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Ronald Childress Jr., Student

Dr. Jack Schieffer, Major Professor

Dr. Michael Reed, Director of Graduate Studies

WATER QUALITY TRADING MARKETS FOR THE KENTUCKY RIVER BASIN
WATERSHED: A POINT SOURCE PROFILE

THESIS

A thesis submitted in partial fulfillment of the
requirements for the degree of Master of Science in the
College of Agriculture
at the University of Kentucky

By

Ronald Childress Jr.

Lexington, KY

Director: Dr. Jack Schieffer, Associate Professor of Agricultural Economics

Lexington, KY

2012

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ABSTRACT OF THESIS

WATER QUALITY TRADING MARKETS FOR THE KENTUCKY RIVER BASIN WATERSHED: A POINT SOURCE PROFILE

This study assessed the feasibility and suitability of a Water Quality Trading (WQT) program within the Kentucky River Basin (KRB). The study's focal point was based on five success factors of a WQT program: environmental suitability, geospatial orientation, participant availability, regulatory incentive, and economic incentive. The study utilized these five success factors, geographical characteristics, and Discharge Monitoring Reports (DMR) to assess the feasibility of a WQT program.

The assessment divided the KRB into five eight digit Hydrologic Unit Codes (HUC), North, Middle, and South Fork, Middle Basin, and Lower Basin, to determine regional impacts caused by the nutrient PSs. Individual nutrient profiles were generated to show the number of point sources (PS) operating in the KRB, their geospatial orientation to one another, and their permitted nutrient limits and nutrient discharges in form of total phosphorus (TP), total nitrogen (TN), and total nitrogen (as ammonia) (TA).

Findings suggest trading is highly unlikely for TP and TN PSs due to the lack of regulatory standards, limited number of TN and TP PSs, and an inadequate demand for offset credits. Trading is also unlikely in all the HUC 8 watersheds except for the Lower Basin due to the lack of nutrient impaired waters.

Key Words: Point Source, Non-Point Source, Water Quality Trading, TMDL, Impaired Waters

Ronald Childress Jr.
October, 2012

WATER QUALITY TRADING MARKETS FOR THE KENTUCKY RIVER BASIN
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By

Ronald Childress Jr.

Dr. Jack Schieffer

Director of Thesis

Dr. Michael R. Reed

Director of Graduate Studies

October 2012

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CH. 1

1.1 Water Regulation

In 1972, the Federal Water Pollution Control Act, also known as the Clean Water Act (CWA), was established to restore and maintain the chemical, physical, and biological integrity of the Nation's waters (FWPCA 2002). At the time of the enactment of the CWA, 33% of rivers, lakes, and coastal waters were considered fishable and swimmable and thirty plus years later about 66% of the Nation's waters were considered healthy (EPA 2001). The CWA achieved these results by utilizing regulatory and non-regulatory pressures, such as; National Pollution Discharge Elimination System (NPDES) permits, technology-based effluent limitations (TBEL), water quality based effluent limitations (WQBEL), and total maximum daily loads (TMDL), and federally funded research grants. In the early years of the CWA, these pressures were primarily directed to regulating point source (PS) polluters, such as municipal wastewater plants and industrial PSs via National Pollution Discharge Elimination System (NPDES) permits (EPA 2008). The CWA made it illegal for any entity to directly discharge into the Nation's waters, which are all forms of surface water in the U.S., without a NPDES permits.

NPDES permits were established to track and limit the amount of pollutant discharge by PSs into the Nation's waters. PSs are entities that directly pollute into the U.S. waters from precise locations, such as, pipes, drainage ditches, sewer systems and etc. When PSs are faced with high compliance cost to comply with their permits, PSs have an alternative option to comply with their permits and that is to participate in a water quality trading (WQT) market. In recent years the EPA has allowed PSs to use

WQT as a tool to comply with their NPDES permits to help achieve water quality (WQ) standards. In 2003, the EPA issued the Water Quality Trading Policy that allows and supports the adoption of market-based programs and encourages the trading of nutrients (e.g. total phosphorus and total nitrogen) and sediments for improving water quality (EPA 2004). Water quality trading allows pollution sources with a high compliance cost of meeting their NPDES permitted limits to buy credits from pollution sources with lower compliance cost. Pollution credits are generated when the pollution source with the lower cost of compliance, due to better technologies or techniques of abating pollution, abate below their permitted limits. The excess reduction that the lower cost pollution source has created can then be sold as pounds of pollution reduced to pollutions sources with higher compliance cost. To better understand WQT, we must understand some basics about the CWA and the impact that non-regulatory and regulatory pressures have on WQT.

Under section 303(d) of the CWA states are required to (Roberts 2005):

1. Identify waters that fail to meet WQ standards after PSs have complied with their NPDES permits requirements.
2. For these water bodies calculate the TMDL that can be discharged into the water body without causing the water body to fail WQ standards.
3. Allocate this pollutant among all sources of discharges to this water body.

The first requirement above is the backbone on which WQT rests. The identification and location of impaired waters and the compliance status of PSs are critical in establishing a WQT market. Without the presence of non-compliant PSs and/or impaired waters WQT becomes obsolete because the ability to improve WQ or to generate

pollution credits does not exist. WQT is designed to help improve or sustain WQ of impaired waters. However, when impaired waters fail to exist so does the existence of a WQT program. When impaired waters do exist, one must determine potential pollution sources that are causing the impairment, PS or non-point source (NPS), and then look at the compliance status of NPDES permits. NPDES permits contain effluent limitations on specific pollutants that PSs discharge. If PSs do not comply with these effluent limitations they will be subject to penalty. There are two effluent limitations: TBEL and WQBEL both enforceable by the EPA. The EPA has established effluent limitation guidelines (ELG) for each industry and requires every PS to comply with these limitations by implementing TBELs. The intent of a TBEL is to require a minimum level of treatment for industrial/municipal PSs based on currently available treatment technologies while allowing the discharger to use any available control technique to meet the limitations (EPA 2010). There are two types of requirements that the TBELs can follow:

1. National or
2. Facility Specific

National requirements are standards applied to all PSs within the same industrial category nationwide. When these standards are not suitable for a particular facility a facility specific standard approach is applied. In the instance of a facility specific TBEL the permit writer must employ their Best Professional Judgment (BPJ) by considering the best practicable control technology currently available (BPT), the best available technology economically achievable (BAT), and the best conventional pollutant control technology (BCT) for conventional pollutants (EPA 2010). When all considerations and

implementations of TBELs are met and still fail to meet the reductions needed then the EPA will implement more stringent WQBEL.

WQBELs are stringent effluent limitations to ensure that State WQ standards are met when TBELs fail. Section 303(c)(1) requires every state to establish WQ standards and at least once every three years to review the existing WQ standards to see if existing WQ standards are adequate and if not new standards should be adopted (FWPCA 2002). Under section 303(2) (A) states:

“....standards shall be established taking into consideration their use and value for public water supplies, propagation of fish and wildlife, recreational purposes, and agricultural, industrial, and other purposes, and also taking into consideration their use and value for navigation.”

The focal point of WQBELs is to maintain section 303(2)(A) and to ensure that State WQ standards are achieved by analyzing PS effluent discharges and the effect discharges have on the receiving water. WQBELs are established when States determine pollutants that are causing impairments to a particular water body. Then States establish numerical criteria for all toxic pollutants that are under the CWA for that particular water body.

Another alternative that helps maintain section 303(2) is the development of TMDLs. TMDLs are necessary when a water body is not supporting one or more of its designated uses. This takes us to the second and third requirement under section 303(d) of the CWA. Once States identify impaired water bodies they are required to develop TMDLs for that water body. TMDLs determine the maximum amount of a pollutant a water body can receive, while satisfying WQ standards. This maximum amount is then

divided into waste load allocations (WLA) to each PS discharging to that body of water. Then WQBEL are established based on each PS's WLA to maintain WQ standards. After States complete their WQ assessments they are obligated to report their findings to Congress every two years in the form of Integrated Reports (IR).

Over the past decade the EPA has been promoting the assessment of the Nation's waters, which resulted in an explosion in TMDLs. Figure 1-1 depicts the number of TMDLs approved since October 1, 1995 to 2008 (EPA 2008).

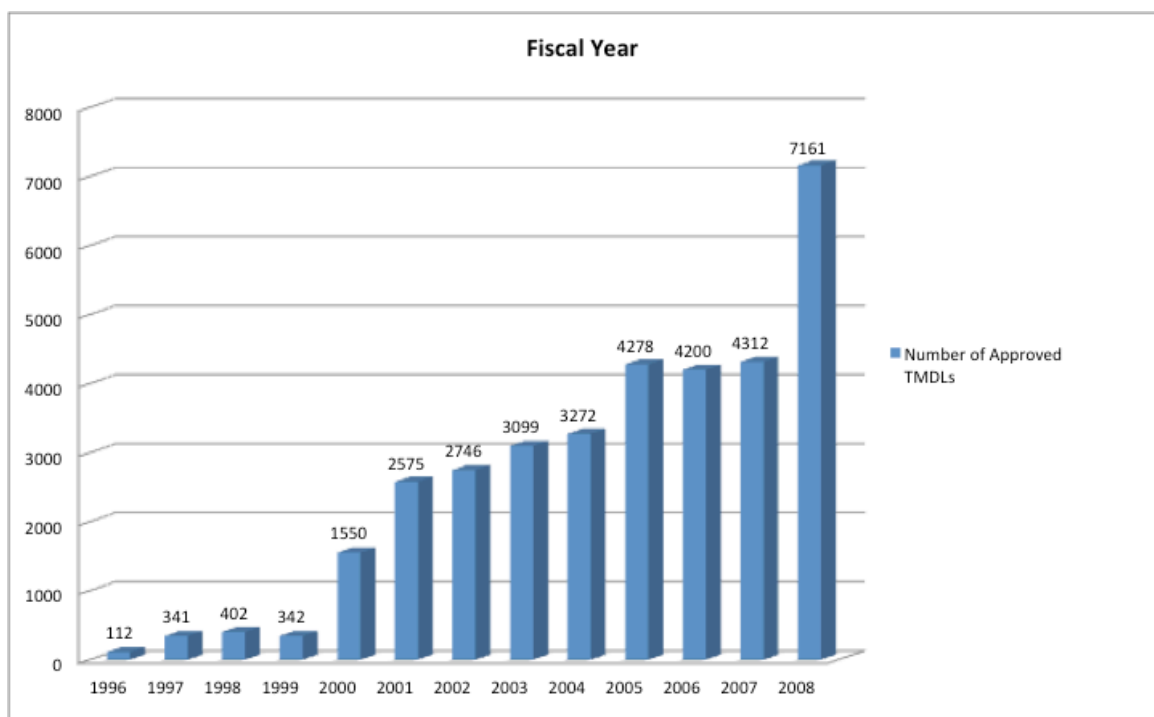


Figure 1-1 Number of TMDLs Approved by Fiscal Year Since October 1, 1995

Since October 1, 1995 to 2008 there has been a 6,394% increase in TMDL approvals consisting of approximately 34,390 TMDL approvals within the US. The establishment of these TMDLs has addressed more than 36,000 impairments, but the States have also discovered 70,000 more TMDLs still to be developed (EPA 2008). As

of 2010 Kentucky had 200 approved TMDLs. Figure 1-2 below shows the total TMDL status for Kentucky (KDOW 2010).

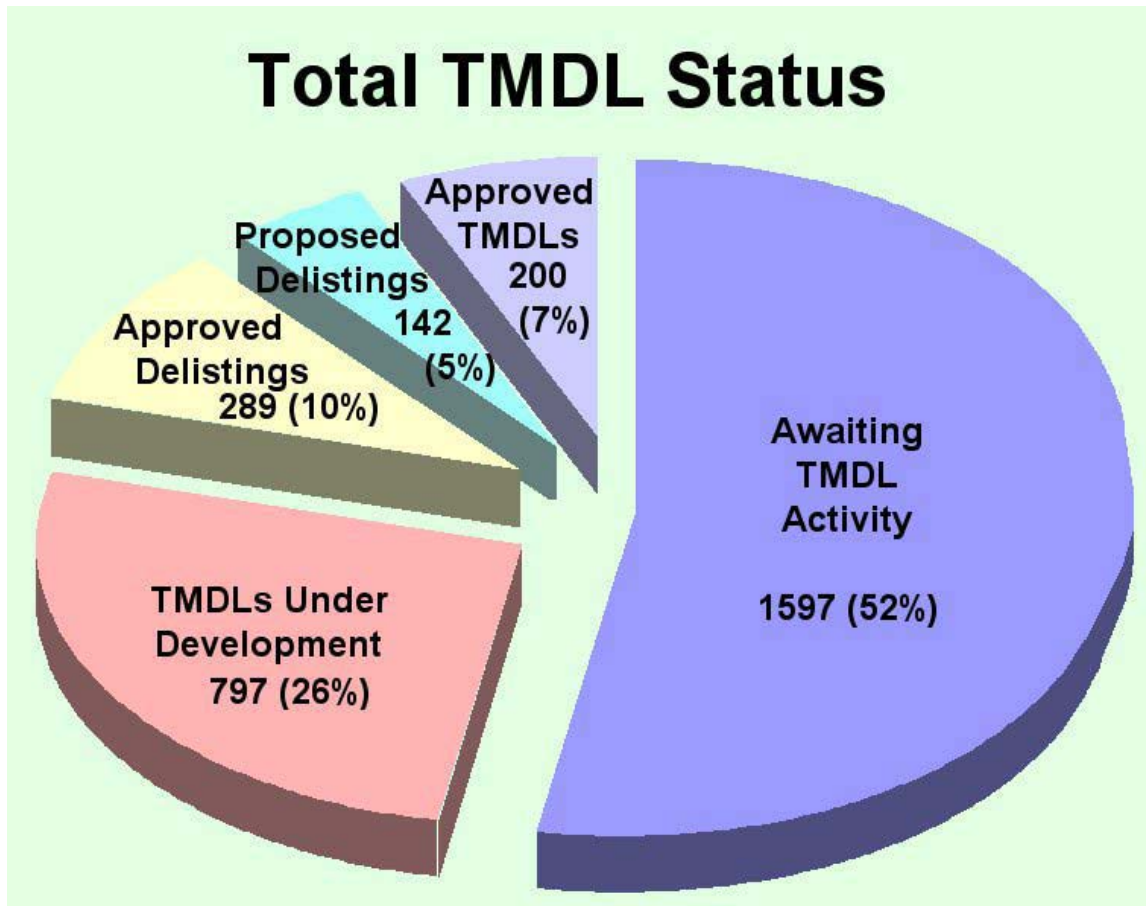


Figure 1-2 Kentucky TMDLs Status

Currently, there are a small number of TMDLs for the KRB. TMDLs are the leading market drivers for WQT markets today because they typically create the “need” to alter behavior by identifying pollutant reductions needed to meet water quality standards (EPA 2004).

1.2 Concerns

Water is a precious resource and the degradation to WQ can have a huge impact on human health, wildlife, and the environment. Water impairments are not only in

major lakes, rivers, and streams. They are also located in smaller bodies of water that are right in our backyards. Many of the impairments are caused by everyday activities, such as, chemical runoff from roads and parking lots, fertilizer used to treat lawns, municipal discharges, and agriculture runoff. These discharges lead to water bodies that do not sustain aquatic life and/or are unfit for recreational use. Our everyday activities not only impact our local environment, but also our Nation's environment. Figure 1-3 below illustrates the many hypoxic areas around the U.S. (WRI 2008).

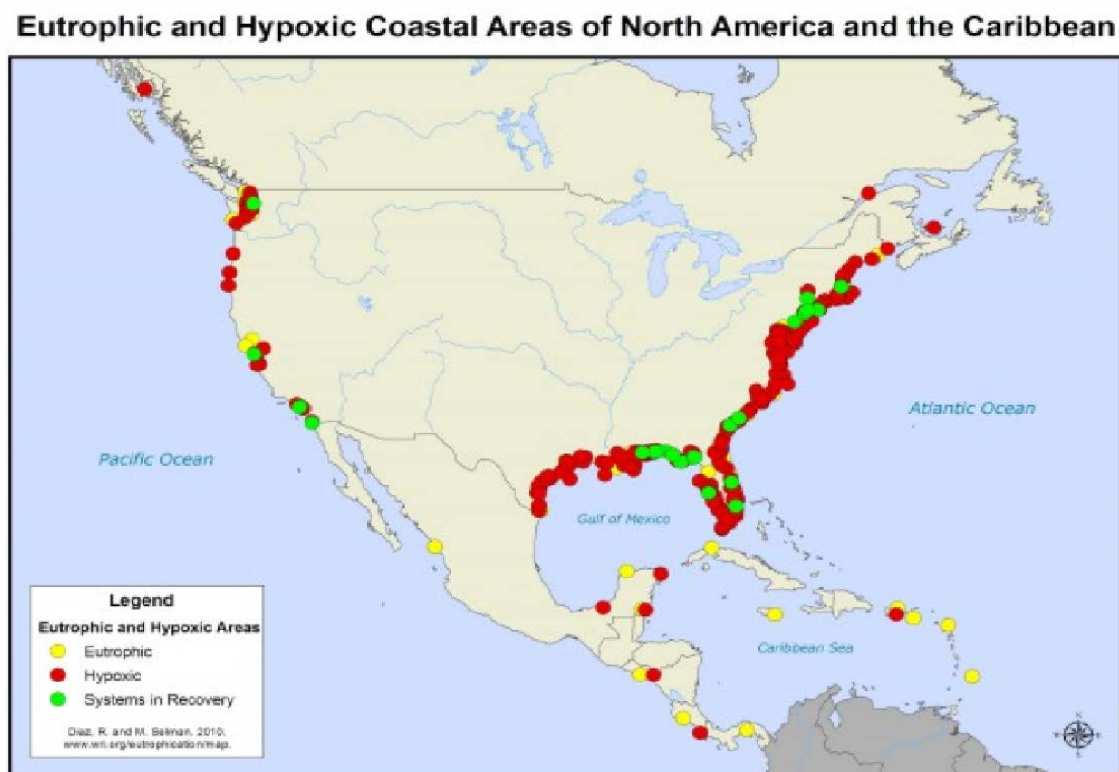


Figure 1-3 Eutrophic and Hypoxic Coastal Areas of North America and the Caribbean

One can see the hypoxic and eutrophic regions are contained along the coastlines. These regions are where streams and rivers empty into the ocean, discharging all the pollutants that pollution sources have discharged into the Nation's waters.

In recent years there has been a growing concern for the hypoxic zone in the Gulf of Mexico, which is home to one of the world's largest hypoxic zones. In 2010 the hypoxic zone was estimated to be approximately the size of Massachusetts (EPA 2012). The creation of the hypoxic zone is due to the collection of excessive nutrient, sediment, and other oxygen depleting pollutant discharges. The culmination of these various pollutants has had a massive impact on aquatic life. The KRB is one of the contributing regions to the degradation of the Gulf of Mexico. The KRB empties out into the Ohio River and then the Ohio River empties into the Mississippi River, which empties out into the Gulf of Mexico.

