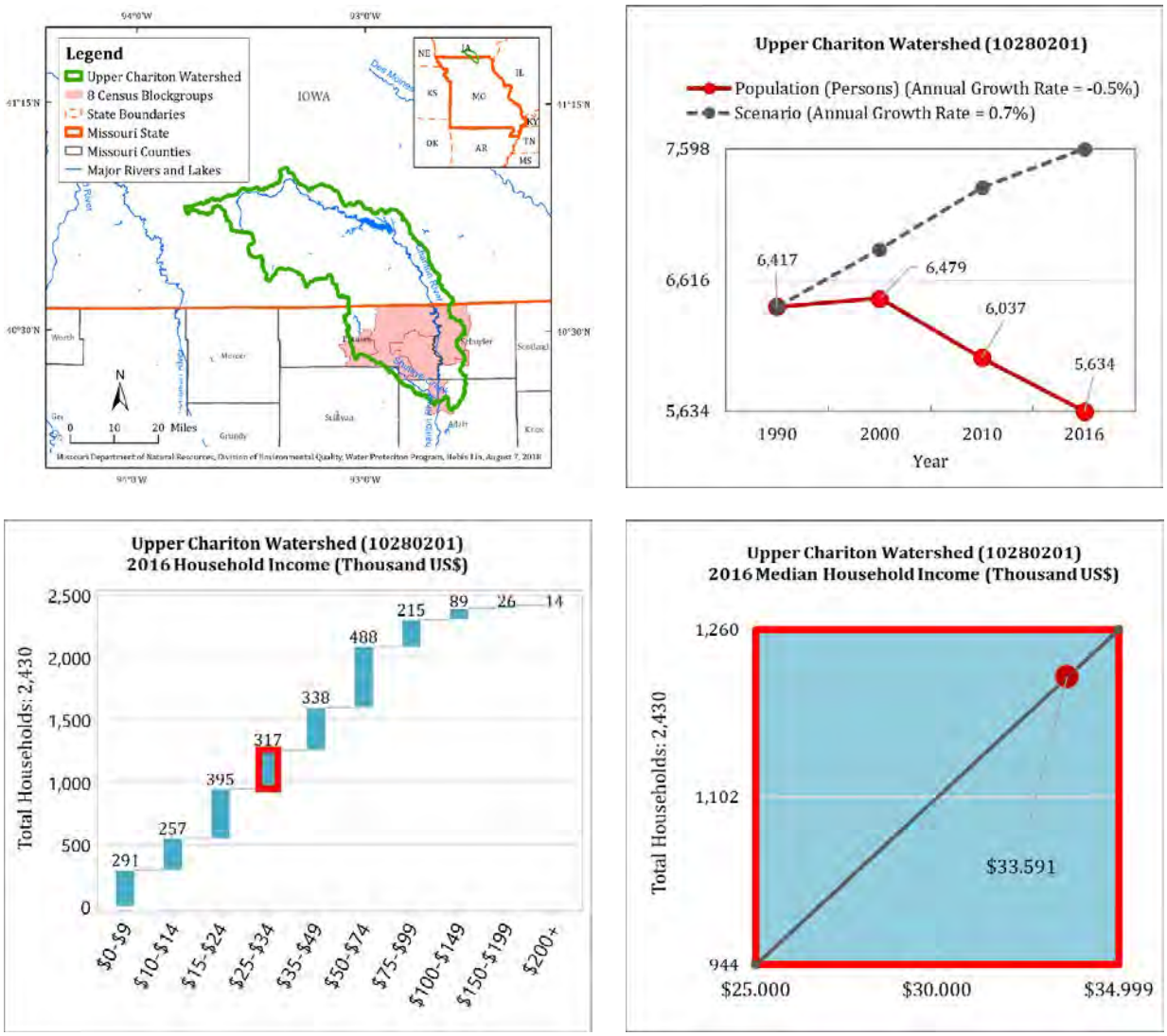


Figure 3-35. Upper Chariton Watershed: Population Growth and Median Household Income

3.1.36 Lower Chariton Watershed (HUC 10280202)

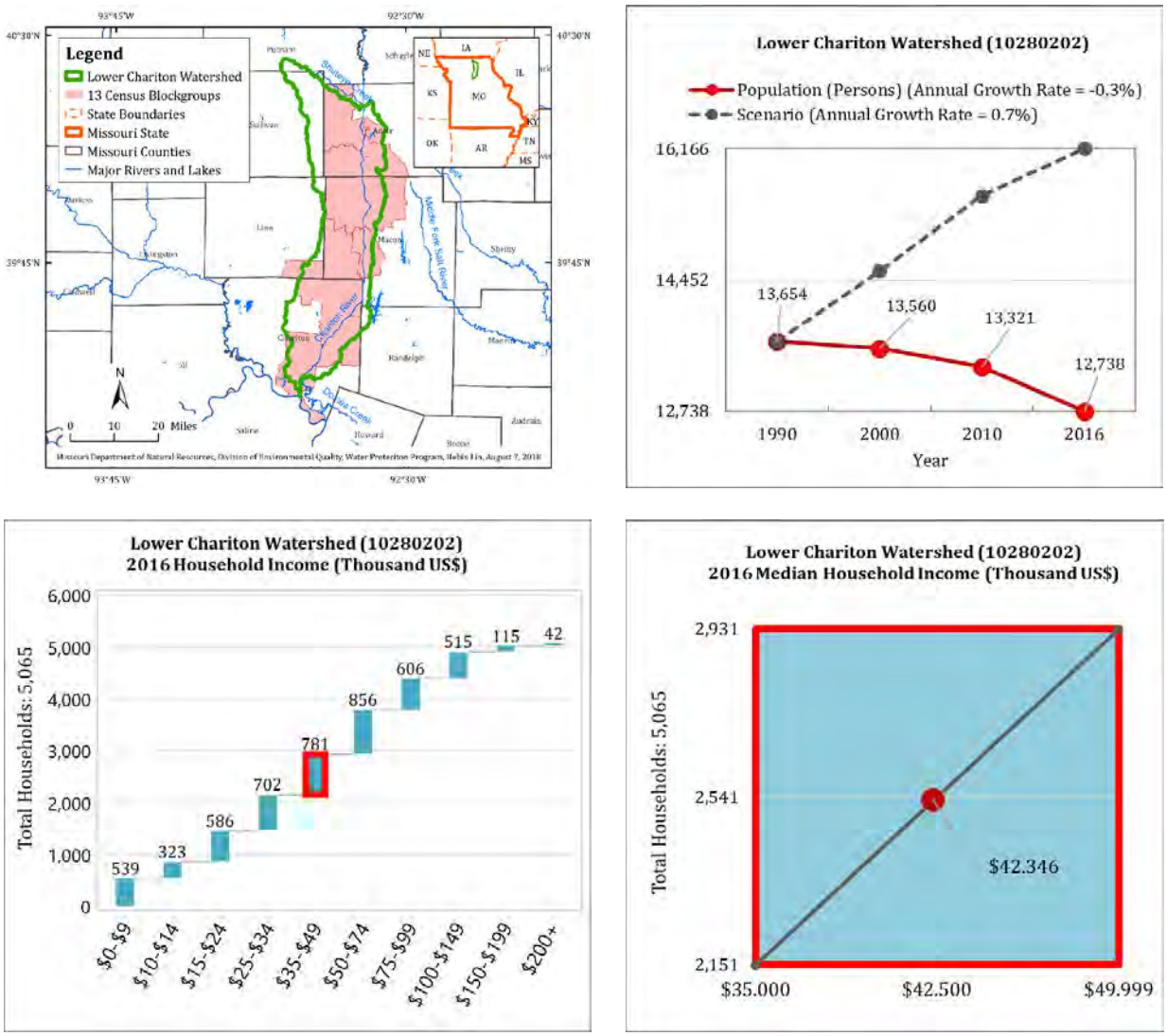


Figure 3-36. Lower Chariton Watershed: Population Growth and Median Household Income

3.1.37 Little Chariton Watershed (HUC 10280203)

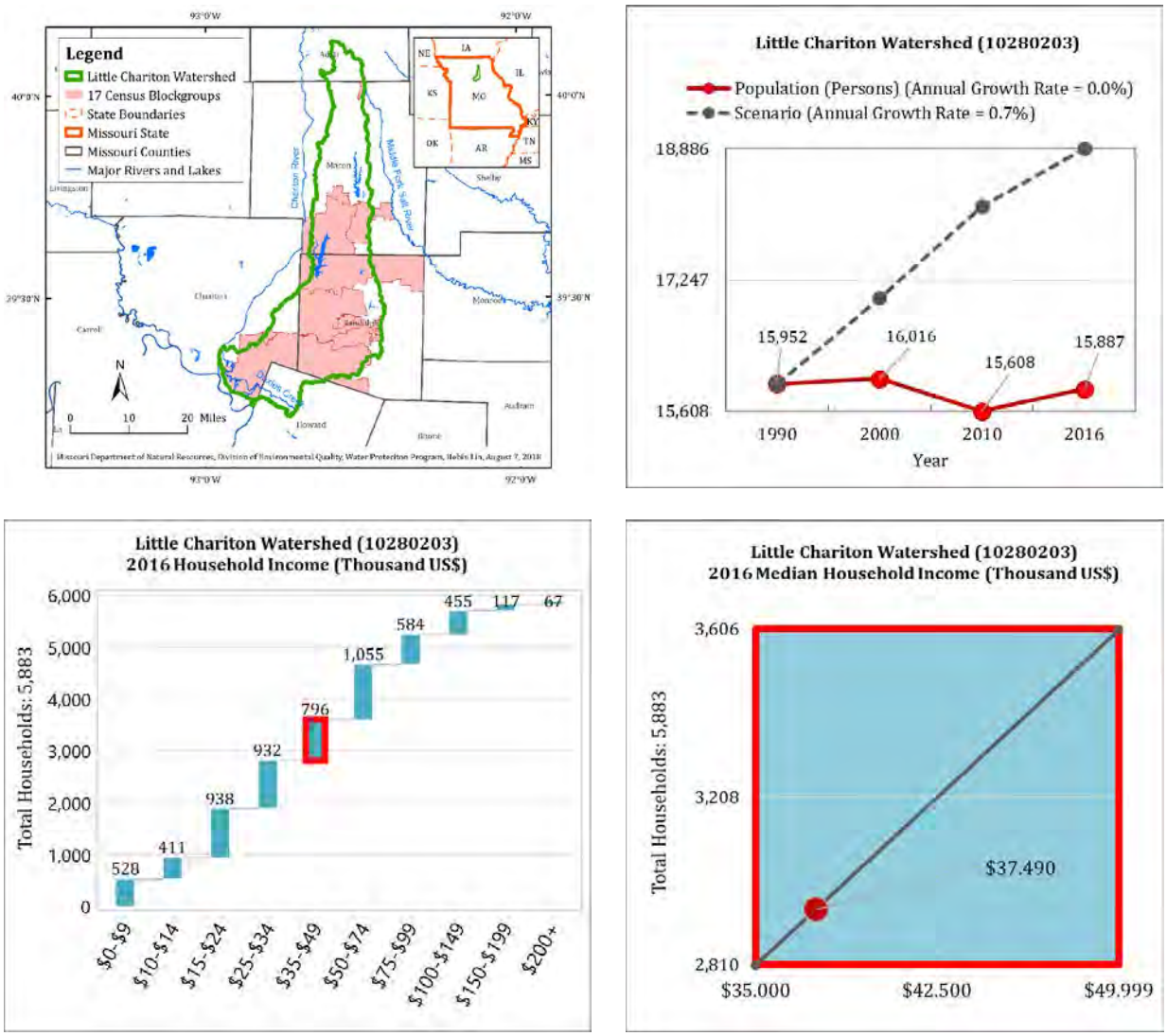


Figure 3-37. Little Chariton Watershed: Population Growth and Median Household Income

3.1.38 Lower Marais Des Cygnes Watershed (HUC 10290102)

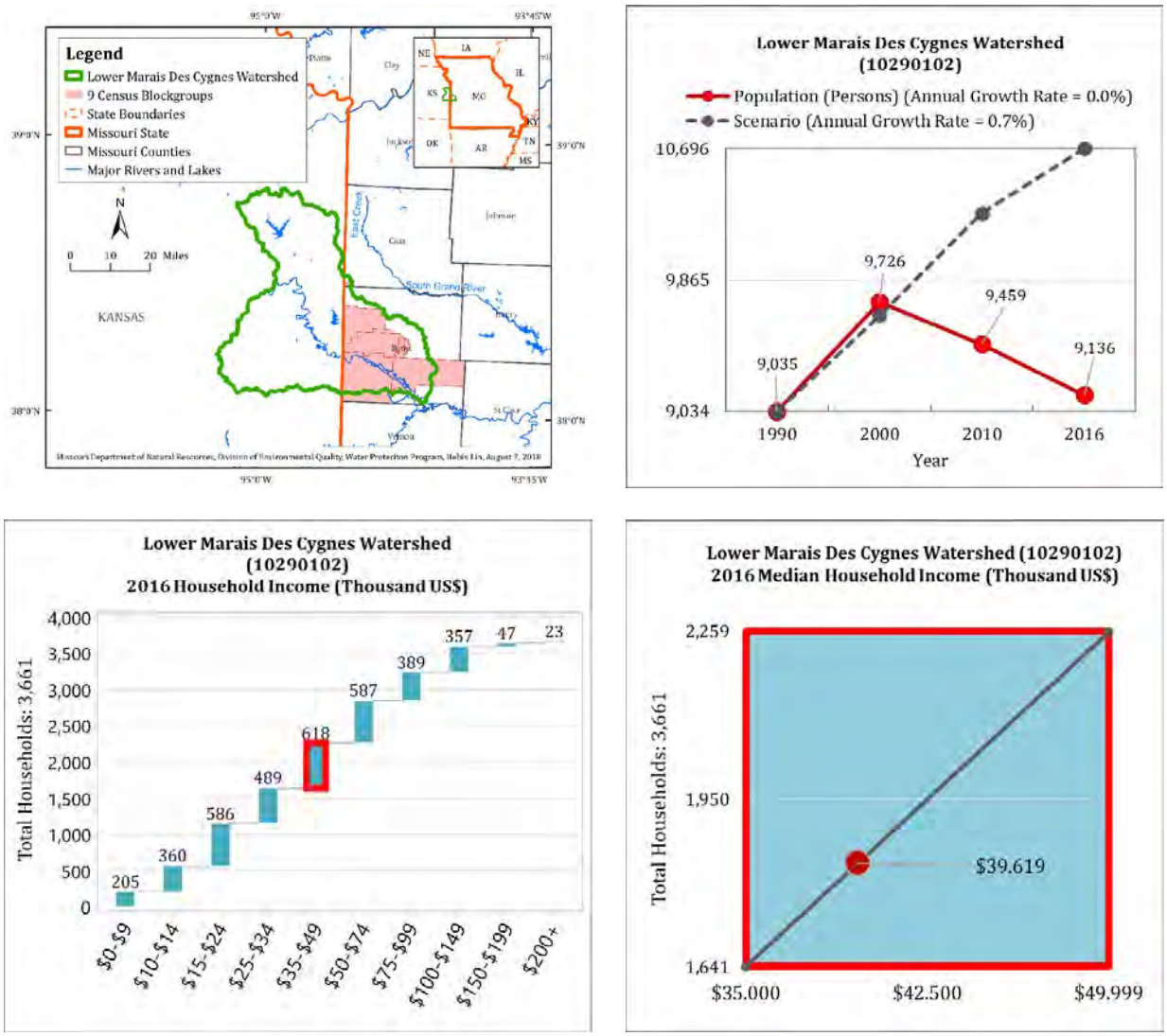


Figure 3-38. Lower Marais Des Cygnes Watershed: Population Growth and Median Household Income

3.1.39 Little Osage Watershed (HUC 10290103)

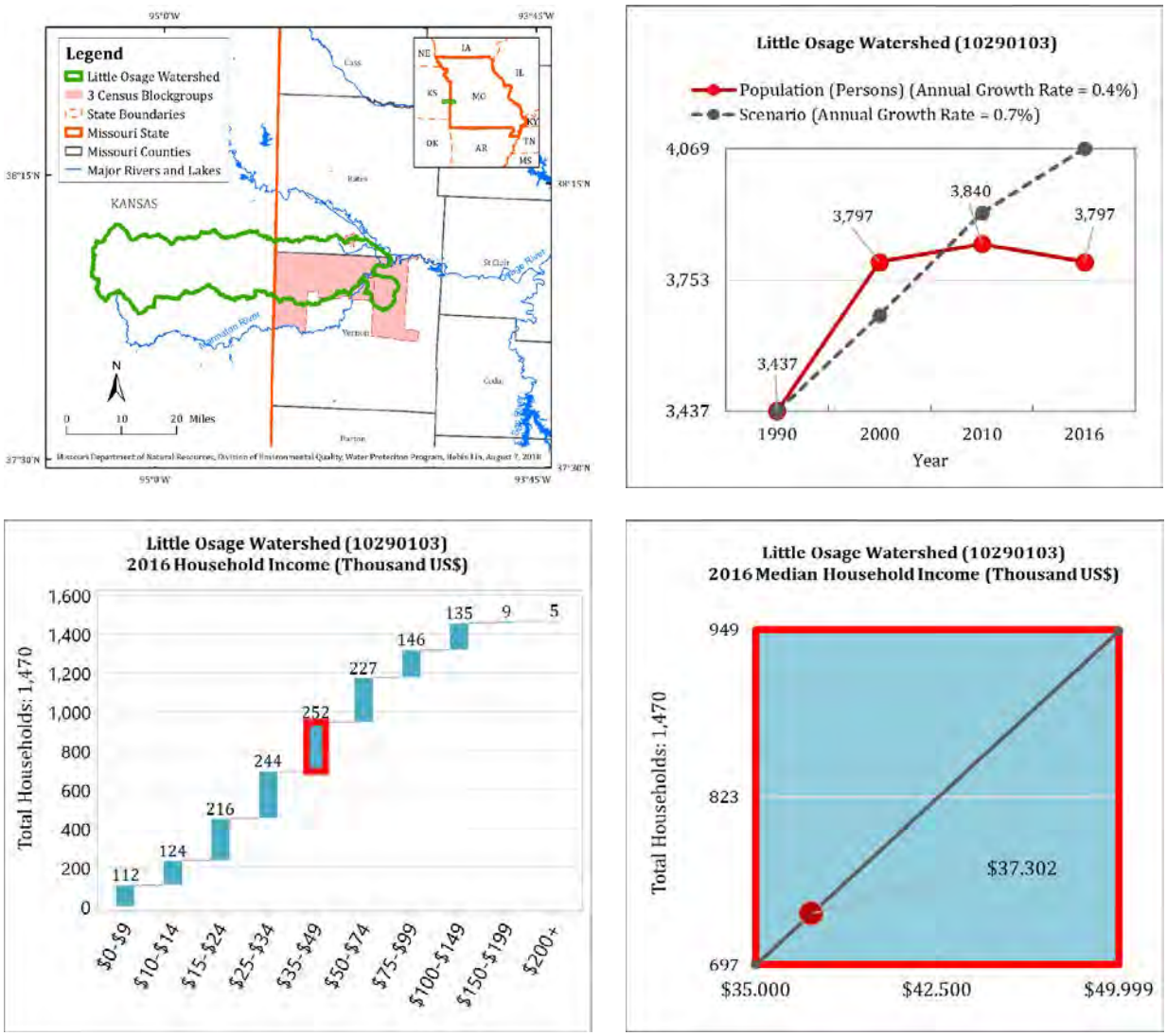


Figure 3-39. Little Osage Watershed: Population Growth and Median Household Income

