HSPF Recharge Models for the San Antonio Segment of the Balcones Fault Zone Edwards Aquifer

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in association with
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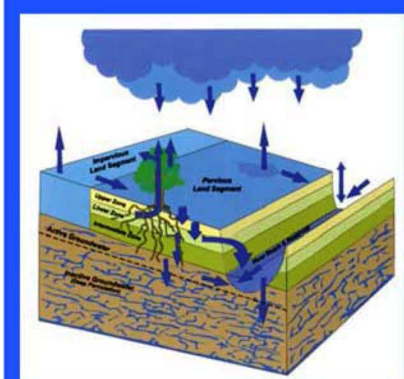
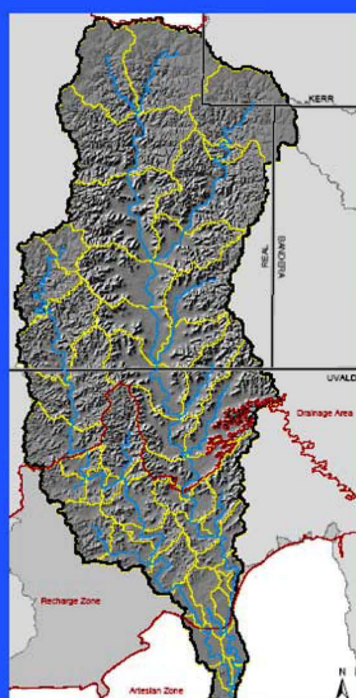
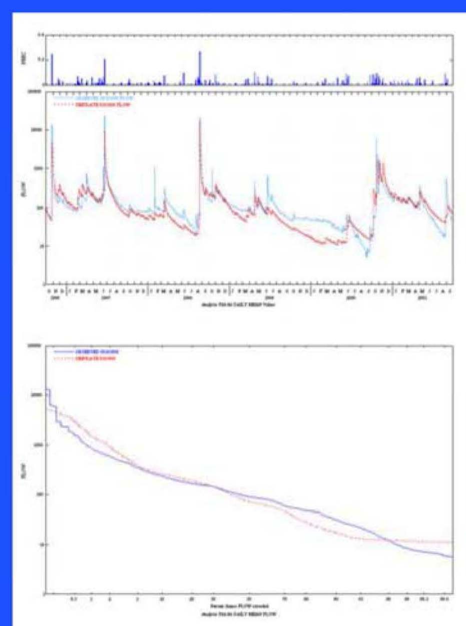
Part 2







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APPENDIX C

DETAILED DESCRIPTION OF HSPF CAPABILITIES

HYDROLOGICAL SIMULATION PROGRAM-FORTRAN (HSPF) MODEL DESCRIPTION

In the mid-1970s, the U.S. EPA Environmental Research Laboratory in Athens, Georgia, was in the beginning stages of model development and testing efforts that focused on tools and procedures for quantifying nonpoint sources (NPS) of pollution. Initiated by legislative mandates that required assessment of both urban and agricultural NPS contaminants, the laboratory was supporting development and field testing of mathematical models (along with companion data collection programs) to be used to estimate these NPS loadings and, ultimately, to evaluate potential management and control alternatives. However, EPA scientists realized that although these field-scale models could provide loading values, they alone would not be sufficient to evaluate water quality impacts at the larger watershed, or regional scale. Thus, an extensive, comprehensive watershed model development effort was begun to integrate the field-scale models with instream hydraulic and water quality process models within a flexible, modular framework, to allow continuous simulation of complex watersheds with multiple land uses, both point and nonpoint contaminant sources, networked channels and drainage patterns, and lakes and reservoirs. The HSPF model produced by this development effort has been applied throughout North America and numerous countries and climates; it has the joint sponsorship of both the EPA and USGS, and continues to undergo refinement and enhancement of its component simulation capabilities along with user support and code maintenance activities.

Overview

The Hydrological Simulation Program-FORTRAN, known as HSPF, is a mathematical model developed under EPA sponsorship for use on digital computers to simulate hydrologic and water quality processes in natural and man-made water systems. It is an analytical tool that has application in the planning, design, and operation of water resources systems. The model enables the use of probabilistic analysis in the fields of hydrology and water quality management. HSPF uses such information as the time history of rainfall, temperature, evaporation, and parameters related to land use patterns, soil characteristics, and agricultural practices to simulate the processes that occur in a watershed. The initial result of an HSPF simulation is a time history of the quantity and quality of water transported over the land surface and through various soil zones down to the groundwater aquifers. Runoff flow rate, sediment loads, nutrients, pesticides, toxic chemicals, and other water quality constituent concentrations can be predicted. The model uses these results and stream channel information to simulate instream processes. From this information, HSPF produces a time history of water quantity and quality at any point in the watershed.

HSPF is currently one of the most comprehensive and flexible models of watershed hydrology and water quality available. It is one of a small number of available models that can simulate the continuous, dynamic event, or steady-state behavior of both hydrologic/hydraulic and water quality processes in a watershed, with an integrated linkage of surface, soil, and stream processes. The model is also unusual in its ability to represent the hydrologic regimes of a wide variety of streams and rivers with reasonable accuracy. It has been applied to such diverse climatic regimes as the tropical rain forests of the Caribbean, the arid conditions of Saudi Arabia and the southwestern U.S., the humid eastern U.S. and Europe, and the snow-covered regions of eastern Canada. The potential applications and uses of the model are comparatively large and include the following:

- Flood control planning and operations.
- Hydropower studies.
- River basin and watershed planning.
- Storm drainage analyses.
- Water quality planning and management.
- Point and nonpoint source pollution analyses.
- Soil erosion and sediment transport studies.
- Evaluation of urban and agricultural best management practices.
- Fate, transport, exposure assessment, and control of pesticides, nutrients, and toxic substances.
- Time-series data storage, analysis, and display.

HSPF is designed so that it can be applied to most watersheds using existing meteorologic and hydrologic data; soils and topographic information; and land use, drainage, and system (physical and man-made) characteristics. The inputs required by HSPF are not different from those needed by most other simpler models. The primary difference in data needs is that long, rather than short time-series records are preferred. Typical long time-series records include precipitation, waste discharges, and calibration data such as streamflow and constituent concentrations.

Historical Development

HSPF is an extension and improvement of three previously developed models: 1) The EPA Agricultural Runoff Management Model - ARM (Donigian and Davis, 1978), 2) The EPA Nonpoint Source Runoff Model - NPS (Donigian and Crawford, 1979), and 3) The Hydrologic Simulation Program (HSP), including HSP Quality (Hydrocomp, 1977), a privately developed proprietary program. In the late 1970s EPA recognized that the continuous simulation approach contained in these models would be valuable in solving many complex water resource problems. Thus, a fairly large investment was devoted to developing a highly flexible nonproprietary FORTRAN program containing the capabilities of these three models, plus many extensions.

HSPF incorporates the field-scale ARM and NPS models into a watershed-scale analysis framework that includes the capabilities needed to model fate and transport in one-dimensional stream channels. It is the only comprehensive model of watershed hydrology and water quality that allows the integrated simulation of land and soil contaminant runoff processes with instream hydraulic and sediment-chemical interactions.

HSPF was first released publicly in 1980, as Release No. 5 (Johanson et al., 1980), by the U.S. EPA Water Quality Modeling Center (now the Center for Exposure Assessment Modeling). Since its initial release, the model has maintained a reputation as perhaps the most useful watershed-scale hydrology/water quality model available within the public domain. The development of HSPF in the late 1970s represented an integration of a variety of EPA-sponsored model development and testing efforts. The basic watershed modeling philosophy and approach embodied in HSP was chosen, a highly modular code design and structure was developed, and all the individual models were redesigned and recoded into FORTRAN to make the resulting package widely usable and available to potential model users. Throughout the 1980s and 1990s, HSPF underwent a series of code and algorithm enhancements producing a continuing succession of new releases of the code, culminating in the release of Version No. 12 (Bicknell et al., 2001).

Since 1981, USGS has been developing software to facilitate watershed modeling by providing interactive capabilities for model input development, data storage and data analysis, and model output analysis including hydrologic calibration assistance. The ANNIE, WDM, Scenario Generator (GenScn), and HSPEXP software are USGS products that have greatly advanced and facilitated watershed model applications, not only for HSPF but also for many other USGS models. For example, the WDM (Watershed Data Management) file has effectively replaced the Time Series Store (TSS) file used in the earlier versions of HSPF due to the expanded data analysis and graphical capabilities of the ANNIE software (Flynn et al., 1995), which is designed to interact with WDM files.

In 1994 efforts began to develop EPA's Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) modeling system. The BASINS system combines environmental databases, models, assessment tools, pre- and post-processing utilities, and report generating software to provide the full range of tools and data, integrated into a single modeling package, needed for performing watershed and water quality analyses. HSPF was incorporated into BASINS as the core watershed model. Since 1998 BASINS has benefited from considerable efforts to integrate and enhance the strongest features of HSPF and the USGS software products (including GenScn) within a common framework. Today HSPF/BASINS serves as a focal point for cooperation and integration of watershed modeling and model support activities between the USGS and the EPA.

Since its initial release in 1980, HSPF applications have been worldwide and number in the hundreds; many active applications continue around the world with the greatest concentration in North America. Numerous studies have been completed or are continuing in the Pacific Northwest, the Washington, DC, metropolitan area, and the Chesapeake Bay region. Today the model serves as the focal point for cooperation and integration of watershed modeling and model support efforts between EPA and USGS. Over the years, development activities and model enhancements, along with these model applications, have continued to improve the model's capabilities and preserve its status as a state-of-the-art tool for watershed analysis.

Overview of HSPF Capabilities and Components

HSPF contains three application modules and eight utility modules. The three application modules simulate the hydrologic/hydraulic and water quality components of the watershed. The utility modules are used to manipulate, analyze, and report time-series data; the most recently added utility module computes pollutant removal via control measures. Table C-1 summarizes the constituents and capabilities of the HSPF modules. A brief description of the three modules follows:

1) PERLND-Simulates runoff and water quality constituents from pervious land areas in the watershed.

2) IMPLND-Simulates impervious land area runoff and water quality.

3) RCHRES-Simulates the movement of runoff water and its associated water quality constituents in stream channels and mixed reservoirs.

Typically the results of PERLND or IMPLND simulations are either evaluated as endpoints or are input to a RCHRES network to enable simulation of instream phenomena. To support simulation of a broader range of hydrological phenomena and settings at a watershed scale, HSPF also allows linkage of a PERLND land surface to another PERLND or to an IMPLND land surface.

PERLND Module

Because PERLND simulates the water quality and quantity processes that occur on pervious land areas, it is the most frequently used part of HSPF. To simulate these processes, PERLND models the movement of water along three paths: overland flow, interflow, and groundwater flow. Each of these three paths experiences differences in time delay and differences in interactions between water and its various dissolved constituents. A variety of storage zones are used to represent the processes that occur on the land surface and in the soil horizons.

Table C-1. HSPF Application and Utility Modules

Application Modules		
PERLND	**IMPLND**	**RCHRES**
Snow Water Sediment Soil temperature Water Quality* Pesticide Nitrogen Phosphorus Tracer	Snow Water Solids Water Quality*	Hydraulics Conservative Temperature Sediment Nonconservatives BOD/DO Nitrogen Phosphorus Carbon/pH Plankton
Utility Modules		
COPY	**PLTGEN**	**DISPLAY**
Data transfer	Plot data	Tabulate, summarize
DURANL	**GENER**	**MUSTIN**
Duration	Transform or combine time-series data	Time-series data
BMP	**REPORT**	
Compute pollutant removal via control measures	Customize and view model output	

* Up to 10 user–specified water quality parameters.

Snow accumulation and melt are also included in the PERLND module so that the complete range of physical processes affecting the generation of water and associated water quality constituents can be represented. Some of the many capabilities available in the PERLND module include the simulation of:

- Water budget and runoff components.
- Snow accumulation and melt.
- Sediment production and removal.
- Accumulation and washoff of user-defined nonpoint pollutants.
- Nitrogen and phosphorus fate and runoff.
- Pesticide fate and runoff.
- Movement of a tracer chemical.

Figure C-1 defines the structure and contents of the PERLND module. The PERLND module features individual compartments (i.e., subroutine groups) for specific modeling capabilities, including: air temperature as a function of elevation (ATEMP), snow accumulation and melting (SNOW), hydrologic water budget (PWATER), sediment production and removal (SEDMNT), soil temperature (PSTEMP), surface runoff water temperature and gas concentrations (PWTGAS), generalized water quality constituents (PQUAL), solute transport (MSTLAY), pesticides (PEST), nitrogen (NITR), phosphorus (PHOS), and conservatives (TRACER).

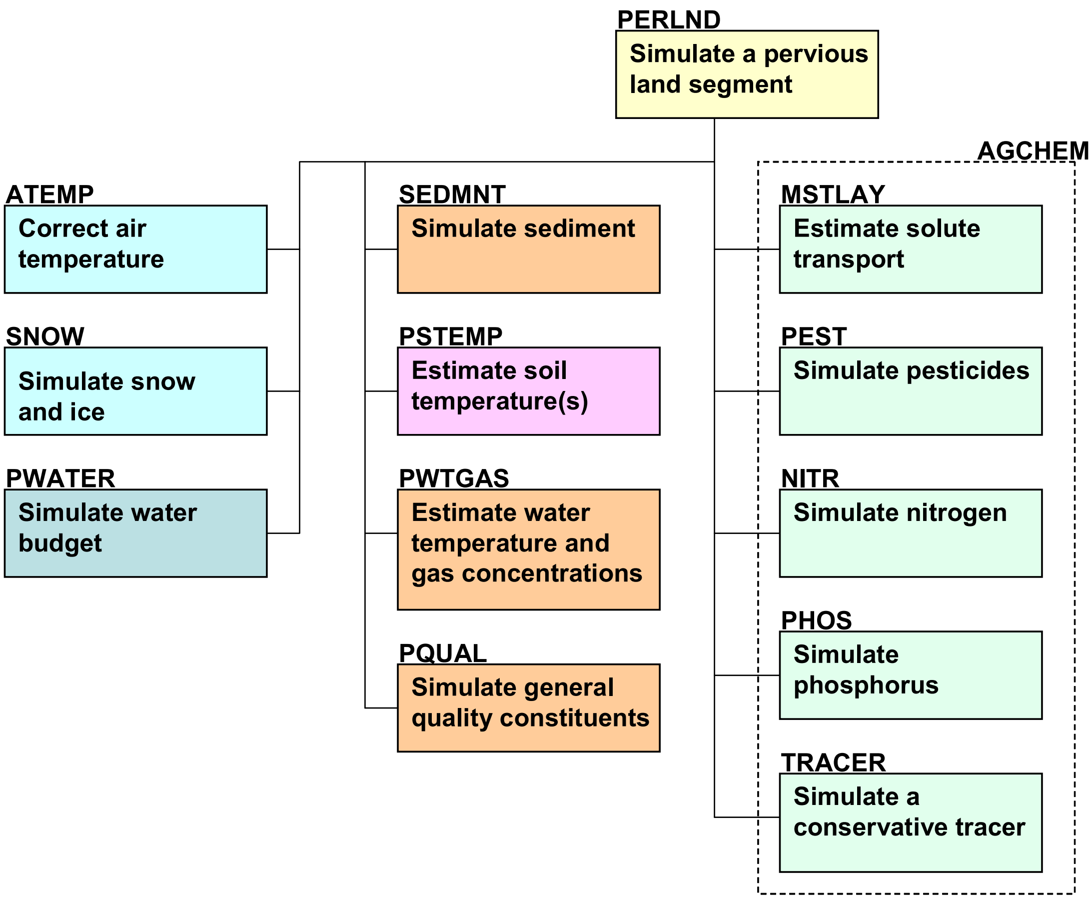
PWATER is used to calculate the water budget components resulting from precipitation on pervious land areas; as a result, it is the key component of the PERLND module. The basis of the water budget computations contained in HSPF is the Stanford Watershed Model (Crawford and Linsley, 1966). Like the SNOW code, the PWATER code uses both physical and empirical formulations to model the movement of water through the hydrologic cycle. PWATER considers such processes as evapotranspiration; surface detention; surface runoff; infiltration; shallow subsurface flow (interflow); baseflow; and percolation to deep groundwater. Lateral inflows to surface and shallow subsurface storages can be modeled, and a wetland module is included that allows a smooth computational transition between 'normal' hydrological conditions and high water table conditions. PWATER also allows representation of irrigation waters applied to pervious land segments.

The equations used in the SEDMNT code to produce and remove sediment are based on the ARM and NPS models, and are modifications of soil and gully erosion equations developed by Negev (1967) and influenced by Meyer and Wischmeier (1969) and Onstad and Foster (1975). Many of the sediment model parameters are derived from the Universal Soil Loss Equation (Wischmeier and Smith, 1978). Removal of sediment by water is simulated as washoff of detached sediment in storage and scour of the soil matrix. Soil detachment is modeled as a function of rainfall, land cover, land management practices, and soil detachment properties. If the modeler so specifies, soil detachment can be incremented by lateral input from an upslope land segment and/or net external additions/removals caused by human activities or wind. Removal of detached sediment and scour of the soil matrix by surface flow are both modeled empirically as a function of surface water storage and surface water outflow.

PWTGAS estimates the water temperature for surface, shallow subsurface (interflow) and groundwater outflows. The temperature of each outflow is considered to be the same as the soil temperature of the layer from which it originates. PWTGAS also computes the dissolved oxygen and carbon dioxide concentrations of overland flow using empirical formulations; concentrations are assumed to be at saturation. PQUAL simulates generalized water quality constituents in the outflows (surface and subsurface) from a pervious land segment using simple relationships with water and/or sediment yield. The behavior of a constituent in surface outflow is considered more complex and dynamic than the behavior in subsurface flow. The code allows quantities in surface outflow to be simulated by one, or both, of two methods. Either (1) a constituent can be modeled using "potency factors" to indicate constituent strength relative to the sediment removal computed by SEDMNT, or (2) storage of a constituent on the land surface can be modeled, considering accumulation and depletion/removal, and a first-order washoff rate of the available constituent can be removed by overland flow, as computed by PWATER. In addition, both formulations can be used for representing the washoff behavior of particulate and dissolved components of a specific pollutant.

The remaining five code compartments in PERLND are used together to model detailed behavior of soil nutrients (i.e., nitrogen and phosphorus) and non-reactive tracer chemicals (e.g., chloride). These five code sections have been referred to as the AGCHEM module because their primary use to date has been for modeling the mass balance and runoff of agricultural chemicals. MSTLAY estimates the storages and fluxes of moisture in the four soil layers—surface, upper, lower, groundwater - that define soil layers used by the remaining four code compartments. MSTLAY is required because the moisture storages and fluxes computed by PWATER must be modified to effectively simulate solute transport through the soil. Estimates of solute flux are computed based on the assumption that the concentration of solute being transported is the same as that for storage; uniform flow through the layers and continuous mixing of solutes is also assumed. Leaching retardation factors are computed to modify the solute fluxes from the top three soil layers based on user-defined model parameters.

Figure C-1 - PERLND Structure Chart



PEST simulates pesticide behavior in the soil and runoff from pervious land segments in three forms: dissolved, adsorbed, and crystallized. The PEST code utilizes time-series data generated by other compartments of PERLND (i.e., PWATER, SEDMNT, MSTLAY) to compute transport (runoff and leaching), adsorption/desorption, and degradation. Pesticide transport is modeled as a function of water flow and/or association with transported sediment. Chemicals in solution move to, through, and from storages according to the fractions calculated in MSTLAY. Computations are performed that compute the movement of adsorbed pesticide associated with removal of sediment from the surface layer via scour and washoff. Adsorption/desorption is a function of both chemical and soil layer characteristics; several options for characterizing sorption are offered, including a first-order kinetic approach and the use of two different Freundlich isotherm methods. Degradation from all processes is modeled as a lumped rate in each of the four soil layers.

The NITR code section simulates the transport and soil reactions of nitrate, ammonia, and four forms of organic nitrogen. Nitrogen species are transported by the same methods used for pesticides. Nitrate and dissolved ammonium are transported as a function of water flow; organic nitrogen and adsorbed ammonium are removed from the surface layer storage by association with sediment scour and washoff; nitrate and ammonium in the soil water are transported according to the fractions calculated in MSTLAY; and computations are performed that compute the movement of adsorbed organic nitrogen and ammonium associated with removal of sediment from the topsoil surface layer. First-order kinetics or a Freundlich isotherm can be used to model adsorption/desorption. Nitrogen transformation processes (denitrification, nitrification, plant uptake, immobilization, mineralization, volatilization, plant nitrogen return to organic nitrogen) are modeled using temperature-corrected, first-order kinetics with separate rate constants defined for each soil layer. To accommodate simulation of forest nitrogen cycling, NITR allows consideration of both particulate and dissolved fractions of both labile and refractory organic N; representation of both below- and above-ground plant N compartments; cycling of above-ground plant N to the soil through a litter compartment; cycling of below-ground plant N to the soil organic N; and use of saturation kinetics for immobilization and plant N uptake.

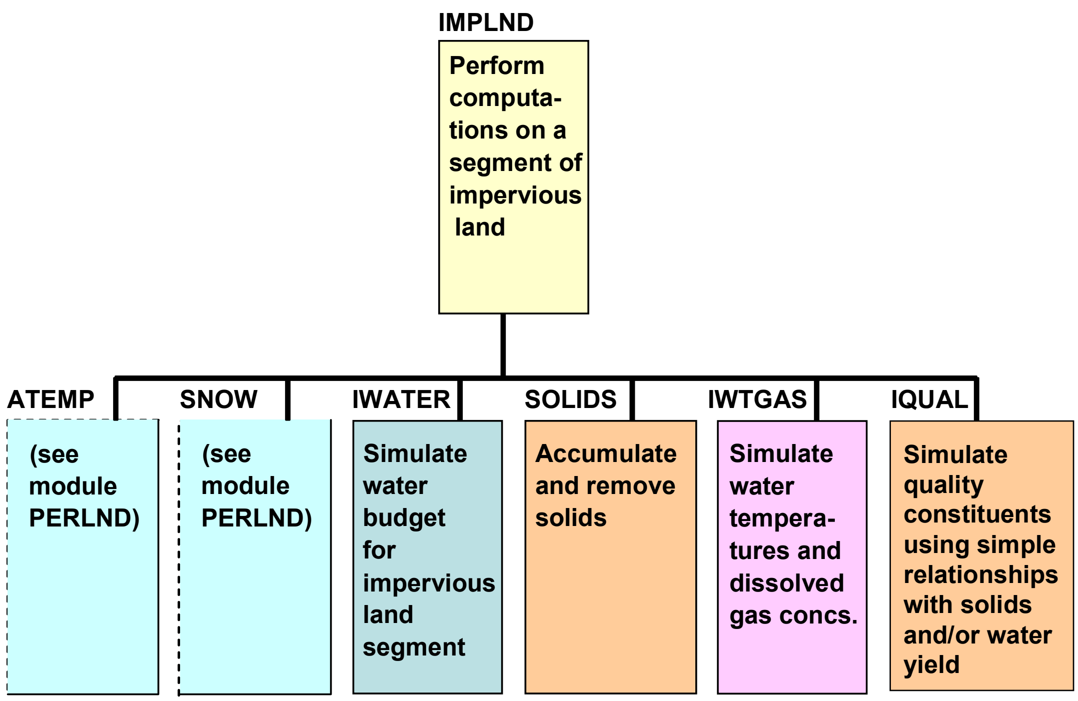
PHOS simulates the transport and reaction of phosphate and organic phosphorus using methods parallel to those used for nitrogen species in NITR. Transport mechanisms for phosphate parallel those modeled for ammonium, and those for organic phosphorus parallel organic nitrogen. Like ammonium, phosphate adsorption/desorption can be modeled using either first-order kinetics or a Freundlich isotherm. Phosphorus transformation processes (plant uptake, immobilization, mineralization) are modeled using temperature-corrected, first-order kinetics with separate rate constants defined for each soil layer.

Typically, the TRACER code is applied to chloride (or bromide) to calibrate solute movement through the soil profile. This involves adjustment of leaching retardation factors until good agreement with observed soil chloride concentrations has been obtained. Once appropriate retardation values have been determined, they are used in PEST, NITR, and PHOS to simulate solute transport.

IMPLND Module

IMPLND is used for impervious land surfaces, primarily for urban land categories, where little or no infiltration occurs. However, some land processes do occur, and water, solids, and various pollutants are removed from the land surface by moving laterally downslope to a pervious area,

Figure C-2 - IMPLND Structure Chart



stream channel, or reservoir. IMPLND includes most of the pollutant washoff capabilities of the commonly used urban runoff models, such as the STORM, SWMM, and NPS models. Figure C-2 defines the structure and contents of the IMPLND module. The module shares much of its code with PERLND, but is simplified since infiltration and other interactions with the subsurface cannot occur. The module features individual compartments for modeling air temperature as a function of elevation (ATEMP), snow accumulation and melting (SNOW), hydrologic water budget (IWATER), solids accumulation and removal (SOLIDS), surface runoff water temperature and gas concentrations (IWTGAS), and generalized water quality constituents (IQUAL).

One difference between PERLND and IMPLND process representation is of note. In the SOLIDS code section, IMPLND offers the capability to model the accumulation and removal of urban solids (i.e., solids on impervious areas) by processes that are independent of storm events (e.g., street cleaning, decay, wind deposition or scour). To use this option, the modeler needs to assign monthly or constant rates of solids accumulation and removal, estimate parameter values for impervious solids washoff (analogous to methods in the SEDMNT module of PERLND), and provide 'potency factor' values for constituents associated with the solids removed. Alternatively, the IQUAL module can be used to represent accumulation and removal processes for each constituent individually, analogous to the PQUAL approach.

RCHRES Module

RCHRES is used to route runoff and water quality constituents simulated by PERLND and IMPLND through stream channel networks and reservoirs. The module simulates the processes that occur in a series of open or closed channel reaches or a completely mixed lake. Flow is modeled as unidirectional. A number of processes can be modeled, including the following:

- Hydraulic behavior.
- Heat balance processes that determine water temperature.
- Inorganic sediment deposition, scour, and transport by particle size.
- Chemical partitioning, hydrolysis, volatilization, oxidation, biodegradation, and generalized first-order (e.g., radionuclides) decay, parent chemical/metabolite transformations.
- DO and BOD balances.
- Inorganic nitrogen and phosphorus balances.
- Plankton populations.
- pH, carbon dioxide, total inorganic carbon, and alkalinity.

Figure C-3 defines the structure and contents of the RCHRES module. The module features individual compartments for modeling hydraulics (HYDR), constituent advection (ADCALC), conservatives (CONS), water temperature (HTRCH), inorganic sediment (SEDTRN), generalized quality constituents (GQUAL), specific constituents involved in biochemical transformations (RQUAL), and acid mine drainage phenomena (ACIDPH).

1) HYDR simulates the processes that occur in a single reach of an open channel or a completely mixed lake. Hydraulic behavior is modeled using the kinematic wave assumption. All inflows to a reach are assumed to enter at a single upstream point. The outflow of a reach may be distributed across several targets that might represent normal outflows, diversions, and multiple gates of a reservoir. In HSPF, outflows can be represented by either, or both, of two methods: Outflow can be modeled as a function of reach volume for situations where there is no control of flows, or gate settings are only a function of water level.

2) Outflow can be modeled as a function of time to represent demands for municipal, industrial, or agricultural use. To do so, the modeler must provide a time series of outflow values for the outflow target that is time-dependent and independent of reach volume.

If an outflow demand has both volume-dependent and time-dependent components, the modeler can, and must, specify how the components are combined to define the resulting outflow demand. HSPF allows the modeler to define the resulting demand in one of three manners: (1) as the minimum of the two components, (2) as the maximum of the two components, or (3) as the sum of the two components.

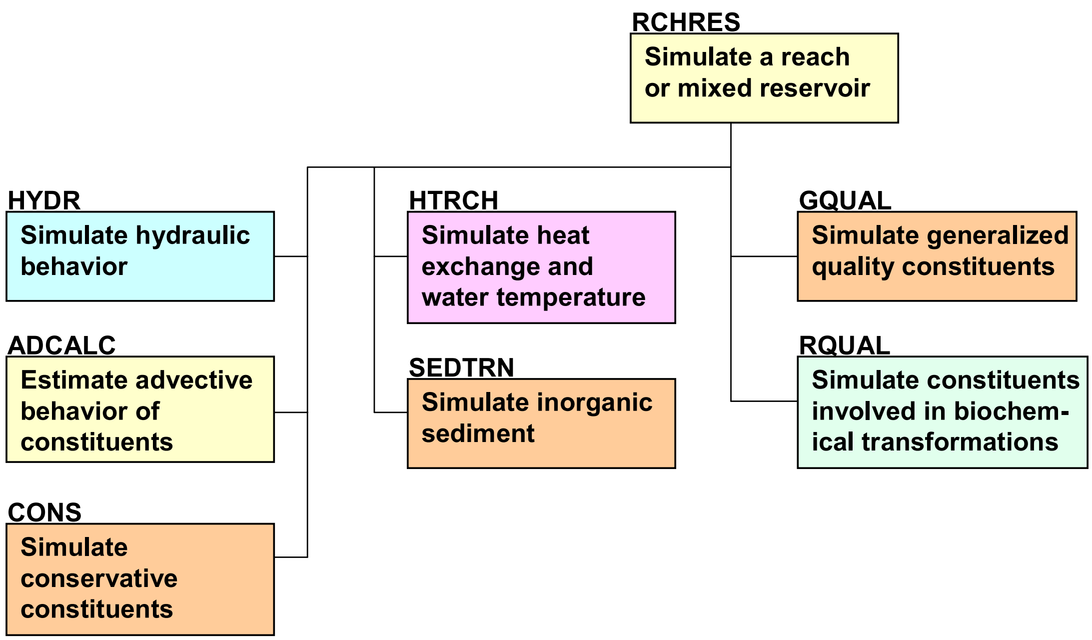
HSPF makes no assumptions regarding the shape of a reach; however, the following assumptions are made:

1) There is a fixed, user-defined relation between water depth, surface area, volume, and discharge. This is specified in a Function Table (FTABLE) defined for each reach by the user.

2) For any outflow demand with a volume-dependent component, the relation between the above variables is usually constant in time; however, predetermined seasonal or daily variations in discharge values can be represented by the user.

These assumptions rule out cases where flow reverses direction (e.g., estuaries) or where one stream reach influences another upstream of it in a time-dependent manner. Momentum is not considered, and the routing technique falls in the class known as “storage routing” or “kinematic wave” methods.

Figure C-3 - RCHRES Structure Chart



In addition to calculating outflow rates and reach water volumes, HYDR computes the values for additional hydraulic parameters that are used in the other code sections of RCHRES including depth, stage, surface area, average depth, top width, hydraulic radius, bed shear stress and shear velocity. A user can also assign the ownership of water inflows and outflows to each reach, with the ownership of outflowing water defined in terms of specified priorities or percentages, or in proportion to the current mixture in the stream segment.

The approach taken by the SEDTRN code compartment to compute transport of channel sediment is based on the SERATRA model developed by Battelle Laboratories (Onishi and Wise, 1979). Both noncohesive (sand) and cohesive (silt, clay) sediments are simulated in SEDTRN; migration of each sediment fraction between suspension in water and the bed is modeled by balancing deposition and scour computations. The code allows the modeler to compute the deposition or scour of noncohesive sediment by selecting one of three empirical formulations:

1) A user-defined power function of streamflow velocity.

2) A relationship (Toffaleti method) dependent upon median sand particle diameter, average stream velocity, reach hydraulic radius, reach slope, settling velocity for sand (user-specified), and water temperature.

3) A relationship (Colby method) dependent upon median sand particle diameter, average stream velocity, reach hydraulic radius, fine sediment load concentration, and water temperature.

The simulation of cohesive sediment transport consists of two steps. First, advective transport is calculated; then deposition and scour are calculated based on the calculated bed shear stress. To evaluate deposition, the modeler is required to provide values for settling velocity and critical shear stress for deposition for each fraction (silt, clay) of cohesive sediment that is modeled. To evaluate resuspension, or scour, the modeler must provide values for the erodibility coefficient and critical shear stress for each fraction.

The focus of the GQUAL code development was to allow simulation of agricultural pesticides and other synthetic organic chemicals. Given the diversity of pesticides that might be modeled, the code provides the user with the capability to model any subset of the following generalized processes: advection of dissolved material; decay of dissolved material by hydrolysis, oxidation by free radical oxygen, photolysis, volatilization, biodegradation, and/or generalized first-order decay; production of one modeled constituent as a result of decay of another constituent; advection of adsorbed suspended material; deposition and scour of adsorbed material; and adsorption/desorption between dissolved and sediment-associated phases. Using the GQUAL section in conjunction with the sediment transport code (SEDTRN), adsorbed chemicals may settle or resuspend during each simulation time step, depending on hydrodynamic conditions. Decomposition of adsorbed chemicals may be simulated, both in suspended materials and in the bed, by using a first-order, temperature-corrected decay formulation.

The RQUAL code provides detailed simulation of constituents involved in biochemical transformations. Included are dissolved oxygen, BOD, ammonia, nitrite, nitrate, phosphate, phytoplankton, benthic algae, zooplankton, refractory organics, and pH. The primary dissolved oxygen and biochemical oxygen demand balances are simulated with provisions for decay, settling, benthic sinks and sources, reaeration, and sinks and sources related to plankton. The primary nitrogen balance is modeled as sequential reactions from ammonia through nitrate. Ammonia volatilization, ammonification, denitrification, and ammonium adsorption/desorption interactions with suspended sediment fractions are also considered. Both ammonium and phosphate adsorption/desorption to suspended sediment fractions are modeled using an equilibrium, linear isotherm approach. Both nitrogen and phosphorus species are considered in modeling three types of plankton—phytoplankton, attached algae, and zooplankton. Phytoplankton processes that are modeled include growth, respiration, sinking, zooplankton predation, and death; zooplankton processes include growth, respiration and death; and benthic algae processes modeled are growth, respiration, and death. Hydrogen ion activity (pH) can be calculated by implementing PHCARB, contained within the RQUAL section. PHCARB computes pH by considering carbon dioxide, total organic carbon, and alkalinity. In doing so, the code considers the effects on the carbon dioxide-bicarbonate system of carbon dioxide invasion, zooplankton respiration, BOD decay, net growth of algae, and benthic releases.

Special Actions

Increasingly complex modeling requirements have led to the development of a suite of Special Actions capabilities within HSPF. Special Actions enable the user to alter the value of variables in PERLND, IMPLND and RCHRES in the following manners:

- Reset – A variable can be reset at any specified time in the simulation to a specified value.
- Increment – A variable can be incremented at any specified time in the simulation by a specified value.
- Repeat - Each SPECIAL ACTION can be "repeated" at regular time intervals. This facilitates application of chemicals several times per year and each year of the simulation.
- Distribution - A SPECIAL ACTION can be "distributed" over time (equal time increments) with a user-defined pattern that is based on fractions of the total amount. This is useful in representing the activities of multiple farmers applying chemicals on different days when all of the farms are represented by a single PERLND.
- User-defined - Several SPECIAL ACTIONS can be combined as a single "user-defined" action which can be invoked multiple times for different PERLNDS and at different times. This reduces the number of actions required to represent incorporation of chemicals in two or more soil layers as a result of plowing, and application of multiple chemical species.
- Conditional - In addition to the enhancements designed to reduce the user-input requirements of SPECIAL ACTIONS, conditional SPECIAL ACTIONS are possible in which an action can be dependent on the value of some other variable in the model. This can be useful for deferring agricultural operations that are dependent on rainfall or soil moisture, and for reservoir operations that are dependent on river flow or reservoir volume.

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APPENDIX D

DETAILED DESCRIPTION OF DATA AVAILABILITY FOR MODEL DEVELOPMENT

This Appendix contains a detailed description of the data that was collected for the model development and calibration. Chapter 3 of the report contains a summary.

Precipitation and Evaporation

The National Climatic Data Center (NCDC) of the National Weather Service (NWS) has the largest active archive of precipitation and evaporation data in the United States. The NCDC maintains a cooperative program with other data collection agencies in the individual states. The NCDC provides the primary hourly and daily precipitation records for the nine-basin modeling region.

Another convenient source of historic data, in terms of station inventory for all regions of the state, is the NOAA Hydrologic Data Systems (NHDS) Group. This group is part of the NWS Office of Hydrologic Development, Hydrology Data Archive Branch. The NHDS group provides quick access to historical data for use in calibration of hydrologic models.

The inventory of historical precipitation and evaporation data includes a copy of other agencies' data that consists of NCDC cooperative and System Acquisition Office (SAO) stations and National Resources Conservation Service SNOTEL (snow survey) sites, among others. The data programs of interest for this study are the "NCDC TD-3240 cooperative hourly precipitation" program and the "NCDC TD-3200 cooperative summary of the day" program.

NHDS archives and displays information about the precipitation and pan evaporation stations from their website. Users can search for precipitation and pan evaporation stations by specifying a time (month and year) and area boundary (north and south latitude, and west and east longitude).

Another source of evaporation data is the Texas Water Development Board. Pan evaporation rates are determined for each one-degree quadrangle in Texas from data collection sites operated by the TWDB and the NWS. These pan evaporation rates from the TWDB encompassed the period of record used in the model.

Precipitation

The NHDS historical data inventory is not up to date and NHDS is in the process of replacing the data with direct data access from the data contributing agencies. For practical purposes the information contained at this website provides the most comprehensive historical data for the study area. The historical data that are available are in their original format and can be downloaded from the Internet.

For the nine-basins study area, a search of precipitation stations was conducted for an area between 30.50 degrees North and 29.00 degrees North, and 98.00 and 100.30 degrees West.

Precipitation stations having hourly data are listed in Table D-1.

Table D-1. Hourly Precipitation Stations

#	Station Name	Station #	Latitude	Longitude	Period of Record (yyyy.mm.dd) [1]
1	Bankersmith	41 0509	30.13	98.82	1948.1.1 thru 1999.12.31
2	Comfort 2	41 1920	29.97	98.90	1990.7.1 thru 1999.12.31
3	Hunt 10 W	41 4375	30.05	99.52	1976.7.1 thru 1999.12.31
4	Leakey	41 5113	29.73	99.77	1948.1.1 thru 1999.12.31
5	San Antonio Int. Airport	41 7945	29.32	98.28	1948.1.1 thru 1999.12.31

[1]year, month, day

The hourly data were downloaded directly from the NHDS website and are available from 1948 through December 1999. The most recent data (up to October 1, 2002) can be purchased on-line from the NCDC website. The data downloaded from NHDS website were found to be identical to that purchased from NCDC except that the purchased data included data for the period after December 1999.

Table D-2 lists the stations that have daily data. Since there are many more daily precipitation stations in the study area compared to hourly stations, the daily precipitation data were obtained directly from a CD-ROM, containing the TD3200 (the Cooperative Summary of the Day data), purchased from NCDC (NOAA Satellite and Information Services). The period of record of each station varies, but most stations include the period of 1950 through 2001.

Table D-2. Daily Precipitation Stations

#	Station Name	Station #	Latitude	Longitude	Period of Record (yyyy.mm.dd)
1	Bankersmith	41 0509	30.13	98.82	1948.6.1 thru 2001.12.31
2	Blanco	41 0832	30.10	98.42	1897.1.1 thru 2001.12.31
3	Boerne	41 0902	29.80	98.73	1897.7.1 thru 2001.12.31
4	Camp Wood	41 1398	29.68	100.02	1944.3.1 thru 2001.12.31
5	Canyon Dam 7	41 1437	29.92	98.22	1948.5.1 thru 1956.12.31
6	Canyon Dam No 7	41 1438	29.92	98.22	1990.10.1 thru 1993.4.30
7	Comfort 2	41 1920	29.97	98.90	1996.8.1 thru 2001.12.31
8	Cottonwood	41 2040	30.17	99.13	1962.7.1 thru 2001.12.31
9	Fredericksburg	41 3329	30.23	98.92	1896.12.1 thru 2001.12.31
10	Harper	41 3954	30.30	99.25	1909.10.1 thru 2001.12.31
11	Hondo	41 4254	29.33	99.13	1900.1.1 thru 2001.12.31
12	Hunt 10 W	41 4375	30.05	99.52	1992.1.1 thru 2001.12.31
13	Ingram NO 2	41 4458	30.07	99.25	1992.1.1 thru 2001.12.31
14	Kerrville	41 4780	30.05	99.15	1897.1.1 thru 1974.7.31
15	Kerrville 3 NNE	41 4782	30.07	99.12	1974.10.1 thru 2001.12.31

Table D-2. Daily Precipitation Stations

#	Station Name	Station #	Latitude	Longitude	Period of Record (yyyy.mm.dd)
16	Leaky	41 5113	29.73	99.77	1963.11.1 thru 1971.1.31
17	Lytle 3 W	41 5454	29.23	98.85	1976.12.1 thru 2001.12.31
18	New Braunfels	41 6276	29.73	98.12	1897.1.1 thru 2001.12.31
19	Northington Ranch	41 6448	29.87	98.65	1986.8.1 thru 2001.12.31
20	Prade Ranch	41 7232	29.92	99.77	1955.10.1 thru 2001.12.31
21	Rio Medina	41 7628	29.43	98.88	1922.8.1 thru 2001.12.31
22	Rock Springs	41 7706	30.02	100.22	1932.04.01 thru 2001.12.31
23	Sabinal	41 7873	29.37	99.48	1903.09.01 thru 2001.12.31
24	San Antonio Int. Airport	41 7945	29.32	98.28	1946.09.01 thru 2001.12.31
25	San Marcos	41 7983	29.85	97.95	1896.12.01 thru 2001.12.31
26	San Antonio Sea World	41 8169	29.45	98.70	1988.06.01 thru 2001.12.31
27	Utopia	41 9260	29.58	99.52	1991.02.01 thru 2001.12.31
28	Uvalde 9 SW	41 9264	29.13	99.90	1996.08.01 thru 1998.08.31
29	Uvalde	41 9265	29.22	99.77	1905.03.01 thru 1985.05.31
30	Uvalde	41 9267	29.22	99.77	1920.03.01 thru 1946.12.20
31	Uvalde 3 SW (Uvalde Research Center)	41 9268	29.18	99.83	1985.08.01 thru 2001.12.31
32	Wimberley 1 NW	41 9815	30.00	98.07	1984.11.1 thru 2001.12.31

Figure 3.1.1 shows the locations of these precipitation stations.

The USGS has also provided the precipitation and evaporation data that was used in two recent HSPF models in the nine-basin area. These models and data are summarized in two reports by the USGS (2002b, 2002c). These data provide more detailed information for the watersheds in northern Bexar County and the upper Seco Creek Basin.

Evaporation

For the nine-basins study area, a search of evaporation stations was conducted for an area between 30.50 degrees North and 29.00 degrees North, and 98.00 and 100.30 degrees West. Table D-3 lists the only five pan evaporation stations found by this search; and only the Canyon Dam and San Antonio Sea World stations are near the study area. None of the stations have more than 40 years of records.

Table D-3. Daily Pan Evaporation Stations

#	Station Name	Station #	Latitude	Longitude	Period of Record (yyyy.mm.dd)
1	Canyon Dam	41 1429	29.87	98.20	1961.06.01 thru 1999.12.31
2	Choke Canyon Dam	41 1720	28.47	98.25	1983.10.01 thru 1999.12.31
3	Dilly	41 2458	28.68	99.18	1948.01.01 thru 1987.06.31
4	San Antonio Sea World	41 8169	29.45	98.70	1988.06.01 thru 1999.12.31
5	Winter Haven Experiment Station	41 9842	28.63	99.87	1952.02.28 thru 1952.11.01

Another source of evaporation data are the hourly point potential evapotranspiration (PTPE) data computed from NCDC TD-3280 Surface Airways Observations in NHDS archives. In Texas, PTPE values have been computed for 19 airport or municipal sites where hourly (or for some stations: 3-hour) surface airways observations were collected. The PTPE time series are computed from meteorological data using a Penman type approach. Input data are mean daily air temperature, dewpoint, wind speed, and daily total solar radiation. These data are summarized in Table D-4.

Table D-4. Hourly Point Potential Evapotranspiration Data Summary

Surface Airway Observation Station Number	Location	Period of Record
13962	Abilene WSO Airport	1948-1999
23047	Amarillo	1948-1999
13958	Austin WSO Airport	1948-1999
12919	Brownsville	1948-1999
12924	Corpus Christi	1948-1999
03927	Dallas/Fort Worth	1958-1999
13960	Dallas/Love Field	1948-1999
23044	El Paso WSO Airport	1948-1999
03951	East Texas	1983-1999
12918	Houston FAA	1948-1999
12960	Houston Int.	1969-1999
23042	Lubbock WSFO Airport	1948-1999
93987	Lufkin	1948-1999
23023	Midland/Odessa WSO	1948-1999
23034	San Angelo WSO Airport	1948-1999
12921	San Antonio WSFO Airport	1948-1999
12912	Victoria WSO Airport	1948-1999

Table D-4. Hourly Point Potential Evapotranspiration Data Summary

Surface Airway Observation Station Number	Location	Period of Record
13959	Waco	1948-1999
13966	Wichita Falls	1948-1999

Of these stations, only the Austin WSO and San Antonio WSFO Airport stations are close to the study area. The data archives for the San Antonio WSFO Airport site and others can be downloaded directly from the NHDS website, however, the record length ends when these sites were converted to the Automated Surface Observation System (ASOS). For example, the San Antonio data ends in May 1995. Following that date the information is no longer supported by the NHDS site and can only be accessed from NCDC directly.

The ASOS program is a joint effort of the NWS, Federal Aviation Administration (FAA), and the Department of Defense (DOD). The ASOS system serves as the nation's primary surface weather observation network. Much of the basic weather elements reported by ASOS, such as type and intensity for rain, precipitation accumulation, precipitation beginning/ending times, ambient air and dew-point temperature, wind speed, etc, were used in this modeling study. ASOS provides updated observations continuously. The ASOS network has increased the number of full-time surface weather observation locations. There are 53 commissioned ASOS sites in Texas. Table D-5 lists the ASOS sites located in or near the study area.

Table D-5. ASOS Sites

Station Name	Station No.	Latitude				Longitude				Commissioned Date yyyy.mm.dd
Austin Municipal Airport	13958	30	17	54	N	-97	42	5	W	1995.07.01
Bergstrom Austin-Bergstrom Int'l Airport	13904	30	10	46	N	-97	40	50	W	1997.10.02
Del Rio International Airport	22010	29	22	1	N	-100	55	18	W	1996.04.01
Hondo Municipal Airport	12962	29	21	34	N	-99	10	27	W	1996.03.15
Junction Kimble County Airport	13973	30	30	39	N	-99	45	59	W	1996.12.02
New Braunfels Municipal Airport	12971	29	42	31	N	-98	2	43	W	1996.02.29
San Antonio International Airport	12921	29	31	58	N	-98	27	49	W	1995.06.01
San Antonio Stinson Municipal Airport	12970	29	20	12	N	-98	28	15	W	1998.05.13

In addition to the National Weather Service, other sources of precipitation and evaporation data are the Texas Water Development Board, the Edwards Aquifer Authority, USGS, San Antonio Sea World, and Texas A&M. Each is described below.

The Texas Water Development Board (TWDB) maintains a FTP site for monthly precipitation and evaporation data. Lake evaporation and precipitation rates are provided for each one-degree quadrangle in Texas (shown in Figure D-1). The quadrangle data were determined from all available data collection sites operated by the NWS and the TWDB.

The TWDB site provides monthly lake evaporation for the period of 1954 to 2000 (see Table D-6) and precipitation data for the period of 1941 to 2000 (see Table D-7 for 1950-2000) for each quadrangle. These data were obtained from the following sources:

(1) TWDB and NWS evaporation stations

(2) Hydrosphere NCDC (National Climatic Data Center), Summary of the Day

(3) NCDC Climatological Data Monthly or Annual for surrounding states: Louisiana, Arkansas, Oklahoma, and New Mexico

(4) Other Internet data sources.