The focal point of this study is to determine the discharge behaviors and impacts of the PSs in the KRB and to shed some light on whether WQT would be a reliable tool to sustain or better WQ within the KRB. Increasing the WQ within this region will not only benefit the local environment, but the Nation's environmental health as well. The next section discusses the basics of WQT and how it can impact WQ.

1.3 Water Quality Trading

The EPA allows PSs, depending on their type, to have options in how they can comply with their permitted limits (listed in preferential order): pollution prevention, recycle/reuse, new technology, and WQT (Virginia 2007). Water quality trading is a market-based approach to maintaining or improving an environmental standard by reducing the abatement cost polluters face. WQT allows individual dischargers to be free to choose the most appropriate means of complying with WQ standards, and to have an economic incentive to reduce emissions below their permitted levels, which generates technological innovation, as new means are sought to reduce pollution cost effectively

(Schaltegger 1996). Trading occurs when one discharger facing higher compliance costs to meet a new or revised permit limit seeks a more cost effective solution by purchasing credits (pounds of pollutant reduced) from another discharger in its watershed (Virginia 1996). The seller of the credits face lower abatement cost, due to better technology or better management practices. Low cost abaters can abate pollution below their permitted limits, generating pounds of pollutants reduced. The reductions can then be sold to high cost abaters as offset credits; so that high cost abaters can comply with their permitted limits.

WQT initiatives began in the 1980s where Wisconsin instituted PS-PS WQT program and Colorado conducted trading involving NPS trading, with both programs experiencing minimal trades (Kieser and Fang 2004). In the mid to late 1990s, with the highly publicized Acid Rain Program, many policy makers were convinced that emissions trading would work for water pollution control, since it worked for air pollution control (Kieser and Fang 2004). Case studies of watersheds in Michigan, Wisconsin, and Minnesota showed that nutrient trading was dramatically less expensive than traditional PS performance requirements (Faeth 2000). In the case of Michigan, the cost of a pound of phosphorus reduced was estimated at \$2.90 versus \$24 per pound when utilizing traditional PS requirements, which is a substantial cost savings (Faeth 2000). In the Minnesota study phosphorus reductions were estimated to between \$4.44 and \$6.14 per pound (Fang 2003). Even though WQT showed a strong potential for cost saving and WQ improvements there were many concerns that arose when establishing the market. There were three major challenges to a successful WQT program development:

equivalence of trades, avoiding hot spots, calculating NPS pollution reduction (Kieser and Fang 2004). These three challenges are addressed in Chapter 2.

Another important concern is trading among different pollution sources. PS-PS trading is generally easier to deal with because each PS knows, on average, how many pounds of a nutrient they discharge from their facilities. But for PS-NPS it becomes less transparent. In PS-NPS trading, a trading ratio must be established between the two sources because it is inherently uncertain to actually know the total reduction caused by NPSs versus PSs (Faeth 2000). Another problem is that NPSs do not have permits that specify the amount of pollutant allowed over a specified time because from an economic perspective, buyers and sellers in a WQT market have permitted limit pollutant discharges over a predetermined time (Kieser and Fang 2004). Thus determining NPS reductions over a particular time period is difficult, which further creates contractual issues between PSs and NPSs. Many studies show that for NPSs to participate in trading they must establish, implement, operate, and/or maintain certain practices that will lead to reductions and come into a contractual agreement with the PSs.

CH. 2

2.1 Literature Review

Throughout the WQT literature, it is evident that over the past 20 years there has been a heightened awareness and interest in utilizing WQT markets as a tool to improve WQ in the U.S. This trading system allows pollution sources to trade offset credits, which allows sources with higher abatement cost to pollute more and sources with lower abatement cost to pollute less. The result is minimum compliance cost without causing further damage to WQ. Many States have an interest in researching the feasibility and the implementation of WQT and its effectiveness in increasing state water quality. As a result, many state initiatives have led to research about the characteristics of an ideal WQT market.

In 2004, there were more than 70 WQT initiatives in the U.S., but many of these programs have not made it past the pre-trading stage (King 2005). The literature reveals that the stunted growth of WQT markets is due to the countless scenarios and factors that change with time and are variable with weather conditions. To better understand many of these factors and scenarios, Kristin Rowles (2005) outlines five general factors that are necessary for evaluating WQT:

1. Environmental suitability
2. Regulatory incentive
3. Participant availability
4. Economic incentive
5. Stakeholder response

These five factors are good foundational principles when analyzing and researching the creation of a WTQ market. For the purpose of this study, only factors one through four are considered. The main focus of this study is to simply construct a physical profile of the KRB to find potential trading areas by utilizing these four factors. The stakeholder's response focuses on the intricate details of trading, such as participant's willingness to engage in trading, policy issues, environmental group impacts, and political rhetoric. Beyond these four factors there is one vital factor that is missing from this list that is critical to the creation of a WQT market. That factor is the Geospatial Orientation of pollution sources. Thus, this paper will focus on these five factors:

1. Environmental suitability
2. Geospatial Orientation
3. Participant availability
4. Regulatory incentive
5. Economic incentive

The culmination of these five factors will construct a detailed profile of the KRB watershed and shed light on whether trading is feasible. Many of these factors are interrelated to some degree. To further understand them, the next five sections will discuss each of the factors in detail.

2.2 Environmental Suitability

For a successful WQT program the watershed's environment must be conducive for trading. A suitable environment takes into account impaired waters, pollutant types, and potential participants. The first step in developing a WQT program is to determine

whether impaired waters are present and if so, do they have a TMDL. The WQT Policy (2003) states:

“All water quality trading should occur within a watershed or a defined area for which a TMDL has been approved. Establishing defined trading areas that coincide with a watershed or TMDL boundary results in trades that affect the same water body or stream segment and helps ensure that water quality standards are maintained or achieved throughout the trading area and contiguous waters “.

Under the CWA, States are required to do three basic things: list and identify impaired waters, rank and prioritize troubled waters, implement TMDLs (Boyd 2000). Once States identify and list the impaired waters, the EPA finalizes this list and adds it to section 303(d) of the CWA. States then have the leeway to rank and prioritize water quality impairments based on their severity, apart from those waters listed as public drinking water supplies and/or impaired water bodies posing a threat toward the species listed under the Endangered Species List (Boyd 2000). When the severity of the impairment is established, States are then obligated by the CWA to implement TMDLs. Knowing that a water body is impaired is not enough if we do not know if the pollutant to be traded is contributing to the impairment (Crutchfield 1994).

WQT also requires that the target pollutant must be a tradable substance in order for trading to take place. The EPA supports trading of nutrients, sediment loads, and other pollutants to improve WQ. WQT works best with conservative pollutants that degrade slowly and that create impacts as a result of their total accumulation in a water system (Ribaud 1998). Phosphorus and nitrogen meet both of these degradation and accumulation characteristics.

Tradability is based on four key trading suitability factors: type/form, impact, time, quantity (EPA 2004). The type of pollutant refers to its scientific classification and the form refers to the pollutants state. For example, total phosphorus is measured in two forms: soluble and non-soluble. Phosphorus in its soluble form is easily absorbed into the environment through plant uptake and the non-soluble form binds with sediments and becomes biologically available over time (Rowles 2004). Depending on the form of the pollutant environmental impacts will vary. The environmental impact is measured by equating the water quality where reductions occur to the water quality where the offset credits are used (Rowles 2004). This ensures that water quality is kept at the same level or better. Which brings us to another obstacle and that is establishing trade equivalence, which is discussed in greater detail in the next section. A potential participant refers to the pollution sources in the watershed, their geospatial orientation from one another and their impacts on the water bodies within the watershed. Section 2.4 will speak on this subject in more detail.

2.3 Geospatial Orientation

Research reveals that the geospatial orientation, the number of pollution sources, and water impairments, in relation to one another, are critical in developing a WQT market. David C. Roberts (2005) claims that the geographical and spatial dimensions are critical to the feasibility of a WQT market and that “the feasibility of a market depends quite crucially upon the relative location of discharge sources both to one another and to water quality impairments”. The main concern with the geographical location of pollution sources is equivalence and generation of hot spots.

Pollution sources' discharges, especially from NPSs, experience dispersion across different land covers and uptake by the soil and plants causing a non-equivalence problem among pollution sources. Non-equivalence is generated by uncertainty in estimating NPS loadings. PS discharges experience relatively lower degrees of uncertainty, due to their distinct discharge points, compared to NPSs (Easter 2006). NPS discharges have to be estimated through various forms of sophisticated modeling, such as, the Revised Universal Soil Loss Equation (RUSLE) used to calculate the effect of cover cropping on soil eroded from the field and the Agricultural Drainage And Pesticide Transport (ADAPT) model to predict soil loss (Fang 2005), and the Soil and Water Assessment Tool (SWAT) model to predict the impact of land management practices on water, sediment, and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time (Kieser 2004). Without adequate monitoring, the applicability and accuracy of these models may become a major point of dispute in a trading program (Fang 2005). The scientific uncertainty in quantifying NPSs emissions makes it difficult to measure and assign ownership to NPSs (Easter 2006).

Uncertainty can also manifest itself through unpredictability of weather conditions, the verifiability of NPS load models, and the lack of knowledge on the long term water quality impact on receiving water bodies (Fang 2005). Thus, geographic distance between discharge points will dictate the pollutants impact on impaired waters through uptake and settlement, and complex intervening hydrology in the waters between those points, which requires more complex models to capture the dynamic relationships (EPA 2004). For example, a pound of TP upstream will be less than a pound of TP

downstream once reaching the impairment, depending on the distance of upstream discharges. Thus to maintain some form of equivalence between credit trades among pollution sources trading ratio must be established.

Trading ratios are utilized to compensate for uncertainty produced by watershed characteristics, geography, hydrology, distances between pollution sources, and trade between PSs and NPSs. Trade will always be affected by the dynamics of a watershed, such as, geography, hydrology, and location of pollution sources. For instance, the geography of a watershed will be different within and across watersheds, such as; terrain slope, imperviousness, land cover, population density, and agriculture. These major factors alter the way pollution sources impact water quality. Hilly, sloped, or impervious terrain can lead to excess soil erosion and pollution runoff into nearby water bodies.

Changes in land use that alter the flow of water through watersheds should also be considered in any management plan (KWRRI 2002). Different types of land cover will have different absorption rates and assimilative capacities for different types of pollutants, thus lessening pollutant impact. Watersheds with higher population densities face wastewater treatment plants (WTP), landfills, construction runoff, and a higher density of impervious surfaces due to major roads. Development also leads to a reduction in the amount of rain that soaks into the ground and to an increase in impervious surfaces such as roofs, pavement, and compacted soil that shed water more rapidly (KWRRI 2002). With a growing population these factors will only be magnified and pollutant runoffs will intensify. Due to population growth sewage systems are lagging because there are now more people who are not served by sewage treatment lagging sewage systems (Faeth 2000). Between 1980 and 1996 the US experienced a 2%

increase in the number of people being served and at the same time the US population grew by 17% with an estimated 75 million people that did not have access to sewage treatment (Faeth 2000).

Past experience suggest that sources in close proximity have similar water quality impacts and may have water quality equivalence ratios of 1:1, so that a 1 unit supplied equals a one unit demanded (Spokane 2005). The preceding digit in the ratio represents the amount of pollution abated and the proceeding digit represents an equivalent reduction downstream. For example, a trading ratio of 5:1 means that for every five pounds reduced upstream one pound maybe added downstream. A large distance between sources, high density of stream vegetation, and/or stream speeds can cause a large trading ratio. Sources can also be in closer proximity and have high trading ratios due to dense land cover and stream vegetation that has a greater uptake capacity, which affects the downstream equivalence.

The hydrological characteristics of the watershed are of extreme importance. Water bodies, such as, lakes and estuaries that have pollutant accumulation overtime and low flow are ideal for WQT because there is less variability in trading equivalence (Rowles 2005). Stream vegetation density and stream speeds alter the nutrient impact downstream due to aquatic plant uptake, settling out, or water diversion for agricultural use (EPA 2004). The speed of the stream can also impact the time vegetation partakes in nutrient uptake. Thus, slower the stream the more likely plant uptake will take place and faster the stream the likelihood of plant uptake is diminished. Climate changes also impact stream speeds and have profound effects on the entire hydrological aspects of a watershed by causing both long-term structural changes to the water cycle and increased

variability and unpredictability, and impacting agricultural productivity (Darghouth 2008). There are countless scenarios that can be generated from trading ratios that are subject to the geographical location of pollution sources and the watershed's characteristics.

Apart from the watershed's characteristics, trading ratios cannot become too large. Larger trading ratios increases the marginal cost of abatement and the advantage low-cost abaters have over the high-cost abaters becomes eliminated (Jarvie 1998). Once low-cost abaters lose their advantage over high-cost abaters trading will cease because it would become too costly to supply offset credits. To keep these trading ratios from becoming too large a trading zone must be established. The goal of a trade zone is to create a 1:1 ratio in specific geographic regions such that a 1 unit supplied equals a 1 unit demanded. To help locate potential trade zones a detailed profile and description of the watershed is essential. Certain watershed characteristics, hydrological traits, and total number of PSs available make certain regions more apt to higher trading ratios. Once the geographical positions of the pollution sources and impaired waters and watershed characteristics are defined, potential trading zones can be ascertained.

A key element in assigning trade zones is the spatial orientation of the PSs. Trades must be conducted from upstream sources to avoid localized hot spots. Hot spots are segments of a water body where pollutant loadings are too high. Figure 2-1 illustrates how hot spots can be created (Kristin Rowles 2005).

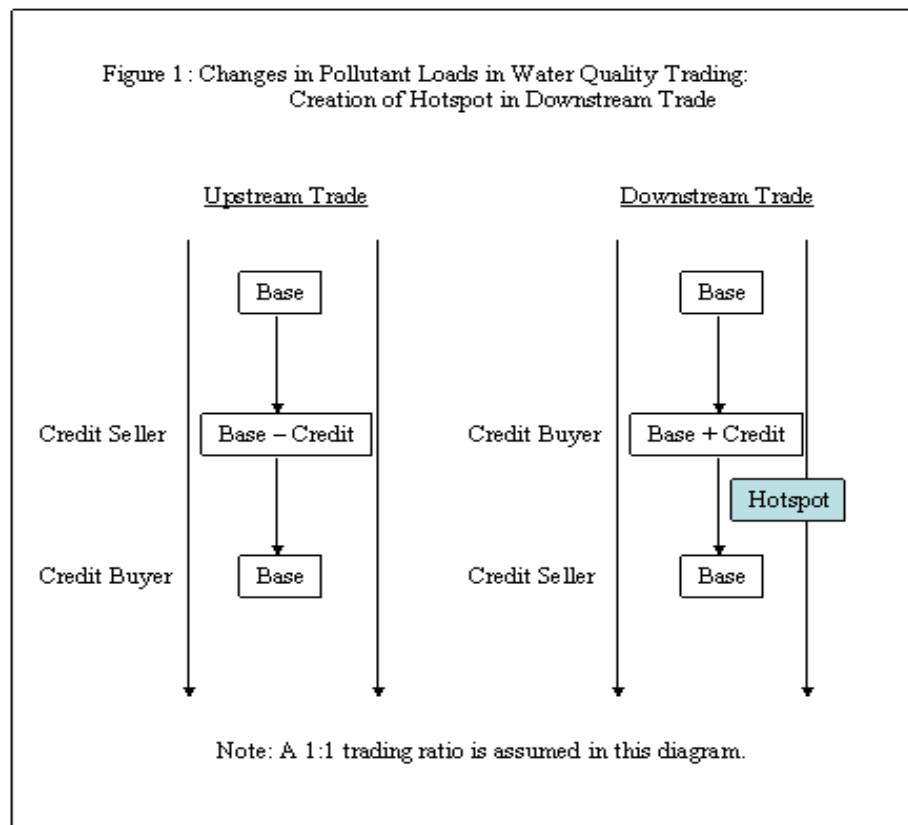


Figure 2-1 Upstream vs. Downstream Trade

Looking at Figure 2-1 one can see that downstream trades create hotspots. These hotspots are created when credit buyers are located upstream of the credit sellers. Credits sellers generate credits when they abated below their regulatory requirements. Once this occurs credit sellers are allowed to sell the amount of their reductions to the credit buyers. This offset credit adds to the amount that the buyer is allowed to pollute to reach compliance. Thus, when credit buyers purchase offset credits downstream the pollutant loadings in the water between the credit buyer and the credit seller becomes too high. But when trading is conducted as an upstream trade, where the credit seller is upstream of the credit buyer, hotspots are unlikely to occur. The severity of the hot spot will depend

on the amount of discharges, stream flow rate, stream vegetation, and assimilative capacity of the stream segment.

Another important aspect of trading ratios is the timing of trades. Purchased reductions should be produced during the same time period that a buyer was required to produce them (e.g., during the permit compliance reporting period or during the same season when the permit limit was applicable) (EPA 2004). The WQT Assessment Handbook considers three time dimensions, load variability, compliance determination variability, and compliance deadline variability; if all three can be aligned, trading may be viable (2004). Load variability refers to pollution sources' discharges varying over time. Discharges will have different impacts depending on the source and the season. Timing of discharges must line up with the buyer and seller's needs. For example, if the TMDL requires a source to reduce discharges during the summer, a seller typically cannot produce reductions in the winter for exchange (Spokane 2005). Compliance determination variability refers to the specified monitoring period of the NPDES permits. PSs monitoring periods vary between daily, weekly, monthly, quarterly, or annual limits. For trade to occur reductions generated by the seller must be aligned with the monitoring period of the buyer. The compliance deadline variability refers to the different deadlines that pollution sources have to achieve the necessary reductions assigned by the TMDL or the NPDES permit. The more accurate these three dimensions of variability are aligned trading becomes more likely. Given this information the geospatial orientation of trading partners has a direct effect on participant availability.

2.4 Participant Availability

The participants are the backbone of WQT. They provide the physical structure as buyers and sellers to the market and the commodity to be traded. WQT involves two types of participants: PS, NPS. PS polluters are the entities that directly discharge into the U.S. waters from precise location, such as, pipes, drainage ditches, sewer systems etc. These sources can fall under three major categories: wastewater treatment plants, power plants, industrial sources (Crutchfield 1994). The EPA classifies PSs into two categories: Major and Minor. Major facilities meet one of three criteria (Dietrich 2004):

1. Possess a discharge flow of 1 million gallons per day
2. Serve a population of 10,000 or greater; or
3. Cause significant impact on the receiving water body

Industrial and municipal point sources were the worst and most obvious offenders of surface water quality, but are also the easiest to address because of their loadings emerge from a discrete point such as the end of a pipe (Letson 1993). The EPA requires all PSs to attain a NPDES permit, which limits the pollutant discharges from their facilities. Each PS is responsible for monitoring and collecting data on their discharge loadings, which are record on their discharge monitoring report (DMR). The DMR is then submitted to the State to determine their compliance status based on their NPDES permitted limits. States then enter the DMR into the federal permit compliance system (PCS) so the EPA can oversee the States Permitting Program.

