SURFACE WATERS MOST LIKELY IMPACTED BY

HORMONES FROM LAND-APPLIED CAFO WASTES IN MISSOURI

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by

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The undersigned, appointed by the dean of the Graduate School, have examined the thesis entitled

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And hereby certify that in their opinion it is worthy of acceptance.

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ABSTRACT

The land application of livestock wastes is a significant potential contributor of environmental hormone contamination. Hormones from land-applied wastes have been detected in field runoff and in downstream surface waters. Contamination risks are especially significant when, "…manure is applied to areas where the majority of stream water derive from drainage water…" (Kjaer et al., 2007). "In areas where manure application is intensive, estrogens have been found in surface waters in concentrations known to affect the endocrine system of fish and amphibians… how the estrogens reach the surface waters is unclear…" (Laegsdmand et al., 2009). Environmental estrogen exposure is linked to reproductive maladies and altered sex characteristics in wildlife and to reproductive disorders and a variety of cancers in humans.

Previous study findings indicate that it may be very difficult to predict fine scale transformation or degradation rates of hormones across complex, broad-scale environmental gradients. This study identifies important fine scale chemical processes and broad scale transport mechanisms and uses a relatively simple model of runoff from CAFO land application fields in Missouri to identify surface waters most likely to be impacted by the hormones those wastes contain.

A recent study in the Shenandoa River valley watershed in Virginia (Ciparis, Iwanowicz and Voshell, 2012) finds that increased density of animal feeding operations correlate to increased hormonal activity in watershed stream reaches. This suggests that in Missouri, increased hormonal activity will be found in areas where CAFO facilities, their animals and wastes are concentrated.

INTRODUCTION

Estrogens and other hormones originating in the wastes of humans and animals are nearly ubiquitous in the environment (Kolpin et al., 2002). Environmental estrogens have been linked to the physiological and reproductive impairment of birds, fish, shellfish, turtles, gastropods, and mammals (Colborn, Saal, and Soto, 1993). Researchers have correlated exposure to environmental estrogens to decreased sperm counts and malformations of the male genital tract as well as to certain types of cancer and endocrine related diseases (Soto and Sonnenschein, 2010). The full effect of endocrine disruption from environmental hormones on wildlife and humans is not yet fully understood (Sumpter and Johnson, 2005).

Natural estrogens, those excreted by human and animal bodies, are the most potent endocrine disruptors (Khanal et al., 2006; Combalbert and Hernandez-Raquet, 2010). The large volumes of livestock wastes generated at confined animal feeding operations (CAFOs) are estimated to contribute over 90 percent of natural estrogens to the total environmental estrogen load (Khanal et al. 2006). Livestock-source hormones have been implicated in the alteration of sex characteristics of fish (Rose et al., 2002; Orlando et al., 2007; Sellin et al., 2009; Dammann et al., 2011; and Dequattro et al., 2011), turtles (Irwin, Grey, and Oberdörster, 2001), and frogs (Kvarnryd et al., 2011). The alteration of sex characteristics of aquatic species has the potential to disrupt whole aquatic ecosystems.

The land application of livestock wastes has been identified as a significant potential contributor of environmental hormone contamination (Kolpin et al., 2002;

Hanselman, Graetz, and Wilkie, 2003; Burkholder et al., 2007). Hormones from land-applied wastes have been detected in runoff and in downstream surface waters (Nichols et al., 1998; Finlay-Moore, Hartel and Cabrera, 2002; Soto et al., 2004; Johnson, Williams, and Matthiessen, 2006; Sarmah et al., 2006; Lorenzen et al., 2006; Matthiessen et al., 2006; S.J. Khan et al., 2008, Olsen et al., 2009; and Dutta et al., 2010). Contamination of surface waters is especially significant when, "…manure is applied to areas where the majority of stream water derive from drainage water…" (Kjaer, 2007). "In areas where manure application is intensive, estrogens have been found in surface waters in concentrations known to affect the endocrine system of fish and amphibians… how the estrogens reach the surface waters is unclear…" (Laegsdmand, 2009).

Description of Study Area

Study Area Extent

This study investigates which surface waters are most likely to be impacted by hormones found in land-applied CAFO livestock wastes across the state of Missouri. A state-extent study is of interest to residents and regulators alike, because it takes into consideration all CAFOs, lands, and stream networks within the jurisdiction of the State of Missouri. The state of Missouri (Figure 1.) is approximately 178,038 square kilometers (68,741 square miles) in area, with dimensions of approximately 450km (280 miles) north to south and 400km (250 miles) east to west. The Missouri River forms the northern portion of the western boundary of the state, from the Iowa border to Kansas City, where it turns and flows easterly, crossing the state to St. Louis on the eastern edge. Just north of St. Louis the Missouri River comes into confluence with the southerlyflowing Mississippi River, which is the eastern boundary of the state. The Missouri River roughly divides the state into northern and southern regions, each region with its own characteristics. The physical and agricultural economic differences between the northern and southern regions make Missouri an interesting setting for this study.

Northern Missouri

The region north of the Missouri River, approximately one-third of the state's area, is generally rolling to hilly in the western two-thirds and relatively flat in the eastern third. The Chariton River divides the western portion of the region from the eastern portion. The western portion has poorly drained silt loam, clay loam, and silty clay soils formed from loess and glacial till. Cultivated fields are often found on ridge tops and valleys with pastures and trees on steeper slopes and in narrow valleys (Allgood, 1979). The eastern portion has poorly drained silt loam to well-drained loams with and poorly drained clay pan subsoils. Cultivated fields are found on more level uplands with pasture and forest on steeper slopes (Allgood, 1979). Upland wooded oak and hickory forests are located along the Chariton River in the central portion of the region and Missouri River to the south and Mississippi River to the east. Northern Missouri is largely rural and agricultural with high production of grains, corn, soybeans, cattle, and hogs.

Southern Missouri

The region south of the Missouri River, approximately two-thirds of the state's area, is dominated by the Ozark Plateau, with a mix of Cherokee Prairie and agricultural lands on the western edge and drained Mississippi delta land in the southeastern Missouri Bootheel. Land along the western edge of southern Missouri is level to hilly with generally poorly to moderately well drained clayey and loamy soils. Cultivated fields are located on level and gently sloping lands; pasturelands are located on steeper side slopes (Allgood, 1979). The Ozark Plateau is generally forested hilly land, from gentle slopes to very steep mountain ridges. The area has moderately well drained to excessively drained loamy and cobbly soils with boulders and areas of exposed granite, dolomite, and sandstone formations. Narrow pastures or fields are generally found in valleys (Allgood, 1979), but may also be found on ridge tops. The Missouri Bootheel is relatively level land with poorly drained clayey soils to well drained loams. Most of the agricultural land cultivated for crops, with some pastures and orchards on slopes and ridges (Allgood, 1979). Southern Missouri also has complex karst geology, which complicates regional subsurface hydrology patterns.

Southern Missouri is also largely rural but its three distinct regions are different agriculturally. Historically, communities in the Ozark Plateau have had economies based less on agriculture and more on resource extraction, such as lead and zinc mining, iron mining, and timber; however, the resource extraction-based economy has contracted. Livestock ranching and dairy and beef cattle farming are the primary agricultural endeavors found on the Ozark Plateau. The western portion of this region has a mix of cultivated crops and animal agriculture, while the Bootheel is predominantly cultivated crops. With the exception of the Bootheel, southern Missouri, especially the Ozark Plateau, has had historically lower farm product values and lower farm incomes than the rest of the state (Rafferty, 1983; USDA, 2007).

CAFOs in Missouri

There are 566 permitted CAFOs in Missouri (MoDNR, 2011a); Table 1., below, lists the type and number of each CAFO in Missouri. A map of these facilities by animal type is attached as Figure 2.

CAFO by Animal Type	***No.***
Beef Feedlots	6
Dairy Farms	14
General Farms	2
Hog Operations	287
Poultry & Egg Operations (Includes chickens, turkeys, and eggs)	257
Total	***566***

Table 1. Number of Missouri CAFOs by Type

There are a large number of hog operations and poultry and egg operations in Missouri. Generally, hog operations are loosely cluster and dispersed in northern, wet-central and southeast Missouri, and along the west side of the state. Poultry operations are generally clustered in the west-central, southwest, and southeast parts of the state, with few operations, mostly chicken egg facilities, dispersed elsewhere. Beef feedlots are located in Bates County (3) on the western border of the state, and in Chariton (1), Randolph (1), and Cooper (1) counties in the central part of the state. Dairy farms are dispersed along the southwest (8), northeast (2), east central (3) and southeast (1) parts of the state.

Not all livestock feeding operations are required to be permitted. Facilities required to be permitted meet a minimum threshold number of animals (MoDNR, 2009). Some examples of these thresholds are listed in Table 2., below.

Minimum Animal Number Thresholds for MoDNR Permitting

Beef Cattle	300
Dairy Cows	200
Hogs (over 55lbs)	750
Broiler Chickens	30,000
Laying Hens	9,000

Table 2. Minimum Animal Number Thresholds for MoDNR Permitting (MoDNR, 2009)

Based on these minimum thresholds, it should be understood that unpermitted facilities may contain facilities with significant numbers of animals that there are no available records for, and so they are not considered in the scope of this study.

The agency in charge of permitting and regulation of CAFOs and land-application of wastes in Missouri is Missouri Department of Natural Resources (MoDNR). To meet MoDNR "no discharge" requirements for permitting, all CAFOs in the state of Missouri are required to dispose of livestock wastes by prescriptive, field-specific land application following guidelines set forth in a Nutrient Management Plan (NMP) (MoDNR, 2009). Each facility will require land application acreage large enough to dispose of their wastes or documentation of transfer of wastes to another responsible party. All land-application fields must be under the direct control of the CAFO facility, through ownership, rent or lease.

Land spreading amounts and land application locations are documented in the NMP; these amounts and locations may change from year to year based on the nutrient content of wastes and nutrient needs of soils and crops. Wastes and soils are sampled and tested yearly for nutrients (MoDNR, 2009; MoDNR 2011b, MoDNR, 2011c). Wastes and soils are not required to be tested for hormones or other contaminants livestock wastes may contain, such as pathogens, salts, or heavy metals (Burkholder et al, 2007). Storing wastes onsite and hauling wastes offsite are costly (Clawson, 1971; Gleick, 2000), so wastes are generally spread in relatively close proximity to the facilities where they are generated (Miner, Humenik and Overcash, 2000; Bradford et al., 2008). The spatial concentration of CAFO facilities, such as in the north, central, and southwest portions of Missouri, may constrain the amount of nearby land available for disposal and limit the effectiveness of waste management (Bradford et al., 2008).

The hormone content of land-applied wastes depends upon the animals in the CAFO and the transformation of wastes through collection and storage (Combalbert and Hernandez-Raquet, 2010). The hormone content of land application fields will depend on land application rates and practices. Residence time on soils and variable local conditions and environmental gradients will affect the transformation and biodegradation. These variables make it impossible to estimate the hormone load that comes off of fields or that enters into downstream environments. We may not be able to predict the hormone load that may enter into streams and lakes, but this study identifies where they will most likely be found.

Many researchers have expressed the need for further investigation into the transport and fate of hormones from CAFOs waste land-application fields. Previous study findings indicate that it may be very difficult to predict changing hormonal loads across broad-scale environmental gradients. Using hierarchy theory as it applies to landscape ecology and principles of scale, this study reviews current literature with the purpose of identifying key fine scale processes and broad scale transport mechanisms and uses these to create a relatively simple model of runoff from CAFO land application fields in Missouri. This model reveals the surface waters most likely to be impacted by hormones from the land application of CAFO wastes in Missouri.

Across a broad landscape, hormones move with the flow of water. They have been measured in runoff from fields, in drain tiles and ditches, and in downgradient streams. Hormones also leach to groundwater, where they can then move to surface waters. Because of the complexity of hydrology in Missouri, which includes complicated groundwater flows, karst geology and loosing streams, this study considers only the transport of hormones by surficial flow via stormwater runoff.

When facilities are spatially concentrated, the availability of land in close proximity to those facilities is constrained. Likelihood of impacts is greater in areas where CAFO facilities and the total number of animals (animal units) are spatially concentrated. In Virginia, researchers have found a proportional increase in hormonal activity relative to the density of CAFOs in the Shenandoah River Valley (Ciparis, Iwanowicz, and Voshell, 2012). Using a limiting distance from the CAFO facility to create buffers in which wastes are likely to be spread and the number of animal units at each permitted CAFO facility in Missouri, this study calculates the density of CAFOs by their relative size.   Animal unit densities are mapped and locations where animal concentrations are highest are used to identify surface waters in the immediate area that are most likely impacted by hormones from land-applied wastes.

LITERATURE REVIEW

Hormones and their breakdown products originating in wastes land applied to agricultural fields have been detected in runoff and in downstream surface waters (Nichols et al., 1998; Finlay-Moore Hartel and Carbrera, 2002; Johnson, Williams, and Matthiessen, 2006; Sarmah et al., 2006; Lorenzen et al., 2006; Matthiessen et al., 2006; S.J. Khan et al., 2008, Olsen et al., 2009; and Dutta et al., 2010). Land application of CAFO livestock wastes is a potentially significant non-point source for downstream hormone load. From field to stream, hormones are transformed and degraded by fine scale processes and hormone transport is facilitated by broad scale hydrology.

A review of current and applicable literature indicated that livestock waste hormone transformation and transport are investigated at three subjective scales – fine, local, and landscape. Fine scale studies are generally batch or column studies with extents of a few inches to a few feet. These studies often attempt to measure both transformation and transport through relatively homogenous soils, sediments or other matrices. Local scale studies generally are those that look at transformation or transport of hormones across experiment plots or fields with various characteristics. Landscape scale studies, of which there are fewer than any other scale of study, investigated the transport and fate of hormones or quantified resulting downstream hormonal loads across an agricultural landscape extent that included a CAFO facility or land application fields, downgradient waters (surface and ground), and the land (or geology) in between.

Findings from reviewed studies can be categorized into two categories important to a discussion about livestock waste-source hormone transformation and transport discussion: fine scale processes and broad scale mechanisms. Fine scale processes are primarily influential on the determination of hormone load; these processes inform us about what we are likely to find. Broad scale mechanisms are primarily important to the movement of hormones in the environment; these mechanisms inform us about where hormones are likely to be found.

Fine scale studies findings indicate that hormone transformation parameters are dynamic, related to the environmental factors in which they take place. Fine scale laboratory measurements are a snapshot of a specific situation and they may not accurately describe the dynamic way in which hormones morph and persist in and through large heterogeneous landscapes between where they are deposited and where then end up in downstream environments.

Some broad scale studies investigate the movement of hormones across large heterogeneous extents and the resulting hormonal loads downstream. Most broad scale studies consider both broad extent investigations of fine scale processes and broad scale mechanisms. Some broad scale studies investigate fine scale processes that then dictate the movement of livestock waste-source hormones over large extents and over time; these fine scale processes are then considered to be broad scale mechanisms. Many broad scale studies have sampling schemes over several months to more than one year to account for influences of precipitation and seasonality. Some broad scale studies assessed the breakdown of hormones based on residence time and the movement of hormones through waste treatment systems, experimental plots and fields, with sampling in ditches, drain tile, and downgradient ground and surface waters.

This literature review begins with a discussion of hormones found in livestock wastes, then identifies, summarizes, and discusses the fine scale processes and broad scale mechanisms important to the dispersion of hormones from land-applied CAFO wastes into the environment. Some studies looking at the transformation of hormones in waste treatment studies and the movement of hormones to groundwater were also reviewed in an attempt to better understand hormone movement and breakdown characteristics.

Hormones in Livestock Waste

All livestock wastes contain endogenous steroid sex hormones excreted by the animal's endocrine system. The type and concentration of endogenous hormones in an animal's waste depends on the animal species, sex, age, and stage of life or reproductive cycle or castration (Lange et al, 2002). Steroid sex hormones are produced in the gonads (ovaries and testes) and include progestins (also called gestagens), estrogens, and androgens (Squires, 2003, Ch. 1, provides tables and descriptions of these hormones). Progestins are involved in the regulation of the ovarian cycle and in preparation and maintenance of pregnancy. Progesterone is a major progestin (Squires, 2003). Estrogens and androgens are involved in the sexual development and behavior of females and males, respectively. Estradiol is a major estrogen and testosterone is a major androgen (Squires, 2003). Endogenous estrogens are the most potent endocrine disruptors, even at ultra low (nanogram per liter) doses (Khanal, 2006). Estrogens are of high concern for aquatic environments because of their high endocrine disruption potential (Ying, Kookana, and Ru, 2002).

The wastes of livestock that have been administered pharmaceutical hormones are known to have pharmaceutical hormones or metabolites in their waste (BMJ, 1956; Calvert and Smith, 1976; Lange et al., 2002; S.J. Khan, 2008). The types and concentrations of pharmaceutical hormones and metabolites found in fresh livestock waste depend on the type and dose of pharmaceutical administered and on the species, age, and stage of life or reproductive cycle of the animal (S.J. Khan, 2008; Combalbert and Hernandez-Raquet, 2010).

Low-cost veterinary pharmaceuticals, such as growth hormones, are employed to increase weight gain, reduce feed requirements, and reduce time to slaughter weight (Field, 2007). Pharmaceutical hormonal supplements maybe natural or synthetic and are generally administered as subcutaneous implants and may be added to feed formulations (Field, 2007). Each class of hormone is administered to augment a particular facet of meat development (Field, 2007; B. Khan, 2008). There is a significant economic incentive for farmers and CAFO managers to use pharmaceutical inputs such as hormones because they "… can amount to a 40-fold return on their investment…" (Raloff, 2002). Upwards of 90 percent of U.S. slaughter cattle are administered pharmaceutical hormones to enhance growth (Balter, 1999).

Lange et al. (2002) calculate amounts exogenous and pharmaceutical hormones found in U.S. livestock wastes. These amounts are averages for animals, male and female, over their lifespan (including gestation and castration). Tables of calculated estimates are attached as Appendix A. These values indicate that, per animal, boars excrete the largest daily volume of endogenous estrogens, followed by bulls. Using values of combined endogenous and pharmaceutical excretion, Bradford (2008) and others suggest that dairy cows contribute 80 percent of the CAFO-sourced estrogens to the environment. While this statistic may be true for the extent of the whole U.S. it must be understood that a watershed with dairies, hog operations, and beef feedlots may not actually be most impacted by the hormone load from dairy cows. Hormone load is determined by many factors, including number and type of animals, waste storage and treatment, and the land and environment on and in which wastes are applied. The impacts of dairies may be significant in one place, but the impacts of hog or poultry operations may be more significant in another.

Transformation and Transport of Hormones

Fine Scale Processes and Factors

The transformation and mobility of hormones in soils is influenced by fine to micro-scale processes and factors. Many fine scale studies are laboratory batch experiments performed to measure rates of transport and transformation or other behavioral characteristics in and through fairly homogenous soil or sediment samples. Laboratory experiments reveal fine-scale abiotic soil characteristics, chemical characteristics, and biotic processes that impact the transformation and mobility of hormones in waste-amended soils across relatively small extents.

Estrogens have a high affinity for sorption in soils (Lee et al., 2003; Casey et al., 2005; Hildebrand, 2006;) and sediments (Williams, Jürgens and Johnson, 1999; Bradley et al., 2009; Writer et al., 2011). The sorption of hormones to soils correlates strongly to soil texture and particle distribution. Estrogens sorb rapidly to a variety of soil types, from silty clays to sands (Lee, 2003). Estrogens sorb rapidly to sandy soils, but are also desorbed from this soil type to the greatest degree (Hildebrand, Londry, and Farenhorst 2006). Estrogen sorption is fast and reversible (Lee, 2003) and estrogens are easily released under aqueous conditions (Hildebrand, Londry, and Faranhorst, 2006), such as when soils are saturated during and after storms and during snowmelt. The release of estrogens into an aqueous phase facilitates leaching and downgradient migration (Laegdsmand et al., 2009).

The sorption of estrogens is investigated more than androgens or progestins, likely because estrogens are the most potent endocrine disruptors (Khanal et al., 2006). Some studies indicate that estrogens are dissipated from agricultural soils and have relatively short half-lives (Lorenzen et al., 2006). “Dissipation” is a term that was found to mean that parent compounds were not recoverable; it does not explicitly mean that hormones were degraded. Dissipation includes both transformation into degradates or metabolites and sorption to soil.

The strongest factor determining the amount of estrogen sorbed to different soil types is soil organic carbon (SOC) content (Kozarek et al., 2008; Caron et al., 2010). The affinity of estrogen to available SOC is high; soils with low SOC have greater sorption per unit SOC (Caron et al., 2010) because of estrogen’s high SOC sorption preference. Sorption to colliodal organic carbon (COC) and dissolved organic carbon (DOC) also enhance the persistence (estrogens remain sorbed) and mobility of some estrogens via particle movement and erosion (Zitnick et al., 2011). Estrogens were found to sorb to waste slurry solids (Amin, Petersen, and Laegdsmand, 2012). It is even suggested by Stumpe and Marschner (2010) that long-term organic waste application results in increased SOC contents, which encourages increased estrogen sorption; the possibility of increased hormonal loading or increased desorption under saturated conditions was not discussed in their study.

The bulk of hormonal breakdown proceeds via biodegradation by microbes. Volatilization of hormones is negligible (Williams, Jürgens and Johnson, 1999) and there is little photodegradation (Leech, Snyder and Wetzel, 2009). Some estrogens degrade poorly in sterilized soil, but degrade rapidly in non-sterilized soil, "…indicating that microorganisms are directly responsible for rapid degradation," (Xuan, Blassengale, and Wang, 2008). Carr et al. (2011) found that high biological activity in anaerobic soils rapidly degraded estrogens and resulted in very short half-lives of 0.7 to 6.3 days.

Different microbial communities are responsible for estrogen degradation (Stumpe and Marschner, 2009). Several bacterial strains found in soil are capable of using estrogens as carbon sources, thus degrading them (Kurisu et al., 2010). In some cases, algae and fungi also degrade hormones in soils (Lai et al., 2000; Catjthami et al., 2009; Stumpe and Marschner, 2009). The wetting of soil may create conditions favorable to rapid microbial transformation of hormones (Mansell et al., 2011). Based on biodegradation potential, some studies conclude that hormones are rapidly attenuated in aerated soils (Lorenzen et al., 2006) and that they are not persistent in agricultural soils (Lucas and Jones, 2006).

Hormones may be unaffected by anaerobic or aerobic conditions, but the microbial life which can degrade them have preferential conditions. Czajka and Londry (2006) found that the degradation of estrogens in anaerobic conditions was minimal. Williams, Jürgens and Johnson (1999) suspect anaerobic riverbed sediments to be a sink for estrogens. These findings suggest that estrogens would accumulate in environments with anaerobic conditions (Ying and Kokana, 2003). Hormones degrade rapidly under aerobic conditions (Ying and Kookana, 2003), mostly because the microbes that biodegrade them prefer oxygenated environments. Stream biofilms are found to attenuate hormones through biodegradation and sorption; however, hormones sorb to biofilms at a greater rate than they are biodegraded, so it is suspected that hormones will accumulate in stream biofilms (Writer et al., 2011) before they are biodegraded.

Physical characteristics of the hormones themselves affect their transport and transformation. Sex steroid hormones are organic chemicals that exist as stereoisomers. Stereoisomers are compounds, "…which have their atoms connected in the same order but differ in three-dimensional orientation," (McMurry, 2000). Stereoisomers may have different rates and strengths of sorption; the lower the sorption rate or strength, the higher the likelihood of leaching (Mashtare, B. Khan, and Lee, 2011). Hormones may also exist as free forms or as conjugates (Dutta et al., 2010). Conjugates are compounds with alternating double and single bonds (McMurry, 2000); combination of hormones with another molecule, such as sulfate, results in conjugation. Conjugates are not endocrine disrupting like free forms, but they can be converted back to free forms under the right environmental conditions (Dutta et al., 2010).