Table D-6. TWDB Annual Evaporation Data

QUAD	709	708	707	807	808	809	12921
Counties	Hays, Blanco, Kendall, and Kerr	Kerr, Edwards, and Real	Edwards	Real, Uvalde, and Edwards	Uvalde, Medina, Benedera, Kerr, and Real	Medina, Bexar, Comal, Quadalupe, Kendall and Hays	San Antonio Airport
1954	62.0	64.9	67.2	70.5	64.7	62.3	66.9
1955	54.9	55.6	56.6	63.1	59.0	56.5	62.5
1956	62.3	62.7	62.8	73.4	65.3	65.2	68.7
1957	46.2	55.9	69.6	65.5	55.3	48.2	54.0
1958	46.6	54.9	52.6	53.6	49.7	44.9	52.8
1959	43.1	45.3	54.3	57.0	52.9	48.1	55.5
1960	44.1	47.1	55.6	56.6	51.7	47.4	54.3
1961	43.8	45.6	53.1	55.2	49.7	47.2	57.2
1962	49.8	57.0	76.8	61.7	59.2	55.3	65.3
1963	50.5	58.1	78.7	80.5	63.5	58.8	61.4
1964	60.4	72.6	79.9	74.2	60.7	58.4	60.4
1965	53.6	63.5	71.7	69.8	56.0	52.7	54.5
1966	53.1	62.7	70.0	67.2	55.8	53.3	51.9
1967	59.9	65.7	77.7	79.7	64.3	59.7	57.3
1968	47.2	51.5	62.1	63.7	51.4	50.1	49.5
1969	52.3	54.8	61.5	69.8	52.1	52.6	58.5
1970	51.2	49.4	58.2	61.0	47.3	51.2	53.7
1971	58.2	62.6	69.2	63.9	55.6	56.4	56.8
1972	53.5	63.7	68.2	65.3	56.1	51.7	53.2
1973	50.1	57.7	63.5	64.5	53.3	48.2	52.6

Table D-6. TWDB Annual Evaporation Data

QUAD	709	708	707	807	808	809	12921
Counties	Hays, Blanco, Kendall, and Kerr	Kerr, Edwards, and Real	Edwards	Real, Uvalde, and Edwards	Uvalde, Medina, Benedera, Kerr, and Real	Medina, Bexar, Comal, Quadalupe, Kendall and Hays	San Antonio Airport
1974	56.4	61.3	66.5	72.8	56.6	51.8	54.6
1975	52.8	57.8	62.7	65.3	53.9	49.7	55.0
1976	52.3	51.6	56.0	58.0	52.7	51.4	51.4
1977	59.4	57.3	61.9	64.7	58.0	56.5	56.2
1978	56.8	54.8	59.3	61.3	55.8	54.9	52.7
1979	54.2	54.3	59.4	62.0	55.2	52.0	55.4
1980	59.6	59.4	64.7	68.0	59.6	55.5	60.8
1981	51.4	51.5	53.7	56.5	51.4	49.6	51.4
1982	56.8	56.5	57.1	62.7	58.0	53.2	54.7
1983	54.5	54.0	58.1	62.6	55.7	53.2	59.0
1984	61.9	60.8	65.7	72.2	66.1	64.5	62.4
1985	55.0	53.4	56.8	62.5	59.9	54.1	55.7
1986	50.1	53.7	61.3	64.0	59.7	52.8	54.0
1987	53.0	46.4	52.8	55.0	47.6	54.0	55.2
1988	56.1	55.8	61.3	66.9	61.4	55.6	59.6
1989	59.5	57.2	63.6	70.8	65.9	58.7	60.4
1990	48.3	54.7	58.6	61.4	54.0	53.5	53.2
1991	60.9	61.7	64.1	72.1	68.8	55.2	49.5
1992	58.5	56.7	52.9	59.9	60.3	52.0	53.9
1993	64.2	64.6	69.1	74.8	70.6	62.8	55.1
1994	61.5	61.1	63.7	73.1	64.6	57.5	52.7
1995	54.2	54.9	54.8	66.9	57.4	53.7	56.7
1996	57.8	58.6	60.3	66.5	60.2	59.7	50.6
1997	53.3	56.7	57.7	62.6	55.7	52.1	41.3
1998	54.5	61.4	61.0	70.9	65.1	46.0	48.0
1999	58.4	62.4	64.8	65.6	57.7	53.9	49.1
2000	73.5	74.6	67.2	72.1	63.5	59.4	47.1
2001	53.8	51.7	51.6	65.9	52.6	50.4	42.0
Mean	54.8	57.4	62.4	65.7	57.7	54.0	55.4

[1]Units are inches/year

Table D-7. TWDB Annual Precipitation Data

QUAD [1]	709	708	707	807	808	809
Counties	Hays, Blanco, Kendall, and Kerr	Kerr, Edwards, and Real	Edwards	Real, Uvalde, and Edwards	Uvalde, Medina, Bandera, Kerr, and Real	Medina, Bexar, Comal, Guadalupe, Kendall and Hays
1950	21.9	21.3	18.5	16.0	18.0	20.6
1951	21.1	14.7	9.5	13.8	19.8	22.4
1952	37.1	23.0	9.2	10.9	20.7	31.4
1953	23.0	15.2	11.5	14.5	17.8	22.8
1954	12.6	12.6	14.1	18.3	15.8	13.8
1955	28.8	21.5	16.3	18.6	20.1	19.3
1956	16.1	11.4	9.3	6.7	10.1	12.8
1957	45.7	37.0	33.7	31.8	35.8	45.1
1958	37.5	31.5	28.7	35.8	35.3	41.6
1959	38.7	27.5	25.1	26.5	27.8	32.2
1960	31.5	27.2	19.0	21.0	26.6	36.0
1961	27.2	22.5	23.0	21.6	24.4	27.2
1962	24.0	18.2	16.7	12.7	15.1	22.5
1963	18.9	18.0	16.5	19.5	18.3	18.8
1964	27.4	27.0	23.2	29.4	24.7	28.1
1965	37.6	25.1	20.2	25.2	27.5	38.7
1966	23.3	23.2	23.5	25.7	27.1	26.6
1967	26.4	23.8	22.8	27.7	24.5	31.1
1968	40.0	30.9	27.4	28.7	30.6	37.8
1969	37.0	32.3	29.9	34.5	32.5	34.9
1970	24.4	20.8	20.6	29.0	23.4	25.4
1971	29.9	30.1	27.9	34.2	34.9	31.4
1972	28.5	23.9	25.5	29.4	25.3	31.8
1973	36.1	32.0	29.4	38.8	37.8	49.5
1974	36.1	32.6	35.6	31.2	31.5	36.0
1975	32.1	25.8	28.0	33.8	29.3	31.0
1976	36.5	30.8	32.9	35.7	39.3	43.4
1977	24.4	21.8	23.8	25.5	23.3	27.0
1978	29.0	26.8	26.2	28.1	26.4	32.2
1979	31.1	26.1	24.0	29.8	28.8	34.9
1980	27.7	27.9	21.0	22.6	25.4	27.6
1981	38.8	31.6	28.7	33.5	34.6	36.4
1982	26.5	22.3	21.0	28.6	20.9	25.9
1983	30.4	20.6	19.2	26.0	24.5	29.1
1984	27.0	26.1	22.7	27.5	23.2	23.9
1985	31.8	24.6	24.1	27.3	28.3	38.4

Table D-7. TWDB Annual Precipitation Data

QUAD [1]	709	708	707	807	808	809
Counties	Hays, Blanco, Kendall, and Kerr	Kerr, Edwards, and Real	Edwards	Real, Uvalde, and Edwards	Uvalde, Medina, Bandera, Kerr, and Real	Medina, Bexar, Comal, Guadalupe, Kendall and Hays
1986	38.8	33.8	31.9	32.0	35.8	39.6
1987	34.8	32.1	27.7	35.0	39.1	36.2
1988	22.2	19.5	20.2	24.9	18.7	18.0
1989	26.7	22.2	18.8	23.7	19.6	22.3
1990	31.8	30.6	35.3	40.7	31.7	33.2
1991	43.2	32.0	24.4	26.0	37.8	45.7
1992	40.2	31.7	24.4	27.5	39.3	47.7
1993	27.4	20.5	18.7	14.2	20.3	29.1
1994	33.4	29.7	22.5	25.8	34.1	35.5
1995	31.5	29.2	23.7	25.0	30.3	28.9
1996	23.8	17.7	12.5	12.3	14.1	26.3
1997	43.2	34.5	21.4	24.8	36.5	40.6
1998	35.6	27.3	24.8	30.4	32.3	39.8
1999	19.6	16.5	14.2	17.2	15.1	17.3
2000	30.9	31.6	24.3	23.4	27.9	35.1
Mean	30.5	25.6	22.6	25.1	26.5	31.3

1 Units are inches/year

The Sea World (San Antonio) Weather Station is a member of the NWS cooperative program. Accordingly, the information on this data source has been incorporated into NWS section.

The Texas A&M Evapotranspiration (ET) Network provides daily potential evapotranspiration (PET) data (http:/texaset.tamu.edu/pet.php). This source uses the Penman-Monteith method to calculate PET from meteorological data. Table D-8 provides a summary of average monthly PET data stations in or near the study area. For the period of record used for the averaging (no period was given), the resulting monthly and annual average PET values show little variations across the study area.

Table D-8. Average Monthly PET (from Texas A&M)

City [1]	Longitude	Latitude	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Austin	30° 18'	97° 42'	2.00	2.66	4.30	5.27	7.55	8.28	8.12	8.20	6.22	4.93	3.08	2.08	62.69
Del Rio	29° 22'	100° 47'	1.30	1.80	4.30	5.20	8.01	8.71	8.26	8.24	7.70	6.00	3.00	1.10	63.62
San Antonio	29° 32'	98° 28'	2.07	2.77	4.40	5.33	7.58	8.21	7.96	8.03	6.19	4.95	3.14	2.15	62.78

[1]Units are inches/month

Streamflow

The USGS, through their cooperative station network, provided a complete record of the streamflow data available for the nine basins. Historical daily mean streamflow data for the nine basins were downloaded from the National Water Information System (NWIS) via the USGS website at http://water.usgs.gov/nwis/. Table D-9 provides a list of the gaging stations (location, station ID, contributing drainage area, and period of record) compiled for each of the basins. Although not listed in Table D-9, other stream gauges located in the contributing zone were used during model calibration if they have a sufficient historical record. The contributing zone gauges help ensure that the rainfall-runoff process is simulated adequately and that the simulated flow contributions from individual contributing subbasins is appropriate.

Table D-9. USGS Stream Gauge Stations

Basin Name	Gaging Location	USGS ID#	Latitude	Longitude	Drainage Area (sq. mi.)	Period of Record (yyyy.mm.dd)
Guadalupe	Guadalupe R. above Comal R. at New Braunfels	08168500	29.42'53"	98.06'35"	1,518	1927.12.19 to 2001.09.30
	Comal R. at New Braunfels	08169000	29.42'21"	98.07'20"	130	1927.12.19 to 2001.09.30
	Guadalupe R. at New Braunfels	08169500	29.41'52"	98.06'23"	1,652	1915.02.01 to 1927.12.31
Area between Medina and Cibolo-Dry Comal	Salado C. at Wilderness Rd at San Antonio	08178585	29.37'50"	98.33'55"	23	1997.12.01 to 2001.09.30
	Salado C. at Loop 410 at San Antonio	08178700	29.30'57"	98.25'51"	137	1960.09.01 to 2001.09.30
	Salado C. at Loop 410 at San Antonio	08178800	29.21'25"	98.24'45"	189	1960.09.01 to 2001.09.30
Medina	Medina R. at Bandera	08178880	29.43'25"	99.04'11"	427	1982.10.01 to 2001.09.30
	Medina Canal nr Rio Medina	08180000	29.30'19"	98.54'11"	??	1922.04.01 to 2001.09.30
	USGS Medina R. nr Rio Medina	08180500	29.29'53"	98.54'16"	650	1923.10.01 to 2001.09.30
Cibolo-Dry Comal	Cibolo C. at IH10 above Boerne	08183850	29.48'52"	98.45'12"	29	1996.05.23 to 2001.09.30
	Cibolo C. at Selma	08185000	29.35'38"	98.18'39"	274	1946.04.01 to 2001.09.30
	Cibolo C. nr Falls City	08186000	29.00'50"	97.55'48"	827	1930.10.01 to 2001.09.30
Frio-Dry Frio	Frio R. at Concan	08195000	29.29'18"	99.42'16"	389	1923.11.01 to 2001.09.30
	Dry Frio R. nr Reagan Wells	08196000	29.30'16"	99.46'52"	126	1952.09.01 to 2001.09.30
	Frio R. below Dry Frio R. nr Uvalde	08197500	29.14'44"	99.40'27"	631	1953.10.01 to 2001.09.30

Table D-9. USGS Stream Gauge Stations

Basin Name	Gaging Location	USGS ID#	Latitude	Longitude	Drainage Area (sq. mi.)	Period of Record (yyyy.mm.dd)
Sabinal	Sabinal R. nr Sabinal	08198000	29.29’27”	99.29’33”	206	1942.10.01 to 2001.09.30
	Sabinal R. at Sabinal	08198500	29.18’05”	99.28’46”	241	1952.09.01 to 2001.09.30
Area between Sabinal and Medina	Hondo C. nr Tarpley	08200000	29.34’10”	99.14’47”	95.6	1952.09.01 to 2001.09.30
	Hondo C. at King Waterhole nr Hondo	08200700	29.23’26”	99.09’04”	149	1960.10.01 to 2001.09.30
	Seco C. at Miller Ranch nr Utopia	08201500	29.34’23”	99.24’10”	45	1961.05.01 to 2001.09.30
	Seco C. at Rowe Ranch nr D’Hanis	08202700	29.21’43”	99.17’05”	168	1960.11.01 to 2001.09.30
Nueces	West Nueces River near Brackettville	8190500	29.28’21”	100.14’10”	694	1939.09.28 to 2003.09.30
	Nueces River at Laguna	8190000	29.25'42",	99.59'49"	737	1923.10.01 to 2003.09.30
Blanco	Blanco River at Wimberley	8171000	29.59’39”	98.05’19”	355	1923.09.01 to 2003.09.30
	Blanco River near Kyle	8171300	29.58’45”	97.54’35”	412	1956.06.01 to 2003.09.30

Topography

The National Elevation Database (NED) 30-meter topographic data were used to determine elevation and slope in the basins. The NED was selected because it has several advantages over the previous generation 7.5-min Quadrangle digital elevation model (DEM) data, including seamless and corrected boundary information. Experience has shown that the NED dataset has fewer errors and is more appropriate for calculating watersheds than other DEM data. Figures 3.3.1, 3.3.2, and 3.3.3 show the topography, hillshade perspective, and slope of the nine-basin area, respectively.

Geology and Soils

Digital soil coverages (STATSGO and SSURGO) were downloaded from the Texas State Soil and Water Conservation Board (TSSWCB) and/or Natural Resource Conservation Service (NRCS). The STATSGO database is developed from 1:250,000 scale soil maps and the SSURGO information is developed from 1:24,000 scale soil maps. Figure D-2 shows the STATSGO distribution of the Hydrologic Soil Groups (A, B, C and D). The SSURGO coverage is incomplete and thus not shown. Descriptions of the hydrologic soil groups are summarized in Table D-10.

Table D-10. Hydrologic Soil Groups

Hydrologic Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sands and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Slow infiltration rates. Soils with layers impeding downward movement of water, or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have a high water table, or are shallow to an impervious layer.

There is a significant difference between the STATSGO and SSURGO datasets regarding distribution of hydrologic soil group. These inconsistencies were further evaluated and considered during the designation of PERLNDs. A full discussion of the STATSGO and SSURGO datasets is provided in the Work Plan to Develop HSPF Recharge Models for the Seven Drainage Basins (LBG-Guyton Associates, 2003).

Chapter 5 contains maps of the 1:250,000 scale surface geology of each basin and the mapped geologic faults. It is the likely the combination of the soils (permeability and thickness) and the underlying geology (permeability and stratigraphic characteristics) that determine the difference in the hydrologic response between the contributing zone and the recharge zone. In the contributing zone, vegetation also plays a very important role in determining baseflow of streams that eventually contributes to recharge for the Edwards Aquifer. These characteristics were considered in determining parameters for the model.

Landuse – Vegetation

Digital coverages of the landuse and land cover were downloaded from the USGS. The basic sources of land use compilation data are NASA high-altitude aerial photographs and National High-Altitude Photography (NHAP) program photographs, usually at scales smaller than 1:60,000. Chapter 5 contains maps of the land cover and vegetation data for each basin area.

Infiltration Research

Most of the documented infiltration studies have been concentrated on the western edge of the Plateau but are probably widely applicable due to relatively uniform nature of the soils on the Edwards Plateau. Measured infiltration rates range from 60-200 mm/hr, which are in the same range as the STATSGO and SSURGO data. These data along with more recent simulations (Wilcox, 2003) indicate that in some areas of the plateau, runoff occurs as "saturation overland flow", meaning that runoff occurs after the shallow soil becomes saturated and cannot hold additional water.

Diversions and WAM Assessment

As part of the nine-basin recharge study, historical water use data was incorporated into the recharge model in those recharge basins that have significant historical water use. Available monthly data for each water right in the Nueces, Guadalupe and San Antonio River Basin Water Availability Models (WAMs) were obtained from the Texas Commission on Environmental Quality (TCEQ). This data included the location of each water right diversion, maximum authorized diversion and maximum reported use in the last ten years. Each of the nine-recharge basins was analyzed to determine the number, location; maximum authorized diversion and historical reported water use for the water rights in each basin. Although there are some data limitations, each diversion location, as well as authorized maximum diversion, the maximum annual reported use, and the average annual reported use has been developed for each water right to the degree possible. These data have been incorporated into the GIS database so diversions can be assigned to the appropriate stream reach in the HSPF models. Table D-11 summarizes the historical diversions from each basin, including the authorized maximum diversion, the maximum annual reported use, and the average annual reported use during the recent 10 to 15 years.

Table D-11. Summary of Diversions in Nine Basins

Basin	Number of Active Water Rights	Maximum Authorized Diversion (af/yr)	Maximum Annual Reported Use (af/yr)	Recent Average Annual Use (af/yr)
Nueces	-	-	-	930
Frio-Dry Frio	41	10,573	2,299	590
Sabinal	13	1,317	249	130
Area Between Sabinal and Medina	7	1,607	98	80
Medina	35	121,118	62,742	39,368
Area Between Medina and Cibolo-Dry Comal Creek	3	54	0	0
Cibolo Creek and Dry-Comal Creek	8	892	754	585
Guadalupe	190	115,990	21,621	11,000
Blanco	-	-	0	0

The following discussion is a brief review of the analysis of each basin and determination of the impact of historical water use on surface-water streamflows.

Frio Basin

The Frio-Dry Frio Recharge Basin currently has 41 active water rights [Permits or Certificates of Adjudications (CA)] with a maximum authorized diversion of 10,573 acre-feet per year (ac-ft/yr), a maximum annual reported use of 2,299 ac-ft/yr and an average use over the last 15 years of 590 ac-ft/yr. Prior to the mid 1970s, the historical use dropped significantly. The historical streamflow (recorded by USGS) is significantly greater than the average water use in the recharge basin throughout the period of record. These reported uses were appropriately incorporated into the nine-basins model.

Sabinal Basin

The Sabinal Recharge Basin currently has 13 active water rights [Permits or Certificates of Adjudications (CA)] with a maximum authorized diversion of 1,317 acre-feet per year (ac-ft/yr), a maximum annual reported use of 249 ac-ft/yr and an average use over the last 15 years of 130 ac-ft/yr. Prior to the mid 1970s, the historical use dropped significantly. The historical streamflow is significantly greater than the average water use in the recharge basin throughout the period of record. These reported uses were appropriately incorporated into the nine-basins model.

Area Between Sabinal and Medina Basins

The area between the Sabinal and Medina Recharge Basins currently has 7 active water rights [Permits or Certificates of Adjudications (CA)] with a maximum authorized diversion of 1,607 acre-feet per year (ac-ft/yr), a maximum annual reported use of 98 ac-ft/yr and an average use over the last 15 years of 80 ac-ft/yr. Prior to the mid 1970s, the historical use dropped significantly. The historical streamflow is significantly greater than the average water use in the recharge basin throughout the period of record. These reported uses were appropriately incorporated into the nine-basins model.

Medina Basin

The Medina Recharge Basin currently has 35 active water rights [Permits or Certificates of Adjudications (CA)] with a maximum authorized diversion of 121,118 acre-feet per year (ac-ft/yr), a maximum annual reported use of 62,742 ac-ft/yr and an average use over the last 10 years of 39,368 ac-ft/yr. Water use from Medina Lake accounts for 99% of all water use in the recharge basin. Due to the large amount of historical water use from Medina Lake, the reported water use in the recharge basin was accounted for in the calculation of historical recharge in the recharge model. The reported monthly diversion amounts (obtained from the TCEQ) for the period of record were included at the correct spatial location within the recharge basin.

Area Between Medina Basin and Cibolo-Dry Comal Creek Basins

The area between the Medina Recharge Basin and Cibolo-Dry Comal Creek Basins currently have 3 active water rights [Permits or Certificates of Adjudications (CA)] with a maximum authorized diversion of 54 acre-feet per year (ac-ft/yr), a maximum annual reported use of 0 ac-ft/yr and an average use over the last 15 years of 0 ac-ft/yr. Therefore, there are neither authorized diversions nor reported use for this recharge basin significant enough to be included in the recharge model.

Cibolo Creek and Dry-Comal Creek Basins

The Cibolo Creek and Dry-Comal Creek Recharge Basin currently has 8 active water rights [Permits or Certificates of Adjudications (CA)] with a maximum authorized diversion of 892 acre-feet per year (ac-ft/yr), a maximum annual reported use of 754 ac-ft/yr and an average use over the last 10 years of 585 ac-ft/yr. Water use from the City of Boerne accounts for 99 % of all water use in the recharge basin. Historical reported use for the City of Boerne began in 1991 and there was no additional historical use in the recharge basin prior to 1991. Reported use for this basin was not considered in the Cibolo Creek and Dry-Comal Creek Recharge Basins because there is only 11 years of reported data and the data is not significant when compared to the flow in the last 11 years.

Guadalupe Basin

The Guadalupe Recharge Basin currently has 190 active water rights [Permits or Certificates of Adjudications (CA)] with a maximum authorized diversion of 115,990 acre-feet per year (ac-ft/yr), a maximum annual reported use of 21,621 ac-ft/yr and an average use over the last 10 years of 11,000 ac-ft/yr. Water use from Canyon Lake accounts for approximately 75% of all water use in the recharge basin. Due to the large amount of historical water use from Canyon Lake, the reported water use in the recharge basin was accounted for in the calculation of historical recharge in the recharge model. The reported monthly diversion amounts (obtained from the TCEQ) for the period of record were included at the correct location within the model.

Channel Losses

Channel gain-loss information has been summarized by USGS (2002) for ten different streams in the nine-basin study area. Appendix I contains maps of 112 gain-loss studies completed in the nine basins. This information was used to estimate an apparent loss rate by subtracting the upstream gauge flow from the downstream flow. The loss rates were plotted with the associated upstream USGS flow data to develop a semi-quantitative relationship between loss and flow.

The USGS (2002b) documents streamflow losses at various streamflows in the Salado Creek Basin after the storm during October 17-19, 1998. These data provided a basis for estimating streamflow losses in this basin as well as other nearby basins.

Flood Retardation Structures (FRS)

FRS data have been assimilated from the TCEQ documentation of dam safety inspections and related data as per the National Dam Inventory (NDI) program. These data are no longer available to the public as a result of increased security measures instituted after September 11, 2001. The attached data, circa 1999, includes information for all dams inspected through the end of 1998. Dam information from the National Resource and Conservation Service (NRCS) was also collected. Most of these structures are primarily for flood control, hold minimal amounts of water, and do not stay full between flood events. For some of these structures, drawdown from normal storage pool to near zero can be very rapid. The dams usually contain a principal spillway and therefore do not have gates or associated operations. Neither of the databases reviewed as part of this study include area-capacity curves for the dam facilities.

Selected dam attributes in the database include:

- Normal storage
- Maximum storage
- Height
- Date built
- Surface area
- Drainage area

Most of the flood control structures do not retain water within normal storage between flood events. Most of the SCS dams are made of rolled earth. Rolled earth dams pre-dating 1980 are somewhat susceptible to leakage due to lack of proper compaction at construction combined with the dams' advanced age.

By design, all FRSs serve to dampen the peak flows associated with storm events. FRSs located in the recharge zone and on permeable soil and bedrock may provide a small amount of recharge to the aquifer via vertical infiltration through the bottom of the reservoir or as leakage near the dam, especially in the case of the older dams. FRSs located in the contributing zone and relatively close to the recharge zone may increase the recharge potential by lengthening the recession portion of the hydrograph following storm events and in effect, allowing more time for channel losses to occur in the recharge zone. The locations of these FRSs are shown on the individual basin maps included in Chapter 5.

The San Antonio River Authority (SARA) has provided field data and engineering calculations for several FRSs in the northern Bexar County area. For two structures (SARA Sites 11 and 13A), these data include "recharge rating" curves, which provide an estimate of recharge to the Edwards Aquifer at various stages while the FRS is releasing water. In addition, SARA has provided the HEC-1 model for the northern Bexar County area, which provides the most recent data for FRSs that have been impacted by quarry activities. Based on the information that SARA provided, as well as the stream loss data provided by the USGS (2002b), two components of potential recharge were assessed. First, the recharge rating curves were used to estimate recharge from storm water behind the FRSs. Secondly, stream loss data was used to estimate the recharge in the channels downstream of the FRSs from flow that drains from the FRSs after storm events.

APPENDIX E

Precipitation Data Gaps

Precipitation data from gages in the study area were analyzed to determine where the records were incomplete and where data gaps existed. This Appendix contains the results of the analyses.

The key at the top of the listing explains the meaning of the values in the tables. The results of the analyses were used to gain insight into where sufficient data existed for the model and which gages could be used to help estimate precipitation records for gages that had gaps.

```
Daily Data Gap Analysis Results obtained from NHDS.
                                         INVENTORY OF DAILY OBSERVATION DATA
                                                   KEY TO INVENTORY
                                               - =     100%   MISSING
                                               0 = 00 - 09%   COMPLETE
                                               1 = 10 - 19%   COMPLETE
                                               2 = 20 - 29%   COMPLETE
                                               3 = 30 - 39%   COMPLETE
                                               4 = 40 - 49%   COMPLETE
                                               5 = 50 - 59%   COMPLETE
                                               6 = 60 - 69%   COMPLETE
                                               7 = 70 - 79%   COMPLETE
                                               8 = 80 - 89%   COMPLETE
                                               9 = 90 - 99%   COMPLETE
                                               C =     100%   COMPLETE
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   FEB  ----- -----  ----- -----  ----- ----C  CC--- -----  ----- -----  ----- -----  ----- CCCCC  9CCCC CCCCC  ----- -----  FEB
   MAR  ----- -----  ----- -----  ----- ----C  CC--- -----  ----- -----  ----- -----  ----- CCCCC  9CCCC CCCCC  ----- -----  MAR
   APR  ----- -----  ----- -----  ----- ----C  C9--- -----  ----- -----  ----- -----  ----- CCCCC  CCCC6 CCCCC  ----- -----  APR
   MAY  ----- -----  ----- -----  ----- ----C  CC--- -----  ----- -----  ----- -----  ----- CCCCC  CCCC- CC8CC  ----- -----  MAY
   JUN  ----- -----  ----- -----  ----- ---CC  CC--- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  ----- -----  JUN
   JUL  ----- -----  ----- -----  ----- ---CC  CC--- -----  ----- -----  ----- -----  ----C CCCCC  CCCCC CCCCC  ----- -----  JUL
   AUG  ----- -----  ----- -----  ----- ---CC  CC--- -----  ----- -----  ----- -----  ----C CCCCC  9-CCC CCCCC  ----- -----  AUG
   SEP  ----- -----  ----- -----  ----- ---CC  CC--- -----  ----- -----  ----- -----  ----C CCCCC  CCCCC CCCCC  ----- -----  SEP
   OCT  ----- -----  ----- -----  ----- ---CC  C---- -----  ----- -----  ----- -----  ----C C-CCC  CCCCC CCCCC  ----- -----  OCT
   NOV  ----- -----  ----- -----  ----- ---CC  C---- -----  ----- -----  ----- -----  ----C CCCCC  CCCCC CCCCC  ----- -----  NOV
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   MAR  CCCCC -CCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  MAR
   APR  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  APR
   MAY  CCCCC -CCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  MAY
   JUN  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCC8C  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  JUN
   JUL  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC59C  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  JUL
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   SEP  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC-CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  SEP
```

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    NOV  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC-CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  NOV
    DEC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC-CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  DEC

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    JUN  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  JUN
    JUL  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC5CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  JUL
    AUG  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC-CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  AUG
    SEP  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC-CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  SEP
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    NOV  CCCCC CCCCC  --CCC CCCCC  CCCCC CC-CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  NOV
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    FEB  ----- -----  ----- -----  ----- CCCCC  CC-CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CC-CC CCCCC  ----- -----  FEB
    MAR  ----- -----  ----- -----  ----C CCCCC  CC-CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCC9  CCC-C CCCCC  ----- -----  MAR
    APR  ----- -----  ----- -----  ----C CCCCC  CC-CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CC-CC CCCCC  ----- -----  APR
    MAY  ----- -----  ----- -----  ----C CCCCC  CC-CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCC- CCCCC  ----- -----  MAY
    JUN  ----- -----  ----- -----  ----C CCCCC  CC-CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  -CC-C CCCCC  ----- -----  JUN
    JUL  ----- -----  ----- -----  ----C CC5CC  CC-CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC6CC  CCCCC CCCCC  ----- -----  JUL
    AUG  ----- -----  ----- -----  ----C CC-CC  CC-CC CCCCC  CCCCC CCCCC  CC-CC CCCCC  CCCC- CCCC4  CCCCC CCCCC  ----- -----  AUG
    SEP  ----- -----  ----- -----  ----C CC-CC  C--CC CCCCC  CCCCC CCCCC  CC-CC CCCCC  CCCCC CCCCC  9CC-- CCCCC  ----- -----  SEP
    OCT  ----- -----  ----- -----  ----C CC-CC  C--CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCC-C CCCCC  ----- -----  OCT
    NOV  ----- -----  ----- -----  ----C CC-CC  C--CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCC-C CCCCC  ----- -----  NOV
    DEC  ----- -----  ----- -----  ----C CC-7C  C--CC CCCCC  CCCCC CCCCC  C9CCC CCCCC  CCCCC CCCCC  9CC-C CCCCC  ----- -----  DEC

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```
          <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
          01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

     JAN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC --CCC  CCCCC CC---  ----- -----  JAN
     FEB  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  CCCCC CC---  ----- -----  FEB
     MAR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC -CC-C  CCCCC CC--C  ----- -----  MAR
     APR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC 9C--C  ----- -----  APR
     MAY  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC 9C--C  ----- -----  MAY
     JUN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC 9C---  ----- -----  JUN
     JUL  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC 9----  ----- -----  JUL
     AUG  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCC-- CCCCC  CCCCC 8----  ----- -----  AUG
     SEP  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC -CCCC  CCCCC 9---C  ----- -----  SEP
     OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCC8 9---C  ----- -----  OCT
     NOV  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCC- CCCCC  CCCC- C---C  ----- -----  NOV
     DEC  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCC- C---C  ----- -----  DEC

          PERIOD OF RECORD OF DATA =  3/1975 THRU 12/1999                   OVERALL PERCENTAGE OF NON-MISSING DATA =  84

####################################################################################################################################
0
 NUMBER=41-4780    STATE=TX    NAME=KERRVILLE                   DATA TYPE=PTPX    LAT=  30.05    LON=  99.15    ELEV= 1640
          <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
          01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

     JAN  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCC7C  9CCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  ----- -----  JAN
     FEB  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  ----- -----  FEB
     MAR  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  ----- -----  MAR
     APR  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCC5C  CCCCC -----  ----- -----  ----- -----  ----- -----  APR
     MAY  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCC9C  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  ----- -----  MAY
     JUN  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  ----- -----  JUN
     JUL  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCC- CCCCC  -CCCC -----  ----- -----  ----- -----  ----- -----  JUL
     AUG  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  -CCC- -----  ----- -----  ----- -----  ----- -----  AUG
     SEP  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  C9CCC CCCCC  -CCC- -----  ----- -----  ----- -----  ----- -----  SEP
     OCT  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCC7  7CCC- -----  ----- -----  ----- -----  ----- -----  OCT
     NOV  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCC6  CCCCC CCCCC  CCCCC CCCCC  CCCC- -----  ----- -----  ----- -----  ----- -----  NOV
     DEC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCC0  CCCCC CCCCC  CCCCC CCCCC  CCCC- -----  ----- -----  ----- -----  ----- -----  DEC

          PERIOD OF RECORD OF DATA =  1/1897 THRU  7/1974                   OVERALL PERCENTAGE OF NON-MISSING DATA = 93

####################################################################################################################################
0
 NUMBER=41-4782    STATE=TX    NAME=KERRVILLE 3 NNE             DATA TYPE=PTPX    LAT=  30.07    LON=  99.12    ELEV= 1782
          <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
          01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

     JAN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  JAN
     FEB  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  FEB
     MAR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  MAR
     APR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  APR
     MAY  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  MAY
     JUN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  JUN
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     JUL  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  JUL
     AUG  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CC-CC CCCCC  CCCCC CCCCC  ----- -----  AUG
     SEP  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  SEP
     OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  OCT
     NOV  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  NOV
     DEC  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  DEC

          PERIOD OF RECORD OF DATA = 10/1974 THRU 12/1999                         OVERALL PERCENTAGE OF NON-MISSING DATA = 99

##################################################################################################################################
0
NUMBER=41-5113    STATE=TX    NAME=LEAKEY                         DATA TYPE=PTPX    LAT=  29.73    LON=  99.77    ELEV= 1622
          <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
          01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

     JAN  ----- -----  ----- -----  -CC-4 C--5-  --9CC CCCCC  CCCCC C9CCC  CCCCC CCCCC  CCCC8 C39CC  C7C1C C869C  ----- -----  JAN
     FEB  ----- -----  ----- -----  -CC-C C9-1-  --CCC CCC9C  CCCC9 CCCCC  CCCCC CCCCC  CCCCC C-CCC  C4CCC 09-CC  ----- -----  FEB
     MAR  ----- -----  ----- -----  -CC16 CC---  --CCC CCCCC  CCCCC CCCCC  CCCC9 CCCCC  CCCCC CCCCC  CCCC5 -C-CC  ----- -----  MAR
     APR  ----- -----  ----- -----  CCCC5 C----  --CCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCC8C CCCC-  CCCC- 7C922  ----- -----  APR
     MAY  ----- -----  ----- -----  C7C8C C----  --CCC CCCCC  CCCCC CCCCC  9CCCC CCCCC  CCCCC C98C8  CCCC9 996-4  ----- -----  MAY
     JUN  ----- -----  ----- -----  C631C C3---  --CCC 9CCCC  CCCCC CCCCC  CCCCC CCCCC  C8CCC CCCCC  CCCC4 CCC-2  ----- -----  JUN
     JUL  ----- -----  ----- -----  CCC0C 4C---  --CCC 9CCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCC- CCC7C  ----- -----  JUL
     AUG  ----- -----  ----- -----  C7C-C 3C---  --CCC CCCCC  CCCCC CCCCC  CCCCC CCC4C  CCCCC -8CCC  CCCC7 2CC99  ----- -----  AUG
     SEP  ----- -----  ----- -----  CCC3C CC---  --CCC CCCCC  CCCCC CC9CC  CCCCC CCC-C  CCCCC CCCCC  CCCCC 69C7C  ----- -----  SEP
     OCT  ----- -----  ----- -----  CC4-C 2C---  --CCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  C4CCC 9CCCC  CCCC2 C89CC  ----- -----  OCT
     NOV  ----- -----  ----- -----  CC--C -1---  --CCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  C-CCC CCCC1  CCCCC 05CCC  ----- -----  NOV
     DEC  ----- -----  ----- -----  CC--C --0--  --CCC CCCCC  C9CCC CCCCC  CCCCC CCCCC  CCC1C CCCC8  CCCCC -919C  ----- -----  DEC

          PERIOD OF RECORD OF DATA =  4/1940 THRU 12/1999                         OVERALL PERCENTAGE OF NON-MISSING DATA =  81

##################################################################################################################################
0
NUMBER=41-5114    STATE=TX    NAME=LEAKEY 2                       DATA TYPE=PTPX    LAT=  29.70    LON=  99.83    ELEV= 1601
          <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
          01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

     JAN  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  CC--- -----  ----- -----  ----- -----  ----- -----  JAN
     FEB  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  FEB
     MAR  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  MAR
     APR  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  APR
     MAY  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  MAY
     JUN  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  JUN
     JUL  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  JUL
     AUG  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  AUG
     SEP  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  SEP
     OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----C CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  OCT
     NOV  ----- -----  ----- -----  ----- -----  ----- -----  ---CC CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  NOV
     DEC  ----- -----  ----- -----  ----- -----  ----- -----  ---CC CCCCC  C---- -----  ----- -----  ----- -----  ----- -----  DEC

          PERIOD OF RECORD OF DATA = 11/1963 THRU  1/1971                         OVERALL PERCENTAGE OF NON-MISSING DATA = 100
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####################################################################################################################################
0
 NUMBER=41-5742    STATE=TX    NAME=MEDINA 2 W                 DATA TYPE=PTPX    LAT=  29.78    LON=  99.28    ELEV= 1705
         <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
         01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

    JAN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC C9CCC  CCCCC 9C9CC  CCC9C 9CCCC  ----- -----  JAN
    FEB  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  CCCCC 9-CCC  CCC9C CCCCC  ----- -----  FEB
    MAR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  CC9CC CCCCC  8CCCC CCCCC  ----- -----  MAR
    APR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  CC9CC CCCCC  CCC99 CCCCC  ----- -----  APR
    MAY  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCC9 CCCCC  CCCCC CCCCC  CC9CC CCCCC  ----- -----  MAY
    JUN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCC89 CCCCC  CCCCC CC9CC  C9CCC CCCCC  ----- -----  JUN
    JUL  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCCC CCCCC  CCCCC 9CCCC  CCCCC CCCCC  ----- -----  JUL
    AUG  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CC59C  CCCCC CCC6C  CCCC7 CCCCC  ----- -----  AUG
    SEP  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  SEP
    OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  CCCCC CCCCC  CC1CC CCCCC  ----- -----  OCT
    NOV  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  NOV
    DEC  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCC9C  CCCCC CCCCC  C95CC CCCCC  ----- -----  DEC

         PERIOD OF RECORD OF DATA =  1/1966 THRU 12/1999                    OVERALL PERCENTAGE OF NON-MISSING DATA =  98

####################################################################################################################################
0
 NUMBER=41-5746    STATE=TX    NAME=MEDINA LAKE                DATA TYPE=PTPX    LAT=  29.52    LON=  98.92    ELEV= 1169
         <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
         01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

    JAN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  --CC- C-CCC  ----- -----  JAN
    FEB  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  --CC- C-CCC  ----- -----  FEB
    MAR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  --CC- --CCC  ----- -----  MAR
    APR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  --CC- C-CCC  ----- -----  APR
    MAY  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CCC- C-CCC  ----- -----  MAY
    JUN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -C-C- C-CCC  ----- -----  JUN
    JUL  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CC-- --CCC  ----- -----  JUL
    AUG  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  --CC- -CCCC  ----- -----  AUG
    SEP  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CCC- -CCCC  ----- -----  SEP
    OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CC-- -CCCC  ----- -----  OCT
    NOV  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CC-- -CCCC  ----- -----  NOV
    DEC  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CC-C -CCCC  ----- -----  DEC

         PERIOD OF RECORD OF DATA =  5/1991 THRU 12/1999                    OVERALL PERCENTAGE OF NON-MISSING DATA =  70

####################################################################################################################################
0
 NUMBER=41-6257    STATE=TX    NAME=NELSON RANCH               DATA TYPE=PTPX    LAT=  29.95    LON=  99.52    ELEV= 2125
         <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
         01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

    JAN  ----- -----  ----- -----  ----- -----  ----- -----  ---CC CCCCC  CCCCC CCCCC  CCCC- -----  ----- -----  ----- -----  JAN
    FEB  ----- -----  ----- -----  ----- -----  ----- -----  ---CC CCCCC  CCCCC CCCCC  CCCC- -----  ----- -----  ----- -----  FEB
    MAR  ----- -----  ----- -----  ----- -----  ----- -----  ---CC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  MAR
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   APR  ----- -----  ----- -----  ----- -----  ----- -----  ---CC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  APR
   MAY  ----- -----  ----- -----  ----- -----  ----- -----  ---CC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  MAY
   JUN  ----- -----  ----- -----  ----- -----  ----- -----  ---CC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  JUN
   JUL  ----- -----  ----- -----  ----- -----  ----- -----  --CCC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  JUL
   AUG  ----- -----  ----- -----  ----- -----  ----- -----  --CCC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  AUG
   SEP  ----- -----  ----- -----  ----- -----  ----- -----  --CCC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  SEP
   OCT  ----- -----  ----- -----  ----- -----  ----- -----  --CCC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  OCT
   NOV  ----- -----  ----- -----  ----- -----  ----- -----  --CCC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  NOV
   DEC  ----- -----  ----- -----  ----- -----  ----- -----  --CCC CCCCC  CCCCC CCCCC  CCC-- -----  ----- -----  ----- -----  DEC

        PERIOD OF RECORD OF DATA =  7/1962 THRU  2/1983                         OVERALL PERCENTAGE OF NON-MISSING DATA = 100

##################################################################################################################################
0
 NUMBER=41-6276    STATE=TX    NAME=NEW BRAUNFELS              DATA TYPE=PTPX    LAT=  29.73    LON=  98.12    ELEV=  710
        <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
        01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

   JAN  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC 9CC-C  CCCC- CCCCC  ----- -----  JAN
   FEB  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  C8CCC CCCCC  CCCCC CCCCC  CCCCC CCC-C  -CCCC CCCCC  ----- -----  FEB
   MAR  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  --CCC CCCCC  CCCCC CCC9C  CCCCC CCC-C  -CC9C CCCC9  ----- -----  MAR
   APR  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCC-C CCCCC  C-CCC C9CCC  CCCCC CCCCC  CCCCC CCC-C  CCC-C CCCC8  ----- -----  APR
   MAY  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  C-CCC CCCCC  CCCCC CCCCC  CCCCC CCC-C  CCCCC CCCCC  ----- -----  MAY
   JUN  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  C-CCC CCCCC  CCCCC CCCCC  CCCCC 9CCC1  -CC-C CC999  ----- -----  JUN
   JUL  CCCCC CC6CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  --CCC CCCCC  CCCCC CCCCC  CCCCC CC-CC  CCCCC CC9CC  ----- -----  JUL
   AUG  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CC--C CCCCC  ----- -----  AUG
   SEP  CCCCC CCC8C  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC C8CCC  ----- -----  SEP
   OCT  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC-CC  CCCCC CCC99  ----- -----  OCT
   NOV  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  -CCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CC--C CC99C  ----- -----  NOV
   DEC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCC7C  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC C9-CC  CCC-C C99CC  ----- -----  DEC

        PERIOD OF RECORD OF DATA =  1/1897 THRU 12/1999                         OVERALL PERCENTAGE OF NON-MISSING DATA =  95

 #################################################################################################################################
0
 NUMBER=41-6448    STATE=TX    NAME=NORTHINGTON RANCH          DATA TYPE=PTPX    LAT=  29.87    LON=  98.65    ELEV= 1524
        <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
        01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

   JAN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCCC CCCCC  ----- -----  JAN
   FEB  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCCC CCCCC  ----- -----  FEB
   MAR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCC- CCCCC  ----- -----  MAR
   APR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCCC CCCCC  ----- -----  APR
   MAY  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCCC CCCCC  ----- -----  MAY
   JUN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCCC CCC-C  ----- -----  JUN
   JUL  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCCC CCCCC  ----- -----  JUL
   AUG  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  ----- -----  AUG
   SEP  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  ----- -----  SEP
   OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  ----- -----  OCT
   NOV  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  ----- -----  NOV
   DEC  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  ----- -----  DEC
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       PERIOD OF RECORD OF DATA =  8/1986 THRU 12/1999                        OVERALL PERCENTAGE OF NON-MISSING DATA =  98

####################################################################################################################################
0
 NUMBER=41-7232    STATE=TX    NAME=PRADE RANCH                 DATA TYPE=PTPX    LAT=  29.92    LON=  99.77    ELEV= 2052
        <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
        01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

   JAN  ----- -----  ----- -----  ----- -----  ----- -9CCC  CCCCC CCCCC  C-CCC CCCCC  CCC-- ----C  CCCCC CCCCC  ----- -----  JAN
   FEB  ----- -----  ----- -----  ----- -----  ----- -9CCC  CCCCC CCCCC  C-CCC CCCCC  CC--- ----C  CCCCC CCCCC  ----- -----  FEB
   MAR  ----- -----  ----- -----  ----- -----  ----- -9CCC  CCCCC CC-CC  --CCC CCCCC  CC--- ----C  9CCCC CCCCC  ----- -----  MAR
   APR  ----- -----  ----- -----  ----- -----  ----- -CCCC  CC9CC CCCCC  C-CCC CCCCC  CC--- ----C  CCCCC CCCCC  ----- -----  APR
   MAY  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  C-C-C CCCCC  CC--- ---CC  CCCCC 8CCCC  ----- -----  MAY
   JUN  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  --9CC CCCCC  CC--- ---CC  CCCCC CCCCC  ----- -----  JUN
   JUL  ----- -----  ----- -----  ----- -----  ----- -C9CC  CCCCC CCCCC  --CCC CCCCC  C---- ---CC  CCCCC CCCCC  ----- -----  JUL
   AUG  ----- -----  ----- -----  ----- -----  ----- -9CCC  CCCCC CCCCC  --CCC CCCCC  CC--- ---CC  CCCCC CCCC-  ----- -----  AUG
   SEP  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCCC  --CCC CCCCC  CC--- ---CC  CCCCC CCCCC  ----- -----  SEP
   OCT  ----- -----  ----- -----  ----- -----  ----- 8CCCC  CCCCC CCCCC  --CCC CCCCC  C9--- ---C9  CCCC9 CCCCC  ----- -----  OCT
   NOV  ----- -----  ----- -----  ----- -----  ----- 8C9CC  CCCCC CCCCC  -CCCC CCCCC  C---- ---CC  CCCCC CCCCC  ----- -----  NOV
   DEC  ----- -----  ----- -----  ----- -----  ----- 7CCC9  CCCCC CCCC-  -CCCC CCCCC  C---- ---CC  CCCC9 CCCCC  ----- -----  DEC

        PERIOD OF RECORD OF DATA = 10/1955 THRU 12/1999                        OVERALL PERCENTAGE OF NON-MISSING DATA =  80

####################################################################################################################################
0
 NUMBER=41-7628    STATE=TX    NAME=RIO MEDINA                  DATA TYPE=PTPX    LAT=  29.43    LON=  98.88    ELEV=  850
        <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
        01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

   JAN  ---CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  8-CCC CCCCC  CCC-- 3CCCC  CCCCC --CCC  ----- -----  JAN
   FEB  ---CC CCCCC  CCCCC CCCCC  CCCCC CCC67  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC --CCC  ----- -----  FEB
   MAR  ---CC CCCCC  CCCCC CCCCC  CCCCC CCC7C  CCCCC CCCCC  CCCCC CCCC-  CCCCC CCCCC  CCCCC CCCCC  CCCCC C-CCC  ----- -----  MAR
   APR  ---CC CCCCC  CCCCC CCCCC  CC9CC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CC7CC  CCCCC CCCCC  ----- -----  APR
   MAY  ---C- C-CCC  CCCCC CCCCC  9CCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  ----- -----  MAY
   JUN  ---CC C-CCC  CCCCC CCCCC  CCCCC CCCCC  7CCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -CCCC  ----- -----  JUN
   JUL  ---C- C-CCC  CCCC- CCCCC  CCCCC CCCCC  3CCCC CCCCC  CCCCC CCCCC  CCCCC C6CCC  CCCCC CCCCC  CCCCC -CCCC  ----- -----  JUL
   AUG  --6CC CCCCC  CCCCC CCCCC  CCCCC CCC7C  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -CCCC  ----- -----  AUG
   SEP  --CC- CCCCC  CCCCC CCCCC  CCCCC CC-CC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC C-CCC  CCCCC -CCCC  ----- -----  SEP
   OCT  --C-C C-CCC  CCCCC CCCCC  CCCCC CCCC9  7CCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  9C--- -CCCC  ----- -----  OCT
   NOV  --CCC C-CCC  CCCCC CCCCC  CCCCC CCCC8  CCCCC CCCCC  CCCCC CCCC5  CCCC9 CCCCC  CCCCC -CCCC  CCC-- -CCCC  ----- -----  NOV
   DEC  --CCC C-CCC  CCCCC CCCCC  CCCCC CC757  CCCCC CCCCC  CCCCC CCCC9  CCCCC CCCCC  CC-CC 6CCCC  CC--- -CCCC  ----- -----  DEC