3.1.40 Marmaton Watershed (HUC 10290104)

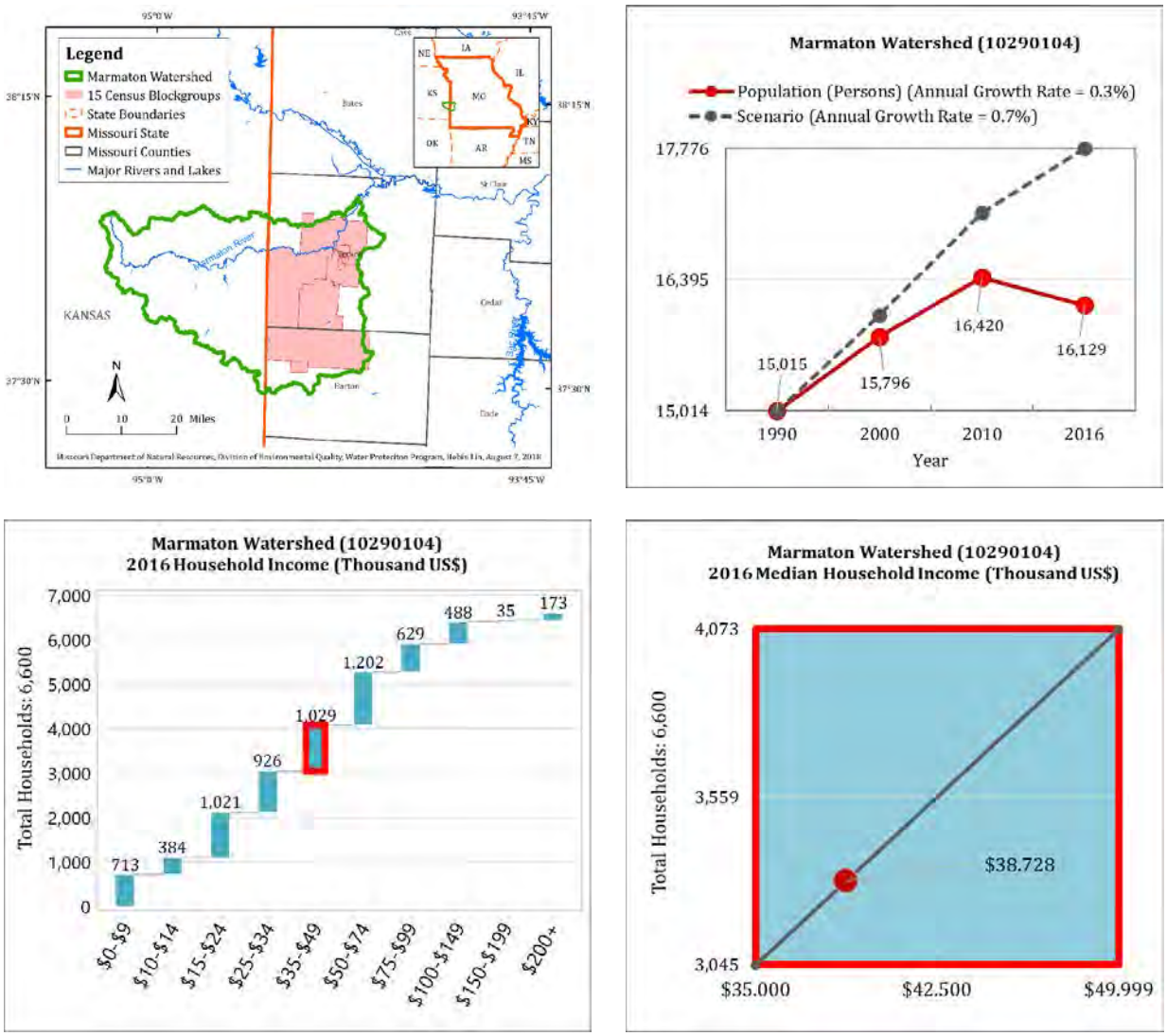


Figure 3-40. Marmaton Watershed: Population Growth and Median Household Income

3.1.41 Harry S. Truman Reservoir Watershed (HUC 10290105)

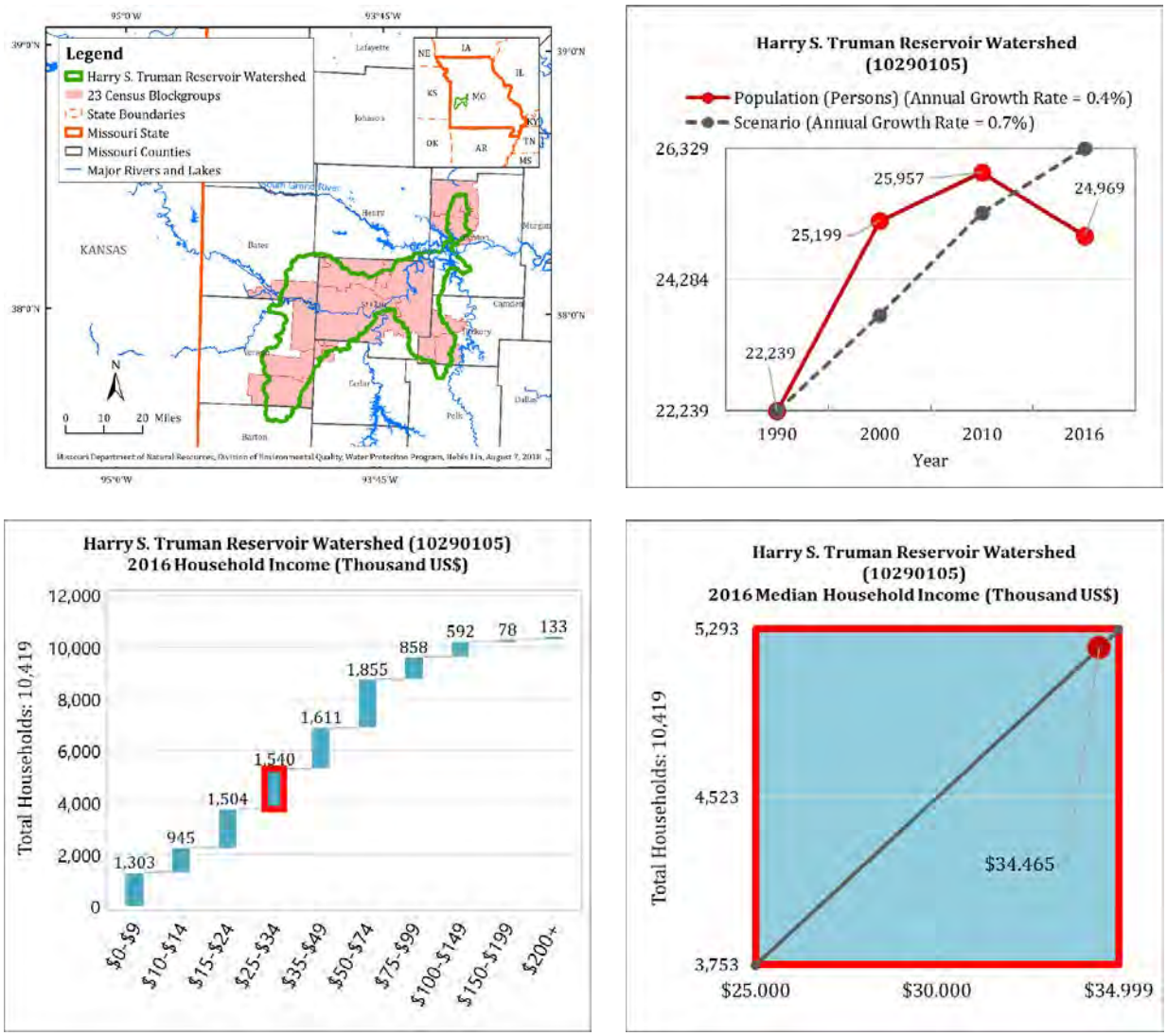


Figure 3-41. Harry S. Truman Reservoir Watershed: Population Growth and Median Household Income

3.1.42 Sac Watershed (HUC 10290106)

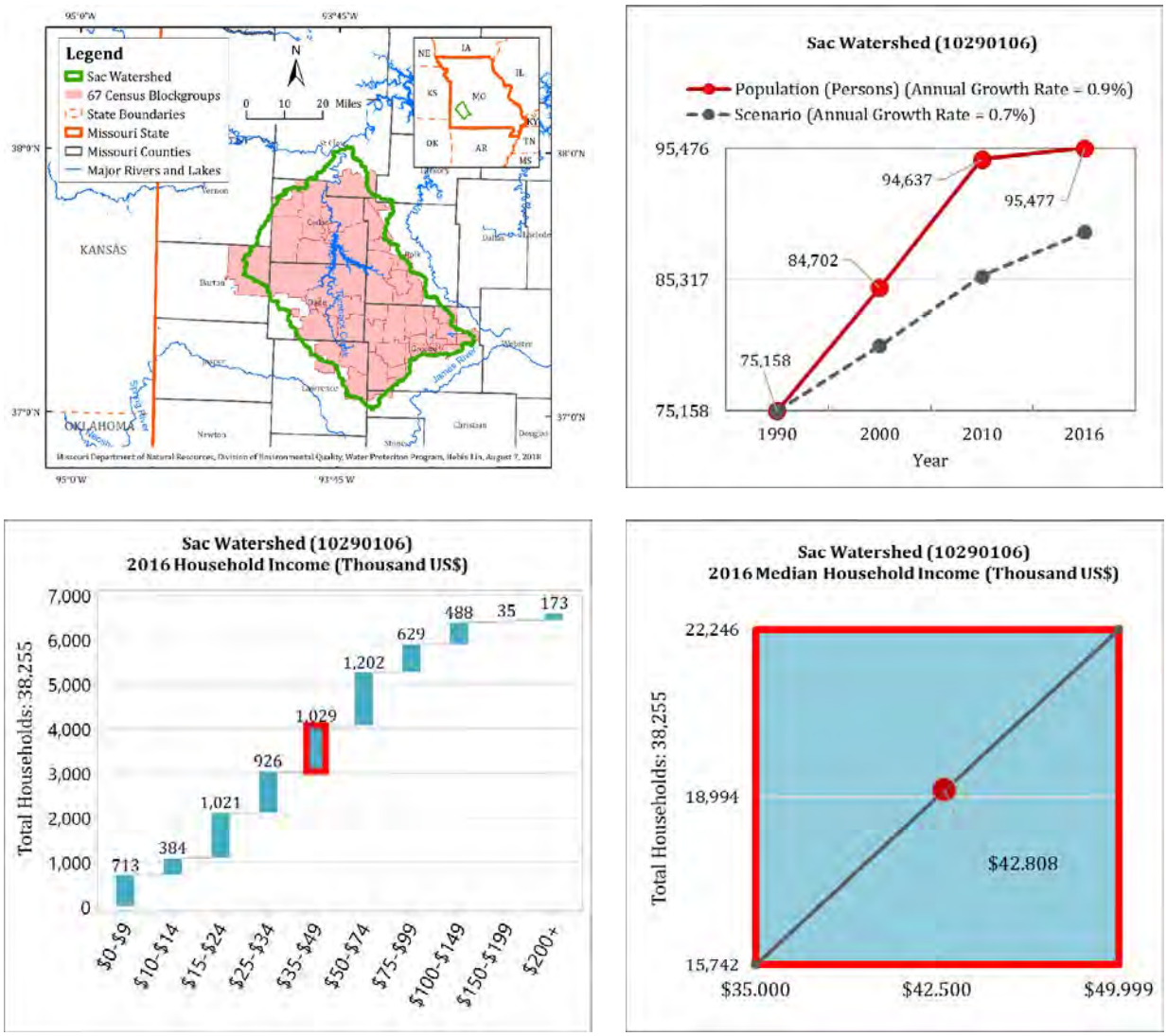


Figure 3-42. Sac Watershed: Population Growth and Median Household Income

3.1.43 Pomme De Terre Watershed (HUC 10290107)

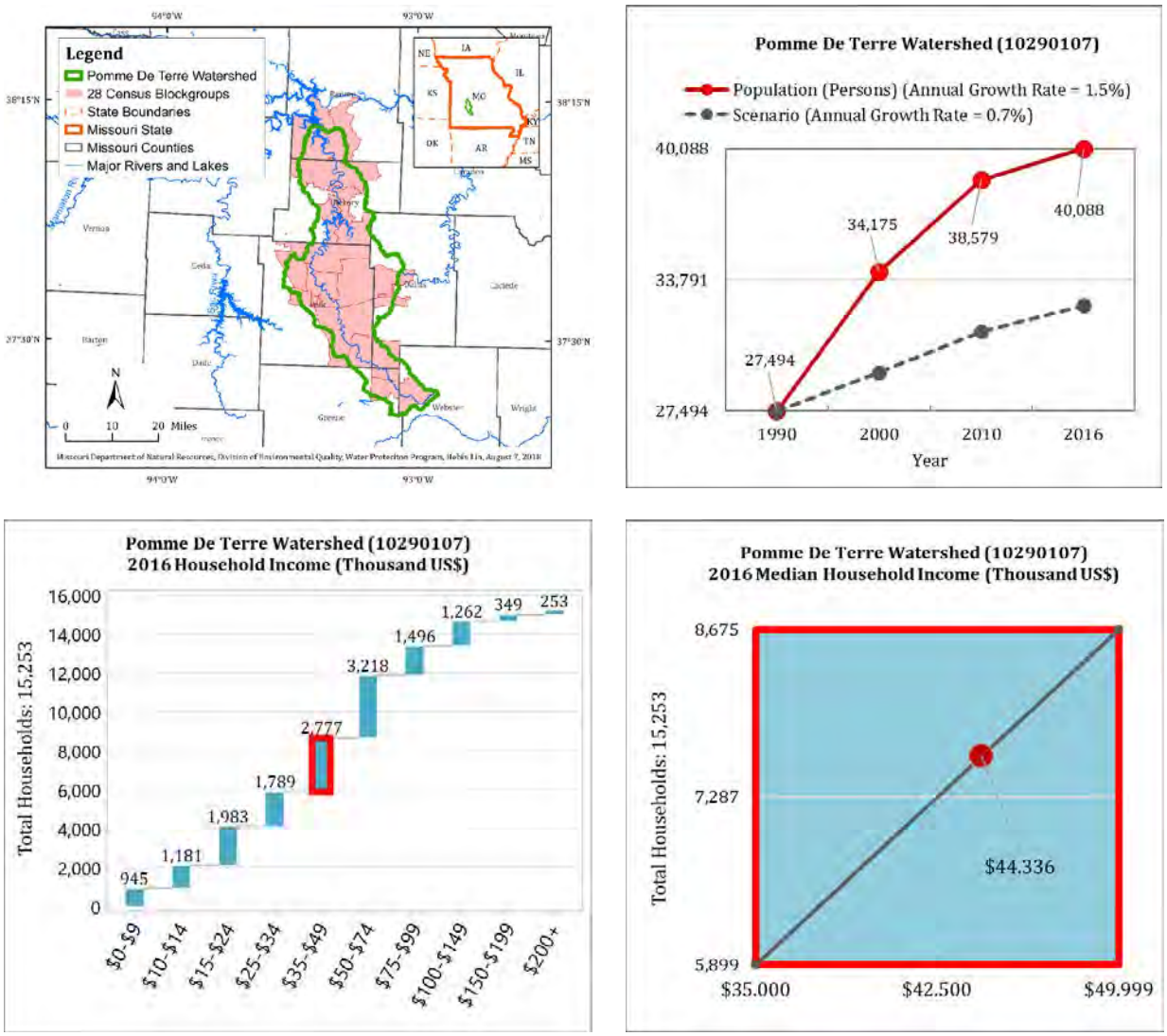


Figure 3-43. Pomme De Terre Watershed: Population Growth and Median Household Income

3.1.44 South Grand Watershed (HUC 10290108)

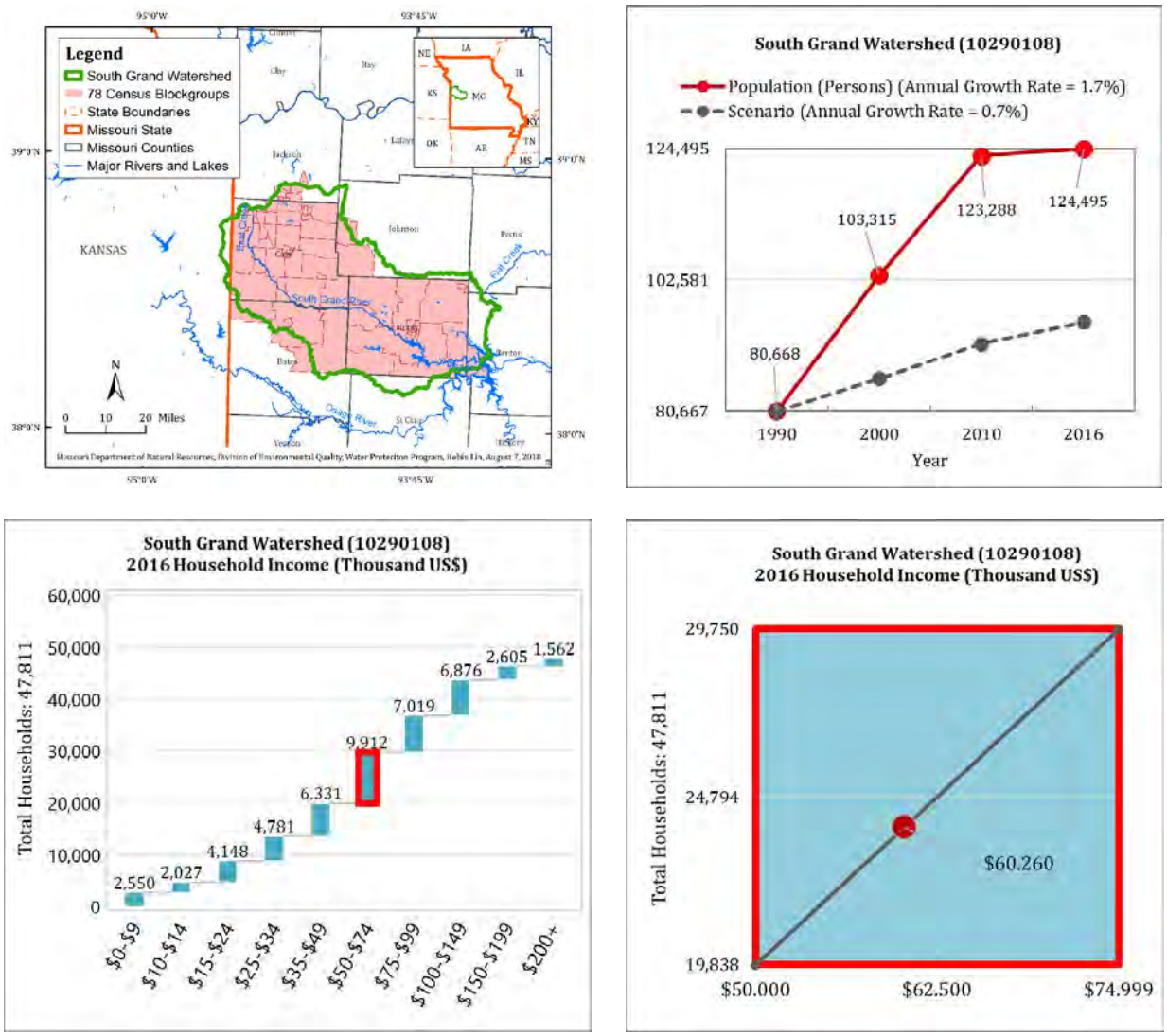


Figure 3-44. South Grand Watershed: Population Growth and Median Household Income

3.1.45 Lake of the Ozarks Watershed (HUC 10290109)

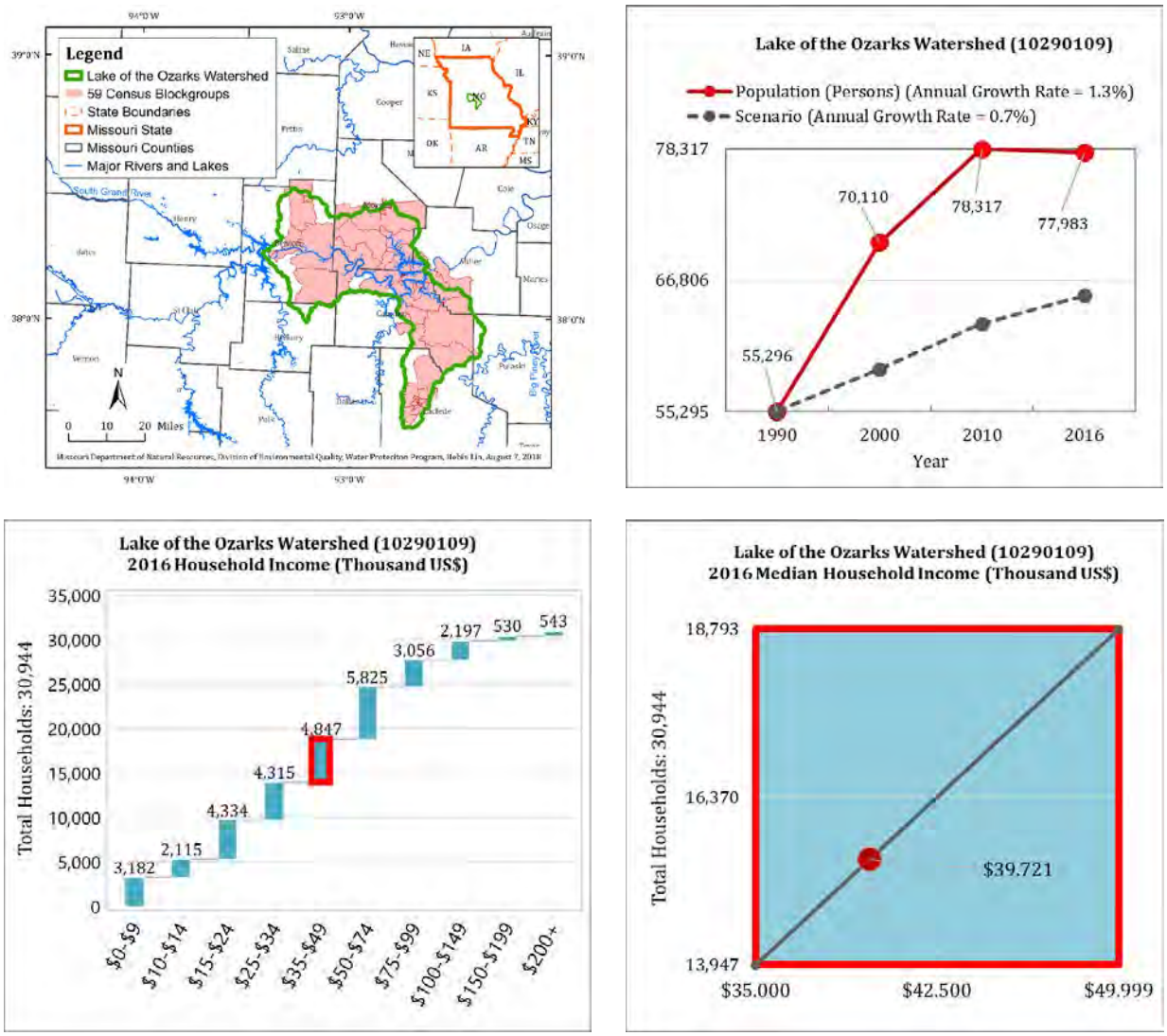


Figure 3-45. Lake of the Ozarks Watershed: Population Growth and Median Household Income