Fine scale laboratory experiments identify mechanisms by which hormones transform, degrade and bind up in certain matrices under controlled conditions, but the design of these experiments may be unhelpful in informing us about rates of transport and transformation across complex environmental gradients or large and heterogeneous extents. Controls make lab study situations quite unlike real world conditions. Controls include maintaining consistent temperatures; using non-reactive equipment; using uniform matrices (air drying, autoclaving, sieving or crushing material); using specific concentrations and mixtures of solutes, solvents, and solutions; using controlled mixing strategies; and covering batches to minimize reactions to light. Controls can alter in situ variables like soil particle and pore sizes, soil compaction, soil moisture, and microbial residence. In situ soil microcosms have heterogenic characteristics much unlike prepared samples. Even across a space a few inches wide and a few inches deep, sunlight exposure, temperature, particle size, microbes, and organic material can vary and may have a significant impact on the transformation and transport of hormones across the microcosm.

Variations in laboratory equipment can also alter experiment measurements. For example, filter materials adsorb estrogens – glass filters adsorb the least, stainless steel and polycarbonate filters adsorb "significant amounts", and nylon filters adsorb "…nearly all the estrogen that contacted them during filtration" (Walker and Watson, 2010). This means that glass bottles and other containers used to collect samples may affect experiment outcomes, too.

Lastly, from study to study, rates of transformation and transport are not always comparable. A number of sample-handling protocols, experimental methods and several methods of detection and measurement are used. There are no standard protocols for the measurement of hormones in these types of studies (Dutta et al., 2010). There are no clear comparisons between assays for estrogens (Raman et al., 2001) or other hormones. Several detection methods are used and more than one are known to overestimate hormone concentrations or hormonal activity (Dutta et al., 2010). Results are also expressed inconsistently, a function of methodologies used. Generally, transport and transformation are measured in percent of parent compound and transformation products recovered.

CAFO Waste Storage and Treatment

Fine and Broad Scale Processes and Factors

The storage and treatment of waste at the facility will determine the hormone load of land-applied wastes. The hormone load of land-applied wastes varies considerably from CAFO to CAFO due to differences in animals, animal management and waste collection, storage and treatment practices (Miner, Humenik, and Overcash, 2000; Bradford et al., 2008). In the review that follows, specific hormones and their hormonal potencies will not be discussed, rather, the terms *hormone load* and *hormonal activity* are used. Hormone load is the total amount of all hormones, parent chemicals and transformation and degradation products. Hormonal activity is a measurement that accounts for the strong potency of parent compounds and less potent transformation products and degradates, without calling out specific hormone amounts and types. Hormonal activity is a term that also accounts for the dynamic transformation possibilities of hormones, as well as degradation. For example, as strong estrogens are transformed into their breakdown products, which are less potent estrogens, hormonal activity decreases.

While advanced treatment technologies have been developed (Vanotti et al., 2007), some of which are able to remove up to 97 percent of hormones in wastes (Furuichi et al., 2004), lagoons remain the most popular CAFO waste treatment choice because they are technologically simple and relatively low cost to construct when compared to more complex systems (Miner, Humenik and Overcash, 2000). Generally, other than impoundment in lagoons, livestock wastes are not treated before they are transported off site or applied to agricultural fields (Bradford et al., 2008). Bradford et al. (2008) indicate that there will be "considerable variability" in the concentration of contaminants such as hormones from facility to facility "…due to differences in animal and waste management practices." A review of literature suggests that the geographic location of a CAFO and the environmental conditions on site will also influence the transformation of hormones in storage or waste treatment systems.

Estrogens are rapidly transformed by microorganisms in manure, but may be converted back under anaerobic conditions (Zheng, Yates, and Bradford, 2008). Estrogen transformation in lagoons and constructed wetland treatment systems varies with waste storage system (Raman et al., 2004) and with seasonality (Shappell et al., 2007). Increasing the residence time of wastewater in sequencing lagoons and increasing the storage time of solid wastes are economical and efficient agricultural practices to extend the degradation time of hormones in waste (Zheng, Yates, and Bradford, 2008). Shappell et al. (2007) found estrogenic activity in the lagoon and wetland inlets sampled in November were significantly higher than samples from the same location collected in April and June and hypothesize that this is most likely a reflection of decreased microbial degradation and photolysis "…due to seasonal changes in environmental temperatures and angle, intensity, and duration of sunlight."

Lagoons in series, constructed wetland systems (CWSs), and ecologically engineered treatment systems (EETs) have been found to significantly reduce hormone loads. A.K. Kumar et al. (2011) explored the ability of an EET to remove hormones and other contaminants from wastewater. EETs are typically a series of tanks containing diverse varieties of aquatic plants, wetland plants, snails, algae and bacteria, protozoa and plankton. The set up is designed to "…mimic the natural cleansing functions of wetlands" (A.K. Kumar et al., 2011). The EET of Kumar et al. removed over 90 percent of estrogens through the natural attenuation by EET biota. Additionally, Kumar and team state, "The designed EET is ecologically complex and mechanically simple and has very low energy consumption and function based on a natural cleansing mechanism (attenuation) with esthetic value."

In a year-long study in northeast Ireland, Cai et al. (2012) investigated the attenuation of hormones from dairy wastewater through a five pond, gravity flow CWS with a hydraulic residence time of 65-100 days. Pond 1 was open (without plant cover), while Pond 2 through Pond 5 were planted with different mixed varieties of wetland plants. The CWS reduced estrogenic and androgenic activity of the wastewater by more than 90 percent. Because the amount of hormones in the CWA correlate to the amounts being excreted at the dairy, the researchers note that dairy cow pregnancy rates ranged "…from a minimum of 39% in November and a maximum of 79% in July and August," which they were able to correspond to "…the highest concentration and earlier rise of testosterone in comparison to estrogen in July." In an eight-month study, a combination anaerobic lagoon and four pond CWS in North Carolina with wetland hydraulic residence times of between 22 to 50 days removed between 83 and 93 percent of estrogenic activity (Shappell et al., 2007). In this study, too, the CWS was responsible for the bulk of hormone biodegradation.

Lagoon, CWS and EET studies indicate that biotic interactions and residence time in these structures are important factors in the natural attenuation of livestock-waste source hormones. These kinds of treatment systems are effective at preventing the bulk of hormonal activity from ending up in land-applied wastes.

Manure treatment literature reviewed for this study indicates that hormones found in livestock wastes are biodegraded best by sewage microbes and that complex constructed wetland and engineered ecological systems have the capacity to effectively attenuate hormones in wastewaters. Therefore, treatment of wastes on-site should be considered the best strategy for minimizing the contamination of surface waters downstream from land-application fields.

Hormones Move Downgradient

Broad Scale Processes and Factors

Hormones have been detected downstream from dairies, and other beef, hog and sheep farms in the U.K. with hormonal activity higher in samples closer to these facilities (Matthiessen et al., 2006). Estrogens have been found to migrate horizontally and vertically, detected in soils and groundwater downgradient dairy facilities (Li et al., 2011). Testosterone and estrogen were detected in sediments 45 and 32 meters deep, respectively, and in groundwater below a dairy wastewater lagoon (Arnon et al., 2008).

While there are established concerns about localized non-point release of hormones from CAFO facilities and their associated waste collection and storage structures, the land-application of waste creates a significant and widespread non-point source for the hormones livestock wastes contain. In 2004, Soto et al. attempted to compare hormonal activity in the runoff from feedlots administering pharmaceutical hormones to cattle feedlots that do not. They were unable to identify any feedlots where animals were raised without hormone supplements. Soto and team collected runoff from Nebraska feedlots and analyzed the sample for androgenic and estrogenic hormonal activity to assess the presence of feedlot waste-source hormones at different points downstream from the feedlots. They found that total hormonal activity originated in the feedlot and decreased at downstream sampling locations. The researchers conclude that their data showed that significant amounts of hormones are released by feedlots into nearby surface waters. However, hormonal activity also appeared in reference (control) site samples. The researchers were unaware that manure slurry had been applied to crop fields in the vicinity of the reference sites at some point prior to sample collection. Hormones are transported from land application fields to surface waters by runoff, interflow through soils, or migration to groundwaters that feed into surface waters.

After wastes leave a CAFO facility's storage and treatment systems, few things have been identified that can be done by man to definitively influence the transformation and transport of hormones in land-applied wastes. Methods of waste application, soil tillage, and the use of vegetated buffer strips may affect hormone transport and transformation at a field scale. Dutta et al. (2010) compared the release of estrogen from pelletized poultry litter and raw poultry litter and found that "…exports of estrogens were much lower from soils amended with pelletized poultry litter than the raw form of litter." Dutta et al. (2010) also found that no tillage practices "… resulted in lower export of estrogens with surface runoff compared with reduced tillage." Nichols et al. (1998) find that Fescue grass filter strips effectively reduce the runoff transport of estrogens from land-applied poultry litter; the longer the filter strip, the lower the concentration of estrogens in the runoff. Using agar amended soil test plots, Sakurai et al. (2009) found that "…vegetation such as clover may significantly contribute to the removal of estrogens when estrogens in aqueous phase are discharged with surface runoff…" Sakurai and team used agar to support microbes in the clover's rhizosphere to transform estrogens.

Time and precipitation are also identified in broad scale investigations as significant factors in the release of hormones into the environment. Schuh et al. (2011) took several samples from a field before and at several dates after swine manure was applied. They found that a significant increase in detectable estrogens six months after manure application appeared to be related to a precipitation event. Hormone concentrations did not return to "original levels" until 17 months after manure application. Schuh et al. suggest that soil may act as a long-term reservoir for estrogens in the environment where estrogens may be periodically released through desorption during precipitation events. In a one-year study, Kjaer et al. (2007) found that estrogens leached from the root zone of a loamy soil and were detected in tile drainage water three months after land application of hog waste. Estrogens can become easily desorbed, leached from the soil and transported in water to aquatic environments (Hildebrand, 2006; Kjaer, 2007).

Gall et al. (2011) monitored water flow in drain tile and ditches associated with fields land applied with livestock wastes and wastewater and took samples from these locations during baseline flow and during storm events. Gall et al. found that the concentration of hormones in water samples increased during effluent irrigation and during storm events. Hormone concentrations also increased with spring thaw and snowmelt. "The highest concentrations of hormones in the ditch waters were observed in June, which coincides with the early life stage development period of many aquatic species in the Midwest" (Gall et al., 2011). The concurrent timing of peak concentrations and developmental stages may indicate that the timing of exposure is important to the endocrine disruption of aquatic species by livestock waste-source hormones.

Zhao et al. (2010) investigated the movement of endogenous hormones from an organic CAFO where no pharmaceutical hormonal inputs are used over one year's time. Using monthly monitoring events, they found constant, low concentrations of estrogen in downgradient streams. These concentrations increased in the spring, "…likely due to mobilization of estrogens from soils upon snow melt and precipitation…" Estrogens were also detected in streams during dry periods, "…indicating possible contributions from groundwater."

In their 2004 watershed washout study, Shore et al. measured the flow of testosterone and estrogen in streams after precipitation. Following a week of heavy rains, researchers measured "…an initial large increase in the concentration of testosterone accompanied by high estrogen which gradually declined to no detect." They suspect that hormones in surface water runoff were followed by hormone discharge from saturated soils.

Land Application of CAFO Wastes

Kolpin et al. (2002) carried out an extensive reconnaissance of organic wastewater contaminants in US stream networks and their results indicate a connection between CAFOs and the presence of hormones in streams. The land application of

CAFO wastes creates a widespread non-point source from which hormones are transported into surface waters.

Animal wastes (manure, manure slurry) are managed for nutrient content and are applied to farm fields accordingly (Casey et al., 2005). In addition to nutrients (nitrogen and phosphorus), manure is a source of ammonia, odorous compounds, salts, trace metals, pathogens, antibiotics and hormones (USEPA, 1998). Because wastes are not managed for pathogen or pharmaceutical content, the prescriptive spreading of waste has the potential to contaminate soil, groundwater and surface water with these agents.

Waste from CAFOs was not considered a cost to livestock production until the 1960s when these facilities, their wastes and waste disposal methods, had become an environmental quality concern (Clawson, 1971). Although it was understood that no one waste management strategy would be universally suitable for all animal agriculture, the main strategy suggested to keep costs down was to minimize the distance that wastes were transported and to spread manure on cropland near the CAFO facility (Clawson, 1971). With the exception of poultry litter, dry manure spreading was abandoned for liquid manure application. Liquid manure collection and application systems increased manure values, reduced labor requirements, and were more convenient than traditional manure spreading (Casler, 1969). Additionally, this system was deemed appropriate for CAFOs because it becomes more economical when the cost is spread over more head of livestock (Clawson, 1971).

With the exception of poultry litter, which may be economical to transport further (Bosch and Napit, 1992), the cost of transporting livestock wastes off-site is costly over long distances. Additionally, the storage and treatment of livestock wastes at CAFOs is expensive (Gleick, 2000) and the combination of large volumes of wastes and a lack of disposal area constrains effective waste management at CAFOs (Bradford, 2008). Over application of wastes to fields short distances from CAFOs has been documented in some places as a major and ill-regulated non-point source of pollution in downstream surface waters (ECCSCM, 2010).

Animal manure can be an excellent and economical fertilizer if it is applied at appropriate rates and properly incorporated into soil. However, aside from being a good source of ammonia and nutrients (primarily nitrogen and phosphorus) for crops, manure is also a source of salts, heavy metals, pathogens, antibiotics, and hormones (Bradford et al., 2008). While advanced treatment technologies have been developed (Vanotti, et al., 2007), lagoons remain the most popular CAFO waste treatment choice. Other than impoundment in lagoons, livestock wastes are generally not treated after deposition by livestock or before they are transported off site or applied to agricultural fields (Bradford et al., 2008). Therefore, improper onsite storage of wastes on site and improper or over-application of wastes on fields may result in nutrient overload and the contamination of downstream waters and environments with the compounds CAFO wastes contain. “Based on available data, generally accepted livestock waste management practices do not adequately or effectively protect water resources from contamination with excessive nutrients, microbial pathogens, and pharmaceuticals present in the waste” (Burkholder et al., 2007).

Summary of Literature Findings

Studies reviewed indicate that the types and amounts of hormones found in freshly excreted livestock wastes are not the same types and amounts of hormones that are found in land applied wastes. Likewise, the hormone load of land-applied wastes may be different than the hormone load released into downstream environments. Transformation and degradation of hormones will take place at a multiplicity of stages and situations, at varying rates, through onsite collection and storage structures, post-land application, during their residence on and in field soils, and during their residence in downstream environments.

The amount and type of hormones found in land applied livestock wastes depend on the characteristics of the CAFO animals, facility, and waste storage and treatment systems in place at a CAFO facility. Once wastes are applied to or incorporated into agricultural soils, hormones will generally sorb strongly to soil organic carbon or remain sorbed to organic carbon found in the waste matrix. Most hormone biodegradation happens in waste or in soils under conditions preferred by microbes while hormones are sorbed. The sorption of hormones to soil creates a hormone sink in fields where wastes are land applied. Hormones are released in saturated and aqueous conditions brought on by liquid manure application, precipitation events, and snowmelt. When hormones desorb, they are leached from and through soil and are transported in aqueous solution, downgradient to groundwaters and to downstream surface waters. Hormones sorbed to soils may also be transported through erosion. Hormones naturally attenuate in complex environmental systems. Microbes and other biota mediate hormone degradation and removal from the environment; however, hormones may also accumulate in anoxic environments (such as in deep stream sediments) or under other conditions unfavorable to microbial degradation.

The characteristics of wastes, hormones, agricultural lands, and the landscapes in which CAFOs and land application fields are situated contribute to the complexity of the transformation and transport of hormones from site to stream. The mechanisms by which hormones are transformed and transported are dynamic, influenced by the variable environments in which they are situated. This review indicates that rates of transformation and transport may be difficult to measure or predict over a large, heterogeneous landscape. However, the understanding that hormones are likely moved by hydrologic flow of water downgradient from land application site to stream supports the use of a simple topographic flow model to identify stream reaches most likely impacted by the land application of CAFO livestock wastes.

RESEARCH DESIGN

Objective

The objective of this study is to identify surface waters in Missouri that are most likely to be impacted by hormones from land-applied CAFO wastes. First, the likelihood of impacts to surface waters based on land-application extent, or distance from the CAFO facility, will be investigated. Second, the likelihood of impacts from the spatial concentration of CAFO animals (animal units) will be investigated. The results of these approaches are compared to identify most-likely impacted surface waters.

Hauling CAFO livestock waste is expensive, therefore it is assumed that preference will be given to spreading wastes as close as possible to CAFO facilities, extending outwards, further away from the facility, when necessary. Hormones remaining in the soils of agricultural fields on which CAFO livestock wastes are spread are likely to be desorbed and moved downgradient during precipitation events or heavy snowmelt. Hormones will flow with runoff, overland or through drain tile to downstream surface waters. Based on the hydrologic transport mechanisms of hormones and the preference for land application fields near the CAFO facility, it is expected that surface waters receiving runoff from land application fields in close proximity to CAFO facilities are most likely impacted and increasing the extent of land application will increase the extent of possible impacts. Furthermore, because wastes are not hauled long distances for disposal by land application, areas where there is a spatial concentration of CAFO facilities, and thus animals and wastes, will land apply wastes to more available nearby agricultural lands than facilities with less animals and waste. Higher animal densities will correlate to higher likelihood of impacts on downgradient surface waters.

Theory

Based on the literature review findings and the objective of this study, landscape ecology principles of scale (Turner, Gardner and O'Neill, 2001) were used to select appropriate data layers, scales of data, and methodologies for data analysis. Below is an explanation of these principles as the rationale for the selection of data layers follows here. The selection of properly scaled data and methodologies for data analysis are described throughout the Data Analysis section that follows.

Fine scale processes or components average away to become constants. Hormone transformation and biodegradation are fine scale processes dependent on all of the variables in the process context, such as temperature, oxygen availability, moisture, and microbial communities. These fine scale processes may average away to become some constant or a function that reaches a limit of zero or a minute half-life. Because of environmental and landscape complexities, this constant or limit would be very difficult to calculate. However, what happens at fine scales informs us of what to expect at broader scales. Understanding fine scale hormone transformation processes give us an idea of what will be found in a sample taken downstream.

Relative importance of explanatory variables changes with scale. The focal level of this study is an agricultural landscape, which includes land application fields, surface waters, and the land in between, over which runoff will flow. In the agricultural landscape, the most important factor in the transport of hormones is the flow of runoff.

This study will model the flow of runoff from land application fields over a DEM to see which surface waters will be impacted by that runoff.

At larger extents, parameters that were constant become variables. The movement of hormones in runoff through a landscape is constrained by the landscape's context – not only its climate, seasonality, and precipitation, but also the spatial concentration of CAFOs and their land application fields. As we increase our extent from one Missouri agricultural landscape to many, we will see the combined impact of many CAFOs and associated land application areas and are likely to see increased impacts in areas where CAFO facilities, their animals and wastes are concentrated. We may also see a change in landscape context that influences how much runoff there is in a season or year.

New interactions may arise as the extent of inquiry increases. If we widen our extent further, past Missouri's borders to the larger region, we may see significant impacts from neighboring states, Iowa and Nebraska, Oklahoma and Arkansas. If we expand our scope to include other hormone sources within our extent, such as wastewater treatment plants (WWTPs), there is potential to find additional surface water impacts, or surface waters impacted by more than one source of hormones. Additionally, the depth of investigation could be increased to compare surface waters impacted by land application runoff to the locations of surface water drinking water intakes, impaired waters and critical habitats.

While hormones move and change from land application field to stream, environmental complexity can hinder us from effectively predicting hormonal loads. At the focal level of the agricultural landscape, the important data sets to consider are the location of land application fields, the location of surface waters, and the topography of the land in between. This study also takes into consideration that hormones are moved with the hydrologic flow of stormwater runoff or snowmelt. These phenomena are dependent on the larger context of the agricultural landscape, its climate, seasonality, and precipitation patterns. The scope of this study does not include the investigation of hormone impacts from WWTPs and does not include additional investigation concerning drinking water intakes or critical species habitat.

Data Analysis

To determine the extent of surface waters in Missouri likely to be impacted by hormones from land-applied CAFO wastes, land application fields are located and then runoff from across these areas is modeled. Channelized runoff patterns are layered over surface water data; surface waters intersecting with runoff patterns are selected as the likely impacted extent.

To identify surface water reaches most likely impacted by the land application of CAFO wastes, the spatial density of CAFOs, considering their size in animal units, is determined. Areas of greatest animal unit density are used to identify stream reaches in close proximities and downgradient most likely to be impacted.

Data manipulation, data analysis and map-making was completed using ArcGIS 10, ArcEditor 10.1 and Extensions, Education Edition, ESRI, Redlands, CA, USA. All data used in analysis is current, free, and readily available via online download from reputable sources.

This study has a statewide extent. This extent is of interest to state residents and regulators or any other party interested in a state-wide environmental monitoring program for CAFO waste-source hormones because it takes into consideration all CAFO facilities, land application areas and stream networks within the jurisdiction of the State of Missouri. The study extent is defined by the State Boundary of Missouri (MoDNR, 2009). County Boundaries of Missouri (MoDNR, 2009) and MOHUC8 watershed boundaries (MoDNR, 2008) are used to describe locations in the analysis and results. The selection of other data is discussed in the Data Analysis section that follows.

Defining the Spatial Extent of Land Application Fields

In Missouri, CAFOs are required to land apply livestock wastes to meet *no discharge* criteria required for permitting (MoDNR, 2009; MoDNR, 2011b; MoDNR 2011c). MoDNR permitting also requires wastes to be applied to lands under the direct control of a CAFO facility via ownership, rent, or lease. The acreage needed for land application of wastes will vary from CAFO to CAFO depending on the type and number of animals at the facility.

A data set of NPDES permitted features associated with CAFOs in Missouri is made publicly available by MoDNR (MoDNR, 2011). This data set is the only set of this type available for CAFOs in Missouri. This data set is compiled from information submitted by CAFOs on NPDES permit applications. Permits can be reviewed online through the MODNR Water Protection Program permit lookup web page. A permit for a large dairy with several permitted features is attached as Appendix B. Please note that when searching the permit lookup, some permits may be listed by facility name, corporation name, owner name, or other moniker. Additionally, misspellings and abbreviations make searching for specific permits difficult.

Neither the permitted feature data set attribute table or the permits include location data for land application fields. Land application fields are accounted for in facility specific Nutrient Management Plans (NMPs) and the fields to which wastes are applied may change from year to year (MoDNR, 2009). Land application field locations were not found readily or publicly available for the current or any previous year.

There are significant discrepancies between land application acreage listed in the NPDES permitted features data set and the land application acreage listed on permits found through the MoDNR permit lookup. According to the NPDES permitted features data set, the largest land application acreage is 5673 acres. Permits for large Missouri CAFOs (that could be identified by name through the online permit search) indicate that actual land application acreage may be much higher and that land application acreage listed in the permitted features dataset may be unreliable for accounting purposes. For example, the large dairy permit, attached as Appendix B, indicates that this facility has 9680 acres available for land application of wastes. Note that the permit does not state explicitly whether or not all of this acreage is actually used. The same facility is listed in the permitted features data set as having “0” acres for land application.

It has been documented that wastes are generally not hauled very far from the CAFO facility where they are generated and the amount of land necessary for waste disposal will vary from facility to facility. Land application areas are documented in facility-specific NMPs, but this information is not readily or publicly available. Therefore, the investigation into the extent of impacts will employ a series of buffers to illustrate runoff in situations where wastes are spread within increasing distances from a CAFO facility.