        PERIOD OF RECORD OF DATA =  8/1922 THRU 12/1999                        OVERALL PERCENTAGE OF NON-MISSING DATA =  95

####################################################################################################################################
0
 NUMBER=41-7873    STATE=TX    NAME=SABINAL                     DATA TYPE=PTPX    LAT=  29.37    LON=  99.48    ELEV=  953
        <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
        01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789
```

JAN	CCCCC CCCCC	CCCCC CCCCC	CC-CC CC---	-CCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCC-	----- -----	JAN
FEB	CCCCC CCCCC	CCCCC CCCCC	CC-CC CC-92	-CCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCC-	----- -----	FEB
MAR	CCCCC CCCCC	CCCCC CCCCC	CC-CC CC-4-	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCC-	----- -----	MAR
APR	CCCCC CCCCC	CCCCC CCCCC	CC-CC CC-4-	CCCCC CCCCC	CCCCC CCCCC	CCC-C CCCCC	CCCCC CCCCC	CCCCC CCCC-	----- -----	APR
MAY	CCCCC CCCCC	CCCCC CCCCC	CCCCC CC-2-	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC C-CCC	CCCCC CCCC-	----- -----	MAY
JUN	CCCCC CCCCC	CCCCC CCCCC	CCCC- CC-4-	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCC-	----- -----	JUN
JUL	CCCCC CCCCC	CCCCC CCCCC	CCCC- C--24	CCCCC CCCCC	CCCCC CCC-C	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCC-	----- -----	JUL
AUG	CCCCC CCCCC	CCCCC CC-C-	CCCCC C----	CCCCC CCCCC	CCCCC CCCCC	CCCC- CCCCC	CCCCC CCCCC	CCCCC CCCC-	----- -----	AUG
SEP	CCCCC CCCCC	CCCCC CC-CC	CCCCC CC-7-	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCC-C	----- -----	SEP
OCT	CCCCC CCCCC	CCCCC CC-CC	C-CCC C--2-	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCC-C	----- -----	OCT
NOV	CCCCC CCCCC	CCCCC CC-CC	C-CCC C--2-	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCC-C	----- -----	NOV
DEC	CCCCC CCCCC	CCCCC CC-CC	C-CCC C--2-	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCC-C	----- -----	DEC

PERIOD OF RECORD OF DATA = 9/1903 THRU 12/1999 **OVERALL PERCENTAGE OF NON-MISSING DATA = 94**

##
0
NUMBER=41-7945 STATE=TX NAME=SAN ANTONIO INTL AP DATA TYPE=PTPX LAT= 29.53 LON= 98.47 ELEV= 809

	<- 1920 ->	<- 1930 ->	<- 1940 ->	<- 1950 ->	<- 1960 ->	<- 1970 ->	<- 1980 ->	<- 1990 ->	<- 2000 ->	
	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	
JAN	----- -----	----- -----	----- --CCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	JAN
FEB	----- -----	----- -----	----- --CCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	FEB
MAR	----- -----	----- -----	----- --CCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	MAR
APR	----- -----	----- -----	----- --CCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CC-CC	CCCCC CCCCC	----- -----	APR
MAY	----- -----	----- -----	----- --C9C	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	MAY
JUN	----- -----	----- -----	----- --CCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	JUN
JUL	----- -----	----- -----	----- --CCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	JUL
AUG	----- -----	----- -----	----- --CCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	AUG
SEP	----- -----	----- -----	----- -CCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	SEP
OCT	----- -----	----- -----	----- -CCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	OCT
NOV	----- -----	----- -----	----- -CCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	NOV
DEC	----- -----	----- -----	----- -CCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	CCCCC CCCCC	----- -----	DEC

PERIOD OF RECORD OF DATA = 9/1946 THRU 12/1999 **OVERALL PERCENTAGE OF NON-MISSING DATA = 99**

##
0
NUMBER=41-8169 STATE=TX NAME=SAN ANTONIO SEAWORLD DATA TYPE=PTPX LAT= 29.45 LON= 98.70 ELEV= 940

	<- 1920 ->	<- 1930 ->	<- 1940 ->	<- 1950 ->	<- 1960 ->	<- 1970 ->	<- 1980 ->	<- 1990 ->	<- 2000 ->	
	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	01234 56789	
JAN	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ----C	CCCCC CCCCC	----- -----	JAN
FEB	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ----C	CCCCC CCCCC	----- -----	FEB
MAR	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ----C	CCCCC CCCCC	----- -----	MAR
APR	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ----C	CCCCC CCCCC	----- -----	APR
MAY	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ----C	CCCCC CCCCC	----- -----	MAY
JUN	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ---CC	CCCCC CCCCC	----- -----	JUN
JUL	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ---CC	CCCCC CCCCC	----- -----	JUL
AUG	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ---CC	CCCCC CCCCC	----- -----	AUG
SEP	----- -----	----- -----	----- -----	----- -----	----- -----	----- -----	----- ---CC	CCCCC CCCCC	----- -----	SEP

```
   OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- ---C9  CCCC9 CCCCC  ----- -----  OCT
   NOV  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- ---CC  CCCCC CCCCC  ----- -----  NOV
   DEC  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- ---C9  CCCC- CCCCC  ----- -----  DEC

        PERIOD OF RECORD OF DATA =  6/1988 THRU 12/1999                        OVERALL PERCENTAGE OF NON-MISSING DATA =  99

####################################################################################################################################
0
 NUMBER=41-9260    STATE=TX    NAME=UTOPIA                      DATA TYPE=PTPX    LAT=  29.58    LON=  99.52    ELEV= 1338
        <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
        01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

   JAN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  --C-C CCCCC  ----- -----  JAN
   FEB  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CC-C CCCCC  ----- -----  FEB
   MAR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CCCC CCCCC  ----- -----  MAR
   APR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CCCC CCCCC  ----- -----  APR
   MAY  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -CCCC CCCCC  ----- -----  MAY
   JUN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -C-CC CCCCC  ----- -----  JUN
   JUL  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -C-CC CCCCC  ----- -----  JUL
   AUG  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -C-CC CCCCC  ----- -----  AUG
   SEP  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -C-CC CCCCC  ----- -----  SEP
   OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -C-CC CCCCC  ----- -----  OCT
   NOV  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -C-CC CCCCC  ----- -----  NOV
   DEC  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  -C-CC CCCCC  ----- -----  DEC

        PERIOD OF RECORD OF DATA =  2/1991 THRU 12/1999                        OVERALL PERCENTAGE OF NON-MISSING DATA =  91

####################################################################################################################################
0
 NUMBER=41-9265    STATE=TX    NAME=UVALDE                      DATA TYPE=PTPX    LAT=  29.22    LON=  99.77    ELEV=  912
        <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
        01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

   JAN  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCC- C----  ----- -----  ----- -----  JAN
   FEB  CCCCC CCCCC  CCCC9 CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  FEB
   MAR  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  MAR
   APR  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC C----  ----- -----  ----- -----  APR
   MAY  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  C9CCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCC-C C----  ----- -----  ----- -----  MAY
   JUN  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  JUN
   JUL  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  JUL
   AUG  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  AUG
   SEP  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  SEP
   OCT  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  OCT
   NOV  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  NOV
   DEC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC CCCCC  CCCCC -----  ----- -----  ----- -----  DEC

        PERIOD OF RECORD OF DATA =  3/1905 THRU  5/1985                        OVERALL PERCENTAGE OF NON-MISSING DATA =  95

####################################################################################################################################
0
 NUMBER=41-9268    STATE=TX    NAME=UVALDE 3 SW                 DATA TYPE=PTPX    LAT=  29.18    LON=  99.83    ELEV=  920
```

```
     <-  1920 ->  <-  1930 ->  <-  1940 ->  <-  1950 ->  <-  1960 ->  <-  1970 ->  <-  1980 ->  <-  1990 ->  <-  2000 ->
     01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789  01234 56789

JAN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCC-  ----- -----  JAN
FEB  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- --CCC  CCCCC CCCC-  ----- -----  FEB
MAR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC CCCC-  ----- -----  MAR
APR  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCCCC 9CCC-  ----- -----  APR
MAY  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CC--C CCCC-  ----- -----  MAY
JUN  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCC-C CCCC-  ----- -----  JUN
JUL  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCC-C CCCCC  ----- -----  JUL
AUG  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCCCC  ----- -----  AUG
SEP  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCCCC CCC-C  ----- -----  SEP
OCT  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCC-C CCCCC  ----- -----  OCT
NOV  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- CCCCC  CCC-C CCCCC  ----- -----  NOV
DEC  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -----  ----- -CCCC  CCC-C CCC-C  ----- -----  DEC

     PERIOD OF RECORD OF DATA =  8/1985 THRU 12/1999                     OVERALL PERCENTAGE OF NON-MISSING DATA =  90

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APPENDIX F
Sensitivity Study of Temporal Resolution of Precipitation Data

INTRODUCTION

Prior to developing the HSPF models for the nine basins, it was necessary to determine an appropriate timestep for the models. The pilot models were used to perform an analysis to assess the impacts of choosing different timesteps for the models. To the degree possible, all HSPF hydrologic parameters in the pilot models remained unchanged.

OBJECTIVE OF SENSITIVITY ANALYSIS

To investigate the sensitivity of simulated recharge volume using an hourly precipitation time series as compared to a daily time series.

Model Used

Pilot Recharge Model for the Blanco Recharge Basin developed by HDR (2002) was adapted for this exercise. Three modeling schemes were used in the sensitivity analysis: a) Daily Model – daily precipitation and daily time step, b) Hourly Model – hourly precipitation and hourly time step, and c) Average Model – daily precipitation and hourly time step.

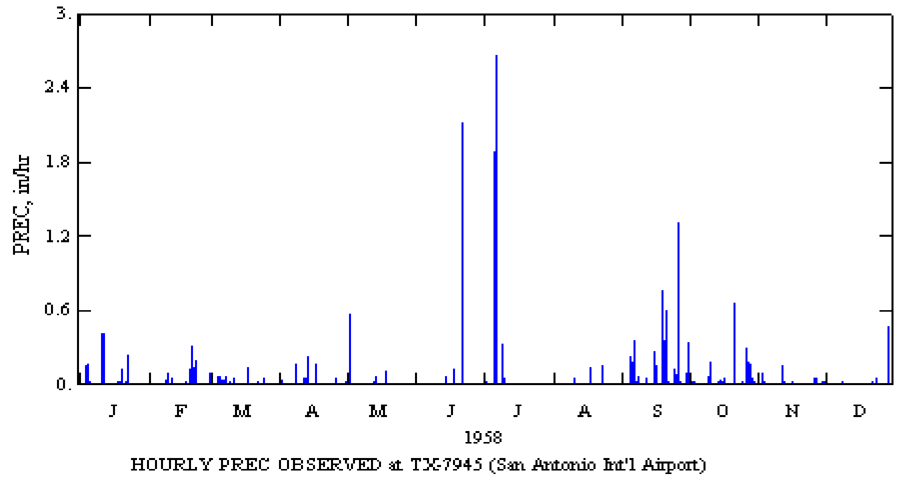
Precipitation Data

Hourly and daily time series at NWS San Antonio Int'l Airport Station was used.

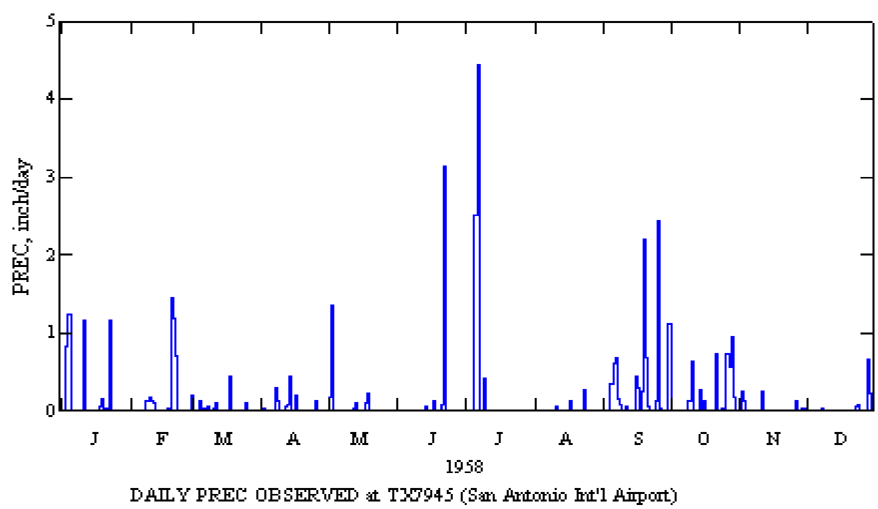
Period of the Study

1. Year 1958 - Several storm events occurred in this year. The storms exhibited high rainfall intensities, ranging from 0.3 to 2.67 inches per hour. Plotted below are the respective hourly and daily precipitation time series at the San Antonio International Airport.

   i. Hourly Time Series (rainfall data are in inches/hr)



ii. Daily Time Series (input rainfall data are in inches/day)



2. Extended Period - Years 1958 to 1998, (continuous hourly rainfall records are available).

Model Outputs Used for the Sensitivity Analysis

1. Stream Recharge - Total direct recharge volume from the stream segments, RCHRES, that is also been referred to as 'channel loss', and

2. Land Recharge - Total direct recharge volume from the land segments, PERLND.

Summary and Recommendation

1. Weighting Factor, KS, needs to be set to less than or equal to 0.2 in the Daily Model otherwise the simulated “channel loss” values will be affected by routing instability.

2. Comparing the three modeling schemes, the Hourly Model produces the highest stream recharge, the Average Model is the next, and the Daily Model the lowest.

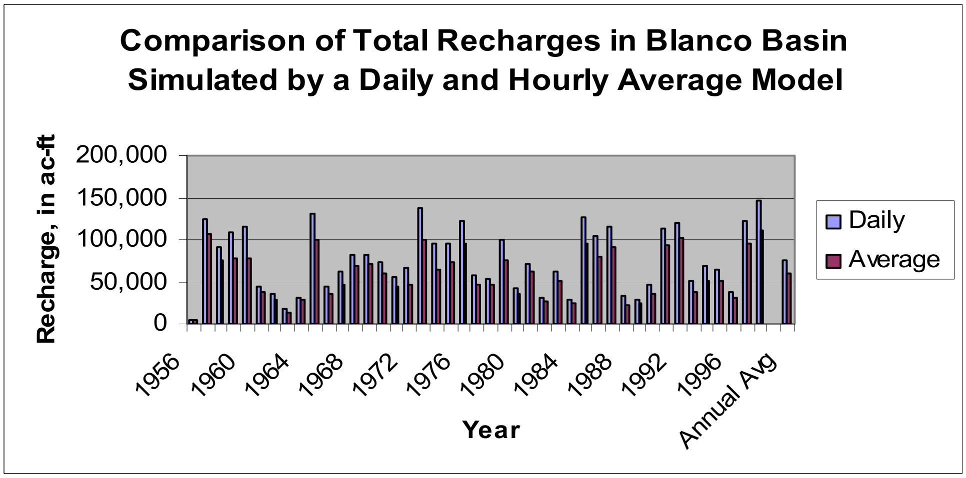
3. The results on the land recharge are opposite, the Hourly Model produces the lowest recharge, the Average Model is the next, and the Daily Model the highest.

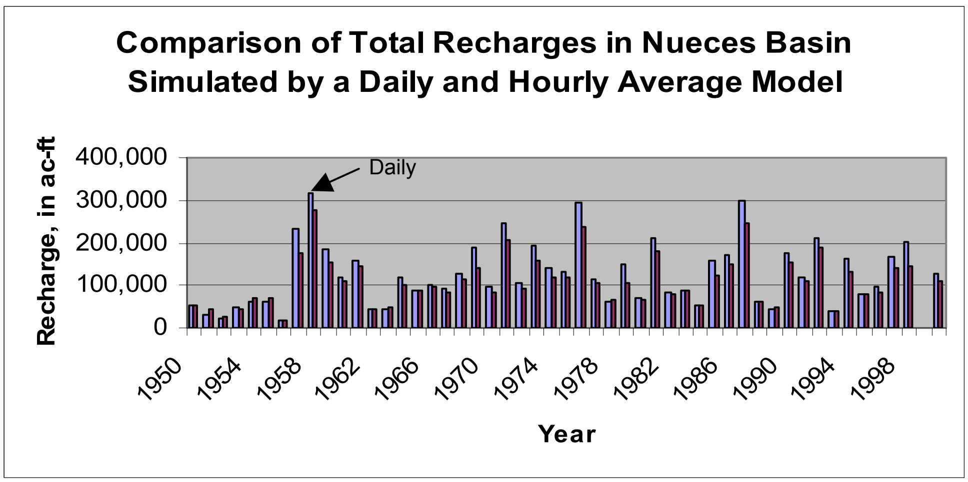
4. Combining recharge from both stream and land segments, the Hourly Model produces the lowest total recharge, the Average Model is the next, and the Daily Model the highest.

5. The above results can be explained from the perspective of the modeled system and the model itself. First, the study area is frequented with thunderstorms. These storms have high rainfall intensities (in./hr). In the HSPF model, the infiltration and the stream runoff are based on the *difference* between the rainfall intensity and the mean infiltration capacity over the land segment in a given time interval. During any time interval the greater the rainfall intensity compared to the infiltration capacity, the greater the runoff and the smaller infiltrated water. Rainfall in a storm event is typically distributed over a few hours in the Hourly Model compared to the aggregated 24-hour time span in the Daily Model. Thus for the same event, the Hourly Model produces higher rainfall intensities than the Daily Model. In addition, the soil moisture storage is more liable to be filled more quickly by the intensive rainfall making the *difference* even more pronounced. The simulation results from the sensitivity study reflect this effect. The Hourly Model produces more runoff and stream recharge. The Daily Model simulates more infiltration. This results in more land recharge and less runoff, thus less stream recharge. The Average Model produces results (47,779 ac-ft of annual average of total recharge over 1958-1998 period) that are in between of these two models (39,841 ac-ft for the Hourly Model and 62,100 ac-ft for the Daily Model).

6. In a less intensive storm event, for example the events that occurred in February 1958, the difference in total recharge between the Hourly and Daily Models is negligible, 2209 to 2159 ac-ft, respectively.

7. The HDR Pilot Recharge Models for Blanco and Nueces Basins were re-run with the same daily rainfall data previously used but using an hourly time step (referred to here as the Average Model). The graphs below show a comparison of total annual recharges simulated by the Daily and Average Models for the respective Basins. The Daily Model gives a much higher total recharge than that of the Average Model.





8. We recommend to use hourly simulation time interval and KS=0.5.

9. We recommend that the Seven Basins Models should be run in hourly time step in the absence of hourly precipitation data.

Results

Notes:

a) To prevent routing stabilities to occur in a daily simulation, a KS value of 0.2 (the weighting factor in the HSPF model) was used,
b) DSNs 75 to 85 correspond to the RCHRES where channel losses are occurring and the DSN increases in the upstream to downstream order, and
c) The steady recharge amount shown in the upstream reaches (DSNs 75 to 78) is due to the effect of a steady streamflow provided from the upstream contributing zone.

A) Recharges from Flooding Retardation Structures and River Channel (RCHRES)

Monthly Recharge (ac-ft) using hourly precipitation data (KS=0.2)

Location	75	76	77	78	79	80	81	82	83	84	85	Sum
Constituent	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg
1958/01	172	350	435	31	551	65	71	246	239	199	46	2,404
1958/02	156	317	394	28	1,160	71	81	213	1,050	231	85	3,785
1958/03	172	351	437	31	2	65	90	136	1	66	15	1,365
1958/04	167	339	423	30	1	1	1	1	0	0	0	962
1958/05	172	351	437	31	104	15	16	61	44	41	9	1,282
1958/06	167	339	423	30	34	5	5	16	15	11	3	1,047
1958/07	172	351	437	31	3,360	162	192	490	3,380	1,230	191	9,996
1958/08	172	351	437	31	0	10	24	14	0	11	0	1,050
1958/09	167	339	423	30	2,290	75	92	213	2,090	380	129	6,227
1958/10	172	351	437	31	1,090	122	158	313	832	298	111	3,915
1958/11	167	339	423	30	11	87	111	194	4	107	24	1,498
1958/12	172	351	437	31	1	2	2	2	0	0	0	999
Annual Total	2,028	4,129	5,143	362	8,604	680	843	1,899	7,656	2,575	612	34,529

Monthly Recharge (ac-ft) using daily precipitation data (KS=0.2)

Location	75	76	77	78	79	80	81	82	83	84	85	Sum
Constituent	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg
1958/01	171	348	434	31	32	11	11	14	12	10	2	1,075
1958/02	156	317	394	28	318	37	40	95	130	90	23	1,628
1958/03	172	351	437	31	12	51	51	95	5	34	4	1,244
1958/04	167	339	423	30	0	1	0	1	0	0	0	961
1958/05	172	351	437	31	0	0	0	0	0	0	0	991
1958/06	167	339	423	30	0	0	0	0	0	0	0	959
1958/07	166	338	422	30	1,440	108	143	283	1,210	407	96	4,643
1958/08	172	351	437	31	1	8	15	10	0	3	0	1,027
1958/09	167	339	423	30	153	19	21	48	58	35	9	1,302
1958/10	172	351	437	31	95	72	72	59	32	36	7	1,363
1958/11	167	339	423	30	13	42	40	25	4	16	3	1,101
1958/12	172	351	437	31	1	1	1	1	0	0	0	995
Annual Total	2,021	4,114	5,127	361	2,066	349	394	631	1,452	631	144	17,288

B) Recharges from Land Segment (PERLND)

Monthly Recharge (ac-ft) using hourly precipitation data (KS=0.2)

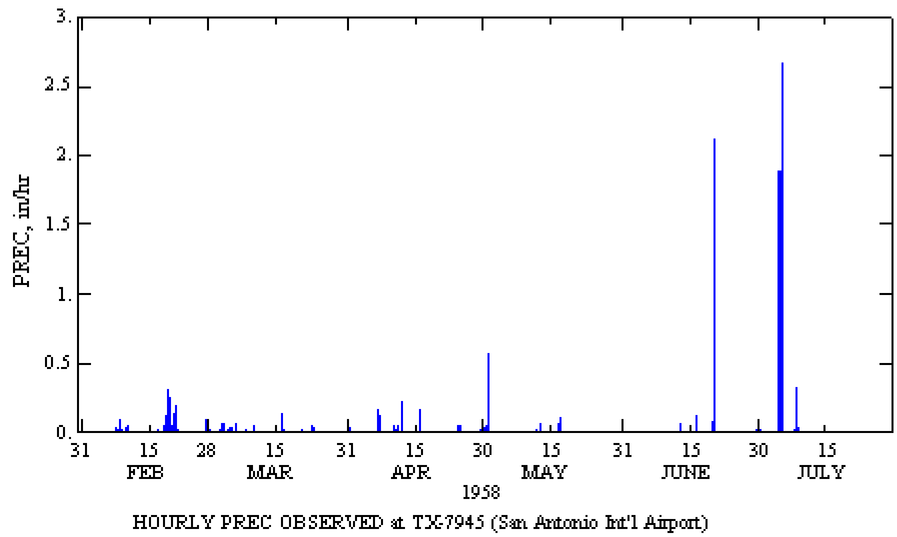
Location	1171	1271	1272	1273	1274	Sum
Constituent	igwi	igwi	igwi	igwi	igwi	igwi
1958/01	290	977	1,530	1,170	714	4,681
1958/02	296	1,050	1,610	1,220	743	4,919
1958/03	36	118	168	128	82	532
1958/04	34	123	178	135	86	556
1958/05	42	156	234	178	109	719
1958/06	79	262	414	315	192	1,262
1958/07	131	499	756	574	350	2,310
1958/08	2	5	7	6	4	24
1958/09	170	651	982	746	457	3,006
1958/10	415	1,500	2,280	1,740	1,060	6,995
1958/11	83	193	306	233	145	960
1958/12	34	122	187	142	87	571
Annual Total	1,611	5,656	8,652	6,587	4,029	26,535

Monthly Recharge (ac-ft) using daily precipitation data (KS=0.2)

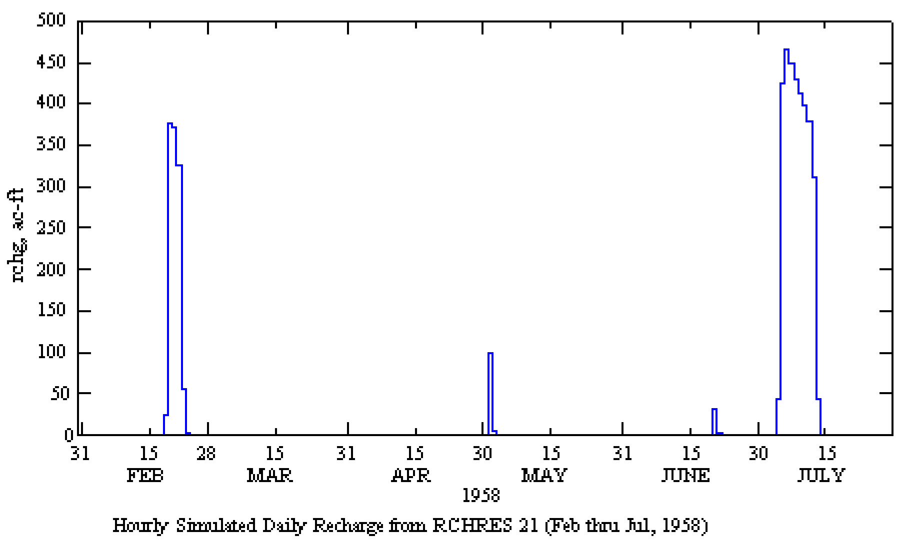
Location	171	271	272	273	274	Total
Constituent	igwi	igwi	igwi	igwi	igwi	igwi
1958/01	405	1,270	2,010	1,530	941	6,156
1958/02	572	1,840	2,960	2,250	1,370	8,992
1958/03	109	310	483	367	235	1,504
1958/04	119	303	475	362	230	1,489
1958/05	131	364	576	438	272	1,781
1958/06	52	141	230	175	107	705
1958/07	406	4,270	6,160	4,670	2,830	18,336
1958/08	4	17	21	16	11	68
1958/09	879	2,730	4,450	3,380	2,080	13,519
1958/10	955	3,150	4,950	3,760	2,310	15,125
1958/11	149	288	450	343	223	1,453
1958/12	161	410	672	514	316	2,073
Annual Total	3,942	15,093	23,437	17,805	10,925	71,202

Plots - a) hourly rainfall time series, b) hourly stream recharge volume (ac-ft) at RCHRES 21 (DSN 79), and c) hourly land recharge volume (ac-ft) at PERLND 201 (DSN 1271). RCHRES 21 is in the recharge zone; it is only minimally affected by the inflow of the contributing zone.

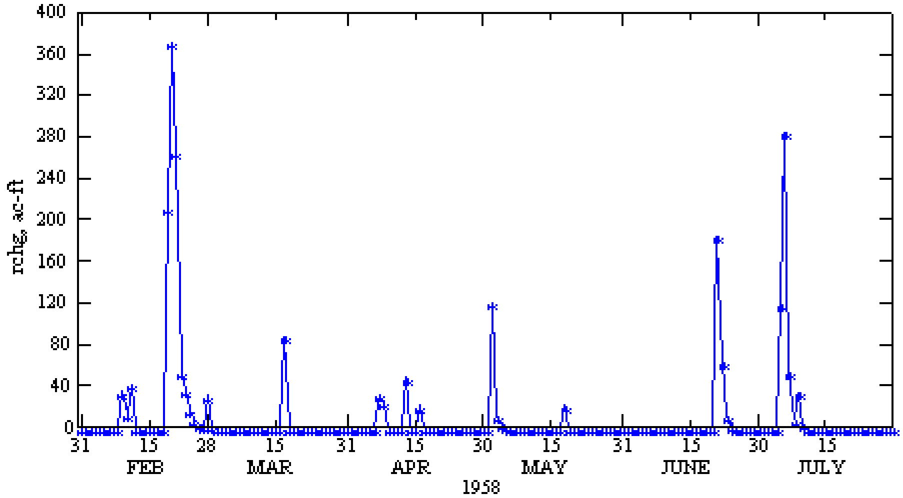
a) Hourly Rainfall Time Series, February 1 through July 31, 1958.



b) Hourly Model Results - Daily Recharge Volume from RCHRES 21, February 1 through July 31, 1958.



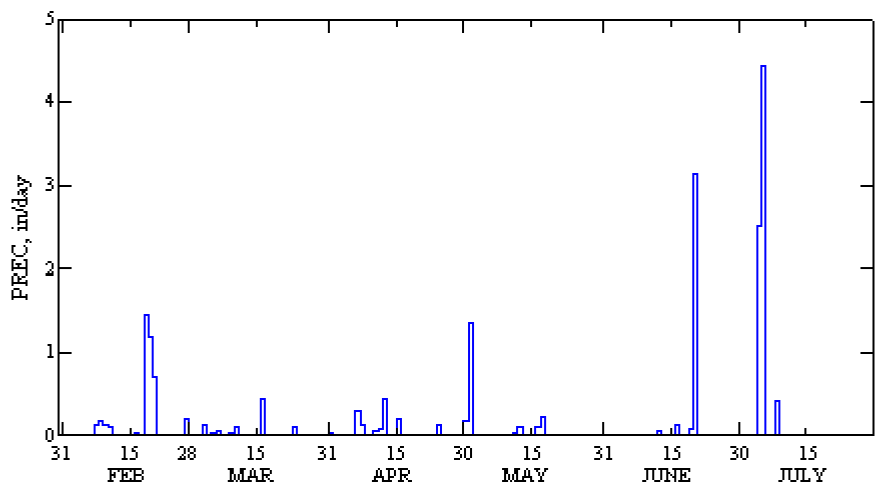
c) Hourly Model Results - Daily Recharge Volume from PERLND 201, February 1 through July 31, 1958.



Hourly Simulated Daily Recharge from PERLND 201 (Feb thru Jul, 1958)

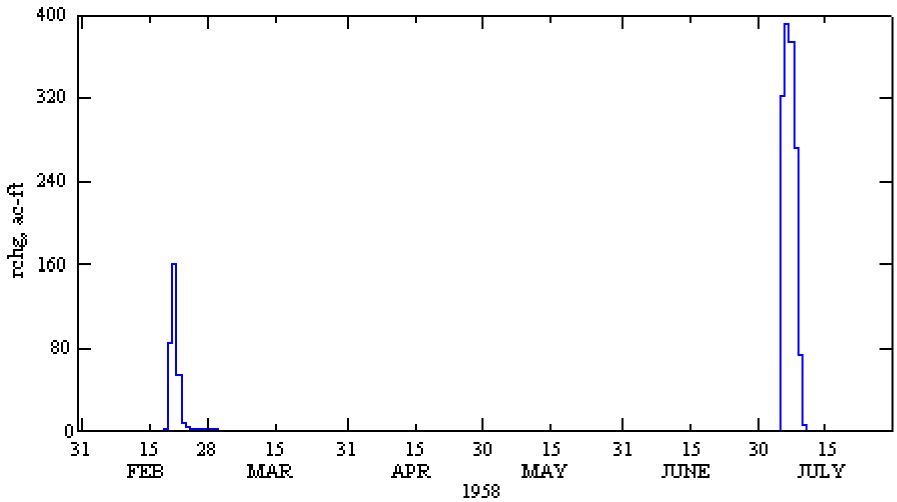
Plots - a) daily rainfall time series, b) daily simulated stream recharge volume (ac-ft) at RCHRES 21 (DSN 79), and c) daily simulated land recharge volume (ac-ft) at PERLND 201 (DSN 1271). RCHRES 21 is in the recharge zone; it is only minimally affected by the inflow of the contributing zone.

a) Daily Rainfall Time Series, February 1 through July 31, 1958.



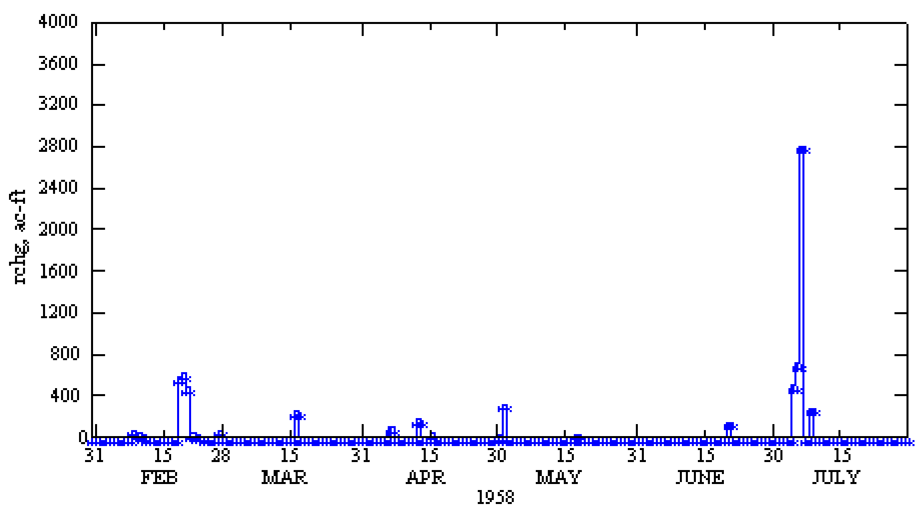
DAILY PREC OBSERVED at TX7945 (San Antonio Int'l Airport)

b) Daily Model Results - Daily Recharge Volume from RCHRES 21, February 1 through July 31, 1958.



Daily Simulated Recharge from RCHRES 21 (Feb thru July, 1958)

c) Daily Model Results - Daily Recharge Volume form PERLND 201, February 1 through July 31, 1958.



Daily Simulated Recharge from RCHRES 21 (Feb thru Jul, 1958)

<u>Sensitivity Analysis on the weighting factor, KS, in HYDR-PARM2 of the HSPF model.</u>

Results: A visible instability appears on the recharge results of the Daily Model when KS value is greater than 0.2. Table below shows such obvious differences between the simulated recharge volumes from Daily Models with KS=0.5 and 0.2.

Daily Model Results - Monthly Recharge (ac-ft) from Stream Segment, with KS=0.5

Location	75	76	77	78	79	80	81	82	83	84	85	Sum
Constituent	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg
1958/01	172	351	437	31	130	42	43	52	46	75	18	1,396
1958/02	156	305	380	27	1,770	68	66	138	1,050	207	73	4,240
1958/03	172	351	437	31	234	114	60	328	95	169	37	2,028
1958/04	167	339	423	30	9	7	2	16	4	6	1	1,004
1958/05	160	326	406	30	9	17	17	1	0	0	0	967
1958/06	153	312	389	28	0	0	0	0	0	0	0	882
1958/07	172	351	437	31	18	5	5	2	2	2	0	1,024
1958/08	172	351	437	31	0	0	0	0	0	0	0	991
1958/09	153	314	391	28	26	27	29	18	16	56	13	1,070
1958/10	167	347	434	31	91	59	57	26	28	37	8	1,285
1958/11	167	339	423	30	46	55	54	32	11	39	7	1,203
1958/12	172	351	437	31	1	1	1	1	0	1	0	996
Annual Total	1,983	4,037	5,031	355	2,334	395	335	614	1,251	590	159	17,084

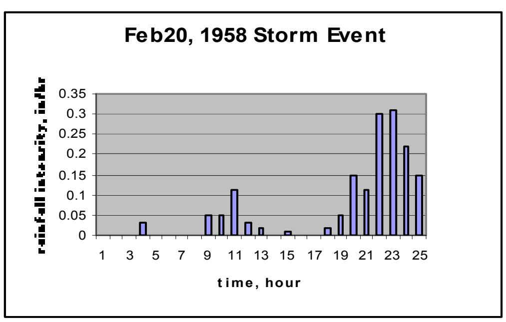
Daily Model Results – Monthly Recharge (ac-ft) from Stream Segment with KS=0.2

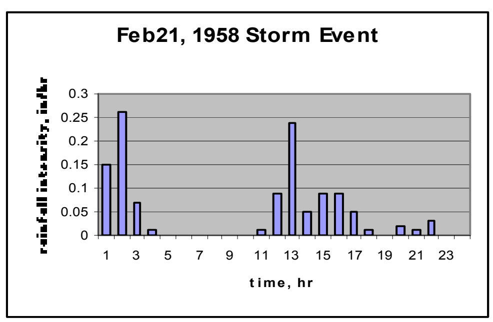
Location	75	76	77	78	79	80	81	82	83	84	85	Sum
Constituent	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg	rchg
1958/01	171	348	434	31	32	11	11	14	12	10	2	1,075
1958/02	156	317	394	28	318	37	40	95	130	90	23	1,628
1958/03	172	351	437	31	12	51	51	95	5	34	4	1,244
1958/04	167	339	423	30	0	1	0	1	0	0	0	961
1958/05	172	351	437	31	0	0	0	0	0	0	0	991
1958/06	167	339	423	30	0	0	0	0	0	0	0	959
1958/07	166	338	422	30	1,440	108	143	283	1,210	407	96	4,643
1958/08	172	351	437	31	1	8	15	10	0	3	0	1,027
1958/09	167	339	423	30	153	19	21	48	58	35	9	1,302
1958/10	172	351	437	31	95	72	72	59	32	36	7	1,363
1958/11	167	339	423	30	13	42	40	25	4	16	3	1,101
1958/12	172	351	437	31	1	1	1	1	0	0	0	995
Annual Total	2,021	4,114	5,127	361	2,066	349	394	631	1,452	631	144	17,288

Comparison of Simulated Stream Recharge Time Series from Daily and Hourly Models following the February 1958 storm event, with KS=0.2;

Unit of Recharge is in ac-ft, and Rainfall, in inches.

Model / Data	Daily	Hourly	Daily	Hourly	Rainfall
Location	RCHRES 21	RCHRES 21	PERLND 201	PERLND 201	417945
Constituent	rchg	rchg	igwi	igwi	PRCP
2/1/58	0.0	0.0	0.0	0.0	0
2/2/58	0.0	0.0	0.0	0.0	0
2/3/58	0.0	0.0	0.0	0.0	0
2/4/58	0.0	0.0	0.0	0.0	0
2/5/58	0.0	0.0	0.0	0.0	0
2/6/58	0.0	0.0	0.0	0.0	0
2/7/58	0.0	0.0	0.0	0.0	0
2/8/58	0.0	0.0	0.0	0.0	0
2/9/58	0.0	0.0	0.0	0.0	0.11
2/10/58	0.0	0.3	63.2	34.8	0.18
2/11/58	0.0	0.0	36.8	13.0	0.13
2/12/58	0.0	0.3	16.6	41.5	0.1
2/13/58	0.0	0.0	0.0	0.0	0
2/14/58	0.0	0.0	0.0	0.0	0
2/15/58	0.0	0.0	0.0	0.0	0
2/16/58	0.0	0.0	0.0	0.0	0
2/17/58	0.0	0.0	0.0	0.0	0
2/18/58	0.0	0.0	0.0	0.0	0.02
2/19/58	0.0	0.0	0.0	0.0	0
2/20/58	1.3	23.9	578.0	211.0	1.46
2/21/58	85.0	376.0	615.0	370.0	1.18
2/22/58	161.0	373.0	474.0	265.0	0.69
2/23/58	54.1	326.0	29.7	53.4	0.01
2/24/58	7.8	55.5	18.7	35.2	0
2/25/58	3.3	1.2	6.6	17.2	0
2/26/58	2.5	0.5	2.0	7.2	0
2/27/58	1.9	0.3	0.4	2.8	0
2/28/58	1.4	0.2	0.0	0.9	0
Total	318.3	1157.2	1841.0	1052.0	

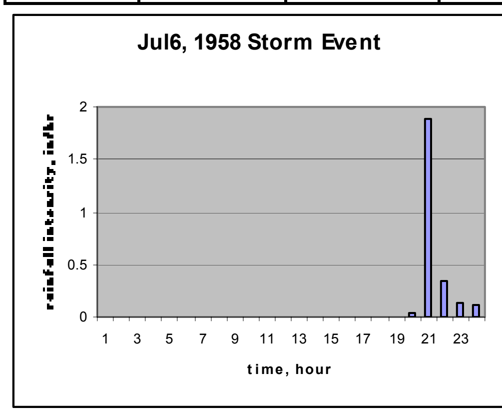


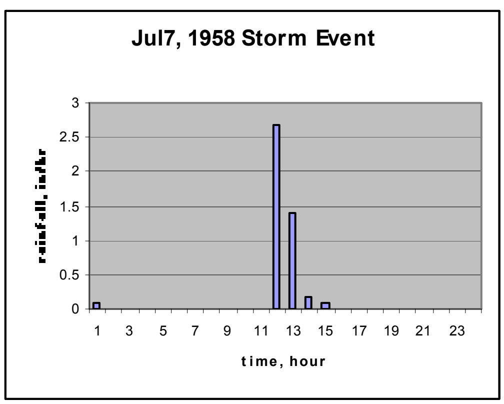


Comparison of Simulated Recharge Time Series from Daily and Hourly Models following the July 1958 storm event, with KS=0.2;

Unit of Recharge is in ac-ft, and Rainfall, in inches.

Model / Data	Daily	Hourly	Daily	Hourly	Rainfall
Location	RCHRES 21	RCHRES 21	PERLND 201	PERLND 201	417945
Constituent	rchg	rchg	igwi	igwi	PRCP
7/1/58	0.0	0.0	0.0	0.0	0.01
7/2/58	0.0	0.0	0.0	0.0	0.01
7/3/58	0.0	0.0	0.0	0.0	0
7/4/58	0.0	0.0	0.0	0.0	0
7/5/58	0.0	0.0	0.0	0.0	0
7/6/58	0.1	43.3	494.0	118.0	2.52
7/7/58	323.0	425.0	708.0	284.0	4.45
7/8/58	391.0	465.0	2800.0	53.6	0
7/9/58	374.0	448.0	0.0	7.6	0
7/10/58	272.0	431.0	275.0	33.4	0.4
7/11/58	74.0	413.0	0.0	2.7	0
7/12/58	6.3	398.0	0.0	0.2	0
7/13/58	0.4	380.0	0.0	0.0	0
7/14/58	0.4	312.0	0.0	0.0	0
7/15/58	0.4	44.2	0.0	0.0	0
7/16/58	0.3	0.4	0.0	0.0	0
7/17/58	0.3	0.0	0.0	0.0	0
7/18/58	0.3	0.0	0.0	0.0	0
7/19/58	0.2	0.0	0.0	0.0	0
7/20/58	0.2	0.0	0.0	0.0	0
7/21/58	0.2	0.0	0.0	0.0	0
7/22/58	0.2	0.0	0.0	0.0	0
7/23/58	0.2	0.0	0.0	0.0	0
7/24/58	0.1	0.0	0.0	0.0	0
7/25/58	0.1	0.0	0.0	0.0	0
7/26/58	0.1	0.0	0.0	0.0	0
7/27/58	0.1	0.0	0.0	0.0	0
7/28/58	0.1	0.0	0.0	0.0	0
7/29/58	0.1	0.0	0.0	0.0	0
7/30/58	0.1	0.0	0.0	0.0	0
7/31/58	0.1	0.0	0.0	0.0	0
Total	1444.3	3359.9	4277.0	499.5	





Results of Recharge Simulations for an Extended Time Period (1958 to 1998):

Note: DSNs 491 to 494 are the stored data of the modeled groundwater elements, RCHRES 91 to 94.

a) Results of Daily Model (KS=0.2), unit is ac-ft.

	Recharge from land segment					Recharge from stream segment				
Model	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily	Daily
Location	171	271	272	273	274	491	492	493	494	Total
Constituent	igwi	igwi	igwi	igwi	igwi	IVOL	IVOL	IVOL	IVOL	Recharge
1958	3,944	15,048	23,489	17,824	10,921	11,600	2,810	2,080	775	88,490
1959	1,341	3,541	5,687	4,315	2,616	11,600	18	1	1	29,120
1960	2,366	6,491	10,137	7,880	4,778	11,700	377	169	78	43,976
1961	3,089	8,261	13,352	10,132	6,257	11,700	744	355	165	54,054
1962	977	2,803	4,451	3,377	2,048	11,600	116	65	32	25,468
1963	889	2,360	3,709	2,814	1,706	9,450	51	7	3	20,989
1964	2,090	5,901	9,396	7,130	4,437	9,340	127	28	13	38,460
1965	3,944	11,359	17,802	13,509	8,418	11,600	3,440	2,790	994	73,856
1966	1,867	4,868	7,665	5,816	3,640	11,700	46	4	2	35,608
1967	2,484	7,819	12,363	9,381	5,802	10,400	2,460	2,060	692	53,461
1968	3,654	10,179	16,566	12,571	7,849	11,700	1,880	1,520	474	66,393
1969	2,590	7,524	11,868	9,006	5,688	11,700	71	23	11	48,480
1970	2,103	5,606	9,148	6,942	4,323	11,700	187	16	8	40,033
1971	3,707	10,327	16,566	12,571	7,736	10,600	948	477	220	63,151
1972	3,536	10,474	16,813	12,759	7,849	11,700	761	331	154	64,377
1973	8,768	27,145	43,763	33,210	20,249	11,700	4,240	2,790	1,120	152,984
1974	4,101	12,392	19,780	15,010	9,214	11,600	3,200	2,380	906	78,584
1975	2,734	7,524	12,115	9,194	5,574	11,700	817	409	185	50,252
1976	4,482	13,425	21,264	16,136	9,897	11,700	1,150	546	238	78,837
1977	3,799	10,474	17,060	12,946	7,963	11,700	1,840	1,440	461	67,684
1978	3,628	10,327	16,566	12,571	7,736	11,500	1,050	812	268	64,457
1979	5,495	14,162	22,747	17,262	10,580	11,700	657	95	43	82,740
1980	1,067	3,393	5,192	3,940	2,503	11,600	44	18	9	27,766
1981	3,365	10,327	16,071	12,196	7,622	11,700	3,540	2,960	833	68,614
1982	1,065	3,098	4,945	3,753	2,275	11,700	16	8	4	26,863
1983	1,512	4,278	6,923	5,066	3,185	11,700	32	8	4	32,708
1984	1,354	3,983	6,429	4,691	2,958	10,500	20	5	2	29,941
1985	6,612	18,293	29,423	22,327	13,651	11,600	1,690	955	340	104,891
1986	5,600	20,801	33,132	25,142	15,357	11,600	2,850	2,100	686	117,267
1987	5,915	18,293	28,928	21,952	13,310	11,700	4,590	3,730	1,100	109,518
1988	995	2,508	4,203	3,190	2,048	11,700	47	15	7	24,713
1989	680	2,065	3,214	2,439	1,479	10,800	1	1	1	20,680
1990	4,101	11,359	18,049	13,509	8,304	11,400	2,190	1,640	550	71,103
1991	5,679	16,523	26,456	20,076	12,286	11,700	1,970	1,220	474	96,383
1992	6,034	23,752	38,077	28,894	17,633	11,700	7,580	6,010	2,090	141,768
1993	3,654	12,245	19,286	14,635	8,987	11,700	2,010	1,290	477	74,283
1994	4,561	11,950	19,533	14,822	9,101	11,700	1,580	947	440	74,634
1995	1,169	3,393	5,192	3,940	2,503	11,700	19	4	2	27,922
1996	310	885	1,484	1,126	683	9,840	0	0	0	14,327
1997	2,892	7,966	12,610	9,569	5,915	11,700	1,300	943	337	53,232
1998	5,915	18,293	29,176	22,140	13,537	11,700	3,390	2,860	1,040	108,051
Annual Avg	3,270	9,791	15,625	11,848	7,283	11,401	1,460	1,052	372	62,100

b) Results of Hourly Model (KS=0.2), unit in ac-ft.