NPDES permit requires PSs to implement TBELs, which are limits that are based on the technology that a facility employs, to reduce the amount of pollutants being discharged. PSs must employ technology that is able to meet the necessary pollutant

reductions required by their permit. Technology-based requirements (and their associated effluent standards) are non-negotiable under the CWA, thus all point source dischargers must install appropriate treatment to achieve these required discharge levels (Boyd 2000). If the technology fails to produce the necessary reductions required by the NPDES permit then the facility would be subject to a WQBEL or a fine. Trade allows PSs to avoid potential fines through trade.

NPS discharges enter water bodies from a diffuse area, such as, forestry, agricultural operations, and urban area run off from streets, yards, and construction activities (Stephenson 1998). NPS sources consist of logging and construction activities (significant source of sediment contamination), urban and suburban areas due to the increase of residential and commercial and population density via unfiltered runoff from roads and parking lots, chemically treated lawns, and commercial establishments (Boyd 2000). Crutchfield categorizes NPS into four different types: run off from urban, cropland, pasture, or barren lands (1994). Agriculture is considered the largest contributor to the impairments of rivers and lakes via pesticides, fertilizer, and animal waste runoff (Boyd 2000). The means for controlling agricultural NPSs are cheaper than urban runoff and more controllable than runoff from forestland or barren lands (Crutchfield 1994). Farm runoff in the Kentucky drainage seems seldom to contain significant levels of pesticides, but it can wash excess nitrogen and phosphorus, bacteria, organic matter, and sediment into streams (KWRRRI 2002). NPS problems are harder to manage because monitoring and enforcement become more difficult when sources have diffused discharges (Letson 1993). Due to the diffused nature of NPS discharges NPSs are exempted from regulation due to monitoring difficulties and political sensitivities

(Breetz 2005). Kentucky farmers who own 10 acres or more are required to have an Agricultural Water Quality Plan to assure that groundwater and surface water are protected (KWRRRI 2002). Failure to control NPS discharges could lead to a failure to achieve WQ standards (Stephenson 1998).

Having suitable trading partners is critical to the success of a WTQ program because having too few or too many can stop trading (Rowles 2005). Having too few trading partners may lead to supply and demand issues, such as, supply not being sufficient enough to cover the demand for offset credits. Having too many trading partners can lead to coordination problems and transaction costs that are too high. The amount of credits generated by potential sellers must sufficiently cover the load reductions demanded by potential credit buyers (Rowles 2005). The number and size of pollutant sources that could participate in a PS-NPS trading program are important considerations because they jointly determine where the reductions might be traded (Crutchfield 1994). Participation rates can be affected from several perspectives; number and size of participants, geospatial orientation of pollution sources, and a plethora of uncertainty that impacts transaction cost (EPA 2004).

If the suitable size and/or number of participants have not been established a thin market can ensue. In Robert's study on potential WQT markets in Tennessee there was strong evidence of thin markets, which deterred trade. The Tennessee study only had 28 of the 40 markets to contain a single Nitrogen-Contributing PS, while 32 of the 40 contained two or fewer such PS (Roberts 2008). Offset trades from one PS to another were not feasible in 70% of the Tennessee markets (Roberts 2008). This study showed that if there were too few participants, in this case two or fewer, trading would not occur.

For pollution sources to consider participating in a WQT program they must determine if the opportunity cost of buying or selling offset credits outweighs the opportunity cost of implementing new technological standards required by their permit. Abatement costs vary depending on the amount of regulatory pressure that a facility faces, the size of the facility, and their technology. PSs are generally the buyers of offset credits and rarely the sellers in a WQT market because their contributions to water quality impairments are easily measured and monitored. Due to uncertainty of NPS discharges, NPS's willingness to supply credits depends on how it will affect their ability to continue receiving subsidies and payments and to fend off future regulation (King 2005). Trading guidelines nearly always prohibit farmers from selling credits for undertaking land use/land management changes that are legally required (e.g., by state regulation) or for which the farmer has already been paid (e.g., green payments) (King 2005). Uncertainty alone is a driving force in participation rates because it can have a profound impact on transaction costs that pollution sources face.

Transaction costs are the costs policymakers and/or polluters take on to address uncertainty (Easter 2006). Many of these costs include information gathering, trade execution, and any additional monitoring which are driven largely by the procedures, trade execution methods, and tracking infrastructure established in the watershed (EPA 2004). Failure to manage market uncertainty and high transaction cost effectively will substantially constrain and may entirely stifle otherwise environmentally equivalent and financially attractive trades (EPA 2004). The goal of the infrastructure of the market is to create the smoothest transaction path consistent with regulatory requirements and water quality improvement goals (EPA 2004).

2.5 Regulatory Incentives

For policy officials the administrative burden of a relatively untried approach to trading is probably not worth undertaking unless the watershed is under pressure to improve water quality (Crutchfield 1994). Regulatory pressures play an essential role in WQT markets because regulatory pressures creates drivers for the market, such as, implementing nutrient limits, TBELs, WBELs, or TMDLs on PSs to help improve or sustain WQ impairments and also help generate supply and demand for credit trading. The EPA assigns pollutant limits via NPDES permits that specify the amount of pollutant a PS facility is allowed to discharge, such as, phosphorus or nitrogen. To maintain the pollutant effluent limits, required by the NPDES permit, PSs have to implement TBELs to maintain the target level of emissions. Some PSs are more efficient in reaching their target emissions through their technology and other PSs have a hard time reaching their target emissions. Some facilities might be faced with out dated technology that cannot keep up with the reduction needs that is required by their permits and when they do not meet the emissions targets the EPA can impose a WQBEL, which is more severe than TBELs and they can face stiff penalties for non-compliance.

If the State finds any facility in violation of any permit condition or limitation implementation under section 402 of the CWA, States may assess a class I civil penalty or a class II civil penalty (FWPCA 2002). A class I civil penalty may not exceed \$10,000 per violation; except that the maximum amount of any class I civil penalty shall not exceed \$25,000 (FWPCA 2002). A class II civil penalty may not exceed \$10,000 per day for each day during which the violation continues; except that the maximum amount of any class II civil penalty shall not exceed \$125,000 (FWPCA 2002). If PSs that have

higher abatement cost will find trading very beneficial to comply with their permits to avoid such penalties.

Compliance pressure helps drive trading because PSs that face compliance issues usually are confronted with higher abatement cost which in turn stimulates demand for pollution credits. PSs with higher abatement cost are now able to meet their reduction needs by buying emission credits from PSs that have lower abatement cost, thus allowing PSs with higher abatement cost to pollute a little more and the PSs that face lower abatement cost to pollute a little less, as long as the WQ is sustained or healthier through the trade.

TMDLs, along with WQBELs, are the market drivers that quantify the reductions needed for the watershed or from individual pollution sources. A TMDL specifies the maximum amount of a pollutant that a water body can receive and still meet water quality standards and allocates pollutant loadings among point and nonpoint pollutant sources (EPA 2008). Restrictions on loading will induce supply and demand of offset credits, depending on the source's degree of abatement cost, and incentivize pollution sources to over control. Regulatory pressures often lead to cost savings in a WQT program, which gives pollution sources the economic incentive to participate.

2.6 Economic Incentives

Market based approaches to water quality and other environmental problems are often considered to increase the cost effectiveness and to provide incentives for technological innovation compared to the traditional command and control approach to environmental regulations (Cline 2006). When trading is an option, a discharger is allowed to choose between reducing its pollutant loads or purchase offset credits from

another source that has exceeded its own pollution reduction obligation (Rowles 2005). The EPA, in their WQT Policy Statement, stated that allowing flexibility in controlling water quality could lead to an estimated \$900 million dollar savings (EPA 2003). Connecticut was involved in nitrogen trading with an estimated cost savings of over \$200 million dollars in control cost (EPA 2003). Allowing PSs to buy offset credits from other pollution sources that have lower cost of abatement allows them to avoid investments in new technologies that could cost millions of dollars to capture the required reductions. Potential savings from point-point trading alone are estimated to be as high as \$1.9 billion per year (Boyd 2000).

WQT often takes advantage of large differences in pollution reduction costs between PSs and NPSs of pollution (Rowles 2004). The cost of pollutant reduction from PSs is frequently much higher than NPSs (Rowles 2004). One estimate suggested that the cost of PS reduction could be 65% higher than NPS reduction (Faeth 2000). Pollution trading programs generally seek to achieve a certain level of environmental quality while minimizing the abatement costs incurred by polluters (Cline 2006). If the expected cost of not complying is lower than the cost of complying by purchasing credits, there is no economic incentive to purchase credits (King 2005). Thus if WQT is too costly for PSs to participate trading will not occur.

Since effluents from polluters vary from source to source, qualitatively and quantitatively, which causes differences in compliance cost, which will encourage sources to engage in trading (Jarvie 1998). Trading allows PSs to seek the most efficient means of compliance either through innovation or other methods (Rowles 2004). For the PSs with lower costs of pollution reduction can take advantage of market forces by

selling unwanted pollution credits to those with higher cost, which also provides incentives for investment innovation in pollution control technologies (Crutchfield 1994).

The close association between regulatory requirements and treatment costs is the driving factor for the economic incentive for trading (Rowles 2005). The main incentive for pollution sources to participate in trading programs is compliance cost saving by avoiding sizable transaction costs, administrative costs of bargaining and initiating a trade, the cost of collecting data to accurately predict trading results, the cost of monitoring to ensure trade conditions are met, and the cost of developing and implementing best management practice (BMP) controls to reduce nonpoint sources (Jarvie 1998). Thus for trading to occur the total cost of trading must be significantly less than the cost of implementing new technologies at the point source to meet water quality standards (Jarvie 1998).

CH. 3

3.1 Study Area

In the U.S., watersheds are geographically identified by a hydrologic unit code (HUC). HUC boundaries were developed by the U.S. Geological Survey to identify watersheds based on a national standard hierarchical system, which is based on surface hydrologic features (USDA 2007). HUCs begin with two digits, which correspond to regional watersheds, and as more numbers are added to a HUC the geographical area that it defines becomes smaller and more localized. Figure 3-1 illustrates the geographical orientation of each regional watershed within the U.S (Echeverria 2010). The KRB is located within region 05, the Ohio Region.

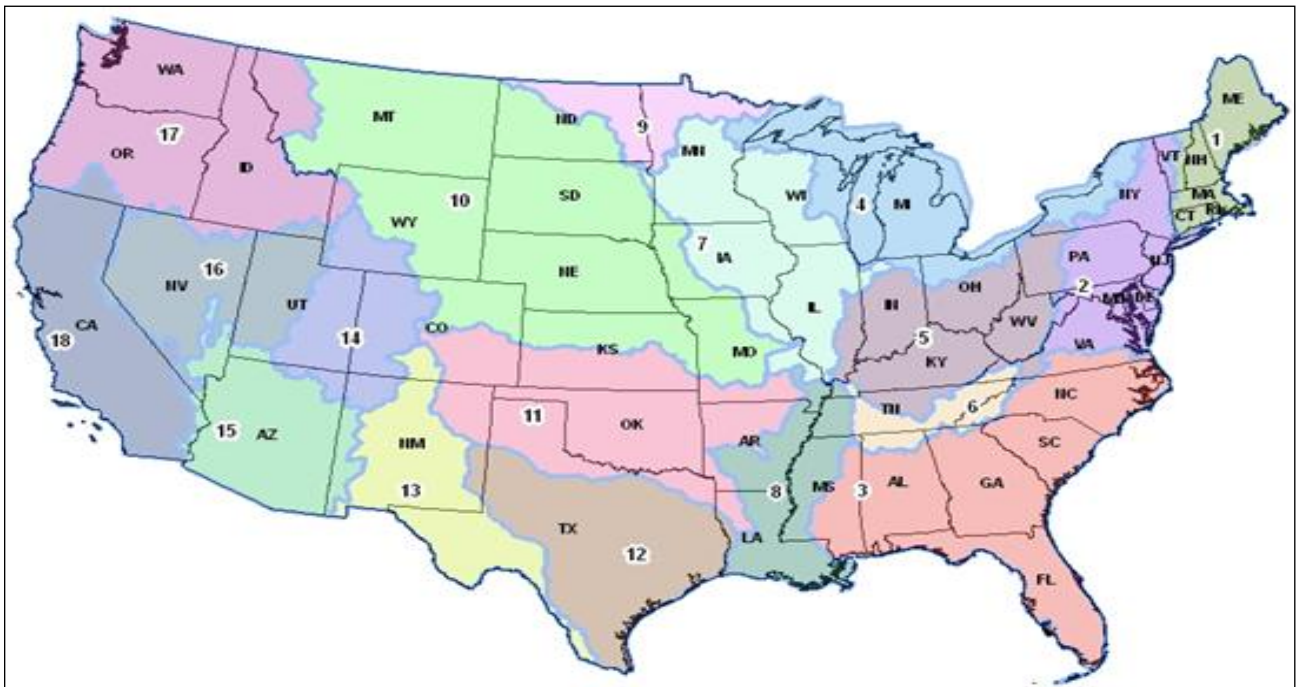


Figure 3-1 Two-Digit HUC Regions

The Ohio region drains parts of Illinois, Indiana, Kentucky, Maryland, New York, North Carolina, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia (USGS 2010). The KRB is a sub-watershed of the Ohio region and is geographically located by HUC 051002 in the eastern region of Kentucky. Figure 3-2 illustrates the geographical location of the KRB.

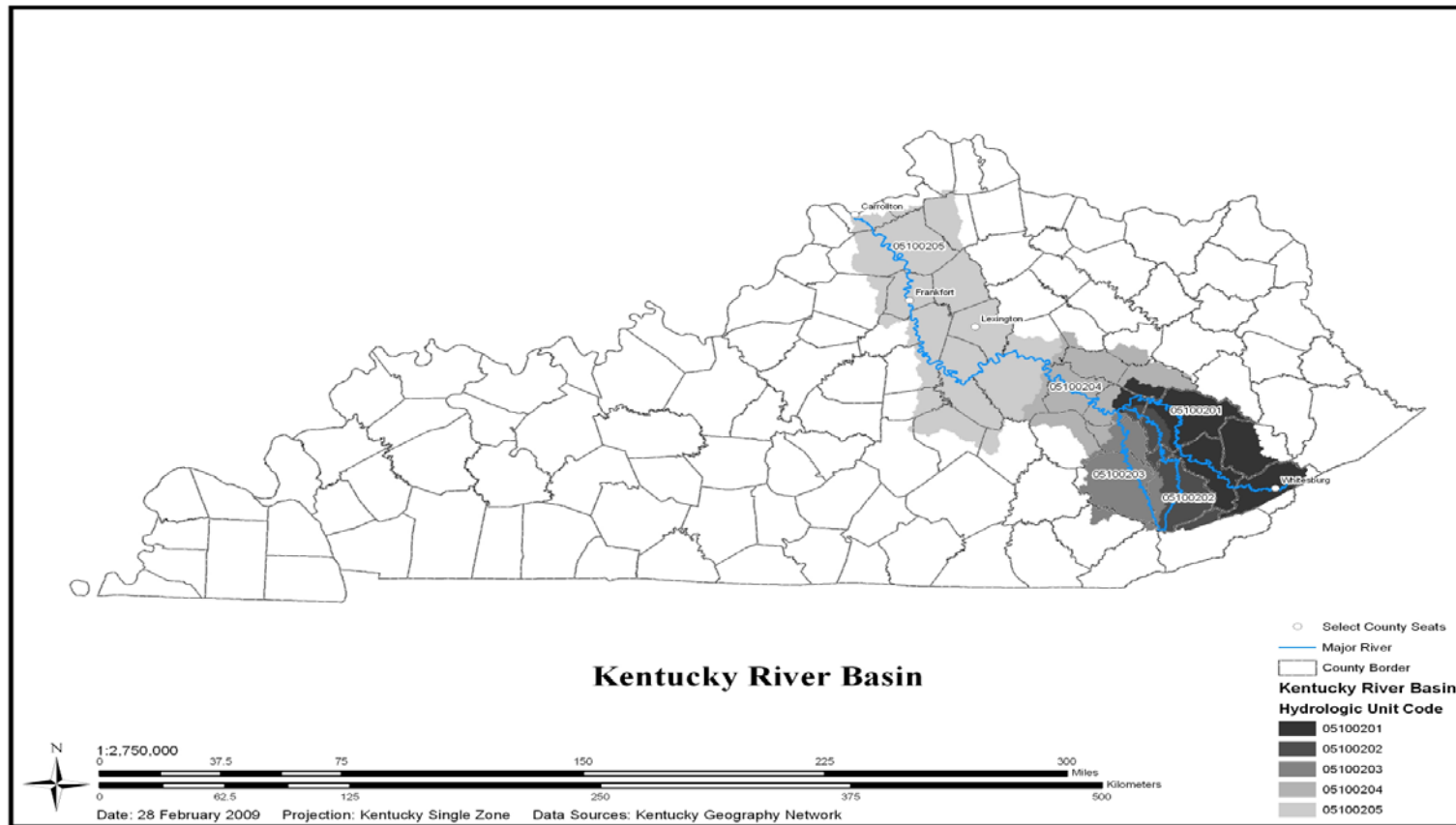


Figure 3-2 Kentucky River Basin

The KRB is approximately 259 miles in length and covers an area of approximately 6,947 square miles, spanning over 46 counties that contain a population of approximately 700,000 people (Ormsbee 2006). There were approximately 16,071 stream miles within the Basin, of which 1,238 miles were impaired streams and 227 miles were nutrient impaired streams (KDOW 2010). The KRB can be further broken down into 5 individual HUC 8 sub-watersheds illustrated by the five shaded regions in Figure 3-2 and Figure 3-3 as a magnification (Ormsbee 2006). The Kentucky River, illustrated in Figure 3-2, flows downstream from the eastern part of the basin to the Ohio River located on the Northwestern side of the basin. The KRB contains 46 counties of which some are fully or partly within the watershed.