Extents of Land Application

Bradford, et al. (2008) estimate that manure and wastewater are usually land-applied on agricultural fields "… within about 16km of CAFO facilities." Using this distance, a buffer constructed around a CAFO facility is approximately 198,600 acres in size. Permits indicate that some smaller operations need less than 400 acres to spread their waste. Based on the variety of CAFO facilities and associated waste generation volumes and Bradford's estimate, buffers of 4, 8, and 16 kilometers will be used.

Buffer Radius	Buffer Area (acres)
4km	12,414 acres
8km	49,658 acres
16km	198,658 acres

Table 3: Buffer Radii and Buffer Area

Locating CAFOs and Drawing Buffers

If we choose to use buffers around CAFOs to estimate the locations of land application fields, we first need to know where the CAFO facilities are. The NPDES permitted features data set includes on-site and off-site "outfalls" (features) subject to permitting. A single CAFO generally has multiple permitted features listed on its NPDES permit. Facilities with multiple permitted outfalls were selected ad hoc from the data set and permits for these facilities were reviewed. Referring again to the large dairy permit (Appendix B), we see that this facility's on-site permitted features include lagoons, storage basins, feed storage areas, compost areas, waste treatment and storage structures, and domestic wastewater structures. Off-site permitted features include on-stream water-monitoring sites for stormwater runoff. These water-monitoring sites are not identified as such in NPDES permitted feature data set.

Of the 1095 permitted feature data points listed in the attribute table of the permitted features data set, only six data points are listed as *receiving water monitoring*. An online review of permits indicates there may be many more. Using the identification tool, points on and very near streams were investigated. Some are identified as *storm water outfall* locations, but not all storm water outfalls are located on streams. After a review of several NPDES permit applications and close inspection of the mapped permitted feature data points it was concluded that points on and very close to streams are most likely water monitoring locations.

To identify CAFO facilities, onsite permitted features must be distinguished from offsite permitted features. Onsite permitted features are generally features that collect, manage, or store wastes and can be used to approximate the location and extent of the associated CAFO facility. Offsite permitted features are likely water monitoring sites.

The resolution and accuracy of both the NPDES permitted feature data points and the surface water data sets are considered in the sorting of onsite and offsite features. According to the metadata for Missouri rivers and lakes, data sets are based on 1:24,000 source data. Most points in the MoDNR permitted feature dataset are listed as having locations that have been "interpolated from map" (maps with a scale of 1:24,000). These points are listed in the metadata as having a horizontal accuracy of 25 meters.

With the listed accuracy of all datasets in mind, it was desired to find a threshold distance from streams and lakes below which permitted features would likely be water monitoring sites and beyond which permitted features would likely be onsite. To do this, all permitted features within 25 meters of surface waters were selected. Then, all permitted features within 30 meters, and 35 meters were selected, and so on, until the number of selected permitted features leveled off. This selection exercise was continued, in increments of 5 meters until the number of selected permitted features leveled off a second time. The results of this selection are listed in the table below.

Distance from Surface Water	No. Permitted Features Selected	Distance from Surface Water	No. Permitted Features Selected
5 m	44	45 m	71
10 m	58	50 m	71
15 m	62	55 m	71
20 m	64	60 m	72
25 m	65	65 m	73
30 m	67	70 m	75
35 m	69	75 m	75
40 m	69	80 m	75

Table 4: Number of Permitted Features Located Different Distances from Surface Waters

The number of permitted features selected level off between 45, 50, and 55 meters and again between 75 and 80 meters. To investigate further, three data layers of permitted features within 25 meters, 50 meters, and 75 meters of surface waters were created. Unique symbols were chosen for each data set. Largest symbols were used for features 75 meters away, medium-sized symbols for features 50 meters away, and small symbols 25 meters away. Data layers are ordered so that symbols stacked small on top of medium on top of large. This technique revealed the location of those permitted features between 26 and 50 meters and between 51 and 75 meters away from surface waters. A map depicting this technique is attached as Figure 3.

Permitted features located between 26 and 50 meters from surface waters were spot checked by their coordinate location (listed in the MoDNR permitted feature attributes) using Google Earth aerial imagery. Features were selected and identified in aerial imagery as locations on bridge crossings or locations where roadways were close to streams. Based on this information, permitted features located 50 meters or closer to streams are likely water-monitoring sites. A total of 71 water monitoring sites were removed from the permitted features data set and were used to create a data set of permitted water monitoring sites.

Permitted features located between 51 and 75 meters from surface waters were selected and spot checked by their coordinate location using Google Earth aerial imagery. These features were identified in aerial imagery as lagoons or other structures at CAFO facilities. Based on this information, these permitted features are considered to be onsite.

A review of the onsite permitted features indicated two facilities identified as sausage and meat-processing facilities had permitted features associated with them. These facilities are not likely to generate, manage, or store livestock wastes, so all permitted features associated with sausage and meat processing were removed from the data set. The remaining 1022 permitted features represent the locations and extents of CAFOs in Missouri. A map of CAFO permitted features in Missouri by animal type is attached as Figure 2.

Buffers were constructed around the on-site permitted feature data points, effectively creating a buffer around each CAFO facility. Many buffers overlap, especially in areas where CAFOs are concentrated. The spatial concentration of CAFO facilities and land application fields is investigated later in this section. Buffer boundaries were dissolved to create a single data layer representing the possible extent of land application areas across the state of Missouri. A map of land application buffers by size is attached as Figure 4.

Before runoff is modeled over the buffers, the land cover/land use (LULC) of areas within the buffer is checked to make sure that agricultural lands are present, and to what degree. Two sets of land cover/land use (LULC) data were considered. The Land Use Land Class (lulc05) dataset for Missouri (MRAP, 2005) is a 15-class LULC that calls out “Cropland” and “Grassland”, but is not explicit in the classification of which grasslands might also be used for agricultural purposes. The National Land Cover Dataset (NLCD) for Missouri (MRLC, 2006) is a 21-class LULC data set that calls out “Cultivated Crops”, “Pasture/Hay”, and “Grasslands” separately. Because the application of CAFO wastes on agricultural lands may include application to both cultivated crops and pasture lands, the NLCD for Missouri is used.

Cultivated crops and pasture/hay classifications were called out separately from the rest of the LULC classes and compared to with the buffers. This comparison can be seen in Figure 5. For each buffer size it was found that cultivated crops or pasture/hay lands were available for the land application of wastes; however, the amount of acreage needed by each facility was not checked. The acreage necessary for the disposal of waste from each facility is found on permits and in facility NMPs; it was deemed impractical given the large number of facilities and previous difficulties using the MoDNR online permit look up.

Modeling Runoff From Buffers

Runoff from buffers is modeled over a digital elevation model (DEM). 10-meter, 30-meter, 50-meter 60-meter, and 100-meter DEMs are available for the state extent through Missouri Spatial Data Information Service (MSDIS). DEMs are generalizations of true topography; a finer resolution DEM will result in a finer representation of runoff. However, at broad scales and large extents, fine scale data contains unnecessary detail that makes data files larger and computer processing more time consuming. When the resolution of other data used in this analysis is considered, the 30-meter and 60-meter (GRC, 1999) DEMs are considered to be most appropriate. The 60-meter DEM was used first and was found to be more easily processed and fine enough to model the flow of runoff from land application areas so the 30-meter DEM was not used in this study.

The Missouri Primary Rivers data set (USGS, 1994; MISDIS, 1997) and the Missouri Lakes data set (USGS and EPA, 2005) were selected to represent the surface waters within the state. The primary rivers data set is an expansion of the National Hydrography Dataset (NHD) for Missouri. Metadata for NHD data indicates that state and local governments or NGOs will provide more detailed local data. Indeed, the Missouri NHD-based primary rivers data set includes more creeks and headwater tributaries than NHD data. This detail is important for identifying specific streams most likely to be affected by contamination from the land application of CAFO wastes.

To simulate runoff, the flow of runoff over the DEM within the buffers was modeled. Sinks within the DEM were filled and flow direction and flow accumulation were calculated across the buffers. The resulting flow accumulation grid was used to create a new grid that identified only those cells with a flow accumulation of 50 acres or more. This flow accumulation data was reclassified to display the pattern of runoff over the buffers.

Runoff from all land within each buffer was modeled. The runoff from buffered areas includes runoff from land application fields; therefore, surface water impacted by runoff from the buffered area is impacted by runoff from the land application fields the buffer contains. Figure 6., attached, shows the 50-acre runoff pattern from across a 4-kilometer buffer. This particular buffered area was chosen because, compared to other buffers, it had a minimum of available land application acreage. This figure illustrates that this practice is acceptable for broad scale analyses using 30- and 60-meter grain data as undertaken by this study. The resolution of data used here or this practice in general may not acceptable for localized or fine scale studies.

The resulting runoff pattern was compared to the primary rivers layer. These two data sets did not overlay perfectly (different scales/ cell sizes) but they matched up well. Surface waters that intersected with the buffer runoff pattern were selected for each buffer. These surface waters represent the possible extents of surface waters most likely impacted by hormones from the land application of CAFO livestock wastes (Figure 6).

Spatial Concentration of CAFOs (Animal Units)

The Shenandoah River Valley study by Ciparis, Iwanowicz, and Voshell (2012) finds that hormonal activity in watershed stream reaches correlated positively to the density of animal feeding operations. If we hypothesize that the same phenomenon will occur in Missouri surface waters, we need to first determine the density of CAFOs and then located the surface water reaches in close proximity and downgradient from high concentration areas.

While the density of CAFOs is significant, the concentration of facilities does not directly tell us about the potential significance of impacts. For example, say that there are ten CAFOs, each with 200 animal units in very close proximity to each other in one area and a single CAFO with 10,000 animal units in another area. Containing the same type of animal, the single facility with 10,000 animal units may have a more significant impact on nearby surface waters (such as hormonal load) than the cluster of ten CAFOs with a total of 2,000 animal units. Therefore, this study will consider the population, in animal units, of each CAFO and will identify areas of high animal unit density.

During the investigation into the possible extents of impacts, all onsite permitted features were used to determine the extent of the CAFO facilities. For this part of the study, we want to represent each CAFO with a single point, so that the ArcGIS point density calculation can be used. The primary permitted feature for each permitted CAFO facility in the MoDNR permitted features data set was seleted; these features serve as the point representing the location of each CAFO. All but four of the CAFOs in the data set (566 facilities in all) were listed with a number of animals by type and associated number of animal units. Unfortunately, these numbers were not found, so these four facilities are not accurately represented. Since animal units are equivalents based on volumes of wastes produced, this number is used as the CAFO population for calculating animal unit density.

Animal unit densities were calculated per square kilometer using the same buffer radii as in the first part of the study. For each radius, the density results were analyzed for natural breaks and the same density classes were assigned for all three buffer radii. Surface waters in the vicinity and downgradient of areas of highest animal unit densities for each buffer radius were identified as the surface waters most likely impacted by the land application of CAFO wastes based on the spatial concentration of CAFO facilities (Figures 7, 8, and 9).

RESULTS

Surface waters receiving runoff from land-application fields are likely to be impacted by hormones runoff may contain. Based on the economics of waste hauling and the desire to spread wastes on lands in close proximity to CAFO facilities, surface waters fed by runoff from lands closer to CAFO facilities are most likely to be impacted by the hormones in that runoff. This study investigated likely impacts using two approaches. The first approach used three buffers of increasing extent from CAFO facilities to identify surface waters likely, more likely, and most likely to be impacted by runoff from within those buffers. The second approach calculated the density of CAFO animals (animal units) to locate areas where animal density was greatest. Surface waters within and immediately downgradient from the highest densities of animals were identified as most likely to be impacted. The two approaches were then compared to find surface waters identified by both as most likely to be impacted.

Likelihood of Impacts: Land Application Extent

Surface waters most likely to be impacted are those that receive runoff from land-application fields within 4km of CAFO facilities and are color-coded red, orange, and yellow in order of increasing likelihood of impacts based on increasing land-application extent (Figure 7). At increasing distances from CAFO facilities, likelihood of impacts declines, while the extent of possible impacts increases.

MoDNR CAFO permits list the HUC8 watersheds of surface waters considered receiving streams, so this study will use this watershed designation to describe results.

Sixty-six HUC8 watersheds drain Missouri; 50 watersheds contain surface waters likely to be impacted by CAFO wastes applied on lands within 4km of CAFO facilities (Figure 8). Table 5, lists stream reaches and major lakes (50 acres or larger) in each watershed most likely impacted by hormones in land-applied CAFO wastes spread within 4km of CAFO facilities.

Table 5: Surface Waters Most Likely Affected by Land Applied Wastes Within 4km of CAFO Facilities. Includes stream reaches and lakes 50 acres or larger.

Surface Waters Most Likely Affected by Land Applied Wastes, 4km Buffer		
MOHUC8 Watershed	**Sub-Basin Name**	**Surface Waters**
7100009	Lower Des Moines	Des Moines River
7110001	Bear-Wyaconda	Little Fox River, North Wyaconda River, South Wyaconda River, Little Wyaconda River, North Fabius River, Mississippi River
7110002	North Fabius	North Fork North Fabius River, North Fabius River, Foreman Creek, Indian Creek, North Fork Middle Fabius River, Brushy Creek, Middle Fabius River, Bridge Creek, Bear Creek
7110003	South Fabius	North Fork South Fabius River, Troublesome Creek, Hawkins Branch, South Fabius River, Million Creek, Seebers Branch, Henry Sever Lake
7110004	The Sny	North River and unnamed tributaries, Sees Creek, Big Branch, South Fork and unnamed tributary, South River, Bear Creek, Hunnewell Lake
7110005	North Fork Salt	Salt River, Saling Branch, Goodman Branch, Ten Mile Creek, Black Creek, Crooked Creek, Otter Creek, Daniel Boone Lake, Mark Twain Lake
7110006	South Fork Salt	Winn Branch, Hoover Creek, Middle Fork Salt River, Flat Creek, Elk Fork Salt River, Galbreaths Creek, Hardin Creek, Milligan Creek, Bee Creek, Brush Creek, South Brush Creek, Fish Branch, Littleby Creek, Goodwater Creek, South Fork Salt River, Mark Twain Lake
7110007	Salt	Cedar Creek, Nichols Creek, Ely Creek, Indian Creek, Lick Creek, Gallaher Creek, West Lick Creek, Middle Lick Creek, Eas Lick Creek, Spencer Creek, Monroe City Lake, Mark Twain Lake
7110008	Cuivre	West Fork Cuivre River, Johns Branch, Hickory Creek, Sandy Creek, Coon Creek, Elkhorn Creek, White Oak Creek, Two Mile Branch, Shady Creek, Indian Creek, Lick Creek, Cuivre River, West Fork Cuivre River, Lead Creek, North Fork Cuivre River
7110009	Peruque-Piasa	None
7140101	Cahokia-Joachim	None
7140102	Meramec	Brush Creek, Meramec River

7140103	Borbeuse	Dry Fork, Lower Peavine Creek, Borbeuse River, Lanes Fork, Pinoak Branch, Dry Fork Creek
7140104	Big	Terre Bleue Creek, Bear Creek, Salem Creek
7140105	Upper Mississippi-Cape Giradeau	None
7140107	Whitewater	Two unnamed tributaries to the Castor River
8010100	Lower Mississippi-Memphis	None
8020201	New Madrid-St. Johns	Blue Ditch, North Cut Ditch, Glade Drain, St. Johns Ditch, Ash Ditch
8020202	Upper St. Francis	St. Francis River, Stouts Creek, Rock Creek
8020203	Lower St. Francis	Brush Creek, Otter Slough, St. Francis River
8020204	Little River Ditches	Ditch No. 1, Ditch No. 2, Little River
8020302	Cache	None
10240001	Keg-Weeping Water	None
10240004	Nishnabotna	None
10240005	Tarkio-Wolf	Middle Tarkio Creek, Tarkio River, Little Tarkio Creek, East Fork Little Tarkio Creek, Hickory Branch, Mill Creek
10240010	Nodaway	None
10240011	Indepenence-Sugar	Horseshoe Lake
10240012	Platte	Platte River, Little Platte River, unnamed creek
10240013	One Hundred and Two	None
10270104	Lower Kansas, Kansas	None
10280101	Upper Grand	Middle Fork Grand River, East Fork Grand River, Big Muddy Creek, Little Muddy Creek, unnamed tributary of the West Fork Grand River, unnamed tributary of West Fork Little Creek, West Fork Big Creek, Shain Creek, East Fork Big Creek, Lost Creek, Owl Creek, Hickory Creek, Campbell Creek, Grand River, Sampson Creek, Big Creek, Cypress Creek and unnamed tributary, Brushy Creek, Big Muddy Creek, Little Muddy Creek, Mason Creek, Pilot Grove Creek, Lost Creek, Thompson Creek, Haw Branch, Lick Fork, Shoal Creek, Cameron Reservoirs (north reservoir)
10280102	Thompson	Panther Creek, Weldon Fork Grand River, Little Muddy Creek, Muddy Creek, Weldon River, West Fork Honey Creek, No Creek, Rock House Lake
10280103	Lower Grand	West Medicine Creek, Medicine Creek, Elm Branch, East Medicine Creek, unnamed tributary to East Medicine Creek, West Fork Locust Creek, West Locust Creek, East Locust Creek, Little East Fork Locust Creek, Locust Creek, Yellow Creek, East Yellow Creek, unnamed tributary to East Yellow Creek, unnamed tributaries to Grand River, Salt Creek, Grand River, Swan Lake
10280201	Upper Chariton	Shoal Creek, Sandy Creek, Little Sandy Creek, Chariton River, Elm Creek, Wildcat Creek, South Blackbird Creek

10280202	Lower Chariton	North Spring Creek, Mussel Creek, Mussel Fork Creek, Long Branch, Jones Branch, Puzzle Creek, Chariton River, Lake Nehai Tonayea
10280203	Little Chariton	Sweezer Creek, Middle Fork Chariton River, East Fork Chariton River, Dark Creek, Walnut Creek, Silver Creek, Coal Creek, Turners Fork, Long Branch Lake
10290102	Lower Marais Des Cygnes	Bates County Drainage Ditch, Marais Des Cygnes River, Walnut Creek, New Home Creek
10290103	Little Osage	Christian Creek, Marmaton River, Hightower Creek
10290104	Marmaton	Twomile Creek, Douglas Branch, Old Town Branch
10290105	Harry S. Truman Reservoir	Bee Branch, Campbell Branch, Panther Creek, Osage River, Ladies Branch, Miller Branch, Wells Branch, Kitten Creek, Clear Creek, Robinson Branch, West Fork Clear Creek, McCarty Creek, Barber Lake
10290106	Sac	Sac River, Stockton Branch, Silver Creek, Horse Creek, Maples Branch, Bear Creek, Cedar Creek, West Limestone Creek, Sons Creek
10290107	Pomme De Terre	Piper Creek
10290108	South Grand	Tennesee Creek, Eight Mile Creek, unnamed tributary to Big Creek, Bear Creek, Stewart Creek, Spruce Creek, Brushy Creek, Deepwater Creek, Sand Creek, unnamed tributary to Wades Creek, Middle Fork Tebo Creek, East Fork Tebo Creek, Number 111 Lake
10290109	Lake of the Ozarks	Cole Camp Creek, Indian Creek, Ross Creek, Duran Creek, Gravois Creek, Rocky Fork Creek, Locust Creek, Clabber Creek, Mill Creek, Brumley Creek Grand Auglaisze Creek, Deane Creek, Dry Auglaize Creek, Wet Glaize Creek
10290110	Niangua	Little Niangua River, Macks Creek, Greasy Creek
10290111	Lower Osage	Longan Branch, Blue Spring Creek, Little Saline Creek, East Fork Little Gravois Creek, Wrights Creek, Coon Creek, Dog Creek, Osage River, Little Bear Creek, Wolf Creek, Bear Creek, Tavern Creek, Bois Brule Creek, Weimer Creek, Brushy Fork, Barren Fork, Bailey Branch, Little Tavern Creek, Maries River, Loose Creek, Little Maries River, Prairie Creek, Fly Creek
10290201	Upper Gasconade	Stein Creek, Elk Creek
10290202	Big Piney	None
10290203	Lower Gasconade	Gasconade River, Second Creek, Punceon Creek, Turkey Creek, Pointers Creek, Owens Creek, Indian Creek, Wolf Creek, Cedar Creek, Dry Creek, Eastland Creek
10300101	Lower Missouri-Crooked	Cottonwood Creek, Little Tabo Creek, Missouri River, Bear Creek

10300102	Lower Missouri-Moreau	Fish Creek, Missouri River, Petite Saline Creek, Tutt Branch, Hutchinson Branch, Clarks Fork Creek, Moniteau Creek and unnamed tributaries, North Moreau Creek, Straight Fork Moreau Creek, Smith Fork Moreau Creek, Burris Fork Moreau Creek, Jones Creek, Gracey Creek, Wilkes Creek, South Moreau Creek, Beard Creek, Blythes Creek, Brush Creek, Honey Creek, Hominy Creek, Hinkson Creek, North Fork, South Fork, Gans Creek, Bonne Femme Creek, Millers Creek, Stinson Creek, Richland Creek, Cedar Creek, Four Mile Branch, Auxvasse Creek, Harrison Creek, Yates Branch
10300103	Lamine	Long Branch, Muddy Creek, Elk Fork, Flat Creek, Pepper Creek, South Flat Creek, Basin Fork, Spring Fork, Camp Creek, McGee Branch, Lake Creek, Haw Creek, Gabriel Creek, Buck Branch, Richland Creek, Middle Richland Creek, Messer Creek, Otter Creek, Lamine River, Muddy Creek, Heaths Creek and unnamed tributaries, Lake Tebo, Spring Fork
10300104	Blackwater	Flagstaff Creek, Mulkey Creek, Peavine Creek, Panther Creek, Beaverdam Creek, Johnson Creek, Davis Creek, Jordan Creek, Salt Pond Creek, East Fork Salt Pond Creek, Wes Fork, Crooked Creek, North Fork, Finney Creek, Blackwater River, Dry Creek, Salt Fork, Elm Branch, Pass Branch, Salt Branch, Muddy Creek, Camp Creek, Flat Creek, Edwin A. Pape Lake, Higginsville Reservoir, Blind Pony Lake
10300200	Lower Missouri	Loutre River, Bachelor Creek, Whitestone Creek, Bates Branch, Big Berger Creek, Cedar Fork, Boeuf Creek, St. Johns Creek, Labaddie Creek, Charrette Creek, Kochs Creek, Toque Creek, Wolf Creek, Missouri River, Femme Osage Creek, Lake Sherwood
11010001	Beaver Reservoir	Roaring River, Table Rock Lake
11010002	James	Goff Creek, James River, Crane Creek, Horse Creek, Flat Creek, Railey Creek, Jenkins Creek, Gunter Creek, Rockinghouse Creek, Fortune Branch, Little Flat Creek, Table Rock Lake
11010003	Bull Shoals Lake	None
11010006	North Fork White	Little Pine Creek
11010007	Upper Black	St. Francis River
11010008	Current	None
11010009	Lower Black	None
11010010	Spring (Upper White Basin)	None
11010011	Eleven Point	None
11070206	Lake O' The Cherokees	Mason Spring Creek
11070207	Spring (Neosho Basin)	Pettis Creek, North Fork Spring River, Coon Creek, Deer Creek, Dry Creek, Whiteoak Creek, Spring River, Center Creek, Rickman Branch, Jenkins Creek, Grove Creek, Motley Branch, Dry Valley Branch, Jones Creek, Williams Creek, Honey Creek, Shoal Creek, Carver Branch, Baynham Branch, Cedar Creek Hickory Creek, Pryor Branch, Douthit Branch, Clear Creek, Capps Creek

11070208	Elk	Buffalo Creek, Patterson Creek, Elk River, Bull Skin Creek, Indian Creek, Elkhorn Creek, North Elkhorn Creek, Kings Valley, Big Sugar Creek, Little Sugar Creek, Missouri Creek, Bear Creek, Star Hollow, Tent Creek, Sugar Creek

Likelihood of Impacts: Spatial Concentration of Facilities and Animals

Figures 9, 10, and 11 illustrate the density of CAFO animals (animal units) when they are spread over 4km, 8km, and 16km buffers, respectively. Over a 16km buffer, the highest animal unit (AU) density is 100-200 AU/sq km, followed by 50-100 AU/sq km. Over an 8km buffer, the highest density is 200-300 AU/sq km, followed by 100-200 AU/sq km. Over a 4km buffer, density in some areas reaches 500-600 AU/sq km, with other high densities of 400-500, 300-400, and 200-300 AU/sq km.