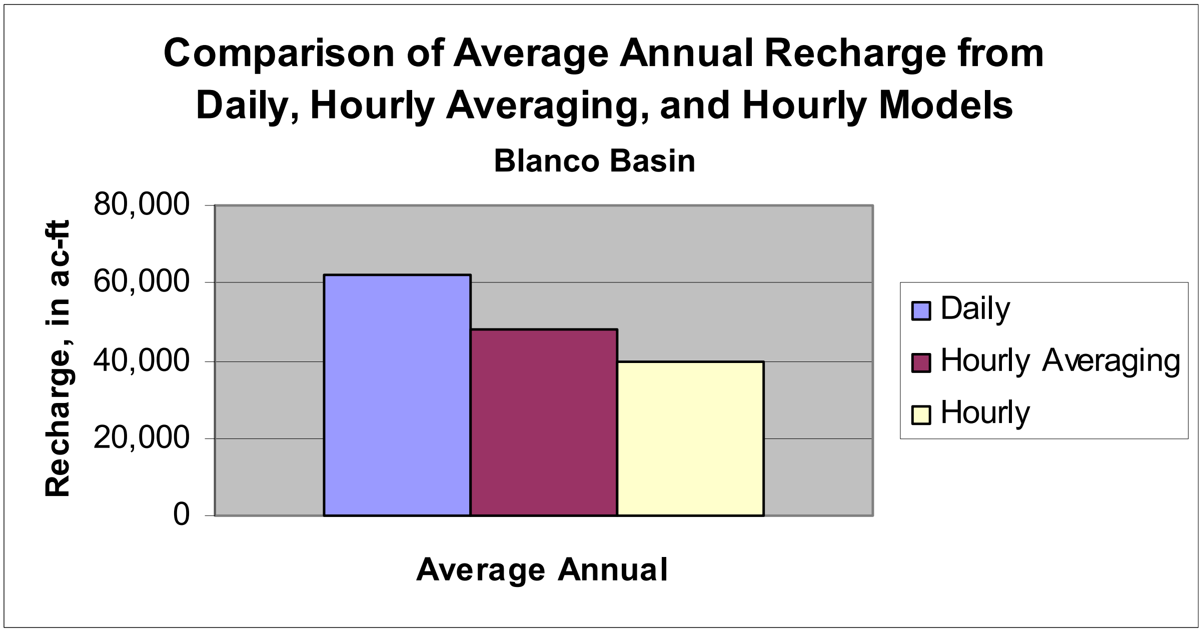
	Recharge from land segment					Recharge from stream segment				
Model	Hourly	Hourly	Hourly	Hourly	Hourly	Hourly	Hourly	Hourly	Hourly	Hourly
Location	171	271	272	273	274	491	492	493	494	Total
Constituent	igwi	igwi	igwi	igwi	igwi	IVOL	IVOL	IVOL	IVOL	Recharge
1958	1,617	5,650	8,654	6,586	4,027	11,700	10,100	9,550	3,180	61,063
1959	442	1,505	2,267	1,721	1,075	11,700	1,120	946	337	21,112
1960	799	2,773	4,203	3,190	1,979	11,700	4,760	4,370	1,480	35,255
1961	680	2,523	3,783	2,889	1,763	11,700	5,420	4,960	1,740	35,458
1962	331	1,198	1,827	1,388	861	11,600	2,560	2,270	769	22,805
1963	248	935	1,409	1,071	661	9,460	1,700	1,390	510	17,385
1964	640	2,478	3,783	2,871	1,752	9,380	4,670	4,010	1,440	31,024
1965	1,354	4,986	7,541	5,741	3,504	11,600	7,530	6,690	2,380	51,326
1966	640	2,065	3,115	2,327	1,433	11,700	244	175	77	21,777
1967	915	3,614	5,390	4,109	2,503	10,400	5,000	4,570	1,520	38,021
1968	1,253	4,337	6,602	5,010	3,083	11,700	4,000	3,750	1,410	41,144
1969	799	2,995	4,500	3,415	2,105	11,700	2,950	2,420	1,000	31,883
1970	454	1,652	2,497	1,895	1,172	11,700	2,750	2,610	854	25,584
1971	1,105	4,145	6,255	4,766	2,912	10,500	6,440	5,630	1,790	43,544
1972	585	2,287	3,412	2,589	1,593	11,700	5,560	5,530	2,220	35,475
1973	1,683	6,535	9,816	7,449	4,528	11,700	15,900	15,400	5,040	78,050
1974	940	3,511	5,242	3,978	2,469	11,700	8,670	8,200	2,800	47,509
1975	776	2,818	4,277	3,246	1,979	11,700	4,250	3,680	1,230	33,956
1976	1,354	5,001	7,591	5,760	3,504	11,700	6,140	5,350	1,900	48,299
1977	1,166	4,086	6,231	4,728	2,901	11,700	5,470	5,130	1,790	43,202
1978	666	2,537	3,808	2,889	1,786	11,500	7,320	6,880	2,440	39,827
1979	1,130	4,160	6,206	4,709	2,901	11,700	7,700	7,040	2,380	47,927
1980	465	1,770	2,670	2,026	1,251	11,600	2,620	2,160	699	25,263
1981	1,176	4,367	6,626	5,028	3,071	11,700	7,060	6,570	2,250	47,849
1982	385	1,400	2,136	1,621	1,003	11,700	1,830	1,600	551	22,227
1983	521	1,918	2,893	2,176	1,342	11,700	2,280	1,860	756	25,446
1984	459	1,682	2,522	1,895	1,172	10,500	1,370	1,020	393	21,012
1985	1,577	5,901	8,852	6,698	4,050	11,700	10,700	9,770	3,400	62,648
1986	1,407	5,281	7,937	6,004	3,663	11,700	12,600	12,100	4,170	64,862
1987	1,525	5,606	8,481	6,436	3,902	11,700	10,400	9,990	3,810	61,849
1988	187	668	999	758	477	11,700	1,900	1,780	604	19,072
1989	252	947	1,434	1,088	671	10,800	1,680	1,380	511	18,764
1990	1,077	4,101	6,107	4,634	2,844	11,400	8,310	7,400	2,650	48,523
1991	1,262	4,927	7,368	5,572	3,401	11,700	10,100	9,500	3,340	57,171
1992	2,734	9,368	14,464	10,976	6,689	11,700	15,000	13,600	4,480	89,011
1993	810	3,319	4,920	3,734	2,275	11,700	7,460	6,850	2,300	43,368
1994	1,061	4,013	6,082	4,616	2,810	11,700	8,320	7,610	2,440	48,651
1995	339	1,276	1,941	1,471	901	11,700	1,430	1,140	462	20,660
1996	114	395	596	452	287	9,830	2	2	1	11,679
1997	751	2,759	4,129	3,115	1,934	11,700	2,980	2,550	940	30,857
1998	1,433	5,370	8,135	6,210	3,788	11,700	10,800	11,500	4,000	62,936
Annual Avg	905	3,338	5,041	3,825	2,342	11,411	5,783	5,340	1,855	39,841

Note: DSN 491 is the upper most reach and its recharge depends largely from the inflow of upstream contributing area and the steady inflow thus provide steady recharge number when compares it with reaches located in the recharge zone.

c) Results of Average Model (KS=0.2), unit in ac-ft.

	Recharge from land segment					Recharge from stream segment				
Model	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
Location	171	271	272	273	274	491	492	493	494	Total
Constituent	igwi	igwi	igwi	igwi	igwi	IVOL	IVOL	IVOL	IVOL	Recharge
1958	3,155	10,179	15,873	12,083	7,417	11,700	4,720	4,070	1,470	70,668
1959	912	2,655	4,129	3,133	1,945	11,700	446	341	164	25,426
1960	1,564	5,016	7,714	5,854	3,606	11,700	1,970	1,620	578	39,622
1961	1,485	5,016	7,739	5,873	3,606	11,700	2,660	2,230	755	41,064
1962	712	2,360	3,659	2,796	1,729	11,600	1,030	837	304	25,028
1963	553	1,770	2,794	2,120	1,308	9,450	158	106	50	18,310
1964	1,208	4,278	6,527	4,953	3,049	9,370	1,730	1,400	525	33,041
1965	2,747	9,294	14,266	10,845	6,643	11,600	4,150	3,460	1,230	64,236
1966	1,237	3,393	5,242	3,921	2,423	11,700	33	14	6	27,970
1967	1,722	5,606	8,753	6,642	4,084	10,400	2,650	2,290	797	42,943
1968	1,919	6,196	9,445	7,167	4,391	11,700	3,280	2,960	1,070	48,129
1969	1,814	5,458	8,456	6,417	3,993	11,700	94	60	30	38,022
1970	1,081	3,246	5,019	3,809	2,366	11,700	1,300	1,090	364	29,974
1971	2,708	8,261	13,005	9,888	6,086	10,500	1,760	1,190	495	53,894
1972	1,630	5,163	7,986	6,060	3,754	11,700	3,240	3,150	1,140	43,824
1973	3,865	13,720	20,893	15,854	9,704	11,700	11,600	10,600	3,760	101,695
1974	2,287	7,966	12,091	9,194	5,631	11,700	4,530	3,860	1,350	58,609
1975	1,656	5,606	8,555	6,511	3,982	11,700	2,640	2,020	728	43,397
1976	2,918	9,294	14,439	10,939	6,734	11,700	2,560	1,920	717	61,222
1977	1,814	5,901	9,148	6,942	4,266	11,700	4,210	3,790	1,270	49,041
1978	1,238	4,573	6,923	5,254	3,242	11,500	4,410	4,110	1,510	42,760
1979	2,852	9,294	14,217	10,788	6,621	11,700	3,860	3,140	1,120	63,593
1980	808	2,508	3,956	3,002	1,866	11,600	65	43	21	23,868
1981	2,274	7,966	12,264	9,287	5,688	11,700	5,360	4,630	1,350	60,519
1982	699	2,213	3,462	2,627	1,638	11,700	374	285	139	23,137
1983	1,096	3,246	5,093	3,828	2,389	11,700	20	11	5	27,388
1984	974	2,951	4,624	3,490	2,150	10,500	19	12	5	24,724
1985	3,799	11,654	18,148	13,715	8,384	11,700	4,240	3,650	1,270	76,561
1986	2,931	9,737	14,884	11,258	6,882	11,700	8,380	7,820	2,720	76,312
1987	3,365	11,064	17,184	13,002	7,940	11,700	7,590	6,870	2,470	81,186
1988	431	1,623	2,369	1,797	1,114	11,700	783	626	221	20,664
1989	527	1,623	2,571	1,951	1,206	10,800	7	6	3	18,694
1990	2,235	7,966	12,091	9,156	5,608	11,400	4,300	3,730	1,200	57,686
1991	2,642	8,999	13,821	10,488	6,416	11,700	6,720	6,060	2,290	69,137
1992	4,601	15,785	24,379	18,519	11,342	11,700	11,100	9,300	3,230	109,955
1993	2,037	6,934	10,731	8,124	4,994	11,700	3,770	3,420	1,220	52,930
1994	2,340	8,114	12,486	9,494	5,813	11,700	4,330	3,580	1,240	59,097
1995	819	2,803	4,228	3,208	1,968	11,700	402	301	140	25,569
1996	175	590	826	625	398	9,840	2	2	1	12,458
1997	1,775	5,901	8,950	6,773	4,164	11,700	1,760	1,470	495	42,988
1998	2,734	9,294	14,341	10,920	6,712	11,700	6,950	8,140	2,800	73,590
Annual Avg	1,886	6,225	9,592	7,276	4,470	11,411	3,151	2,786	982	47,779

A comparison of the long-term average total annual recharges (for the period, 1958-1998) generated by the three models is shown by the graph below.


Comparison of Average Annual Recharge from
Daily, Hourly Averaging, and Hourly Models
Blanco Basin
Recharge, in ac-ft
80,000
60,000
40,000
20,000
0
Daily
Hourly Averaging
Hourly
Average Annual

APPENDIX G

HSPF Hydrology Parameters And Value Ranges

Table G- 1 Typical HSPF Parameter Values

			RANGE OF VALUES					
NAME	DEFINITION	UNITS	TYPICAL		POSSIBLE		FUNCTION OF ...	COMMENT
			MIN	MAX	MIN	MAX		
PWAT - PARM2								
FOREST	Fraction forest cover	none	0.0	0.50	0.0	0.95	Forest cover	Only impact when SNOW is active
LZSN	Lower Zone Nominal Soil Moisture Storage	inches	3.0	8.0	2.0	15.0	Soils, climate	**Calibration**
INFILT	Index to Infiltration Capacity	in/hr	0.01	0.25	0.001	0.50	Soils, land use	**Calibration**, divides surface and subsurface flow
LSUR	Length of overland flow	feet	200	500	100	700	Topography	Estimate from high resolution topo maps or GIS
SLSUR	Slope of overland flow plane	ft/ft	0.01	0.15	0.001	0.30	Topography	Estimate from high resolution topo maps or GIS
KVARY	Variable groundwater recession	1/inches	0.0	3.0	0.0	5.0	Baseflow recession variation	Used when recession rate varies with GW levels
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	Baseflow recession	**Calibration**
PWAT - PARM3								
PETMAX	Temp below which ET is reduced	deg. F	35.0	45.0	32.0	48.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
PETMIN	Temp below which ET is set to zero	deg. F	30.0	35.0	30.0	40.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
INFEXP	Exponent in infiltration equation	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
INFILD	Ratio of max/mean infiltration capacities	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
DEEPFR	Fraction of GW inflow to deep recharge	none	0.0	0.20	0.0	0.50	Geology, GW recharge	Accounts for subsurface losses
BASETP	Fraction of remaining ET from baseflow	none	0.0	0.05	0.0	0.20	Riparian vegetation	Direct ET from riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0.0	0.05	0.0	0.20	Marsh/wetlands extent	Direct ET from shallow GW
PWAT - PARM4								
CEPSC	Interception storage capacity	inches	0.03	0.20	0.01	0.40	Vegetation type/density, land use	Monthly values usually used
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1.0	0.05	2.0	Surface soil conditions, land use	Accounts for near surface retention
NSUR	Manning's n (roughness) for overland flow	none	0.15	0.35	0.05	0.50	Surface conditions, residue, etc.	Monthly values often used for croplands
INTFW	Interflow inflow parameter	none	1.0	3.0	1.0	10.0	Soils, topography, land use	**Calibration,** based on hydrograph separation
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	Soils, topography, land use	Often start with a value of 0.7, and then adjust
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	Vegetation type/density, root depth	**Calibration**

NAME	DEFINITION	UNITS	RANGE OF VALUES: TYPICAL MIN	TYPICAL MAX	POSSIBLE MIN	POSSIBLE MAX	FUNCTION OF ...	COMMENT
IWAT - PARM2								
LSUR	Length of overland flow	feet	50	150	50	250	Topography, drainage system	Estimate from maps, GIS, or field survey
SLSUR	Slope of overland flow plane	ft/ft	0.01	0.05	0.001	0.15	Topography, drainage	Estimate from maps, GIS, or field survey
NSUR	Manning's n (roughness) for overland flow	none	0.03	0.10	0.01	0.15	Impervious surface conditions	Typical range is 0.05 to 0.10 for roads/parking lots
RETSC	Retention storage capacity	inches	0.03	0.10	0.01	0.30	Impervious surface conditions	Typical range is 0.03 to 0.10 for roads/parking lots
IWAT - PARM3								
PETMAX	Temp below which ET is reduced by half	deg. F	35.0	45.0	32.0	48.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active
PETMIN	Temp below which ET is set to zero	deg. F	30.0	35.0	30.0	40.0	Climate, vegetation	Reduces ET near freezing, when SNOW is active

HSPF HYDRAULIC PARAMETERS AND VALUE RANGES

NAME	DEFINITION	UNITS	RANGE OF VALUES: TYPICAL MIN	TYPICAL MAX	POSSIBLE MIN	POSSIBLE MAX	FUNCTION OF ...	COMMENT
HYDR - PARM2								
FTBDSN	WDM data set number for FTABLE	none	none	none	1	999	WDM File	Used only if FTABLE is in WDM file
FTABNO	FTABLE number in UCI file	none	none	none	1	999	RCHRES block/ reach numbering	Used only if FTABLE is in UCI file
LEN	Stream reach (RCHRES) length	miles	0.1	1.0	0.01	100	Topography, stream morphology	Used only in computing auxiliary parameters
DELTH	Stream reach length change in elevation	feet	10	100	0.1	1000	Topography, stream morphology	Used only for water quality and sediment
STCOR	Stage correction factor	feet	0.0	none	0.0	none	Topography	Dependent on elevation datum used
KS	Routing weighting factor	none	0.0	0.5	0.0	0.99	Channel slope, flow obstructions	Use KS = 0.5
DB50	Bed sediment diameter	inches	0.01	0.02	0.001	1.00	Channel bed properties	Used only in sediment calculations
ADCALC - DATA								
CRRAT	Ratio of maximum to mean flow velocity	none	1.5	2.0	1.0	3.5	Climate, vegetation	Only used with water quality
VOL	Initial stream channel water volume	acre-feet	0.0	none	0.0	none	Season, channel geometry, climate	Initial volume in reach channel

APPENDIX H

Land Segment Classification Methodology

Development Of Land Segment Classifications

An HSPF model requires the designation of PERLNDs. A PERLND is an application module of HSPF that simulates the water quantity and quality processes that occur on a pervious land segment. The goal in developing land segment classification in the nine basins was to incorporate sufficient variability found in the basins while trying to keep the number of categories used to a reasonable number. For this model, we incorporated five characteristics that would make up all of our PERLND classifications. The five characteristics used were soil slope, soil thickness, land cover/vegetation, Edwards aquifer geology (recharge/contributing zone) and whether or not the PERLND is on the Lower Glen Rose Formation. These characteristics, when combined, make up a total of 96 unique PERLND classifications. GIS was used to combine these characteristics into one continuous coverage of PERLNDs for the entire study area.

The first step in this process is to categorize each individual parameter (i.e. slope, soil thickness, etc.) into a few sub categories. Soil slope was categorized into steep slope and flat slope. This was done by reclassifying all slopes greater than 10% as steep slopes and all slopes less than 10% as flat slopes. Figure H-1 shows the original slope coverage and Figure H-2 shows the reclassified slope coverage.

After soil slope was reclassified into steep and flat we looked to reclassify soil thickness into deep and shallow. This classification is based on the fact that shallow soils have very little moisture storage capacity, while deep soils have a much greater storage capacity. There are a few different soil coverages available for the study area. The two soil datasets that we have are the STATSGO dataset and the SSURGO dataset. As discussed in the work plan for this project, there are significant differences and inconsistencies between these two datasets. These inconsistencies lead us to lose confidence in the ability to classify soil thickness to shallow and deep using these datasets. From fieldwork and talking with others, we came to the conclusion that shallow soils are typically found along ridgelines, hilltops, and on steeper slopes away from valley bottoms. In contrast, deep soils are typically found on flat slopes along the valley floors as a result of alluvium deposition. However, we had no dataset to represent this soil thickness trend so one had to be created. Simply basing this on elevation would not give an accurate representation of soil thickness because of the size of the study area. A valley in the northwestern portion of the study area would likely have a much greater elevation than that of a hilltop in the southeastern portion of the study area. Because of this, we used the slope coverage. Using GIS the slopes were smoothed out over ¼ mile to lump in the hilltops with the steeper sloped sides. Figure H-3 shows the smoothed slopes. These smoothed slopes were then reclassified to greater than 8% and less than 8%. The greater was then classified as shallow soils and the lesser was classified as deep soils. After this, we still had deep soils on the plateaus in the northern portion of the study area, which we felt to be incorrect. From field observation, we knew where the corrections needed to be made. GIS was used to manually change these areas from deep to shallow soils. Figure H-4 shows the final classification of deep and shallow soils.

The next parameter that was considered in the PERLND classification was land cover, or vegetation. Land cover plays a major role in the computation of runoff and recharge. Like the soils, there are a few datasets to choose from when doing this analysis. For our purposes, the USGS Land Cover dataset, shown in Figure H-5, was the most appropriate to use. This dataset originally had 20 different land cover classifications:

Open Water
Low Intensity Residential
High Intensity Residential
Commercial/Industrial/Transportation
Bare Rock/Sand/Clay
Quarries/Strip Mines/Gravel Pits
Transitional
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrubland
Orchards/Vineyards/Other
Grasslands/Herbaceous
Pasture/Hay
Row Crops
Small Grains
Fallow
Urban/Recreational Grasses
Wood Wetlands
Emergent Herbaceous Wetlands

These 20 different land cover types were reclassified to be only 6 types. They were reclassified as follows:

Water:	Open Water
Urban:	Low Intensity Residential High Intensity Residential Commercial/Industrial/Transportation

Non-Forest:	Bare Rock/Sand/Clay Quarries/Strip Mines/Gravel Pits Transitional Shrubland Grasslands/Herbaceous Pasture/Hay Urban/Recreational Grasses Emergent Herbaceous Wetlands
Oak/Mesquite Forest:	Deciduous Forest Mixed Forest Orchards/Vineyards/Other Woody Wetlands
Juniper Forest:	Evergreen Forest
Crops:	Row Crops Small Grains Fallow

Figure H-6 shows this reclassification geographically. We feel that each category accurately represents each one of its sub categories in a hydrological sense.

The forth parameter that went into the creation of the PERLND coverage was the distinction between the recharge zone and the non-recharge zone of the Edwards Aquifer. The dataset used for this was the Edwards Aquifer Geology dataset supplied by the Edwards Aquifer Authority. All the area in the recharge zone was reclassified as recharge zone and all the area outside of the recharge zone was classified as non-recharge zone. The non-recharge zone includes the artesian zone, and the drainage area. Figure H-7 shows the classification of aquifer zones.

The final parameter that we took under consideration during the PERLND creation process was location relative to the Lower Glen Rose Formation. Recent field studies conducted by Texas A&M (personal communication with Brad Wilcox), as well as other studies (Hammond, 1984) indicate that hydraulic conductivity and infiltration rates into the Lower Glen Rose can be significantly higher than for the upper Glen Rose, and therefore, the unit was classified differently. GIS was used to reclassify a digitized version of Geologic Atlas of Texas sheets to only include two types of geology: Lower Glen Rose Formation and Non-Lower Glen Rose Formation. This reclassification is shown in Figure H-8.

The next step in the creation of the PERLND coverage was combining the reclassified datasets into one continuous dataset that covers the entire study area. This was done using GIS. The individual layers were combined, creating 96 unique PERLND classifications. Each of these classifications was given a number to represent it in the actual model. These classifications are listed below, and shown in Figure H-9.

111- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Water
112- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Urban
113- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Non-Forest
114- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Oak, Mesquite Forest
115- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Juniper Forest
116- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Crops
121- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Water
122- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Urban
123- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Non-Forest
124- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Oak, Mesquite Forest
125- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Juniper Forest
126- Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Crops
211- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Water
212- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Urban
213- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Non-Forest
214- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Oak, Mesquite Forest
215- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Juniper Forest
216- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Crops
221- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Water
222- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Urban
223- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Non-Forest
224- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Oak, Mesquite Forest
225- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Juniper Forest
226- Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Crops
311- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Water
312- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Urban
313- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Non-Forest
314- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Oak, Mesquite Forest
315- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Juniper Forest
316- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Deep Soil/Crops
321- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Water
322- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Urban
323- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Non-Forest
324- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Oak, Mesquite Forest
325- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Juniper Forest
326- Non-Recharge Zone/Flat Slope/Non-Lower Glen Rose/Shallow Soil/Crops
411- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Water
412- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Urban
413- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Non-Forest
414- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Oak, Mesquite Forest
415- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Juniper Forest
416- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Deep Soil/Crops
421- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Water
422- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Urban
423- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Non-Forest
424- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Oak, Mesquite Forest

425- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Juniper Forest
426- Non-Recharge Zone/Steep Slope/Non-Lower Glen Rose/Shallow Soil/Crops
511- Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Water
512- Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Urban
513- Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Non-Forest
514- Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Oak, Mesquite Forest
515- Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Juniper Forest
516- Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Crops
521- Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Water
522- Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Urban
523- Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Non-Forest
524- Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Oak, Mesquite Forest
525- Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Juniper Forest
526- Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Crops
611- Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Water
612- Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Urban
613- Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Non-Forest
614- Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Oak, Mesquite Forest
615- Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Juniper Forest
616- Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Crops
621- Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Water
622- Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Urban
623- Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Non-Forest
624- Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Oak, Mesquite Forest
625- Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Juniper Forest
626- Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Crops
711- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Water
712- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Urban
713- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Non-Forest
714- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Oak, Mesquite Forest
715- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Juniper Forest
716- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Deep Soil/Crops
721- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Water
722- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Urban
723- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Non-Forest
724- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Oak, Mesquite Forest
725- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Juniper Forest
726- Non-Recharge Zone/Flat Slope/Lower Glen Rose/Shallow Soil/Crops
811- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Water
812- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Urban
813- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Non-Forest
814- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Oak, Mesquite Forest
815- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Juniper Forest
816- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Deep Soil/Crops
821- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Water
822- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Urban

823- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Non-Forest
824- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Oak, Mesquite Forest
825- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Juniper Forest
826- Non-Recharge Zone/Steep Slope/Lower Glen Rose/Shallow Soil/Crops

Now that the PERLNDs have been created, they needed be aggregated to eliminate insignificant PERLND values. Any PERLND that covered less than 5% of the area in any sub-basin of a larger recharge basin was aggregated into a similar PERLND within that sub-basin. In order to accomplish this a set of rules were developed. These rules are as follows:

1. Keep recharge/non-lower Glen Rose (100s-200s), non-recharge/non-lower Glen Rose (300s-400s), recharge/lower Glen Rose (500s-600s), and non-recharge/lower Glen Rose (700s-800s) PERLND areas separate.

2. Sum all recharge FLAT PERLND areas (111-126) for a single subbasin.

3. Compute % of recharge total subbasin for sum.

4. Sum all recharge STEEP PERLND areas (211-226) for a single subbasin.

5. Compute % of recharge total subbasin for sum.

6. If sum of all recharge FLAT PERLND areas < target % then add individual FLAT PERLND areas to corresponding STEEP PERLND areas and reset FLAT PERLND areas to zero. Go to Step 32.

7. If sum of all recharge STEEP PERLND areas < target % then add individual STEEP PERLND areas to corresponding FLAT PERLND areas and reset STEEP PERLND areas to zero. Go to Step 9.

8. If sum of all recharge FLAT PERLND areas >= target % then go to Step 9.

9. Sum all recharge FLAT DEEP PERLND areas (111-116) for a single subbasin.

10. Compute % of recharge total subbasin for sum.

11. Sum all recharge FLAT SHALLOW PERLND areas (121-126) for a single subbasin.

12. Compute % of recharge total subbasin for sum.

13. If sum of all recharge FLAT DEEP PERLND areas < target % then add individual FLAT DEEP PERLND areas to corresponding FLAT SHALLOW PERLND areas and reset FLAT DEEP PERLND areas to zero. Go to Step 24.

14. If sum of all recharge FLAT SHALLOW PERLND areas < target % then add individual FLAT SHALLOW PERLND areas to corresponding FLAT DEEP PERLND areas and reset FLAT SHALLOW PERLND areas to zero. Go to Step 16.

15. If sum of all recharge FLAT DEEP PERLND areas >= target % then go to Step 16.

16. Compute % of recharge total subbasin for each individual PERLND 111,112,113,114,115,116.

17. If FLAT DEEP WATER PERLND 111 < target % then add to FLAT DEEP GRASS 113 and reset FLAT DEEP WATER PERLND 111 to zero.

18. If FLAT DEEP URBAN PERLND 112 < target % then add to FLAT DEEP GRASS 113 and reset FLAT DEEP URBAN PERLND 112 to zero.

19. If FLAT DEEP OAK PERLND 114 < target % then add to FLAT DEEP GRASS 113 and reset FLAT DEEP OAK PERLND 114 to zero.

20. If FLAT DEEP JUNIPER PERLND 115 < target % then add to FLAT DEEP GRASS 113 and reset FLAT DEEP JUNIPER PERLND 115 to zero.

21. If FLAT DEEP CROP PERLND 116 < target % then add to FLAT DEEP GRASS 113 and reset FLAT DEEP CROP PERLND 116 to zero.

22. If FLAT DEEP GRASS 113 < target % then add to largest of 111,112,114,115,116 and reset FLAT DEEP GRASS PERLND 113 to zero.

23. If sum of all recharge FLAT SHALLOW PERLND areas < target % then go to Step 31.

24. Compute % of recharge total subbasin for each individual PERLND 121,122,123,124,125,126.

25. If FLAT SHALLOW WATER PERLND 121 < target % then add to FLAT SHALLOW GRASS 123 and reset FLAT SHALLOW WATER PERLND 121 to zero.

26. If FLAT SHALLOW URBAN PERLND 122 < target % then add to FLAT SHALLOW GRASS 123 and reset FLAT SHALLOW URBAN PERLND 122 to zero.

27. If FLAT SHALLOW OAK PERLND 124 < target % then add to FLAT SHALLOW GRASS 123 and reset FLAT SHALLOW OAK PERLND 124 to zero.

28. If FLAT SHALLOW JUNIPER PERLND 125 < target % then add to FLAT SHALLOW GRASS 123 and reset FLAT SHALLOW JUNIPER PERLND 125 to zero.

29. If FLAT SHALLOW CROP PERLND 126 < target % then add to FLAT SHALLOW GRASS 123 and reset FLAT SHALLOW CROP PERLND 126 to zero.

30. If FLAT SHALLOW GRASS 123 < target % then add to largest of 121,122,124,125,126 and reset FLAT SHALLOW GRASS PERLND 123 to zero.

31. If sum of all recharge STEEP PERLND areas < target % then go to Step 54.

32. Sum all recharge STEEP DEEP PERLND areas (211-216) for a single subbasin.

33. Compute % of recharge total subbasin for sum.

34. Sum all recharge STEEP SHALLOW PERLND areas (221-226) for a single subbasin.

35. Compute % of recharge total subbasin for sum.

36. If sum of all recharge STEEP DEEP PERLND areas < target % then add individual STEEP DEEP PERLND areas to corresponding STEEP SHALLOW PERLND areas and reset STEEP DEEP PERLND areas to zero. Go to Step 47.

37. If sum of all recharge STEEP SHALLOW PERLND areas < target % then add individual STEEP SHALLOW PERLND areas to corresponding STEEP DEEP PERLND areas and reset STEEP SHALLOW PERLND areas to zero. Go to Step 39.

38. If sum of all recharge STEEP DEEP PERLND areas >= target % then go to Step 39.

39. Compute % of recharge total subbasin for each individual PERLND 211,212,213,214,215,216.

40. If STEEP DEEP WATER PERLND 211 < target % then add to STEEP DEEP GRASS 213 and reset STEEP DEEP WATER PERLND 211 to zero.

41. If STEEP DEEP URBAN PERLND 212 < target % then add to STEEP DEEP GRASS 213 and reset STEEP DEEP URBAN PERLND 212 to zero.

42. If STEEP DEEP OAK PERLND 214 < target % then add to STEEP DEEP GRASS 213 and reset STEEP DEEP OAK PERLND 214 to zero.

43. If STEEP DEEP JUNIPER PERLND 215 < target % then add to STEEP DEEP GRASS 213 and reset STEEP DEEP JUNIPER PERLND 215 to zero.

44. If STEEP DEEP CROP PERLND 216 < target % then add to STEEP DEEP GRASS 213 and reset STEEP DEEP CROP PERLND 216 to zero.

45. If STEEP DEEP GRASS 213 < target % then add to largest of 211,212,214,215,216 and reset STEEP DEEP GRASS PERLND 213 to zero.

46. If sum of all recharge STEEP SHALLOW PERLND areas < target % then go to Step 54.

47. Compute % of recharge total subbasin for each individual PERLND 221,222,223,224,225,226.

48. If STEEP SHALLOW WATER PERLND 221 < target % then add to STEEP SHALLOW GRASS 223 and reset STEEP SHALLOW WATER PERLND 221 to zero.

49. If STEEP SHALLOW URBAN PERLND 222 < target % then add to STEEP SHALLOW GRASS 223 and reset STEEP SHALLOW URBAN PERLND 222 to zero.

50. If STEEP SHALLOW OAK PERLND 224 < target % then add to STEEP SHALLOW GRASS 223 and reset STEEP SHALLOW OAK PERLND 224 to zero.

51. If STEEP SHALLOW JUNIPER PERLND 225 < target % then add to STEEP SHALLOW GRASS 223 and reset STEEP SHALLOW JUNIPER PERLND 225 to zero.

52. If STEEP SHALLOW CROP PERLND 226 < target % then add to STEEP SHALLOW GRASS 223 and reset STEEP SHALLOW CROP PERLND 226 to zero.

53. If STEEP SHALLOW GRASS 223 < target % then add to largest of 221,222,224,225,226 and reset STEEP SHALLOW GRASS PERLND 223 to zero.

54. Repeat for non-recharge/non-lower Glen Rose, recharge/lower Glen Rose, and non-recharge/lower Glen Rose PERLNDs.

The final step in the classification of PERLNDs for the HSPF model was the removal of the water PERLNDs (111, 211, 311, 411, 511, 611, 711, and 811). These were removed because water isn't considered a pervious land segment and they were combined with larger segments. Therefore, the total number of potential PERLNDs is 80.

Table H-1 contains typical HSPF parameters used in each of the PERLNDs.

Table H- 1. HSPF PERLND Parameter Values for the Nine Basins

RZ - Recharge Zone; CZ - Contributing Zone; F - Flat Slope; S - Steep Slope; DS - Deep Soil; SS - Shallow Soil

PERLND #	PERLND Name	LZSN	INFILT	LSUR	SLSUR	KVARY	AGWRC	INFEXP	INFILD	DEEPFR	BASETP	AGWETP	CEPSC	UZSN	NSUR	INTFW	IRC	LZETP
112	RZ, F, DS, Urban	8.0	0.400	400.0	0.0239	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.10	1.00	0.25	1.50	0.700	0.10
113	RZ, F, DS, Non-Forest	8.0	0.800	400.0	0.0288	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.10	1.00	0.25	1.50	0.700	0.15
114	RZ, F, DS, Oak, Mesquite Forest	8.0	0.800	400.0	0.0315	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.15	1.00	0.30	1.50	0.700	0.25
115	RZ, F, DS, Juniper Forest	8.0	0.800	400.0	0.0330	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.20	1.00	0.35	1.50	0.700	0.25
116	RZ, F, DS, Crops	8.0	0.500	400.0	0.0155	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.10	1.00	0.25	1.50	0.700	0.15
122	RZ, F, SS, Urban	4.0	0.200	300.0	0.0568	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.10	0.50	0.25	3.50	0.700	0.10
123	RZ, F, SS, Non-Forest	4.0	0.350	300.0	0.0609	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.10	0.50	0.25	3.50	0.700	0.15
124	RZ, F, SS, Oak, Mesquite Forest	4.0	0.350	300.0	0.0550	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.15	0.50	0.30	3.50	0.700	0.25
125	RZ, F, SS, Juniper Forest	4.0	0.350	300.0	0.0612	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.20	0.50	0.35	3.50	0.700	0.25
126	RZ, F, SS, Crops	4.0	0.300	300.0	0.0497	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.10	0.50	0.25	3.50	0.700	0.15
212	RZ, S, DS, Urban	8.0	0.300	150.0	0.1452	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.10	1.00	0.25	2.00	0.700	0.10
213	RZ, S, DS, Non-Forest	8.0	0.700	150.0	0.1262	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.10	1.00	0.25	2.00	0.700	0.15
214	RZ, S, DS, Oak, Mesquite Forest	8.0	0.700	150.0	0.1373	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.15	1.00	0.30	2.00	0.700	0.25
215	RZ, S, DS, Juniper Forest	8.0	0.700	150.0	0.1293	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.20	1.00	0.35	2.00	0.700	0.25
216	RZ, S, DS, Crops	8.0	0.300	150.0	0.1192	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.10	1.00	0.25	2.00	0.700	0.15
222	RZ, S, SS, Urban	4.0	0.200	100.0	0.1578	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.10	0.50	0.25	4.00	0.700	0.10
223	RZ, S, SS, Non-Forest	4.0	0.300	100.0	0.2299	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.10	0.50	0.25	4.00	0.700	0.15
224	RZ, S, SS, Oak, Mesquite Forest	4.0	0.300	100.0	0.2330	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.15	0.50	0.30	4.00	0.700	0.25
225	RZ, S, SS, Juniper Forest	4.0	0.300	100.0	0.2399	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.20	0.50	0.35	4.00	0.700	0.25
226	RZ, S, SS, Crops	4.0	0.300	100.0	0.2148	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.10	0.50	0.25	4.00	0.700	0.15
312	CZ, F, DS, Urban	8.0	0.300	400.0	0.0291	1.00	0.997	2.0	2.0	0.20	0.02	0.05	0.10	1.00	0.25	1.50	0.700	0.10
313	CZ, F, DS, Non-Forest	8.0	0.500	400.0	0.0347	1.00	0.997	2.0	2.0	0.20	0.02	0.05	0.10	1.00	0.25	1.50	0.700	0.15
314	CZ, F, DS, Oak, Mesquite Forest	8.0	0.500	400.0	0.0323	1.00	0.997	2.0	2.0	0.20	0.02	0.05	0.15	1.00	0.30	1.50	0.700	0.25
315	CZ, F, DS, Juniper Forest	8.0	0.500	400.0	0.0358	1.00	0.997	2.0	2.0	0.20	0.02	0.05	0.20	1.00	0.35	1.50	0.700	0.25
316	CZ, F, DS, Crops	8.0	0.400	400.0	0.0153	1.00	0.997	2.0	2.0	0.20	0.02	0.05	0.10	1.00	0.25	1.50	0.700	0.15
322	CZ, F, SS, Urban	5.0	0.250	300.0	0.0612	1.00	0.995	2.0	2.0	0.20	0.00	0.00	0.10	0.60	0.25	3.50	0.700	0.10
323	CZ, F, SS, Non-Forest	5.0	0.250	300.0	0.0602	1.00	0.995	2.0	2.0	0.20	0.00	0.00	0.10	0.60	0.25	3.50	0.700	0.15
324	CZ, F, SS, Oak, Mesquite Forest	5.0	0.250	300.0	0.0583	1.00	0.995	2.0	2.0	0.20	0.00	0.00	0.15	0.60	0.30	3.50	0.700	0.25
325	CZ, F, SS, Juniper Forest	5.0	0.250	300.0	0.0623	1.00	0.995	2.0	2.0	0.20	0.00	0.00	0.20	0.60	0.35	3.50	0.700	0.25
326	CZ, F, SS, Crops	5.0	0.250	300.0	0.0544	1.00	0.995	2.0	2.0	0.20	0.00	0.00	0.10	0.60	0.25	3.50	0.700	0.15
412	CZ, S, DS, Urban	8.0	0.300	150.0	0.1280	1.00	0.995	2.0	2.0	0.20	0.02	0.05	0.10	1.00	0.25	2.00	0.700	0.10
413	CZ, S, DS, Non-Forest	8.0	0.350	150.0	0.1218	1.00	0.995	2.0	2.0	0.20	0.02	0.05	0.10	1.00	0.25	2.00	0.700	0.15
414	CZ, S, DS, Oak, Mesquite Forest	8.0	0.350	150.0	0.1262	1.00	0.995	2.0	2.0	0.20	0.02	0.05	0.15	1.00	0.30	2.00	0.700	0.25
415	CZ, S, DS, Juniper Forest	8.0	0.350	150.0	0.1225	1.00	0.995	2.0	2.0	0.20	0.02	0.05	0.20	1.00	0.35	2.00	0.700	0.25
416	CZ, S, DS, Crops	8.0	0.350	150.0	0.1275	1.00	0.995	2.0	2.0	0.20	0.02	0.05	0.10	1.00	0.25	2.00	0.700	0.15
422	CZ, S, SS, Urban	5.0	0.100	100.0	0.1841	1.00	0.990	2.0	2.0	0.20	0.00	0.00	0.10	0.60	0.25	4.00	0.700	0.10
423	CZ, S, SS, Non-Forest	5.0	0.150	100.0	0.2222	1.00	0.990	2.0	2.0	0.20	0.00	0.00	0.10	0.60	0.25	4.00	0.700	0.15
424	CZ, S, SS, Oak, Mesquite Forest	5.0	0.150	100.0	0.3016	1.00	0.990	2.0	2.0	0.20	0.00	0.00	0.15	0.60	0.30	4.00	0.700	0.25
425	CZ, S, SS, Juniper Forest	5.0	0.150	100.0	0.2889	1.00	0.990	2.0	2.0	0.20	0.00	0.00	0.20	0.60	0.35	4.00	0.700	0.25
426	CZ, S, SS, Crops	5.0	0.150	100.0	0.2577	1.00	0.990	2.0	2.0	0.20	0.00	0.00	0.10	0.60	0.25	4.00	0.700	0.15

HSPF Parameters

LZSN	Lower Zone Storage Nominal
INFILT	Infiltration rate
LSUR	Length of Surface runoff
SLSUR	Slope of Surface runoff
KVARY	Variable non-exponential groundwater release rate
AGWRC	Active Groundwater Recession Constant
INFEXP	Infiltration Exponent
INFILD	Ratio between mean and max infiltration
DEEPFR	Deep Fraction groundwater
BASETP	Base flow Evapotranspiration
AGWETP	Active Groundwater Evapotranspiration
CEPSC	Interception Storage
UZSN	Upper Zone Storage Nominal
NSUR	Surface roughness coefficient
INTFW	Interflow
IRC	Interflow Recession Constant
LZETP	Lower Zone Evapotranspiration

Table H-1. HSPF PERLND Parameter Values for the Nine Basins

RZ - Recharge Zone; CZ - Contributing Zone; F - Flat Slope; S - Steep Slope; DS - Deep Soil; SS - Shallow Soil

PERLND #	PERLND Name	LZSN	INFILT	LSUR	SLSUR*	KVARY	AGWRC	INFEXP	INFILD	DEEPFR	BASETP	AGWETP	CEPSC	UZSN
512	RZ, F, DS, Urban	8.0	0.400	400.0	0.0402	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.10	1.00
513	RZ, F, DS, Non-Forest	8.0	0.800	400.0	0.0398	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.10	1.00
514	RZ, F, DS, Oak, Mesquite Forest	8.0	0.800	400.0	0.0447	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.15	1.00
515	RZ, F, DS, Juniper Forest	8.0	0.800	400.0	0.0467	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.20	1.00
516	RZ, F, DS, Crops	8.0	0.500	400.0	0.0324	1.00	0.997	2.0	2.0	1.00	0.02	0.05	0.10	1.00
522	RZ, F, SS, Urban	4.0	0.200	300.0	0.0844	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.10	0.50
523	RZ, F, SS, Non-Forest	4.0	0.350	300.0	0.0854	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.10	0.50
524	RZ, F, SS, Oak, Mesquite Forest	4.0	0.350	300.0	0.0893	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.15	0.50
525	RZ, F, SS, Juniper Forest	4.0	0.350	300.0	0.0903	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.20	0.50
526	RZ, F, SS, Crops	4.0	0.300	300.0	0.0750	1.00	0.995	2.0	2.0	1.00	0.00	0.00	0.10	0.50
612	RZ, S, DS, Urban	8.0	0.300	150.0	0.0954	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.10	1.00
613	RZ, S, DS, Non-Forest	8.0	0.700	150.0	0.0871	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.10	1.00
614	RZ, S, DS, Oak, Mesquite Forest	8.0	0.700	150.0	0.0880	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.15	1.00
615	RZ, S, DS, Juniper Forest	8.0	0.700	150.0	0.0862	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.20	1.00
616	RZ, S, DS, Crops	8.0	0.300	150.0	0.0787	1.00	0.995	2.0	2.0	1.00	0.02	0.05	0.10	1.00
622	RZ, S, SS, Urban	4.0	0.200	100.0	0.1272	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.10	0.50
623	RZ, S, SS, Non-Forest	4.0	0.300	100.0	0.1327	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.10	0.50
624	RZ, S, SS, Oak, Mesquite Forest	4.0	0.300	100.0	0.1500	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.15	0.50
625	RZ, S, SS, Juniper Forest	4.0	0.300	100.0	0.1591	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.20	0.50
626	RZ, S, SS, Crops	4.0	0.300	100.0	0.1180	1.00	0.990	2.0	2.0	1.00	0.00	0.00	0.10	0.50
712	CZ, F, DS, Urban	8.0	0.300	400.0	0.0496	1.00	0.997	2.0	2.0	0.50	0.02	0.05	0.10	1.00
713	CZ, F, DS, Non-Forest	8.0	0.500	400.0	0.0512	1.00	0.997	2.0	2.0	0.50	0.02	0.05	0.10	1.00
714	CZ, F, DS, Oak, Mesquite Forest	8.0	0.500	400.0	0.0543	1.00	0.997	2.0	2.0	0.50	0.02	0.05	0.15	1.00
715	CZ, F, DS, Juniper Forest	8.0	0.500	400.0	0.0523	1.00	0.997	2.0	2.0	0.50	0.02	0.05	0.20	1.00
716	CZ, F, DS, Crops	8.0	0.400	400.0	0.0409	1.00	0.997	2.0	2.0	0.50	0.02	0.05	0.10	1.00
722	CZ, F, SS, Urban	5.0	0.250	300.0	0.0977	1.00	0.995	2.0	2.0	0.50	0.00	0.00	0.10	0.60
723	CZ, F, SS, Non-Forest	5.0	0.250	300.0	0.0818	1.00	0.995	2.0	2.0	0.50	0.00	0.00	0.10	0.60
724	CZ, F, SS, Oak, Mesquite Forest	5.0	0.250	300.0	0.0972	1.00	0.995	2.0	2.0	0.50	0.00	0.00	0.15	0.60
725	CZ, F, SS, Juniper Forest	5.0	0.250	300.0	0.0806	1.00	0.995	2.0	2.0	0.50	0.00	0.00	0.20	0.60
726	CZ, F, SS, Crops	5.0	0.250	300.0	0.0837	1.00	0.995	2.0	2.0	0.50	0.00	0.00	0.10	0.60
812	CZ, S, DS, Urban	8.0	0.300	150.0	0.1016	1.00	0.995	2.0	2.0	0.50	0.02	0.05	0.10	1.00
813	CZ, S, DS, Non-Forest	8.0	0.350	150.0	0.0965	1.00	0.995	2.0	2.0	0.50	0.02	0.05	0.10	1.00
814	CZ, S, DS, Oak, Mesquite Forest	8.0	0.350	150.0	0.1004	1.00	0.995	2.0	2.0	0.50	0.02	0.05	0.15	1.00
815	CZ, S, DS, Juniper Forest	8.0	0.350	150.0	0.0955	1.00	0.995	2.0	2.0	0.50	0.02	0.05	0.20	1.00
816	CZ, S, DS, Crops	8.0	0.350	150.0	0.1027	1.00	0.995	2.0	2.0	0.50	0.02	0.05	0.10	1.00
822	CZ, S, SS, Urban	5.0	0.100	100.0	0.1302	1.00	0.990	2.0	2.0	0.50	0.00	0.00	0.10	0.60
823	CZ, S, SS, Non-Forest	5.0	0.150	100.0	0.1122	1.00	0.990	2.0	2.0	0.50	0.00	0.00	0.10	0.60
824	CZ, S, SS, Oak, Mesquite Forest	5.0	0.150	100.0	0.1289	1.00	0.990	2.0	2.0	0.50	0.00	0.00	0.15	0.60
825	CZ, S, SS, Juniper Forest	5.0	0.150	100.0	0.1127	1.00	0.990	2.0	2.0	0.50	0.00	0.00	0.20	0.60
826	CZ, S, SS, Crops	5.0	0.150	100.0	0.1193	1.00	0.990	2.0	2.0	0.50	0.00	0.00	0.10	0.60

* SLSUR values are specific slope values for each basin

HSPF Parameters

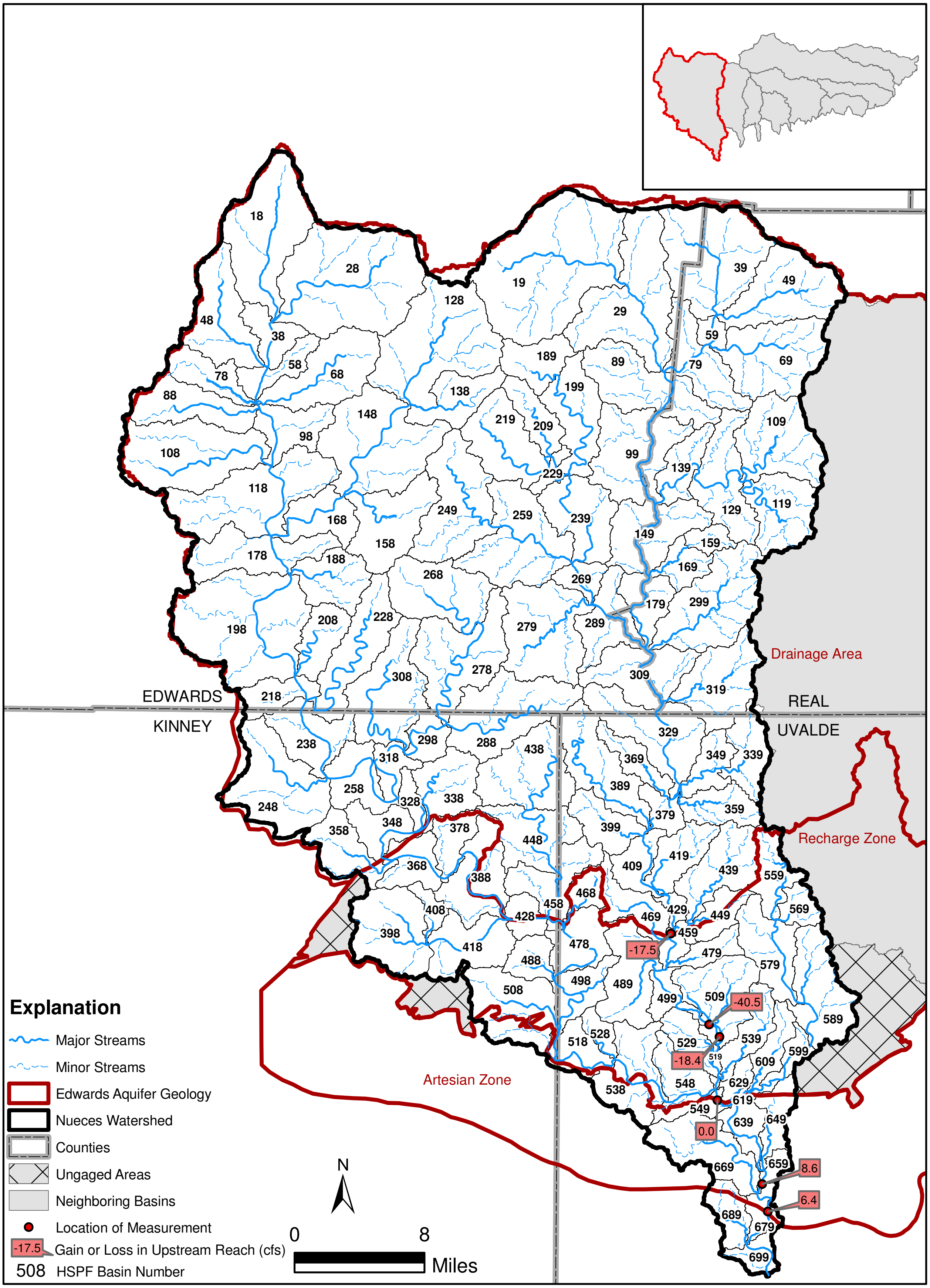
LZSN	Lower Zone Storage Nominal
INFILT	Infiltration rate
LSUR	Length of Surface runoff
SLSUR	Slope of Surface runoff
KVARY	Variable non-exponential groundwater release rate
AGWRC	Active Groundwater Recession Constant
INFEXP	Infiltration Exponent
INFILD	Ratio between mean and max infiltration
DEEPFR	Deep Fraction groundwater
BASETP	Base flow Evapotranspiration
AGWETP	Active Groundwater Evapotranspiration
CEPSC	Interception Storage
UZSN	Upper Zone Storage Nominal

APPENDIX I

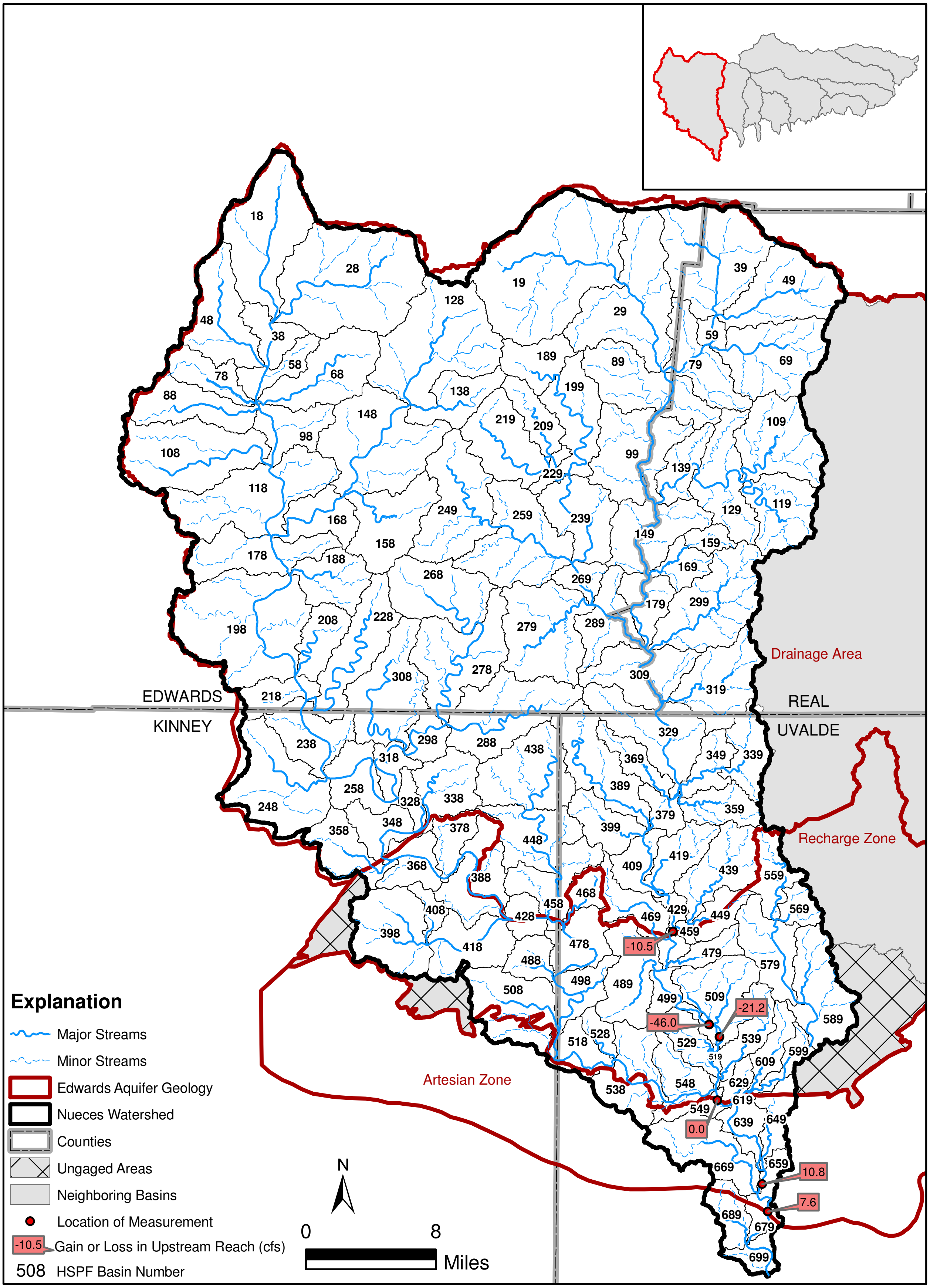
Maps of Gain-Loss Studies

Channel loss information is critical for determining recharge to the Edwards aquifer because a portion of the recharge occurs through this mechanism. Channel gain-loss information that had been collected from many studies over several decades was assimilated and summarized by the USGS (2002) for approximately ten different streams in the nine-basin area. Some of the studies were completed in the contributing zone and others in the recharge zone, and some in both zones. One hundred and fifteen (115) gain-loss studies have been documented in the nine basins. Appendix I contains maps for each study completed in each basin. Each map illustrates the delineated subwatersheds, the watershed number as defined in the HSPF model, and the location of the measurement points for a particular study. At each measurement location, the gain (positive values) or loss (negative values) from the upstream segment is posted. These maps illustrate the location of the studies, and help illustrate the variation in gain or loss estimates that occur in different studies.