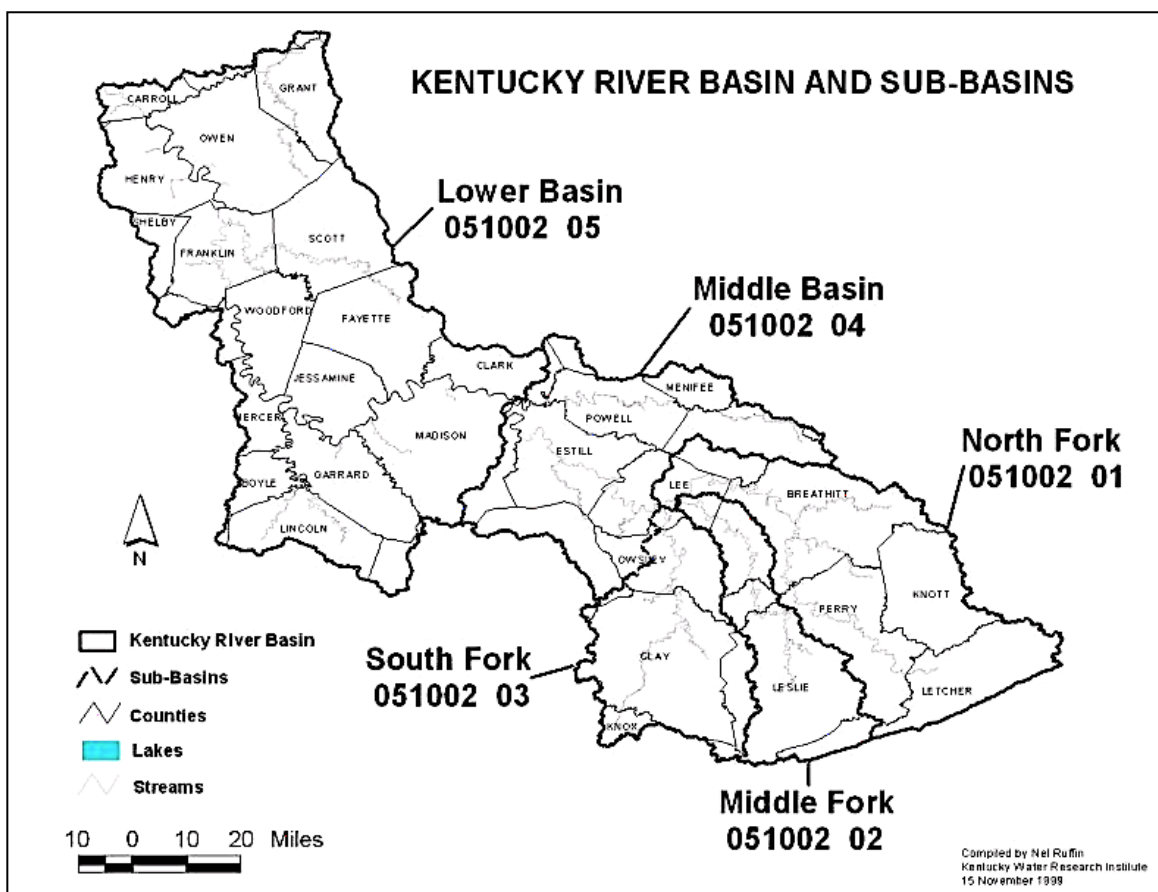


Figure 3-3 Kentucky River Basin Sub-Basins

The eastern region of the KRB contains the North, Middle, and South Fork watersheds, which are mainly known to the coalfield region. The eastern region is underlain by coals, sandstones, and shales and as one transitions to the west one starts to see an increase in clay and limestone content and less and less of the coal lying beneath the watersheds (KWRRRI 2002). The eastern region of the KRB is mainly a rural mountainous region with a high density of forest cover with less than 10% agriculture and as one moves west across the KRB the terrain becomes less mountainous and hilly and more agriculturally intensive (Lee 2010). Some parts of the region were more susceptible to agricultural erosion than the basin average (KWRRRI 2002). An escarpment is located near the eastern boarder of the Middle Basin. The escarpment acts as a transitioning point between the eastern region and the western region of the KRB.

The western region is characterized by the Middle and Lower Basin. Both of these regions share many of the same geographical characteristics. As one moves west across the escarpment into the Middle Basin the terrain gradually becomes less mountainous with less forest cover (Lee 2010). Much of the western region is involved in agriculture and some parts of the region had livestock densities substantially higher than the basin average. Some parts of the region were also more susceptible to agricultural erosion than the basin average. The next three pages exhibits Figures 3-4, 3-5, and 3-6, nutrient PS profiles of the KRB, which pinpoints each nutrient PS and illustrates the density of riparian agriculture across the KRB within HUC 12 sub-watersheds. The riparian agriculture density profile tells us the percentage of riparian area that is involved in agricultural practices, within 200 feet (on either side) of the streams running through the watershed.

Riparian Agriculture and Ammonia Data Points for HUC 12 Watersheds in the Kentucky River Basin

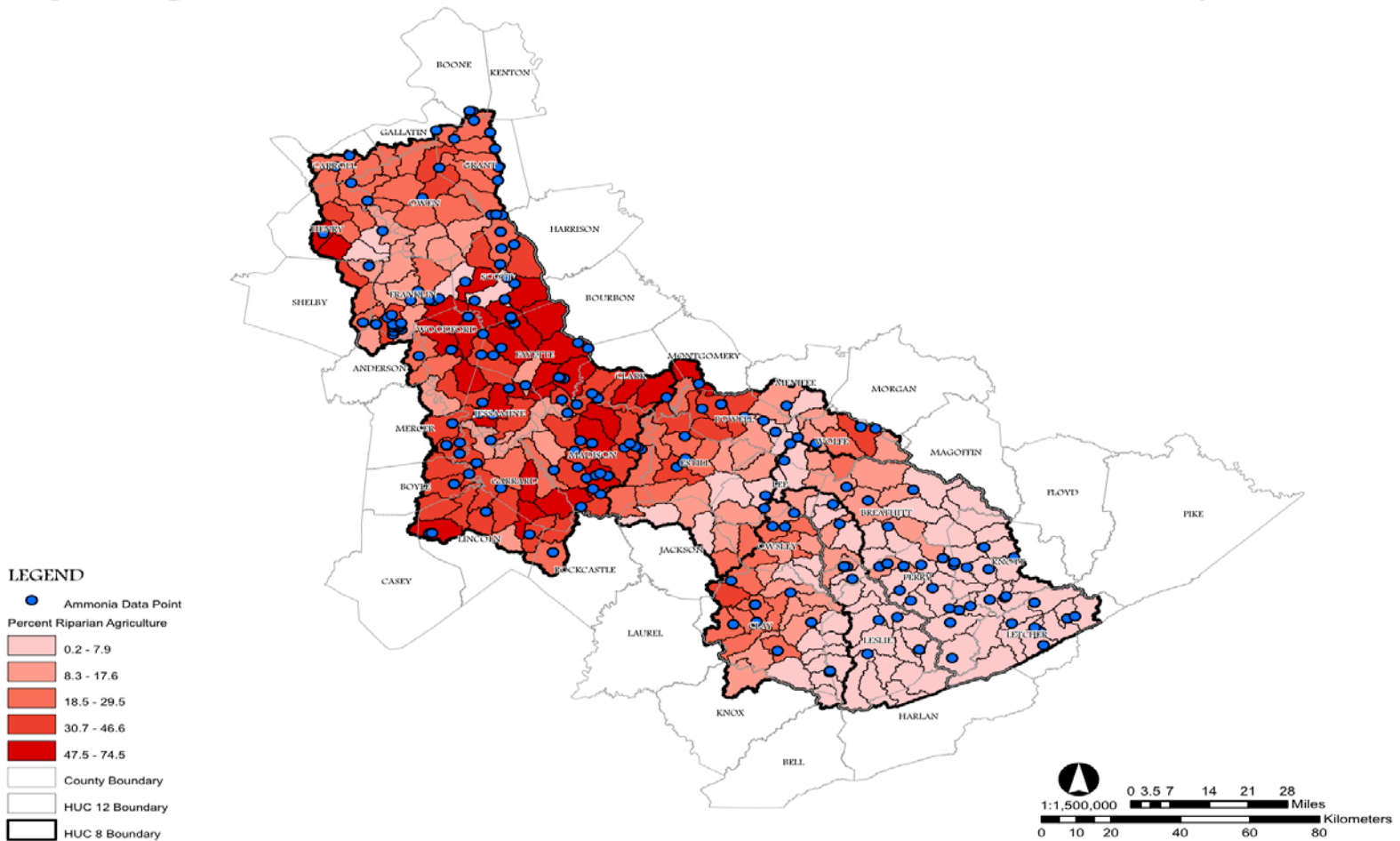


Figure 3-4 Riparian Agriculture and Ammonia Data Points for HUC 12 Watersheds in the Kentucky River Basin

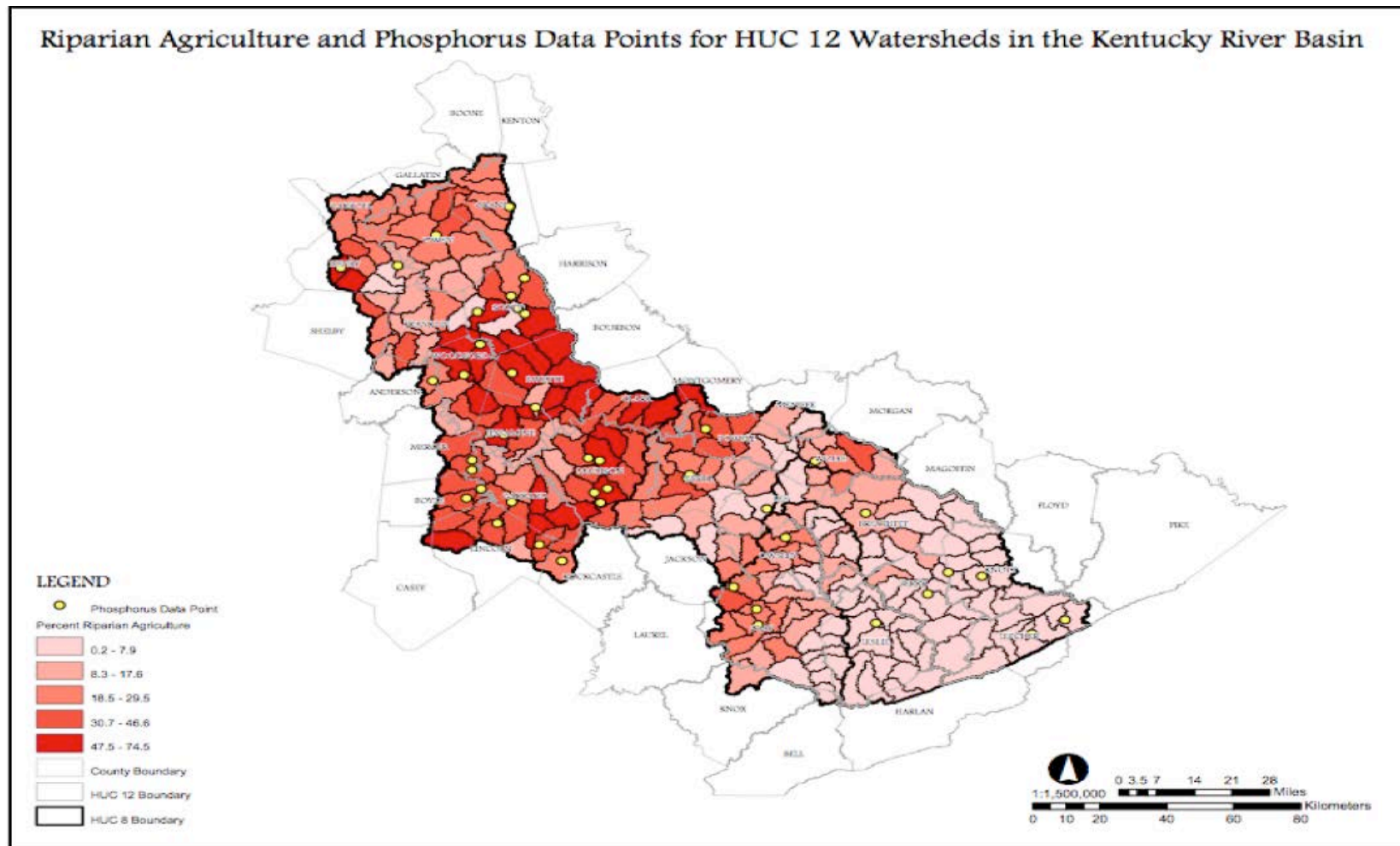


Figure 3-5 Riparian Agriculture and Phosphorus Data Points for HUC 12 Watersheds in the Kentucky River Basin

Riparian Agriculture and Nitrogen Data Points for HUC 12 Watersheds in the Kentucky River Basin

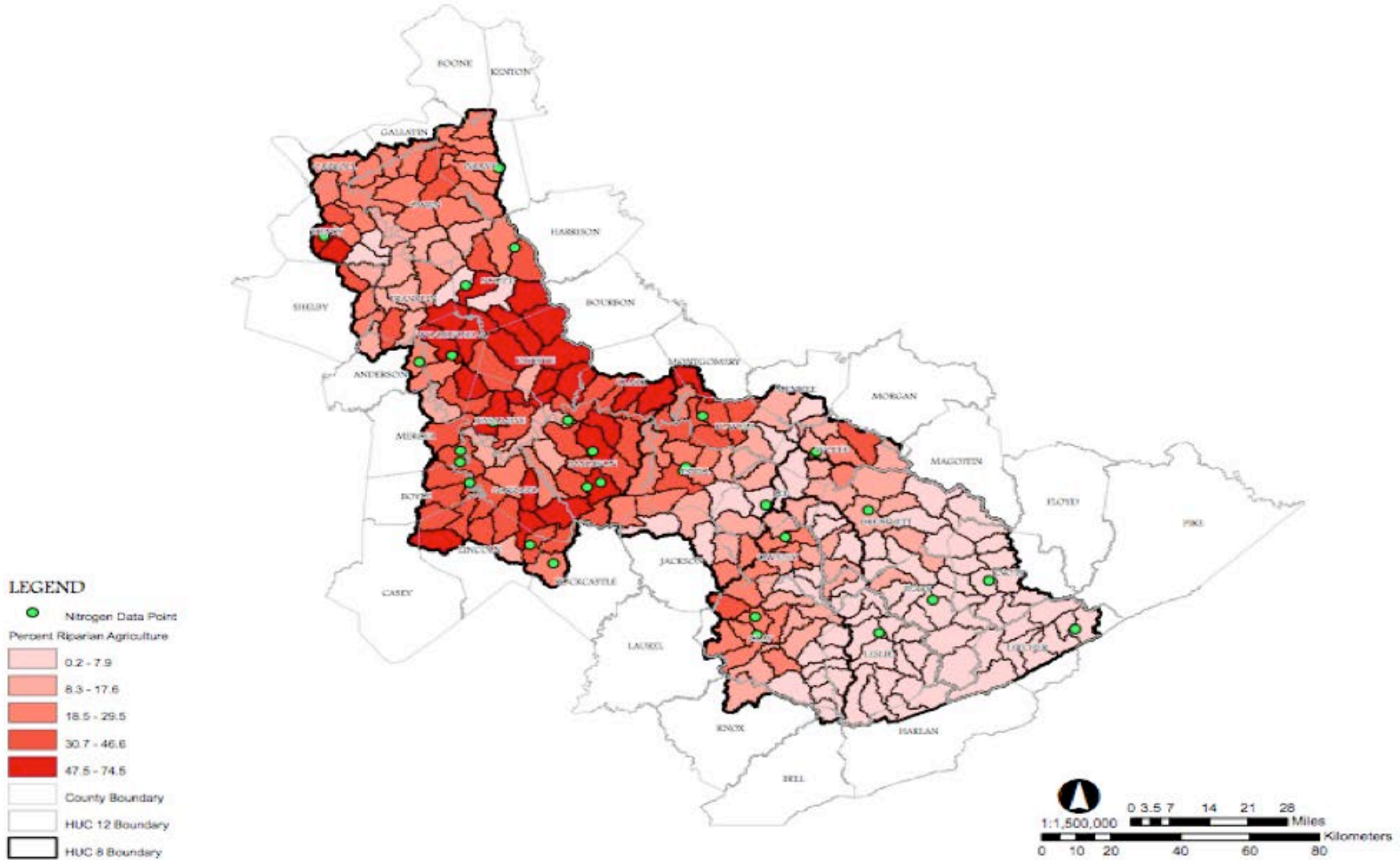


Figure 3-6 Riparian Agriculture and Nitrogen Data Points for HUC 12 Watersheds in the Kentucky River Basin

From the previous Figures one can see that riparian agriculture is quite prominent within the Lower Basin compared to the eastern region. The Lower Basin alone had a 30% to 75% participation rate in riparian agriculture compared to a .2%-8% participation rate in the eastern region. The Lower Basin also contained 64% of the PSs located within the watershed. For a closer look at Figures 3.4, 3.5, 3.6, and Table 3-1, this provides the number of nutrient PSs, the number of HUC 10s and HUC 12s, and the total land area within each HUC 8 sub-watershed, to coincide with the profiles.

KRB Characteristics	North Fork	Middle Fork	South Fork	Middle Basin	Lower Basin	KRB
Number of TA PSs	36	10	14	16	110	186
Number of TP PSs	6	1	4	5	29	45
Number of TN PSs	4	1	3	4	16	28
Number of HUC 10s	7	4	6	5	15	37
Number of HUC 12s	29	10	12	16	66	133
Land Area (sq. miles)	1331	559	748	1085	3224	6947

Table 3-1 Nutrient PS and HUC Distributions

The Lower Basin makes up approximately 46% of the KRB. Since the Lower Basin has a large land area than the rest of the four watersheds majority of the nutrient PSs, HUC 10, and HUC 12 sub-watersheds reside within the Lower Basin. This region also contained the highest concentration of developed urban areas that closely correspond to higher population densities. Figure 3-7 shows the population density of the KRB with majority of the population located within the Lower Basin.