Surface waters impacted by the highest classes of animal unit density for each buffer size are listed in Tables 6, 7, and 8, below.

Table 6. Surface Waters Most Likely Affected by Highest Animal Densities
<u>Calculated over 16km Buffer</u>

County	AU Density	Surface Waters (*HUC8 watershed*)
Barry	100-200	Shoal Creek and tributaries *(Elk, James, Beaver Reservoir)*
	50-100	Shoal Creek, Little Flat Creek, Gunter Creek, Flat Creek, Star Hollow *(Elk, James, Beaver Reservoir)*
McDonald	100-200	South Indian Creek *(Elk)*
	50-100	Kings Valley, Star Hollow, Brush Creek, Little Sugar Creek, Big Sugar Creek, Indian Creek, North Elkhorn Creek, Elkhorn Creek, Bull Skin Creek, Elk River, Patterson Creek, Buffalo Creek *(Elk)*
Newton	100-200	South Indian Creek (*Elk, Spring (Neosho Basin))*
	50-100	Capps Creek, Shoal Creek, Indian Creek, South Indian Creek, Buffalo Creek (*Elk, Spring (Neosho Basin))*
Pettis	50-100	Henry Creek, South Flat Creek, Flat Creek, Basin Fork, Camp Creek, Muddy Creek and tributaries, Elk Fork *(Lamine, South Grand)*
Johnson	50-100	Muddy Creek and tributaries *(Lamine, South Grand)*

Table 7. Streams Most Likely Affected by Highest Animal Densities
Calculated over 8km Buffer

County	AU Density	Stream Names (*HUC8 watershed)*
Barry	200-300	Shoal Creek, South Indian Creek (*Elk, Spring (Neosho Basin))*
	100-200	Capps Creek, Little Flat Creek, Gunter Creek, Flat Creek, Star Hollow (*Elk, Spring (Neosho Basin))*
McDonald	200-300	Patterson Creek (*Elk*)
	100-200	South Indian Creek, Indian Creek, Elk River, Buffalo Creek (*Elk*)
Newton	200-300	South Indian Creek (*Elk, Spring (Neosho Basin))*
	100-200	Shoal Creek (*Elk, Spring (Neosho Basin))*
Pettis	100-200	Muddy Creek, Elk Fork, Elk Creek, Long Branch, Flat Creek, South Flat Creek (*Lamine, Blackwater*)
Johnson	100-200	Muddy Creek and tributaries *Lamine, Blackwater*)

Table 8. Streams Most Likely Affected by Highest Animal Densities
Calculated over 4km Buffer

County	AU Density	Stream Names (*HUC8 watershed*)
McDonald	500-600	Patterson Creek (*Elk*)
	400-500	Patterson Creek (*Elk*)
	300-400	Patterson Creek (*Elk*)
	200-300	Elk River, South Indian Creek (*Elk, Lake O' The Cherokees*)
Barry	300-400	Shoal Creek (*Elk, Spring (Neosho Basin))*
	200-300	Shoal Creek (*Elk, Spring (Neosho Basin))*
Newton	200-300	South Indian Creek, Shoal Creek (*Elk, Spring (Neosho Basin*))
Pettis	400-500	Long Branch, Muddy Creek, Elk Fork (*Lamine*)
Johnson	400-500	Long Branch, Muddy Creek (*Lamine*)
Lincoln	300-400	West Fork Cuivre River, Dry Fork (*Cuivre*)

Highest densities are incurred across 4km buffers (Figure 9., Table 8.). High densities are present in areas where CAFO facilities with higher numbers of animals exist and where buffers from spatially concentrated facilities overlap. Densities decrease as buffer size decreases and densities are relatively low where facility buffers do not overlap. Highest animal unit densities are found over 4km buffers in the southwest counties of McDonald, Barry, and Newton, in the west central counties of Pettis and

Johnson, and in eastern Lincoln County. In all of these counties, poultry and egg production is intense and is the major contributor to CAFO animal density.

Comparing High Animal Unit Density and 4km Buffer Runoff Impacts

The results of the two approaches used in this study are comparable in their extents of likely impacts. Both approaches assume that CAFOs will choose to dispose of their wastes by land application to agricultural lands close to the CAFO facility, expanding outward from the facility only when necessary. In both approaches, land application buffers of 4km, 8km, and 16km were used to represent increasing extents, with 16km having been identified as a maximum distance a CAFO facility will go to dispose of wastes (Bradford et al., 2008).

The first approach identifies surface waters receiving runoff from within 4km land application buffers as most likely to be impacted by hormones in that runoff, when compared to the 8km and 16km buffers. In many cases, longer lengths of stream reaches and additional reaches are identified by this approach near areas of high animal unit density than are identified by the second approach. The second approach, which investigates the impacts of high animal unit density areas on streams in and in close proximity and downgradient from those areas, identifies areas where land application to available agricultural land is likely to be more extensive than in areas where animal unit densities are lower. Streams in high animal unit density areas are most likely to be impacted by hormones in from land application fields in close proximity to CAFO facilities because more animals make more waste and thus more available agricultural land in the vicinity of the CAFO facility is likely to be spread with those wastes.

Based on the results of the two approaches used in this study, surface waters located in or in close proximity and downgradient to high animal unit densities are most likely to be impacted by hormones in runoff from land application fields (Tables 6, 7, and 8). Other surface waters receiving runoff from land application fields within close proximity to CAFO facilities are next most likely to be impacted (Table 5).

DISCUSSION & CONCLUSIONS

The exact contribution of hormones from land-applied CAFO livestock wastes to downstream surface waters, especially at broad extents and considering multiple CAFO facilities, is dependent upon a wide range of locally variable conditions. CAFO facilities and their associated animal and waste management systems vary widely. Land application field locations and rates of application may be variable from one season to the next. From the time wastes are excreted in a CAFO, until they reach surface water somewhere, opportunities exist for hormone transformation and degradation at a multiplicity of stages that may vary over time and season. For these reasons, it is very difficult to predict exactly how much of what kind of hormone will end up in surface waters. Additionally, microbial communities, aerobic conditions, and the volume and depth of flow in downstream surface waters will influence the transformation, degradation, and ultimate fate of hormones.

In this study's simple model of runoff, transport mechanisms of hormones and the land application preferences of CAFO facilities are used to identify downstream surface waters most likely to be impacted by hormones in land-applied CAFO wastes. Hormones remaining in wastes when they are land applied sorb strongly to soils high in organic carbon, weaker to soils low in organic carbon. Microbes biodegrade hormones while they are sorbed to waste or soil organic carbon and microbes biodegrade hormones best when those matrices are moist and aerobic. During drier states, soil microbes will still transform and degrade hormones, albeit slowly and or incompletely. During saturated conditions caused by precipitation events or heavy snowmelt, hormones desorb (to a greater extent from soils to which they were weakly sorbed) and are transported downgradient with the flow of water.

Surface waters downgradient from land applications fields are likely impacted by hormones transported in runoff from those fields. Increased density of CAFOs and the livestock animals they contain results in increased waste generation and constrained access to adequate and nearby land application fields. A higher density of animals correlates to a higher number of land application acres as close to facilities as available. Therefore, surface waters most likely to be impacted are those near to and downgradient from the largest CAFOs or areas of highest animal density.

In a broad scale study of the Shenandoah River watershed, Ciparis, Iwanowicz and Voshell (2012) found significant positive relationships between the density of CAFOs and hormonal activity in watershed streams. Based on these findings it is expected that there is increased hormonal activity in Missouri surface waters in areas where CAFOs, along with their animals and wastes, are spatially concentrated.

In this study, CAFO animal unit density is substituted for CAFO facility density. If a watershed has a high density of CAFOs, it can be reasoned that the watershed also has an associated high density of livestock animals. However, one watershed dense in small CAFOs is likely to have a less intense impact than a similarly sized watershed with a few very large CAFOs. Animal unit density correlates better to the amount of waste produced and disposed. In the case of this study, animal units for almost all permitted CAFOs in Missouri were available and so used for their increased significance.

Approaches used in this study indicate that very few watersheds throughout Missouri are unimpacted by runoff from CAFOs (Figure 8.). It is important to note that the buffers used in this study often crossed watershed divides. Actual land application extents may also extend across watershed divides, especially in the southwest part of the state where many facilities appear to be located on higher elevations along watershed boundaries.

Hormonal Dispersion vs. Hormonal Load

A distinction must be made between hormonal dispersion and hormonal load. Hormonal load is the type and amount of hormones found at any point during their transport from source to their fated destination. Hormonal load determined by a multiplicity of factors from the facility to the field and from the field to the stream. Hormonal load is an extremely difficult thing to predict because it is highly dependent on fine scale and localized conditions and may vary significantly from place to place. The dispersion of hormones by a primary mechanism like stormwater runoff is much easier to predict, especially if you assess the general patterns of runoff at a scale that includes more specific fine and local scale flow pathways, including drain tile.

Appropriateness of Scale

Raster data used in this study has a resolution of 30 meters by 30 meters, with the exception of the DEM, which had a resolution of 60 meters by 60 meters. Vector data used in this study is based on 1:24,000 scale source data; stream network data has been resampled from 1:100,000 data and is the most extensive stream data readily available. The resolution of this data is well suited for looking at surface water *reaches* likely impacted by runoff from agricultural landscapes at the state-wide extent. The resolution of this data allows us to calculate the general pattern of likely impacts by accounting for fine scale hydrologic phenomena such as localized preferential flow routes via drain tile and drainage ditches without requiring us to investigate them at a finer scale. Coarser grain data also allows for the inclusion, but not specification, of all possible land application fields when true locations are not known. Data of this resolution is also easily processed over a statewide extent and results can direct us to where more fine resolution calculations should be performed.

Study Limitations

With the exception of the 16-kilometer distance suggested by Bradford et al. (2008), smaller buffers used in this model were chosen based on an ad hoc review of land acreages listed in permits and based on the desire to compare the extent of runoff impacts at within varying distances from CAFO facilities. A comprehensive sampling of permits or NMPs could produce more realistic or statistically significant buffer sizes of buffer sizes based on animal type, CAFO size classes (number of animals or animal units at a facility) or other appropriate delineation.

There are limitations to using data of this scale and the results calculated in this study may not be directly scalable to more localized investigations; additional detail will often be necessary. In-depth investigation into a single watershed, one or two counties, or a local area should be approached with caution and all variables important to the appropriate scale and extent of investigation should first be carefully vetted out, best by both a literature review and site visit. For example, at more local scales variables like drainage structures may become key to locating optimal locations for receiving water monitoring within a specific surface water reach. At more local scales, actual impacts located at known sites of land application fields may also vary from those calculated in this study where land application locations were probabilistically defined.

Patterns and Spatial Distribution of CAFOs

Geographic concentration of CAFOs may result in high animal densities and constrained access to land application fields. A map of Missouri CAFOs (Figure 2.) illustrates the spatial distribution of these facilities and reveals the distribution patterns of some CAFO types. Poultry production CAFOs are found in three clusters. High volume chicken and turkey production in these areas is intended for distribution to food retail across the region and nation. Meat prepared for out of state sale must be slaughtered in federally inspected facilities (USDA, 2012). Poultry CAFOs in southeast Missouri are clustered around a Tyson processing facility in Dexter, Stoddard County, Missouri. Poultry CAFOs in west-central Missouri are clustered around Tyson and Cargill processing facilities in Sedalia, Pettis County, Missouri. The large cluster of poultry CAOs in southwest Missouri are positioned for access to Tyson processing facilities in Monett, Barry County, Missouri and Noel, McDonald County, Missouri. Other poultry CAFOs dispersed around the state are generally egg production facilities.

Poultry producers in southwest Missouri are also within range of Tyson processing facilities just over the state line in Rogers and Fort Smith, Arkansas and to Tyson and Cargill facilities in Springdale, Arkansas. If we expand our extent of investigation of the spatial distribution of poultry CAFOs in the region, we will find that the cluster of poultry CAFOs in southwest Missouri is part of a much larger cluster that extends southward into Arkansas, Oklahoma, Texas, and Louisiana (USDA NASS, 2007).

Hog CAFOs appear to be more loosely clustered than poultry CAFOs and they are more widely dispersed across the north, central and western parts of the state. Hog operations in northern Mercer, Putnam, Sullivan, Daviess and Gentry counties are generally associated with Premium Standard Farms, a subsidiary of Smithfield Foods, a large corporation that produces over 50 brands of pork products (Smithfield Foods, 2012). Many hog CAFOs are contract operations and hogs are transferred to Iowa for finishing and slaughter (Ulmer, 2006).

Most of Missouri's 566 permitted CAFOs and their land application fields are located in areas that generally have poorly drained soils. Poorly drained soils have high rates of stormwater runoff and low rates of infiltration. In hillier areas of Missouri, such as in the southwestern counties, land best for agricultural use is generally found on level hilltops. Runoff from these hilltop fields would move quickly down hill slopes with little infiltration. Additionally, if slopes are too steep for agricultural use, then topography may further limit access to land application fields in close proximity to CAFO facilities.

Environmental Monitoring

Models such as this can inform existing environmental monitoring efforts. When compared to what Ciparis, Iwanowicz, and Voshell (2012) found in Virginia, it could be expected that increased hormonal activity in Missouri surface waters will be found where CAFOs, their animals and wastes are spatially concentrated (Table 8, Figure9). The maps produced in this study provide some assistance in locating drinking water sources, critical habitats, and other surface water resources that have the potential to be impacted by hormones from land-applied wastes.

Current Receiving Water Monitoring

Several permitted CAFOs in Missouri are required by MoDNR to monitor receiving waters. Most CAFOs with permit-mandated receiving water monitoring sites are hog CAFOs in Putnam, Mercer, Sullivan, Harrison, Gentry and Daviess counties. A few CAFOs in west central Johnson and Pettis counties and in southwestern McDonald County also have compulsory receiving water monitoring sites. The high proportion of hog CAFO water monitoring sites is probably due to the nature of hog waste. Hog waste is generally collected, stored, and applied as slurry. Improper or over-application of hog waste or stormwater runoff of wastes applied at agronomic rates becomes an acute, visible nutrient contamination problem in downstream surface waters, causing observable negative effects like fish kills and eutrophication. While nutrient contamination from the land application of poultry waste is also possible, it is less likely to be visible in runoff because it is land applied as dry litter.

Monitoring for Livestock-Source Hormones

Designing a protocol for detecting or monitoring hormones in surface waters downstream from land application fields requires an understanding of the dynamic and variable way in which they are flushed from those fields. Previous studies (Shore et al., 2004; Kjaer et al, 2007; Zhao et al., 2010; Gall et al., 2011; Shuh et al., 2011) find that hormones are released from land application fields nearly continuously at low (baseline) concentrations with significant increase in hormone concentrations during and after storm events and with seasonal variations such as snowmelt. These studies are significant because they are more than a snapshot in time; they describe time and flow dependent transport of hormones from soils to which wastes are applied. Therefore, any environmental monitoring effort should be long term with regularly scheduled sampling to establish baseline hormone concentrations, and additional sampling when runoff is present, at regular intervals during and after storm events to assess any surges or other patterns of concentration over time. A standard laboratory detection method for hormones should also be established and used consistently, so that temporal results are easily compared. The measurement of estrogenic activity might be more useful and more meaningful than looking for specific chemicals, but may also include phytoestrogens and other naturally occurring compounds with hormonal activity characteristics.

Policy Implications

Of all things revealed by this study, most important is the fact that certain waste and wastewater treatment systems like constructed wetland systems and ecologically engineered treatment systems have been found to attenuate greater than 90 percent of hormones present in livestock wastes. Although they would require the investment of some time and capital by CAFO management or owners, these systems have been described as mechanically simple and energy efficient. If either through environmental monitoring or by the precautionary principle hormones from land-applied CAFO wastes are found to be a risk, requiring the advanced treatment of wastes might be the solution. Onsite waste treatment is the last chance for human management of any significant transformation or degradation of hormones in livestock wastes. What happens to hormones after wastes are land-applied is dependent on many things, most all out of human control.

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SOFTWARE & DATA

ArcGIS 10, ArcEditor 10.1 and Extensions, Education Edition, ESRI, Redlands, CA, USA.

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LIST OF FIGURES

Figure 1. Study Extent - State of Missouri
Shaded Topography, Major Surface Waters
& HUC8 Watershed Boundaries

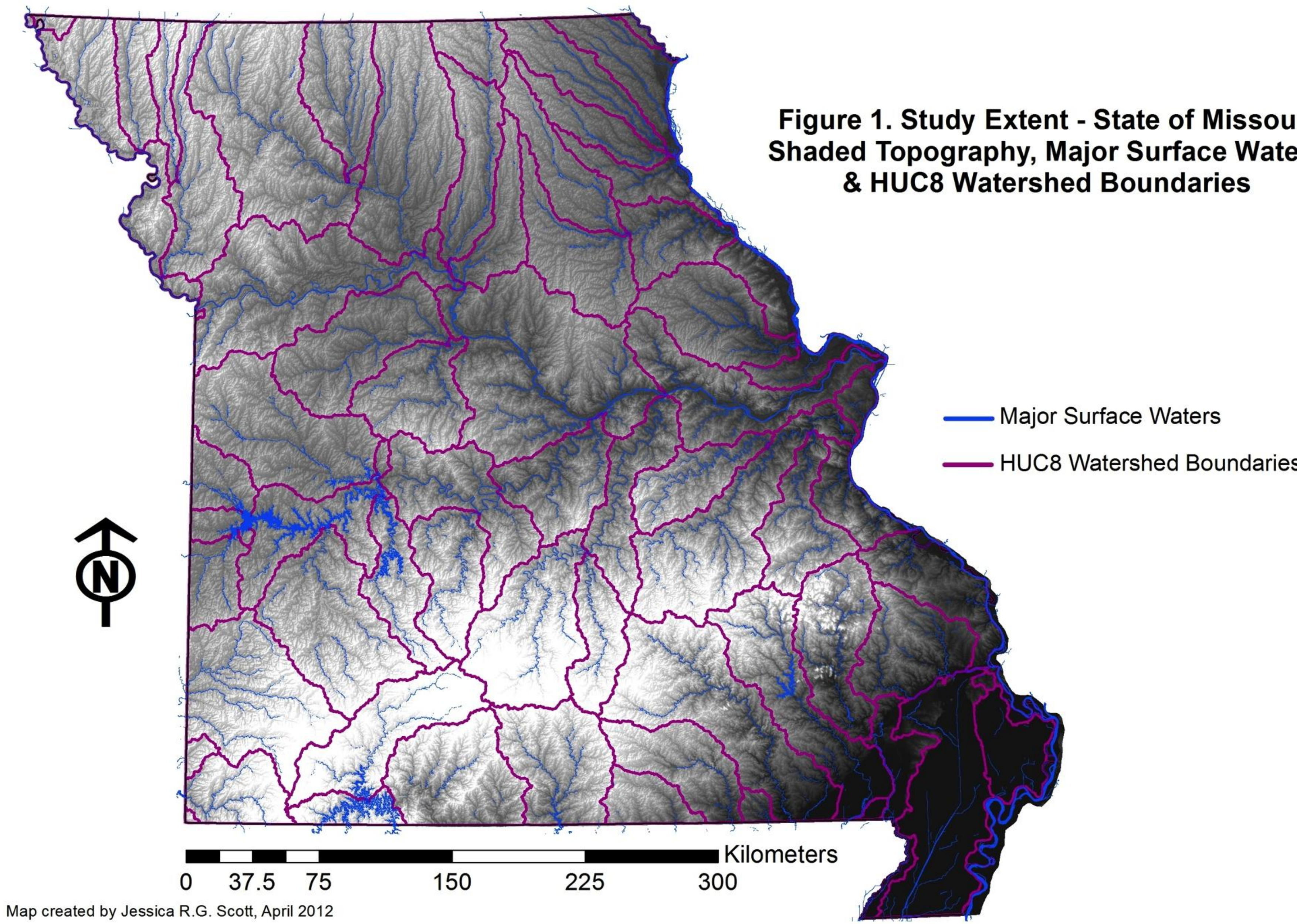
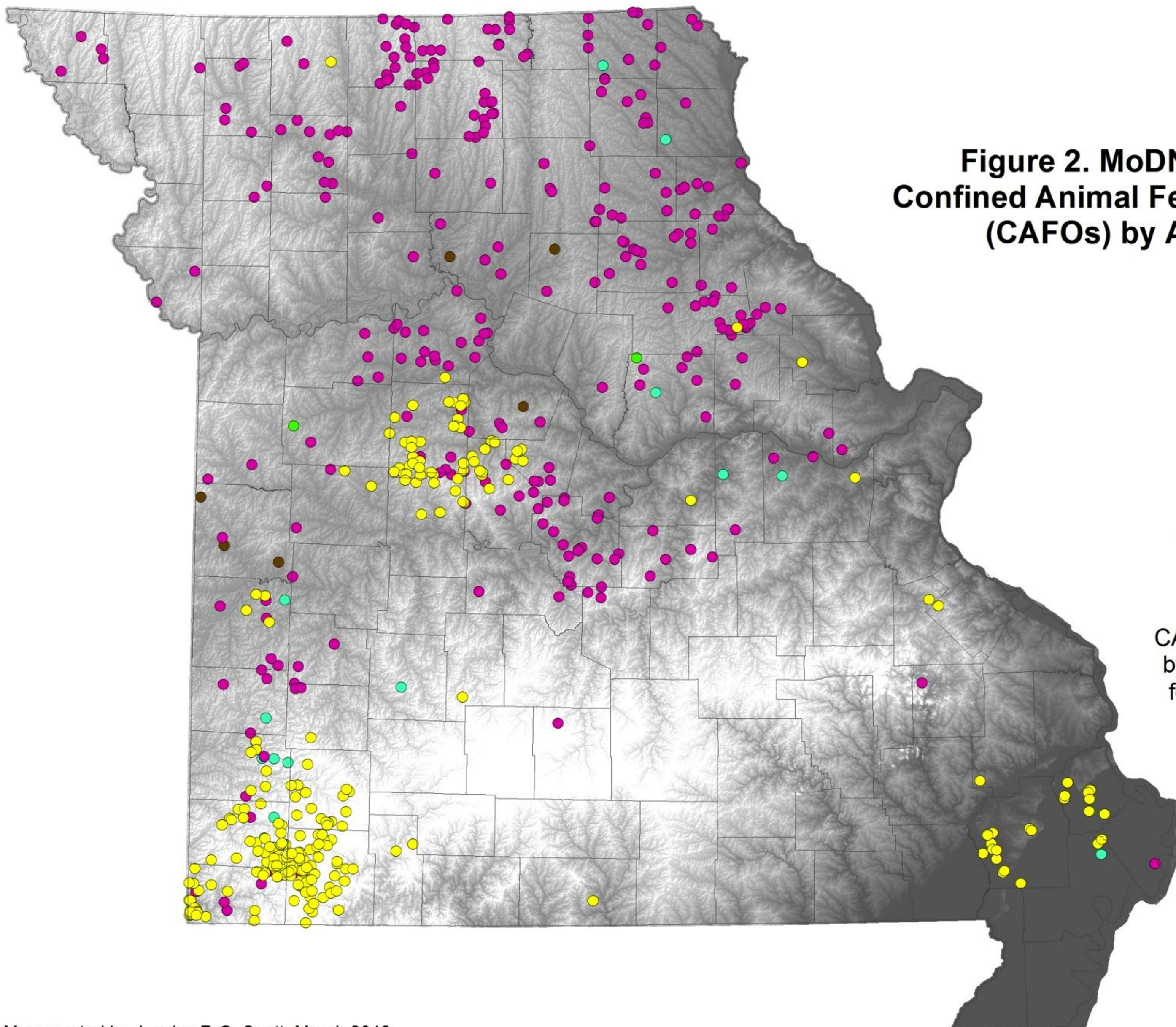


Figure 2. MoDNR Permitted Confined Animal Feeding Operations (CAFOs) by Animal Type



- Beef Cattle Feedlots (6)
- Poultry & Eggs (257)
- Dairy Farms (14)
- General Farms (2)
- Hog Operations (287)

CAFO types were sorted & counted by selecting the primary permitted feature out of the MoDNR (2011) permitted features dataset.