NUECES BASIN



USGS Gain/Loss Study 182 in the Nueces Basin



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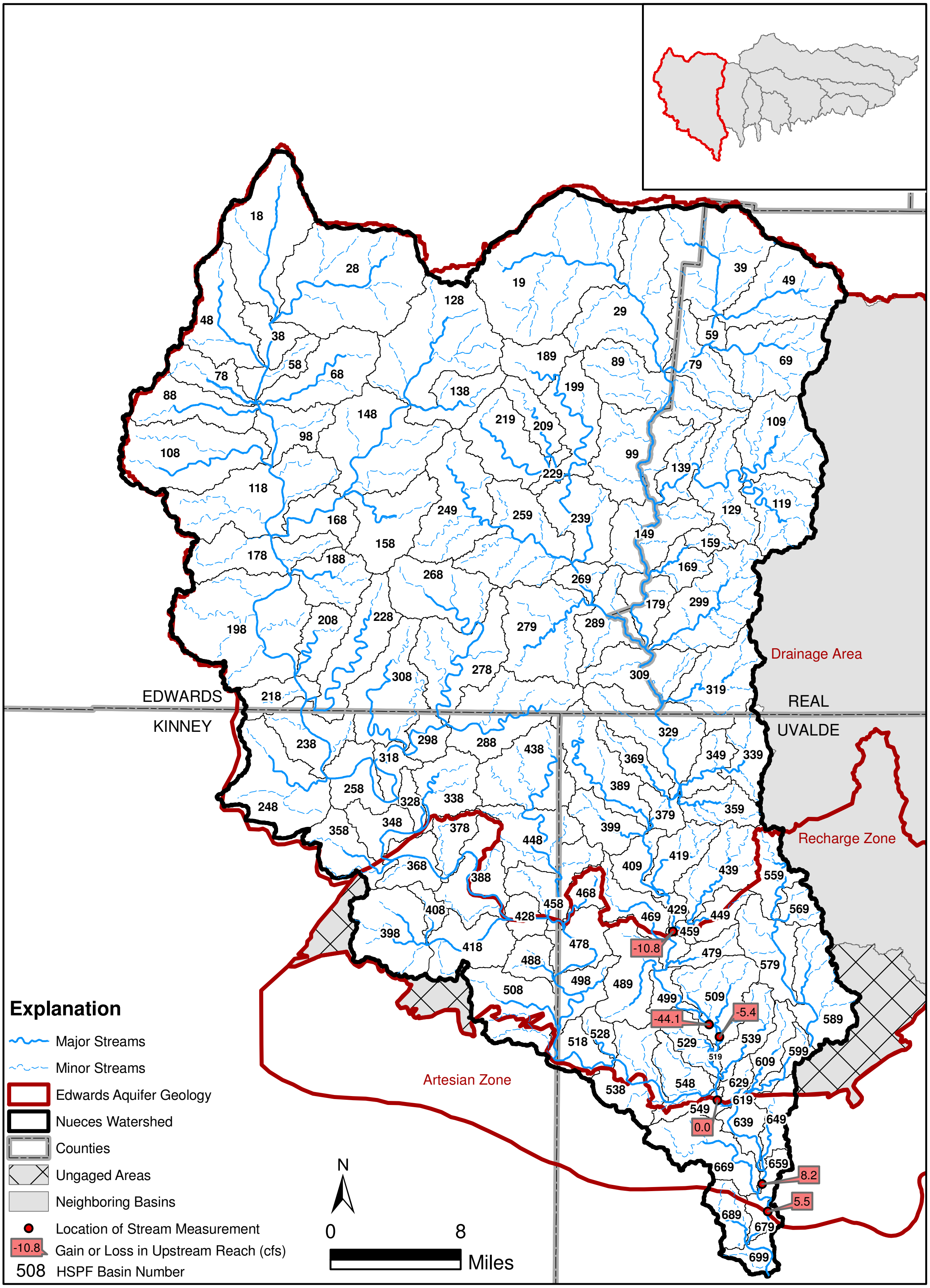

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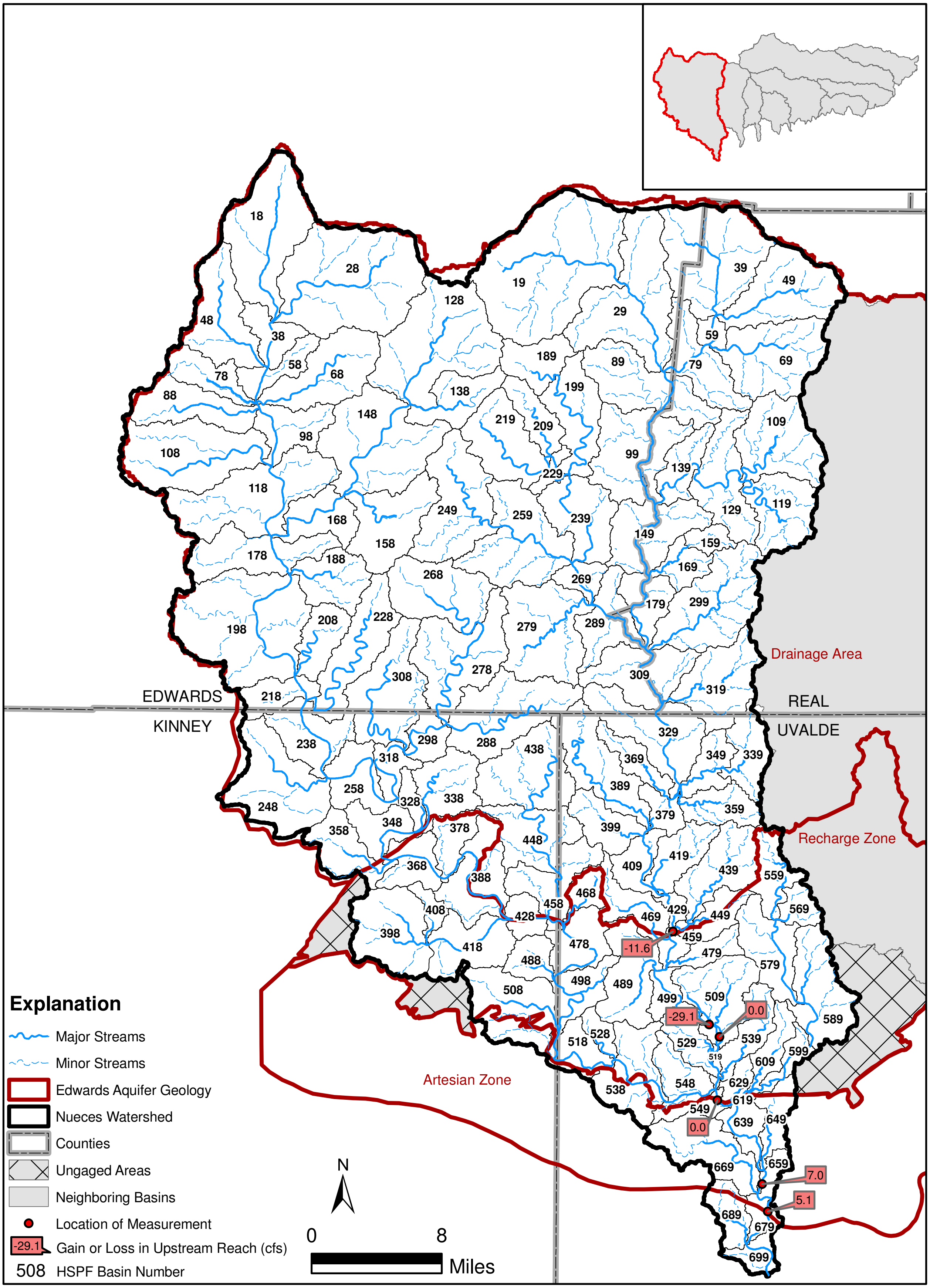

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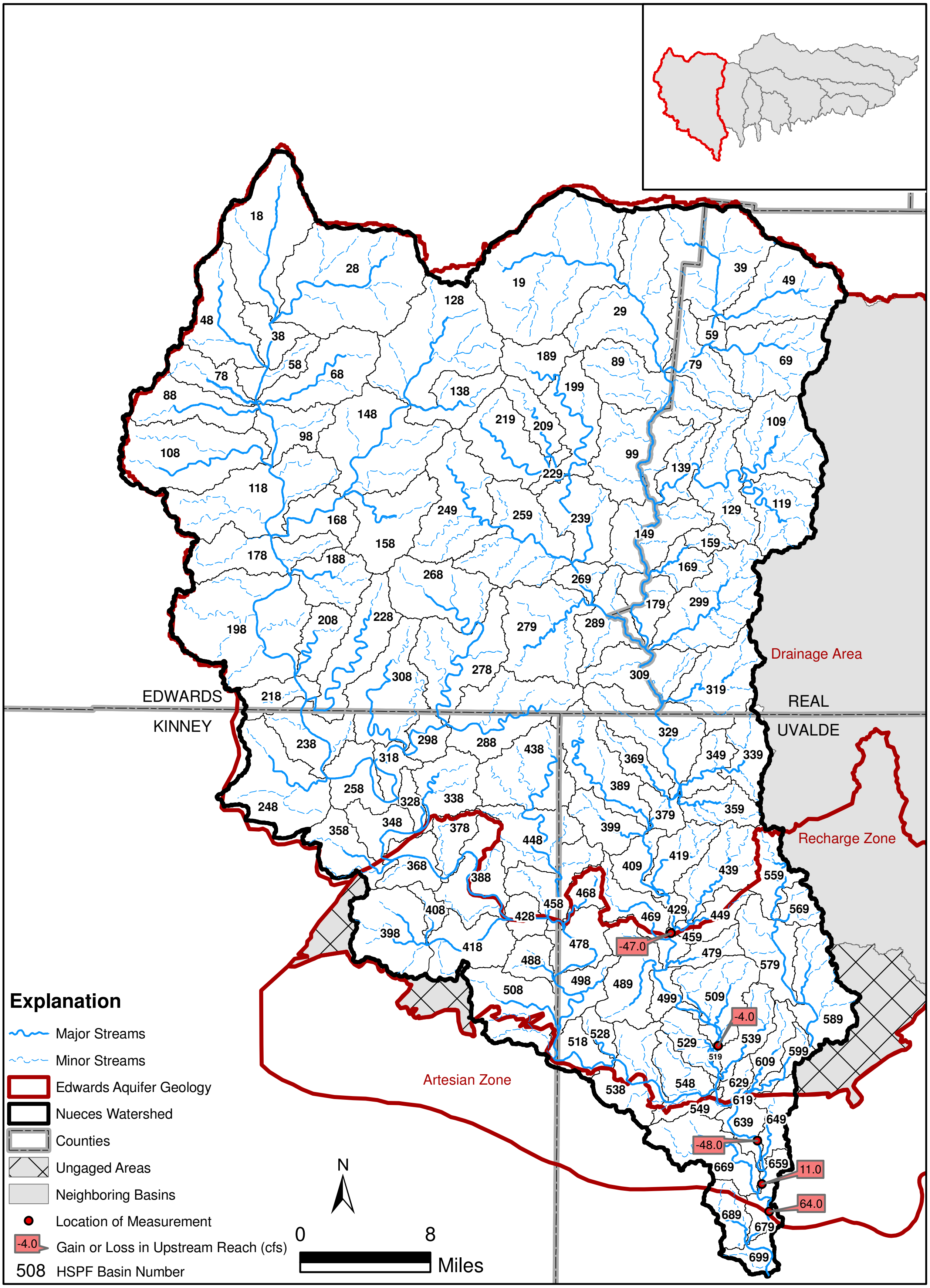

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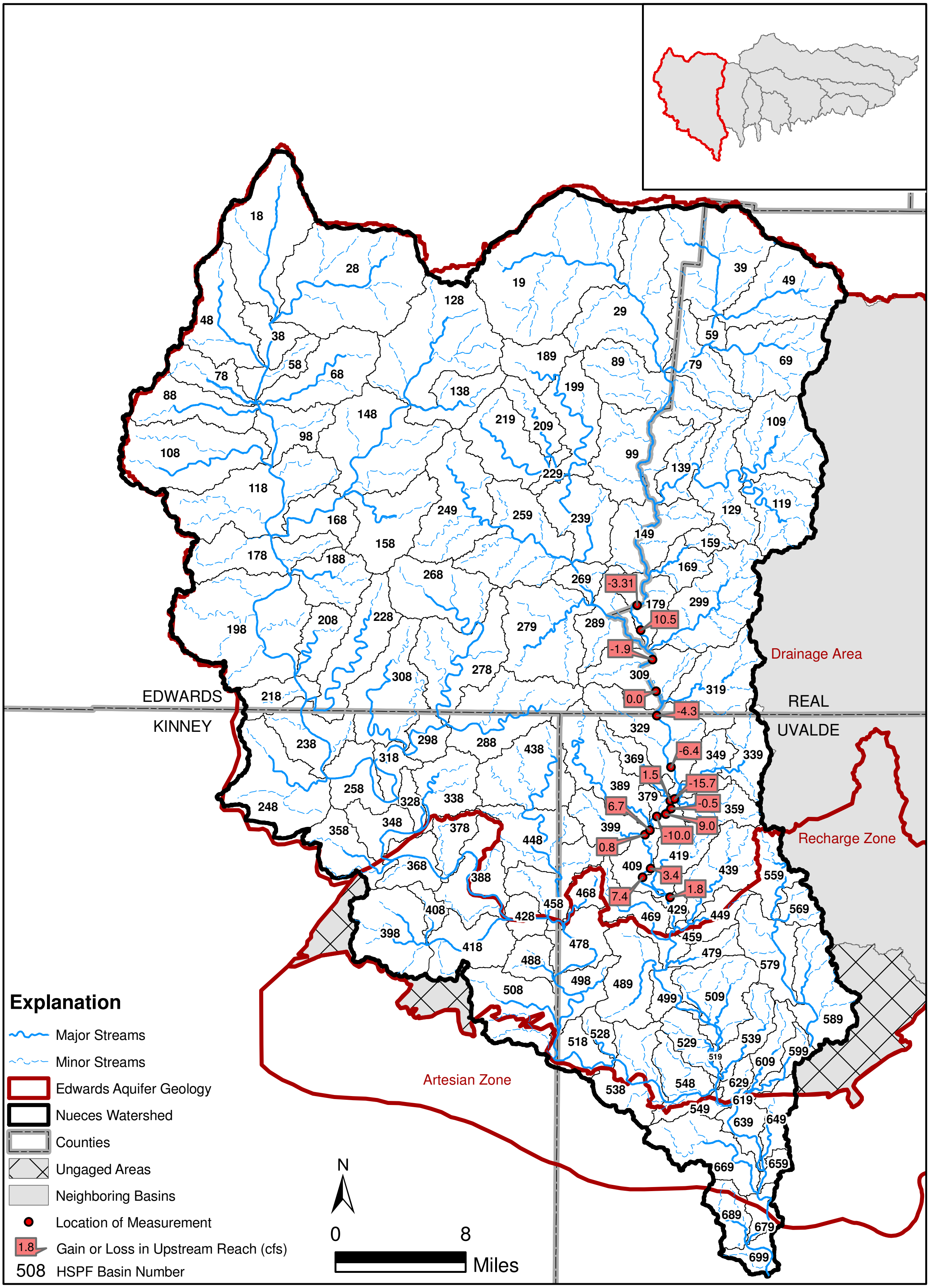

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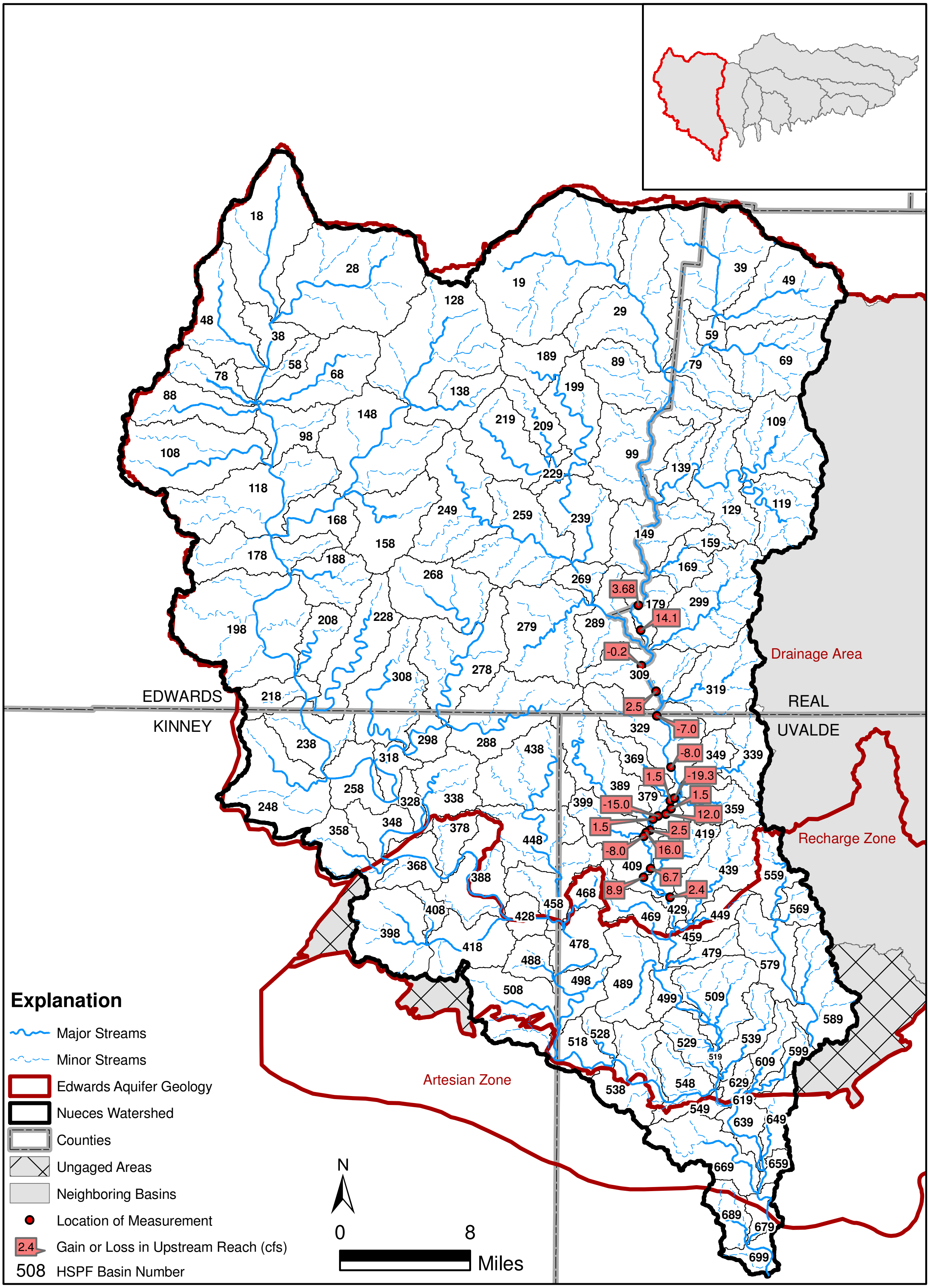

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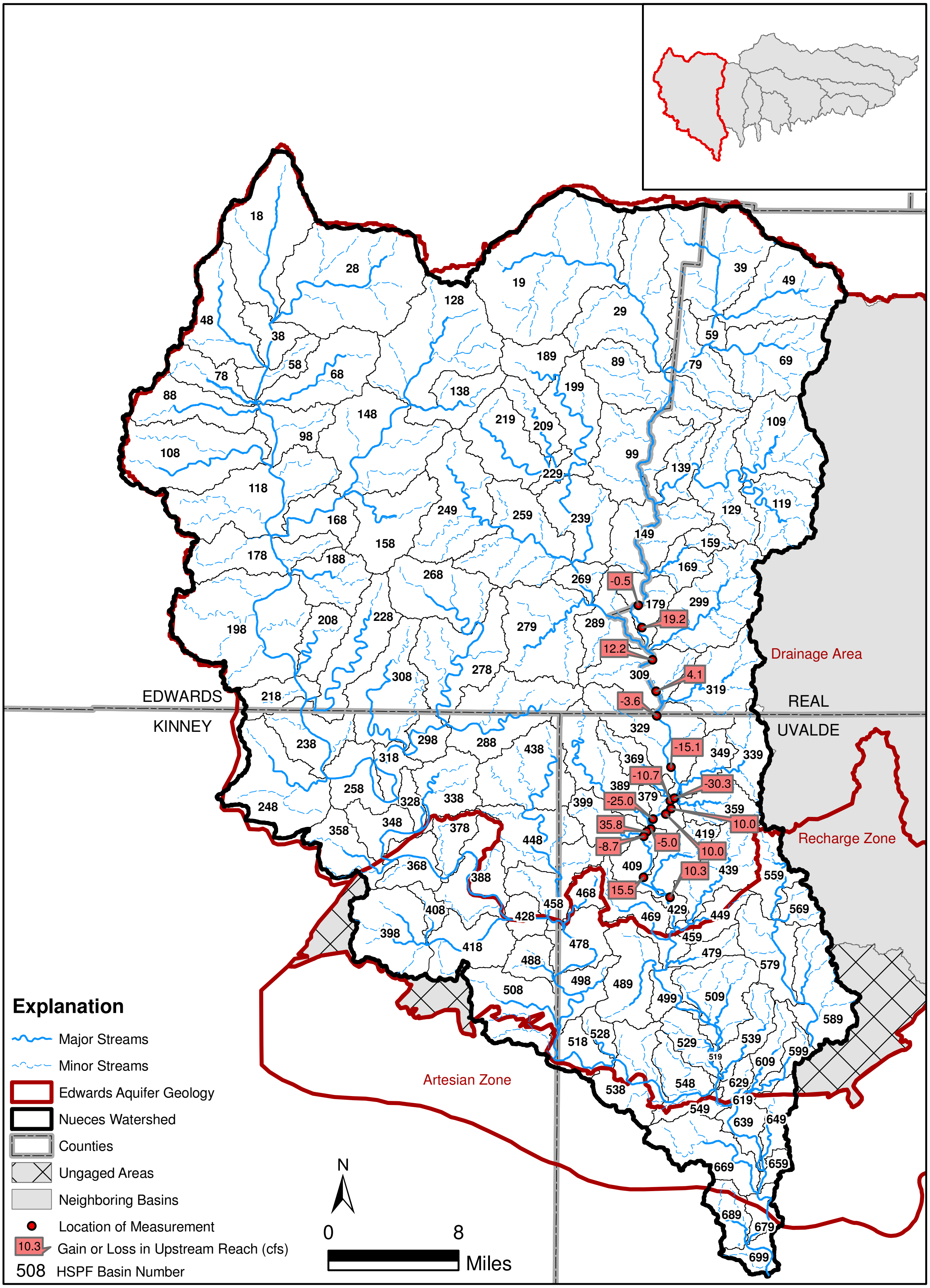

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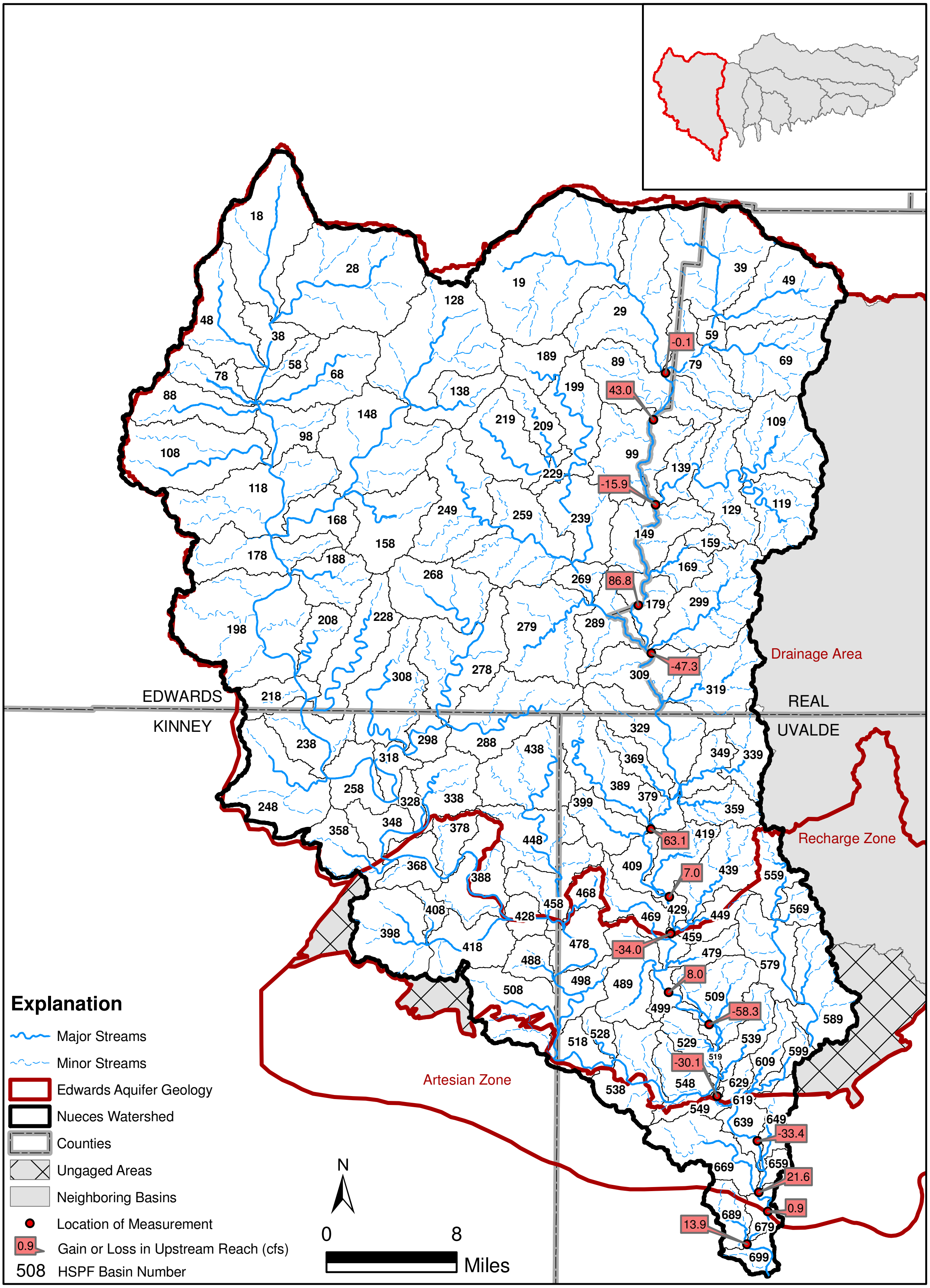

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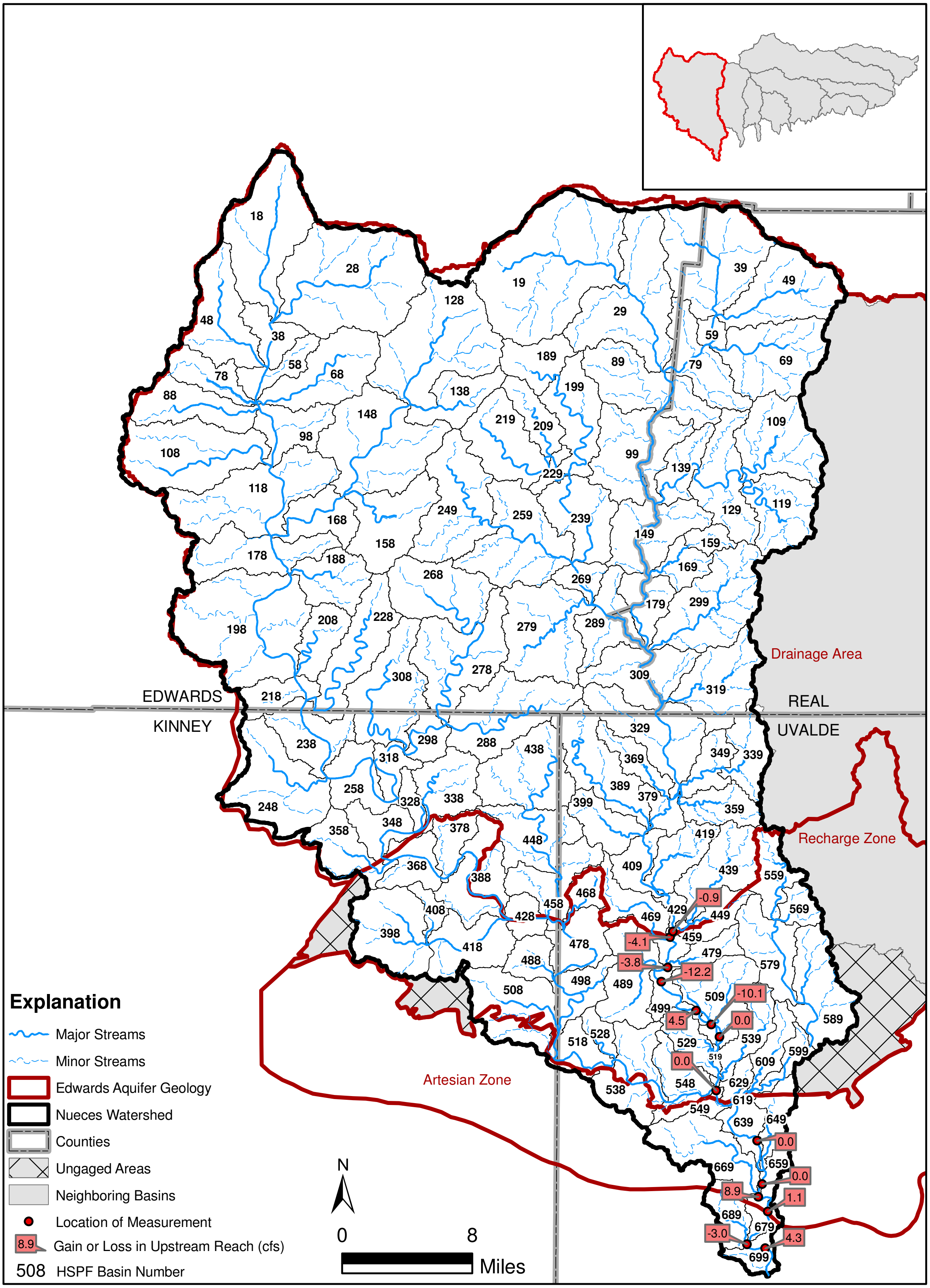

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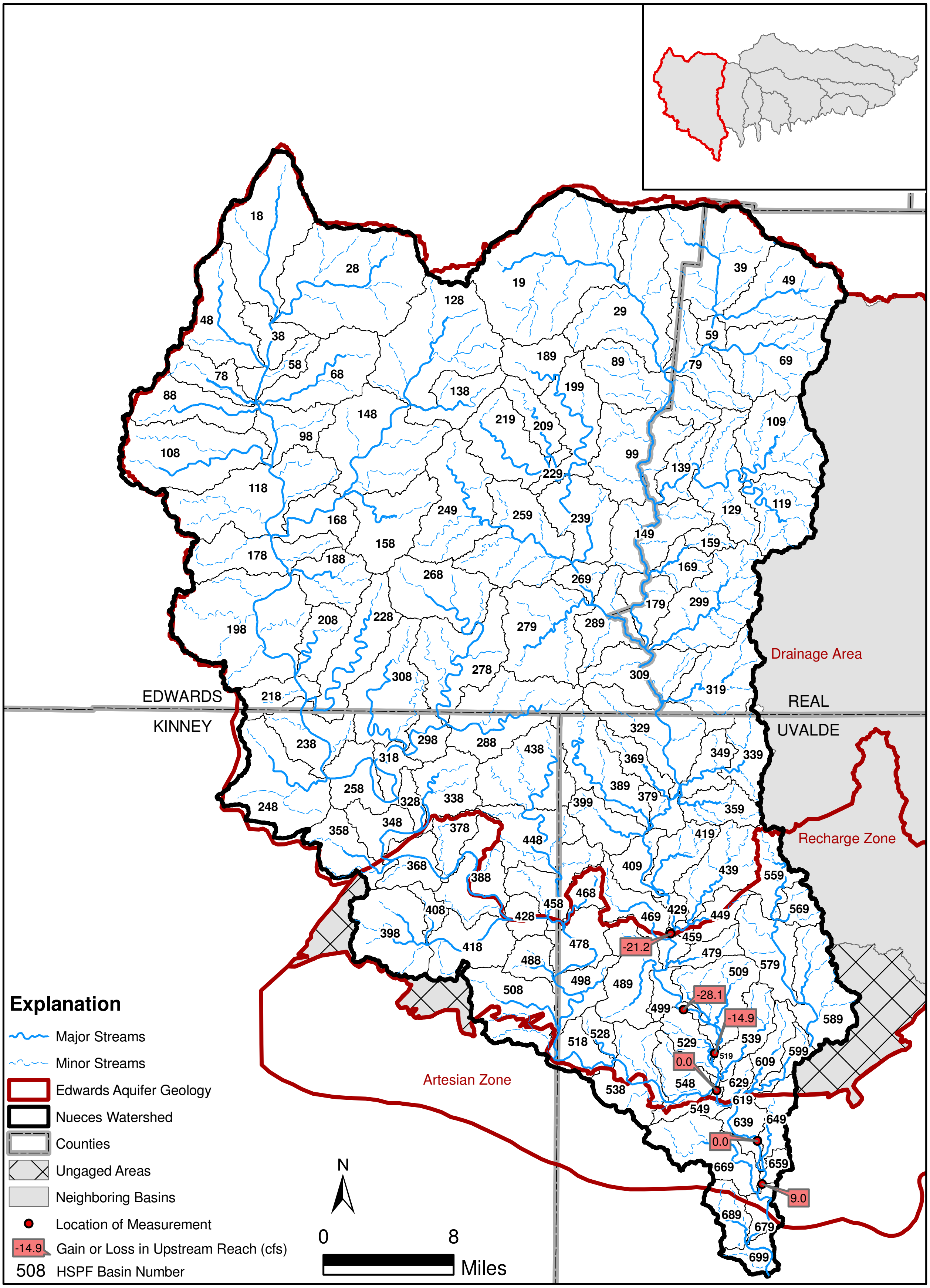

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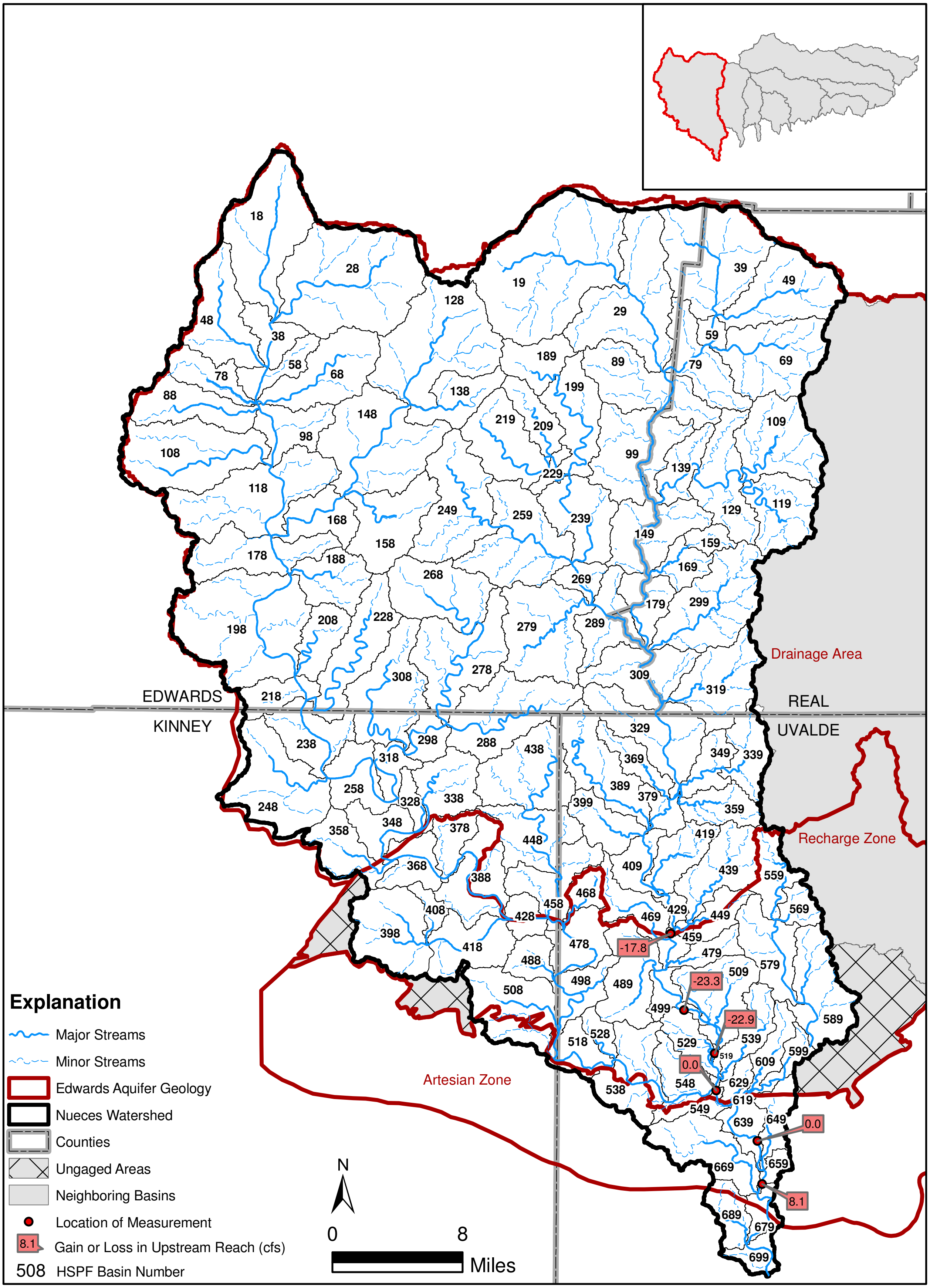

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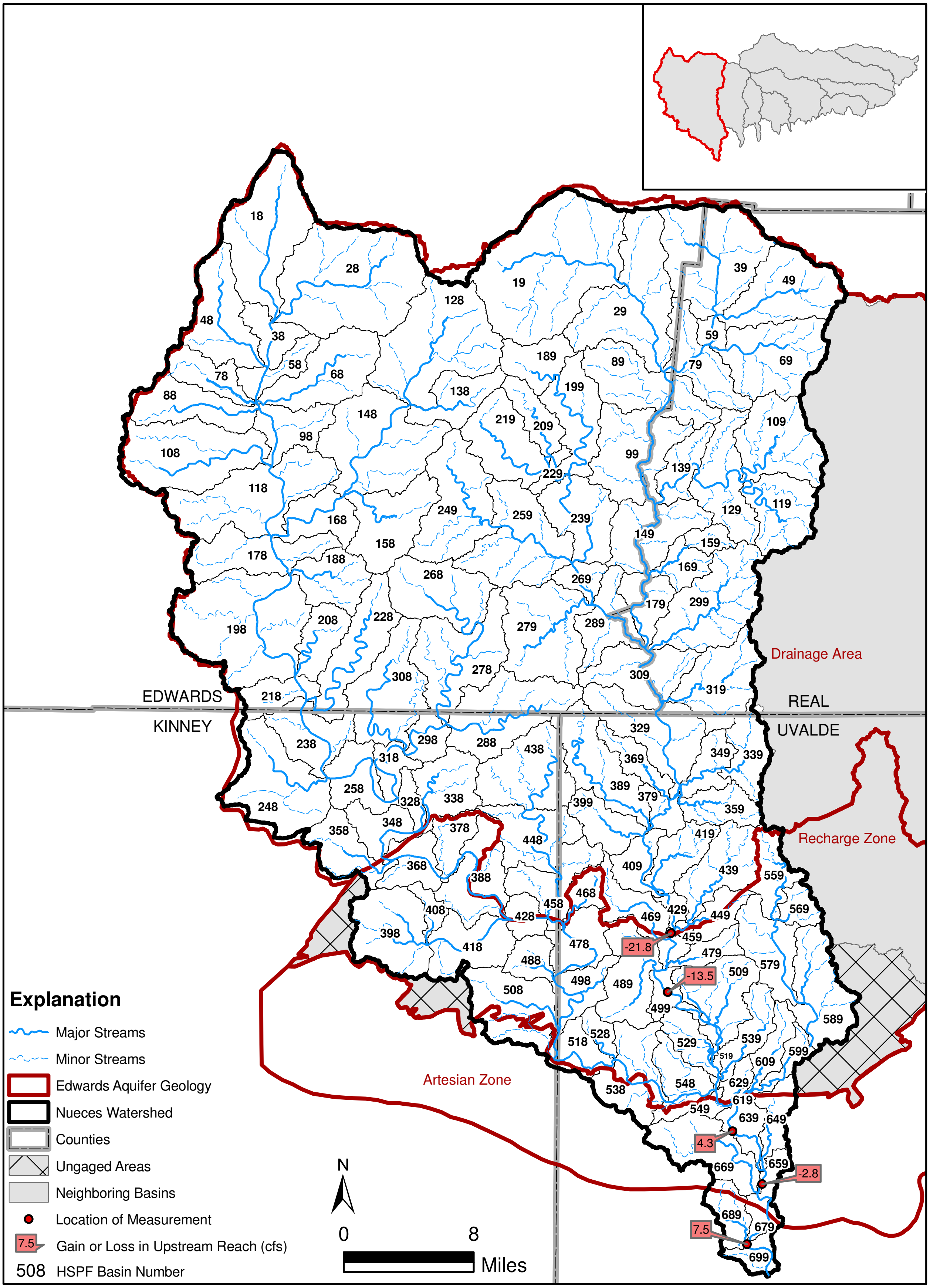