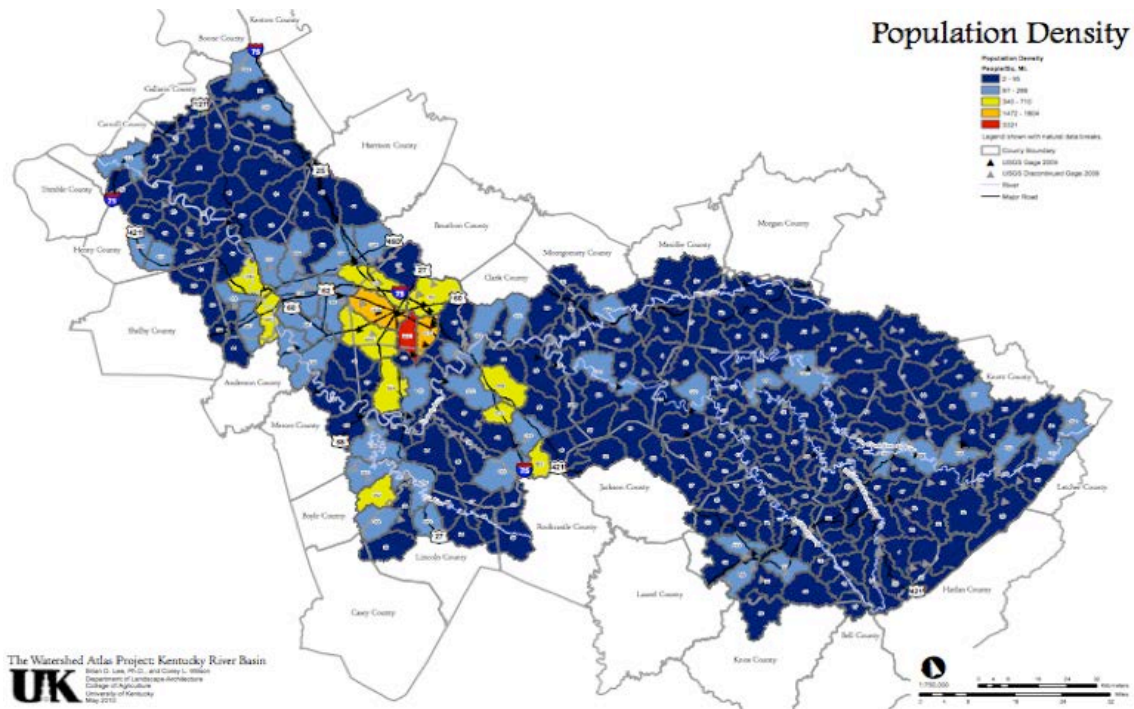


Figure 3-7 KRB Population Densities

The lower basin alone contains 20 counties of which eight have nearly all of their land area within the KRB, shown by Table 3-1. These eight counties make up approximately 82% of the KRB population, with Fayette County being the leader with close to 43% of the KRB's total population. For further description of the KRB the following section describes each of the 5 sub-watersheds based on their hydrology and the type of industries each watershed employs. The following descriptions were based on the KRB's first basin cycle (1997-2002) provided by the Kentucky Water Resources Research Institute (KWRI) and the 2010 Kentucky 303 (d) list.

3.2 HUC 8 Sub-basins

North Fork

The North Fork watershed covers approximately 1,331 square miles, which can be further divided into 7 HUC 10 and 29 HUC 12 sub-watersheds. There were 36 TA, 6 TP, and 4 TN PSs. TA PSs were located within all seven HUC 10 sub-watersheds with an average of five and a maximum of nine TA PSs per HUC 10. Only 24 of the 29 HUC 12 sub-watersheds have TA PSs with an average of one and a maximum of four TA PS per HUC 12. TP PSs were located within only four of the seven HUC 10 sub-watersheds with an average of 1 and a maximum of 2 TP PSs per HUC 10. Only 6 out of the 29 HUC 12 sub-watersheds have TP PSs, with each sub-watershed having one TP PS.

Hydrology

The North Fork contains 249 stream miles and 808 acres (lakes) of impaired waters of which 7 of those miles and all 808 of those acres were nutrient impaired. There were 12 of the 36 PSs that discharge into impaired waters. This watershed contains Carr Fork Reservoir and Panbowl Lake each respectively containing 710 and 98 acres of nutrient impaired waters making up 100% of the impaired acres. Aquatic life in Panbowl Lake is impaired by organic enrichment and low oxygen. Aquatic life is threatened by salinity from resource extraction, sediments, sewage, flow alterations and modifications, and habitat alterations. Throughout the watershed fecal coliform reading were high and were exceeding standards. Water recreation in some parts of the watershed is considered unsafe due to pathogens. The restoration ranking is high in this watershed.

Industry

There were 36 PSs within the watershed that were distributed across 8 different industries with three of the industries, educational services, electric, gas and sanitary services, and real estate, making up approximately 83% of the total industry in the North Fork. Thirty-five of the PSs were minor PSs and only one PS was a major publicly owned municipal PS, Hazard STP, which discharged all three nutrients. Table 3-2 shows the descriptive statistics of PSs discharging to both impaired and non-impaired waters versus PSs that discharged to impaired waters only.

NORTH FORK						
	TA		TP		TN	
	Both	Impaired Waters	Both	Impaired Waters	Both	Impaired Waters
Number of PSs	36	12	6	4	4	2
Number of SIC	8	4	2	1	1	1
Number of Major	1	0	1	0	1	0
Number of Municipal	7	4	5	3	4	2
Number of Major Municipal	1	0	1	0	1	0
Total Discharge	5,635	1,148	3,336	1,038	28,756	6,475

Table 3-2 North Fork Discharge Distributions

All 36 PSs within the region discharged TA. TA PSs discharged a total of 5,635 pounds of TA out of their facilities of which Hazard STP caused 44% of those discharges. There were 12 TA PSs discharged directly into impaired waters discharging 1,148 pounds of TA. These 12 minor PSs belong to four different industries; Education Services, Electric, Gas and Sanitary Services, Real Estate, and Administration of Environmental Quality and Housing Programs of which four were publicly owned municipal PSs; Jackson STP, Hindman STP, Millstone Alternative Treatment System, Whitesburg STP.

Only 6 of the 36 PSs were TP PSs. TP PSs discharged a total of 3,336 pounds of TP out of their facilities of which 4 TP PSs discharged directly into impaired waters discharging 1,038 pounds of TP. These 4 minor PSs belong to two different industries; Electric, Gas and Sanitary Services, and Real Estate of which three were publicly owned municipal PSs; Jackson STP, Hindman STP, Whitesburg STP.

There were 4 TN PSs that discharged a total of 28,756 pounds of TN of which 2 TN PSs discharged directly into impaired waters, discharging 6,475 pounds of TN. These 2 minor PSs belong to a single industry, Electric, Gas and Sanitary Services and were publicly owned municipal PSs; Jackson STP, Hindman STP, Whitesburg STP.

Middle Fork

The Middle Fork watershed covers approximately 559 square miles, which can be further divided into four HUC 10 and ten HUC 12 sub-watersheds. There were 10 TA, 1 TP, and 1 TN PS. TA PSs were located within all 4 HUC 10 sub-watersheds with an average of two and a maximum of five TA PSs per HUC 10. Only 8 of the 10 HUC 12 sub-watersheds had TA PSs with an average of one and a maximum of three TA PS per HUC 12. The Middle Fork only contains a single TP and TN PS each belonging to their respective HUC 10 and HUC 12 sub-watershed.

Hydrology

The Middle Fork contains 42 miles and 1230 acres of impaired waters of which none were nutrient impaired. There were only 3 of the 13 PSs that discharge into impaired waters.

Aquatic life in parts of the watershed were threatened by over enrichment and partially impaired by unknown causes. Data shows fecal contamination in parts of the watershed. Restoration Ranking is high in this watershed.

Industry

There were 10 PSs within the watershed that were distributed across 4 different industries: Educational Services, Social Services, Amusement and Recreation Services, and Electric, Gas and Sanitary Services. Six of the PSs were involved in the Educational Services industry. All PSs in this region were all minor nutrient PSs. Hyden STP was the only major publicly owned municipal PS that discharged all three nutrients. Table 3-3 shows the distribution of PS that were both discharging into and not discharging into impaired water or discharging to impaired waters only.

	MIDDLE FORK					
	TA		TP		TN	
	Both	Impaired Waters	Both	Impaired Waters	Both	Impaired Waters
Number of PSs	10	3	1	1	1	1
Number of SIC	4	3	1	1	1	1
Number of Major	0	0	0	0	0	0
Number of Municipal	1	1	1	1	1	1
Number of Major Municipal	0	0	0	0	0	0
Total Discharge	428	119	405	405	1,701	1,701

Table 3-3 Middle Fork Discharge Distributions

All 10 PSs within the region discharged TA with a total discharge of 428 pounds. Only 3 of the 10 TA PSs produced 91% of the total TA discharge. There were 3 TA PSs that discharged directly into impaired waters discharging 119 pounds of TA, of which Hyden STP contributed 95 of those pounds. These 3 PSs belonged to the education services, social, electric, gas and sanitary services industries. Hyden STP was the only

TP and TN discharger within this region discharging 405 and 1,701 pounds of TP and TN, respectively, into impaired waters.

South Fork

The South Fork watershed covers approximately 748 square miles, which can be further divided into six HUC 10 and twelve HUC 12 sub-watersheds. The region contained 14 TA, 4 TP, and 3 TN PS. TA PSs were located within all 6 HUC 10 sub-watersheds with an average of two and a maximum of four TA PSs per HUC 10. Only 10 of the 12 HUC 12 sub-watersheds had TA PSs with an average of one and a maximum of three TA PS per HUC 12.

TP PSs were located within 3 of the 6 HUC 10 sub-watersheds with an average of one and a maximum of two TA PSs per HUC 10. There were 4 of the 12 HUC 12 sub-watersheds each having a single TP PSs. TN PSs were located within 2 of the 6 HUC 10 sub-watersheds with an average of one and a maximum of two TA PSs per HUC 10. There were 3 of the 12 HUC 12 sub-watersheds each having a single TP PSs.

Hydrology

The Middle Fork contains 42 miles and 1230 acres of impaired waters of which none were nutrient impaired. There were only 2 of the 21 PSs that discharge into impaired waters. The region has a big problem with impairments caused by sedimentation. Aquatic life in parts of the watershed is considered threatened by over enrichment and low pH. Some of the watershed is consider unsafe for recreation due to pathogens. Restoration Ranking is high in this watershed.

Industry

There were 14 PSs within the watershed that were distributed across 7 different industries with educational services making up 43% of the industry. All PSs in this region were minor PSs except for Manchester STP, which was a major publicly owned municipal company that discharged all three nutrients. Table 3-4 shows the distribution of PS that were both discharging into and not discharging into impaired water or discharging to impaired waters only.

SOUTH FORK						
	TA		TP		TN	
	Both	Impaired Waters	Both	Impaired Waters	Both	Impaired Waters
Number of PSs	14	2	4	1	3	1
Number of SIC	7	2	3	2	2	1
Number of Major	1	0	1	0	1	0
Number of Municipal	2	0	2	0	2	0
Number of Major Municipal	1	0	1	0	1	0
Total Discharge	2,235	38	2,216	12	21,877	133

Table 3-4 South Fork Discharge Distributions

All 14 PSs within the region discharged TA. TA PSs discharged a total of 2,235 pounds of TA out of their facilities of which Manchester STP discharged 59% of those discharges. There were 2 TA PSs that discharged directly into impaired waters discharging 38 pounds of TA. These two minor PSs belong to the health services and education services industries.

Only 4 of the 14 PSs were TP PSs. TP PSs discharged a total of 2,216 pounds of TP out of their facilities of which 1 TP PSs discharged directly into impaired waters discharging 12 pounds of TP. This single PS belonged to the health services industry.

There were 3 TN PSs that discharged a total of 21,877 pounds of TN of which one TN PS discharged directly into impaired waters, discharging 133 pounds of TN. This PS belonged to the health service industry.

Middle Basin

The Middle Basin watershed covers approximately 1,085 square miles, which can be further divided into five HUC 10 and 16 HUC 12 sub-watersheds. There were 16 TA, 5 TP, and 4 TN PS. TA PSs were located within all 5 HUC 10 sub-watersheds with a median of two and a maximum of eight TA PSs per HUC 10. Only 10 of the 16 HUC 12 sub-watersheds have TA PSs with an average of one and a maximum of three TA PS per HUC 12.

TP PSs were located within all 5 HUC 10 sub-watersheds with a single TP PS in each. There were only 5 of the 16 HUC 12 sub-watersheds that contained TP PSs each of them having a single TP PSs. TN PSs were located within 4 of the 5 HUC 10 sub-watersheds each having a single TN PS. There were 4 of the 16 HUC 12 sub-watersheds that contained TN PSs each having a single TP PSs.

Hydrology

The Middle Fork contains 42 miles and 1,230 acres of impaired waters of which none were nutrient impaired. There were only 3 of the 13 PSs that discharge into impaired waters. Aquatic life in parts of the watershed was threatened by over enrichment, low dissolved oxygen, and sedimentation and partially impaired by pesticides and unknown causes. Data shows fecal contamination in parts of the watershed. Pathogens make contact recreation unsafe in parts of the watershed. Restoration Ranking is high in this watershed.

Industry

There were 16 PSs within the watershed that were distributed across 10 different industries with 38% of the industry being electric, gas and sanitary services. All PSs in this region were all minor nutrient PSs. Hyden STP was the only major publicly owned municipal PS that discharged all three nutrients. Table 3-5 shows the distribution of PS that were both discharging into and not discharging into impaired water or discharging to impaired waters only.

MIDDLE BASIN						
	TA		TP		TN	
	Both	Impaired Waters	Both	Impaired Waters	Both	Impaired Waters
Number of PSs	16	2	5	1	4	1
Number of SIC	10	2	1	1	1	1
Number of Major	0	0	0	0	0	0
Number of Municipal	6	1	5	1	4	1
Number of Major Municipal	0	0	0	0	0	0
Total Discharge	5,695	301	2,575	360	25,120	1,283

Table 3-5 Middle Basin Discharge Distributions

All 16 PSs within the region discharged TA with a total discharge of 5,695 pounds. The electric, gas and sanitary services industry was responsible for 97% of those discharges. There were 2 TA PSs that discharged directly into impaired waters discharging 301 pounds of TA, of which Campton STP contributed 275 of those pounds. These 2 PSs belonged to the education services, social, electric, gas and sanitary services industries.

Only 5 of the 16 PSs were TP PSs. TP PSs discharged a total of 2,575 pounds of TP out of their facilities. Campton STP, a publicly owned municipal PS, also discharged TP and TN directly into impaired waters discharging 360 and 1,283 pounds of TP

respectively. In addition to Campton STP there were 3 TN PSs that discharged a total of 23,837 pounds of TN.

Lower Basin

Lower Basin watershed covers approximately 3,224 square miles, which can be further divided into 15 HUC 10 and 66 HUC 12 sub-watersheds. There were 227 PSs within the watershed that were distributed across 35 different industries with the top three industries being educational services, electric, gas and sanitary services, and social services, which makes up approximately 55% of the total industry in the Middle Fork.

There were 110 TA, 29 TP, and 16 TN PS. TA PSs were located within all 15 HUC 10 sub-watersheds with an average of seven and a maximum of fourteen TA PSs per HUC 10. Only 55 of the 66 HUC 12 sub-watersheds have TA PSs with an average of two and a maximum of eleven TA PS per HUC 12. TP PSs were located within 12 of the 15 HUC 10 sub-watersheds with an average of two and a maximum of five TP PS in each. Only 24 of the 66 HUC 12 sub-watersheds contained TP PSs with an average of one and a maximum of three TP PSs per HUC 12. TN PSs were located within 9 of the 15 HUC 10 sub-watersheds with an average of two and a maximum of three TN PS per HUC 10. There were 14 of the 66 HUC 12 sub-watersheds that that contained TN PSs with an average of one and maximum of two TN PSs per HUC 12.

Hydrology

The Middle Fork contains 42 miles and 1230 acres of impaired waters of which none were nutrient impaired. There were only 3 of the 13 PSs that discharge into impaired waters. Aquatic life in parts of the watershed were threatened by over

enrichment, low dissolved oxygen and pesticides and partially impaired by sedimentation and unknown causes. Population without access to public sewers is substantially higher than the basin average, in which data shows fecal contamination in the watershed.

Pathogens make contact recreation unsafe in many parts of the watershed. Livestock density in this region is substantially higher than the basin average. Restoration Ranking was high in this watershed.

Industry

There were 110 PSs within the watershed that were distributed across 18 different industries with two of the industries, real estate and electric, gas and sanitary services making up approximately 60% of the total industry in the Lower Basin. Table 3-6 shows the distribution of PS that were both discharging into and not discharging into impaired water or discharging to impaired waters only.

LOWER BASIN						
	TA		TP		TN	
	Both	Impaired Waters	Both	Impaired Waters	Both	Impaired Waters
Number of PSs	110	30	29	11	16	6
Number of SIC	18	11	4	4	4	4
Number of Major	15	6	12	4	5	1
Number of Municipal	24	9	21	7	11	2
Number of Major Municipal	15	6	12	4	5	1
Total Discharge	2,595,292	31,982	114,423	71,254	134,209	8,290

Table 3-6 Lower Basin Discharge Distributions

All 110 PSs within the region discharged TA of which 15 where major TA PSs. TA PSs discharged about 2.6 million pounds of TA out of their facilities of which Reed Duplex Apartment Building was responsible for 97% of the total discharges. There were 30 TA PSs that discharged directly into impaired waters discharging 31,982 pounds of

TA of which 6 where major publicly owned municipal PSs discharging 21,144 pounds of TA.

Only 29 of the 110 PSs were TP PSs discharging 114,423 pounds of TP of which 71,254 pounds were discharged directly into impaired waters. Lexington Town Branch STP discharged approximately 55,000 of the 71,000 pounds directly discharged into impaired waters. This municipal PS was one of the 12 major publicly owned municipal PSs of which 4 directly discharge into impaired waters. The 12 major municipals discharged approximately 107,000 pounds of TP in which 4 discharged approximately 68,000 pounds directly into impaired waters.

There were 16 TN PSs that discharged a total of 134,209 pounds of TN of which 6 TN PS discharged directly into impaired waters, discharging 8,290 pounds of TN. Approximately 69% of the industry is conducted in the electric, gas and sanitary services industry, which is also responsible for 99% of the total TN discharges and 93% of the total discharges that were directly discharge into impaired waters.

CH. 4

4.1 Data Collection

The overall objective of this study was to develop a PS profile of the KRB based on the availability of PS data and to assess the feasibility of a WQT program. The profile consists of types of PSs, geographical location of PSs, the total number of PSs, and the permitted limits and actual discharges of each PS. Figure 4-1 below illustrates the steps it took to achieve each of these objectives (Kieser and Associates 2004).