Map created by Jessica R.G. Scott, March 2012

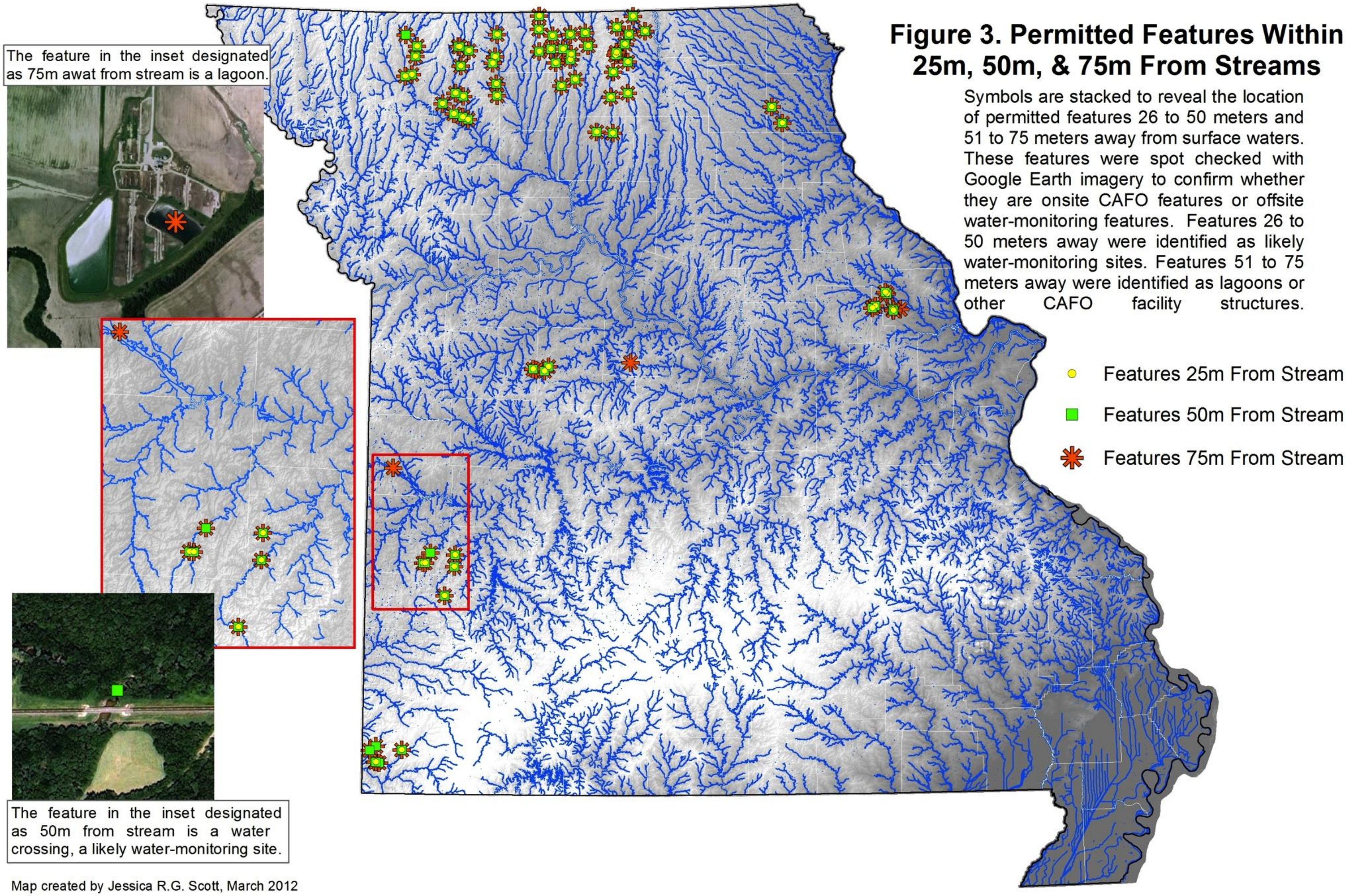


Figure 3. Permitted Features Within 25m, 50m, & 75m From Streams
Symbols are stacked to reveal the location of permitted features 26 to 50 meters and 51 to 75 meters away from surface waters. These features were spot checked with Google Earth imagery to confirm whether they are onsite CAFO features or offsite water-monitoring features. Features 26 to 50 meters away were identified as likely water-monitoring sites. Features 51 to 75 meters away were identified as lagoons or other CAFO facility structures.
Features 25m From Stream
Features 50m From Stream
Features 75m From Stream
The feature in the inset designated as 75m awat from stream is a lagoon.
The feature in the inset designated as 50m from stream is a water crossing, a likely water-monitoring site.
Map created by Jessica R.G. Scott, March 2012

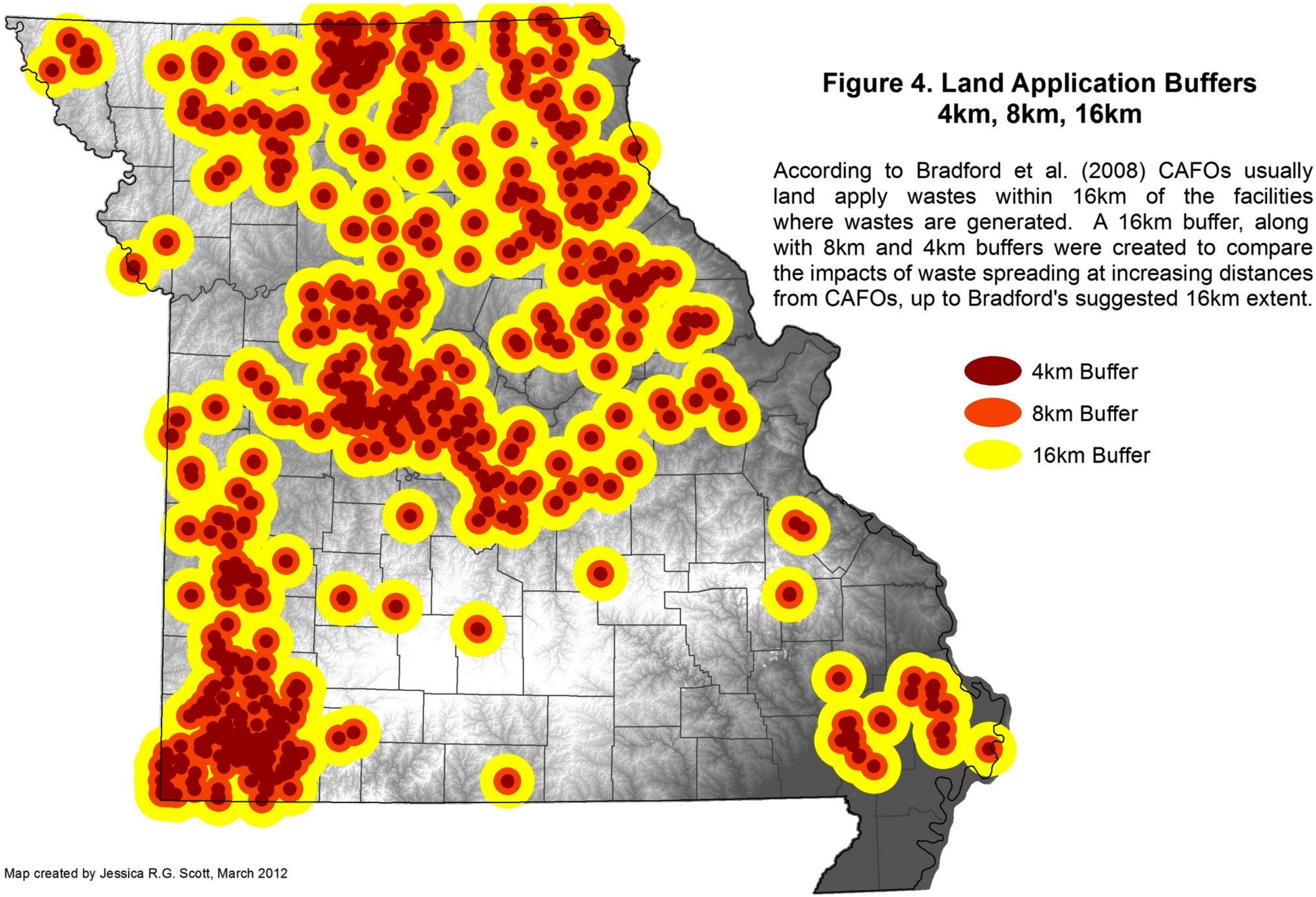
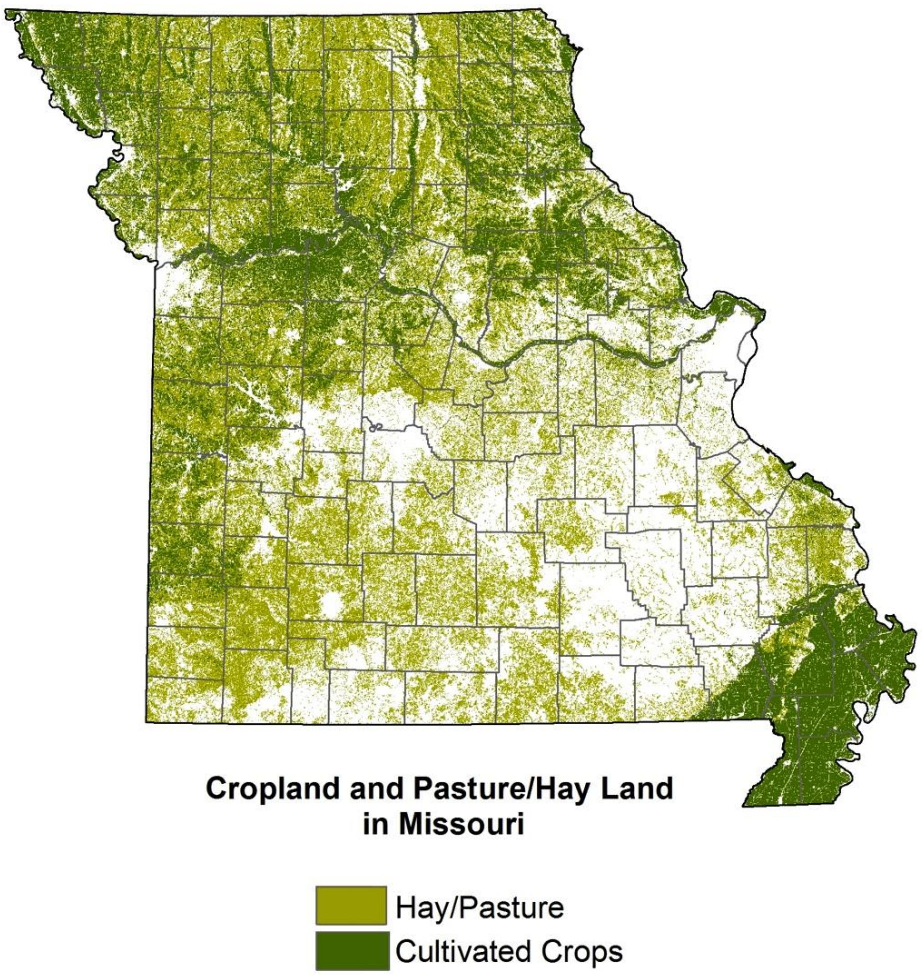
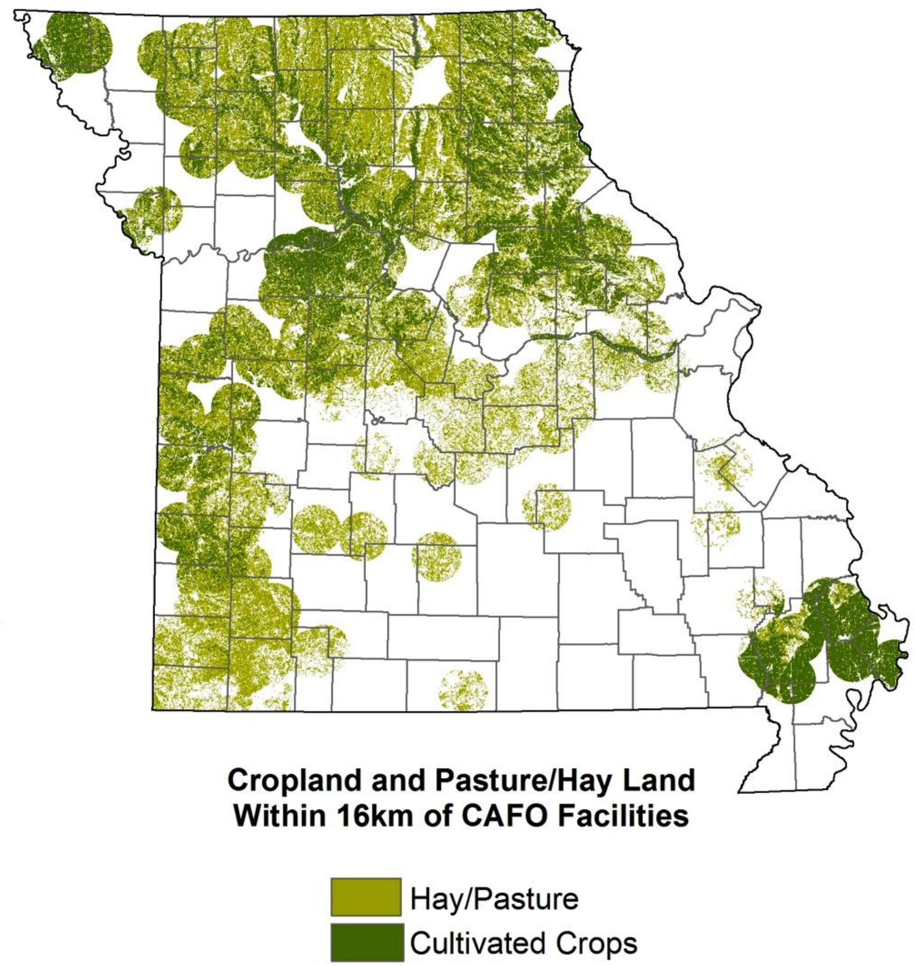


Figure 4. Land Application Buffers 4km, 8km, 16km

According to Bradford et al. (2008) CAFOs usually land apply wastes within 16km of the facilities where wastes are generated. A 16km buffer, along with 8km and 4km buffers were created to compare the impacts of waste spreading at increasing distances from CAFOs, up to Bradford's suggested 16km extent.

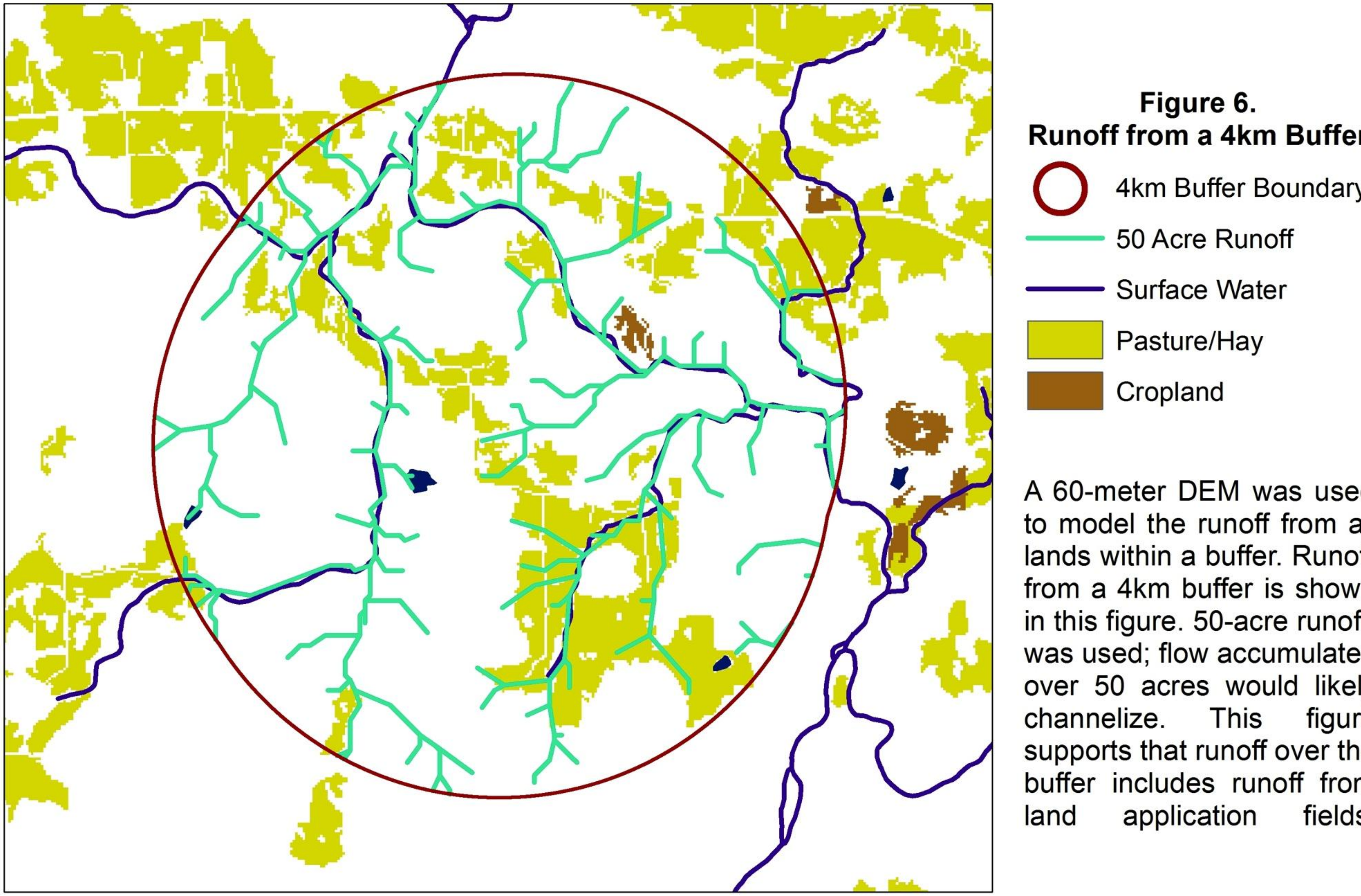
Figure 5. Cropland and Pasture/Hay Land in Missouri & Within 16km of CAFO Facilities





Map created by Jessica R.G. Scott, March 2012

Figure 6.
Runoff from a 4km Buffer



Map created by Jessica R.G. Scott, March 2012

A 60-meter DEM was used to model the runoff from all lands within a buffer. Runoff from a 4km buffer is shown in this figure. 50-acre runoff was used; flow accumulated over 50 acres would likely channelize. This figure supports that runoff over the buffer includes runoff from land application fields.

Figure 7. Surface Waters in Missouri Likely Impacted by Hormones in Land-Applied CAFO Wastes 4km, 8km, and 16km Buffers

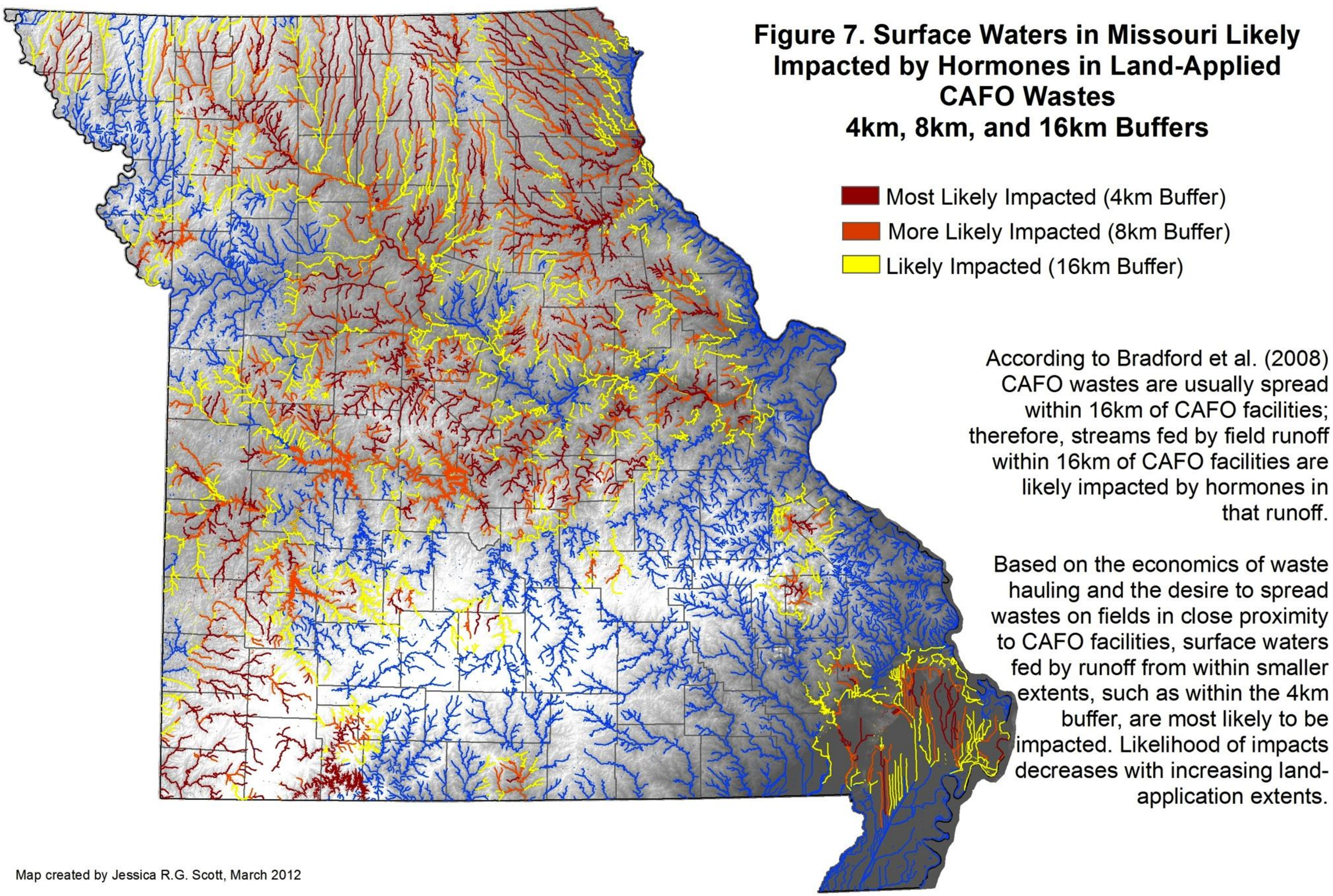
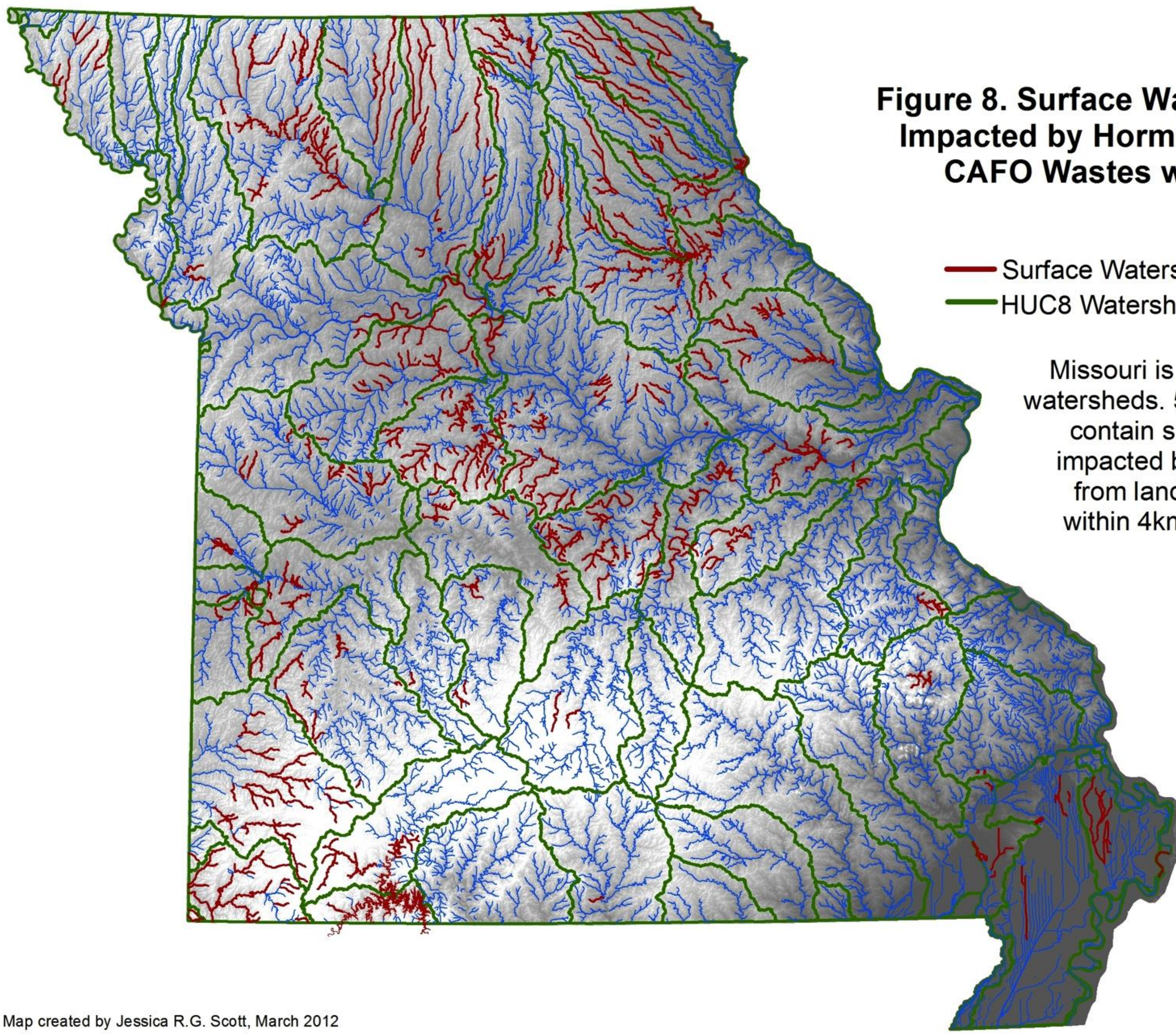