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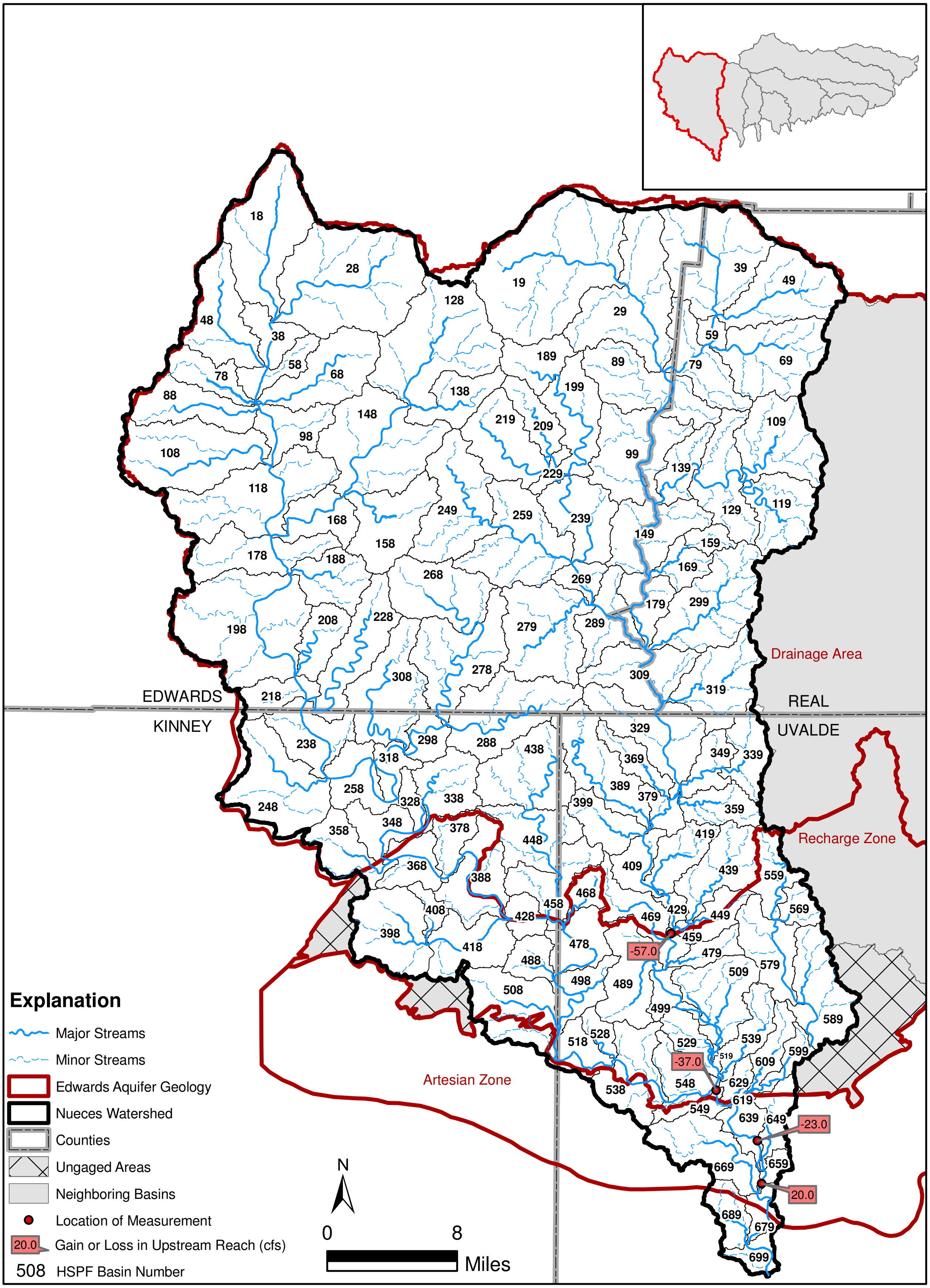

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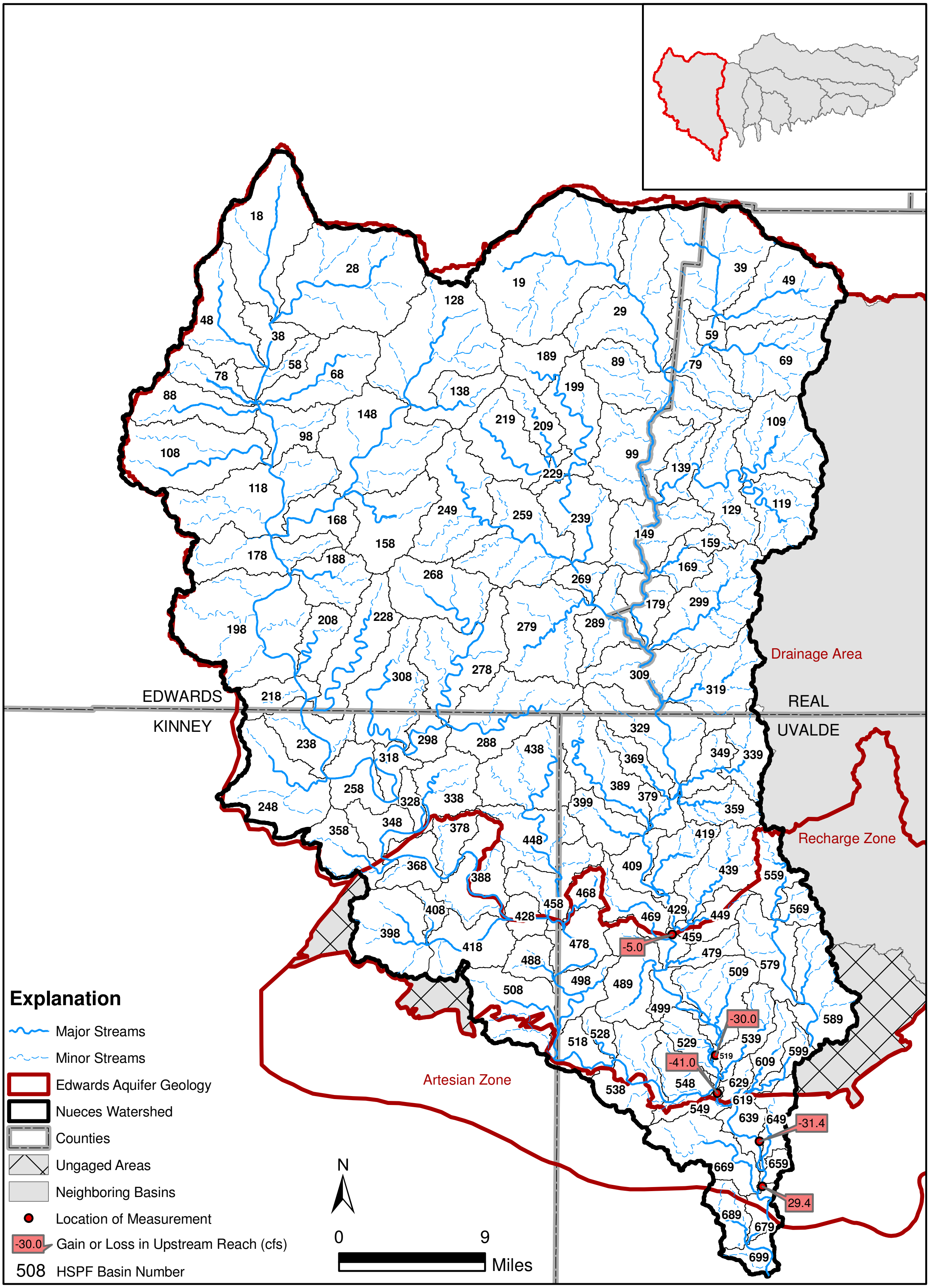

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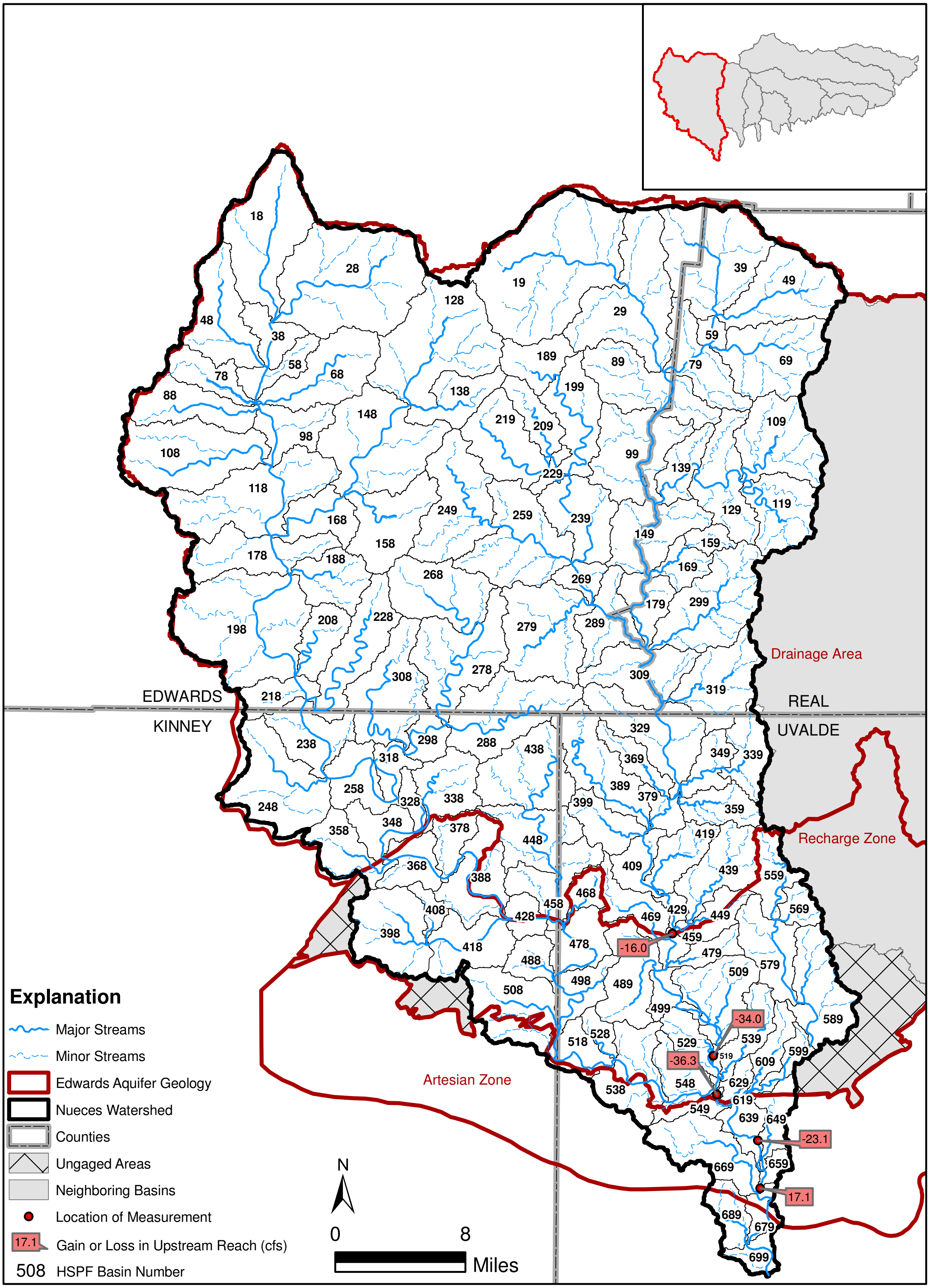

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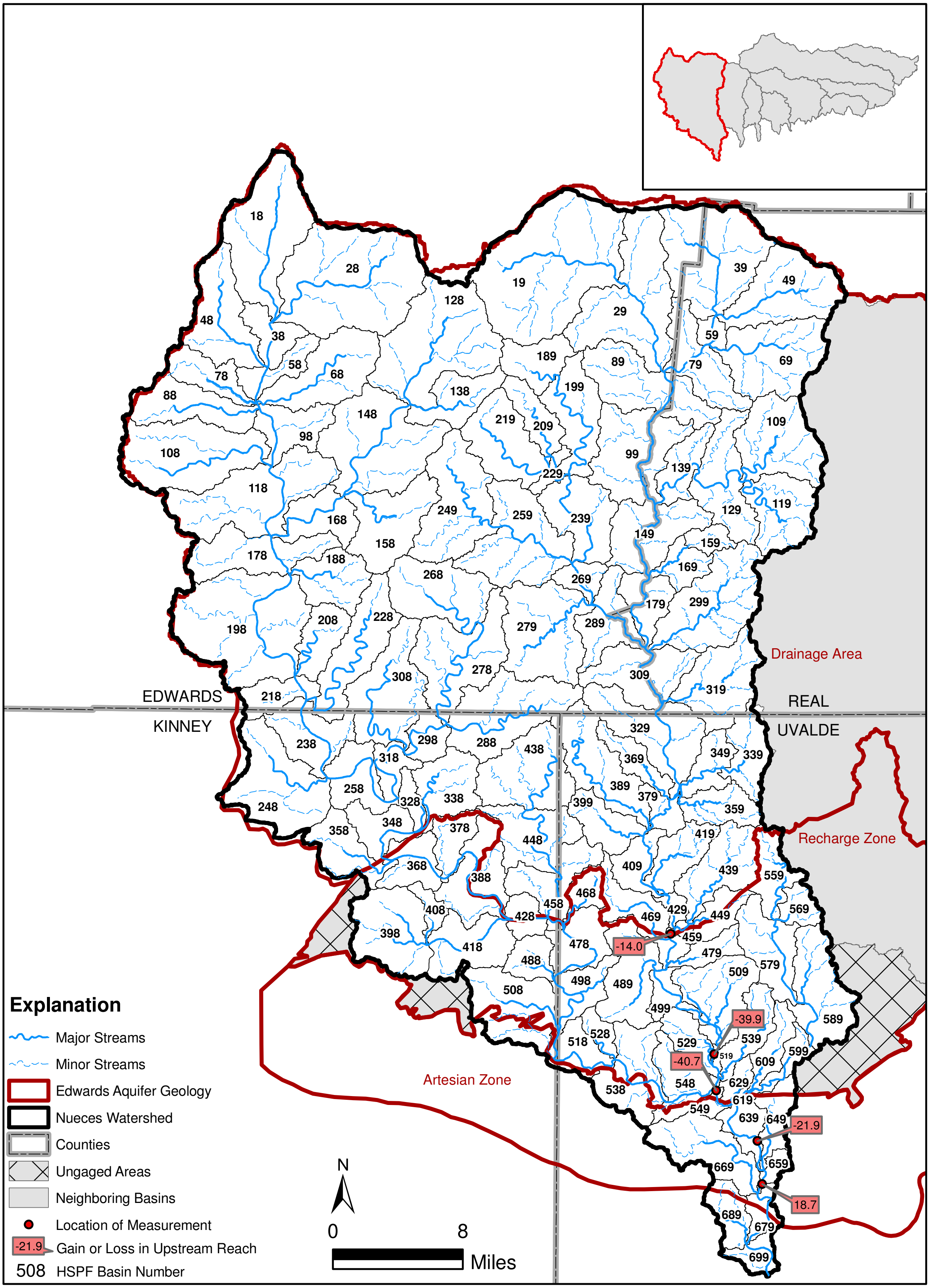

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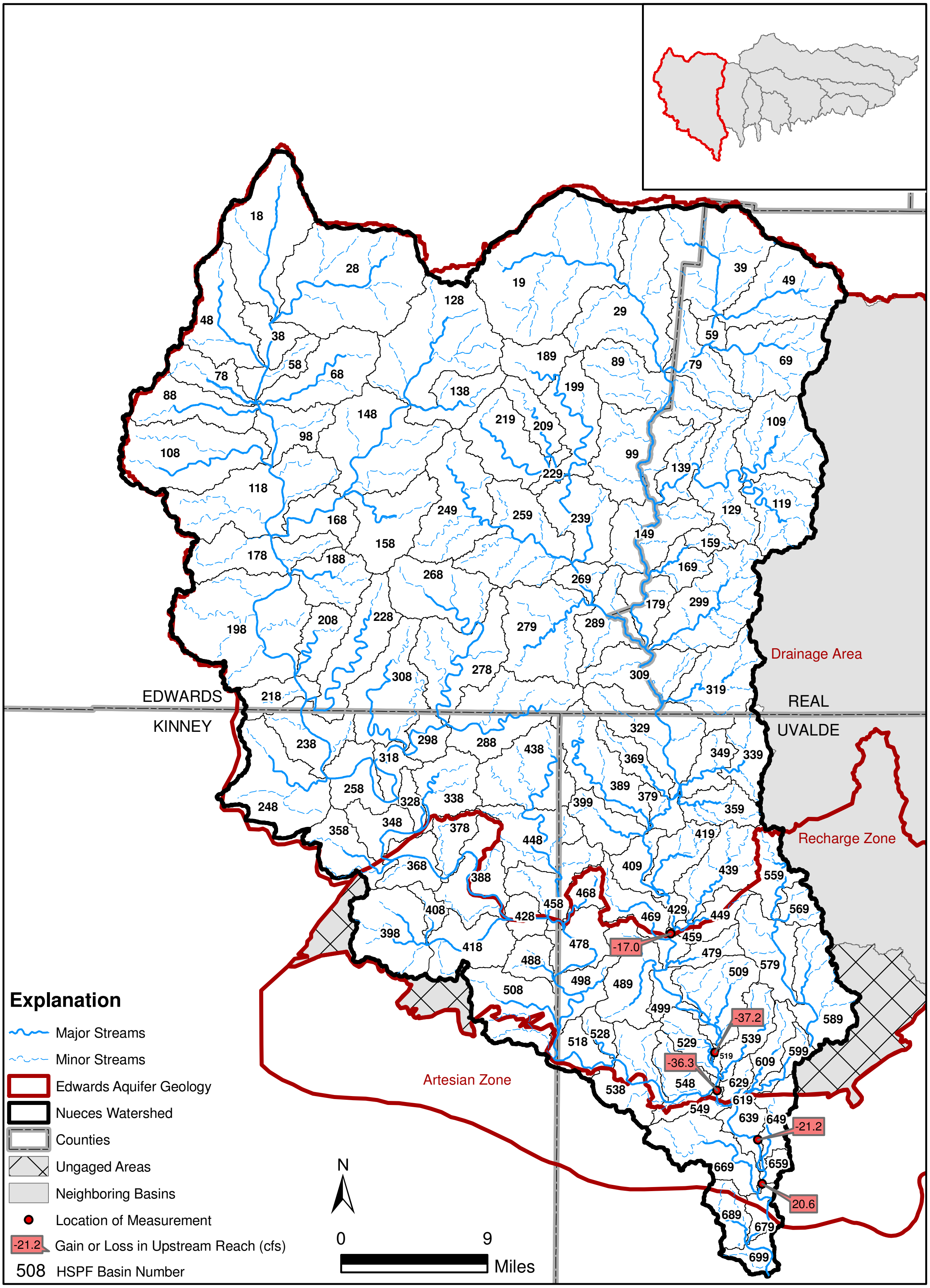

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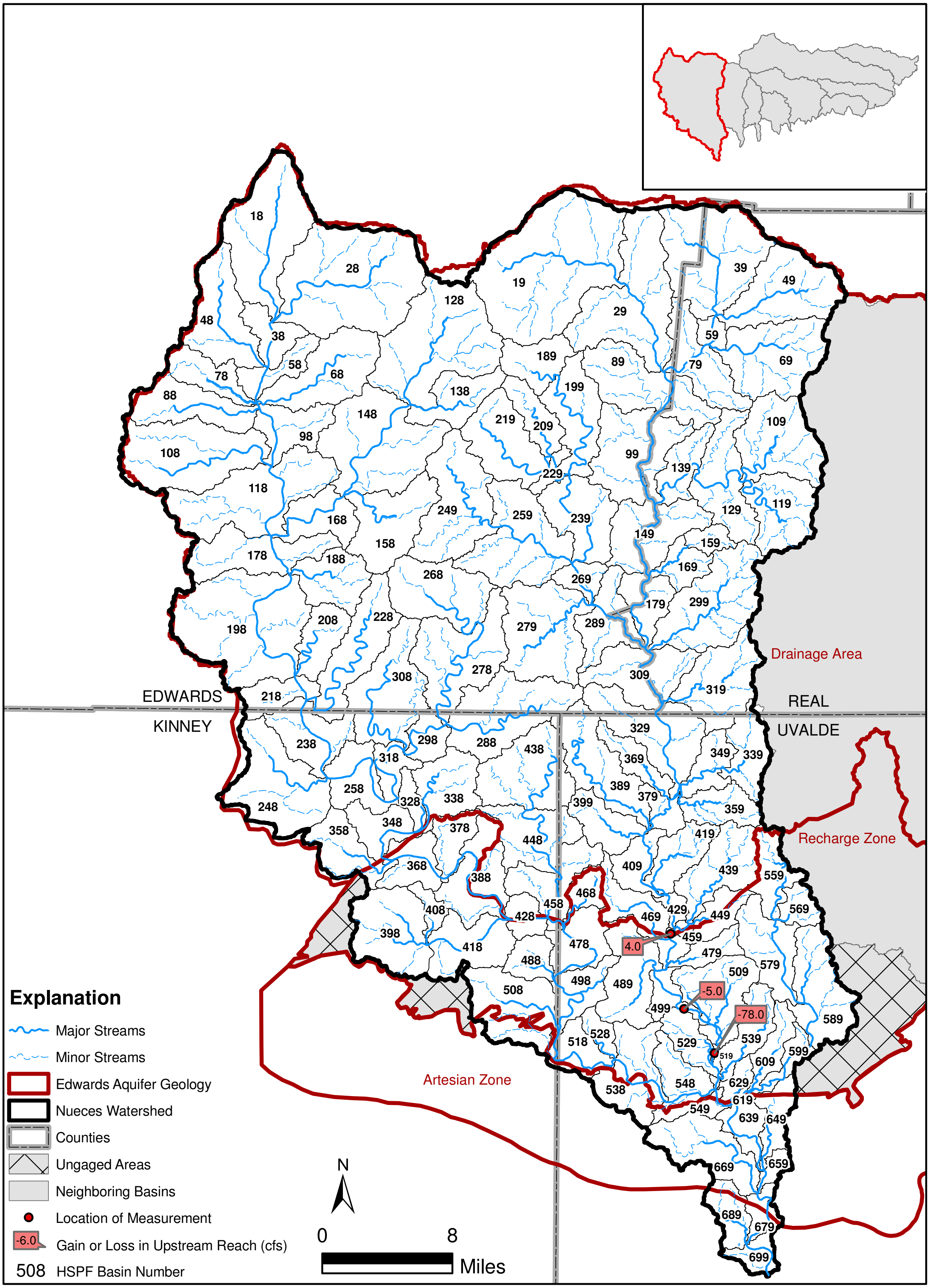

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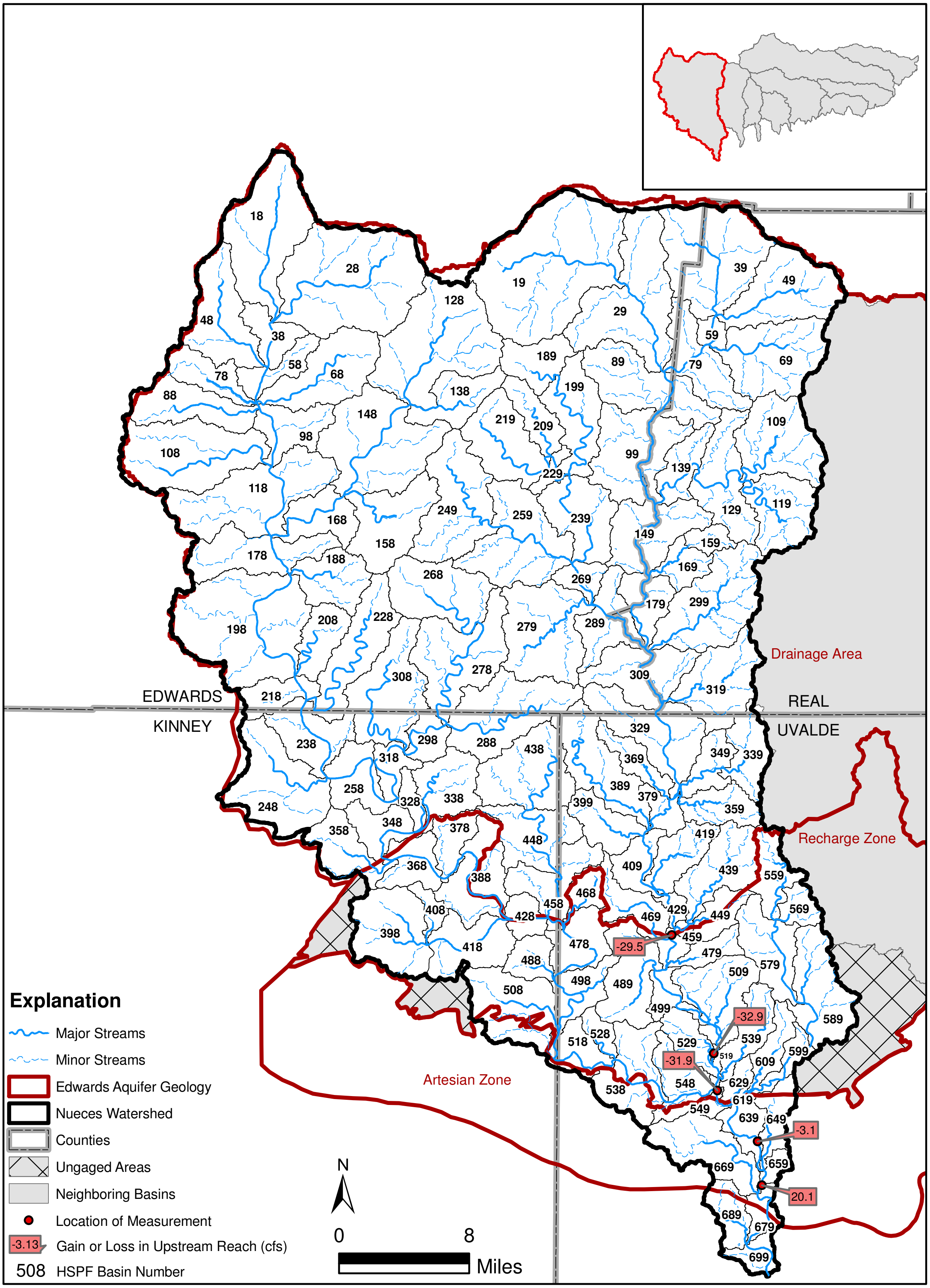

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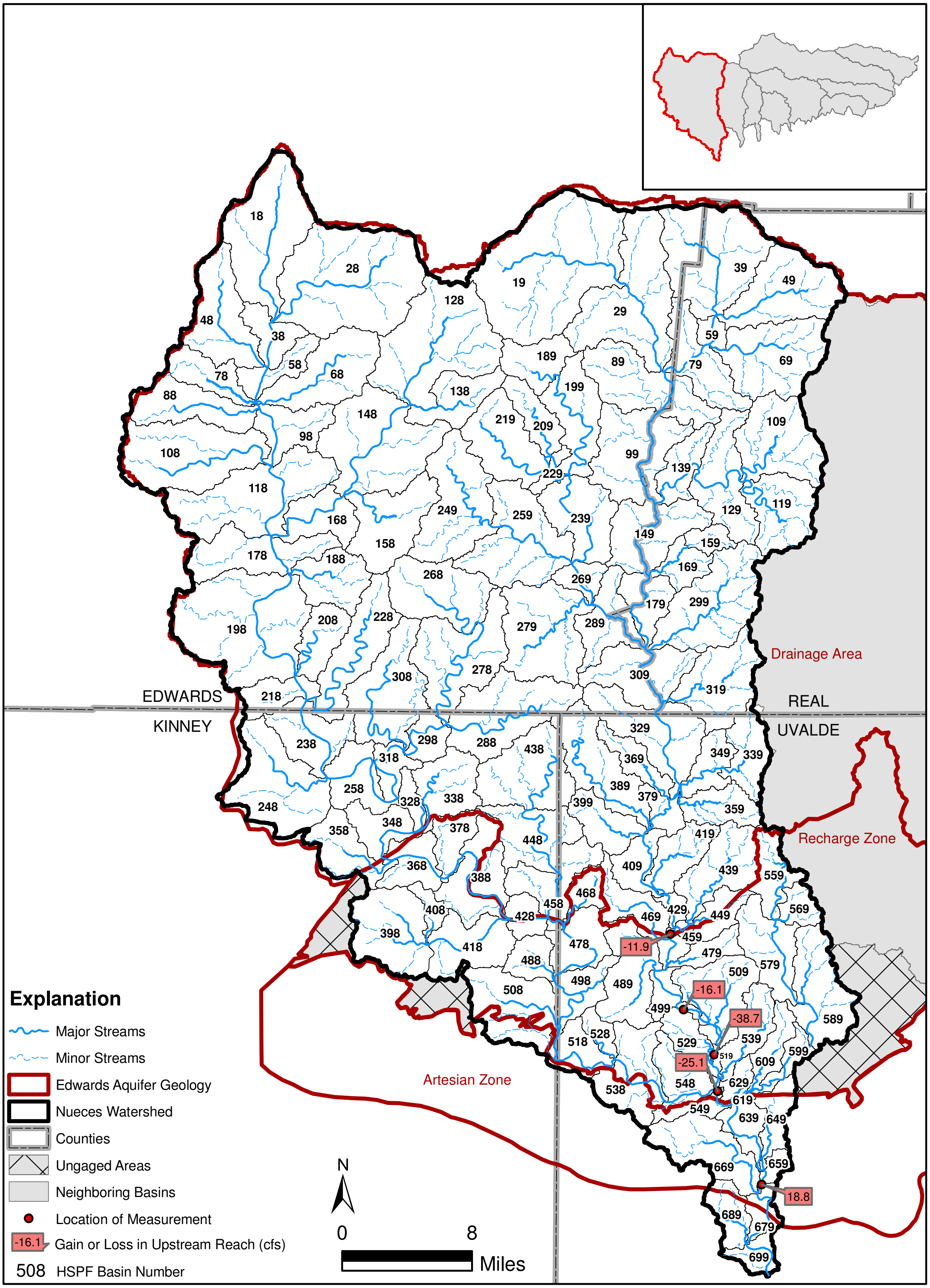

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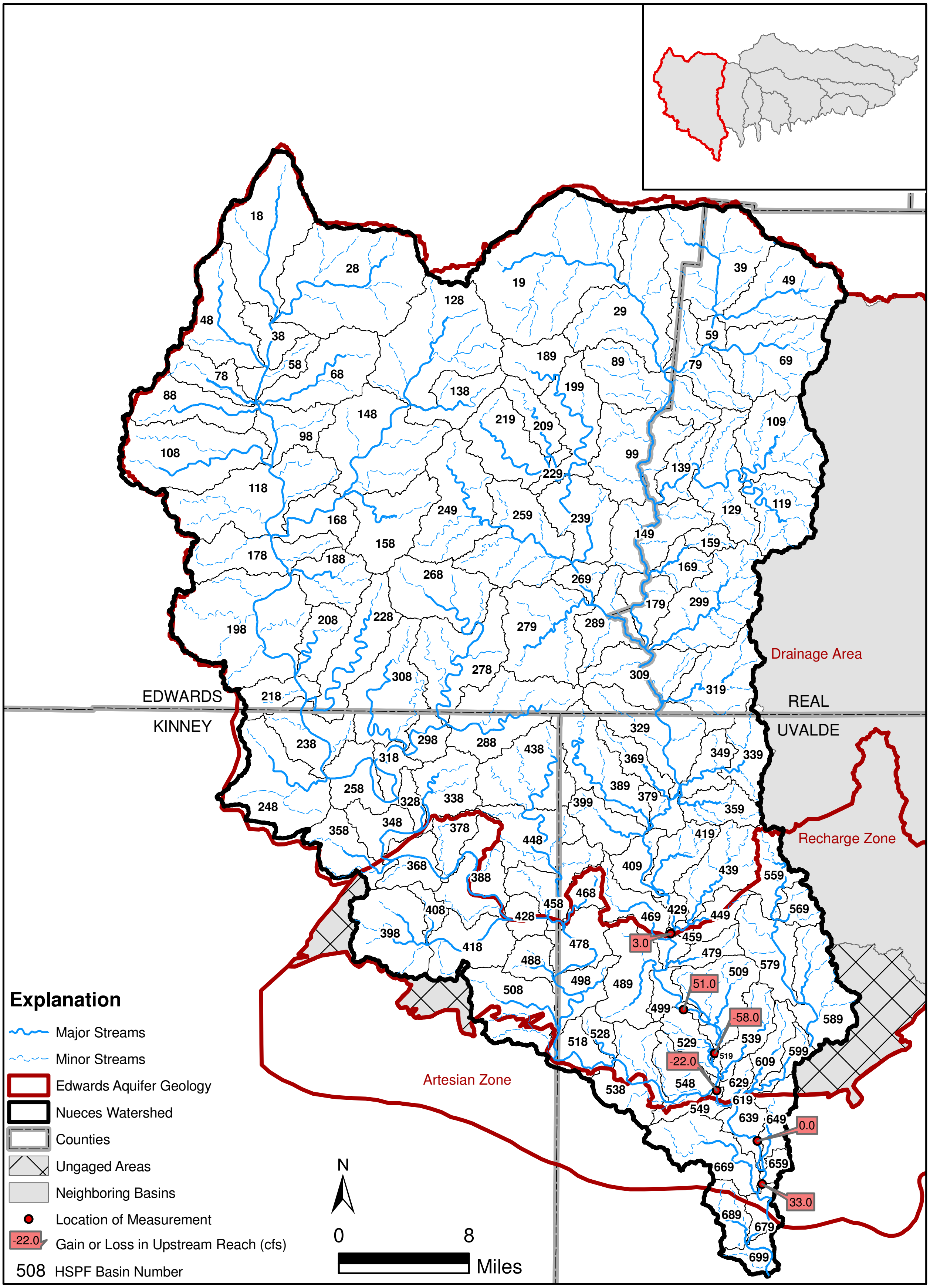

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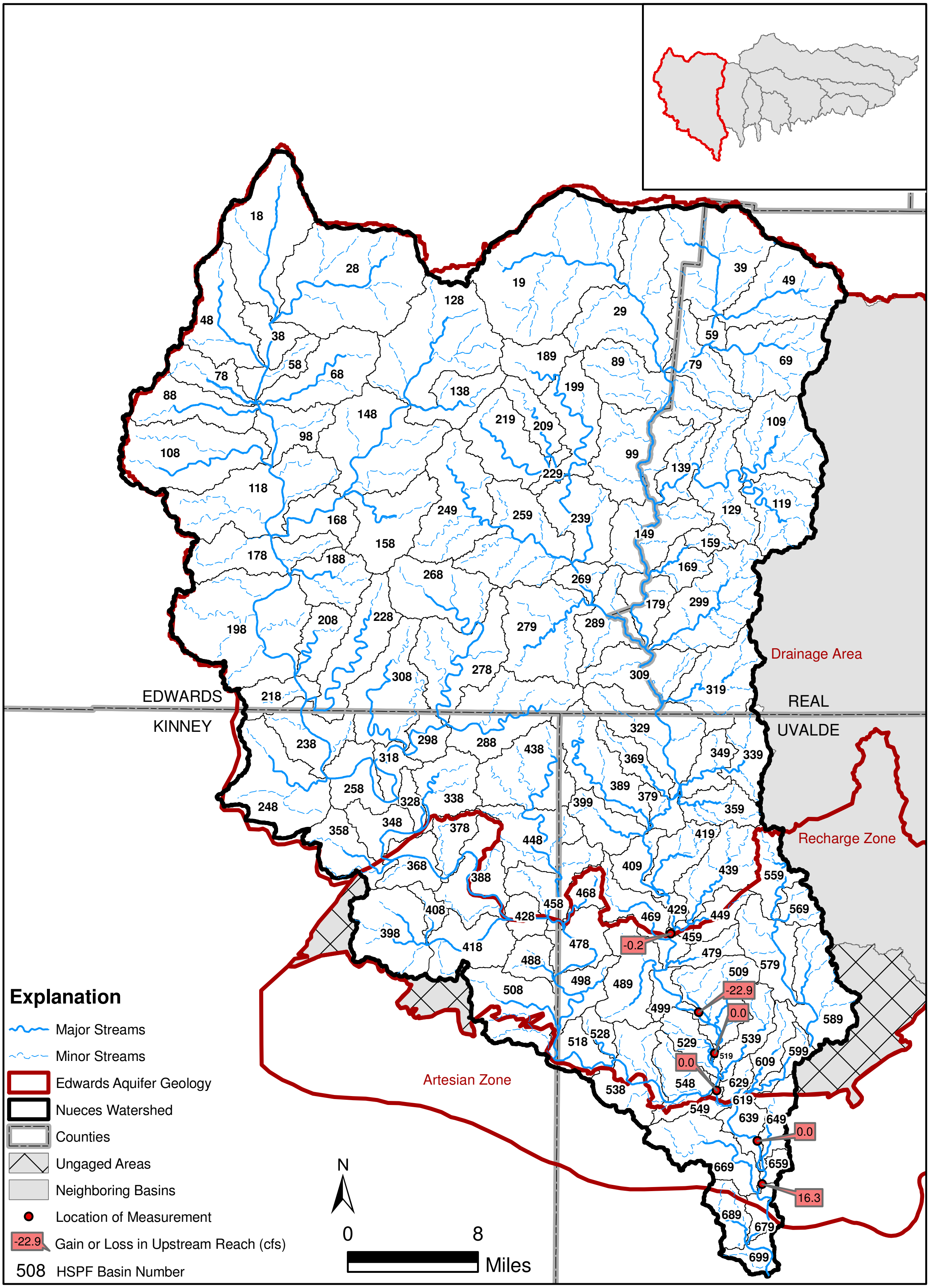

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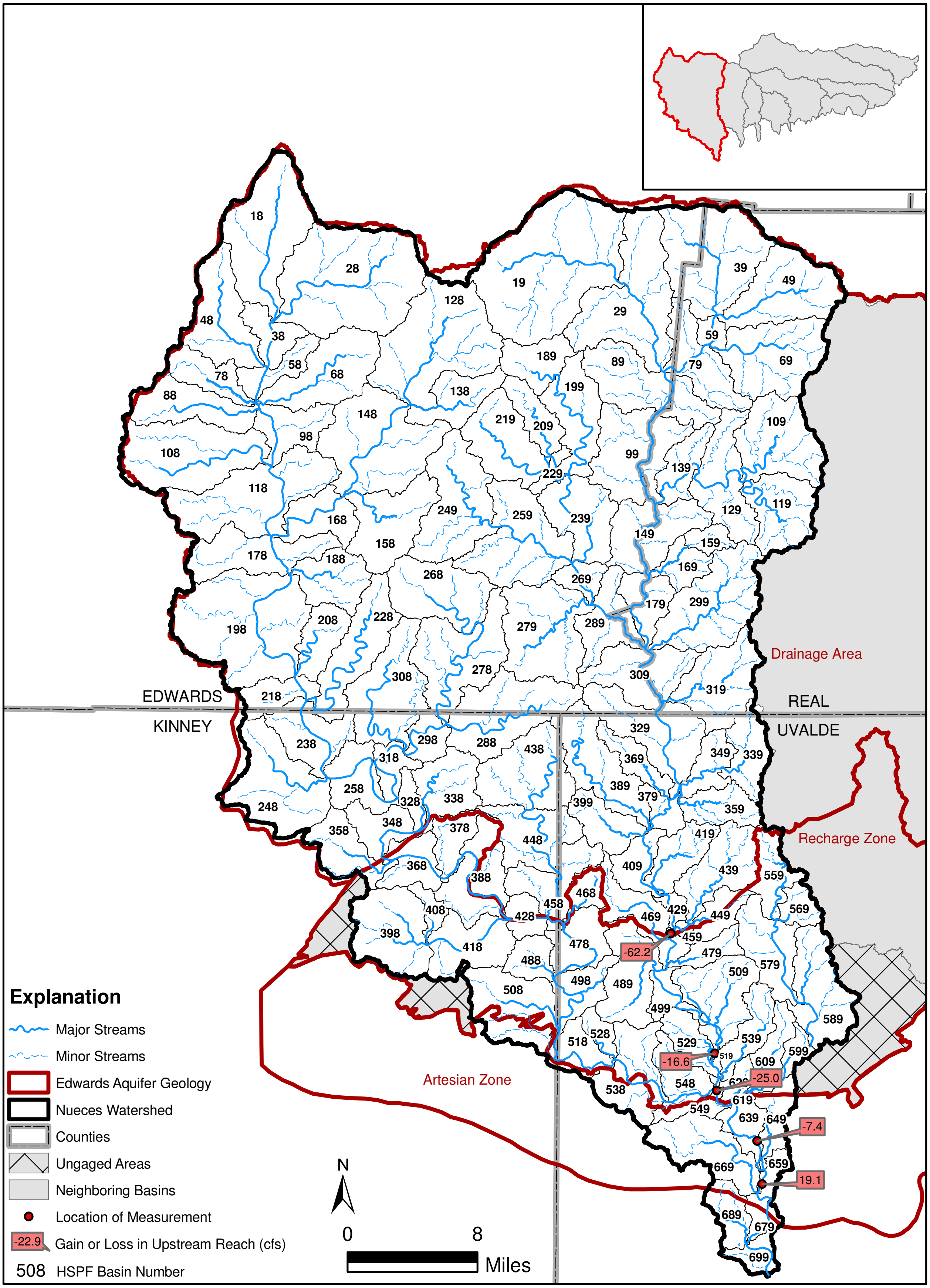

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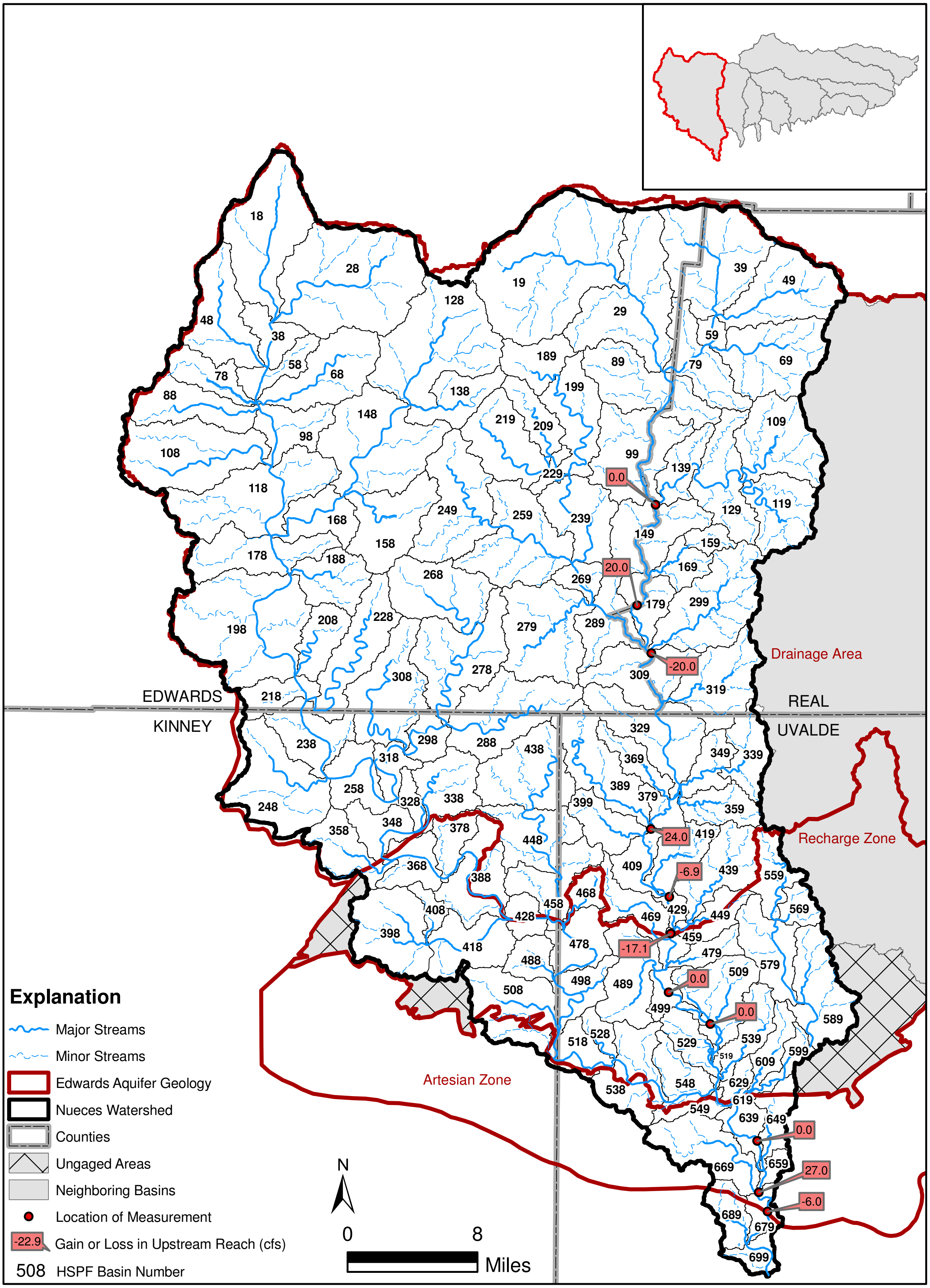

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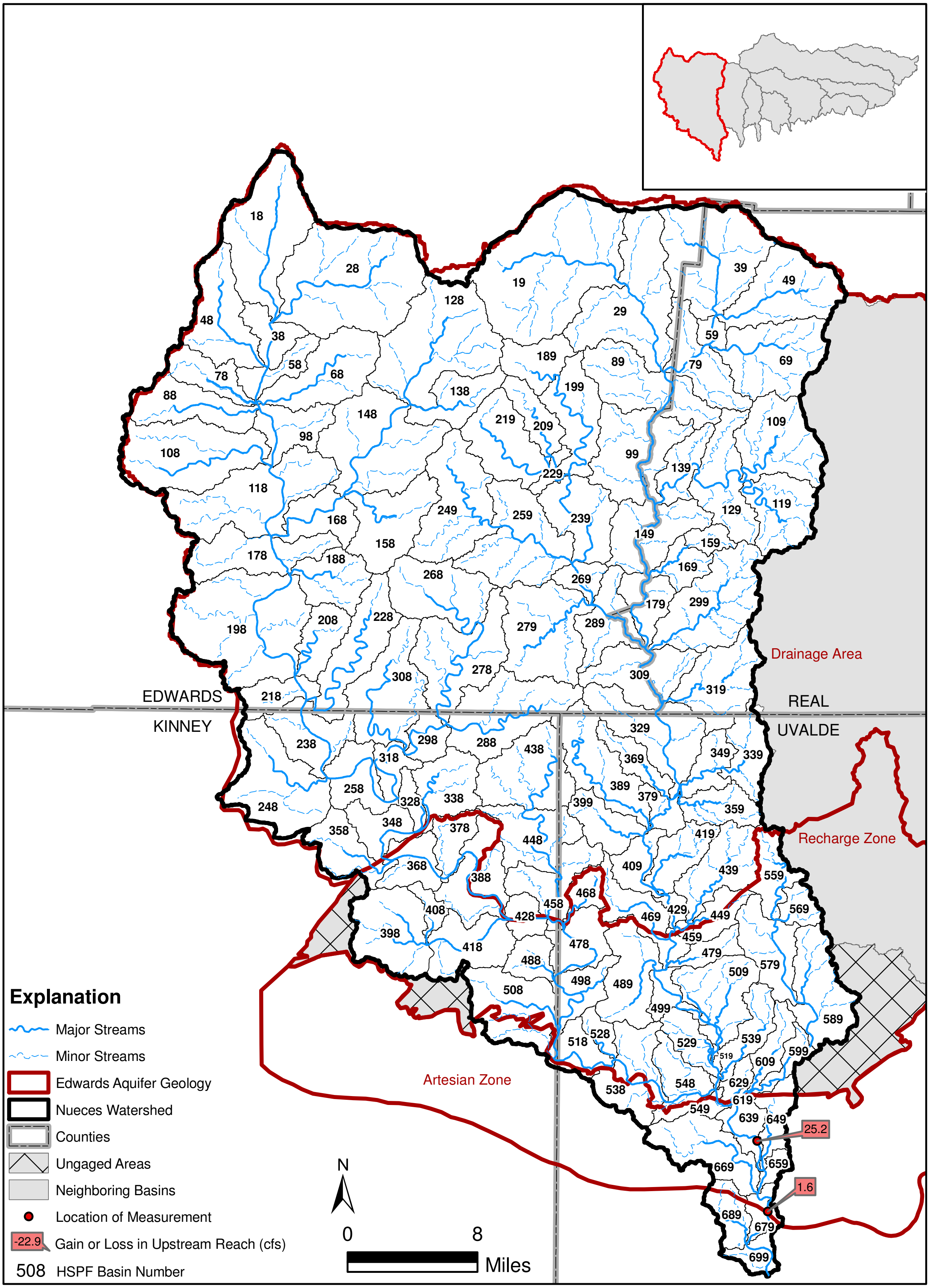