3.1.46 Niangua Watershed (HUC 10290110)

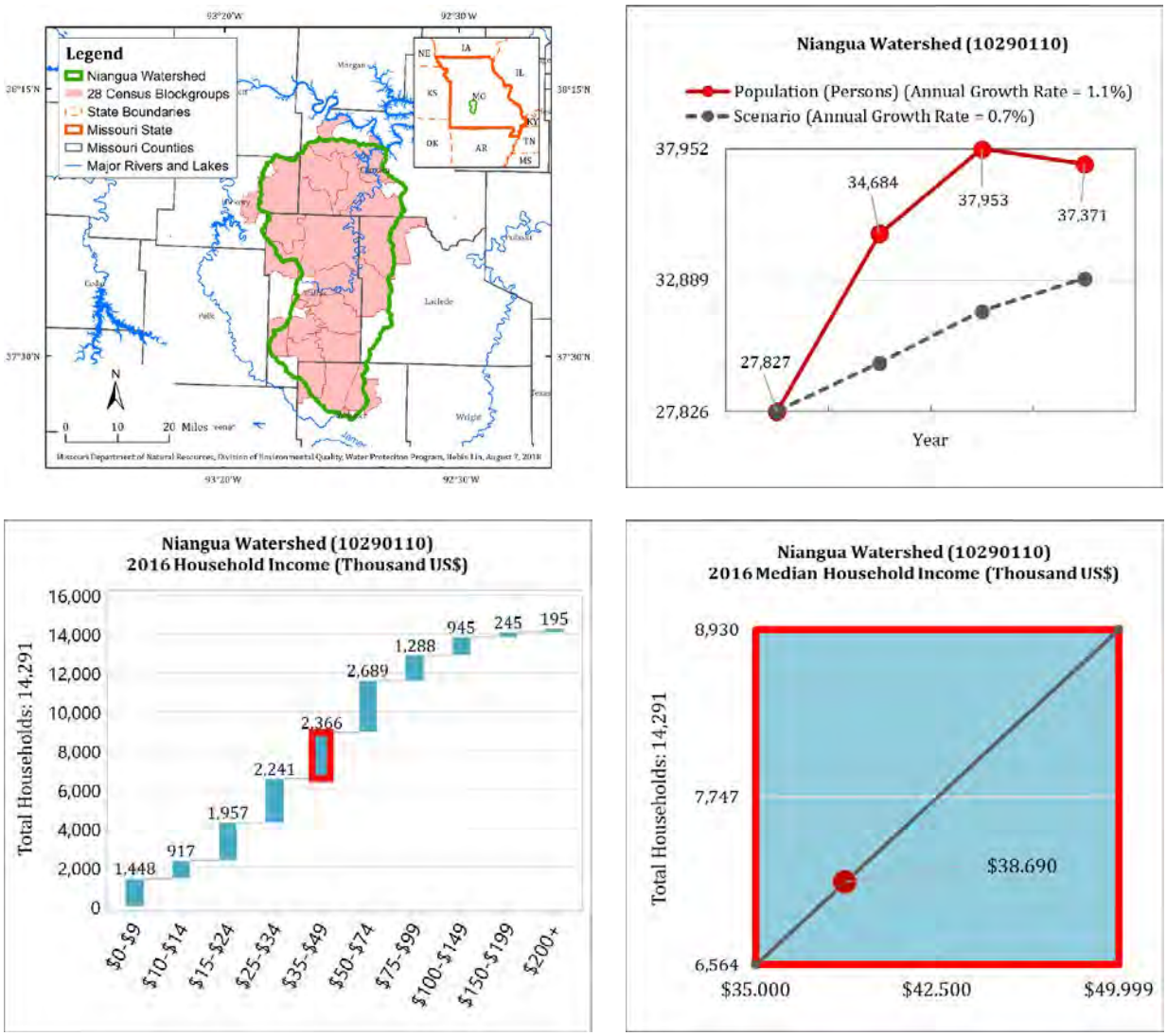


Figure 3-46. Niangua Watershed: Population Growth and Median Household Income

3.1.47 Lower Osage Watershed (HUC 10290111)

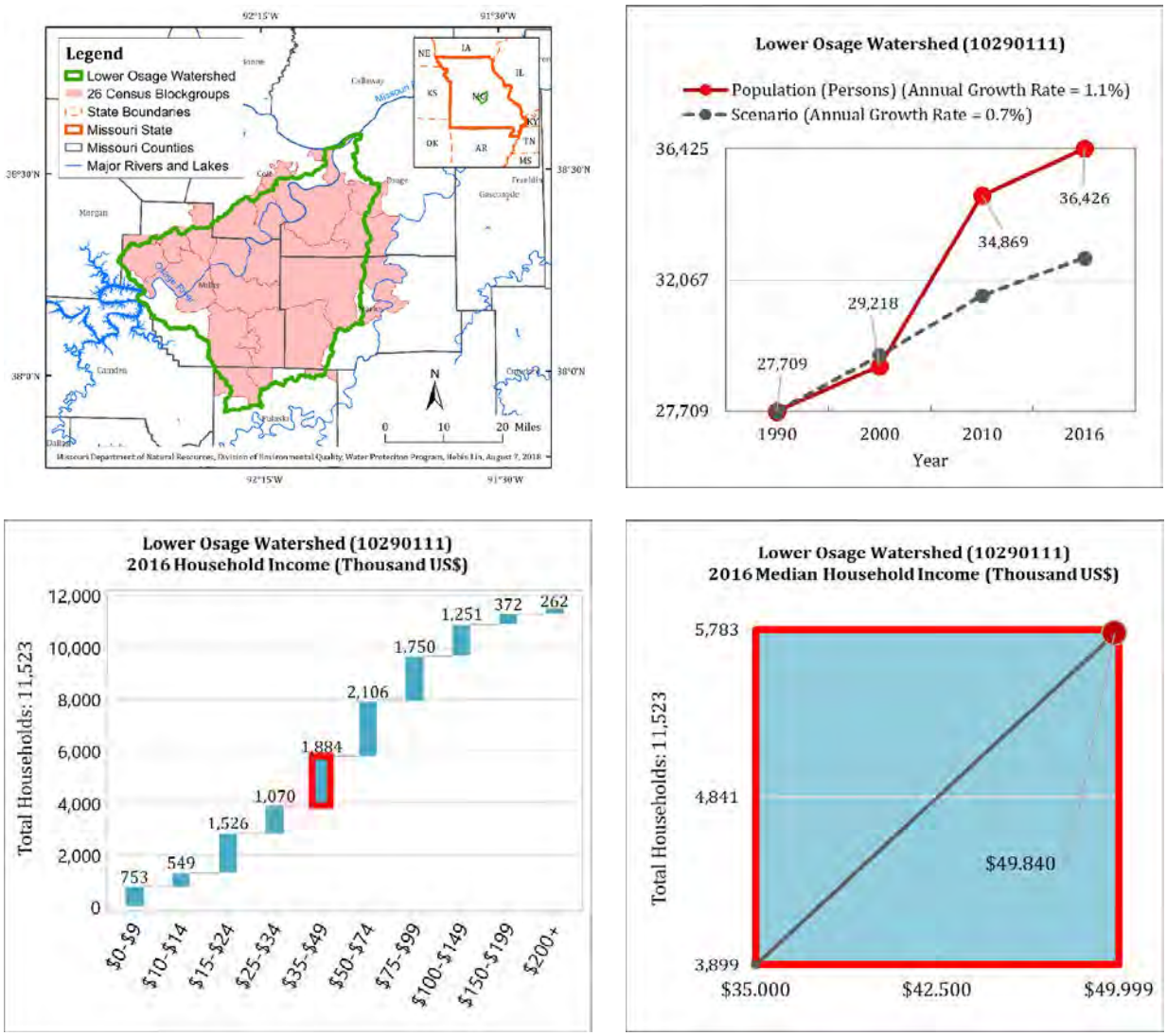


Figure 3-47. Lower Osage Watershed: Population Growth and Median Household Income

3.1.48 Upper Gasconade Watershed (HUC 10290201)

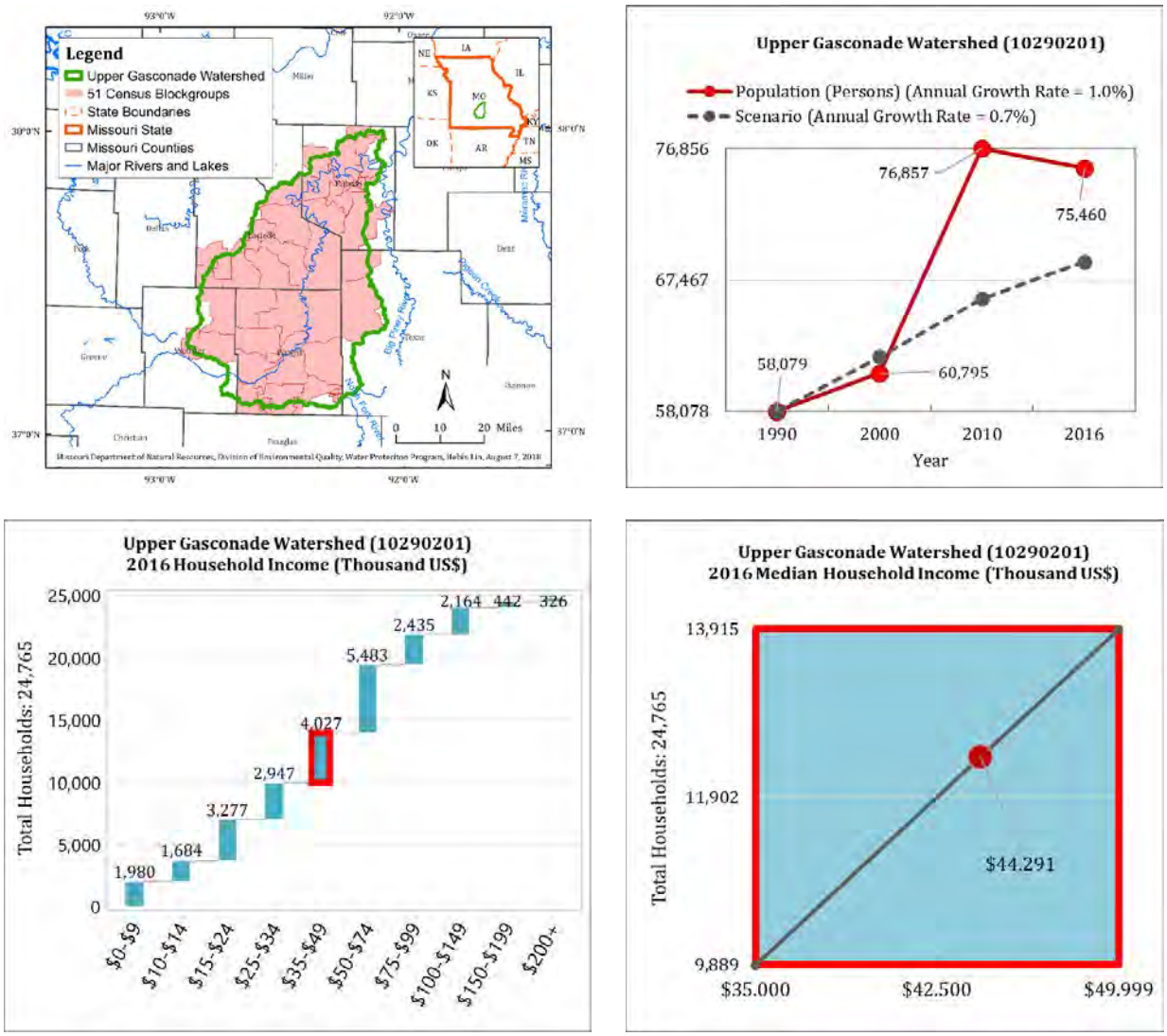


Figure 3-48. Upper Gasconade Watershed: Population Growth and Median Household Income

3.1.49 Big Piney Watershed (HUC 10290202)

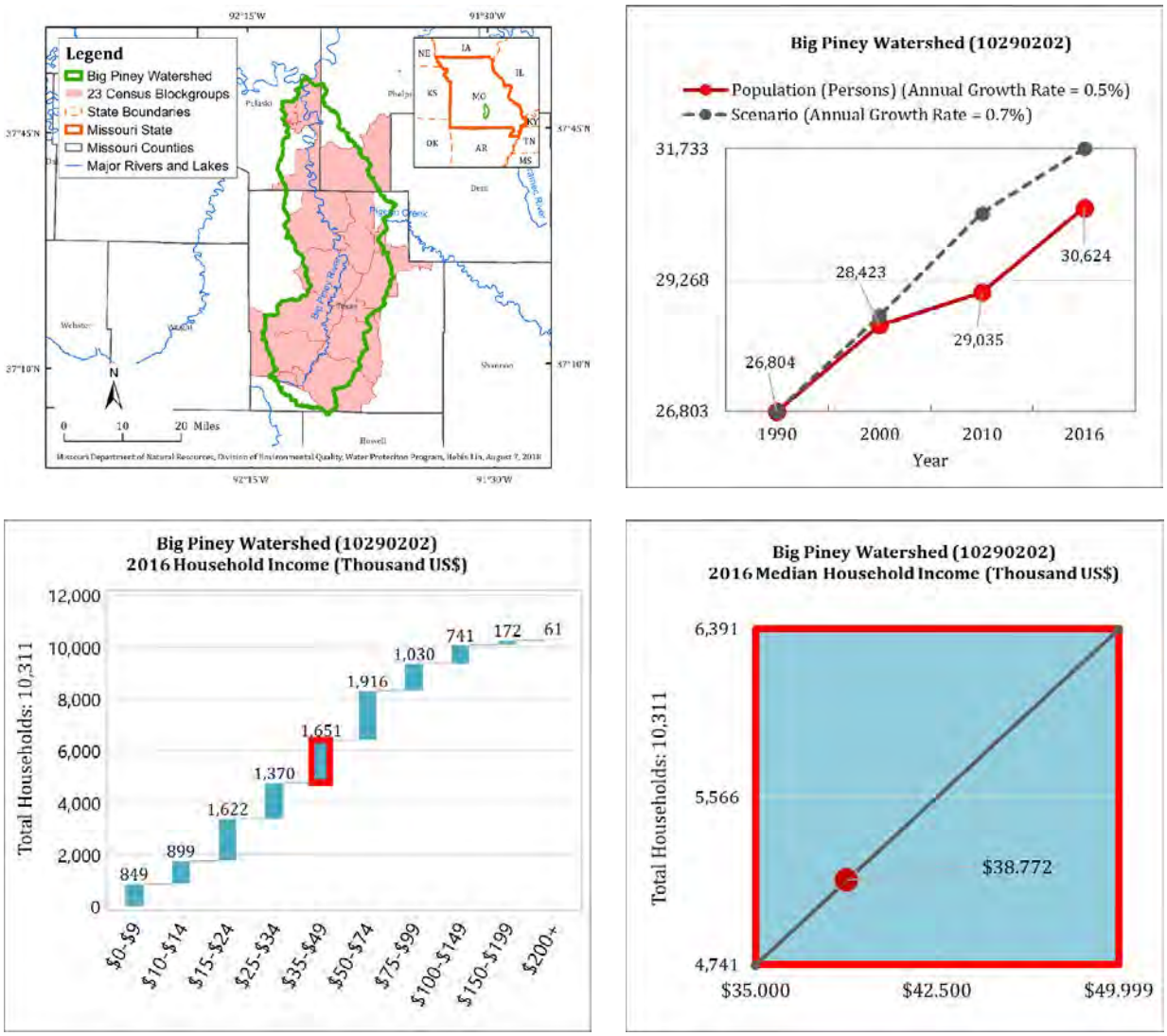


Figure 3-49. Big Piney Watershed: Population Growth and Median Household Income

3.1.50 Lower Gasconade Watershed (HUC 10290203)

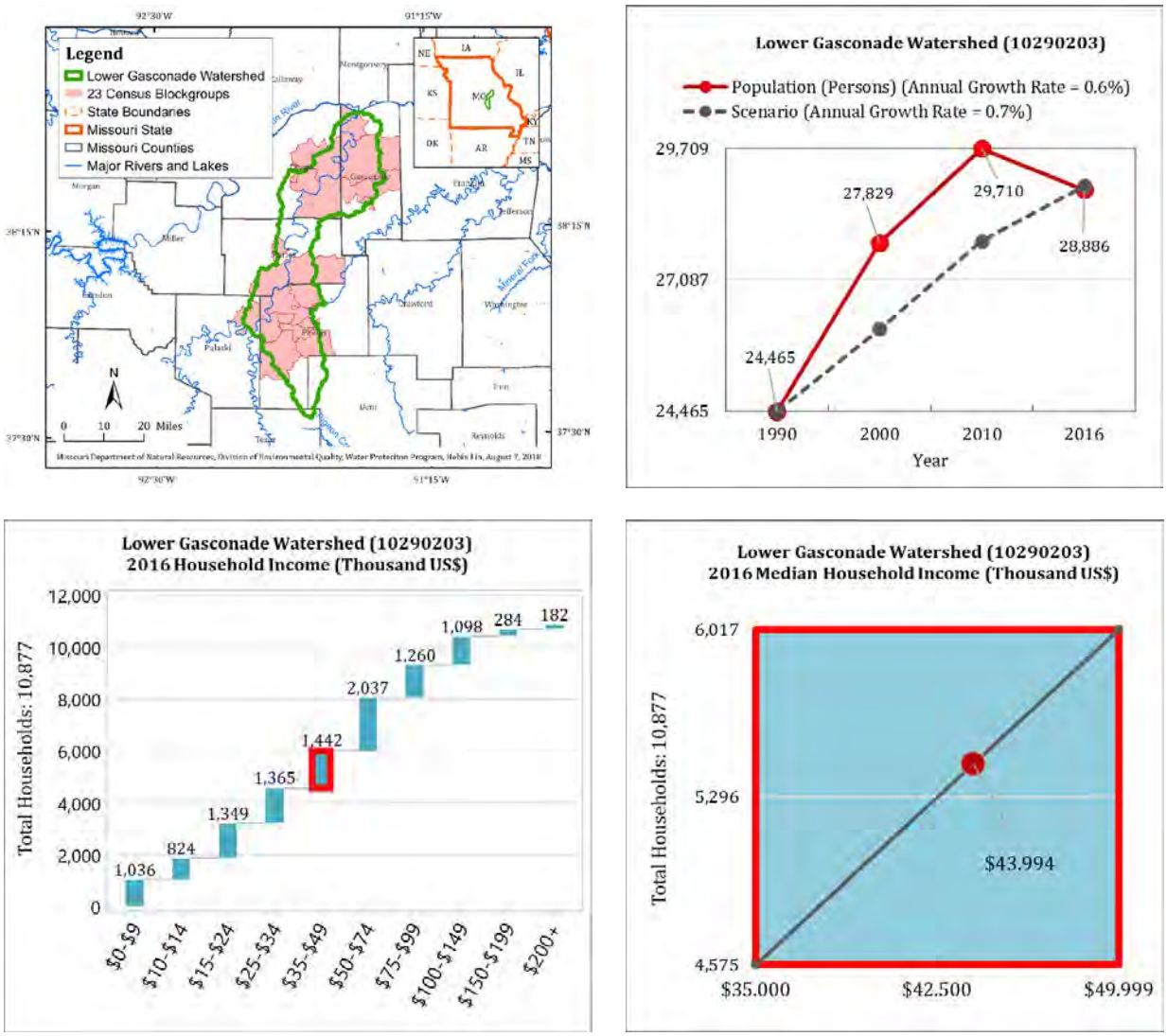


Figure 3-50. Lower Gasconade Watershed: Population Growth and Median Household Income