Figure 8. Surface Waters in Missouri Likely Impacted by Hormones in Land-Applied CAFO Wastes within a 4km Buffer



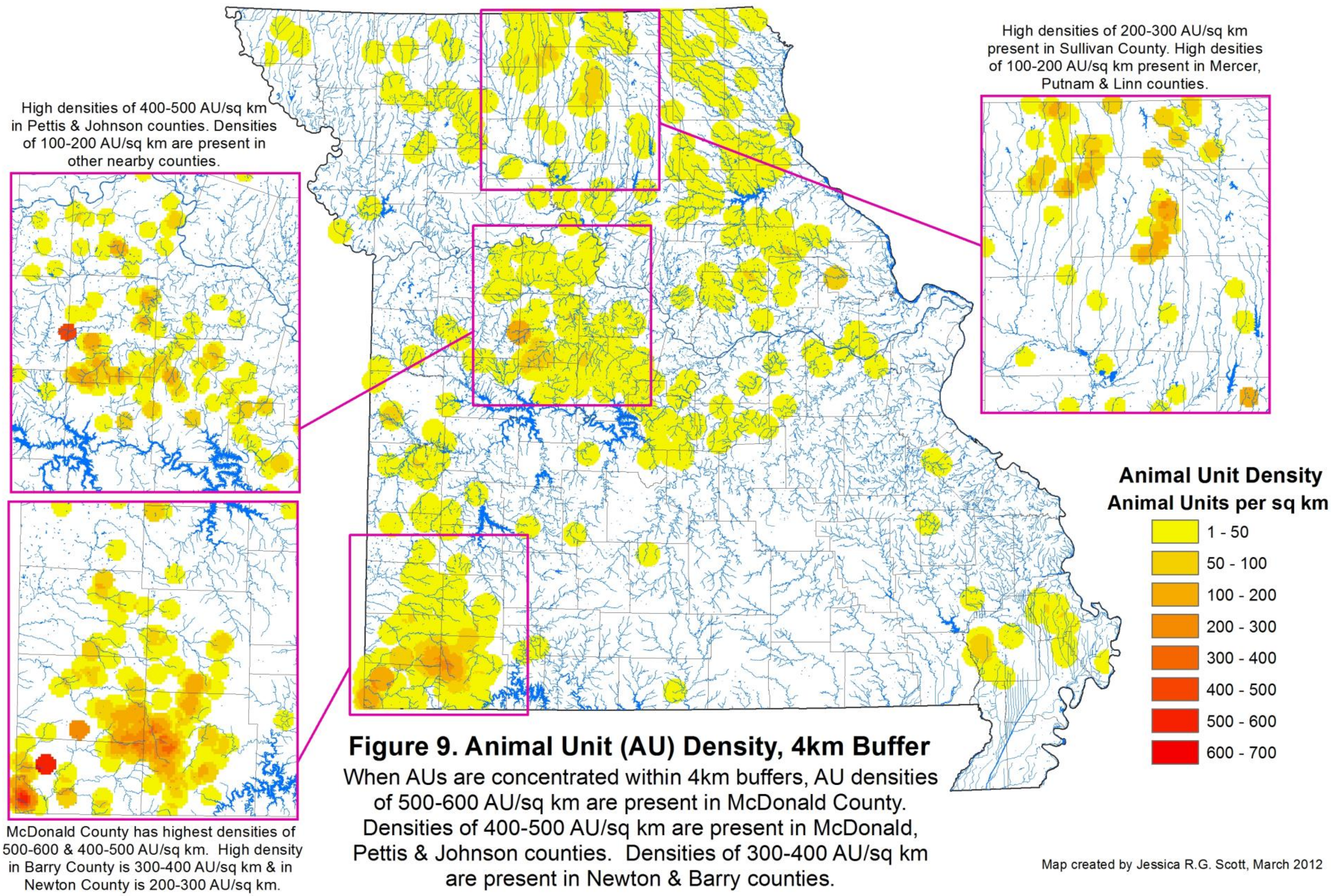


Figure 9. Animal Unit (AU) Density, 4km Buffer
When AUs are concentrated within 4km buffers, AU densities of 500-600 AU/sq km are present in McDonald County. Densities of 400-500 AU/sq km are present in McDonald, Pettis & Johnson counties. Densities of 300-400 AU/sq km are present in Newton & Barry counties.

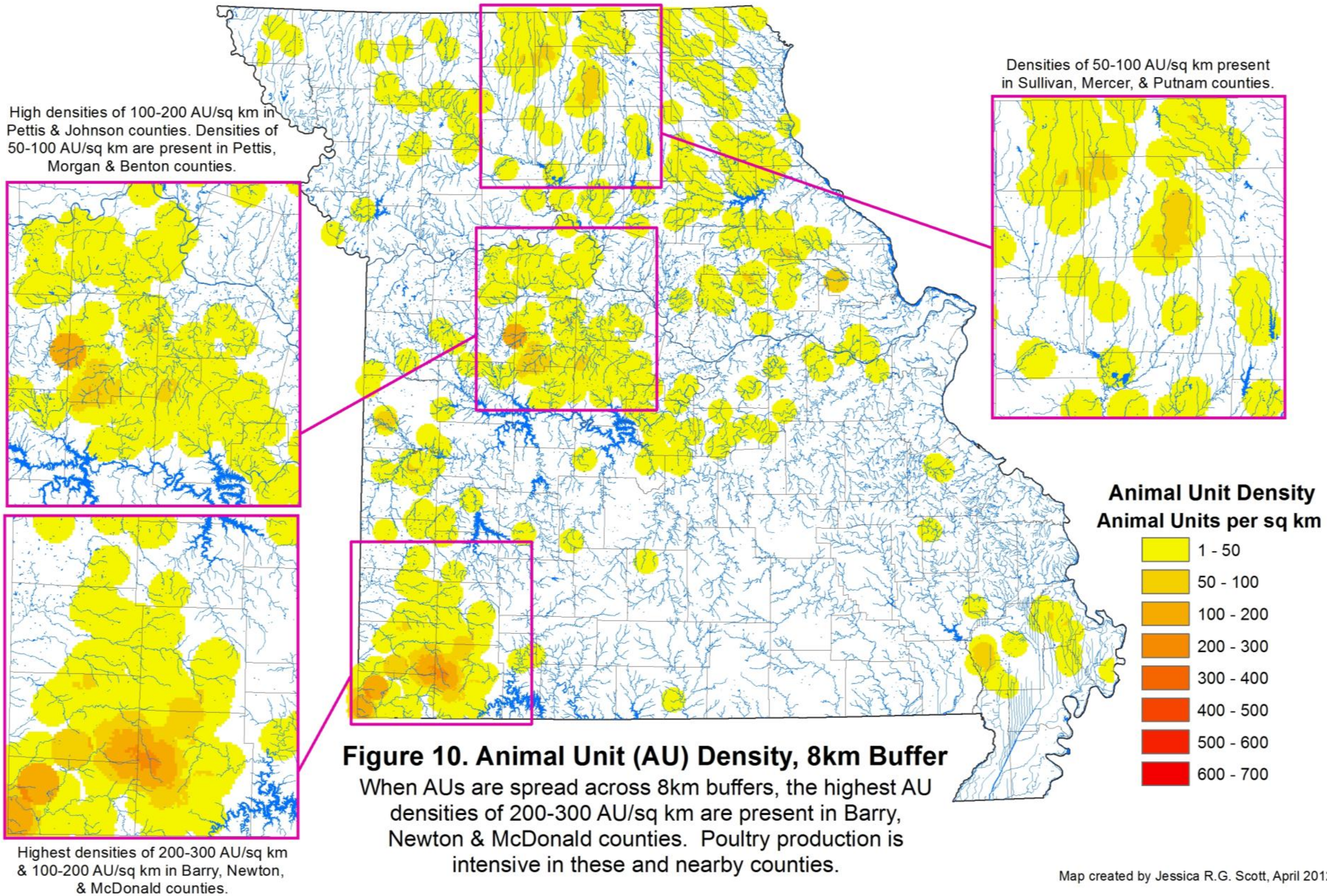


Figure 10. Animal Unit (AU) Density, 8km Buffer

When AUs are spread across 8km buffers, the highest AU densities of 200-300 AU/sq km are present in Barry, Newton & McDonald counties. Poultry production is intensive in these and nearby counties.

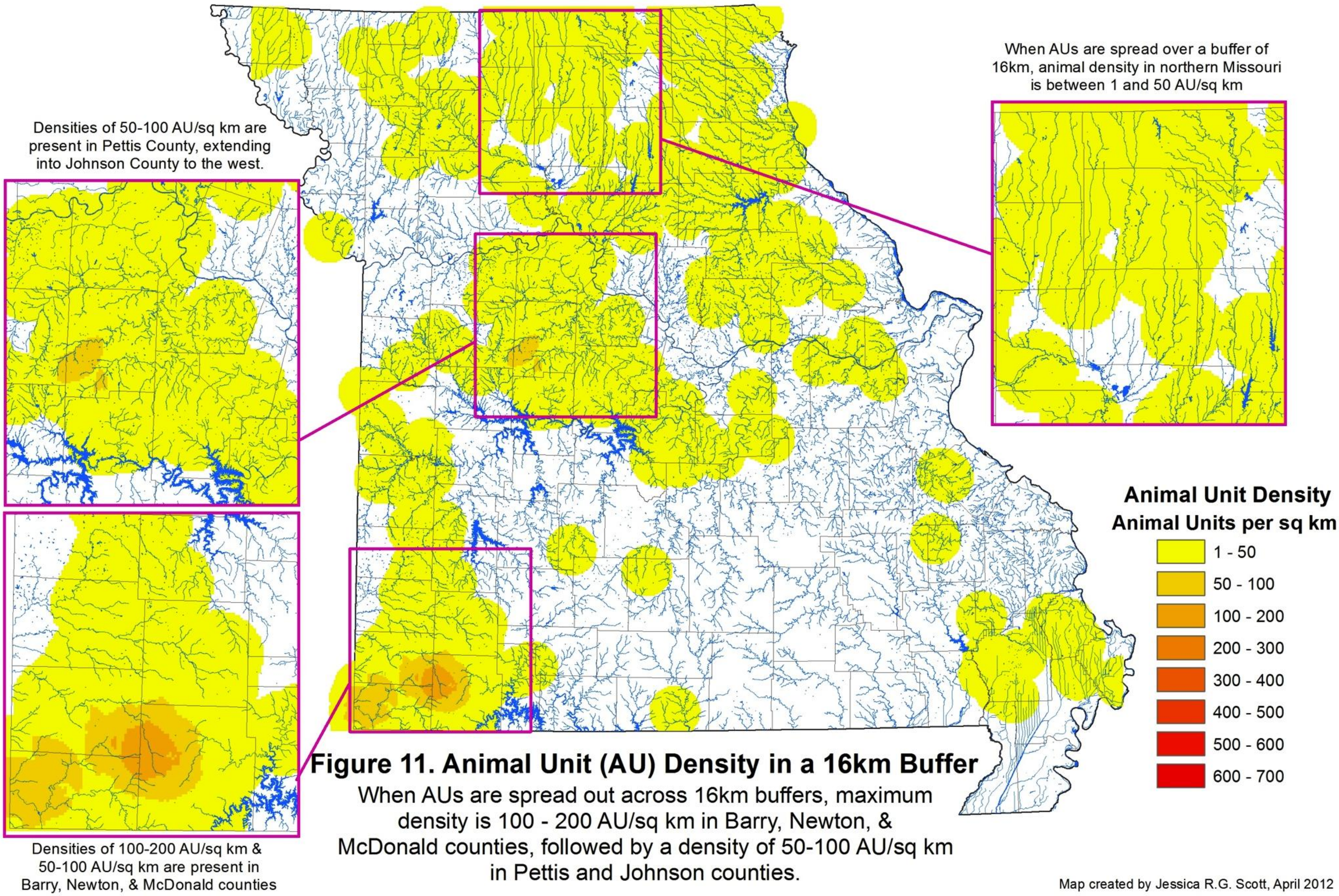


Figure 11. Animal Unit (AU) Density in a 16km Buffer

When AUs are spread out across 16km buffers, maximum density is 100 - 200 AU/sq km in Barry, Newton, & McDonald counties, followed by a density of 50-100 AU/sq km in Pettis and Johnson counties.

APPENDICES

Appendix A. Lange, et al. (2002). Estimates of Endogenous and Total Endogenous and Pharmaceutical Hormones Excreted by Livestock Animals, Two Tables

Appendix B. Permit for Large Dairy: An Example of MoDNR NPDES Permits for CAFOs (attached as PDF)

Appendix A.

Lange, et al. (2002). Estimates of Endogenous and Total Endogenous and Pharmaceutical Hormones Excreted by Livestock Animals, Two Tables

Table 1. Estimates of yearly steroid hormone excretion by cattle, pigs, sheep and chickens, (mg per animal per year), Lange et al. (2002)

Species	Category	Estrogens (mg)	Androgens (mg)	Gestagens (mg)
Cattle	Calves	16	120 (male)	
	Cycling Cows	110		3200
	Pregnant	990		4400
	Bulls	200	390	
Pigs	Cycling Sows	43		1700
	Pregnant	70		3900
	Boar	830	670	
Sheep	Cycling Ewes	8.4		730
	Pregnant	19		850
	Rams	9.1		
Chickens	Female broilers	0.34	0.7	
	Male broilers	0.07	0.7	
	Laying hens	7.1	3.4	
	Cocks	1.2	8.9	

Table 2. Estimated yearly steroid hormones excretion by farm animals in the U.S. – Year 2000 (metric tonnes from all heads in a category per year), Lange et al. (2002)

Animal	Million heads	Estrogens (t)	Androgens (t)	Gestagens (t)
Cattle	*98*	*45*	*1.9*	*253*
Calves	17	0.27	1.0 (male)	
Cycling Cows	20	2.2		64
Pregnant Cows	43	43		189
Steers	17			
Bulls	2.3	0.46	0.9	
Pigs	*59*	*0.83*	*0.35*	*22*
Piglets, young pigs	51			
Cycling Sows				
Pregnant Sows	5.7	0.40		22
Barrows				
Boars	0.52	0.43	0.35	
Others	2.6			
Sheep	*7.7*	*0.092*		*3.9*
Lambs	2.5			
Pregnant Ewes	4.6	0.087		3.9
Rams	0.58	0.005		
Chickens	*1816*	*2.7*	*2.1*	
Female broilers	691	0.23	0.48	
Male broilers	691	0.048	0.48	
Laying hens	332	2.4	1.1	
Total	***1981***	***49***	***4.4***	***279***

STATE OF MISSOURI

DEPARTMENT OF NATURAL RESOURCES

MISSOURI CLEAN WATER COMMISSION

MISSOURI STATE OPERATING PERMIT

In compliance with the Missouri Clean Water Law, (Chapter 644 R.S. Mo. as amended, hereinafter, the Law), and the Federal Water Pollution Control Act (Public Law 92-500, 92nd Congress) as amended,

Permit No.	[redacted]
Owner: Address:	[redacted]
Continuing Authority: Address:	Same as above Same as above
Facility Name: Facility Address:	[redacted]
Legal Description: UTM Coordinates:	See Pages 2-6 See Pages 2-6
Receiving Stream:	Troublesome Creek(C) Seebers Branch (U)
First Classified Stream and ID:	Troublesome Creek(C)(00074) South Fabius River(P)(00071)
USGS Basin & Sub-watershed No.:	(07110003-030001) (07110003-020002)

is authorized to discharge from the facility described herein, in accordance with the effluent limitations and monitoring requirements as set forth herein:

FACILITY DESCRIPTION

Outfalls #001 - #011 and #054 – Concentrated Animal Feeding Operation – SIC Codes #0241 and #0214 – Class 1A
No Discharge of Process Waste
Seven earthen storage basins/one single cell lagoon/one three-cell lagoon/one concrete storage pit/solids separation/liquids and solids are land applied/domestic wastewater systems/stormwater runoff/solids and dead animal composters.
Design flow (animals): 187,313,852 gallons per year. (0.513 mgd)
Design flow (domestic): 7,041,319 gallons per year. (0.019 mgd)
Design flow (total): 194,355,171 gallons per year. (0.532 mgd)
Design number of animals is 8,514 dairy cows and 1200 goats. (12,283 animal units)

This permit authorizes only wastewater discharges under the Missouri Clean Water Law and the National Pollutant Discharge Elimination System; it does not apply to other regulated areas. This permit may be appealed in accordance with Section 644.051.6 of the Law.

December 10, 2010
Effective Date

Kip A. Stetzler, Acting Director, Department of Natural Resources

December 9, 2015
Expiration Date

John Madras, Director, Water Protection Program

FACILITY DESCRIPTION:

The farm consists of 3 animal complexes designated Outfalls 001, 002, 003 and 009. Outfall 001 (west complex) and Outfall 002 (east complex) may contain approximately 2,625 dry cows or equivalent combination of cows, heifers, or calves each. Outfall 003 (dairy milking parlor and free stall barns) may contain approximately 4,464 dairy cows. The number of animals at each complex may vary provided the total number of cows at the operation does not exceed 8,514 head. Lots are concrete surface. Solids will be scraped from the East complex and stored in a concrete pit located at the East complex to be land applied using a solids spreader or to becomposted and used for fertilizer. A PVC pipe drains any precipitation collected in the concrete pit to the earthen storage basin on site. The residual manure from the complex will be washed to an earthen storage basin, via precipitation runoff. Wastes will be removed from the milking parlor using a freshwater flush system and from the free stall barns using recycled water and a solids separator. Remaining wastewater will be transported to an earthen storage basin via PVC pipe. Outfall 009 (Goat Milking Facility) contains 1200 dairy goats, a milk parlor, animal waste lagoon, domestic waste basin and animal loafing buildings. The goats also have access to pasture. The waste from the loafing buildings is kept dry with bedding and the waste is occasionally removed and hauled to the composting operation. Manure solids and dead animals may be composted. Whey production from the creamery and goat facilities that is to be land applied will be placed into the earthen storage basins. Wastewater from the earthen storage basins and lagoons will be land applied in accordance with the approved nutrient management plan.