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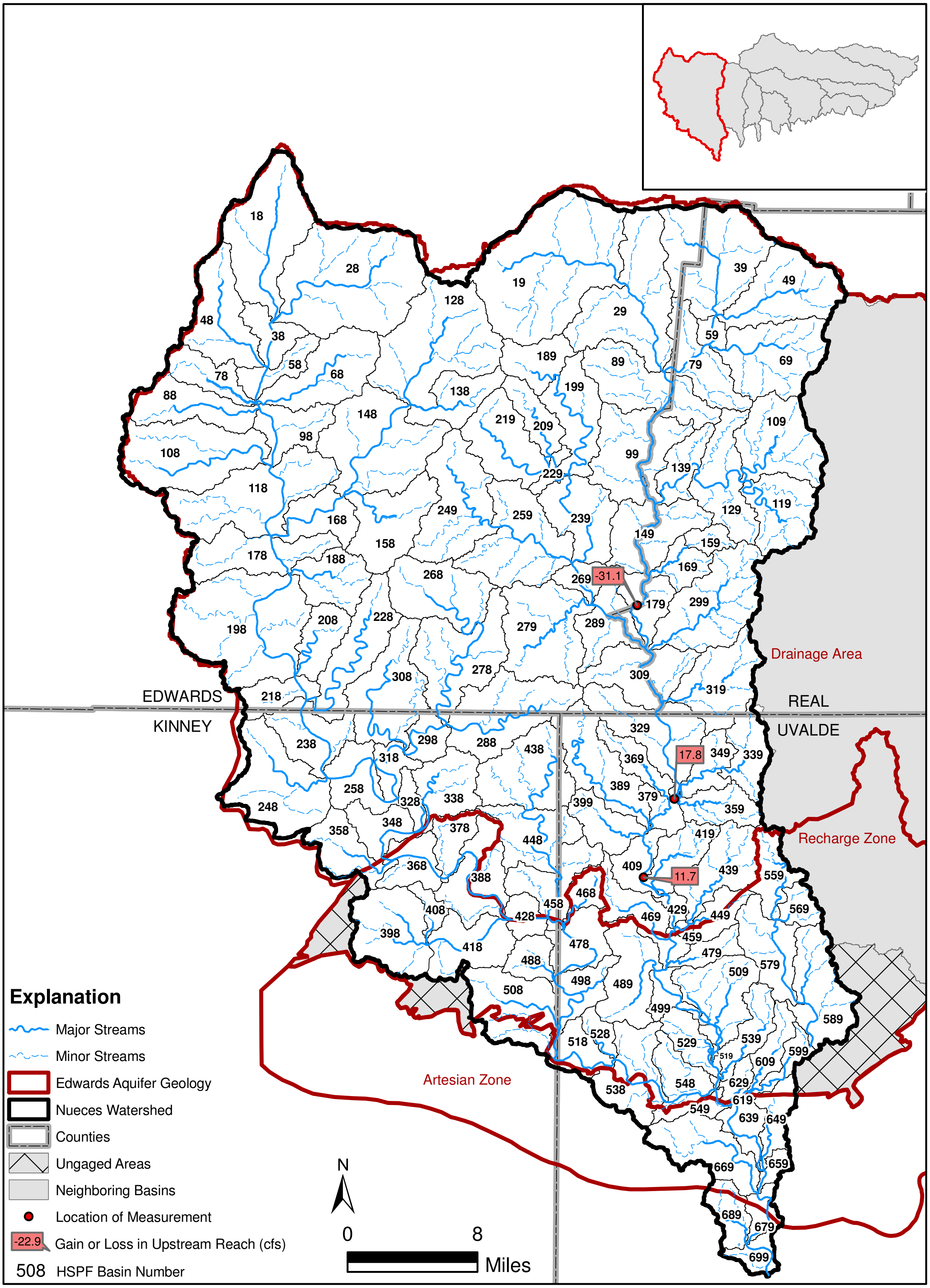

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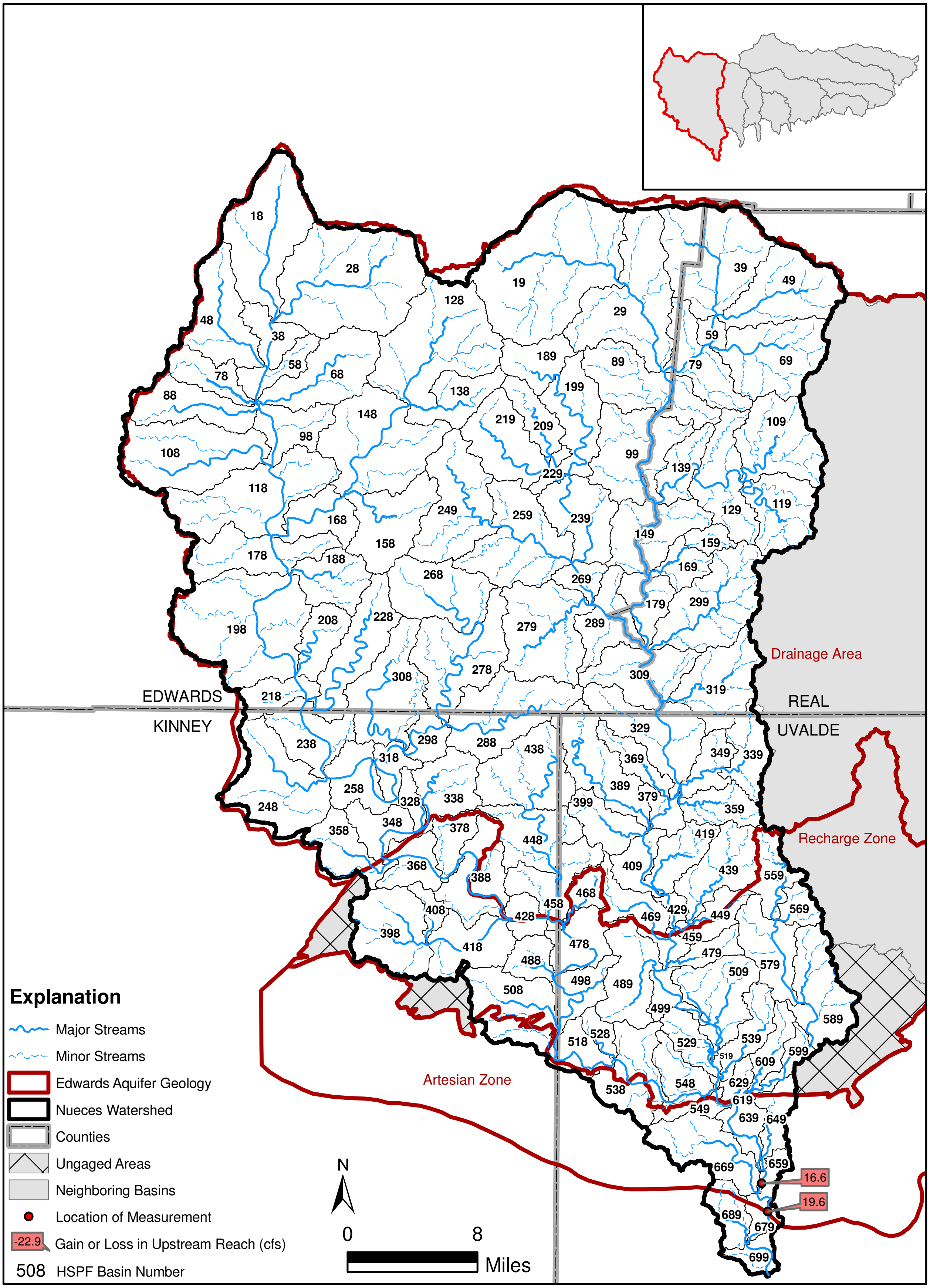

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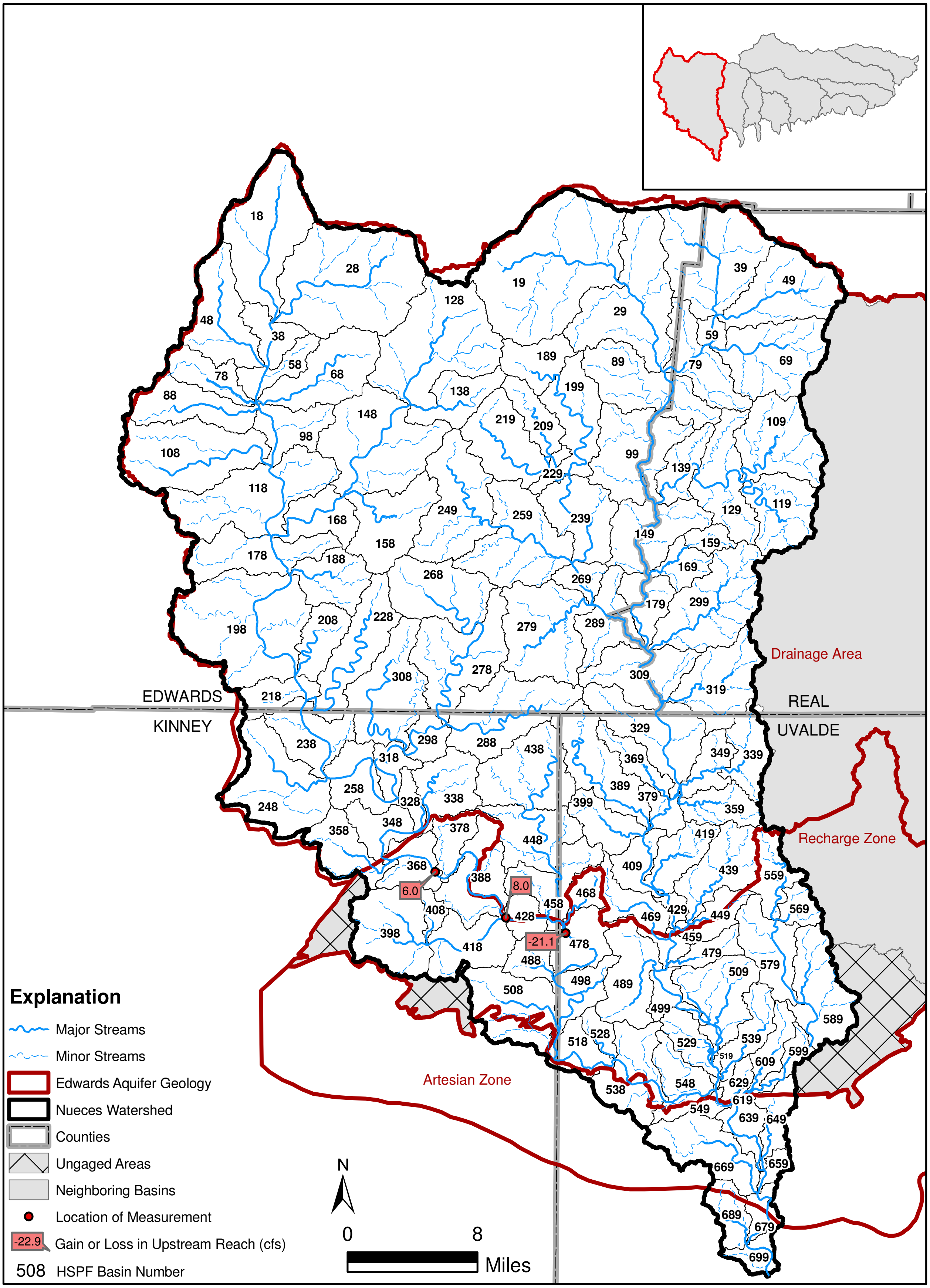

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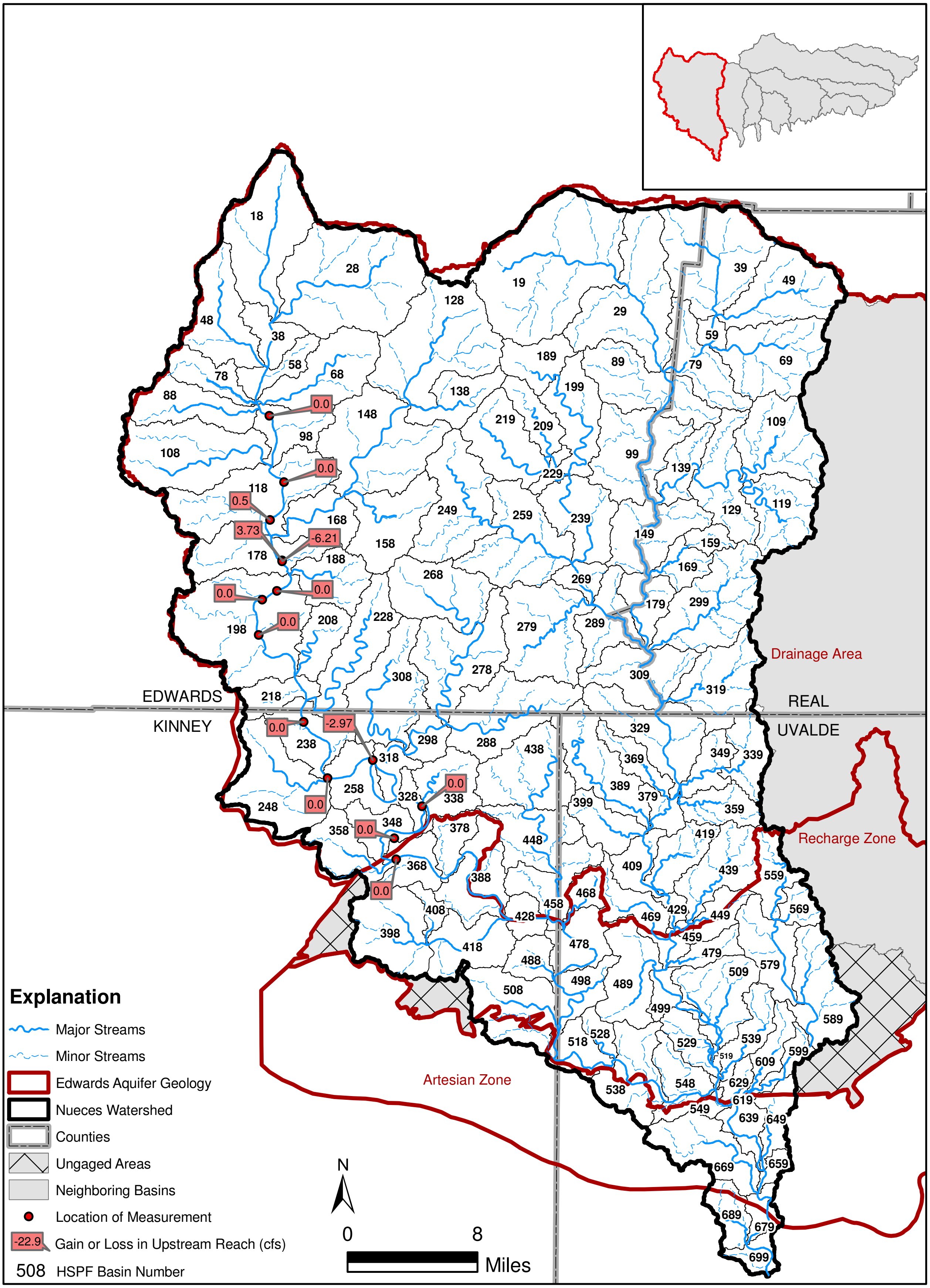

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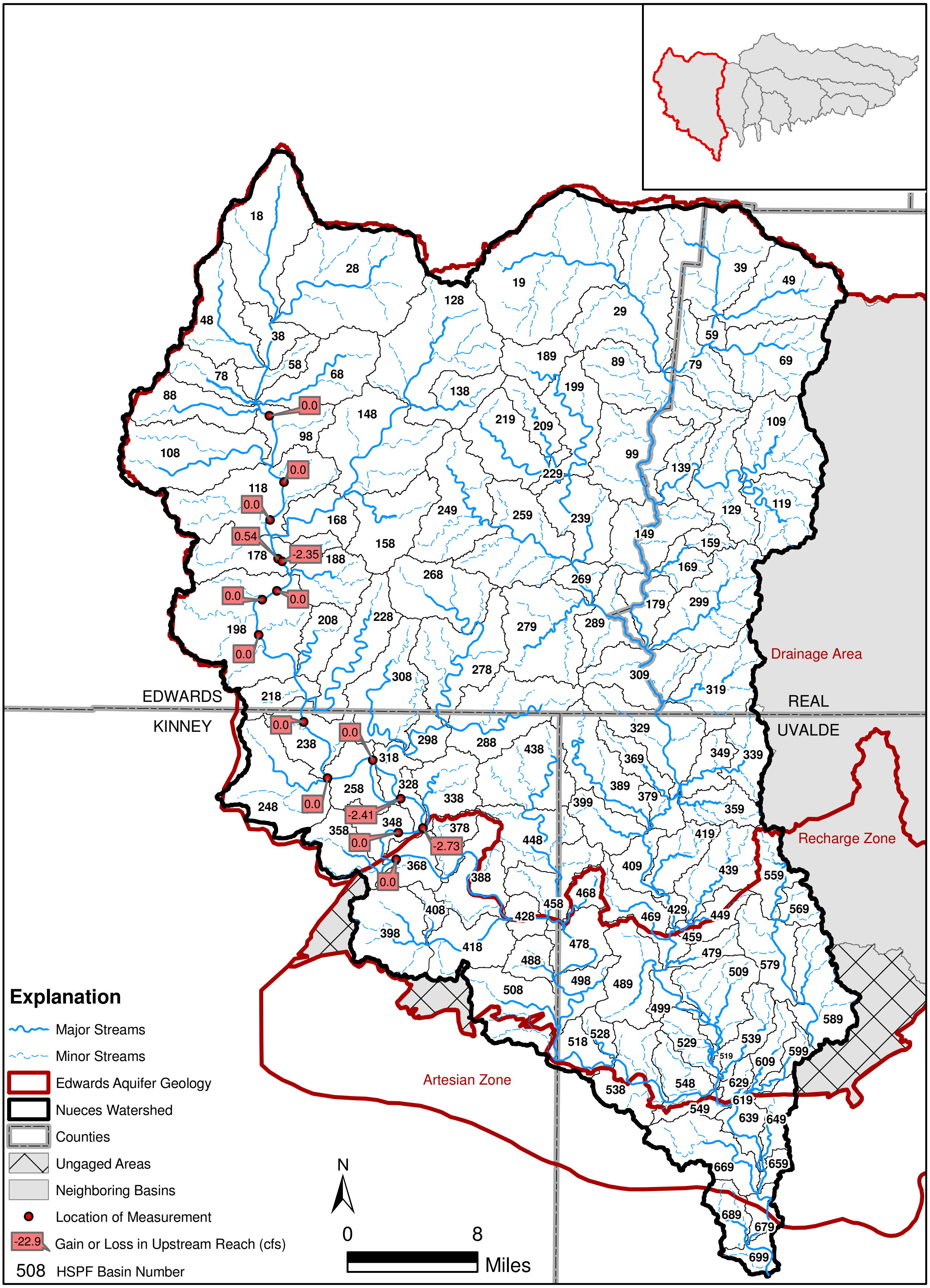

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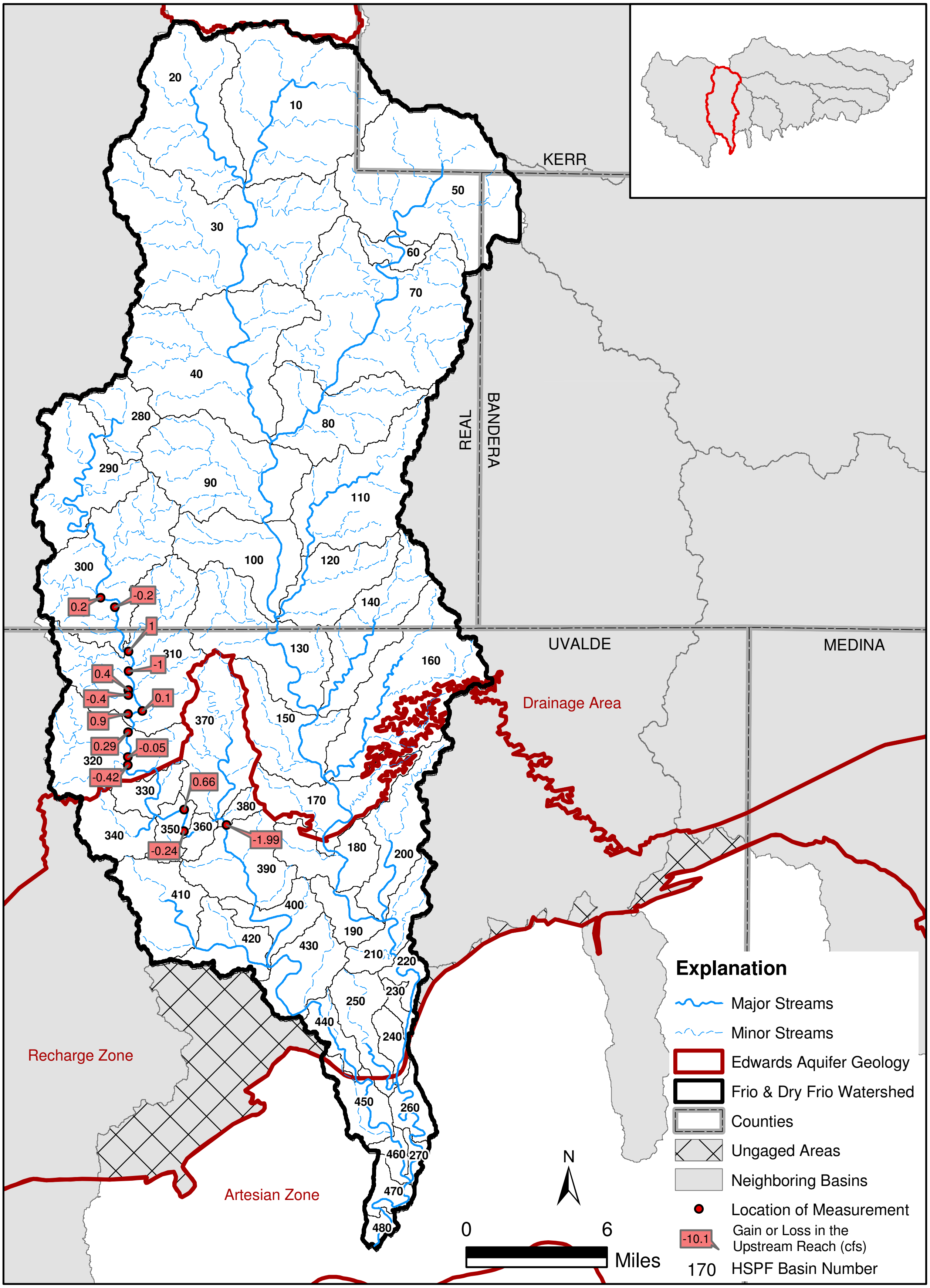
FRIO - DRY FRIO BASIN



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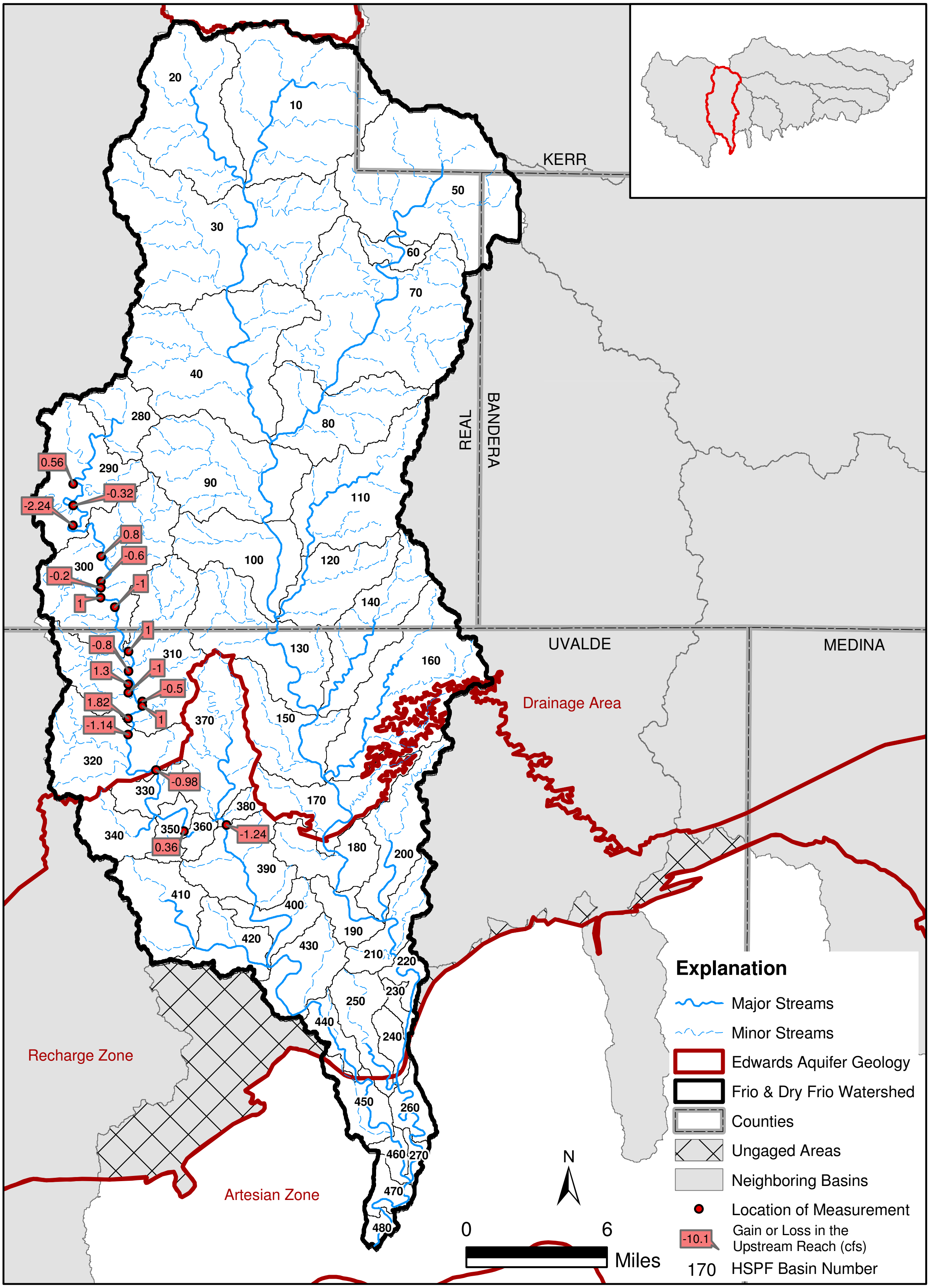

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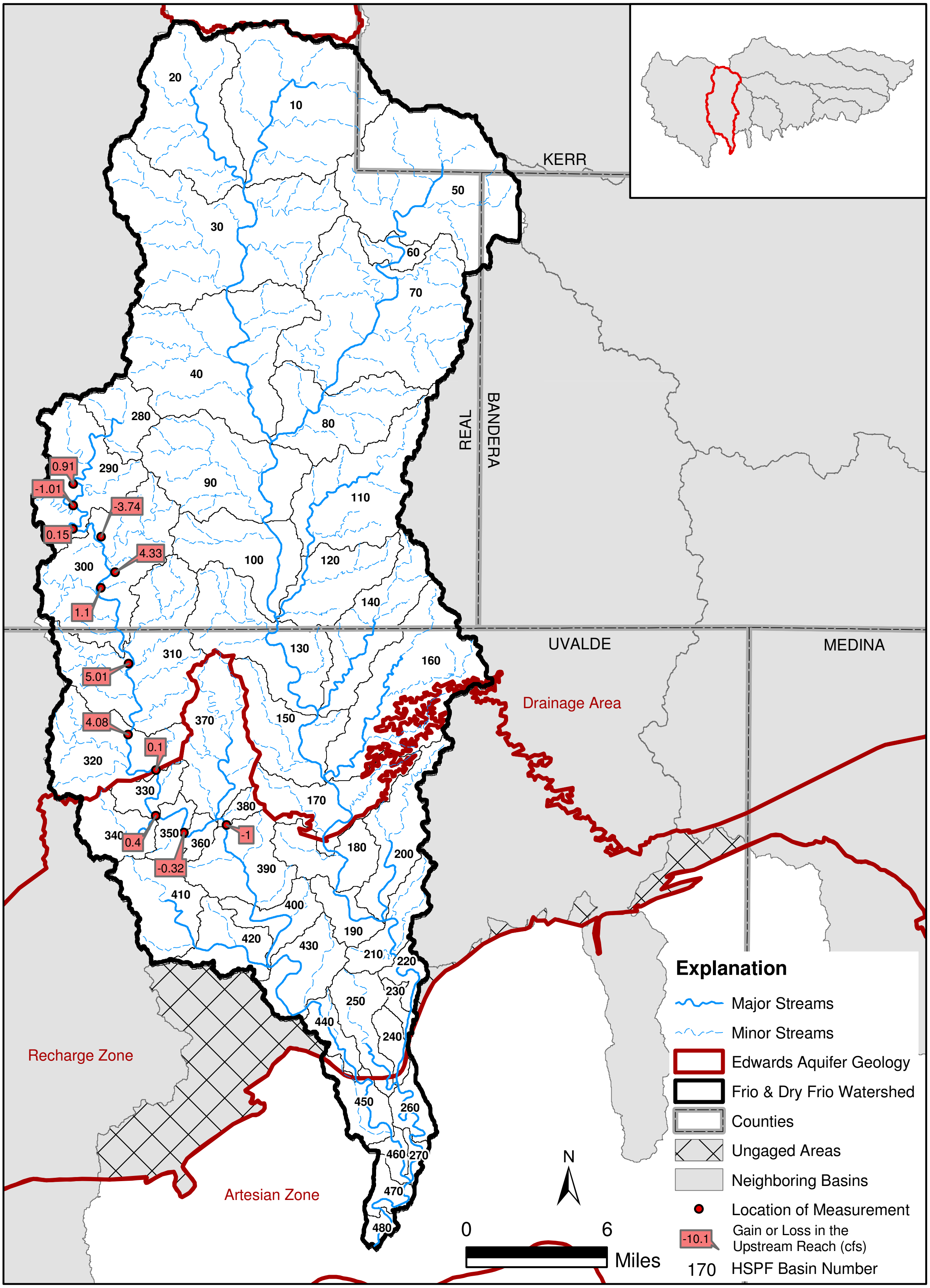

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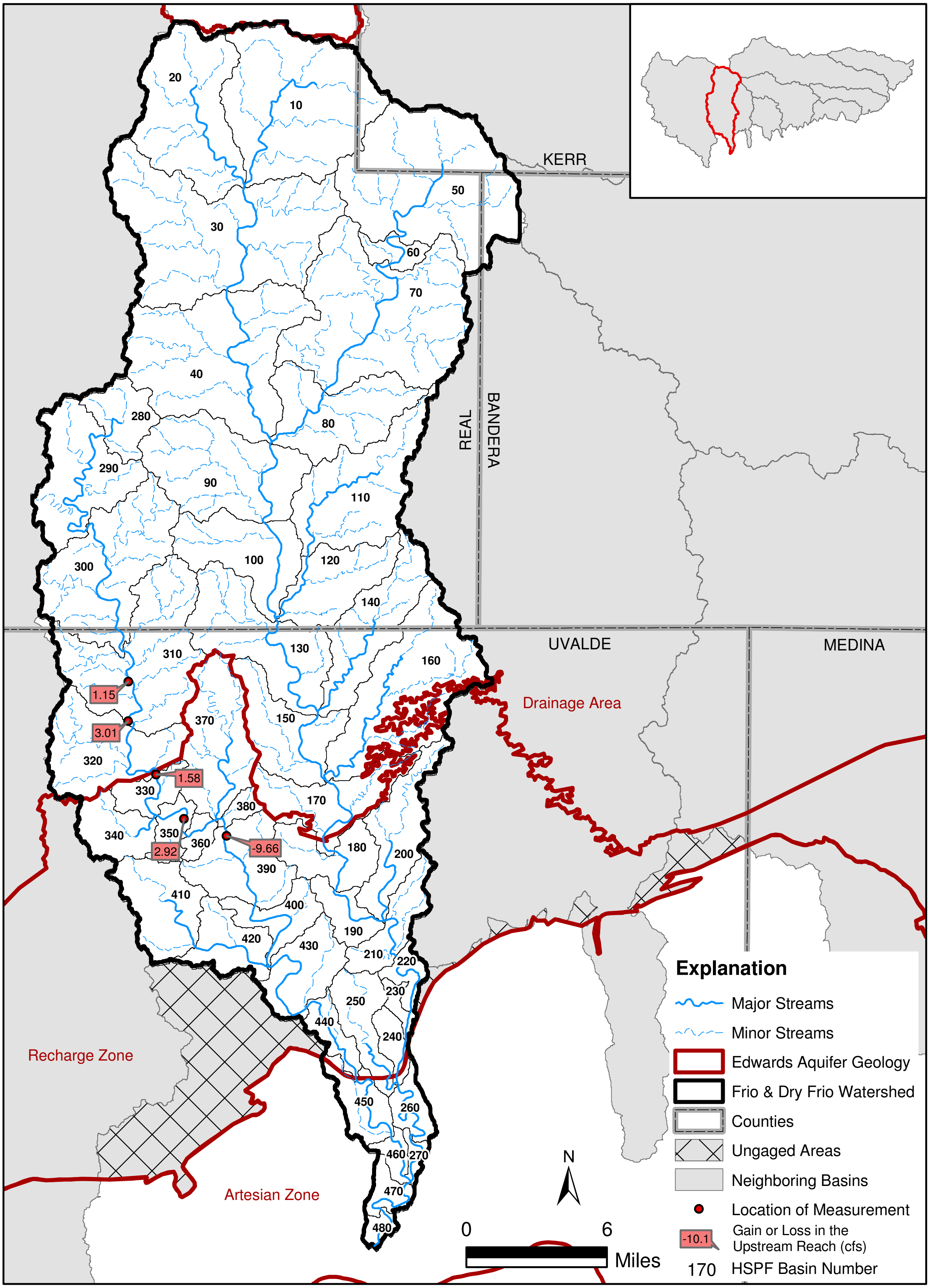

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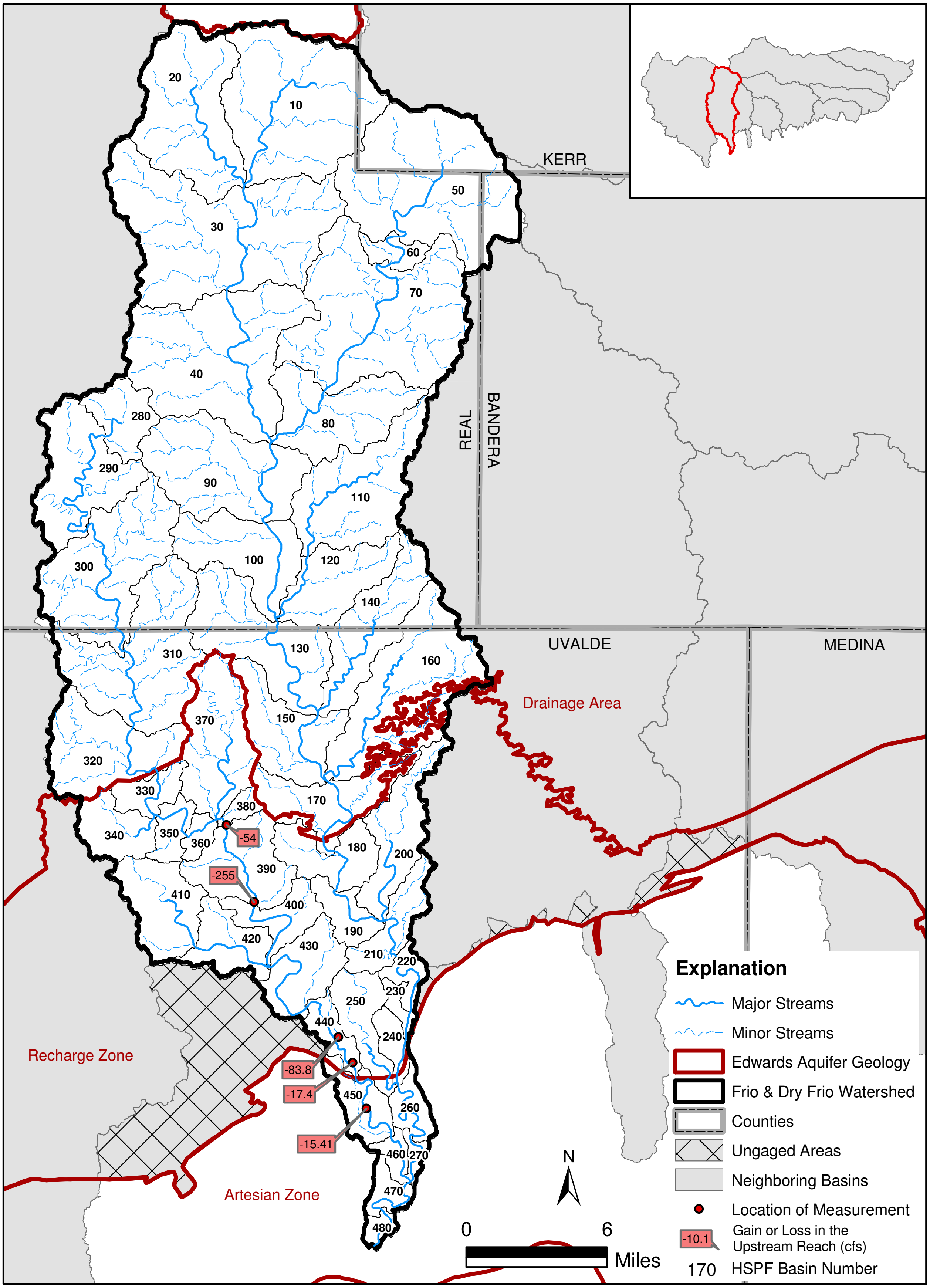

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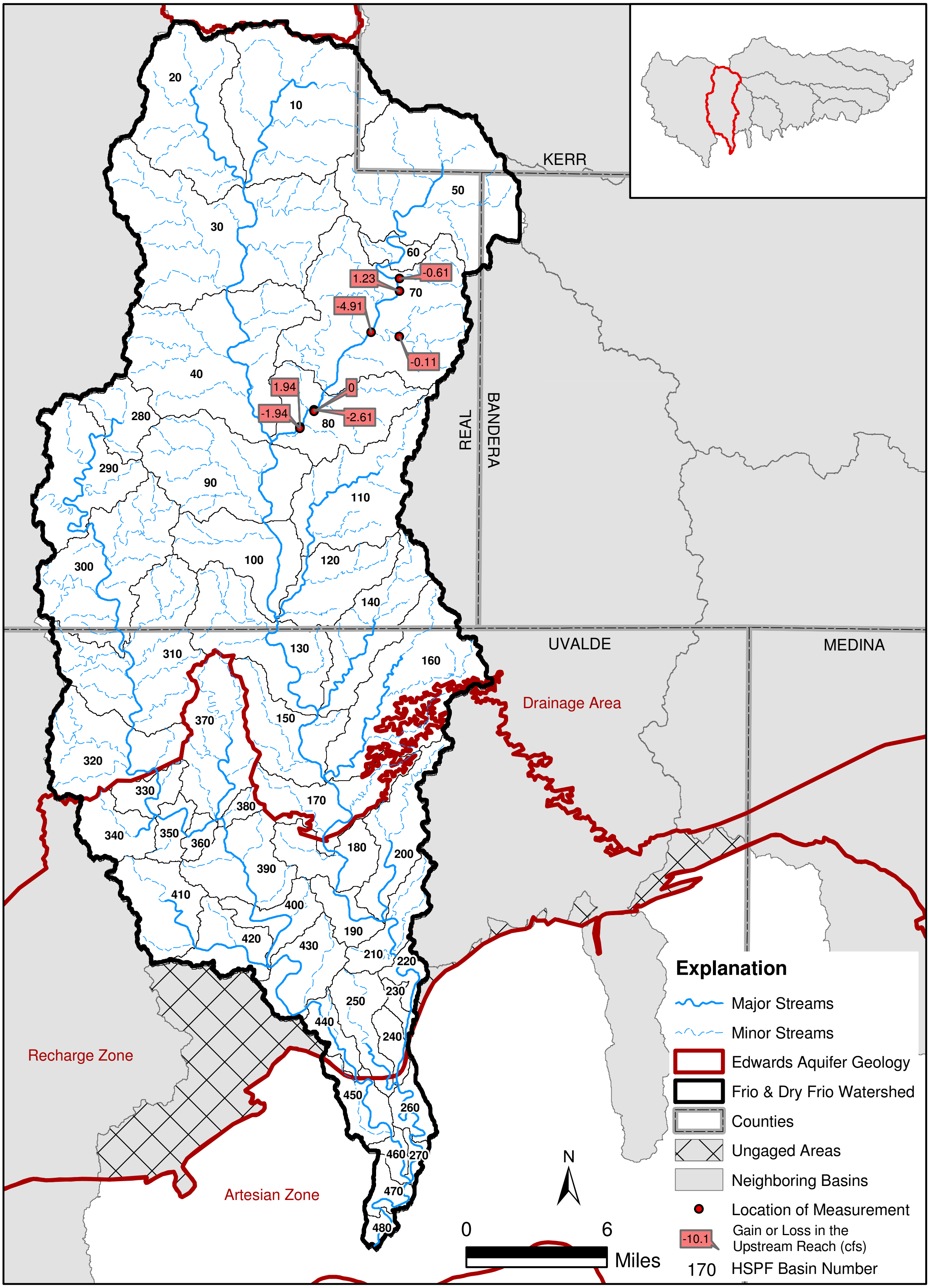

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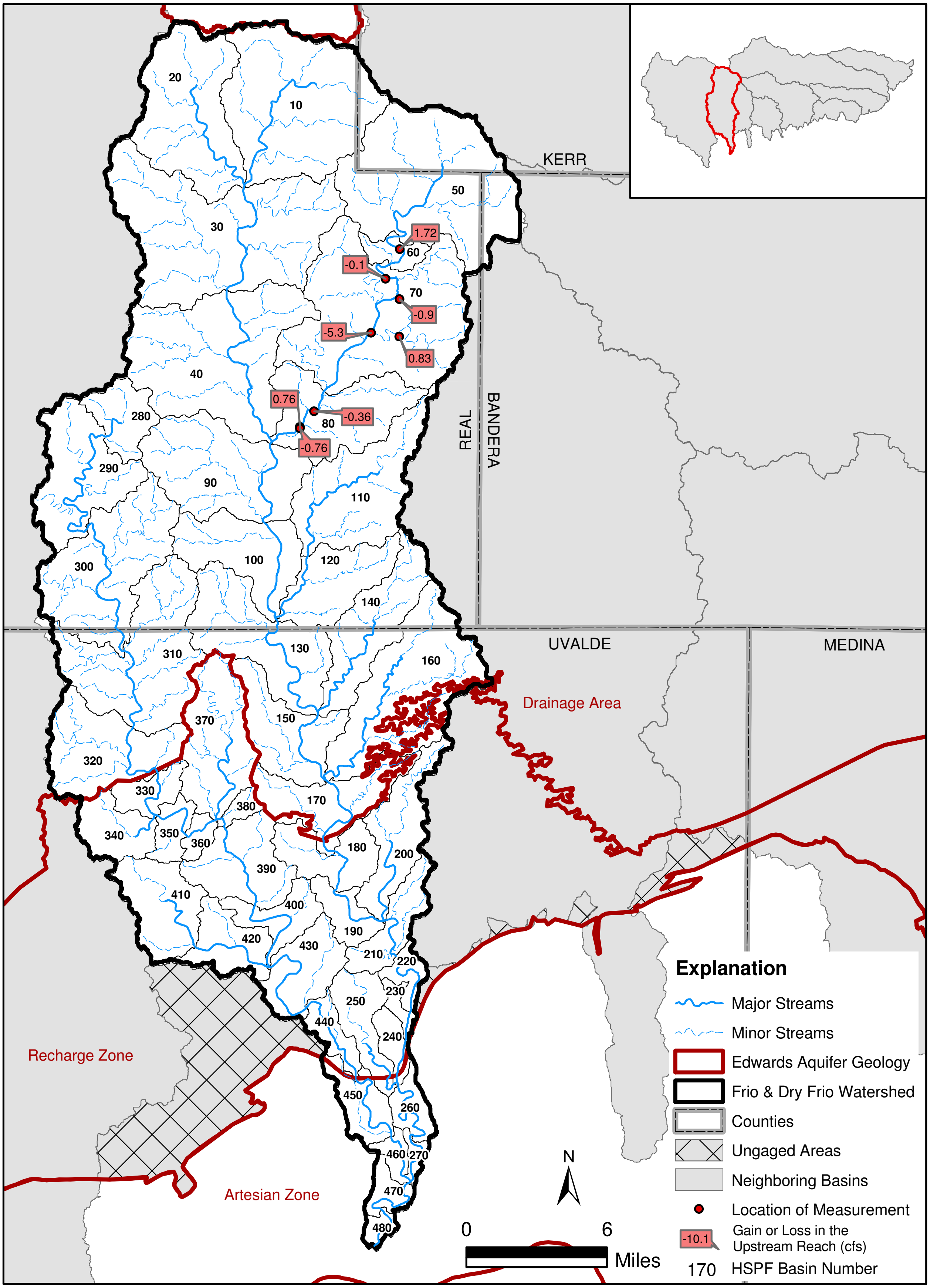

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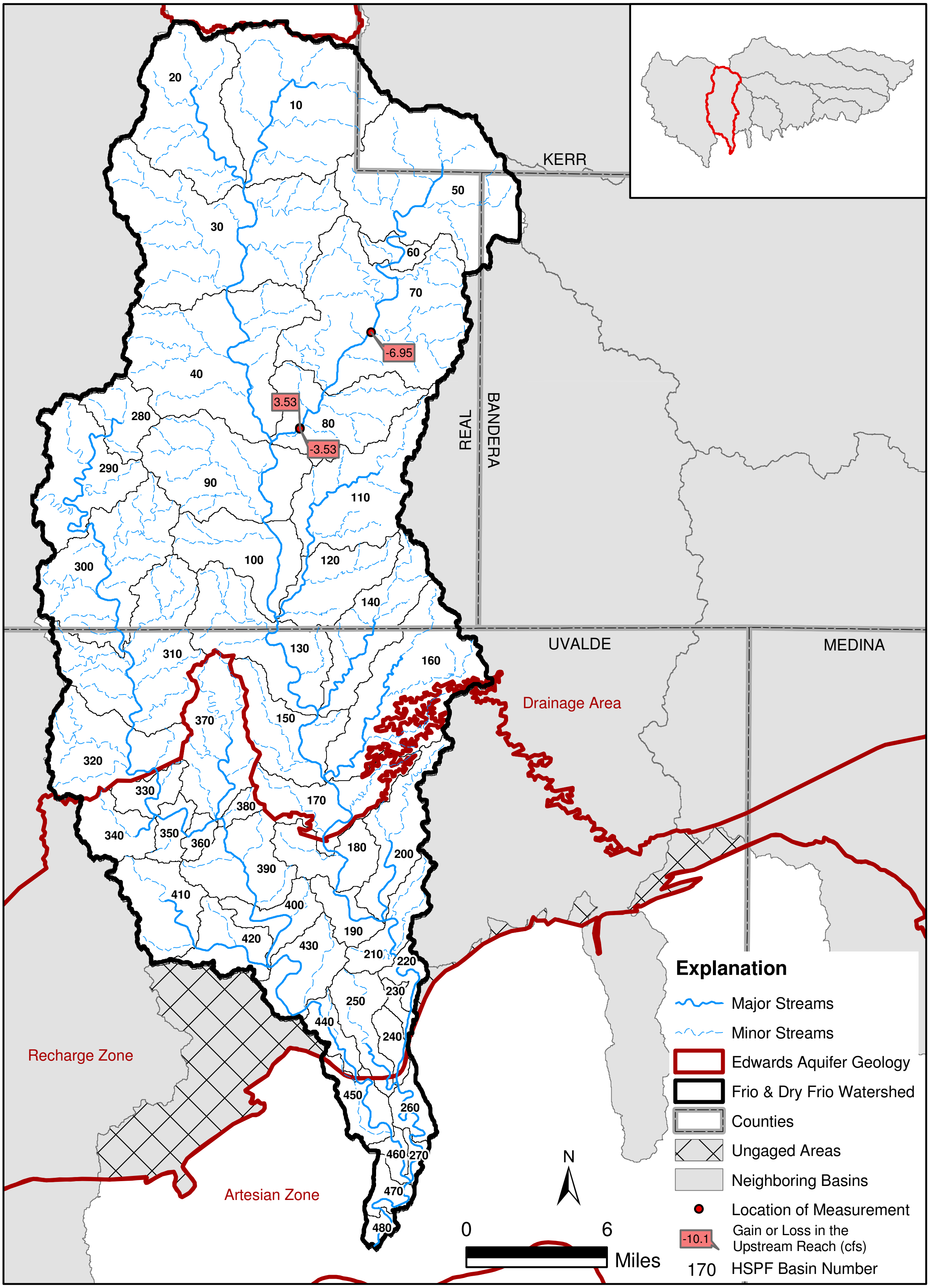