3.1.51 Lower Missouri-Crooked Watershed (HUC 10300101)

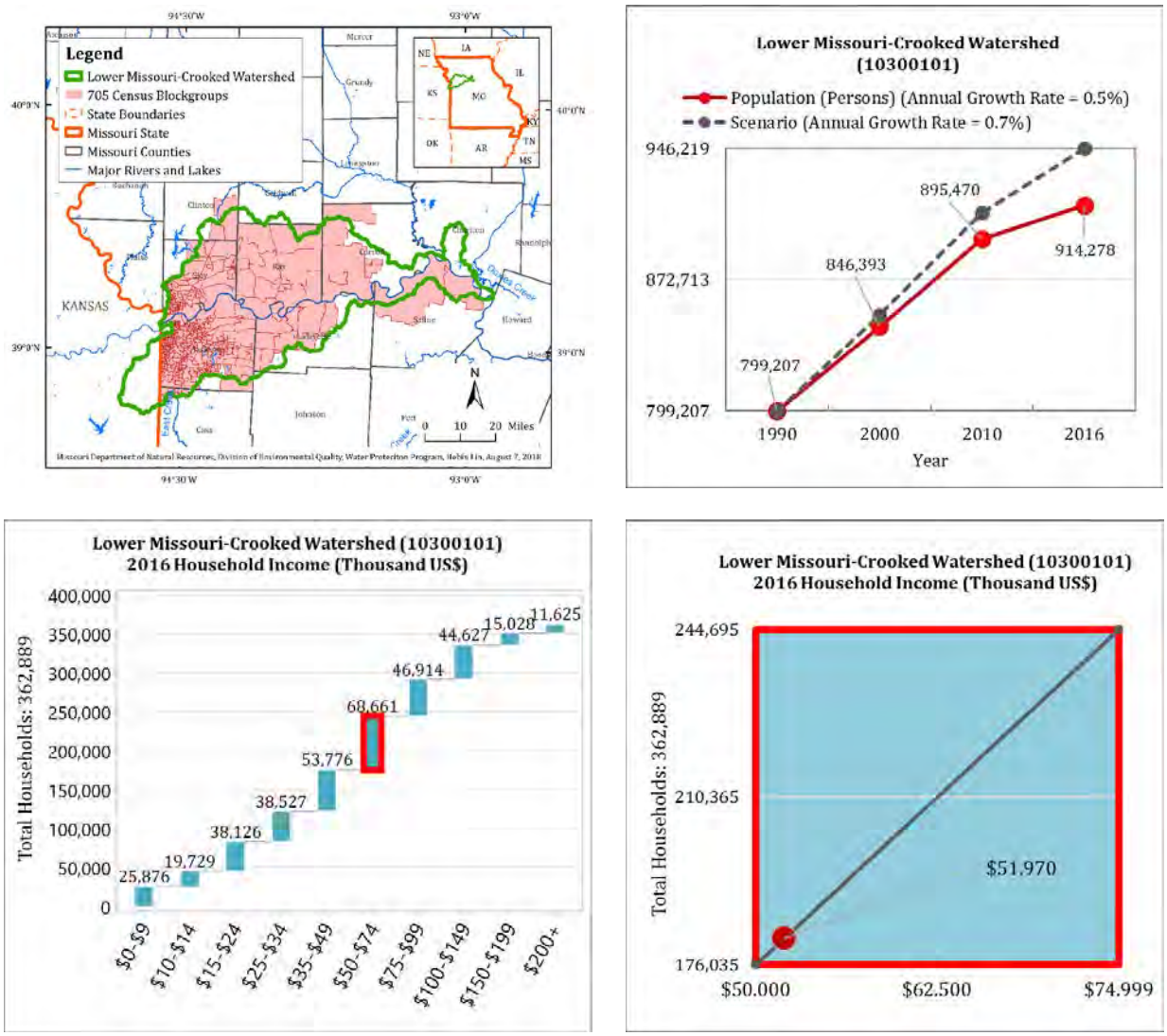


Figure 3-51. Lower Missouri-Crooked Watershed: Population Growth and Median Household Income

3.1.52 Lower Missouri-Moreau Watershed (HUC 10300102)

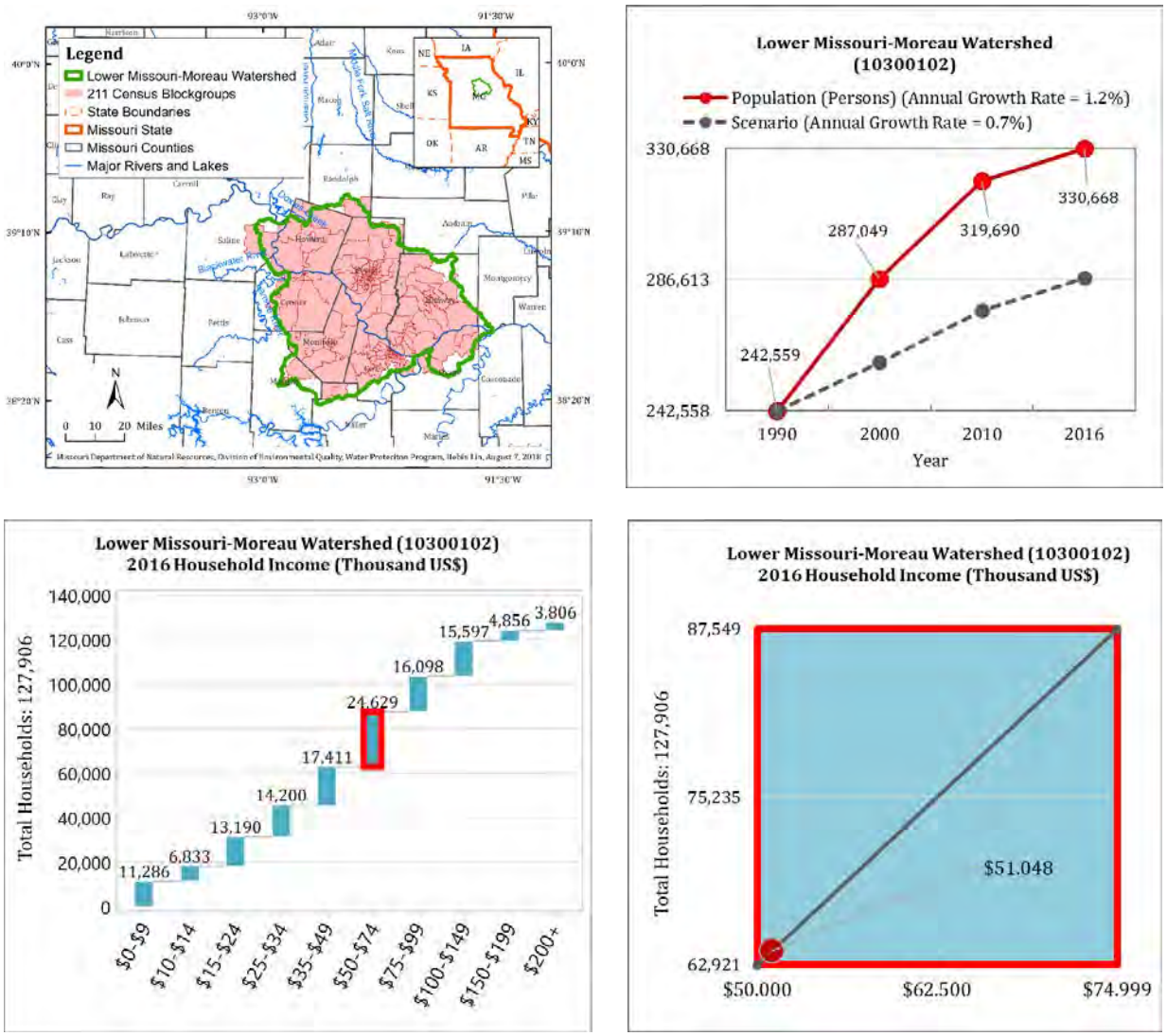


Figure 3-52. Lower Missouri-Moreau Watershed: Population Growth and Median Household Income

3.1.53 Lamine Watershed (HUC 10300103)

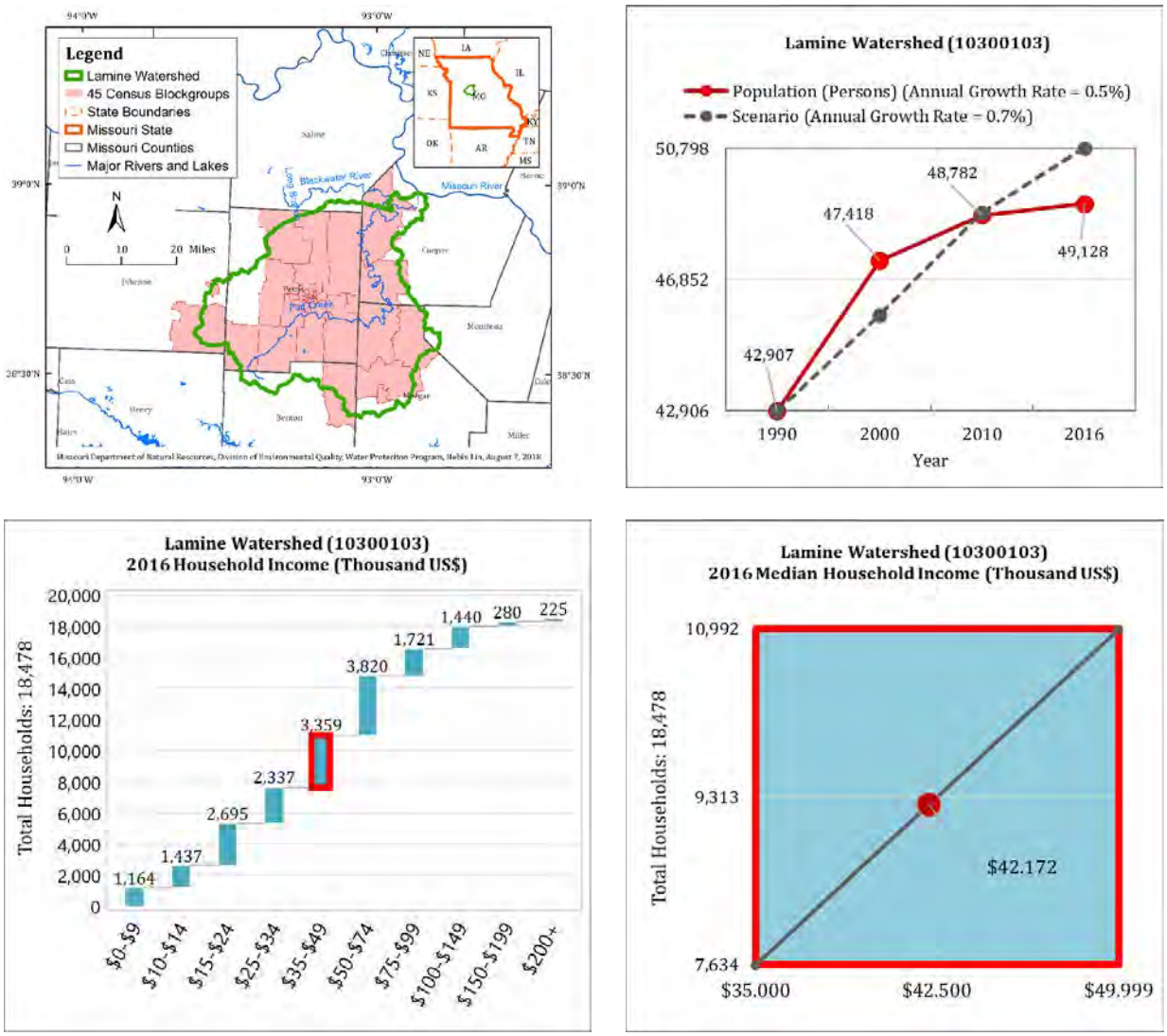


Figure 3-53. Lamine Watershed: Population Growth and Median Household Income

3.1.54 Blackwater Watershed (HUC 10300104)

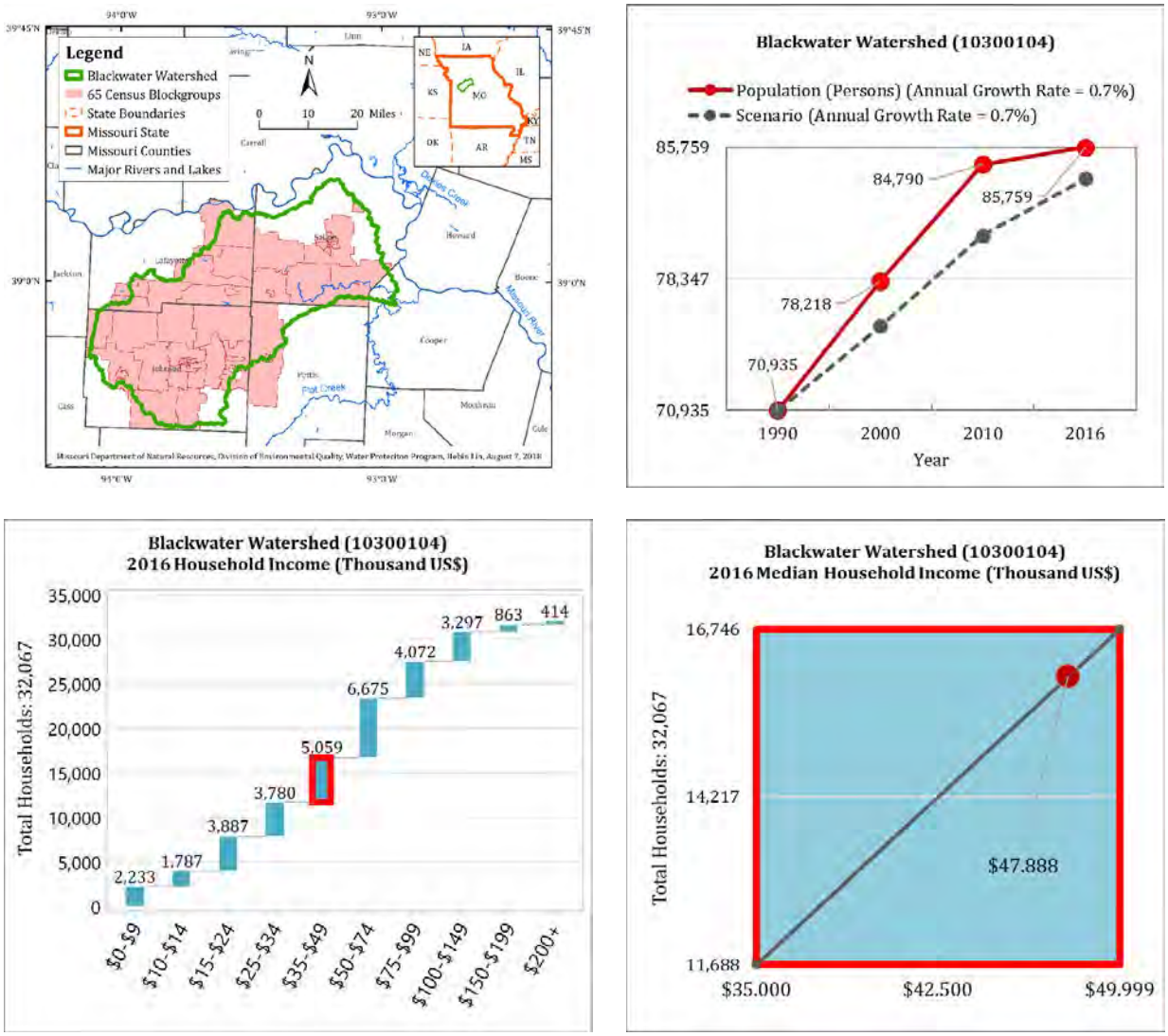


Figure 3-54. Blackwater Watershed: Population Growth and Median Household Income

3.1.55 Lower Missouri Watershed (HUC 10300200)

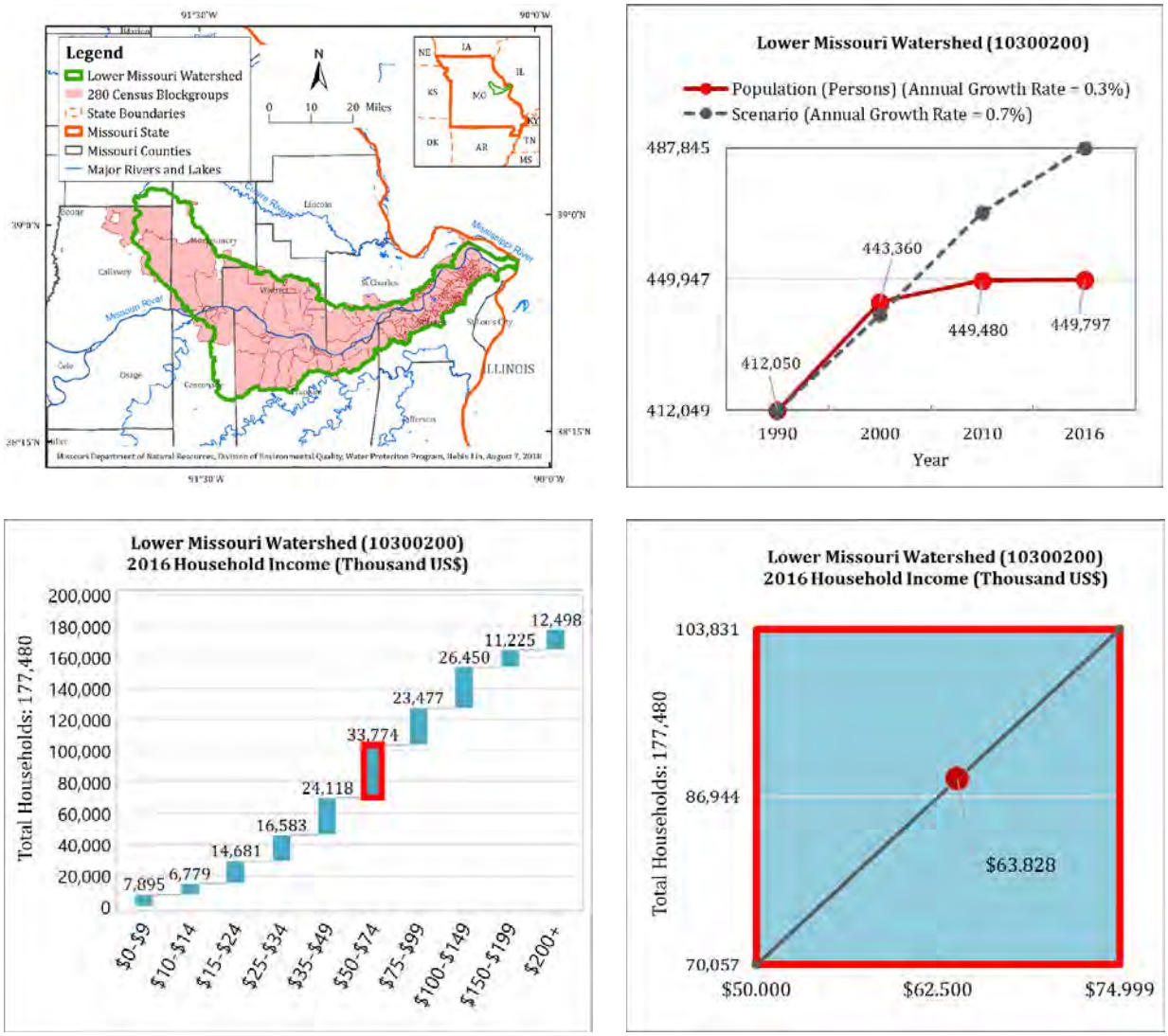


Figure 3-55. Lower Missouri Watershed: Population Growth and Median Household Income

3.1.56 Beaver Reservoir Watershed (HUC 11010001)

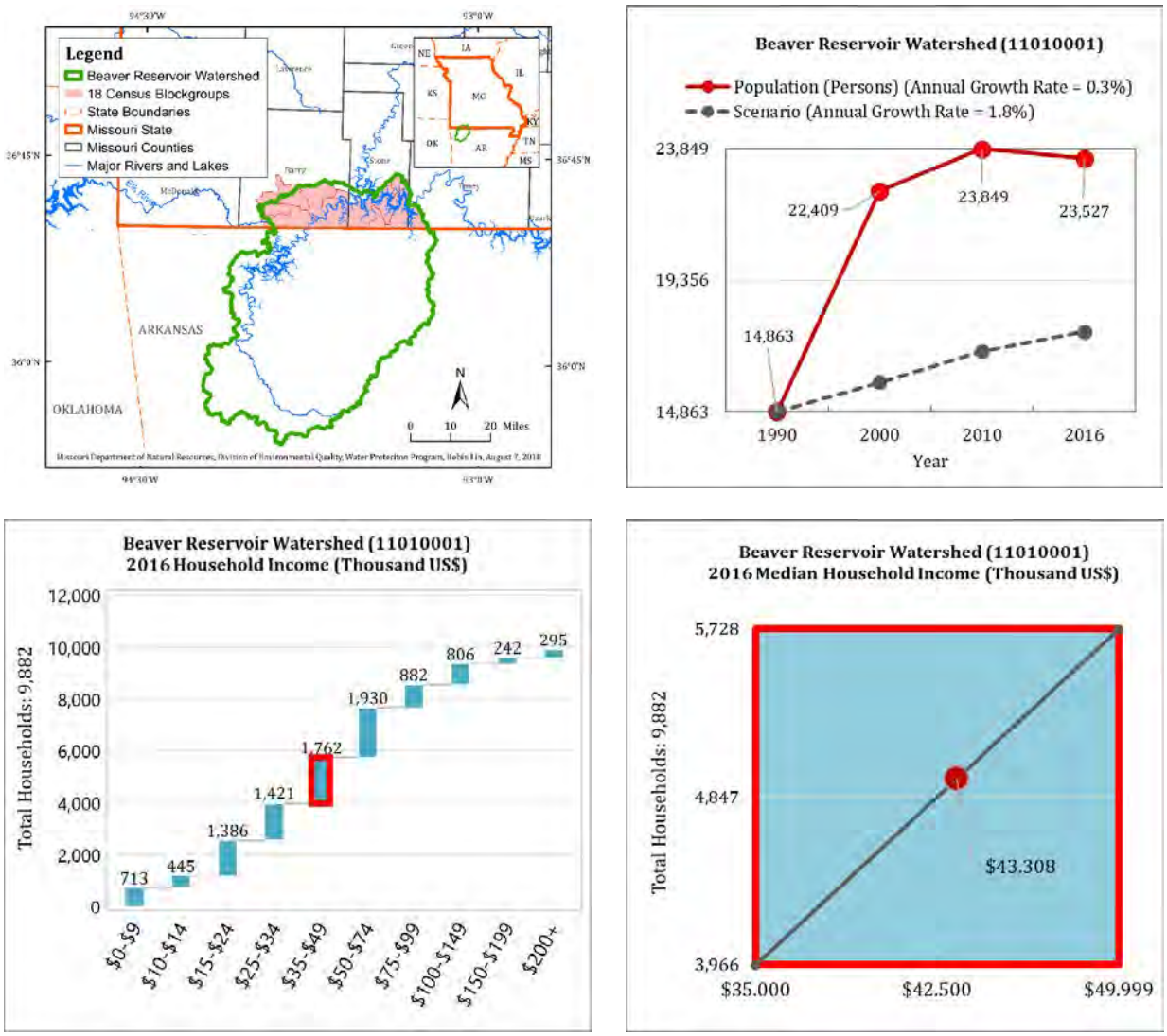


Figure 3-56. Beaver Reservoir Watershed: Population Growth and Median Household Income