Total Number of Acres Available for Land Application: 9680

Outfall #001 – West Complex
System Type: Earthen storage basin/solids composter
Legal Description: SW¼, NW¼, SE¼, Sec. 4, T60N, R9W, Lewis County
UTM Coordinates X=593713, Y=4431094
Receiving stream: Tributary to Troublesome Creek (C)
First classified stream and ID: Troublesome Creek (C) 00074
USGS Basin & Subwatershed No. 07110003-030001
Design Number of Animals: 2,625 dairy dry cows, or equivalent combination of cows, heifers and calves
Runoff Areas to Storage: 550,041 sq.ft. Concrete – Concrete lots may be used for composting solids.
Design Flow: 27,840,375 gallons per year
Design Storage: 618 days
Storage volume: 47,199,300 gallons
Total Basin Depth: 16 feet below overflow level
Upper Operating Level: 1.5 feet below overflow level

Lower Operating Level: 14 feet below overflow level

Outfall #002 - East Complex
System Type: Earthen storage basin/feed storage area/composting areas for solids and dead animals.
Legal Description: NE¼, SW ¼, NW ¼, Sec. 2, T60N, R9W, Lewis County
UTM Coordinates X=596127, Y=4431796
Receiving stream: Tributary to Troublesome Creek (C)
First classified stream and ID: Troublesome Creek (C) 00074
USGS Basin & Subwatershed No. 07110003-030001
Design Number of Animals: 2,625 dry cows or equivalent combination of cows, heifers and calves.
Runoff Areas to Storage: 242,682 sq.ft. Concrete.
Design Flow: 23,564,400 gallons per year
Design Storage 293 days
Storage Volume: 18,962,770 gallons
Total Basin Depth: 15 feet below overflow level
Upper Operating Level: 1.5 feet below overflow level
Lower Operating Level: 13 feet below overflow level

FACILITY DESCRIPTION: (continued)

Outfall #003 - Dairy Complex
System Type: Two earthen storage basins/one reserve storage basin/mechanical solids separation/secondary containment.
Legal Description: NE ¼, NE ¼, SE ¼, Sec. 3, T60N, R9W, Lewis County
UTM Coordinates X=595714, Y=4431427
Receiving stream: Tributary to Troublesome Creek (C)
First classified stream and ID: Troublesome Creek (C) 00074
USGS Basin & Subwatershed No. 07110003-030001
Design Number of Animals: 4,464
Animal Units: 6,377
Runoff Areas to Storage: 91,760 sq.ft. concrete, 78,000 sq. ft. soil
Design Flow (1 in 10 years): 130,389,000 gallons per year
Design Storage: 330 days total; includes two earthen storage basins
Biosolids Volume: 11,000 tons per year

North Basin:
Storage Volume: 43,362,000 gallons
Total Basin Depth: 14 feet below overflow level
Upper Operating Level: 1.0 feet below overflow level
Lower Operating Level: 12 feet below overflow level

South Basin:
Storage Volume: 73,829,000 gallons
Total Basin Depth: 18.5 feet below overflow level
Upper Operating Level: 1.0 feet below overflow level
Lower Operating Level: 16.5 feet below overflow level

Outfall #004 - Concrete Storage Pit – Deleted, Flow is into outfall #002

Outfall #005 - Domestic Wastewater - SIC #4952
No-discharge domestic wastewater system consisting of a single cell earthen basin and irrigation serving a total of 34 employees, 5 visitors, and 36 residents.
Legal description is NW¼, SW¼, Sec. 2, T60N, R9W, Lewis County
UTM Coordinates X=596108, Y=4431488
Receiving stream: Tributary to Troublesome Creek (C)
First classified stream and ID: Troublesome Creek (C) 00074
USGS Basin & Subwatershed No. 07110003-030001
Design population equivalent is 47
Design Flow: 1,814,050 gallons per year including storm water flows
Storage capacity: 730,270 gallons
Design Storage: 120 days
Upper operating level: 1.0 feet below overflow elevation
Lower operating level: 7.0 feet below overflow elevation

Outfall #006 – Fresh Water Lake Monitoring
This is a privately owned lake located on permittee property that is used as a water source for livestock. The sample location is within the lake at a lake surface location near the discharge structure.
Legal Description: NE ¼, SW ¼, SE ¼, Sec 4, T60N, R9W, Lewis County
UTM Coordinates X=594329, Y=4431008
Receiving stream: Unnamed Tributary to Troublesome Creek (C)
First classified stream and ID: Troublesome Creek (C) 00074
USGS Basin & Subwatershed No. 07110003-030001

Outfall #007 – Deleted - Stream Monitoring

Outfall #008 – Deleted - Stream Monitoring

FACILITY DESCRIPTION: (continued)

Outfall #009 – Goat Milking Complex – SIC #0214
System Type: Earthen basin for milking parlor waste/milking parlor using fresh water only
Legal Description: SW ¼, NW ¼, Sec. 16, T60N, R9W, Lewis County
UTM coordinates X= 592844, Y= 4428644
Receiving stream: Seebers Branch (U)
First classified stream and ID: South Fabius River (P) 0071
USGS Basin & Subwatershed No. 07110003-020002
Design Number of Animals: 1200 goats
Animal Units: 120
Storage Size: 633,000 gallons at overflow level
Design Flow: 620,077 gallons per year
Design Storage: 365+ days
Total Basin Depth: 11 feet below overflow level
Upper Operating Level: 1.0 feet below overflow level
Lower Operating Level: 9.0 feet below overflow level
Biosolids Volume: 2026 Tons per year

Outfall #010 – Washburn Lagoon
System Type: Earthen storage basin for additional wastewater storage
Legal Description: SE ¼, NE ¼, Sec. 1, T60N, R10W, Knox County
UTM Coordinates X=589185, Y=4431702
Receiving stream: Seebers Branch (U)
First classified stream and ID: South Fabius River (P) 0071
USGS Basin & Subwatershed No.: 07110003-020002
Storage Volume: 66,941,414 gallons
Design Flow: 4,900,000 gallons per year (stormwater only)
Total Basin Depth: 21 feet below overflow level
Upper Operating Level: 1.0 feet below overflow level
Lower Operating Level: 19.0 feet below overflow level

Outfall #011: Office/Cafeteria/Rehabilitation Complex: Three-cell lagoon/wastewater irrigation/sludge is retained in lagoon
Legal description is NE¼, SE¼, Sec. 4, T60N, R9W, Lewis County, located adjacent to West Basin site
UTM Coordinates X=593728, Y= 4431270
Receiving stream: Tributary to Troublesome Creek (C)
First classified stream and ID: Troublesome Creek (C) 00074
USGS Basin & Subwatershed No. 07110003-030001
Design population equivalent is 145
Storage Size: 1,560,474 gallons
Design Storage: 141 days
Design Flow: 5,159,640 gallons per year including storm water flows
Operating levels of cell 3 are:
Upper level of two (2) feet below overflow elevation
Lower level of five (5) feet below overflow elevation

Outfall#054 Domestic Waste Basin: SIC #4952
No-discharge domestic waste earthen basin for employees at the Goat Complex.
Legal Description: SW ¼, NW ¼, Sec. 16, T60N, R9W, Lewis County
UTM coordinates X=592826, Y=4428599
Receiving stream: Seebers Branch (U)
First classified stream and ID: Fabius River (P) 0071
USGS Basin & Subwatershed No. 07110003-020002
Storage Size: 57,147 gallons at overflow level
Design Flow: 67,629 gallons per year
Design Storage: 275 days
Total Basin Depth: 8.3 feet below overflow level
Upper Operating Level: 1.0 feet below overflow level
Lower Operating Level: 6.3 feet below overflow level

FACILITY DESCRIPTION: (continued)

Outfall #S1 – Stream Monitoring Troublesome Creek at Highway D (Class C)
Legal Description: SW ¼, Sec 16, T61N, R9W, Lewis County
UTM Coordinates X=592624, Y=4437575
Receiving stream: Troublesome Creek (C)
First classified stream and ID: Troublesome Creek (C) 00074
USGS Basin & Subwatershed No. 07110003-030001

Outfall #S2 – Stream Monitoring Troublesome Creek at Highway 156 (Class C)
Legal Description: SE ¼, Sec 13, T60N, R9W, Lewis County
UTM Coordinates X=598710, Y=4428157
Receiving stream: Troublesome Creek (C)
First classified stream and ID: Troublesome Creek (C) 00074
USGS Basin & Subwatershed No. 07110003-030001

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Permit No. MO-0119962

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

OUTFALL NUMBER AND EFFLUENT PARAMETER(S)	UNITS	MONITORING REQUIREMENTS		
		REQUIREMENTS	MEASUREMENT FREQUENCY	SAMPLE TYPE
Outfalls #001 – 003, 005, 009 – 011, 054 and Land Application Fields - Emergency and/or Unauthorized Discharge Monitoring				
Flow	mgd		once/day during discharge	24 hr. estimate
Dissolved Oxygen	mg/L		once/day during discharge	grab
Ammonia Nitrogen as N	mg/L		once/day during discharge	grab
Biochemical Oxygen Demand$_5$	mg/L		once/day during discharge	grab
pH – Units	SU		once/day during discharge	grab
Temperature	°C		once/day during discharge	grab
Duration	hours		once/day during discharge	grab

Samples shall be collected of the discharge at the down gradient property boundary. Samples shall also be collected from the receiving waters above and below the discharge point. If the receiving drainage is dry above the discharge point, report as no stream flow above the discharge point.

Outfall #006 – Fresh Water Lake Discharge Monitoring				
Flow	mgd	Sample 2 times per year, once during April and once during October from the discharge pipe, or from a location near the discharge inlet, during a discharge.	2/year	24 hr. estimate
pH – Units	SU		2/year	grab
Ammonia Nitrogen as N	mg/L		2/year	grab
Total N	mg/L		2/year	grab
Total Phosphorus as P	mg/L		2/year	grab
Temperature	°C		2/year	grab

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Permit No. MO-0119962

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

OUTFALL NUMBER AND EFFLUENT PARAMETER(S)	UNITS	MONITORING REQUIREMENTS		
		REQUIREMENTS	MEASUREMENT FREQUENCY	SAMPLE TYPE
Outfalls #S1 and #S2 - Stream Monitoring				
Flow	mgd	Samples shall be collected on a pre-determined sampling date. Collect 4 samples per year, once during March, May, August, and October on the 17th day of the month. Samples shall be only collected from flowing water. Samples from riffles are preferred. Do not collect a sample from pools that do not have water flowing into or out of the pool. If there is no flow on the 17th day of the month, alternate date(s) shall be chosen. Monitoring requirement only.	4/year	24 hr estimate
pH - Units	SU		4/year	grab
Ammonia Nitrogen as N	mg/L		4/year	grab
Total N	mg/L		4/year	grab
Total Phosphorus as P	mg/L		4/year	grab
Temperature	°C		4/year	grab
Dissolved oxygen	**mg/L**		**4/year**	grab

Outfall #003 – **Secondary Containment Monitoring**

Process waste or storm water in the secondary containment	Gallons	See Special Condition #5	Each proposed release or pumping*	estimate
Ammonia Nitrogen as N	mg/L	Storm water may be released at <2.5 mg/L *Every test shall be recorded. Report the suspected reason for tests above 2.5mg/L. Report the fate of the water: whether it was released, pumped to a lagoon or land applied.	Each proposed release or pumping*	grab

B. GENERAL CONDITIONS

1. Standard Conditions

In addition to other conditions stated herein, this permit is subject to the attached Part I STANDARD CONDITIONS dated October 1, 1980, and hereby incorporated as though fully set forth herein.

2. Definitions

Definitions are as listed in the "Missouri Concentrated Animal Feeding Operation Nutrient Management Technical Standard" and in State Regulations under 10 CSR 20 Chapter 2 and Chapter 6.300.

3. Permit Exemptions

(a) All wastewater systems and major system modifications shall be constructed in accordance with a construction permit. As allowed in state regulations under 10 CSR 20-6.300 (2)(B), certain minor modifications and piping changes are exempted from the requirement for a construction permit. Minor modifications would include small sections of buried pipelines, normal repair or replacement of existing wastewater lines, installation of manholes, wet wells, and any other minor change that does not significantly impact the normal operation of the waste management system.

(b) In accordance with 10 CSR 20-6.300(2)(B)4, permits are not required for storage buildings for dry litter, compost, or similar materials, if the storage structure is roofed and has impermeable floors.

4. Effluent Limitations

The permittee is authorized to discharge process wastewater and storm water in accordance with the effluent limitations in this permit. The effluent limitations shall become effective upon issuance and remain in effect until such time this permit is no longer effective. Such discharges shall be managed, controlled, limited and monitored by the permittee as specified below.

(a) CAFO Production Area

(1) Requirements applicable to all CAFO production area(s):

The Production Area is that part of an operation which includes the animal confinement area, the manure storage area, the raw materials storage area, and the waste containment areas. Also included is any area used in the storage or treatment of animal mortalities or material containing mortality products.

There shall be no discharge of manure, litter, or process wastewater into waters of the state from production area point sources except as provided in subsection b. below.

A chronic weather event is a series of wet weather conditions that can delay planting, harvesting, and prevent land application and dewatering practices at wastewater storage structures. When wastewater storage structures are in danger of an overflow due to a chronic weather event, CAFO owners shall take reasonable steps to lower the liquid level in the structure through land application, or other suitable means, to prevent overflow from the storage structure. Reasonable steps may include, but are not limited to, following the department's current guidance on "Wet Weather Management Practices for CAFOs". These practices shall be designed by the department to specifically help minimize or eliminate water quality impacts from CAFOs during extreme wet weather periods. The Missouri Climate Center will determine, within a reasonable timeframe, when a chronic weather event is occurring for any given county in Missouri. The Climate Center's determination will be based upon an evaluation of the 1 in 10 year return rainfall frequency over a 10-day, 180-day and 365-day operating period.

B. GENERAL CONDITIONS (continued)

Manure, litter or wastewater management activities occurring outside of the discrete point sources structures, barns or areas but upon land controlled by the permittee shall be identified in the permittee's Nutrient Management Plan (NMP). Activities that should be addressed include, but are not limited to, winter feeding areas, stockpiling of raw materials, manure, or litter or other animal feeding related items that have the potential to contribute pollutants to waters of the state. As necessary, the NMP shall identify controls, measures or BMPs to manage stormwater runoff and meet applicable water quality standards. This paragraph applies only to activities on land that is under the control of the CAFO owner or operator, whether it is owned, rented, or leased.

(2) Additional Requirements for Uncovered Liquid Storage Structures:

Whenever a precipitation related event causes an overflow of manure, litter, or process wastewater; pollutants may be discharged through the emergency spillway of the lagoon or uncovered storage structure provided:

(a) The storage structure is properly designed, constructed, operated and maintained to contain all manure, litter, process wastewater plus the runoff and direct precipitation from the 25-year, 24-hour design storm event for the location of the CAFO.

(b) The design storage volume is adequate to contain all manure, litter, and process wastewater accumulated during the storage period including the following:
- (1) The volume of manure, litter, process wastewater, and other wastes accumulated during the storage period;
- (2) 1 in 10 year 365 day annual rainfall minus evaporation during the storage period;
- (3) 1 in 10 year 365 day normal runoff during the storage period;
- (4) The direct precipitation from the 25-year, 24-hour storm;
- (5) The runoff from the 25-year, 24-hour storm event;
- (6) Necessary freeboard to maintain structural integrity; and
- (7) A minimum treatment volume for treatment lagoons.

(c) Discharge is allowed via overflow through the emergency spillway of the lagoon or uncovered storage structure when caused by a storm event that exceeds the design storm event(s). Only that portion of storm water flow, which exceeds the design storm event(s) may be discharged. Process wastewater discharge is not allowed by pumping, siphoning, cutting of berms, or by any other method, except as authorized herein, unless prior approval is obtained from the department.

(d) Upper and Lower Storage Operating Levels:
- (1) During normal weather conditions, the liquid level in the storage structure shall be maintained below the upper operating level, as identified in the FACILITY DESCRIPTION, so that adequate storage capacity is available for use during adverse weather periods when conditions are not suitable for proper land application. The lower operating level shall be used as an operational guideline; however, under normal operating conditions the level should not be lower than two feet above the lagoon floor.
- (2) The liquid level in the storage structure should be lowered on a routine schedule based on the design storage period and Nutrient Management Plan. Typically this should be accomplished prior to expected seasonal wet and winter climate periods.
- (3) The upper operating level for uncovered storage structures is one foot below the emergency overflow level unless specified otherwise in the FACILITY DESCRIPTION.
- (4) The operation shall be managed so that the level of liquids in the storage structure does not exceed the upper operating level except when a 25-year, 24-hour storm or a 1 in 10-year chronic storm occurs, in accordance with General Conditions 4.(a)(2)(e)(1), below.

(e) Storage Safety Volume:
- (1) When a chronic or catastrophic design storm event occurs, the "safety volume" may be used to contain the stormwater until conditions are suitable for land application.
- (2) The required safety volume shall be maintained between the overflow level and the upper operating level.

B. GENERAL CONDITIONS (continued)

(b) CAFO Land Application Areas

The Land Application Area is agricultural land which is under the control of the CAFO owner or operator, whether it is owned, rented, or leased, to which manure, litter or process wastewater from the production area is or may be applied.

There shall be no discharge of manure, litter, or process wastewater to waters of the state from a CAFO as a result of the land application of manure, litter or process wastewater to land application areas under the direct control of the CAFO, except where it is an agricultural storm water discharge. When manure, litter, or process wastewater has been land applied in accordance with this permit, a precipitation related discharge of manure, litter or process wastewater from land areas under the control of the CAFO is considered to be an agricultural storm water discharge.

5. Nutrient Management Plan

In accordance with 10 CSR 20-6.300(3)(G), the permittee shall implement a Nutrient Management Plan that at a minimum addresses the following.
- (a) Ensures adequate storage of manure, litter and process wastewater, including procedures to ensure proper operation and maintenance of the storage facilities.
- (b) Ensures proper management of mortalities.
- (c) Ensures that clean water is diverted from the production area.
- (d) Prevents direct contact of confined animals with waters of the state.
- (e) Ensures that chemicals and other contaminants handled on site are not disposed of in any manure, litter, process wastewater, or storm water storage or treatment system unless specifically designed to treat such chemicals and other contaminants.

(f) Identifies appropriate site specific conservation practices to be implemented, including as appropriate buffers or equivalent practices, to control runoff of pollutants to waters of the state.
(g) Identifies protocols for appropriate testing of manure, litter, process wastewater, and soil.
(h) Establishes protocols to land apply manure, litter, or process wastewater in accordance with site specific nutrient management practices that ensure appropriate agricultural utilization of the nutrients in the manure, litter, or process wastewater.
(i) Identifies specific records that will be maintained.

6. Nutrient Management Technical Standard

The permittee shall follow Attachment A - "Missouri Concentrated Animal Feeding Operation Nutrient Management Technical Standard" (NMTS), except where otherwise stipulated in this permit. The NMTS, dated March 4, 2009, is hereby incorporated as though fully set forth herein.

7. Transfer of Manure, Litter, and Process Wastewater to Other Persons

In cases where CAFO-generated manure, litter, or process wastewater is sold, given away, or applied on land not under the direct control of the CAFO, the permittee must comply with the following conditions:
(a) Maintain records showing the date and amount of manure, litter, and/or process wastewater that leaves the permitted operation.
(b) Record the name and address of the recipient. (The recipient is the broker or end user, not merely the truck driver.)
(c) Provide the recipient(s) with representative information on the nutrient content of the manure, litter, and/or process wastewater.
(d) These records must be retained on-site, for a period of five (5) years.
(e) Provide the recipient with a copy of the NMTS.

B. GENERAL CONDITIONS (continued)

8. Mortality Management

Mortalities must not be disposed of in any liquid manure or process wastewater system that is not designed to treat animal mortalities. Animals shall be disposed of in a manner to prevent contamination of waters of the state or creation of a public health hazard.

9. Water Quality Standards

Any discharges to waters of the state, including those discharges allowed for within this permit, shall not cause a violation of the state water quality standards rule under 10 CSR 20-7.031, including both specific and general criteria.

General Criteria. The following general water quality criteria shall be applicable to all waters of the state at all times including mixing zones. No water contaminant, by itself or in combination with other substances, shall prevent the waters of the state from meeting the following conditions:
(a) Waters shall be free from substances in sufficient amounts to cause the formation of putrescent, unsightly or harmful bottom deposits or prevent full maintenance of beneficial uses;
(b) Waters shall be free from oil, scum and floating debris in sufficient amounts to be unsightly or prevent full maintenance of beneficial uses;
(c) Waters shall be free from substances in sufficient amounts to cause unsightly color or turbidity, offensive odor or prevent full maintenance of beneficial uses;
(d) Waters shall be free from substances or conditions in sufficient amounts to result in toxicity to human, animal or aquatic life;
(e) There shall be no significant human health hazard from incidental contact with the water;
(f) There shall be no acute toxicity to livestock or wildlife watering;
(g) Waters shall be free from physical, chemical or hydrologic changes that would impair the natural biological community;
(h) Waters shall be free from scrap tires, car bodies, appliances, demolition debris, used vehicles or equipment and solid waste as defined in Missouri's Solid Waste Law, section 260.200, RSMo, except as the use of such materials is specifically permitted pursuant to section 260.200-260.247.

10. Closure of Waste Storage Structures

CAFOs that plan to close a lagoon or other liquid waste storage structure shall submit for department review and approval a closure plan that complies with the following minimum closure requirements:

(a) Lagoons and waste storage structures shall be closed by removal and land application of wastewater and sludge.
(b) The removed wastewater and sludge shall be transferred or land applied in accordance with the terms of this permit.
(c) After removal and proper land application of wastewater and sludge, the earthen basins may be demolished by removing the berms, grading, and revegetating the site; or the basin may be left in place for future use as a farm pond or similar uses when water quality monitoring shows such uses are attainable.

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B. GENERAL CONDITIONS (continued)

11. Reopener Clause

This permit may be reopened and modified, or alternatively revoked and reissued, to:

(a) Comply with any applicable effluent standard or limitation issued or approved under Sections 301(b)(2)(C) and (D), 304(b)(2), and 307(a) (2) of the Clean Water Act, if the effluent standard or limitation so issued or approved:
   (1) contains different conditions or is otherwise more stringent than any effluent limitation in the permit; or
   (2) controls any pollutant not limited in the permit.
(b) Incorporate new or modified State of Missouri Statutes or Regulations.
(c) Incorporate new or modified effluent limitations or other conditions, if the result of a waste load allocation study, toxicity test or other information indicates changes are necessary to assure compliance with Missouri's Water Quality Standards.
(d) Incorporate new or modified effluent limitations or other conditions if, as the result of a watershed analysis, a Total Maximum Daily Load (TMDL) limitation is developed for the receiving waters which are currently included in Missouri's list of waters of the state not fully achieving the state's water quality standards, also called the 303(d) list.

The permit as modified or reissued under this paragraph shall also contain any other requirements of the Clean Water Act then applicable.

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C. SPECIAL CONDITIONS

1. Nutrient Management Plan

The permittee shall submit an updated nutrient management plan (NMP) that complies with the requirements listed in this permit within six months of the effective date of this permit. The NMP shall include operation and maintenance procedures for wastewater handling systems as necessary to maintain compliance with the terms and conditions of this permit. As operational changes are made to site's wastewater handling systems, the permittee shall amend applicable portions of the NMP within three months of said changes. Upon receipt of the plan, the department will conduct a review and, if needed, will submit a comment letter regarding any deficiencies within the nutrient management plan. All comments shall be responded to within 30 days of receipt of a letter. The updated NMP shall be followed beginning on the effective date of the permit.

2. Inspections

The following minimum visual inspections shall be conducted by the CAFO operator.

(a) Confinement barns which regularly utilize a liquid flush/recycle system shall include a visual inspection of the flush and recycle waste management system. Visual inspections shall be made at least once every twelve (12) hours, plus or minus three (3) hours.
(b) Daily inspections must be conducted of water lines including wastewater, drinking water, and cooling water lines that can be visually observed within the production area. The inspection of the drinking water and cooling water lines shall be limited to the lines that possess the ability to leak or drain to wastewater storage structures or may come in contact with any process waste.
(c) Daily inspections of the collection or holding areas for dead animals.
(d) Weekly inspections of all storm water diversion devices, runoff diversion structures, and devices channeling contaminated storm water to the process wastewater storage.
(e) Weekly inspections of the manure, litter, and process wastewater impoundments. The inspection will note the level in liquid impoundments as indicated by the depth marker.
(f) Quarterly inspections, prior to use, of equipment used for land application of manure or process wastewater.

(g) Inspections during land application as follows:
   (1) Monitor the perimeter of the application fields to insure that applied wastewater does not run off the fields where applied.
   (2) Monitor for drifting from spray irrigation.
   (3) Hourly inspections of aboveground irrigation pipelines not contained.
   (4) Twice daily inspections of pressurized underground lines including one inspection that should be completed immediately following startup.

Any deficiencies found as a result of inspections shall be documented and corrected as soon as practicable.

3. Record Keeping

The following records shall be maintained by the CAFO operator for a period of five (5) years from the date they are created and be made available to the department upon request:

(a) A copy of this permit including a current copy of the facility's Nutrient Management Plan and documentation of changes/modifications made to the Nutrient Management Plan.
(b) The daily visual inspections required in Special Condition #2, shall be logged/recorded once per week. This includes a once per week record of the depth of the process wastewater in the liquid impoundments as indicated by the depth marker. Report the liquid level as feet below the emergency overflow level.
(c) Records documenting any actions taken to correct deficiencies. Deficiencies not corrected within thirty (30) days shall be accompanied by an explanation of the factors preventing immediate correction.
(d) Records of mortalities management used by the operation.
(e) Records of the date, time, location, duration and estimated volume of any emergency or unauthorized process waste overflow from a lagoon or any spill exceeding 1000 gallons. Note: Monitor the discharge at the point immediately prior to the receiving stream or at the property boundary, whichever occurs first. Report flow as cubic feet per second (CFS) based on an instantaneous estimate of the flow at the time of sampling. CFS = flow width in feet x flow depth in feet x flow velocity in feet per second. Estimates of stream channel width and depth may be used and flow velocity can be measured by timing how many feet a floating object moves within a one-second interval. Small flows may also be estimated based on gallons per minute (GPM) measurement using a container and stop watch; 450 gpm = 1.0 CFS. Other similar means of estimating may also be used.