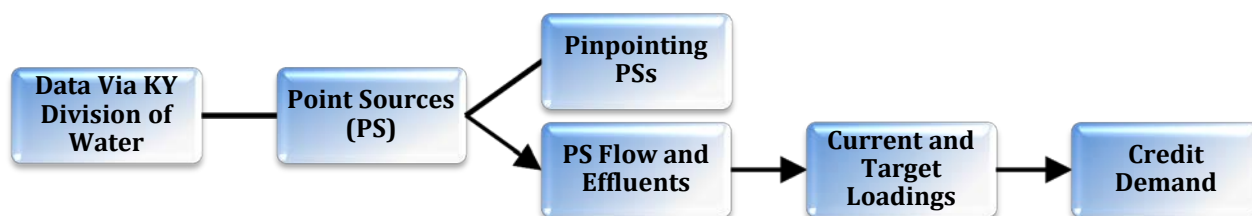


Figure 4-1 Procedure Flow Chart for PS Analysis

The Kentucky Division of Water (KDOW) provided 2009 county level NPDES permit data via the permit compliance system (PCS). The permit data provided facility mailing information, facility types, geospatial data, effluent loadings, permitted nutrient discharges, and actual nutrient discharges. Each PS was acknowledged by their NPDES permit number, which stipulated the allowable pollutant discharge a PS could discharge through their pipes. Each pipe under the permit was assigned to a latitude and longitude to determine geographically where nutrient discharges were occurring. The permit data included data for effluent loadings, nitrogen kjeldah, TN, TP, and TA nutrient discharge

loadings, in which nitrogen kjeldah was dropped from the data set due to too few data points. The data also contained actual raw sewage intake and stream intake, which were not relevant for this study and were dropped from the dataset. The effluent loadings were measured in gallons per minute (GPM), gallons per day (GPD), and million gallons per day (MGD) and all loading were converted to MGD. After applying these conversions to the dataset the data revealed that a few PSs had discharge loadings in both concentration and quantity units. For the purpose of this study I wanted to report loading in pounds. So to convert concentrations to pounds I consulted the 2010 discharge monitoring report (DMR) manual, which provide the following conversion:

$$\text{Quantity (lbs/day)} = \text{Flow (MGD)} \times \text{conc. (mg/l)} \times 8.34$$

I applied the conversion to all loading concentration limits and actual concentration discharges and received an estimated quantity loading limit and an estimated quantity discharge in pounds per day. To get pounds I then multiplied these estimates by the number of days in their monitoring period. To determine which measurement to use as the nutrient loading limit and the actual nutrient discharge, I took the minimum of the quantity loading limit and the estimated quantity loading limit and the maximum of actual discharges and the estimate actual discharges. Then the number of violations that occurred was determined by taking the difference between permitted limits and actual discharges from individual PS's pipes. When the actual discharges were greater than their permitted limit, that PS was considered in violation of their permits.

4.2 Data Transformation and Mapping

For the purpose of this study the facility information, nutrients of interest TN, TP, and TA and the effluent discharge data were kept and all other data was dropped from the dataset. The data then needed to be converted from county boundaries to HUC boundaries because the KRB is defined by HUC boundaries. To help facilitate geographically mapping the KRB boundaries I utilized the Department of Landscape Architecture at the University of Kentucky. They worked with HUC level data from the KY Geo-net, who also received their data from the KDOW. I supplied the Department of Landscape Architecture with the county level data and they determined the county data points that belonged to the KRB by matching up latitudes and longitudes from the county dataset to their HUC level dataset. They determined that 357 PSs from the county level dataset were located within the KRB. Only 186 of the 357 PSs had nutrient discharge data. The remaining 171 PSs did not have recorded nutrient discharge loadings. Table 4-1 shows the distribution of nutrient PSs that the KRB contains.

Individual nutrient PS Type	Number of PSs	Nutrient PS Type	Number of Nutrient PSs
TA	140	TA	186
TA and TN	1	TP	45
TA and TP	18	TN	28
TA, TP, and TN	27	No Discharge	171
Total	186		

Table 4-1 Nutrient PS Distributions

The first column refers to each individual discharger type. These PS only discharge their specified nutrients, which all total to 186 PSs. There were 140 PSs that only discharged TA, 18 that discharged TA and TP, 1 PS discharged TA and TN, and 27 that discharge all

three nutrients. Thus in total there were 186 TA, 45 TP, and 28 TN PSs. To determine the PSs that discharged into impaired waters I utilized the EPA's online facilities registration system (FRS), which specifies whether the receiving waters of the PSs are listed on the 303(d) list. To visualize the nutrient PSs the Department of Landscape Architecture provided nutrient PS maps and density maps that illustrated the geographic location of PSs, riparian agricultural activity, land cover, urban density, and terrain characteristics within the KY River Basin watershed via GIS.

CH. 5

5.1 Analytical Framework

This section assesses the suitability and feasibility of the KRB for WQT, based on the 2009 discharge data and the five success factors: geospatial orientation, environmental suitability, regulatory incentives, participant availability, and economic incentives. General findings revealed that TP and TN trading is unlikely to occur within the KRB due to the lack regulatory monitoring, lack of supply and demand for NPS offset credits, and limited participant availability. Table 5-1 clearly shows TN PSs were only being monitored for their discharges, while TP PSs showed very little to no supply and demand for TP offset credits. Both, TP and TN PSs, have minimum participant availability within each HUC 8 watershed. If there were a TP market it would result in a very thin market due to the lack of participants and the supply and no demand for NPS offset credits.

Only 7 out of the 45 TP PSs contributed to the 355 pounds of TP non-compliant discharges and majority of the TP PSs within the KRB were barely under their permitted limit. These 7 sources had a minimum discharge violation of .004 pounds and a maximum discharge violation of 166 pounds with an average of 9 pounds of discharge violations among them throughout the year. In the grand scheme, these loadings are not substantial enough to support the longevity of a WQT program. Thus, a TN and a TP WQT market would be unlikely to occur within the KRB, especially in the North and Middle Fork where there is essentially little to no supply or demand for TP offset credits. Thus the main focus of this assessment relied on TA PSs.

TP						
HUC8	North Fork	Middle Fork	South Fork	Middle Basin	Lower Basin	KRB
Number of PSs	6	1	4	5	29	45
Total Discharge (lbs)	3,336	405	2,216	2,622	114,423	123,002
Violation (lbs)	0	0	4	144	206	355
Under the Limits (lbs)	0	0	8	0	13,185	13,193
Number of Violation	0	0	6	11	22	39
Number of Unders	4	0	17	1	47	69
Average Monthly Violations (LBS)	0	0	0	12	17	6
TN						
HUC8	North Fork	Middle Fork	South Fork	Middle Basin	Lower Basin	KRB
Number of PSs	4	1	3	4	16	28
Total Discharge (lbs)	28,756	1,701	21,877	25,121	134,209	211,664

Table 5-1 TP and TN 2009 Discharge Statistics

The framework of the analysis was to analyze the KRB as a whole at the HUC 8 boundary level. Summary statistics, such as, the total number of nutrient PSs, the total nutrient discharges (in pounds), the number of pounds that were in violation of the permitted limits, the number of pounds that were under the permitted limit, the number of violations per nutrient PS, and location of the impairments were estimated for each of the five HUC 8 sub-watersheds. The summary statistics, shown in Table 5-2, were used as a baseline for the watershed.

TA						
HUC8	North Fork	Middle Fork	South Fork	Middle Basin	Lower Basin	KRB
Number of PSs	36	10	14	16	110	186
Total Discharge (lbs)	5,635	428	2,235	5,695	2,595,292	2,609,286
Violation (lbs)	572	34	362	427	1,050,113	1,051,508
Under the Limits (lbs)	34,836	1,125	4,263	25,823	4,533,698	4,599,743
Number of Violation	16	3	20	17	111	167
Number of Unders	186	55	72	100	796	1,209
Average Monthly Violations (LBS)	48	3	30	36	87,509	87,626
Nutrient Impaired (Miles)	7	0	1	2	217	227
Nutrient Impaired (Acres)	808	0	0	0	3,562	4,370

Table 5-2 KRB Annual Descriptive Statistics

To address the issue of the distance between the TA PSs the HUC 8 watersheds were further dissected into county boundaries and HUC 10 and HUC 12 sub-watersheds to determine the impact of smaller boundary units on the feasibility and suitability of trading. In order for trading to take place PSs need to be in more localized and concentrated geographical areas to trade pollution credits. Since the HUC 10s and HUC 12s are nested within the same geographical region of each of the HUC 8 regions the summary statistics are consistent for all three HUC levels. The only parameter that changes with the changing of the boundary levels is the number of PSs within each of the HUC regions, which in turn gives another perspective on the participant availability within the KRB.

The assessment of the HUC regions were conducted based on SIC code analysis that revealed who the nutrient PSs were and DMR data analysis that revealed the compliance status of each individual nutrient PS and their geospatial orientation to one another. In addition to the DMR analysis, an auxiliary assessment was conducted from a regulatory perspective that introduced regulatory cuts of the permitted limits. This assessment cuts the PS's permitted limits by 25%, 50%, and 75%, respectively, to detect whether the tightening of regulatory standards would generate additional offset credits. Tightening of regulatory standards may allow those PSs that were barely over or under their permitted limits to participate in the buying or selling of offset credits, thus increasing the potential for trading.

But first I give a brief description of the KRB as a whole and then further dissect and assess the basin at the smaller HUC levels. The next five sections discuss each HUC 8 sub-watershed separately and their suitability for potential TA markets. Each section

individually assesses TA PSs at the HUC 8, HUC 10, and HUC 12 level by determining the number of violations, total discharges, the quantity in violation of regulatory standards, the quantity below permitted limits, and the number of PSs. The analysis is based on the HUC10 and HUC12 summary statistics and the geographical location of the nutrient PSs, depicted in Figure 3.4. For further analysis, TA permitted limits were cut by 25%, 50%, and 75% to see if any new credits were generated or induced trading in areas that were not possible before the regulatory cuts.

5.2 Kentucky River Basin

The KRB contained 186 TA PSs that belonged to 22 different industries. The TA PSs discharged approximately 2.6 million pounds of TA, of which 1.1 million of those pounds were non-compliant discharges. Only, 1852 non-compliant pounds of TA were discharged directly into impaired waters. These violations were produced across 13 different industries, with sixty-six contributing TA PSs, resulting in 167 violations across 107 of the 230 HUC 12 sub-watersheds. The majority of these violations were caused by the three biggest industries within the KRB: Real Estate, Educational Services, and Electric, Gas, and Sanitary Services. Table 5-3 shows that the top three industries, real estate, electric, gas and sanitary services, and education services, employ 76% of the TA PSs and are responsible for 78% of the violations that occurred within the KRB.

TA									
SIC2	Industry	Number of PSs	Limit (lbs)	Discharge (lbs)	Violations (lbs)	% of Allowed Emissions in Violation	% of Allowed Emissions Under Limit	Number of Violations	Number of Unders
65	Real Estate	40	5,369,435	2,509,690	1,042,976	19%	73%	50	309
49	Electric, Gas and Sanitary Services	26	664,573	82,193	6,806	1%	89%	29	272
82	Education Services	9	34,863	1,741	181	1%	96%	14	29
70	Hotels, Rooming Houses, Camps, and Other Lodging Places	10	472	165	85	18%	83%	7	56
80	Health Services	2	133	131	27	20%	22%	3	4
55	Automotive Dealers and Gasoline Service Stations	5	151	65	18	12%	69%	3	30
58	Eating and Drinking Places	1	5	20	16	299%	17%	2	1
86	Membership Organizations	3	27	14	4	13%	59%	2	9
54	Food Stores	3	41	12	2	4%	76%	1	18
07	Agricultural Services	1	5	1	0	0%	83%	0	3
20	Food and Kindred Products	3	8,597	951	0	0%	89%	0	32
45	Transportation by Air	1	0	202	0	0%	0%	0	0
59	Miscellaneous Retail	1	39	17	0	0%	56%	0	4
73	Business Services	1	0	11	0	0%	0%	0	0
75	Automotive Repair, Services and Parking	1	0	2	0	0%	0%	0	0
79	Amusement and Recreation Services	1	122	11	0	0%	91%	0	12
83	Social Services	1	6	0	0	0%	94%	0	4
97	National Security and International Affairs	1	185	67	0	0%	64%	0	12
	Min	1	0	0	0	0%	0%	0	0
	Max	40	5,369,435	2,509,690	1,042,976	299%	96%	50	309
	Median	2	82	43	1	0%	71%	1	11
	Mean	6	337,703	144,183	58,340	22%	59%	6	44
	Std	10	1,265,399	590,668	245,738	70%	35%	13	91
	Total	110	6,078,655	2,595,292	1,050,113	387%	1060%	111	795

Table 5-3 KRB Annual Discharges by SIC

From Table 5-3 one can see that most of the industries in the KRB were fairly compliant with regulatory standards. Approximately 86% of the TA industries discharged below 100 pounds of TA non-compliant discharges, which is not a substantial amount of discharges for a WQT program. To see further how these industries affected the KRB the next five sections are spent discussing their impacts.

5.3 North Fork

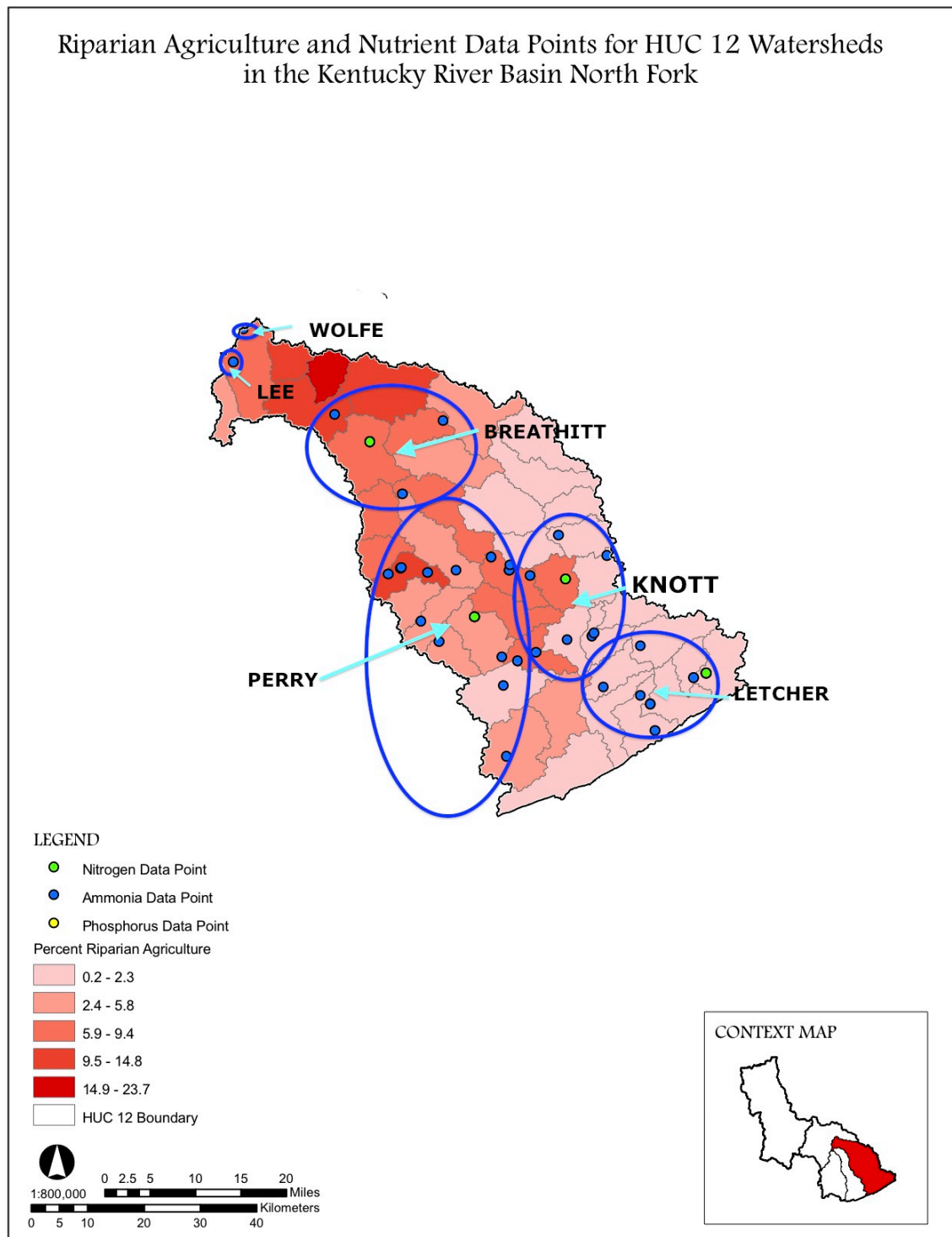


Figure 5-1 North Fork Sub-watersheds

All data points within each of the maps that are presented at the beginning of each of these sections are consistent with TA PS. The North Fork contained 36 TA PSs that were distributed across 8 different industries that, together, discharged 5,635 pounds of TA, 572 of those pounds were in violation of regulatory standards. These non-compliant discharges resulted in 16 violations throughout the year. Only three industries were responsible for all 16 violations: electric, gas and sanitary services, real estate, education services. The TA PSs were disbursed across parts of Breathitt, Knott, Lee, Letcher, Perry, and Wolfe counties. Utilizing Figure 5-1 as a reference one can use the county boundaries to localize the TA PS to better understand loading behavior in that particular region. Table 5-4 lists the six counties that are a part of the North Fork and the loading behavior that has occurred in each of the counties.

North Fork								
COUNTY	Number of TA PSs	Number of TA PSs Discharged to Impaired Waters	Limit (lbs)	Discharges (lbs)	Violations (lbs)	% of Allowed Emissions in Violation	Number of Violations	Number of Counties with Violations
LETCHER	7	2	2,959	1,399	286	10%	8	1
KNOTT	8	3	1,467	813	270	18%	7	1
BREATHITT	4	4	5,432	438	17	0%	1	1
LEE	1	0	44	7	0	0%	0	0
PERRY	15	3	29,976	2,971	0	0%	0	0
WOLFE	1	0	21	7	0	0%	0	0
Total	36	12	39,899	5,635	572	28%	16	3

Table 5-4 North Fork County Descriptive Statistics

Lee and Wolfe County in the northern part of the watershed each contained a single compliant PS that discharged into non-impaired waters. These two TA PSs had minimal impact on the watershed, only discharging 7 pounds of TA for the year. These TA PSs were located in an area that contained less than 8% riparian agriculture. Moving south to Breathitt County, also located in the northern part of the watershed, contained four TA PSs that were located in areas that contained between 8% and 18% riparian agriculture.

These four TA PSs within Breathitt County consisted of one publicly owned municipal PS and three schools of which all discharged directly into impaired waters. These four sources discharged a total of 438 pounds of TA, of which Jackson STP was responsible for 76% of the total discharges. Only 17 of those pounds were in violation of regulatory standards caused by Marie Roberts-Caney Elementary School. These four northern counties consisted of scarce number of TA PSs and very little riparian agriculture, which is not conducive for trading.

Moving farther south to Perry and Knott County, the midsection of the watershed, one can see that TA PSs become more concentrated and geographically closer to one another. Perry County, which spans from the middle regions of the watershed all the way down to the southwestern border of the watershed, contained 15 TA PSs that were responsible for 53% of the total discharges within the North Fork, none of which were in violation of regulatory standards. Hazard STP, a major publicly own municipal PS was responsible for 84% of the total discharges. Vicco STP, a minor publicly own municipal PS, made up 12% of the total discharges. Together these two municipal companies were responsible 96% of TA PS discharges within this region. Only 3 of the 15 TA PSs within in this region discharged directly into impaired waters, only discharging 7 pounds of TA into impaired waters.

Knott County, located east of Perry County along the mid-eastern edge of the watershed, contained eight TA PSs. The TA PSs within this region discharged 14% of the total discharges in the North Fork, of which Hindman STP, a minor publicly owned municipal, and Phoenix Property Owners Association contributed 96% of the total TA discharges. Approximately 421 pounds of TA were discharged directly into impaired

waters, of which Hindman STP was responsible for 99% of the total discharges and the entire 11 pounds of TA that was non-compliant within the region.