3.1.57 James Watershed (HUC 11010002)

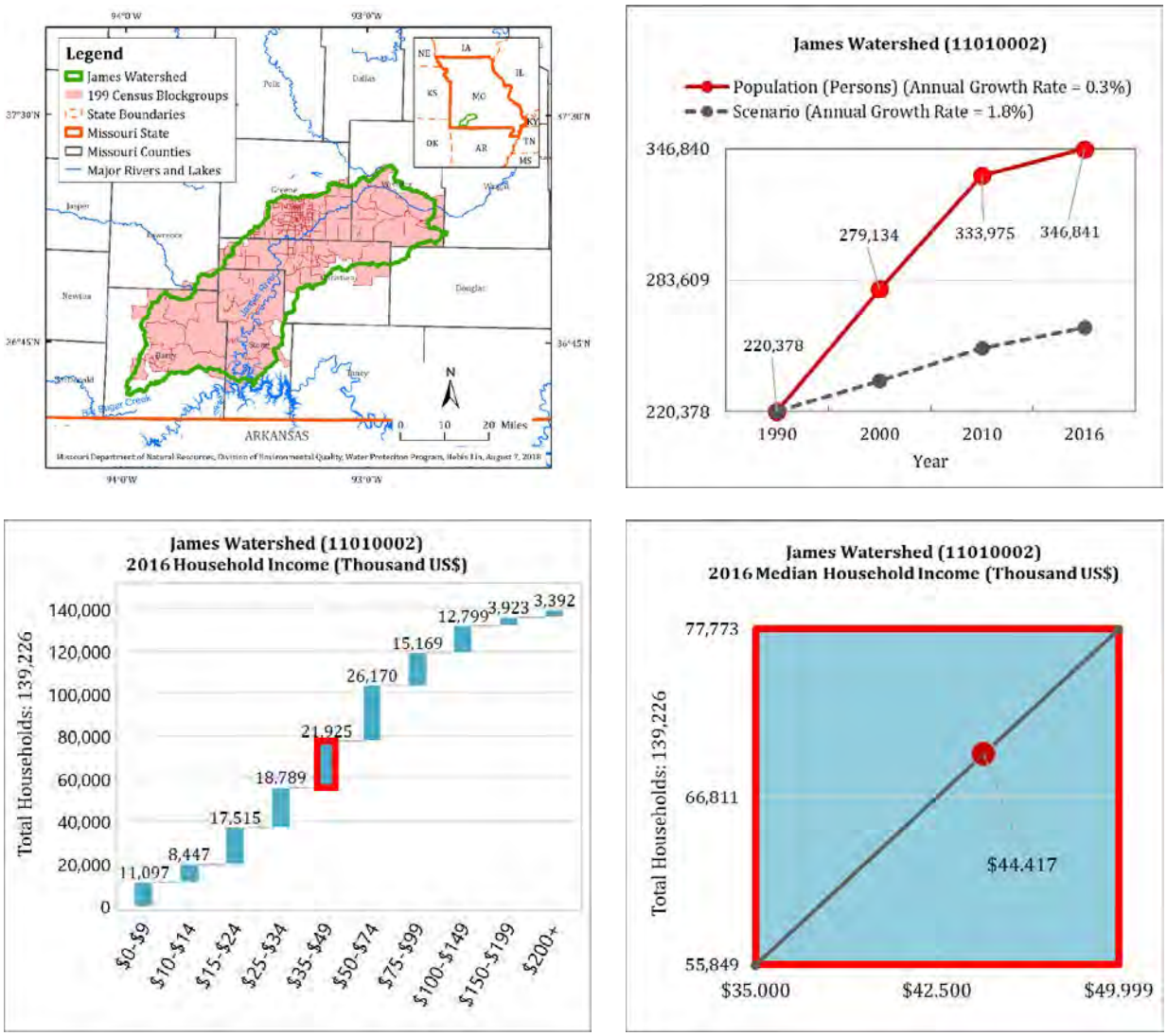


Figure 3-57. James Watershed: Population Growth and Median Household Income

3.1.58 Bull Shoals Lake Watershed (HUC 11010003)

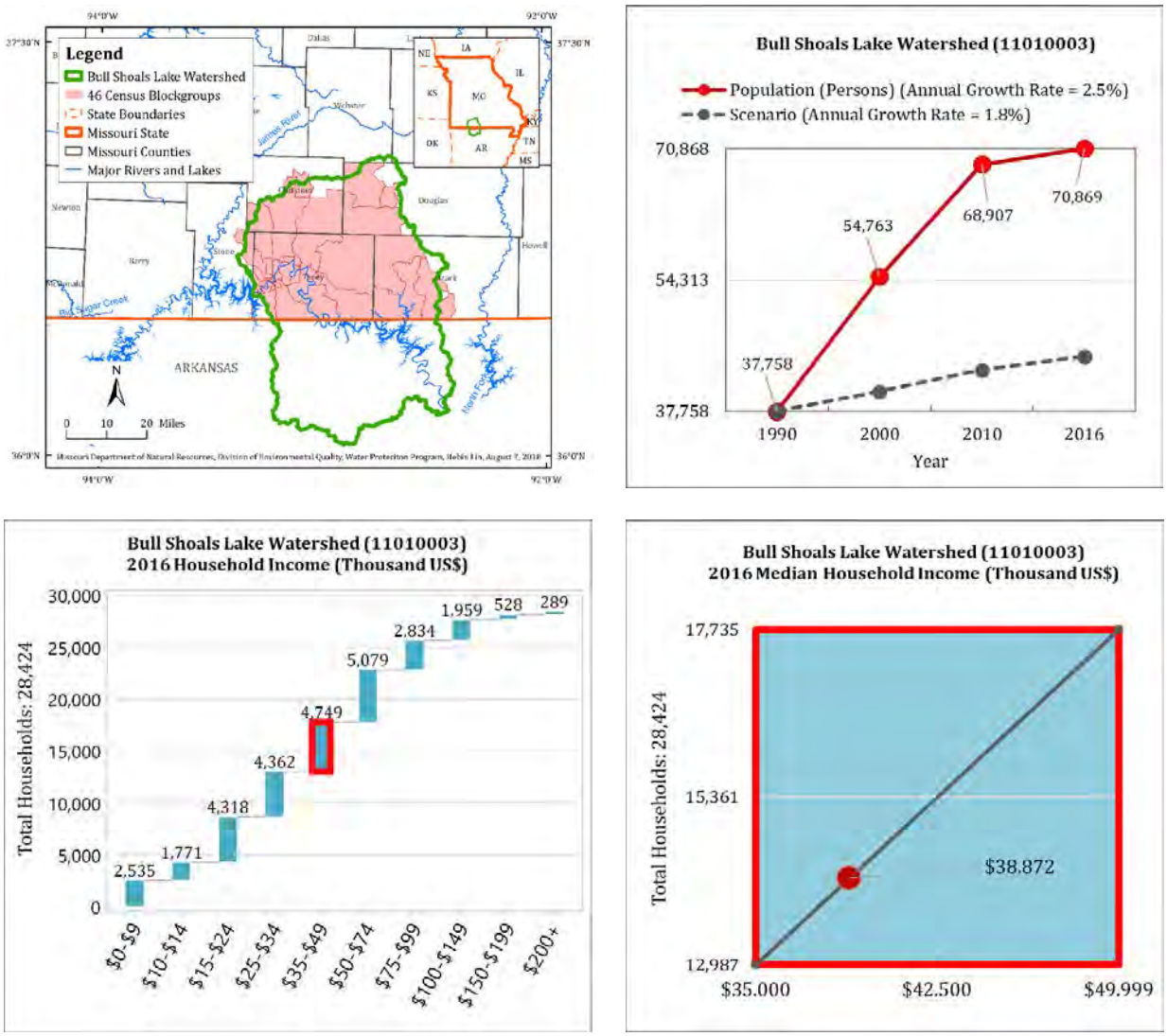


Figure 3-58. Bull Shoals Lake Watershed: Population Growth and Median Household Income

3.1.59 North Fork White Watershed (HUC 11010006)

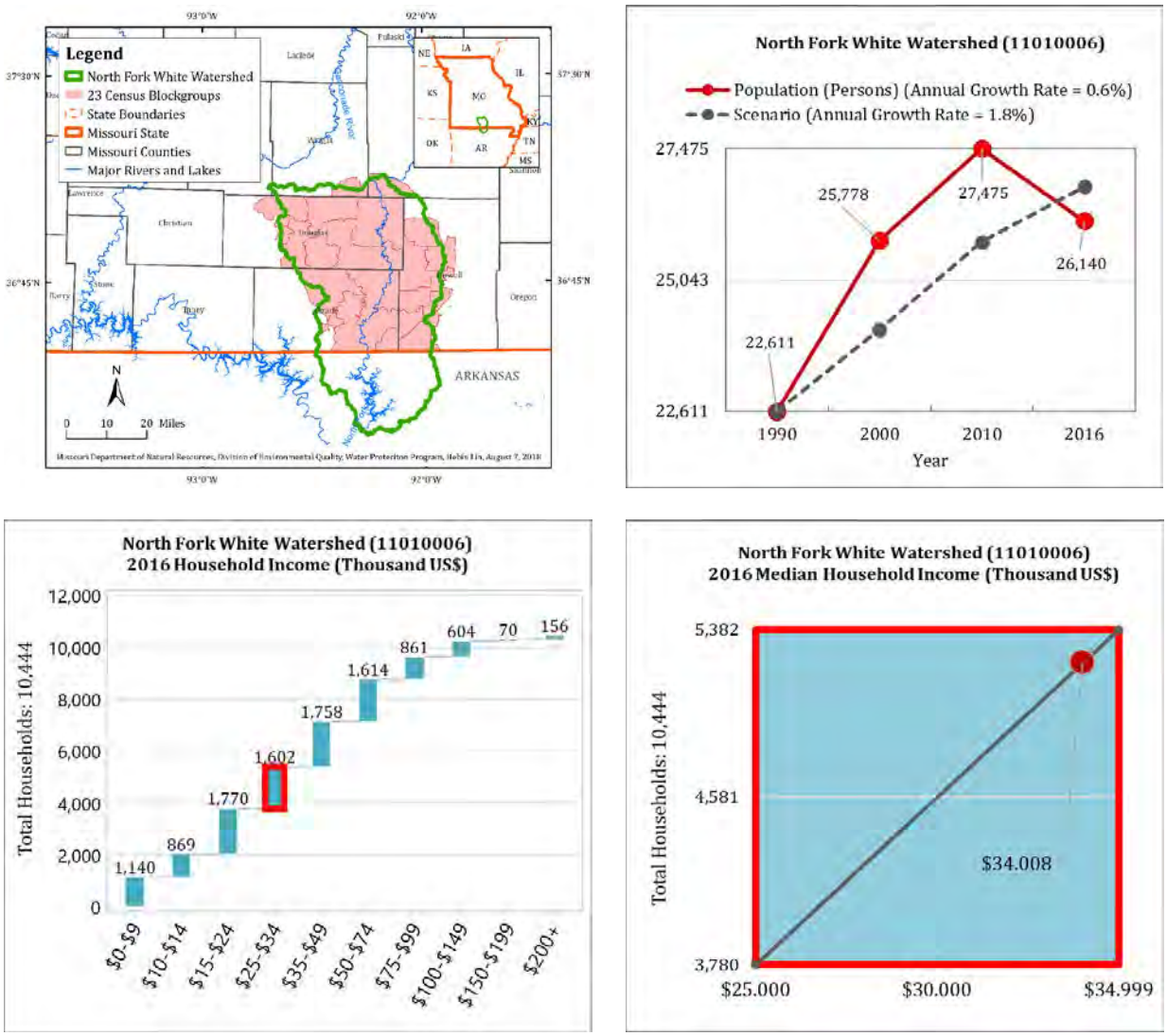


Figure 3-59. North Fork White Watershed: Population Growth and Median Household Income

3.1.60 Upper Black Watershed (HUC 11010007)

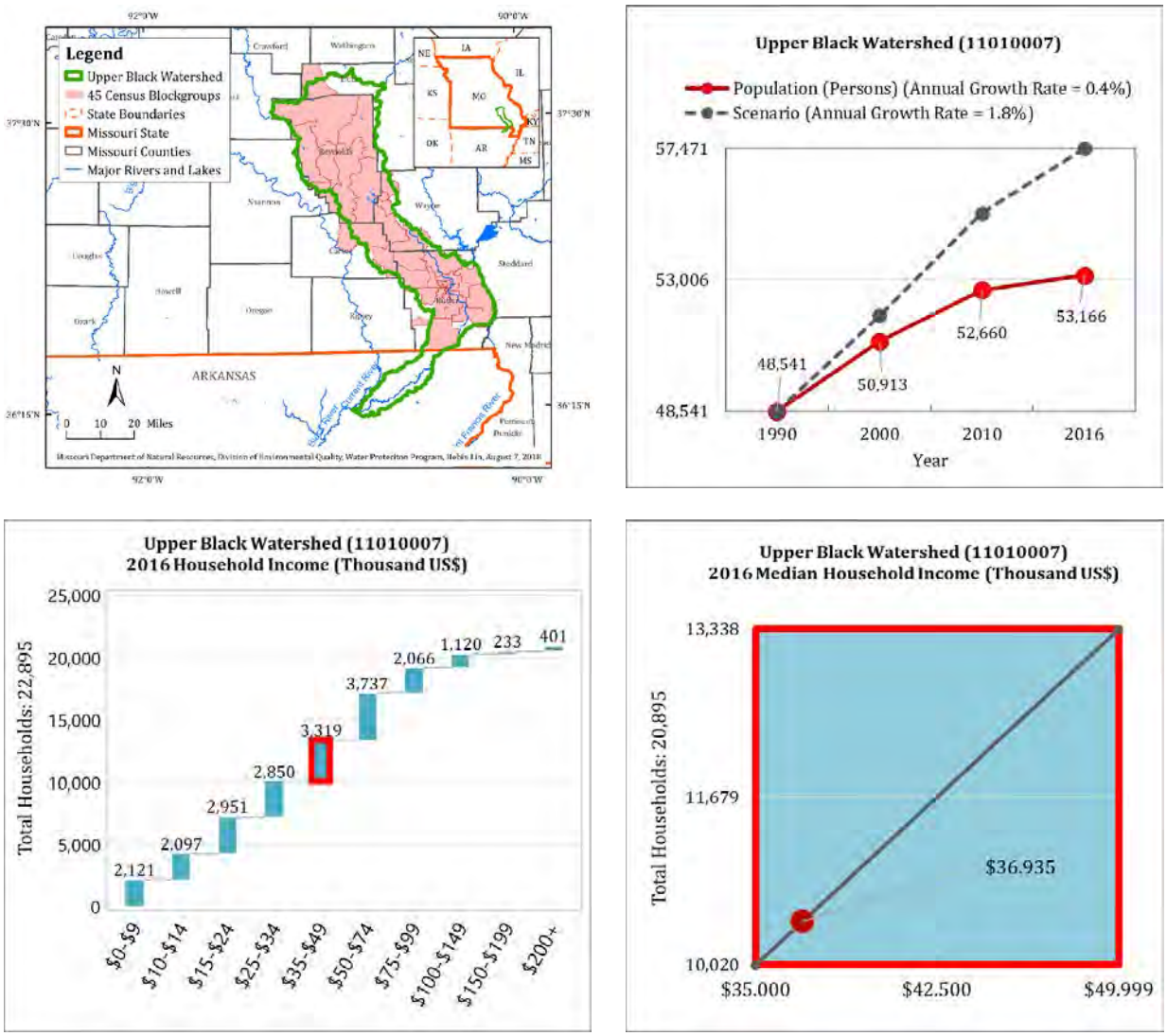


Figure 3-60. Upper Black Watershed: Population Growth and Median Household Income