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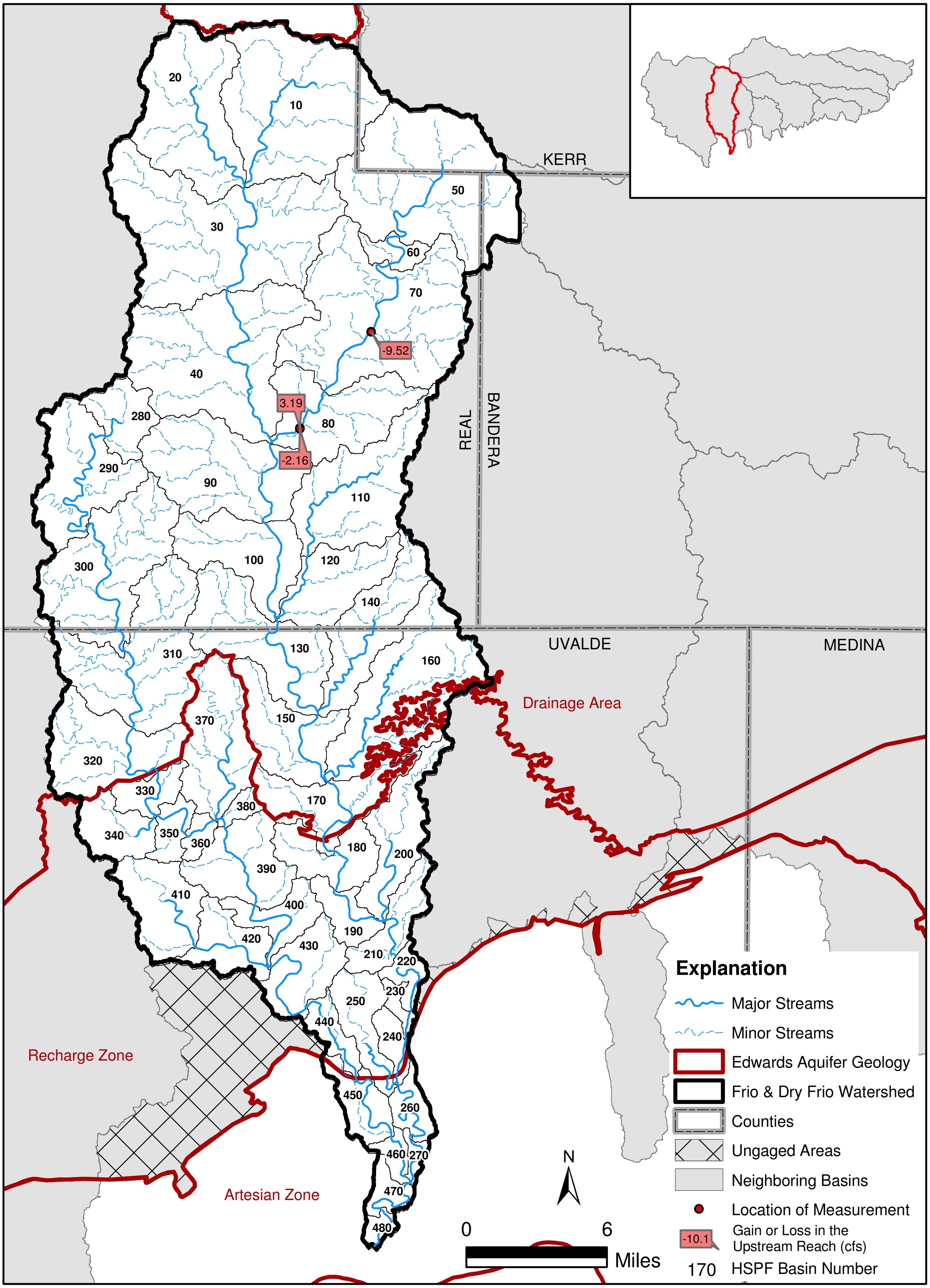

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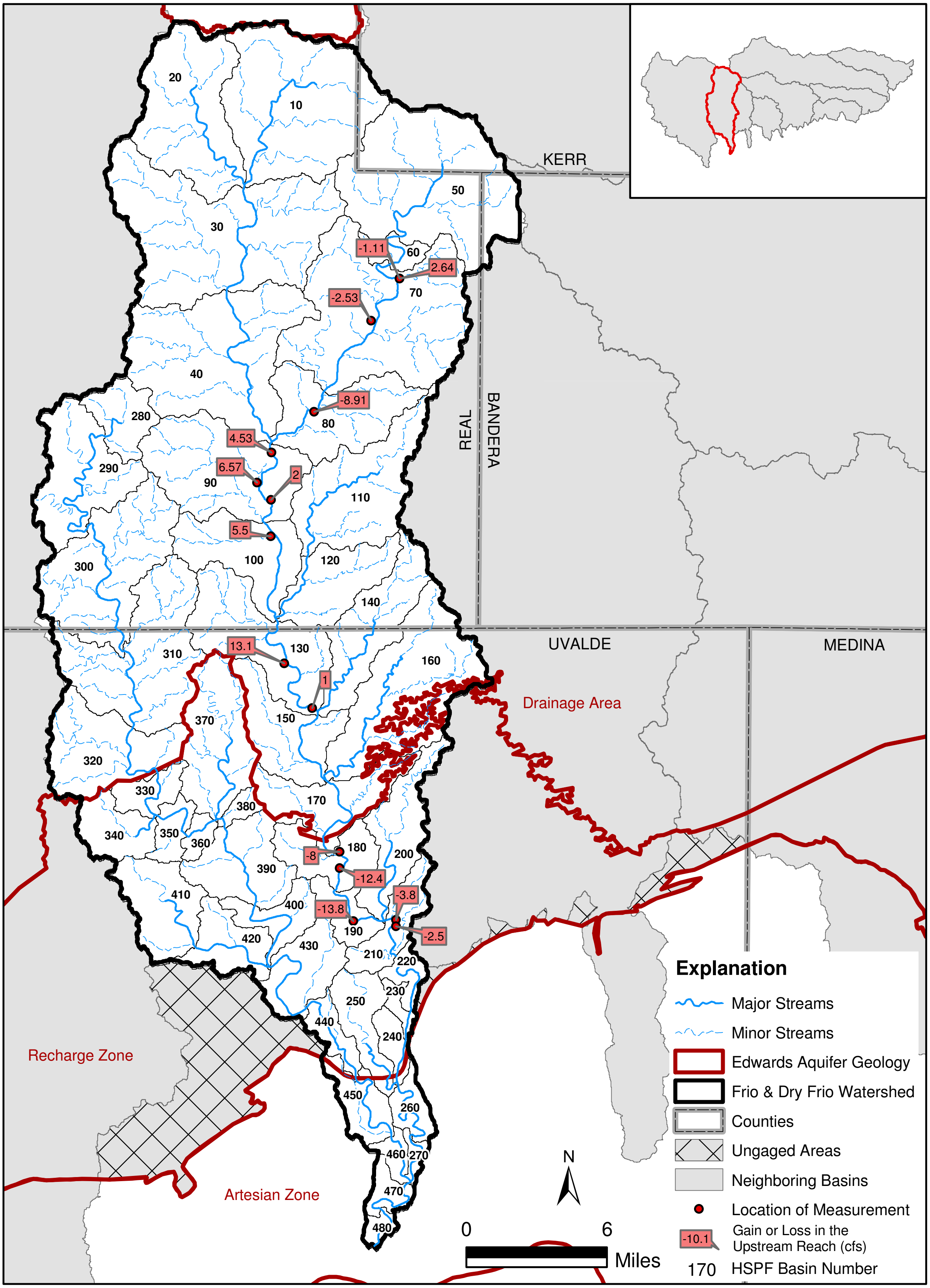

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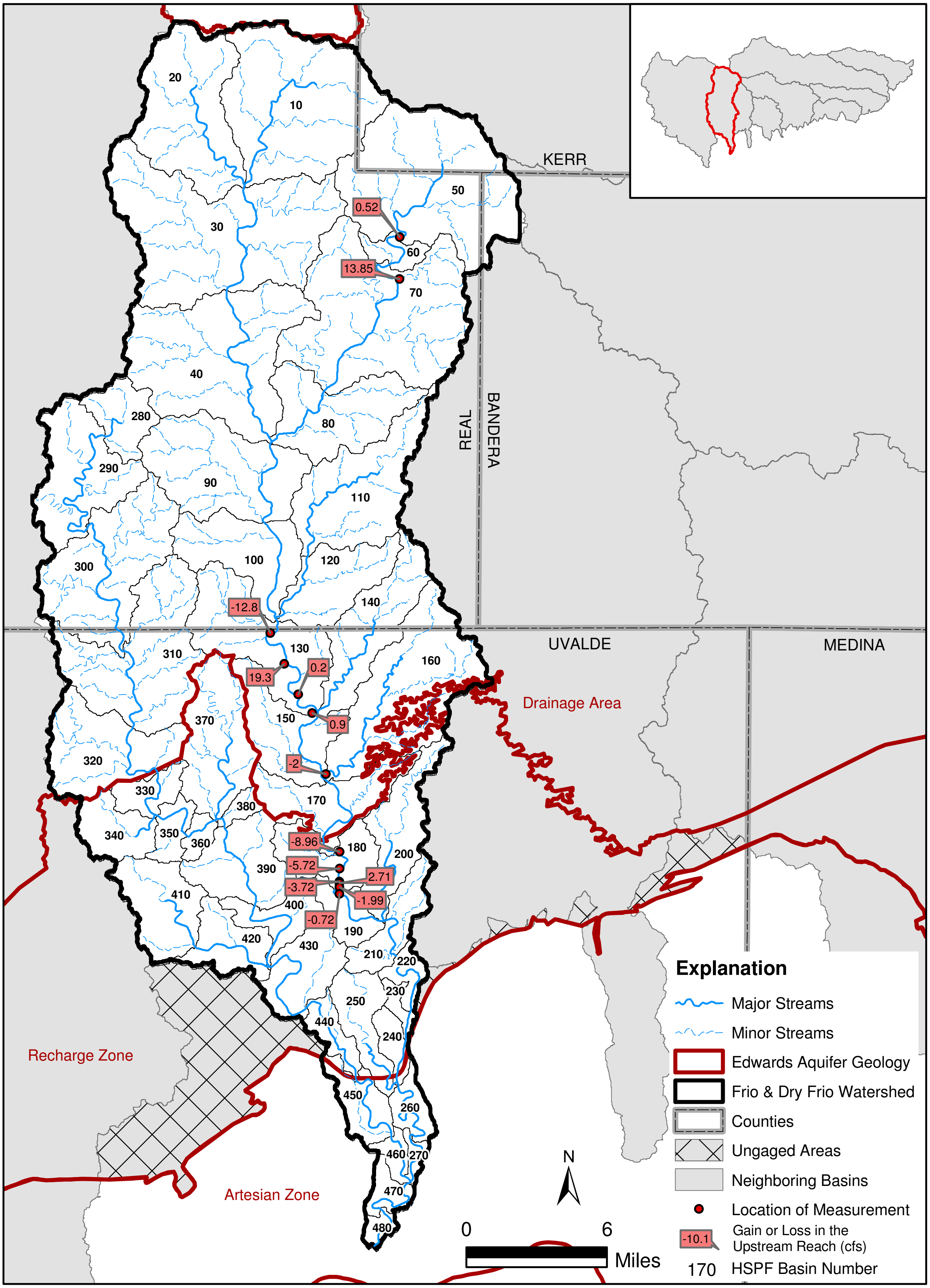

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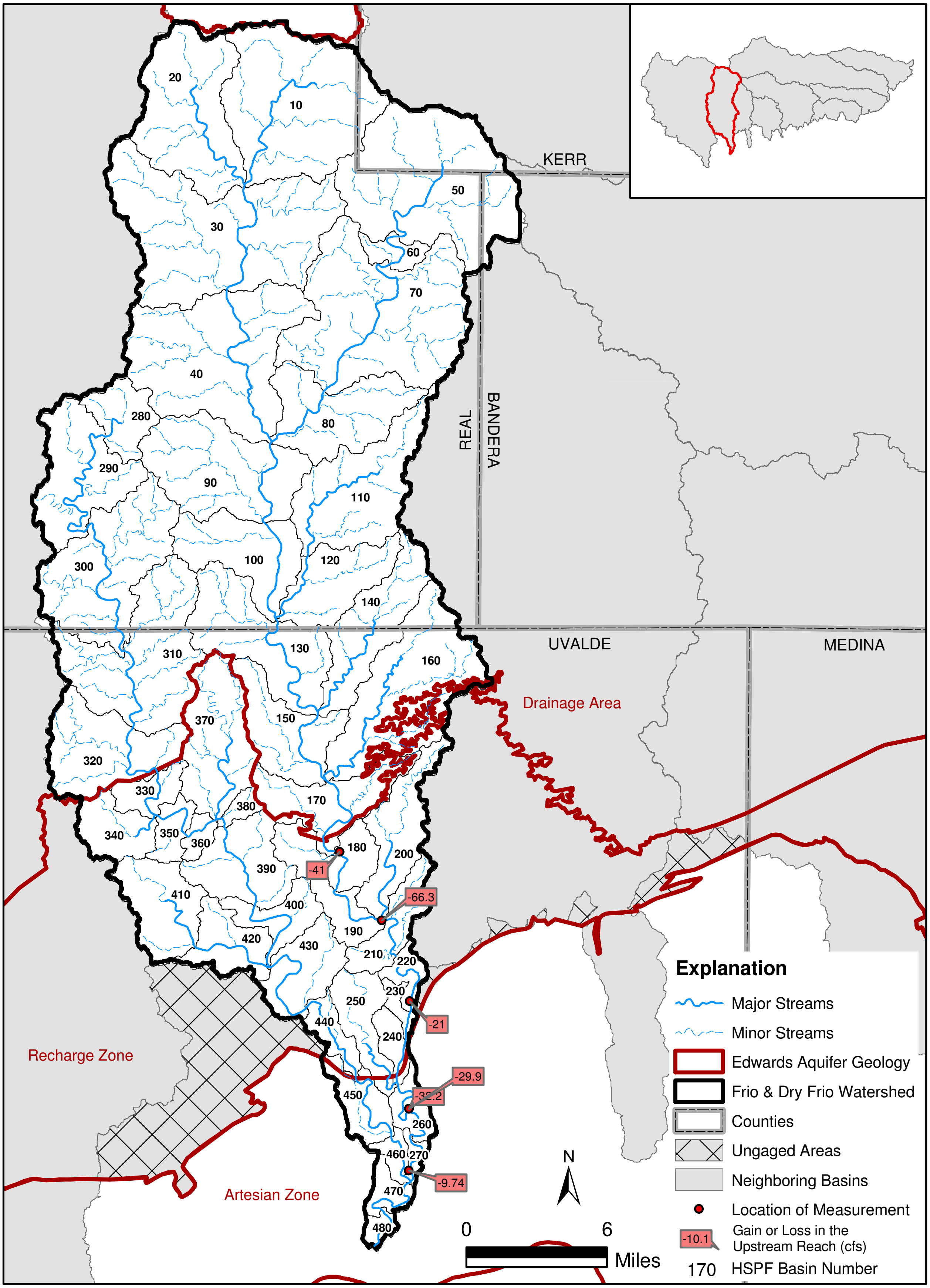

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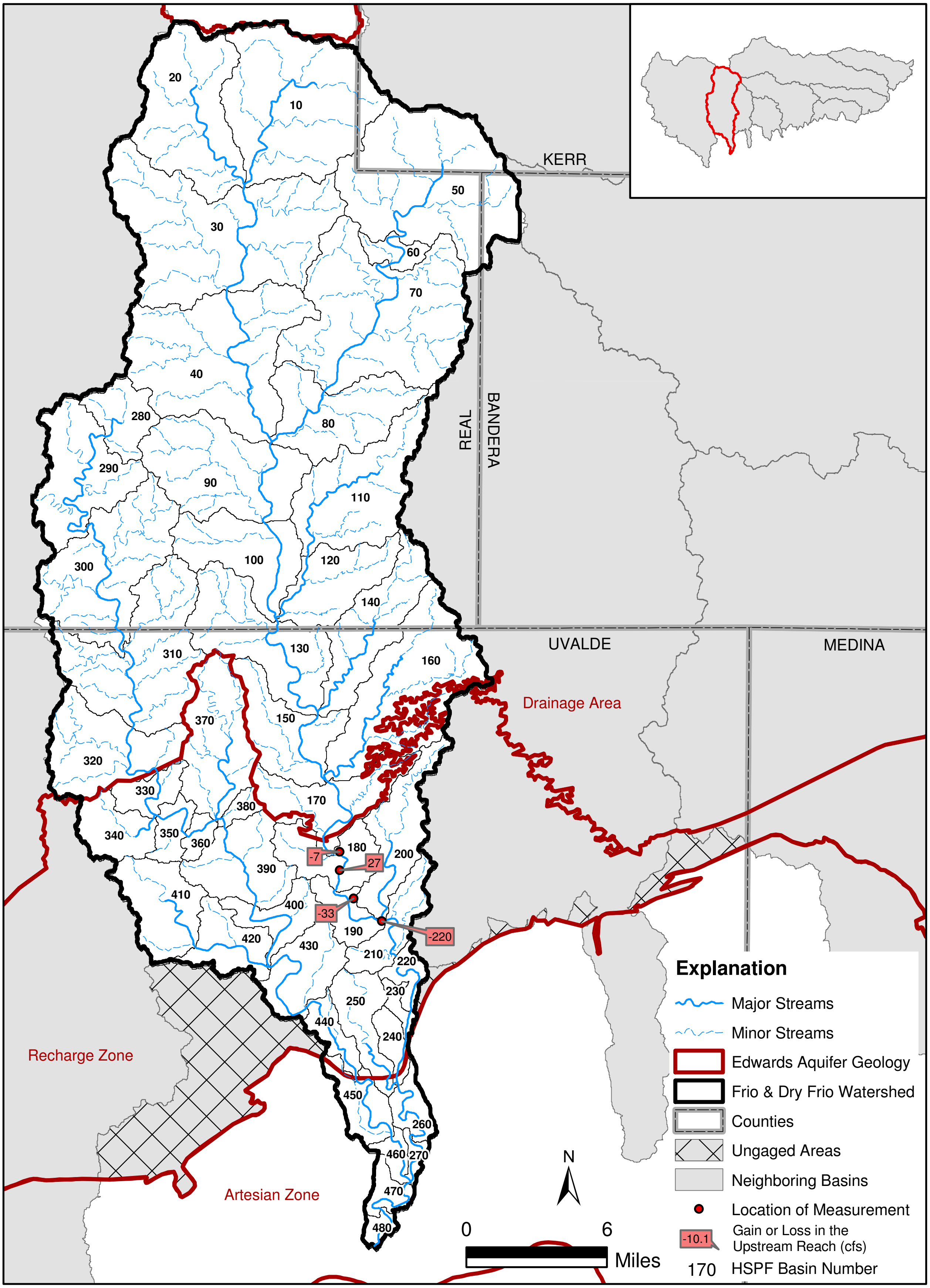

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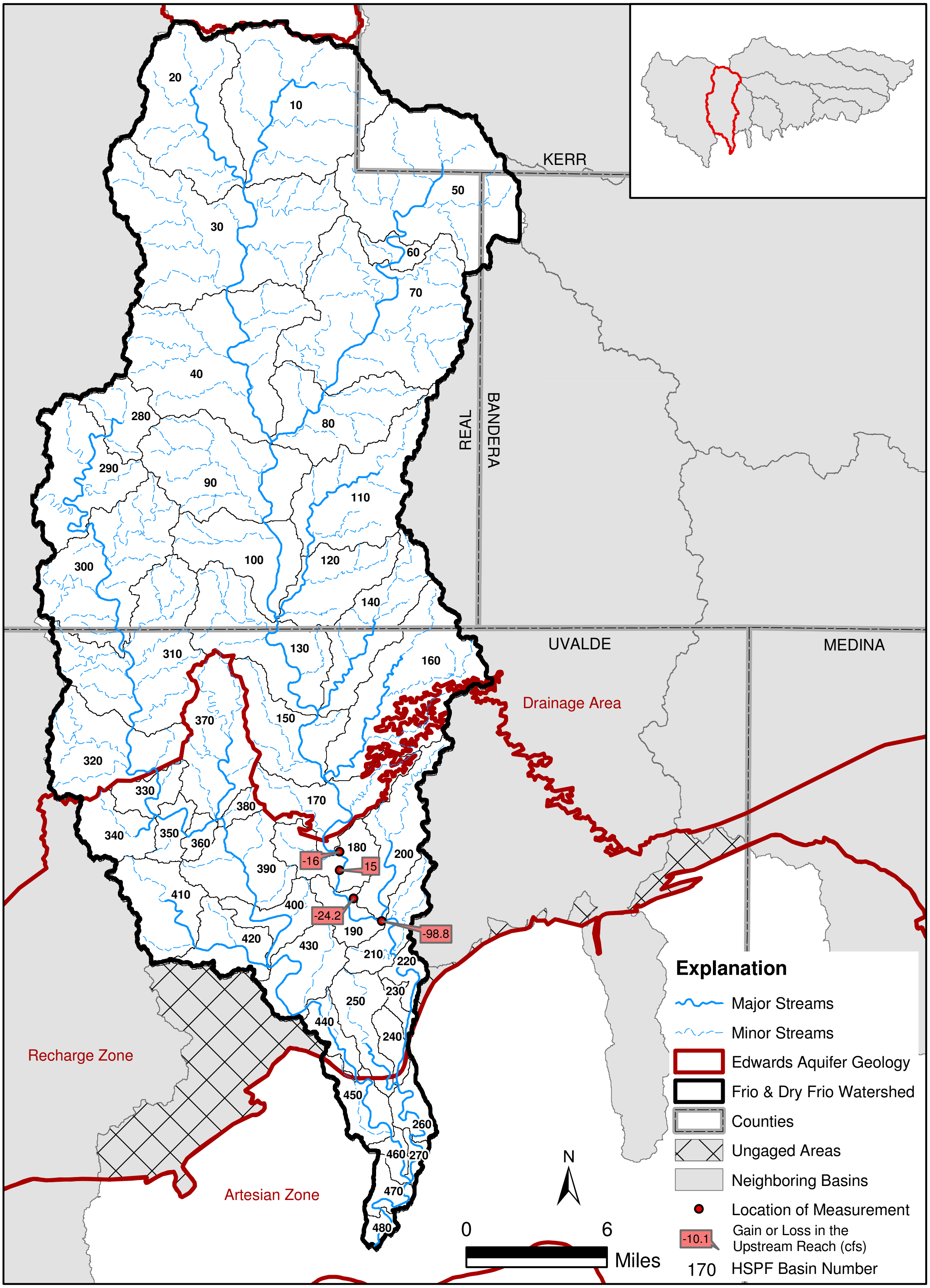

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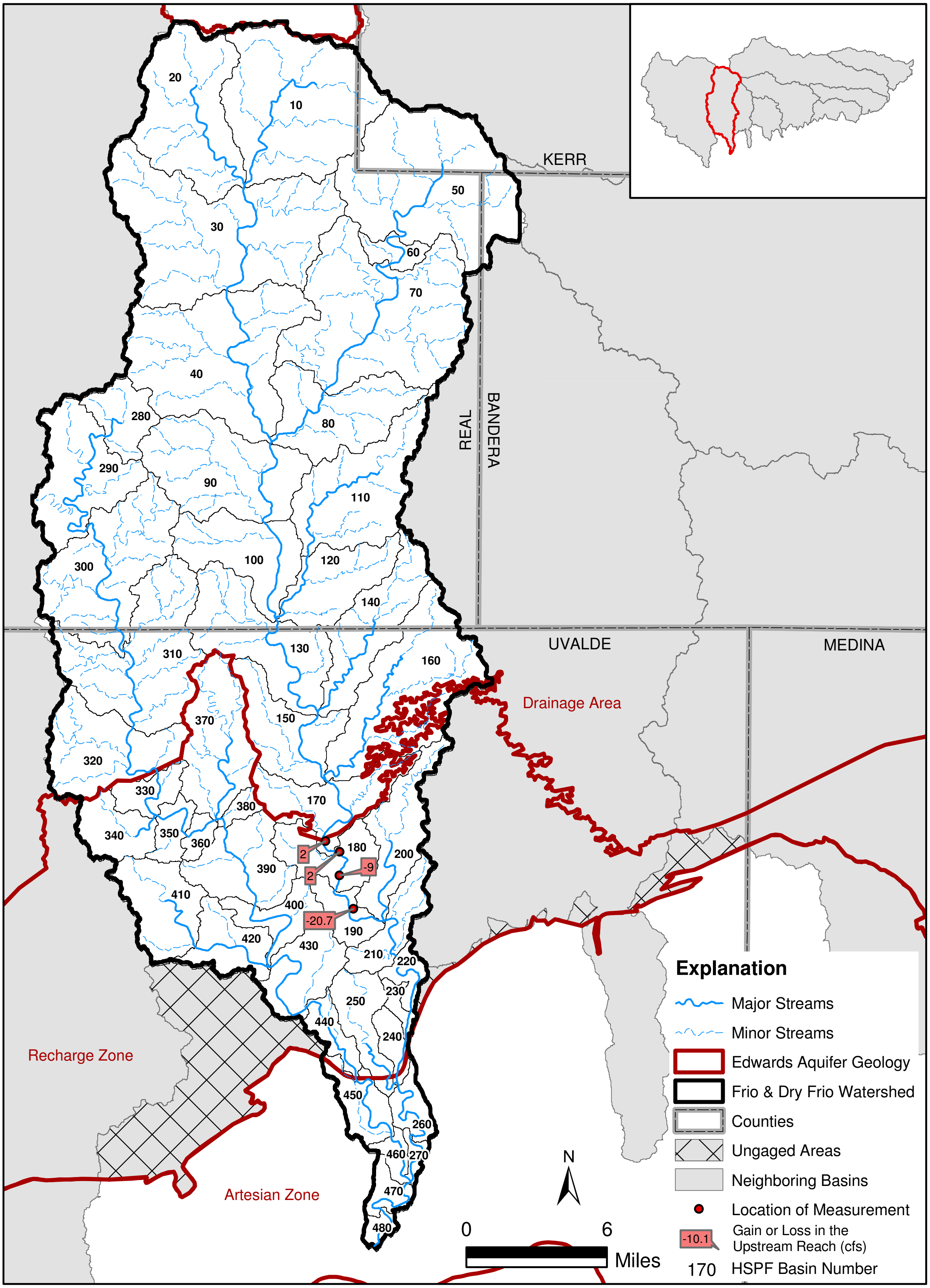

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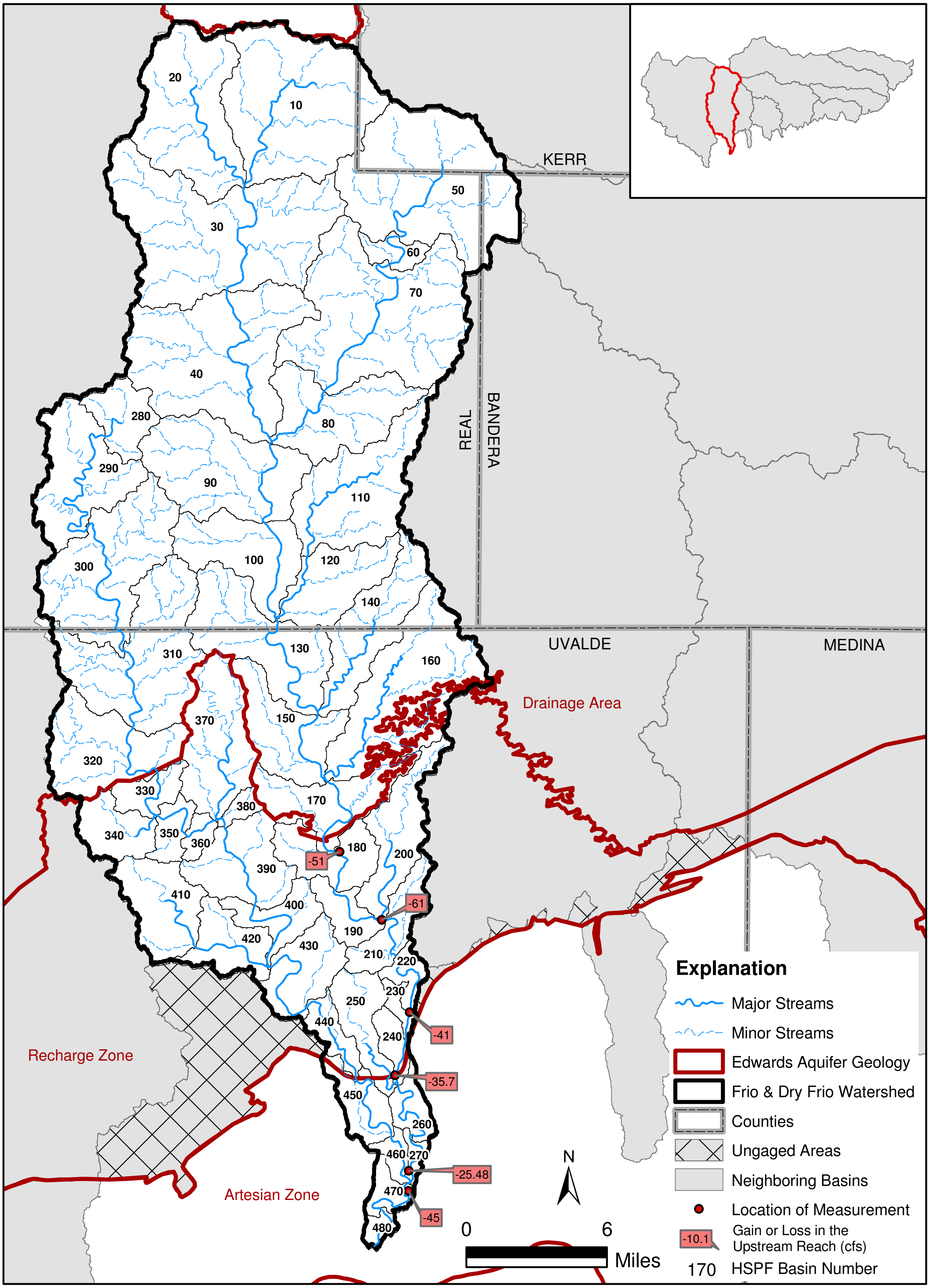

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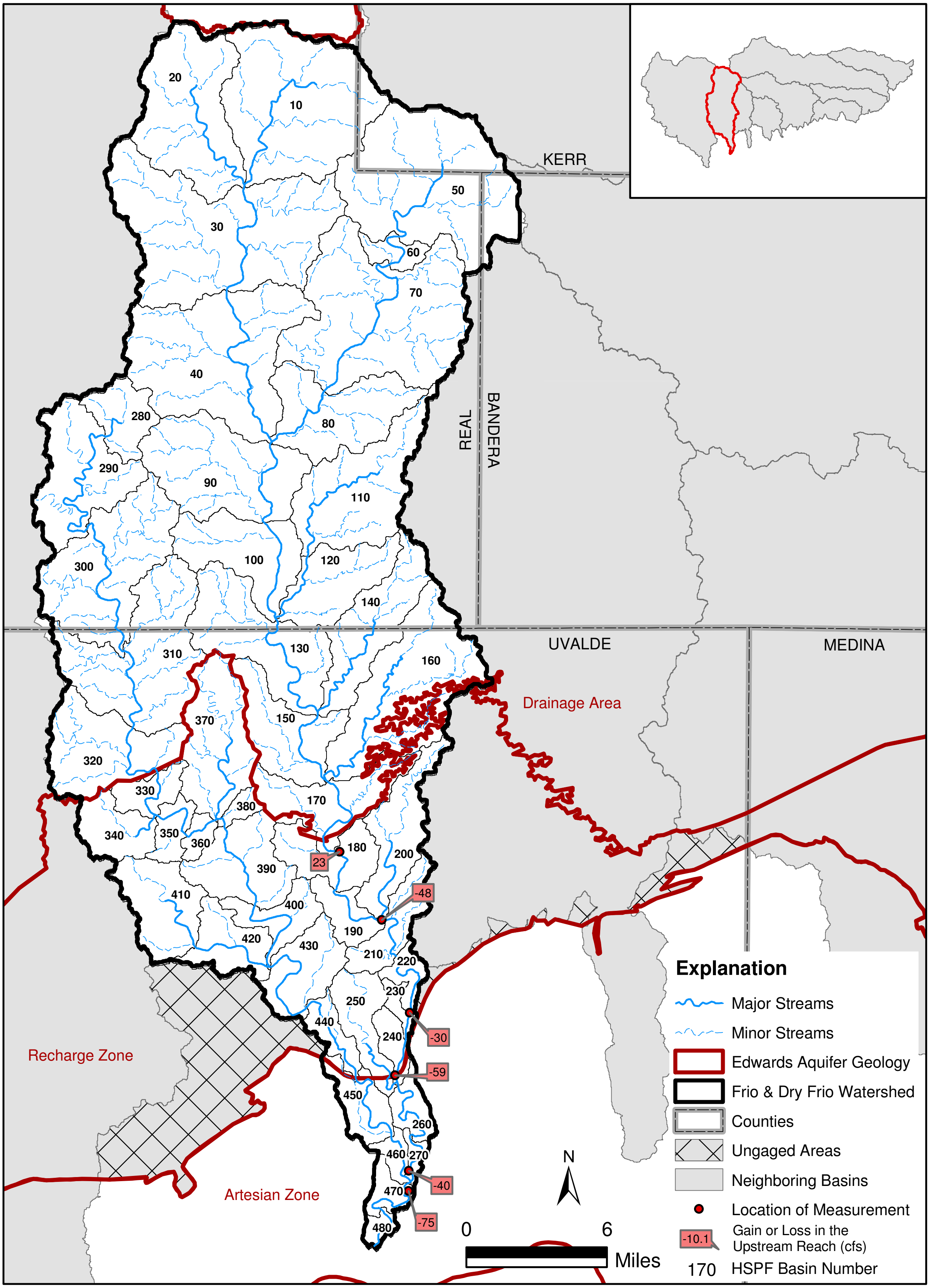

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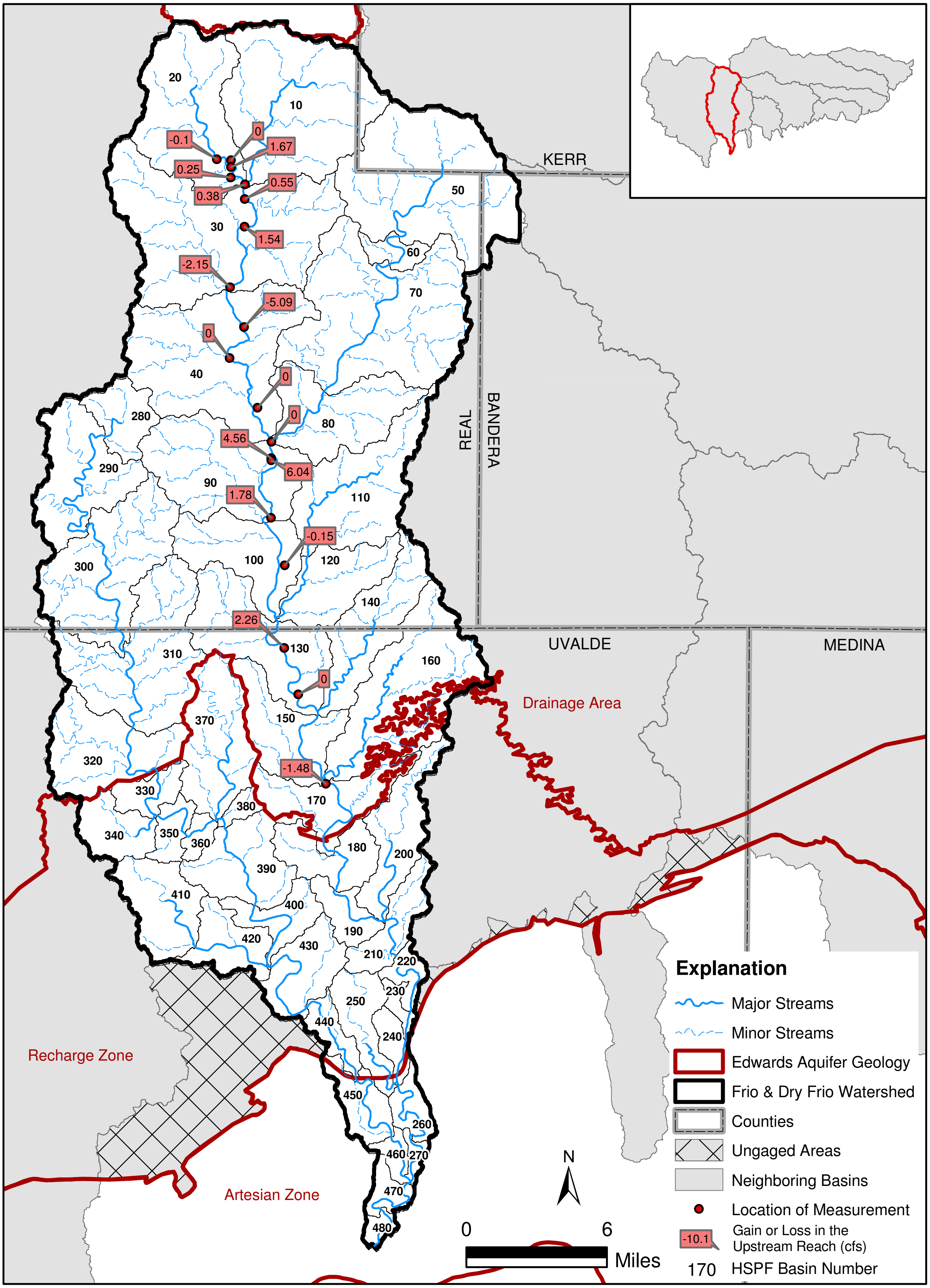

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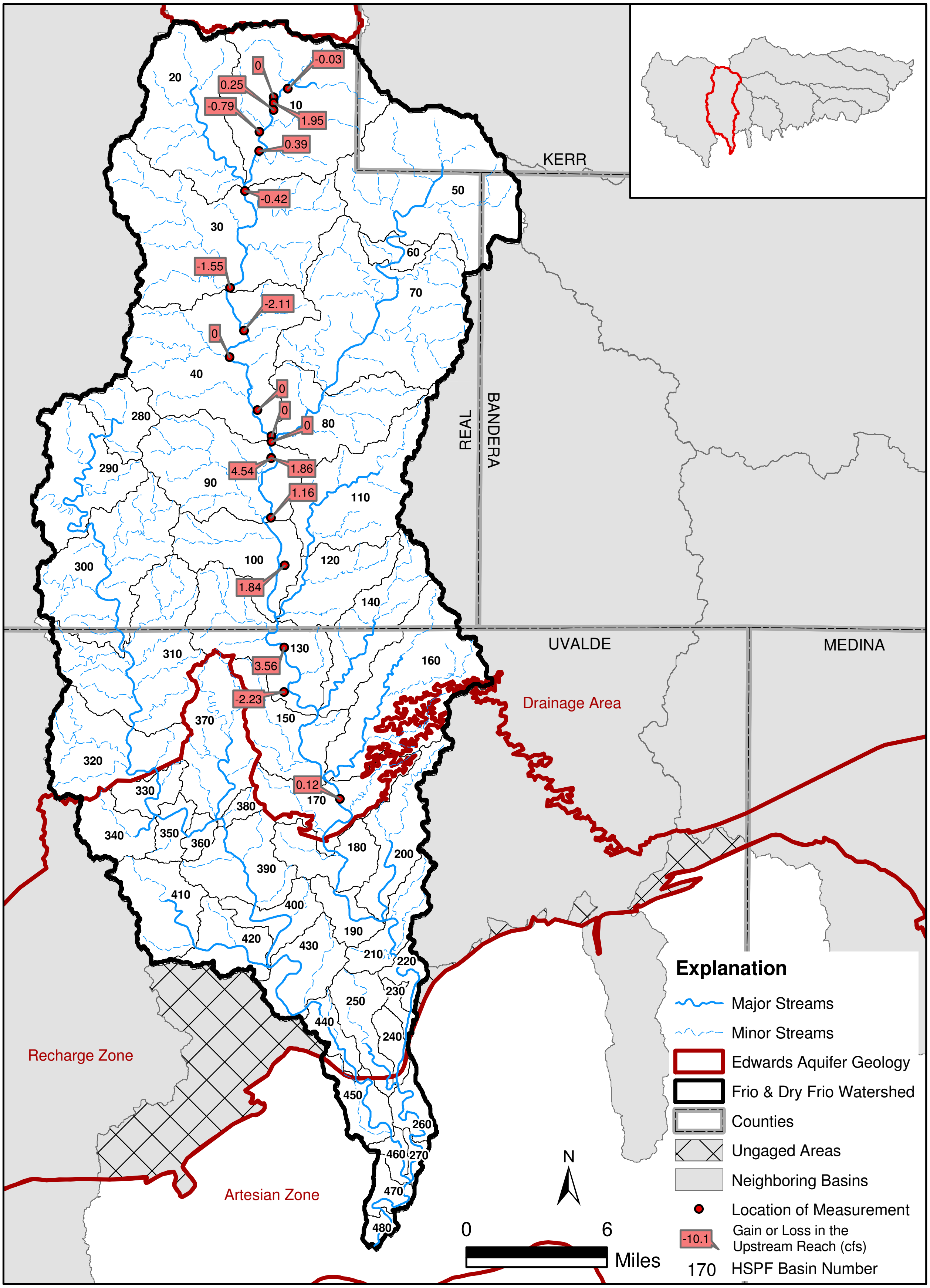

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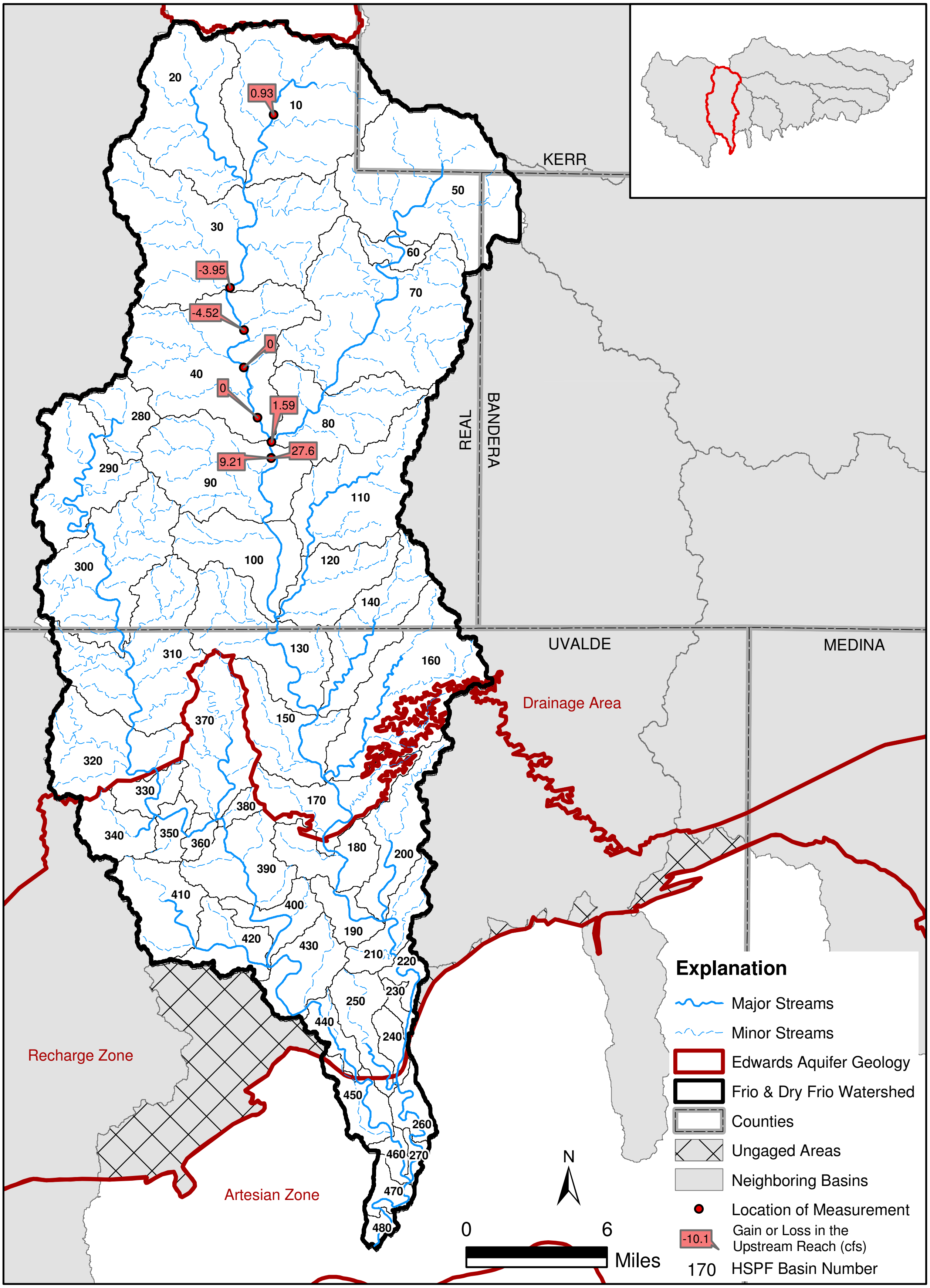

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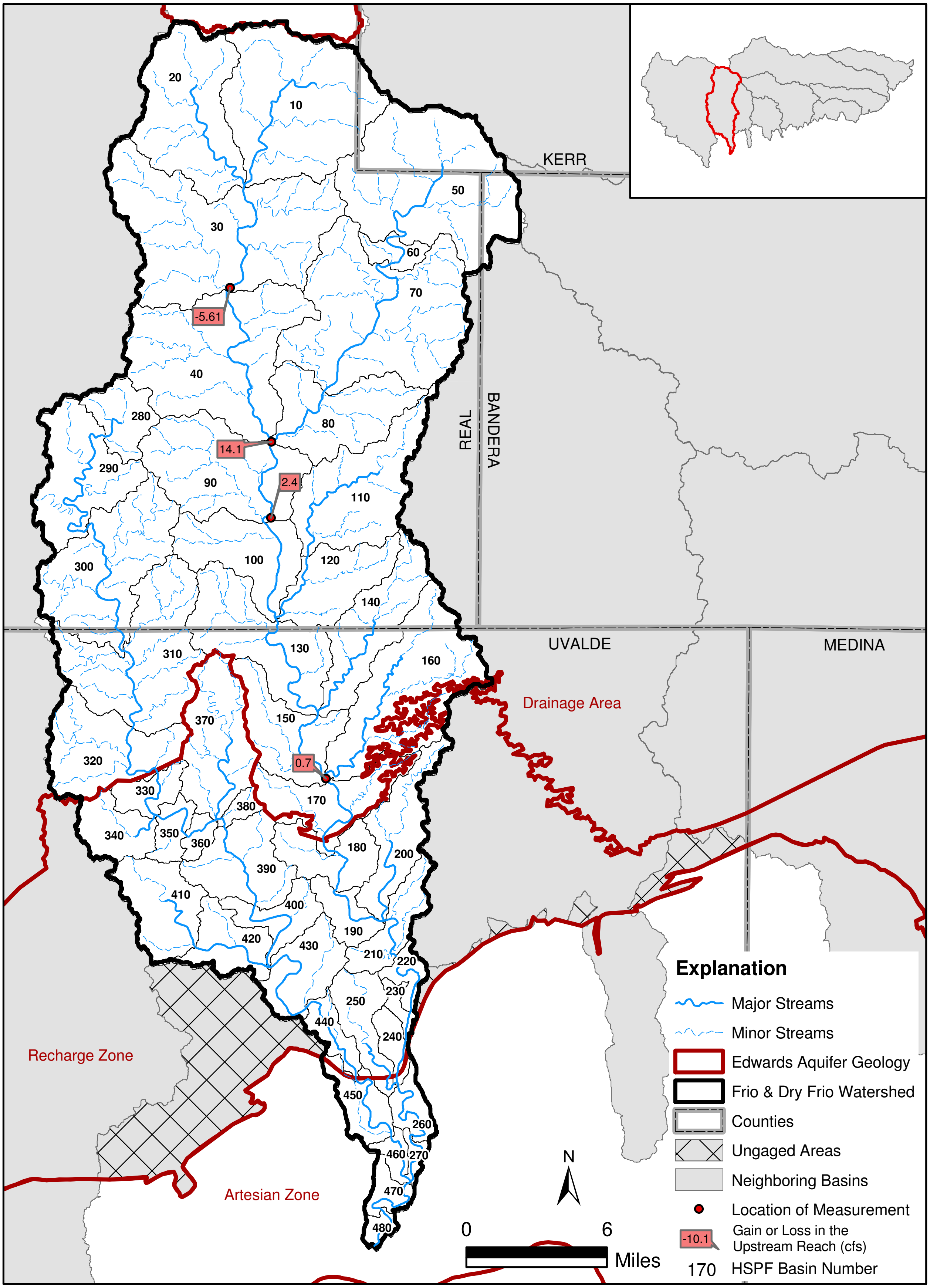

USGS Gain/Loss Study 236 in the Frio and Dry Frio Basin