Moving farther south to Letcher County one can see that there were seven TA PSs, two of which were in close proximity to one another, which discharged 25% of the total TA discharges and 50% of the total non-compliant discharges. Across the midsection and southern part of the watershed riparian agriculture was less than 8%. The geospatial orientation of TA PSs within the North Fork showed very little signs of clustering and there were very little signs of riparian agriculture activity, which in turn lacks the potential for trading. One major concern was the lack of nutrient impaired waters within the watershed. The North Fork lacked an abundance of nutrient impaired waters, only containing seven miles of nutrient impaired streams. Though the TA PSs were geographically located, the current data does not discern which individual PSs discharged directly into nutrient impaired waters. The lack of nutrient impaired miles was not only contained to the North Fork, but also to the Middle and South Fork and the Middle Basin, which is a major issue for WQT.

From an environmental suitability standpoint TA discharges did not seem substantial enough to support trading as a cost effective mechanism to reduce nutrient discharges within the North Fork watershed. Majority of the TA PSs within this region were in compliance with regulatory standards and when violations did occur, a few TA PSs caused the violations. These discharges do not support the longevity of a WQT program because not enough supply and demand for offset credits was being generated to support trading in the short run or the long run.

5.4 Middle Fork

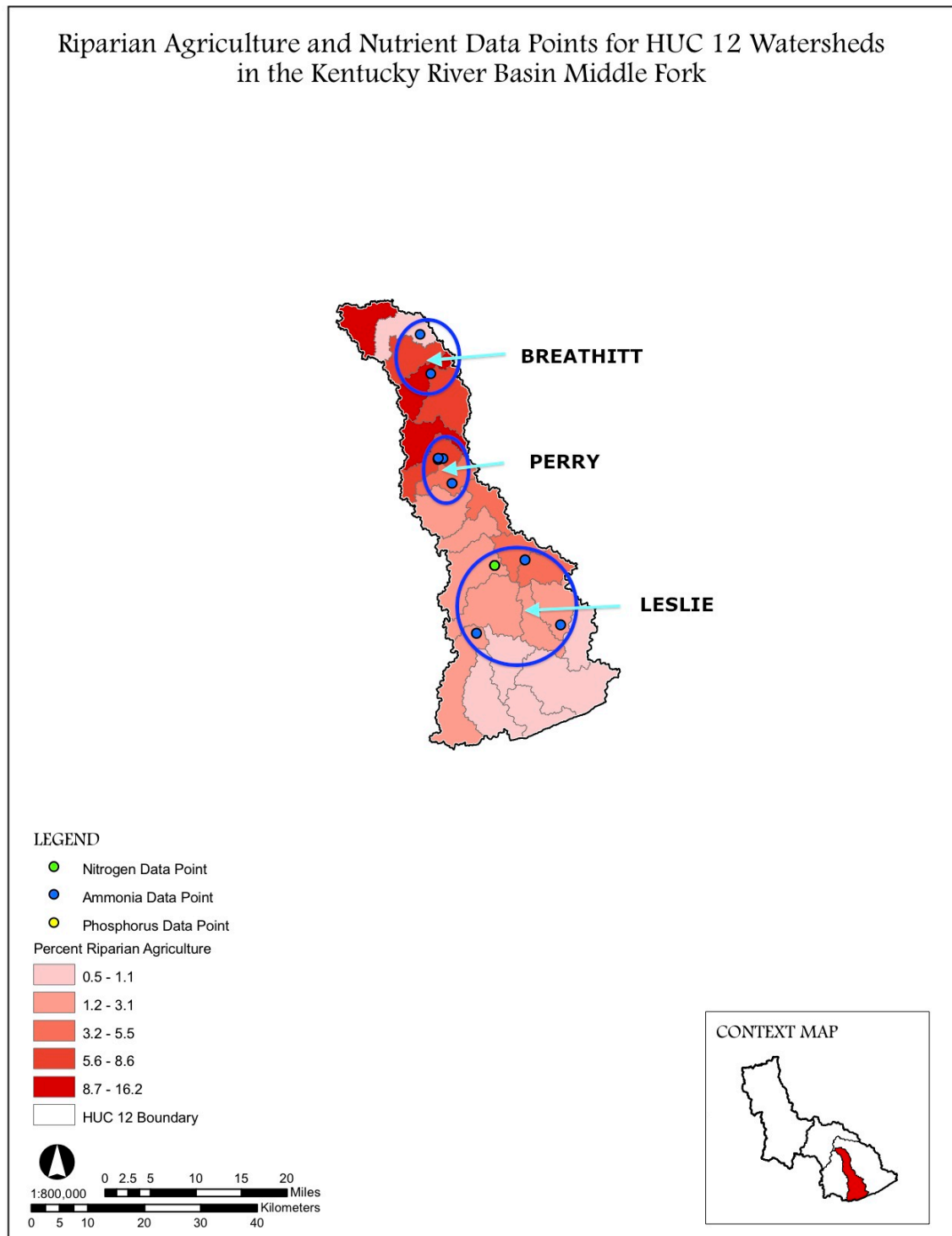


Figure 5-2 Middle Fork Sub-watersheds

The Middle Fork contained 10 TA PSs, illustrated by Figure 5.2, that were distributed across 4 different industries: education services, electric, gas and sanitary services, amusement and recreation services, social services. Together these four industries discharged 428 pounds, of TA of which 119 of those pounds were in violation of regulatory standards. These non-compliant discharges resulted in 3 violations caused by the education services industry.

The TA PSs were disbursed across parts of Breathitt, Leslie, and Perry County. Utilizing Figure 5.2 one can see the county boundaries and the number of TA PSs they contained. Table 5-5 lists the three counties that are a part of the Middle Fork and the loading behavior that has occurred in each of the counties.

Middle Fork								
COUNTY	Number of TA PSs	Number of TAPS Discharged to Impaired Waters	Limit (lbs)	Discharges (lbs)	Violations (lbs)	% of Allowed Emissions in Violation	Number of Violations	Number of Counties with Violations
LESLIE	4	1	675	188	34	5%	3	1
PERRY	4	2	680	235	0	0%	0	0
BREATHITT	2	0	164	5	0	0%	0	0
Total	10	3	1,519	428	34	5%	3	1

Table 5-5 Middle Fork County Descriptive Statistics

Breathitt County in the northern part of the watershed only contained two TA PSs

Highland Turner Elementary School and Oakdale Christian High School. These two PSs were in compliance with regulatory standards and discharged into non-impaired waters.

Moving south one can see that Perry County contained four TA PSs that are geographically clustered together. These TA PSs were in compliance with regulatory standards of which two discharged into impaired waters. In the southern part of the watershed is Leslie County, which contained four TA PSs. Only two TA PSs were non-

compliant with regulatory standards by discharging 34 pounds of non-compliant discharges into non-impaired waters. Hyden STP, a minor publicly owned municipal, discharge into impaired waters but was in compliance with their permitted limits.

Overall trading would be highly unlikely to occur within the Middle Fork watershed.

Almost all of the TA PSs were in compliance with regulatory standards, the PSs were sparse, and violations were minuscule. Also riparian agriculture within the region was less than 10%, which makes it more unlikely for PS-NPS trading

5.5 South Fork

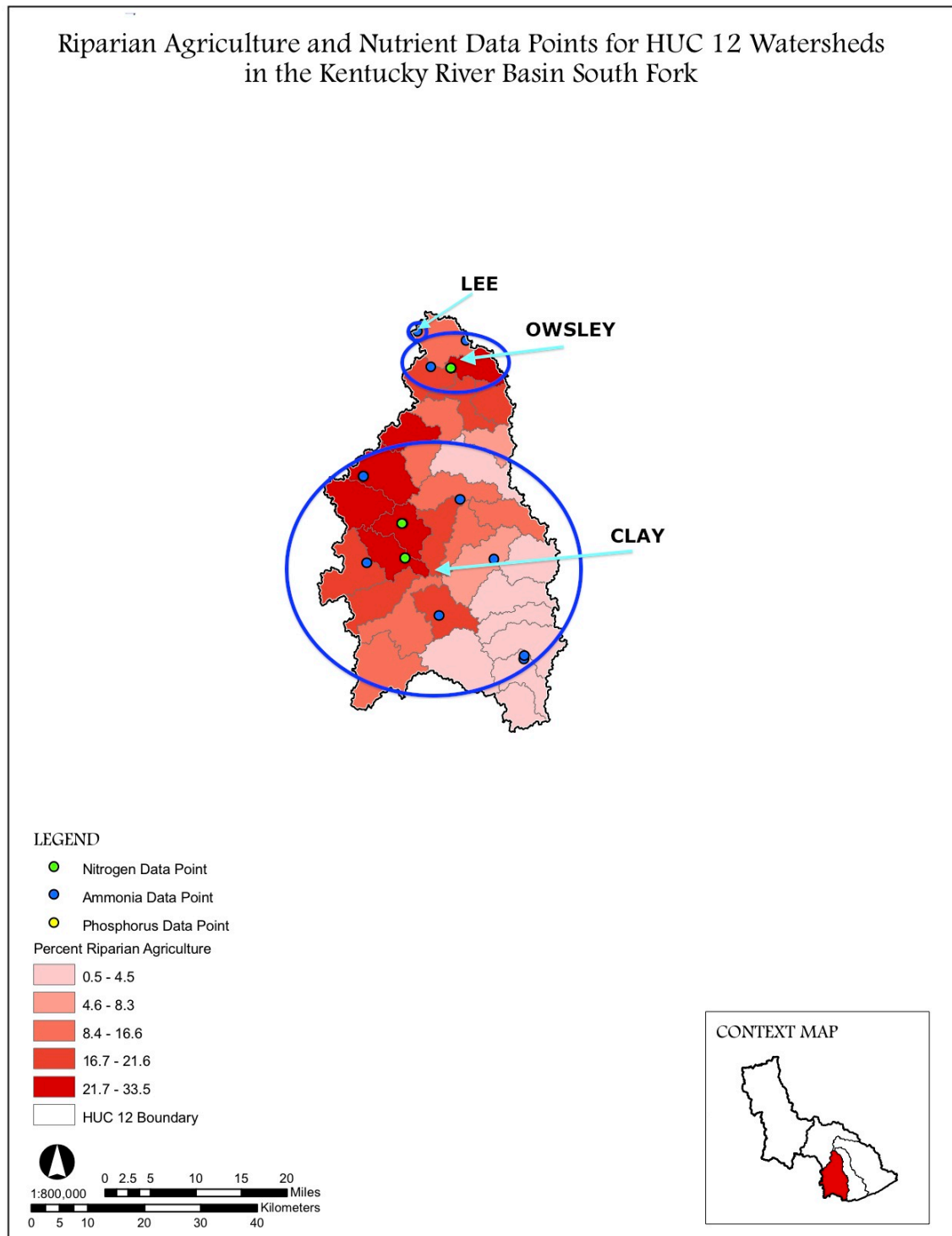


Figure 5-3 South Fork Sub-watersheds

The South Fork contained 14 TA PSs, illustrated by Figure 5.1, that were distributed among 7 different industries that, together, discharged 2,235 pounds, of TA of which 362 of those pounds were in violation of regulatory standards. These non-compliant discharges resulted in 20 violations across 4 different industries: social services, education services, health services, electric, gas and sanitary services.

The TA PSs were disbursed across parts of Lee, Owsley, and Clay County. Utilizing Figure 5.3 one can see the county boundaries and the TA PSs they contained. By looking at the county boundary one can see the loading behavior in that particular region. Table 5-6 lists the three counties that are apart of the South Fork and the loading behavior that has occurred in each of the counties.

South Fork								
COUNTY	Number of TA PSs	Number of TAPS Discharged to Impaired Waters	Limit (lbs)	Discharges (lbs)	Violations (lbs)	% of Allowed Emissions in Violation	Number of Violations	Number of Counties with Violations
CLAY	10	2	4,660	1,945	346	7%	19	1
OWSLEY	3	0	1,461	289	16	1%	1	1
LEE	1	0	12	1	0	0%	0	0
Total	14	2	6,133	2,235	362	8%	20	2

Table 5-6 South Fork County Descriptive Statistics

Lee County, in the northern part of the watershed, contained a single compliant TA PS that had miniscule discharges. Owsley County to the south contained two TA PSs that were compliant and Booneville STP, a minor publicly owned municipal, which had a total of 16 pounds of non-compliance discharges of TA. All the TA PSs within Lee and Owsley County discharged into non-impaired waters. Moving to Clay County in the southern region of the watershed there were ten TA PSs widely disbursed across the

county. Six of the ten TA PSs within this County were responsible for 96% of the total violations, with Goose Rock elementary school contributing 67% of those pounds.

Over 64% of the TA PSs within the South Fork watershed resided in regions that were consistent with 19%-30% riparian agricultural activity. The general lack of TA PSs, as well as their dispersed geospatial distribution, indicates little potential for PS-PS trading. Based on the riparian agricultural density the region does show some potential for PS-NPS trading on a smaller scale.

5.6 Middle Basin

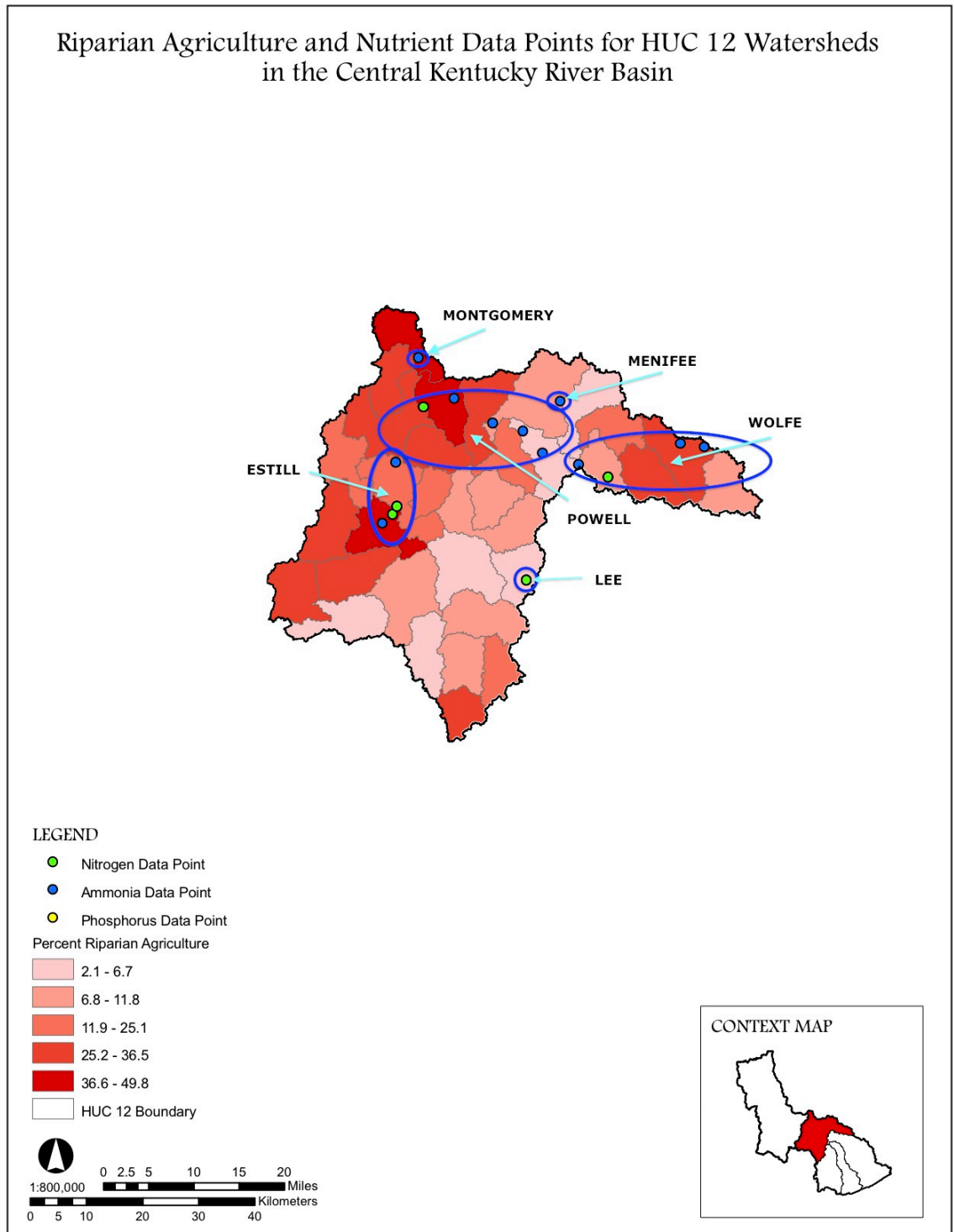


Figure 5-4 Middle Basin Sub-watersheds

The Middle Basin contained 16 TA PSs, illustrated by Figure 5.1, that were distributed among 10 different industries that, together, discharged 5,695 pounds of TA of which 427 of those pounds were in violation of regulatory standards. These non-compliant discharges resulted in 17 violations across 6 different industries.

The TA PSs were disbursed across parts of Montgomery, Menifee, Powell, Wolfe, Estill, and Lee Counties. Utilizing Figure 5.4 one can see the county boundaries and the TA PSs they contained. Table 5-7 lists the six counties that are apart of the Middle Basin and the loading behavior that has occurred in each of the counties.

Middle Basin								
COUNTY	Number of TA PSs	Number of TA PSs Discharged to Impaired Waters	Limit (lbs)	Discharges (lbs)	Violations (lbs)	% of Allowed Emissions in Violation	Number of Violations	Number of Counties with Violations
ESTILL	4	0	18,415	4,603	389	2%	8	1
WOLFE	4	2	1,797	327	19	0%	2	1
POWELL	5	0	5,279	534	15	0%	5	1
MENIFEE	1	0	64	27	4	0%	2	1
LEE	1	0	5,516	196	0	0%	0	0
MONTGOMERY	1	0	19	8	0	0%	0	0
Total	16	2	31,091	5,695	427	2%	17	4

Table 5-7 Middle Basin County Descriptive Statistics

Montgomery, Menifee, and Lee County only contained a single TA PS. All three of these TA PSs, together, only discharged 231 pounds of TA, which were all discharged to non-impaired waters. Of the three counties Menifee was the only county with non-compliant TA discharges, discharging only 4 pounds of TA. To the south of Montgomery County sits Powell County with five TA PSs that discharged 534 pounds, which were discharged into non-impaired waters. Powell County contained two minor publically own municipal companies, Clay City STP and Slade Nada STP. Clay City STP discharged 79% of the total discharges within the region and was in compliance with regulatory standards. Slade Nada STP discharged 11% of the TA within Powell County

and had a total violation of 7 pounds for the year. Discharges within this region were minimal. Three of the five TA PSs were non-compliant at some point throughout the year discharging 15 pounds of non-compliant TA.