3.1.61 Current Watershed (HUC 11010008)

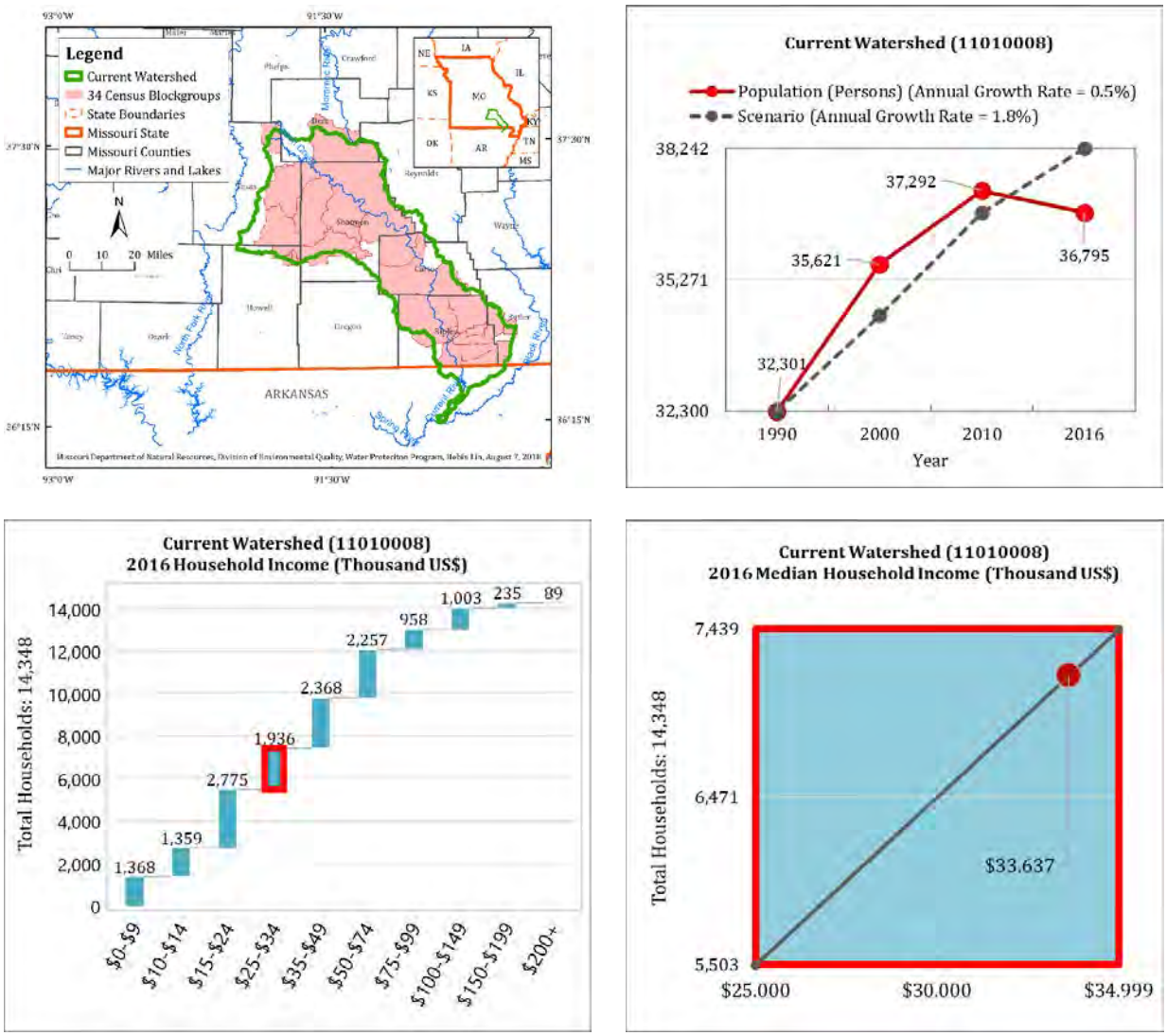


Figure 3-61. Current Watershed: Population Growth and Median Household Income

3.1.62 Lower Black Watershed (HUC 11010009)

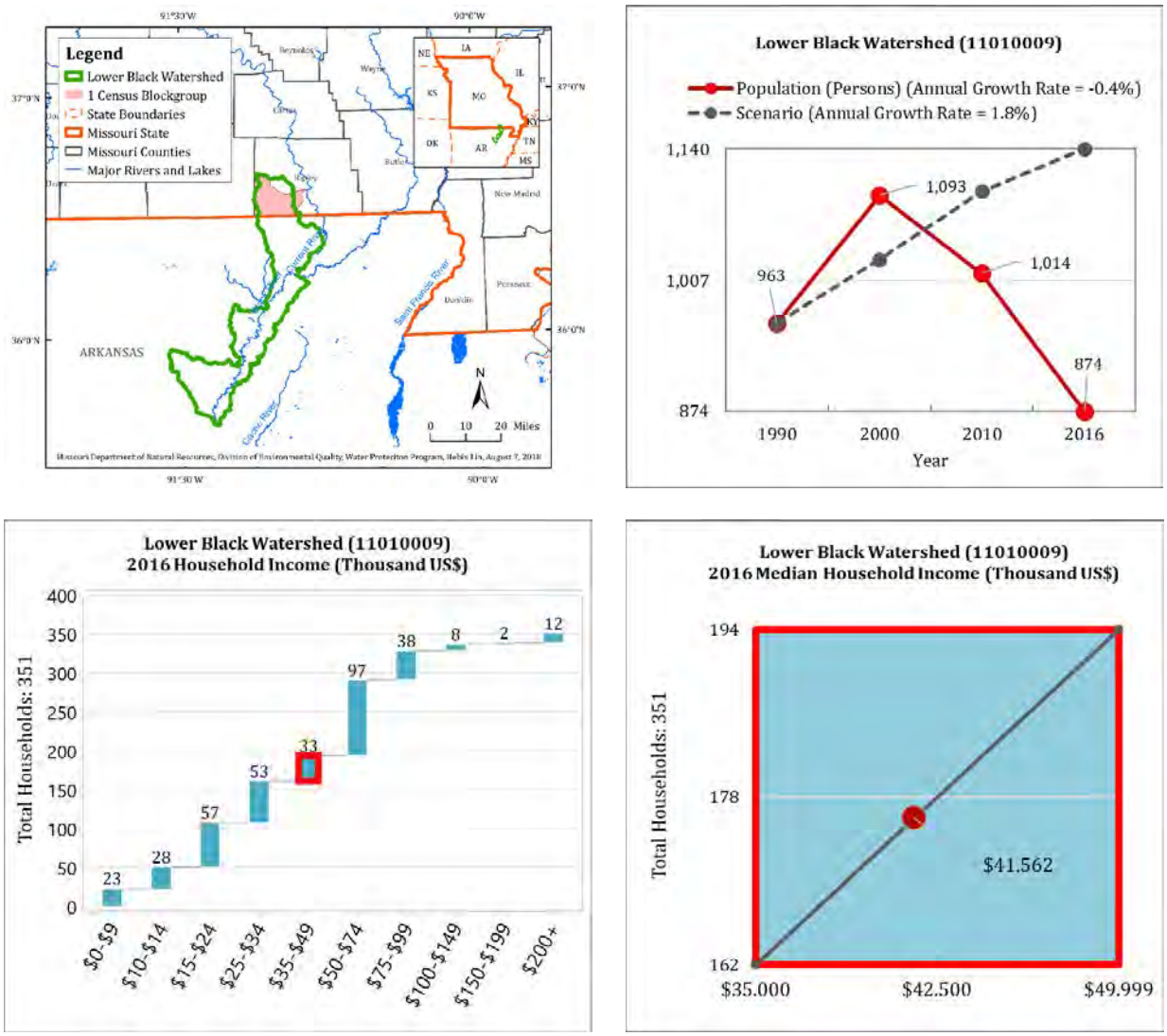


Figure 3-62. Lower Black Watershed: Population Growth and Median Household Income

3.1.63 Upper White-Spring Watershed (HUC 11010010)

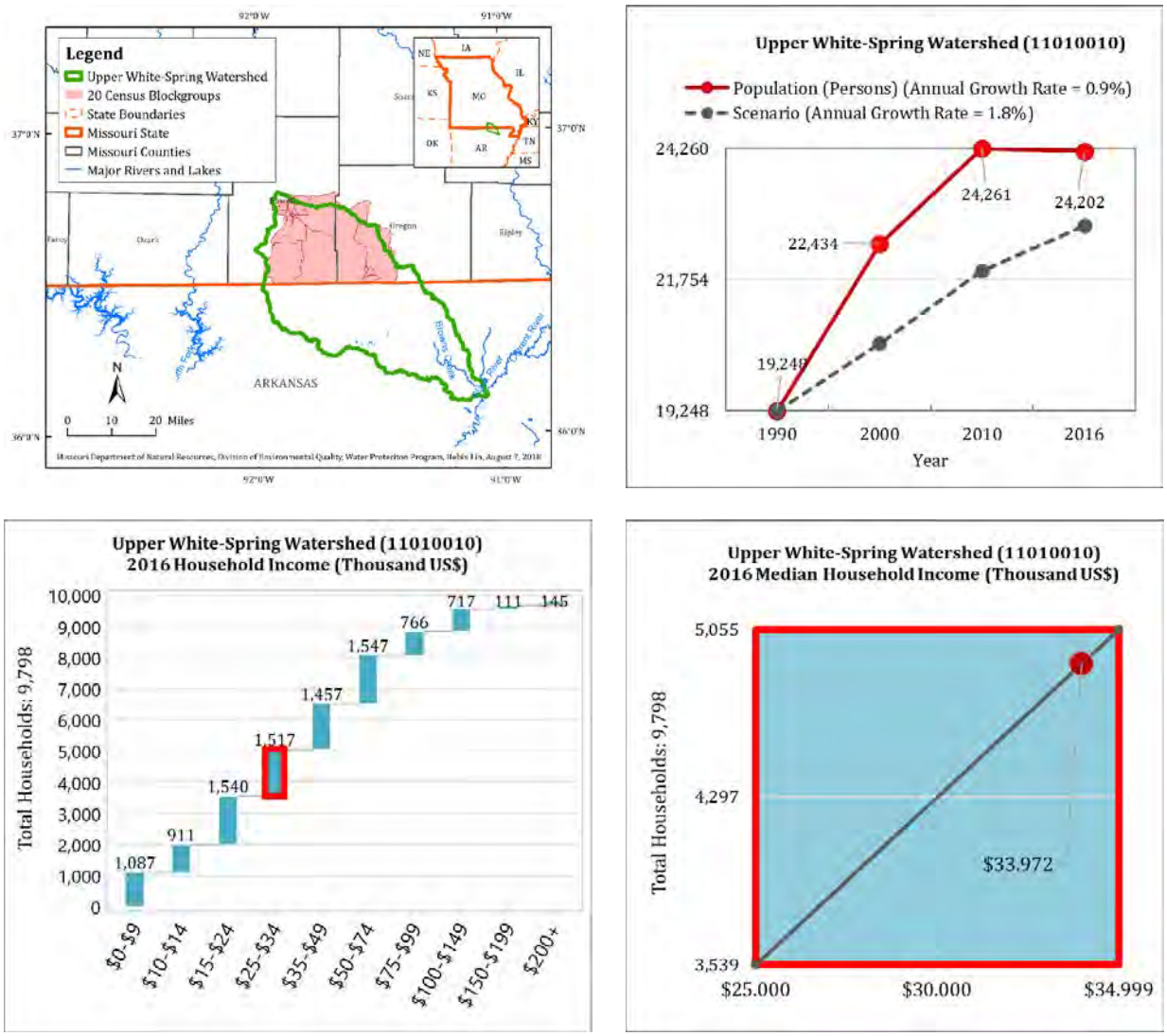


Figure 3-63. Upper White-Spring Watershed: Population Growth and Median Household Income

3.1.64 Eleven Point Watershed (HUC 11010011)

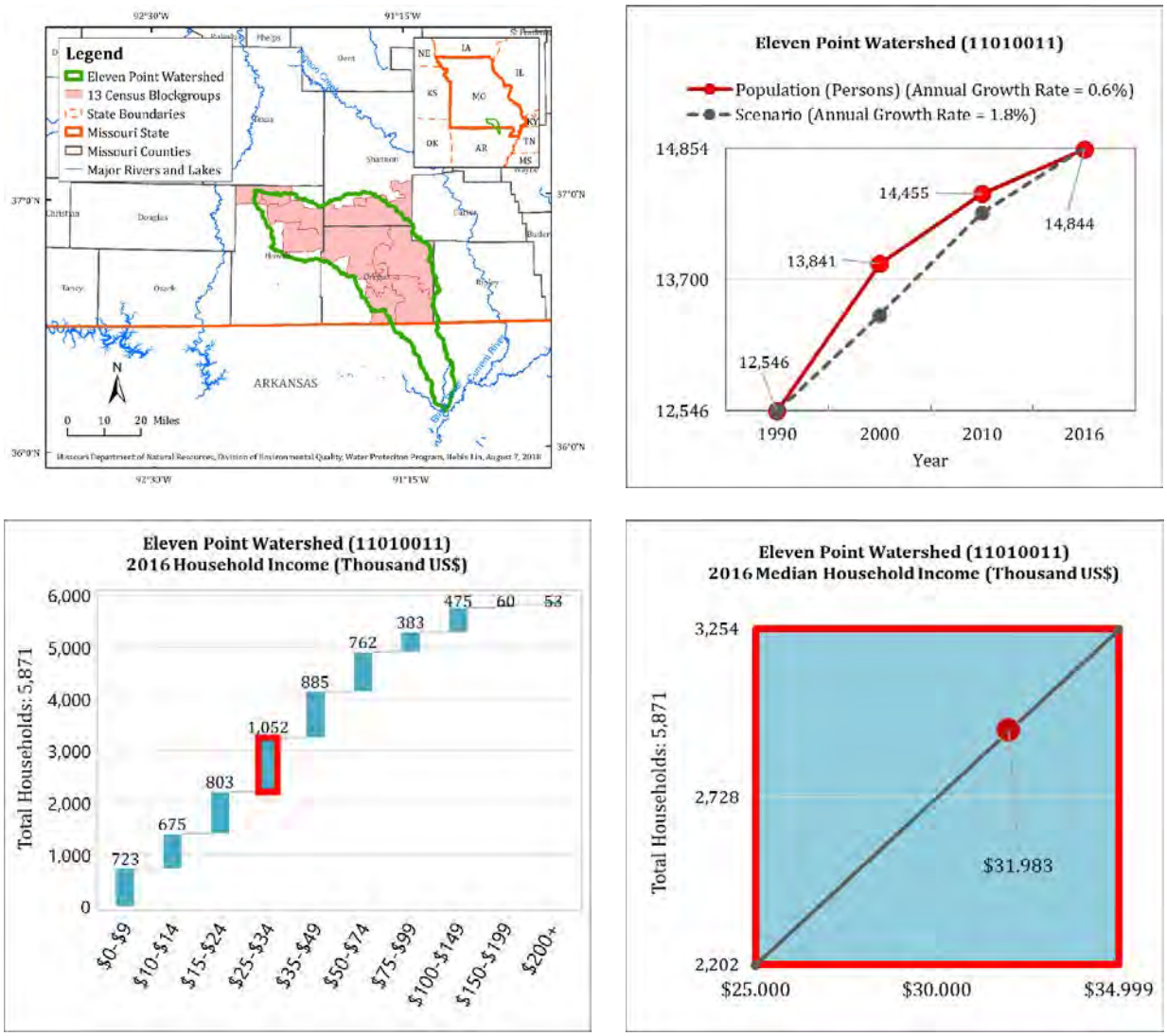


Figure 3-64. Eleven Point Watershed: Population Growth and Median Household Income

3.1.65 Lake O' The Cherokees Watershed (HUC 11070206)

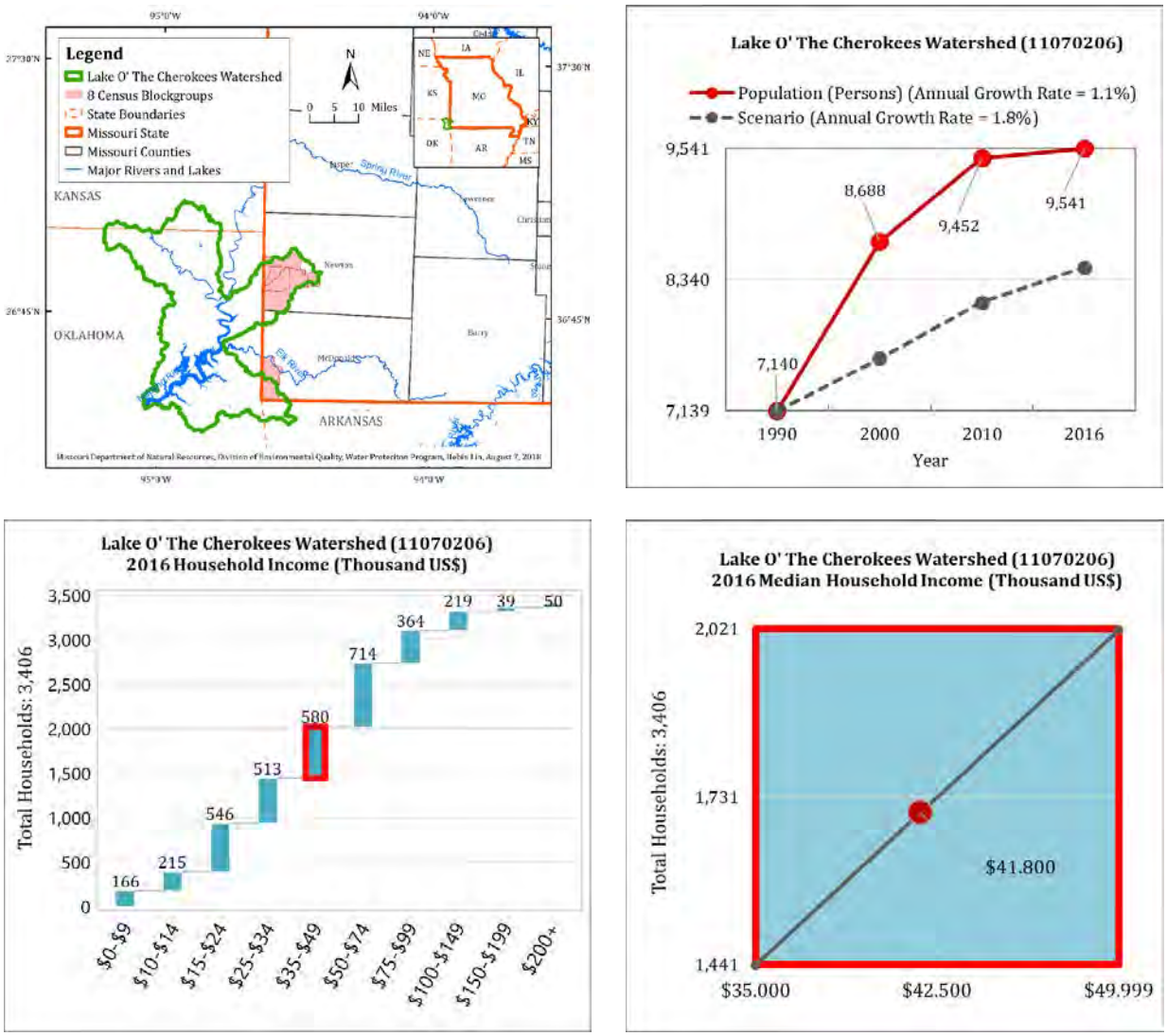


Figure 3-65. Lake O' The Cherokees Watershed: Population Growth and Median Household Income

3.1.66 Neosho-Spring Watershed (HUC 11070207)

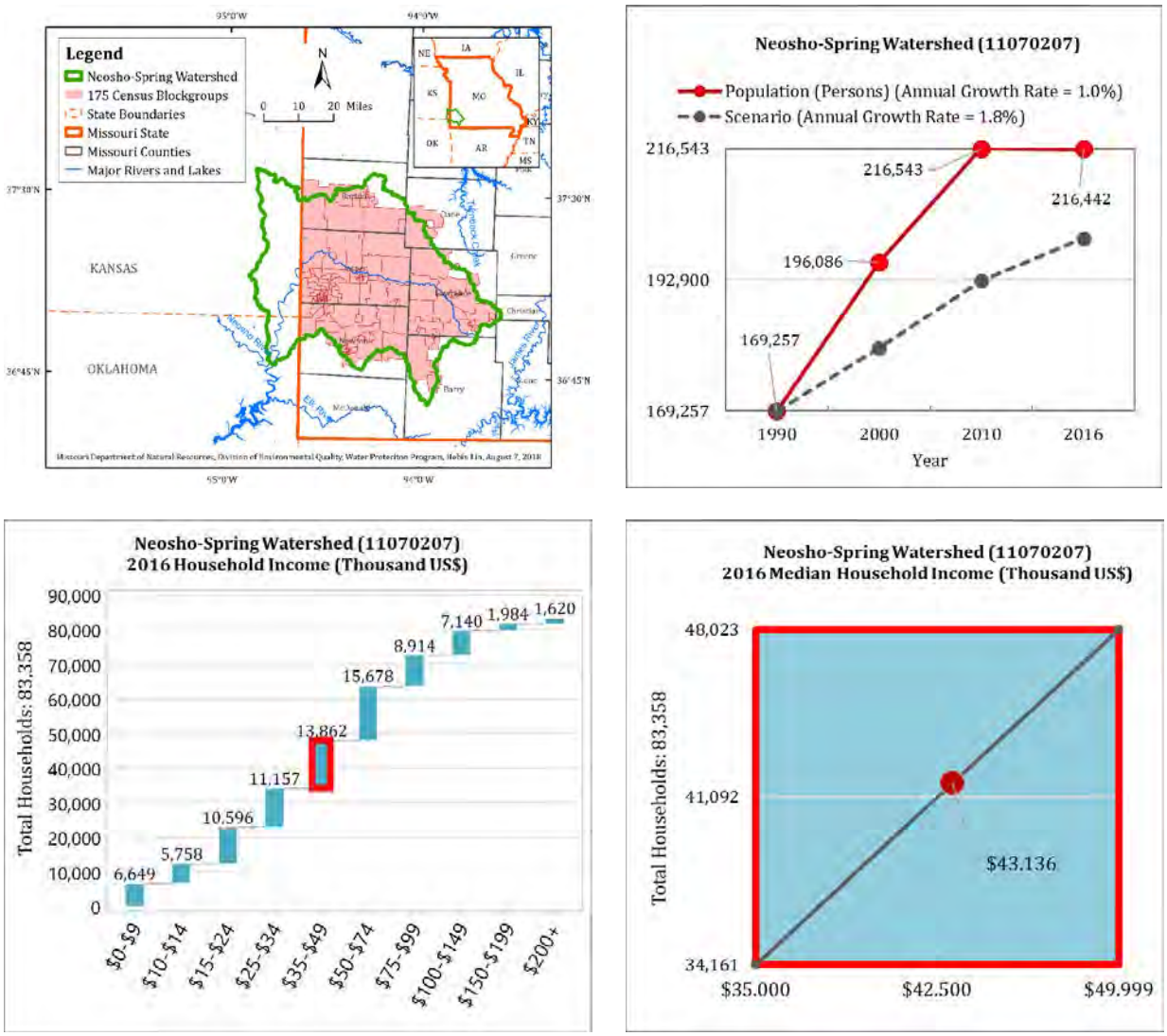


Figure 3-66. Neosho-Spring Watershed: Population Growth and Median Household Income

3.1.67 Elk Watershed (HUC 11070208)

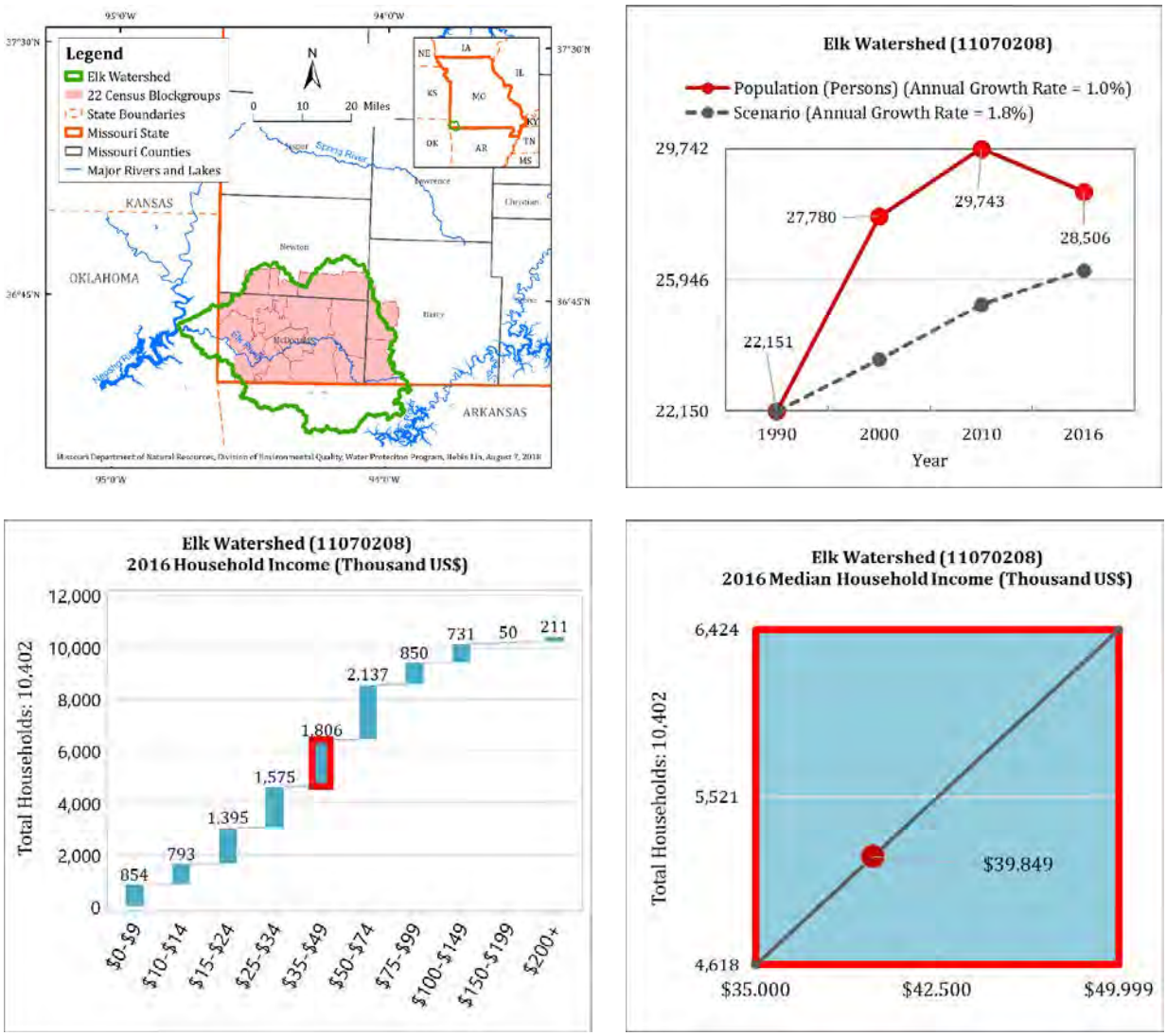


Figure 3-67. Elk Watershed: Population Growth and Median Household Income

3.2 Summary Table

The results of the estimated population growth and MHIs presented in Subsection 3.1 for the State of Missouri and for the 66 individual HUC-8 watersheds are summarized in Table 3-1 below. Note that the IDs for the HUC-8 watersheds in Table 3-1 correspond to the IDs for the HUC-8 watersheds on Map 2-1. Sorted in the ascending order of the IDs, Table 3-1 presents the numbers of households in the year 2016, the MHIs in 2016 US$ in the year 2016, the populations in the years of 1990, 2000, 2010 and 2016, and the annual population growth rates between the years of 1990 and 2016 for the State of Missouri and for the 66 individual HUC-8 watersheds.

Table 3-1. Population Growth and MHIs for 66 Individual HUC-8 Watersheds in Missouri

ID	HUC-8 Name	HUC-8 Code	2016 Number of Households	2016 MHI (2016 US$)	Population				
					1990	2000	2010	2016	Annual Growth Rate
	Missouri State		2,372,362	$49,683	5,118,177	5,597,169	5,991,676	6,059,651	0.7%
01	Lower Des Moines	07100009	575	$43,544	546	494	516	536	-0.1%
02	Bear-Wyaconda	07110001	4,831	$45,499	13,163	13,236	12,683	12,217	-0.3%
03	North Fabius	07110002	3,835	$43,011	9,971	10,263	10,085	10,383	0.2%
04	South Fabius	07110003	2,849	$44,981	7,360	7,379	7,241	6,971	-0.2%
05	The Sny	07110004	21,977	$45,372	50,990	54,490	57,827	57,901	0.5%
06	North Fork Salt	07110005	10,436	$38,245	28,509	28,264	28,325	27,936	-0.1%
07	South Fork Salt	07110006	18,332	$41,249	47,061	48,760	49,270	49,313	0.2%
08	Salt	07110007	5,542	$44,495	12,722	16,683	16,904	17,523	1.2%
09	Cuivre	07110008	33,955	$59,343	49,706	63,764	93,665	96,525	2.6%
10	Peruque-Piasa	07110009	111,929	$75,106	169,842	228,488	284,017	302,183	2.2%
11	Cahokia-Joachim	07140101	371,188	$47,123	971,891	927,198	894,548	889,096	-0.3%
12	Meramec	07140102	142,708	$66,984	311,263	350,611	368,177	370,724	0.7%
13	Bourbeuse	07140103	23,346	$44,475	45,751	52,268	58,418	59,164	1.0%
14	Upper Mississippi-Big	07140104	37,308	$47,984	80,560	91,169	102,150	103,285	1.0%
15	Upper Mississippi-Cape Girardeau	07140105	29,011	$47,155	65,423	69,398	73,540	74,623	0.5%
16	Whitewater	07140107	18,479	$48,374	36,257	43,410	47,583	48,956	1.2%
17	Lower Mississippi-Memphis	08010100	259	$15,000	981	894	634	678	-1.4%
18	New Madrid-St. Johns	08020201	12,921	$36,597	32,643	32,321	33,619	33,805	0.1%
19	Upper St. Francis	08020202	19,897	$38,466	41,438	46,151	50,129	51,350	0.8%
20	Lower St. Francis	08020203	10,439	$37,744	23,841	26,150	26,580	25,765	0.3%
21	Little River Ditches	08020204	34,939	$33,460	98,798	95,419	90,184	87,423	-0.5%
22	Cache	08020302	288	$32,040	986	946	907	767	-1.0%
23	Keg-Weeping Water	10240001	180	$58,966	8	7	6	4	-2.6%
24	Nishnabotna	10240004	180	$58,966	294	243	200	162	-2.3%
25	Tarkio-Wolf	10240005	4,213	$45,048	12251	10710	9626	9,094	-1.1%
26	Nodaway	10240010	2,253	$49,867	6,550	6,061	5,830	5,622	-0.6%
27	Independence-Sugar	10240011	64,425	$55,889	133,909	150,445	160,982	164,748	0.8%

Table 3-1. Population Growth and MHIs for 66 Individual HUC-8 Watersheds in Missouri (Cont.)

ID	HUC-8 Name	HUC-8 Code	2016 Number of Households	2016 MHI (2016 US$)	Population				
					1990	2000	2010	2016	Annual Growth Rate
28	Platte	10240012	27,469	$70,168	45,388	55,490	69,377	72,724	1.8%
29	One Hundred and Two	10240013	15,037	$46,085	30,562	34,898	39,239	39,751	1.0%
30	Lower Kansas	10270104	10,019	$33,859	24,418	22,277	21,709	20,347	-0.7%
31	Upper Grand	10280101	21,716	$44,326	53,355	56,700	59,067	57,263	0.3%
32	Thompson	10280102	6,706	$40,445	17,233	17,263	17,078	16,903	-0.1%
33	Lower Grand	10280103	11,003	$43,266	29,841	30,516	29,835	29,432	-0.1%
34	Upper Chariton	10280201	2,430	$33,591	6,417	6,479	6,037	5,634	-0.5%
35	Lower Chariton	10280202	5,065	$42,346	13,654	13,560	13,321	12,738	-0.3%
36	Little Chariton	10280203	5,883	$37,490	15,952	16,016	15,608	15,887	0.0%
37	Lower Marais Des Cygnes	10290102	3,661	$39,619	9,035	9,726	9,459	9,136	0.0%
38	Little Osage	10290103	1,470	$37,302	3,437	3,797	3,840	3,797	0.4%
39	Marmaton	10290104	6,600	$38,728	15,015	15,796	16,420	16,129	0.3%
40	Harry S. Truman Reservoir	10290105	10,419	$34,465	22,239	25,199	25,957	24,969	0.4%
41	Sac	10290106	38,255	$42,808	75,158	84,702	94,637	95,477	0.9%
42	Pomme De Terre	10290107	15,253	$44,336	27,494	34,175	38,579	40,088	1.5%
43	South Grand	10290108	47,811	$60,260	80,668	103,315	123,288	124,495	1.7%
44	Lake of the Ozarks	10290109	30,944	$39,721	55,296	70,110	78,317	77,983	1.3%
45	Niangua	10290110	14,291	$38,690	27,827	34,684	37,953	37,371	1.1%
46	Lower Osage	10290111	11,523	$49,840	27,709	29,218	34,869	36,426	1.1%
47	Upper Gasconade	10290201	24,765	$44,291	58,079	60,795	76,857	75,460	1.0%
48	Big Piney	10290202	10,311	$38,772	26,804	28,423	29,035	30,624	0.5%
49	Lower Gasconade	10290203	10,877	$43,994	24,465	27,829	29,710	28,886	0.6%
50	Lower Missouri-Crooked	10300101	362,889	$51,970	799,207	846,393	895,470	914,278	0.5%
51	Lower Missouri-Moreau	10300102	127,906	$51,048	242,559	287,049	319,690	330,668	1.2%
52	Lamine	10300103	18,478	$42,172	42,907	47,418	48,782	49,128	0.5%
53	Blackwater	10300104	32,067	$47,888	70,935	78,218	84,790	85,759	0.7%
54	Lower Missouri	10300200	177,480	$63,828	412,050	443,360	449,480	449,797	0.3%
55	Beaver Reservoir	11010001	9,882	$43,308	14,863	22,409	23,849	23,527	1.8%
56	James	11010002	139,226	$44,417	220,378	279,134	333,975	346,841	1.8%
57	Bull Shoals Lake	11010003	28,424	$38,872	37,758	54,763	68,907	70,869	2.5%
58	North Fork White	11010006	10,444	$34,008	22,611	25,778	27,475	26,140	0.6%
59	Upper Black	11010007	20,895	$36,935	48,541	50,913	52,660	53,166	0.4%
60	Current	11010008	14,348	$33,637	32,301	35,621	37,292	36,795	0.5%
61	Lower Black	11010009	351	$41,562	963	1,093	1,014	874	-0.4%
62	Upper White-Spring	11010010	9,798	$33,972	19,248	22,434	24,261	24,202	0.9%
63	Eleven Point	11010011	5,871	$31,983	12,546	13,841	14,455	14,844	0.6%
64	Lake O' The Cherokees	11070206	3,406	$41,800	7,140	8,688	9,452	9,541	1.1%
65	Neosho-Spring	11070207	83,358	$43,136	169,257	196,086	216,543	216,442	1.0%
66	Elk	11070208	10,402	$39,849	22,151	27,780	29,743	28,506	1.0%

3.3 Trends in GIS Maps

Looking at the big picture, the following four trends in population growth rates can be observed among the 66 HUC-8 watersheds when compared with that of Missouri.

(1) 6 HUC-8 watersheds exhibit a decreasing population growth rate of from -2.7% to less than -0.7%. These 6 watersheds are located at the northwest and southeast corners of Missouri. They are presented with blue bubbles within their respective boundaries on Map 3-1. An example of watershed in this category is the Nishnabotna watershed, HUC 10240004 (No. 23 on Map 3-1), located at northern border of Missouri.

(2) 13 HUC-8 watersheds exhibit a decreasing population growth rate of from -0.7% to less than 0%. These 13 watersheds are located in northern and eastern Missouri. They are presented with a purple dots within their respective boundaries on Map 3-1. An example of watershed in this category is the Nodaway watershed, HUC 10240010 (No. 26 on Map 3-1), located at northern border of Missouri.

(3) 20 HUC-8 watersheds exhibit an increasing population growth rate of from 0% to less than 0.7%. These 20 watersheds are generally spread across Missouri except in the southwest corner of Missouri. They are presented with pink crosshatches within their respective boundaries on Map 3-1. An example of watershed in this category is the North Fabius watershed, HUC 07110002 (No. 3 on Map 3-1), located at northeastern Missouri.

(4) 27 HUC-8 watersheds exhibit an increasing population growth rate of from 0.7% to less than 2.7%. These 27 watersheds are also generally spread across Missouri with a concentration at the southwest corner of Missouri. They are presented with orange stripes within their respective boundaries on Map 3-1. An example of watershed in this category is the Peruque-Piasa watershed, HUC 07110009 (No. 10 on Map 3-1), located at the center of Missouri.

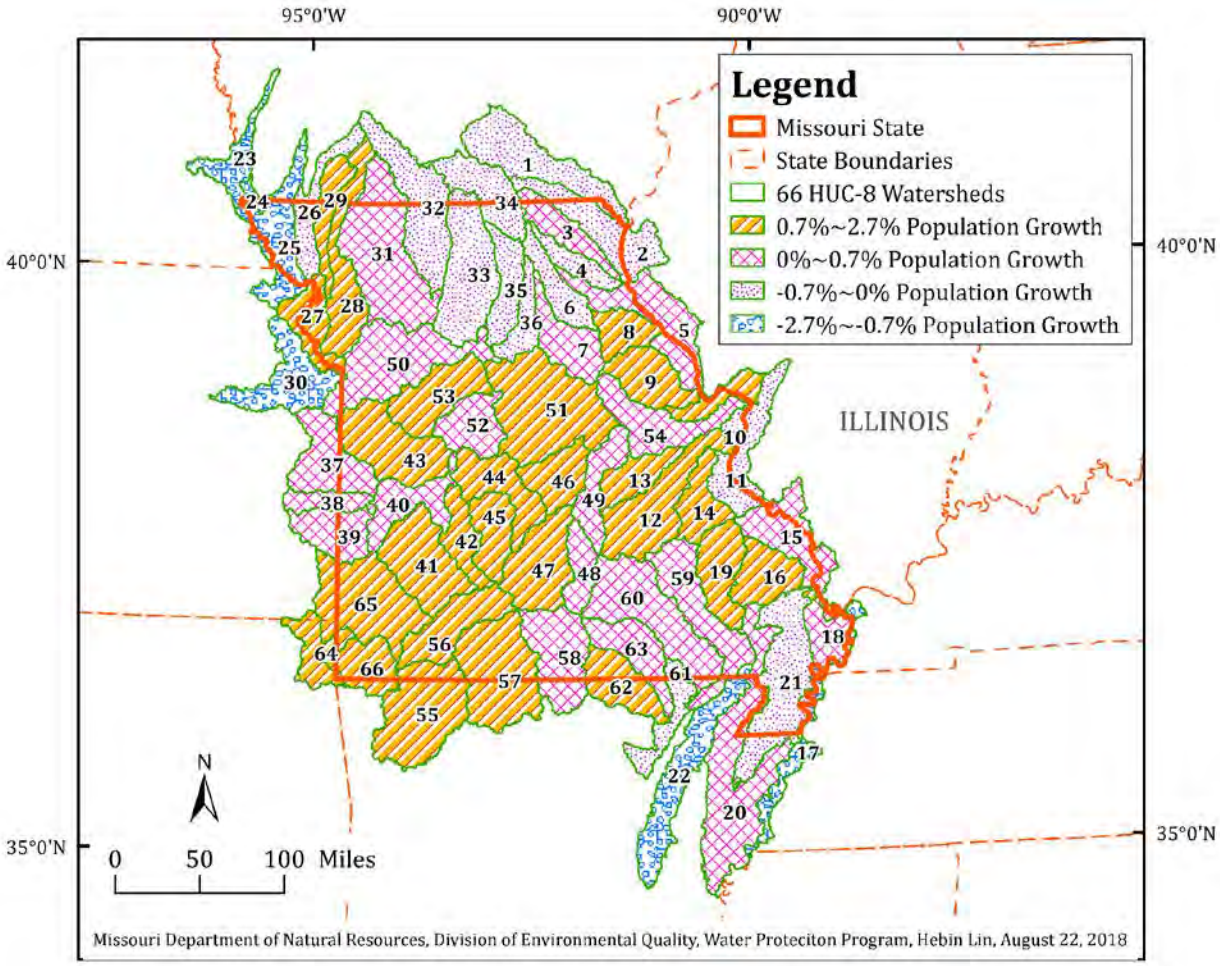
Similarly, the following four trends of MHIs can be observed among the 66 HUC-8 watersheds when compared with that of Missouri.

(1) 12 HUC-8 watersheds have an MHI from 30% to less than 75% of the Missouri MHI. These 12 watersheds are located mostly at the southeast corner of Missouri. They are presented with blue bubbles within their respective boundaries on Map 3-2. An example of watershed in this category is the Lower Mississippi-Memphis watershed, HUC 08010100 (No. 17 on Map 3-2), located at southeastern border of Missouri.

(2) 41 HUC-8 watersheds have an MHI from 75% to less than 100% of the Missouri MHI. These 41 watersheds are generally spread across Missouri with concentrations at the northeastern and southwestern Missouri. They are presented with a purple dots within their respective boundaries on Map 3-2. An example of watershed in this category is the Lower Black watershed, HUC 11010009 (No. 61 on Map 3-2), located at southern border of Missouri.

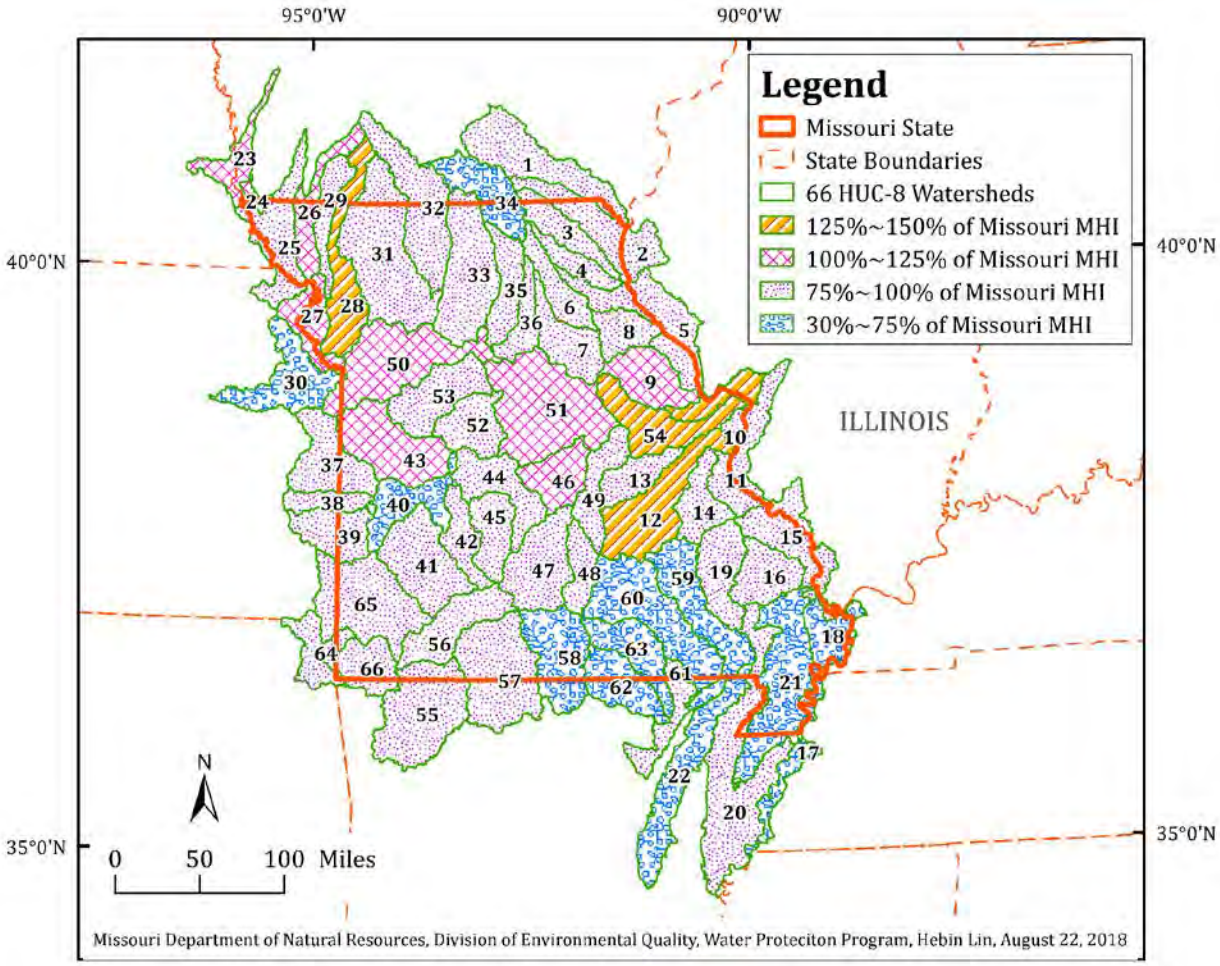
(3) 9 HUC-8 watersheds have an MHI from 100% to less than 125% of the Missouri MHI. These 9 watersheds are located mostly at central Missouri along both banks of Missouri River. They are presented with pink crosshatches within their respective boundaries on Map 3-2. An example of watershed in this category is the Nodaway watershed, HUC 10240010 (No. 26 on Map 3-2), located at northern border of Missouri.

(4) 4 HUC-8 watersheds have an MHI from 125% to less than 150% of the Missouri MHI. These 4 watersheds are located mostly at the confluence of Missouri River and Mississippi River. They are presented with orange stripes within their respective boundaries on Map 3-2. An example of watershed in this category is the Peruque-Piasa watershed, HUC 07110009 (No. 10 on Map 3-2), located at the center of Missouri.