Heading southwest of Powell County we come to Estill County that contained four TA PSs, none of which discharged to impaired waters. As one can see from Table 5-7 Estill County is the major contributor to compliant and non-compliant TA discharges within the Middle Basin. Estill contained Irvine STP and Estill County Water District #1 STP, which were responsible for 99.8% of the total discharges within Estill County. Estill County Water District #1 STP was responsible for 91% of the total discharge violations for the South Fork watershed. Moving east to Wolfe County one can see that there are four TA PSs that discharged a total of 327 pounds of TA of which 92% of those discharges were directly discharged into impaired waters. Only 19 pounds of the total TA discharges were in non-compliance and were discharged into impaired waters.

Approximately 50% of the TA PSs within the Middle Basin watershed were located within regions that were consistent with 31%-47% riparian agricultural activity. Based on the geospatial orientation of TA PSs and the lack of TA PSs showed very little signs of potential PS-PS trading. However, based on the riparian agricultural density, the region does show some potential for PS-NPS trading on a smaller scale.

5.7 Lower Basin

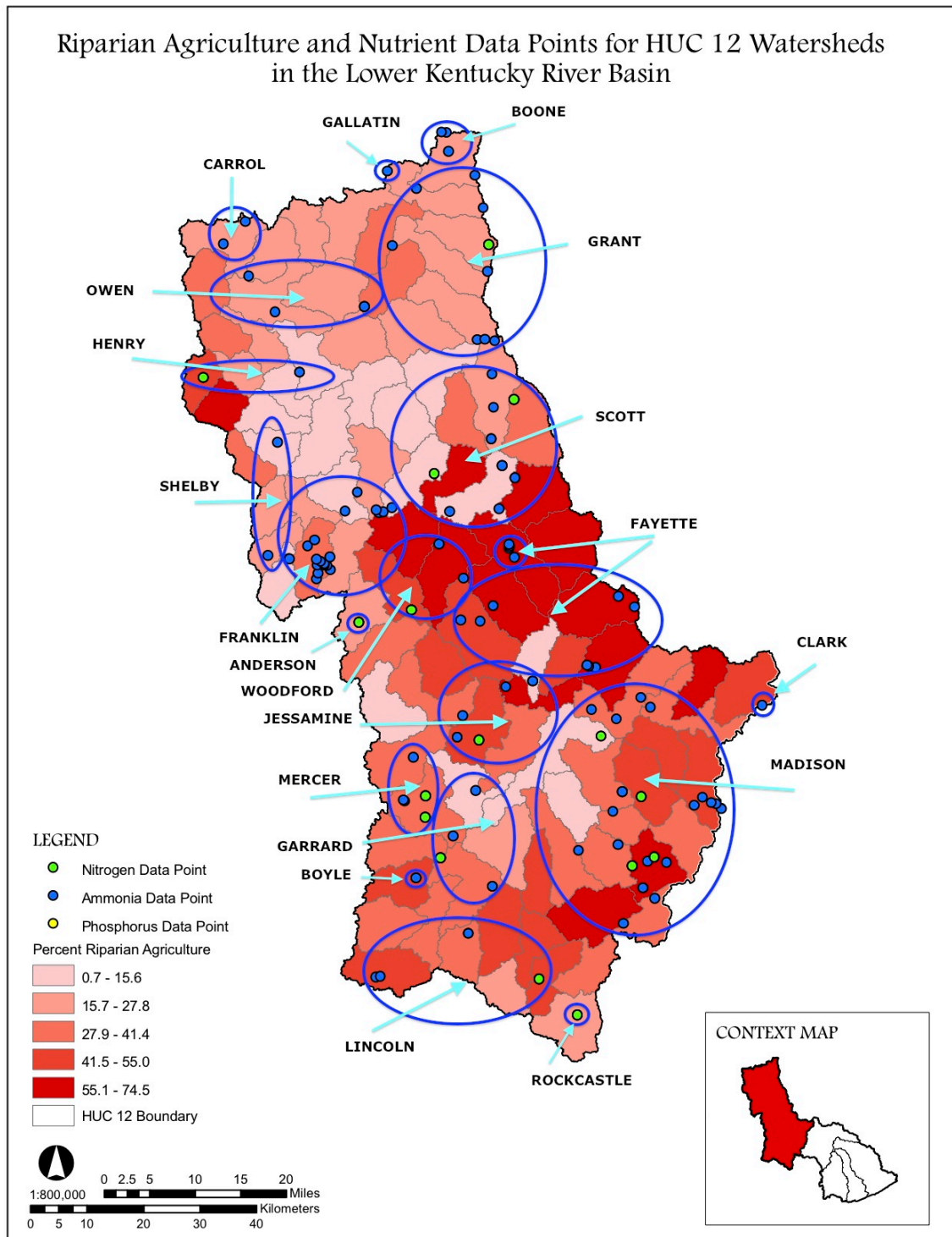


Figure 5-5 Lower Basin Sub-watersheds

The Lower Basin contained 110 TA PSs, illustrated by Figure 5.5, that were distributed across 18 different industries that, together, discharged approximately 2.6 million pounds. Approximately one million pounds were in violation of regulatory standards resulting in 111 violations across 9 different industries. Findings show that approximately 37% of the TA PSs were responsible for the 111 violations; roughly discharging 32,000 pounds of TA directly into impaired waters, 6% of those pounds were in violation of regulatory standards. To get a better understanding of the discharge loadings within the watershed county boundaries were considered.

The TA PSs were disbursed across 20 different counties where each county was either partly or fully within the watershed. Table 5-8 lists the 20 counties that are apart of the Lower Basin and the loading behavior that has occurred in each of the counties.

Lower Basin								
COUNTY	Number of TA PSs	Number of TA PSs Discharged to Impaired Waters	Limit (lbs)	Discharges (lbs)	Violations (lbs)	% of Allowed Emissions in Violation	Number of Violations	Number of Counties with Violations
MADISON	22	8	48,519	2,541,132	1,043,587	2151%	18	1
JESSAMINE	5	1	210,200	15,793	2,919	1%	5	1
LINCOLN	4	1	0	7,080	1,441	0%	5	1
FAYETTE	11	5	117,214	9,320	1,251	1%	18	1
FRANKLIN	20	3	48,255	4,325	348	1%	29	1
GARRARD	4	2	3,468	1,206	142	4%	3	1
HENRY	2	1	0	5,791	123	0%	5	1
SCOTT	9	1	13,812	1,987	116	1%	11	1
MERCER	5	2	0	52	16	0%	2	1
BOONE	3	1	0	33	11	0%	4	1
OWEN	3	1	0	332	7	0%	3	1
ANDERSON	1	1	894	220	0	0%	0	0
BOYLE	1	1	17,338	5,174	0	0%	0	0
CARROLL	2	0	0	1	0	0%	0	0
CLARK	1	0	0	1	0	0%	0	0
GALLATIN	1	0	0	0	0	0%	0	0
WOODFORD	3	2	0	1,353	0	0%	0	0
Total	97	30	459,701	2,593,799	1,049,960	2159%	103	11

Table 5-8 Lower Basin County Descriptive Statistics

Madison and Franklin County contained the most TA PSs compared to any other county. These two counties also had the highest density of TA PS clustering than the rest of the watershed. These clusters were located within riparian agricultural intense regions with four or more TA PS per cluster, with the southern part of Franklin County with ten or more TA PS in its cluster. Madison County contained 20% of the TA PSs, 98% of the TA total discharges and 99% of the TA total discharge violations both as a result of the Reed Duplex Apartment Buildings' discharges.

The Reed Duplex Apartment Buildings were responsible for nearly all the TA discharges that were compliant and non-compliant with regulatory standards. These duplex apartments buildings only had recorded discharges for June and September of 2009, which were discharged into non-impaired waters. Discharges in June reached 2.32 million pounds with a total violation of 1.04 million pounds of TA and by September discharges were down to approximately 185,000 pounds of TA with no recorded discharge violations. It seems that the discharges was an isolated event, but it is uncertain due to the nature of the data. Assuming that this was an isolated event and Reed Duplex Apartments did not have any discharge violations the total non-compliant discharges would have been a total of 7,710 pounds. Appendix A shows revised HUC 8 descriptive statistics and regulatory cuts for the KRB. Over all the Reed duplex apartment buildings masked the underlying discharge impacts that pollution sources were having on Lower Basin.

Approximately 83% of the counties in the Lower Basin discharged less than 1,000 pounds of non-compliant TA and 26% of the counties were in compliance with regulatory standards. Majority of the Lower Basin contained 31%-75% riparian

agriculture. Based on the geospatial orientation of TA PSs, the abundance of TA PSs, and the higher density of riparian agriculture are ideal conditions for PS-PS and PS-NPS trading.

5.8 HUC 10 and HUC 12 Sub-Watersheds

The geo-spatial orientation of pollution sources is critical to WQT. This section dissects the KRB into HUC 10 and HUC 12 sub-watersheds to learn whether smaller boundary units allow trading. Table 5-9 shows the descriptive statistics for the HUC 10 and HUC 12 sub-watersheds.

Stats	TA PSs		HUC 10				HUC 12			
HUC 8	Number of TA PS	Number of TA PS in Violation	Total Number of HUC 10s	Average Number of TA PS	Average Violations (lbs)	Average Unders (lbs)	Total Number of HUC 12s	Average Number of TA PS	Average Violations (lbs)	Average Unders (lbs)
North Fork	36	7	7	5	82	4,924	24	2	24	1,436
Middle Fork	10	2	4	3	9	274	8	1	4	137
South Fork	14	8	6	2	60	681	10	1	36	409
Middle Basin	16	8	5	3	85	5,125	10	2	43	2,563
Lower Basin	110	41	15	7	70,008	139,290	55	2	19,093	37,988

Table 5-9 HUC 10 and HUC 12 Descriptive Statistics

Findings revealed that trading at the HUC 10 and HUC 12 boundary units would be implausible for all the HUC 8 watersheds, except for the Lower Basin. If trade were conducted at the HUC 10 and HUC 12 watershed, participant availability would be scarce. The HUC 10 and HUC 12 sub-watersheds contained a small number of PSs that on average had minimal discharge violations, which would be easily offset by the TA PS discharges that were under permitted limits. Trading at boundary units smaller than HUC 10 watershed seems to be unlikely because smaller geographic boundary units would lead to insufficient number of PSs, which potentially would lead to less discharge violations.

The Lower Basin, at the HUC 10 level, is the only watershed that showed potential for trading based on the average number of TA PSs within each HUC 10 watershed. Trading based on the average number of TA PSs within each HUC 10 would be ultimately dependent on the geospatial orientation of the buyers and sellers in the market.

5.9 Regulatory Cuts

Regulatory pressures are the catalyst that drives WQT. Since the KRB lacks TMDLs for the watershed, this study utilizes a hypothetical scenario where regulatory limits were cut by 25%, 50%, and 75% to see how this would affect potential trade.

Table 5-10 below compares discharge violations and TA PS discharges that were under the permitted limit at the various regulatory cuts.

Regulatory Cuts	Stats	North Fork	Middle Fork	South Fork	Middle Basin	Lower Basin	KRB
100% Limit	Violations (lbs)	572	34	362	427	1,050,113	1,051,508
	Unders (lbs)	34,836	1,125	4,260	25,823	4,533,690	4,599,734
	Number of TA PSs	36	10	14	16	110	186
	Number of TA PSs in Violation	7	2	8	8	41	66
25% Cut	Violations (lbs)	747	45	422	950	1,374,591	1,376,755
	Unders (lbs)	25,036	756	2,787	18,573	3,338,505	3,385,657
	Number of TA PSs in Violation	13	2	10	8	47	80
50% Cut	Violations (lbs)	1,116	108	527	1,610	1,704,168	1,707,529
	Unders (lbs)	15,430	439	1,359	11,461	2,148,418	2,177,107
	Number of TA PSs in Violation	18	3	11	12	59	103
75% Cut	Violations (lbs)	1,710	201	1,081	2,714	2,040,879	2,046,585
	Unders (lbs)	6,049	152	379	4,792	965,466	976,838
	Number of TA PSs in Violation	22	6	12	13	85	138

Table 5-10 KRB Regulatory Cuts

Utilizing 100% of the permitted limit one can see that the amount of TA demanded was easily covered by the supply of TA reductions, all the way up to 50% of the original permitted limit. When regulatory cuts reached a 75% cut, supply and demand sort of traded places. The Middle Fork, South Fork, and Lower Basin were now

in excess demand for off set credits, where the amount of TA supplied reduction could not cover the quantity demanded. Combined with substantial increase in the number of TA PSs in violation of regulatory standards, the market would be flooded with excess demand.

CH. 6

6.1 Conclusion

Overall nutrient PS-PS trading within the KRB is implausible for TP and TN PSs due to the lack of regulatory standards, limited number of TN and TP PSs, and an inadequate demand for offset credits. TMDLs and permitted limits for TN currently do not exist in the KRB making it impossible to initiate a TN market. However, establishing TMDLs for the KRB will merely be the first of many steps that will all need to be taken quickly if WQ trading is to be given a fair chance to succeed (King 2005). The number of TP and TN PSs are too few, even at the different HUC and county levels.

Majority of the PSs in the KRB were in compliance with regulatory standards. When violations did occur they were miniscule or caused by a couple of PSs, which would result in just a couple of buyers and a lot of sellers in the market, especially TP PSs. When regulatory cuts were applied a substantial increase in the number of TA PSs in violation was realized, which is great for trading. But, the geospatial arrangements of the TA PSs were not ideal. Many of the TA PSs were disburse across the KRB with very like clustering.

The data reveals the Lower Basin as being the region with the most potential for TA trading, not only for PS-PS trading but PS-NPS trading as well. Trade is restricted to geographical boundary units no smaller than HUC 10 watershed because any smaller would result in a lack of TA PSs. This region contained the highest concentration of nutrient PSs and discharges, violations, riparian agriculture, urban development, and nutrient PSs. More importantly, the Lower Basin contained 96% of the nutrient impaired

streams and 82% of the nutrient impaired lakes, which provided ample opportunity for nutrient trading. There were little to no nutrient impaired stream miles within the other four watersheds making nutrient trading even more unlikely. Very little non-compliant discharges were discharged into impaired waters, which seems that NPSs in the region have substantial contributions to the impaired waters.

In order for trading to occur in KRB one has to know the pollution source's marginal cost of abatement and the condition and age of their machinery because these key elements will ultimately determine whether participants will engage in trading. Depending on the age and condition of the machinery, PSs may not be able to keep up with the population growth and weather conditions further down the road. These two factors changes the marginal cost of abatement that PSs face over time, which can lead to PSs having to finding alternatives ways to handle their nutrient discharges. It could cost millions of dollars for some PSs to abate a few more pounds of nutrient discharges at the margin due to new investments in order to handle the new reductions. Also, TMDLs and regulatory standards for TN must be established in order to even start thinking about planning a WQT program.

Appendix A

A. Table 5.2 KRB Annual Descriptive Statistics

HUC8	North Fork	Middle Fork	South Fork	Middle Basin	Lower Basin	KRB
Number of PSs	36	10	14	16	110	186
Total Discharge (lbs)	5,635	428	2,235	5,695	89,107	103,100
Violation (lbs)	572	34	362	427	7,710	9,105
Under the Limits (lbs)	34,836	1,125	4,263	25,823	636,688	702,733
Number of Violations	16	3	20	17	110	166
Number of Unders	186	55	72	100	793	1,206
Average Monthly Violations (LBS)	48	3	30	36	2,849	2,965
Nutrient Impaired (Miles)	7	0	1	2	217	227
Nutrient Impaired (Acres)	808	0	0	0	3562	4,370

B. Table 5.8 Lower Basin County Descriptive Statistics

Lower Basin Without Reed Duplex Apartments									
COUNTY	Number of TA PSs	Number of TA PSs Discharged to Impaired Waters	Discharges (lbs)	% of Total Discharges	Violations (lbs)	% of Violations (lbs)	Number of Violations	Number of Counties with Violations	% of Violations
MADISON	22	8	34,946	39%	-1,183	15%	17	1	15%
JESSAMINE	5	1	15,793	18%	-2,919	38%	5	1	5%
LINCOLN	4	1	7,080	8%	-1,441	19%	5	1	5%
FAYETTE	11	5	9,320	10%	-1,251	16%	18	1	16%
FRANKLIN	20	3	4,325	5%	-348	5%	29	1	26%
GARRARD	4	2	1,206	1%	-142	2%	3	1	3%
HENRY	2	1	5,791	6%	-123	2%	5	1	5%
SCOTT	9	1	1,987	2%	-116	2%	11	1	10%
SHELBY	2	0	124	0%	-70	1%	4	1	4%
GRANT	10	0	1,088	1%	-57	1%	3	1	3%
ROCKCASTLE	1	0	280	0%	-26	0%	1	1	1%
MERCER	5	2	52	0%	-16	0%	2	1	2%
BOONE	3	1	33	0%	-11	0%	4	1	4%
OWEN	3	1	332	0%	-7	0%	3	1	3%
ANDERSON	1	1	220	0%	0	0%	0	0	0%
WOODFORD	3	2	1,353	2%	0	0%	0	0	0%
CARROLL	2	0	1	0%	0	0%	0	0	0%
BOYLE	1	1	5,174	6%	0	0%	0	0	0%
CLARK	1	0	1	0%	0	0%	0	0	0%
GALLATIN	1	0	0	0%	0	0%	0	0	0%
Total	110	30	89,107	100%	-7,710	100%	110	14	100%

C. Table 5.10 KRB Regulatory Cuts

Regulatory Cuts	Stats	North Fork	Middle Fork	South Fork	Middle Basin	Lower Basin	KRB
100% Limit	Violations (lbs)	572	34	362	427	7,710	9,105
	Unders (lbs)	34,836	1,125	4,260	25,823	636,688	702,732
	Number of TA PSs	36	10	14	16	110	186
	Number of TA PSs in Violation	7	2	8	8	40	65
25% Cut	Violations (lbs)	747	45	422	950	12,432	14,596
	Unders (lbs)	25,036	756	2,787	18,573	461,943	509,095
	Number of TA PSs in Violation	13	2	10	8	46	79
50% Cut	Violations (lbs)	1,116	108	527	1,610	22,253	25,614
	Unders (lbs)	15,430	439	1,359	11,461	292,297	320,986
	Number of TA PSs in Violation	18	3	11	12	58	102
75% Cut	Violations (lbs)	1,710	201	1,081	2,714	39,209	44,915
	Unders (lbs)	6,049	152	379	4,792	129,785	141,157
	Number of TA PSs in Violation	22	6	12	13	84	137

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Vita

Name: Ronald Childress Jr.

Date and Place of Birth: 04/20/1983 Louisville, Kentucky

Education: B.A. Economics, University of Kentucky December 2006