ID	HUC-8 Name	ID	HUC-8 Name	ID	HUC-8 Name	ID	HUC-8 Name
1	Lower Des Moines	18	New Madrid-St. Johns	34	Upper Chariton	51	Lower Missouri-Moreau
2	Bear-Wyaconda	19	Upper St. Francis	35	Lower Chariton	52	Lamine
3	North Fabius	20	Lower St. Francis	36	Little Chariton	53	Blackwater
4	South Fabius	21	Little River Ditches	37	Lower Marais Des Cygnes	54	Lower Missouri
5	The Sny	22	Cache	38	Little Osage	55	Beaver Reservoir
6	North Fork Salt	23	Keg-Weeping Water	39	Marmaton	56	James
7	South Fork Salt	24	Nishnabotna	40	Harry S. Truman Reservoir	57	Bull Shoals Lake
8	Salt	25	Tarkio-Wolf	41	Sac	58	North Fork White
9	Cuivre	26	Nodaway	42	Pomme De Terre	59	Upper Black
10	Peruque-Piasa	27	Independence-Sugar	43	South Grand	60	Current
11	Cahokia-Joachim	28	Platte	44	Lake of the Ozarks	61	Lower Black
12	Meramec	29	One Hundred and Two	45	Niangua	62	Upper White-Spring
13	Bourbeuse	30	Lower Kansas	46	Lower Osage	63	Eleven Point
14	Upper Mississippi-Big	31	Upper Grand	47	Upper Gasconade	64	Lake O' The Cherokees
15	Upper Mississippi-Cape Girardeau	32	Thompson	48	Big Piney	65	Neosho-Spring
16	Whitewater	33	Lower Grand	49	Lower Gasconade	66	Elk
17	Lower Mississippi-Memphis			50	Lower Missouri-Crooked		

Map 3-1. Trends of Population Growth among 66 HUC-8 Watersheds



ID	HUC-8 Name	ID	HUC-8 Name	ID	HUC-8 Name	ID	HUC-8 Name
1	Lower Des Moines	18	New Madrid-St. Johns	34	Upper Chariton	51	Lower Missouri-Moreau
2	Bear-Wyaconda	19	Upper St. Francis	35	Lower Chariton	52	Lamine
3	North Fabius	20	Lower St. Francis	36	Little Chariton	53	Blackwater
4	South Fabius	21	Little River Ditches	37	Lower Marais Des Cygnes	54	Lower Missouri
5	The Sny	22	Cache	38	Little Osage	55	Beaver Reservoir
6	North Fork Salt	23	Keg-Weeping Water	39	Marmaton	56	James
7	South Fork Salt	24	Nishnabotna	40	Harry S. Truman Reservoir	57	Bull Shoals Lake
8	Salt	25	Tarkio-Wolf	41	Sac	58	North Fork White
9	Cuivre	26	Nodaway	42	Pomme De Terre	59	Upper Black
10	Peruque-Piasa	27	Independence-Sugar	43	South Grand	60	Current
11	Cahokia-Joachim	28	Platte	44	Lake of the Ozarks	61	Lower Black
12	Meramec	29	One Hundred and Two	45	Niangua	62	Upper White-Spring
13	Bourbeuse	30	Lower Kansas	46	Lower Osage	63	Eleven Point
14	Upper Mississippi-Big	31	Upper Grand	47	Upper Gasconade	64	Lake O' The Cherokees
15	Upper Mississippi-Cape Girardeau	32	Thompson	48	Big Piney	65	Neosho-Spring
16	Whitewater	33	Lower Grand	49	Lower Gasconade	66	Elk
17	Lower Mississippi-Memphis			50	Lower Missouri-Crooked		

Map 3-2. Trends of MHIs among 66 HUC-8 Watersheds

3.4 Implications for Water Quality Standard Implementation

When considered together, the trends of population growth and MHIs in the 66 HUC-8 watersheds provide some useful insights for water quality standard implementation in Missouri in identifying the comparative needs for upgrading wastewater treatment infrastructure and the comparative financial capabilities of industries and local residents to finance these upgrades at the watershed scale. Accordingly, the 66 HUC-8 watersheds can be categorized as presented in Table 3-2.

Category I watersheds are watersheds which have a decreasing population growth and an MHI above the Missouri MHI; hence they have a relatively low need for upgrading wastewater treatment infrastructure and a relatively strong financial capability, given a same level of stringency in implementing water quality standards. Out of the 66 HUC-8 watersheds, 3 watersheds belong to this category (Table 3-2). They are presented with blue bubbles within their respective boundaries on Map 3-3. An example of watershed in this category is the Nodaway watershed, HUC 10240010 (No. 26 on Map 3-3), located at northern border of Missouri.

Category II watersheds are watersheds which have an increasing population growth and an MHI above the Missouri MHI; hence they have a relatively greater need for upgrading wastewater treatment infrastructure and a relatively strong financial capability, given a same level of stringency in implementing water quality standards. Out of the 66 HUC-8 watersheds, 10 watersheds belong to this category (Table 3-2). They are presented with a purple dots within their respective boundaries on Map 3-3. An example of watershed in this category is the Peruque-Piasa watershed, HUC 07110009 (No. 10 on Map 3-3), located at the center of Missouri.

Category III watersheds are watersheds which have a decreasing population growth and an MHI below the Missouri MHI; hence they have a relatively low need for upgrading wastewater treatment infrastructure and a relatively weak financial capability, given a same level of stringency in implementing water quality standards. Out of the 66 HUC-8 watersheds, 16 watersheds belong to this category (Table 3-2). They are presented with pink crosshatches within their respective boundaries on Map 3-3. An example of watershed in this category is the Lower Black watershed, HUC 11010009 (No. 61 on Map 3-3), located at southern border of Missouri.

Category IV watersheds are watersheds which have an increasing population growth and an MHI below the Missouri MHI; hence they have a relatively greater need for upgrading wastewater treatment infrastructure and a relatively weak financial capability, given a same level of stringency in implementing water quality standards. Out of the 66 HUC-8 watersheds, 37 watersheds belong to this category (Table 3-2). They are presented with orange stripes within their respective boundaries on Map 3-3. An example of watershed in this category is the Lake O' The Cherokees watershed, HUC 11070206 (No. 64 on Map 3-3), located at western border of Missouri.

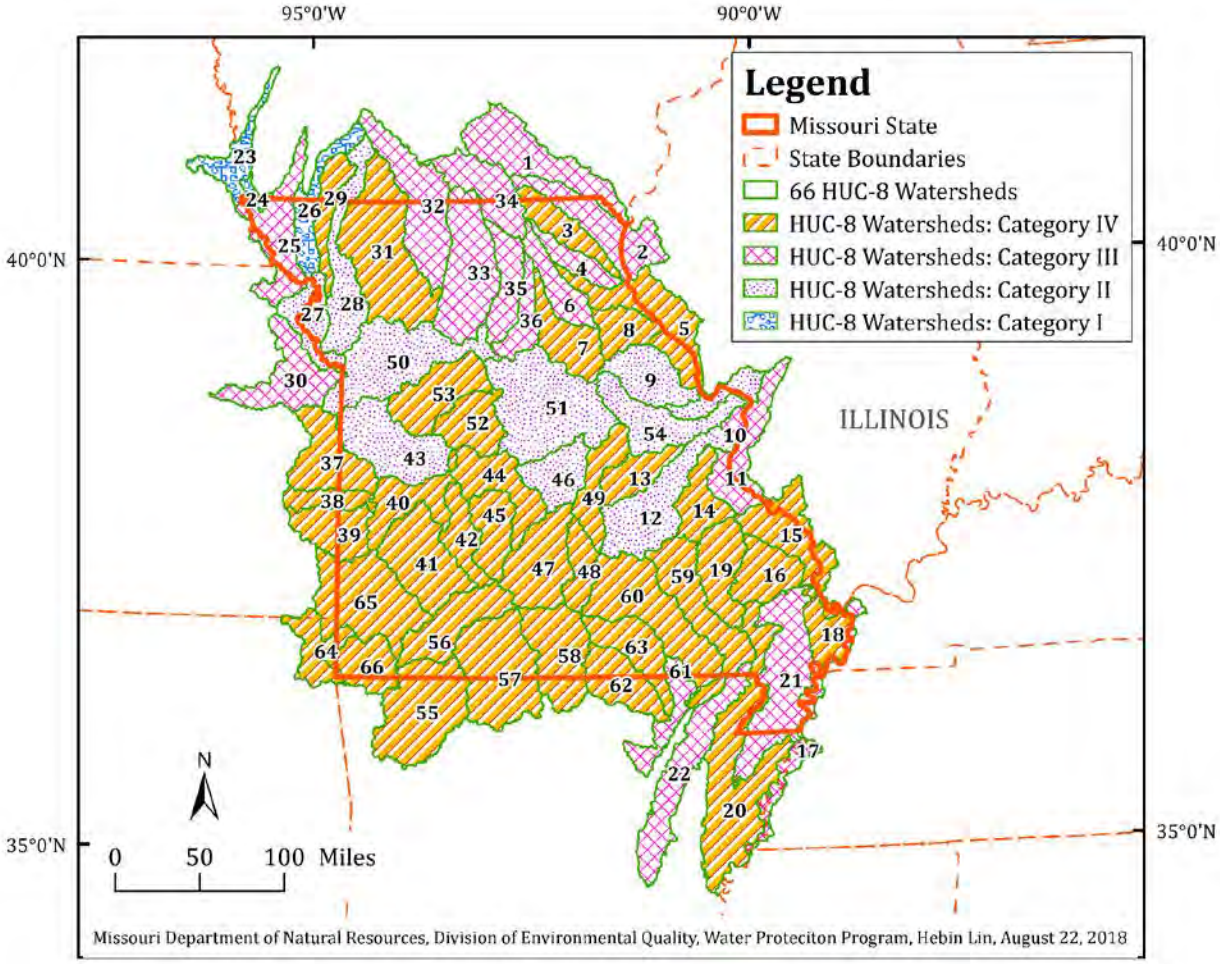
Overall, from Category I to Category IV, these HUC-8 watersheds will have an increasing challenge in adapting to the same level of stringency in implementing water quality standards, with the communities in Category IV having the greatest challenge in upgrading or replacing existing wastewater treatment infrastructure.

Table 3-2. Four Categories of HUC-8 Watersheds by Trends of Population Growth and MHIs

		Watershed Population Growth	
		Decreasing	Increasing
Watershed MHI	Above Missouri MHI	*Category I*	*Category II*
	Below Missouri MHI	*Category III*	*Category IV*

ID	HUC-8 Name	HUC-8 Code	HUC-8 Category
23	Keg-Weeping Water	10240001	
24	Nishnabotna	10240004	*Category I*
26	Nodaway	10240010	
09	Cuivre	07110008	
10	Peruque-Piasa	07110009	
12	Meramec	07140102	
27	Independence-Sugar	10240011	
28	Platte	10240012	
43	South Grand	10290108	*Category II*
46	Lower Osage	10290111	
50	Lower Missouri-Crooked	10300101	
51	Lower Missouri-Moreau	10300102	
54	Lower Missouri	10300200	
01	Lower Des Moines	07100009	
02	Bear-Wyaconda	07110001	
04	South Fabius	07110003	
06	North Fork Salt	07110005	
11	Cahokia-Joachim	07140101	
17	Lower Mississippi-Memphis	08010100	
21	Little River Ditches	08020204	
22	Cache	08020302	*Category III*
25	Tarkio-Wolf	10240005	
30	Lower Kansas	10270104	
32	Thompson	10280102	
33	Lower Grand	10280103	
34	Upper Chariton	10280201	
35	Lower Chariton	10280202	
36	Little Chariton	10280203	
61	Lower Black	11010009	

ID	HUC-8 Name	HUC-8 Code	HUC-8 Category
03	North Fabius	07110002	
05	The Sny	07110004	
07	South Fork Salt	07110006	
08	Salt	07110007	
13	Bourbeuse	07140103	
14	Upper Mississippi-Big	07140104	
15	Upper Mississippi-Cape Girardeau	07140105	
16	Whitewater	07140107	
18	New Madrid-St. Johns	08020201	
19	Upper St. Francis	08020202	
20	Lower St. Francis	08020203	
29	One Hundred and Two	10240013	
31	Upper Grand	10280101	
37	Lower Marais Des Cygnes	10290102	
38	Little Osage	10290103	
39	Marmaton	10290104	
40	Harry S. Truman Reservoir	10290105	
41	Sac	10290106	*Category IV*
42	Pomme De Terre	10290107	
44	Lake of the Ozarks	10290109	
45	Niangua	10290110	
47	Upper Gasconade	10290201	
48	Big Piney	10290202	
49	Lower Gasconade	10290203	
52	Lamine	10300103	
53	Blackwater	10300104	
55	Beaver Reservoir	11010001	
56	James	11010002	
57	Bull Shoals Lake	11010003	
58	North Fork White	11010006	
59	Upper Black	11010007	
60	Current	11010008	
62	Upper White-Spring	11010010	
63	Eleven Point	11010011	
64	Lake O' The Cherokees	11070206	
65	Neosho-Spring	11070207	
66	Elk	11070208	



ID	HUC-8 Name	ID	HUC-8 Name	ID	HUC-8 Name	ID	HUC-8 Name
1	Lower Des Moines	18	New Madrid-St. Johns	34	Upper Chariton	51	Lower Missouri-Moreau
2	Bear-Wyaconda	19	Upper St. Francis	35	Lower Chariton	52	Lamine
3	North Fabius	20	Lower St. Francis	36	Little Chariton	53	Blackwater
4	South Fabius	21	Little River Ditches	37	Lower Marais Des Cygnes	54	Lower Missouri
5	The Sny	22	Cache	38	Little Osage	55	Beaver Reservoir
6	North Fork Salt	23	Keg-Weeping Water	39	Marmaton	56	James
7	South Fork Salt	24	Nishnabotna	40	Harry S. Truman Reservoir	57	Bull Shoals Lake
8	Salt	25	Tarkio-Wolf	41	Sac	58	North Fork White
9	Cuivre	26	Nodaway	42	Pomme De Terre	59	Upper Black
10	Peruque-Piasa	27	Independence-Sugar	43	South Grand	60	Current
11	Cahokia-Joachim	28	Platte	44	Lake of the Ozarks	61	Lower Black
12	Meramec	29	One Hundred and Two	45	Niangua	62	Upper White-Spring
13	Bourbeuse	30	Lower Kansas	46	Lower Osage	63	Eleven Point
14	Upper Mississippi-Big	31	Upper Grand	47	Upper Gasconade	64	Lake O' The Cherokees
15	Upper Mississippi-Cape Girardeau	32	Thompson	48	Big Piney	65	Neosho-Spring
16	Whitewater	33	Lower Grand	49	Lower Gasconade	66	Elk
17	Lower Mississippi-Memphis			50	Lower Missouri-Crooked		

Map 3-3. Four Categories of HUC-8 Watersheds by Trends of Population Growth and MHIs

4. Conclusion

This in-depth analysis develops a method for accurately and consistently estimating population growth rates and MHIs for Missouri and for 66 individual HUC-8 watersheds in Missouri, through using data from 4,506 census block groups published by the U.S. Census Bureau, to support the analysis of the socioeconomic impacts of implementing water quality standards in Missouri per Section 644.058 of the Revised Statutes of Missouri. The estimation method is replicable and applicable to various watershed levels. Extensions could be carried out to HUC-10 and HUC-12 levels especially if data for distributions of household incomes become available at the census block level. The results and insights presented in this analysis provide a practically meaningful perspective to assess the advantages to and constraints on the communities in the same watershed, collectively affecting and benefiting from water resources and other ecosystem services of the same watershed.

This document was prepared by Hebin Lin, PhD, Economist, Operating Permits Section, Water Protection Program, Missouri Department of Natural Resources, August, 2018.

Appendix: Communication of Requests

From: Poudel, Krishna <Krishna.Poudel@dnr.mo.gov>
Sent: Friday, May 18, 2018 10:00 AM
To: Lin, Hebin <Hebin.Lin@dnr.mo.gov>
Subject: Request for Information

Morning Dr. Hebin

As you know WPS is taking initiative to Environmental and Economic Impact analysis in 8 digit HUC wise subbasin level.

Would help us providing average median income for respective HUC-8. Please find the attachment.

Happy Friday.

Krishna Poudel, PhD

Economist

Water Protection Program

Missouri Department of Natural Resources

1101 Riverside Drive

Jefferson City, MO 65102

Phone: 573-522-0573, Fax; 573-526-6802

Email: krishna.poudel@dnr.mo.gov

http://www.dnr.mo.gov

HUC_8	HU_8_NAME	POP10	Median Income
07100009	Lower Des Moines	605	
07110001	Bear-Wyaconda	13089	
07110002	North Fabius	10121	
07110003	South Fabius	7436	
07110004	The Sny	57487	
07110005	North Fork Salt	27602	
07110006	South Fork Salt	48637	
07110007	Salt	18451	
07110008	Cuivre	88023	
07110009	Peruque-Piasa	289089	
07140101	Cahokia-Joachim	892709	
07140102	Meramec	364002	

	07140103	Bourbeuse	65714		
	07140104	Big	98411		
	07140105	Upper Mississippi-Cape Girardeau	73499		
	07140107	Whitewater	46402		
	08010100	Lower Mississippi-Memphis	65		
	08020201	New Madrid-St. Johns	33787		
	08020202	Upper St. Francis	52202		
	08020203	Lower St. Francis	22448		
	08020204	Little River Ditches	92836		
	08020302	Cache	1102		
	10240001	Keg-Weeping Water	6		
	10240004	Nishnabotna	200		
	10240005	Tarkio-Wolf	9611		
	10240010	Nodaway	5058		
	10240011	Independence-Sugar	167689		
	10240012	Platte	67201		
	10240013	One Hundred and Two	35890		
	10270104	Lower Kansas, Kansas	22969		
	10280101	Upper Grand	62413		
	10280102	Thompson	15896		
	10280103	Lower Grand	25359		
	10280201	Upper Chariton	5739		
	10280202	Lower Chariton	12507		
	10280203	Little Chariton	20000		
	10290102	Lower Marais Des Cygnes	10750		
	10290103	Little Osage	2452		
	10290104	Marmaton	18423		
	10290105	Harry S. Truman Reservoir	21897		
	10290106	Sac	94239		
	10290107	Pomme De Terre	42899		
	10290108	South Grand	133048		
	10290109	Lake of the Ozarks	79594		
	10290110	Niangua	38236		
	10290111	Lower Osage	32911		
	10290201	Upper Gasconade	64056		
	10290202	Big Piney	35685		
	10290203	Lower Gasconade	25662		
	10300101	Lower Missouri-Crooked	886090		
	10300102	Lower Missouri-Moreau	329807		
	10300103	Lamine	49801		
	10300104	Blackwater	83044		

10300200	Lower Missouri	451760	
11010001	Beaver Reservoir	22225	
11010002	James	332057	
11010003	Bull Shoals Lake	68996	
11010006	North Fork White	21299	
11010007	Upper Black	52495	
11010008	Current	36370	
11010009	Lower Black	977	
11010010	Spring	25603	
11010011	Eleven Point	17040	
11070206	Lake O' The Cherokees	9352	
11070207	Spring	215971	
11070208	Elk	31933	

From: Lin, Hebin <Hebin.Lin@dnr.mo.gov>
Sent: Friday, May 18, 2018 11:05 AM
To: Poudel, Krishna <Krishna.Poudel@dnr.mo.gov>
Cc: Abbott, Michael <Michael.Abbott@dnr.mo.gov>; Hoke, John <John.Hoke@dnr.mo.gov>; Falls, Angela <Angela.Falls@dnr.mo.gov>
Subject: Re: Request for Information

Hello Krishna,

Thank you for your contact! I am very happy to assist the task.

As you may know, data for Median Household Income or Per Capita Income data at the HUC8 levels are not readily available from the U.S. Census Bureau. I will review the attachment and provide you with a general timeframe for me to develop a methodology to compile data from other census survey levels (county, municipality etc.).

Thanks!

Hebin

Hebin Lin, PhD

Economist, Operating Permits Section

Water Protection Program

Missouri Department of Natural Resources

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573-522-0095

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From: Hoke, John <john.hoke@dnr.mo.gov>
Sent: Friday, May 18, 2018 11:34 AM
To: Lin, Hebin <Hebin.Lin@dnr.mo.gov>; Poudel, Krishna <Krishna.Poudel@dnr.mo.gov>
Cc: Abbott, Michael <Michael.Abbott@dnr.mo.gov>; Falls, Angela <Angela.Falls@dnr.mo.gov>; Boring, Dane <Dane.Boring@dnr.mo.gov>
Subject: RE: Request for Information

Thanks Hebin. We appreciate the assistance. Currently I have Dane working on the GIS analysis for the MHI and other HUC-8 related data knowing it isn't readily available without some estimation. If you'd like an update on where he is in the process, I'm sure he'd be pleased to give one. Thanks

John Hoke

Chief, Watershed Protection Section

Water Protection Program

Missouri Department of Natural Resources

P: 573-526-1446, F: 573-526-6802

We'd like your feedback on the service you received from the Missouri Department of Natural Resources. Please consider taking a few minutes to complete the department's Customer Satisfaction Survey at https://www.surveymonkey.com/r/MoDNRsurvey. Thank you.