C. SPECIAL CONDITIONS (continued)

(f) Additional record keeping requirements are found in Attachment B, "Nutrient Management Technical Standard" that document implementation of appropriate Nutrient Management Plan protocols. In addition to the requirements found in the Nutrient Management Technical Standard, the CAFO shall also test and record the potassium levels in the soils while testing nitrogen and phosphorus.
(g) The inches of precipitation received at the production site, recorded daily and reported for daily amounts, monthly totals, and cumulative total.

4. Reporting Requirements

(a) Any wastewater discharge into waters of the state shall be reported to the Department as soon as practicable but no later than 24 hours after the start of the discharge.
(b) Spills or leaks that are contained on the property shall also be reported to the Department within 24 hours, if the spill or leak exceeds 1,000 gallons per day. This includes leaks from sewer lines, recycle lines, flushing systems, lagoons, irrigation systems etc.
(c) Within seven (7) days of the date that a lagoon's level comes within four (4) inches of the upper operating level, the permittee shall notify the department with information that identifies the lagoon(s), the lagoon level in inches below the emergency spillway and actions taken to reduce the lagoon levels.
(d) The permittee shall notify the Water Protection Program as soon as practicable but no less than 24 hours in advance of implementing the department's "Wet Weather Management Practices for CAFOs" during a chronic weather event.
(e) An Annual Report shall be submitted by January 28 of each year for the previous growing season from October 1 through September 30 or an alternate 12 month period approved by the Department. The report shall include:
   (1) The number and type of animals confined at the operation.
   (2) The estimated amount of manure, litter, and process wastewater generated in the previous twelve months.
   (3) The estimated amount of manure, litter, and process wastewater transferred to other persons in the previous twelve months.
   (4) The total number of acres for land application covered by the Nutrient Management Plan.
   (5) The total number of acres under control of the operation that were used for land application of manure, litter and process wastewater in the previous twelve months.

(6) A summary of all manure, litter, and process wastewater discharges from the production area that have occurred in the previous twelve months, including date, time, and approximate volume. Report as no-discharge, if a discharge did not occur during the monitoring period.
(7) A statement indicating whether the current Nutrient Management Plan was developed or approved by a certified nutrient management planner.
(8) The crops planted and expected yields, the amount and nutrient content of the manure, litter, and process wastewater applied to the land application area(s) and the results of any soil testing from the previous twelve months.
(9) The weekly records of the wastewater depth in the liquid impoundments as required in section C.3.b. above.
(10) The actual operation numbers compared to the permitted design parameters described in Special Condition #6.
(11) All monitoring results from Section A. Effluent Limitations and Monitoring Requirements.

(f) The reports shall include a cover sheet with an original signature of a company representative. The reports may be printed or alternatively, may be saved as pdf files or locked spreadsheets and burned onto two compact discs (CDs). The CDs may be sent via mail with the coversheet to the Northeast Regional and the Jefferson City offices.

5. Secondary Containment Structures Outfall #003

(a) Containment structures or earthen dams shall be maintained down gradient of all confinement buildings and sewer lines, gravity outfall lines, recycle pump stations and recycle force mains in order to collect and retain wastewater discharges from spills or pipeline breaks. The containment structure shall be able to collect a minimum volume equal to the maximum pumping capacity of the recycle pump for the wastewater flushing system in any 24-hour period. Though not required, containment structures may also be located below underground tile outlets from irrigation sites or other areas not already protected by secondary containment.
(b) There shall be no release of process wastewater from secondary containment structures. Any wastewater spills or leaks collected in the containment structures shall be pumped into the lagoon or directly land applied so that there is no discharge of process waste. Before release of any accumulated storm water from the containment structures the water shall be tested for ammonia.

(c) Storm water may be released from the containment structure when the ammonia-N content is less than 2.5 mg/L. Storm water that exceeds these limits shall be pumped into the lagoon or properly land applied.
(d) In-field testing for ammonia nitrogen using colorimetric testing or other approved testing methods may be used for sampling of storm water in the containment structures. Testing and release procedures shall be described in the Nutrient Management Plan.
(e) Existing storm water flows shall not be diverted around or allowed to bypass the secondary containment structure, even when the flush system is not in use, without the prior approval of the Water Protection Program. Additional storm water may be directed to the secondary containment if desired by the permittee.

6. Design Parameters

The facility's design flow in the Facility Description is an estimated parameter that is used to help predict nutrient generation and storage periods. The design flow is based on the maximum annual flows including storm water flows during the one-in-ten year return frequency for annual or 365 day rainfall minus evaporation. The design flow is based on the time period when the flows are generated at the production site and not when flows are land applied. Permittee may exceed the design flow when precipitation in any 365 day period exceeds the one-in-ten year annual precipitation amount. Any proposed increases may require a permit modification prior to the proposed change. Portions of the design flow may be stored and carried over into the following year for land application, as necessary.

7. Land Application Site Locations

The permittee is responsible for all land application area(s) that are owned, rented, leased, or otherwise directly controlled by the permittee. All land application area(s), that fall under the definition of "land application area" as defined in 10 CSR 20-6.300, must be included in the facility's nutrient management plan. The addition of land application area(s) into the facility's nutrient management plan (except for those already in a nutrient management plan) must follow permit modification procedures prior to land application unless otherwise approved by the department. When the permittee applies process wastewater to agricultural lands that are not owned, rented, leased or directly controlled, the permittee shall do so, and maintain records, in accordance with the Missouri Concentrated Animal Feeding Operation Nutrient Management Technical Standard (NMTS).

8. Land Application Limitations

(a) Process wastes should be land applied as close as practicable to when plants will utilize nutrients. Fall application for the spring crop season may be used where appropriate, but should not be the primary application period. Land application of process wastes shall be utilized as a nutrient resource.
(b) Avoid surface application when there is a local, applicable weather forecast or observation by permittee of an imminent or impending storm event that is likely to produce runoff.
(c) Land application equipment shall be operated in such a manner that wastes do not reach an adjoining property line, public use area or into waters of the state. There shall be no visual spray drifts across public roads or property boundaries or into waters of the state. If the employee detects wind blown mist within 100 feet of an adjoining property line or public use area or waters of the state the application equipment shall be either moved farther away or shut down.
(d) The NMP shall include appropriate site specific conservation practices, including as appropriate buffers or equivalent practices, to control runoff of pollutants to waters of the state.
(e) Spray irrigation systems (travelling guns, center pivot, fixed spray nozzles, etc) shall have automatic shut-off devices at the pump in the case of pressure loss.
(f) Land application rate shall be calculated during start up of spray irrigation equipment each day of operation by confirming operational parameters such as pressure, nozzle size, speed and other parameters. Calibration of traveling gun irrigation systems shall be verified at least once/month during the land application season using rain gauges or collection pans within the spray pattern of the equipment to determine application rates.
(g) Implementation procedures for these limitations shall be detailed in the Nutrient Management Plan.
(h) Domestic sludge shall be removed as needed and land applied in accordance with 40 CFR 503 sludge standards for septage and University of Missouri Water Quality Guide publication #WQ422.

C. SPECIAL CONDITIONS (continued)

9. Hydraulic Application Rate Limitations

(a) Hydraulic application rates in inches/application pass and inches/day shall not exceed the soil infiltration capacity and soil moisture holding capacity (saturation capacity) of the soil. In no case shall the application result in the runoff of applied waste during or immediately following application.
(b) For field slopes less than or equal to ten percent (0-10%), surface application rates other than tool bar application shall not exceed 0.5 inches/application pass and 1.0 inch/day depending on soil condition, except for short periods when initial soil moisture is significantly below field capacity in accordance with 10 CSR 20-8.020(15)(F)6. For tool bar application, the rate shall not exceed 1.0 inch/day.
(c) For field slopes greater than ten percent (10%), but less than or equal to twenty percent (20%), surface application rates shall be reduced to one-half the rate for slopes of ten percent (10%) or less. The Nutrient Management Plan shall include a topographic map showing slopes and drainage patterns. The number of acres approved for various slope conditions are listed in the operation description section of this permit.
(d) For subsurface injection, application rates shall be based on soil absorption capacity during land application so that there are no puddles of wastewater on the soil surface. In no case shall the application rate exceed 1.0 inch/day (27,154 gallons/acre). The subsurface application rate and procedures for adjusting the rate to match soil moisture and field slope conditions shall be listed in the Nutrient Management Plan.

10. Design Operating Capacity

This permit authorizes operation of the CAFO waste management system as described in the "FACILITY DESCRIPTION" along with the permit application and associated engineering plans. The Facility Description describes a design animal unit operating capacity (i.e., number of animals) for this facility. For purposes of this permit, the animal unit operating level at any given time shall be based on averaging the weekly facility wide inventory on a rolling 12 month average (i.e., the animal unit operating level will be determined using a "rolling 12 month average" of the "weekly facility-wide average inventory"). The rolling 12 month average should not exceed, the listed facility-wide design animal unit capacity in the Facility Description. The CAFO may change animal numbers and weights as necessary; however, such changes must not adversely impact the storage and handling capacities of the waste management system.

11. Underground Tile Outlets at Land Application Sites

(a) Any underground tile outlets from field terraces or subsurface field drainage tiles shall be shown on the site maps for all land application sites.
(b) To prevent potential discharge of wastewater during irrigation of fields with underground tile the permittee shall either:
   (1) Cap, plug, or otherwise prevent wastewater from entering the inlets during irrigation;
   (2) Provide a 35 foot permanently vegetated buffer area between the inlets and wetted irrigation area;
   (3) Provide a 100 foot separation between the inlets and wetted irrigation area;
   (4) Use subsurface injection type application equipment and a 50 foot separation from the tile inlet; or
   (5) Install secondary containment structures below the tile outlets and follow the testing and reporting procedures for secondary containment described in this permit.

12. Sample Collection, Preservation and Testing Methods

In field testing methods or other approved methods may be used for secondary containment monitoring. Other testing shall be in accordance with the most current version of *Standard Methods for the Examination of Waters and Wastewaters* or other approved methods listed in 10 CSR 20-7.015(9)(A).

13. Dead Animal Disposal

There shall be no-discharge from dead animal collection areas or holding areas (dumpsters, holding tanks, stockpiles within livestock production buildings, refrigeration units, etc). Any liquid drainage or wash water shall be collected and placed into the animal waste lagoon or hauled off-site to a permitted treatment/disposal facility. There shall not be any leakage from the collection or holding areas to the soil surface or subsurface. Dead animals shall be collected and hauled off site for rendering or disposal in accordance with the Dead Animal Disposal Law under Chapter 269 RSMo. Other methods of mortality disposal will require prior approval of from the Water Protection Program.

Missouri Department of Natural Resources
Concentrated Animal Feeding Operation
NPDES Site Specific Permit Factsheet

The Federal Water Pollution Control Act ("Clean Water Act" Section 402 Public Law 92-500 as amended) established the National Pollution Discharge Elimination System (NPDES) permit program. This program regulates the discharge of pollutants from point sources into the waters of the United States, and the release of storm water from certain point sources. All such discharges are unlawful without a permit (Section 301 of the "Clean Water Act"). After a permit is obtained, a discharge not in compliance with all permit terms and conditions is unlawful. Permits in Missouri are issued by the Missouri Department of Natural Resources (department), as the administrative agent for the Missouri Clean Water Commission, under an approved program, operating in accordance with federal and state laws (Federal "Clean Water Act" and "Missouri Clean Water Law" Section 644 as amended). NPDES operating permits are issued for a period of five (5) years unless otherwise specified.

A Factsheet gives pertinent information regarding the applicable regulations, rational for the development of the NPDES Missouri State Operating Permit (operating permit), and the public participation process for operating permit listed below.

A Factsheet is not an enforceable part of an operating permit.

This Factsheet is for a Permit Renewal ☒; Permit Modification ☒; and/or permit with widespread public interest ☐.

Facility Information

NPDES Permit No.: [redacted]

Owner:
Owner Address: [redacted]

Facility Name:
Facility Address: [redacted]

MDNR Region: Northeast Regional Office
Facility County: Lewis

Facility Type: Class 1A-Concentrated Animal Feeding Operation (CAFO)
Facility SIC Code(s): 0241 and 0214

Facility Description:

The farm consists of 3 animal complexes designated Outfalls 001, 002, 003 and 009. Outfall 001 (west complex) and Outfall 002 (east complex) may contain approximately 2,625 dry cows or equivalent combination of cows, heifers, or calves each. Outfall 003 (dairy milking parlor and free stall barns) may contain approximately 4,464 dairy cows. The number of animals at each complex may vary provided the total number of cows at the operation does not exceed 8,514 head. Lots are concrete surface. Solids will be scraped from the East complex and stored in a concrete pit located at the East complex to be land applied using a solids spreader. A PVC pipe drains any precipitation collected in the concrete pit to the earthen storage basin on site. The residual manure from the complex will be washed to an earthen storage basin, via precipitation runoff. Wastes will be removed from the milking parlor using a freshwater flush system and from the free stall barns using recycled water and a solids separator. Remaining wastewater will be transported to an earthen storage basin via PVC pipe. Outfall 009 (Goat Milking Facility) contains 1200 dairy goats, a milk parlor, animal waste lagoon, domestic waste basin and animal loafing buildings. The goats also have access to pasture. The waste from the loafing buildings is kept dry with bedding and the waste is occasionally removed and hauled to the composting operation.

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Effected Outfalls and other Modifications
Note: All outfalls are detailed in the operating permit starting on page 2.

This permit does not include an increase in animal numbers or animal capacity at this site.

The department is renewing, with changes, a Missouri State Operating Permit for the Sharpe Land and Cattle Company located in Lewis County. This facility is a Missouri Class IA Concentrated Animal Feeding Operation (CAFO) which, due to its classification and size has been required by the department to retain a site-specific operating permit. As part of the program's review process, a site visit was conducted on March 11, 2010 to evaluate existing stream monitoring sites.

Water Quality Monitoring -
The Sharpe Land and Cattle Company permit has, in previous permit cycles, required varying amounts of water quality monitoring. The monitoring requirements in previous permits at this site have included sampling locations for storm water, in-stream and fresh water lake monitoring with sampling frequencies of quarterly, monthly and monthly respectfully. The purpose behind the department's monitoring requirements was to help aid in ascertaining any water quality related impacts from the CAFO's operation and land application of manure. Technical staff in both the Permits and Water Quality Monitoring Section have reviewed the results of the past monitoring and generally conclude that further extensive monitoring is unnecessary as there is no indication from past water quality data that a reasonable potential exists for the SLC CAFO to violate water quality standards when it is managed and operated in accordance with permit requirements.

With this in mind, the department has reduced some of the complexity of the monitoring requirements within the SLC permit. Storm water monitoring will be addressed by requiring sampling of the fresh water lake that receives stormwater runoff from land application areas. The fresh water lake on this farm includes land application areas as a significant portion of its watershed. Regular sampling of the impounded water within secondary containment structures will also be required to account for stormwater impacts from the production area. The secondary containment structures are designed to collect and retain stormwater runoff from that portion of the production area that presents the most risk to spills, leaks or other piping system malfunctions. In previous permits, when the ammonia-nitrogen level in the containment water was greater than 2.5 mg/l, the permit required the collected stormwater to either be land applied or pumped back into the lagoon. This permit proposes to require reporting of all testing results at secondary containments, not just when this storm water is released to the environment. In addition, the permittee will report the actual measured value, rather than just reporting <2.5mg/l. In-stream monitoring requirements have been retained and will include two monitoring points (upstream and downstream) on the primary receiving stream for this site and will be sampled four times per year during times that likely coincide with land application.

Secondary Containment Structures -
Secondary containment structures collect storm water runoff from the site as well as accidental spills. As such, they are used in this permit, together with fresh water lake discharge monitoring, to meet the requirements of 10 CSR 20-6.300((3)(H)3.F.(III).

Inspections, Record Keeping, and Reporting Requirements -
On February 28, 2009, the department finalized changes to department's CAFO regulation at 10 CSR 20-6.300. In response to the new regulations, the department made several additions and changes to the inspections, record keeping, and reporting requirements to address the new state requirements.

Prior permits have included submittal of a quarterly report and an annual report in paper format. The annual report contained essentially the same information that was found in the quarterly report. Department staff rarely has the time or the need to regularly review the quarterly reports and the sheer volumes of documents and paper generated by the submittal of these reports fill up file room space in both the regional and central offices. The department plans to reduce the reporting requirement down to an annual report only and will provide Sharpe Land and Cattle Company an option of submitting the annual reports electronically on a CD-ROM. This permit requires that all records required by the permit be made available, upon request, for department review and if deemed necessary can be reviewed by the department during quarterly inspections.

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The department also notes that state statutes and regulation identifies the <u>utilization</u> of a "flush wet handling system" as a precondition for the specific visual inspection requirement found at 10 CSR 20-6.300(3)(H)1. This specific requirement requires visual inspections be conducted of the waste management system at least once every twelve (12) hours at production sites. The department recognizes that flush systems may go un-utilized for short durations (e.g. several weeks) during barn cleanout or during other maintenance related activities and in these circumstances, suspension of this inspection requirement is not authorized.

Nutrient Management -
Proper management and utilization of farm generated manure nutrients at a CAFO is key to its ability to operate in a safe and protective manner. State regulations pertaining to nutrient management at CAFOs have significantly changed since the last permit cycle. In particular, the requirements pertaining to development of application rates, including soil test phosphorus limitations, have become more prescriptive. The following are additions and/or changes that have been proposed for this permit which are direct result from recent updates in the state regulation.

This permit has been updated to reflect new nutrient management requirements. Most notably, new permit conditions have been included that require the CAFO to develop and implement a site-specific Nutrient Management Plan (NMP) that complies with nine specific criteria. The proposed permit stipulates a 6 month compliance schedule, which will begin on the date of issuance, for the development and submittal of this NMP. One of the key reasons the department is allowing the six month compliance date is that the CAFO must have the final permit requirements in order to fully develop a site specific NMP for this site. The permit also now requires Sharpe Land and Cattle Company to complete a phosphorus risk assessment on the land application fields that they own or control. This assessment will identify fields that have a high susceptibility to phosphorus loss and will place application rate restrictions on high risk fields. This protocol provides for a more predictable and systematic approach to phosphorus management as compared to the phosphorus assessments and limitations used in previous permits.

The permit now incorporates by reference the department's "Nutrient Management Technical Standards" (NMTS). This standard was developed to provide a framework for the protocol(s) and method(s) that CAFOs should utilize when determining the form, source, amount, timing, and method of application on individual land application fields. The NMTS represents the department's best professional judgment regarding how to satisfy and/or implement the specific NMP criteria G, H and I within 10 CSR 20-6.300(5)(A). The framework seeks to achieve realistic production goals while ensuring appropriate agricultural utilization of the nutrients in the manure, litter, or process wastewater while also minimizing movement of nitrogen, phosphorus, and other potential water contaminants into surface and/or ground water.

Land Application Areas -
The permit requires the permittee be responsible for all land application area(s) that are owned, rented, leased, or otherwise directly controlled by the permittee. All lands that fall under the definition of "land application area" as defined in 10 CSR 20-6.300, must be included in the facility's nutrient management plan.

When the permittee proposes to include additional land application area into the facility's nutrient management plan (except when such land is already in a nutrient management plan), the permittee must follow permit modification procedures prior to land application unless otherwise approved by the department.

When the permittee conducts land application activities to agricultural lands that are not owned, rented, leased or directly controlled, the proposed permit requires the permittee to conduct those activities, and maintain records, in accordance with the Missouri Concentrated Animal Feeding Operation Nutrient Management Technical Standard (NMTS).

When the permittee sells or gives away CAFO-generated manure the permit requires the CAFO maintain certain records documenting the name of recipient, the date and amount of manure, litter, and process wastewater that leaves the permitted operation. It also requires the permittee provide the recipient with representative information on the nutrient content of the manure, litter, and/or process wastewater along with a copy of the Department's Nutrient Management Technical Standard.

<u>Receiving Stream Information</u>

Please mark the correct designated waters of the state categories of the receiving stream.

Missouri or Mississippi River [10 CSR 20-7.015(2)]:	Yes ☐; No ☒
Lake or Reservoir [10 CSR 20-7.015(3)]:	Yes ☐; No ☒
Losing [10 CSR 20-7.015(4)]:	Yes ☐; No ☒
Metropolitan No-Discharge [10 CSR 20-7.015(5)]:	Yes ☐; No ☒
Special Stream [10 CSR 20-7.015(6)]:	Yes ☐; No ☒
Subsurface Water [10 CSR 20-7.015(7)]:	Yes ☐; No ☒
All Other Waters [10 CSR 20-7.015(8)]:	Yes ☒; No ☐

10 CSR 20-7.031 Missouri Water Quality Standards, the department defines the Clean Water Commission water quality objectives in terms of "water uses to be maintained and the criteria to protect those uses." The receiving stream and/or 1st classified receiving stream's beneficial water uses are to be maintained in accordance with 10 CSR 20-7.031(3)

Receiving Stream Monitoring Requirements:

Over ten years of water quality stream data has been collected by SLC in order to analyze stream impacts from their facility. In analyzing data from both the monitoring required previously by this permit along with USGS monitoring locations, the department has found no obvious problems or differences in watersheds that house large CAFOs compared to those that do not. Water quality data generally show that the effects on water quality from agricultural non-point source activities, like unconfined livestock and commercial fertilizer use, appears to be similar to that of CAFOs that are reasonably well managed. With that said, the department has included two stream monitoring locations (upstream and downstream) within the primary receiving stream be retained in this permit with a frequency of four times per year.

<u>RATIONALE AND DERIVATION OF EFFLUENT LIMITATIONS & PERMIT CONDITIONS</u>

PERMIT APPLICABILITY:
National Pollutant Discharge Elimination System (NPDES) permits are required for operations defined in 10 CSR 20-6.300 as a Concentrated Animal Feeding Operation (CAFO). Site-specific permits are required for CAFO operations that fall within the class IA category. Operations that fall under this category confine 7,000 or more animal units. The department, however, can require site specific permits to other class I operations if it is determined that the quality of the waters of the state would be better protected with one.

PERMIT COVERAGE

This site specific permit will cover all production areas, which include the confinement, storage, and handling areas, as well as the land application activities at sites that are under the ownership or control of the permitted CAFO owner/operator. This permit applies only to requirements of, and regulations promulgated under, the Missouri Clean Water Law and Federal Clean Water Act and does not apply to other environmental laws and regulations. This permit does not recognize, supersede nor remove liability from compliance with county and other local ordinances.

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WHAT CONSTITUTES A DISCHARGE FROM A CAFO:
A discharge of process waste is the discharge of pollutants into surface or subsurface waters of the state from the animal confinement or storage and handling areas of a CAFO including in some circumstances the land application area(s) under the ownership or control of the CAFO operator.

Discharges prohibited by this permit include, but are not limited to, the following:
- Discharge from manure storage structures (lagoons, basins, pits, etc.), unless discharge was due to storm events exceeding the chronic or catastrophic storm events for the design storage period.*
- Discharge of contaminated runoff from non-vegetated feedlots, stockpiled manure, and other feedstock storage;
- Discharges associated with improper land application of manure and/or wastewater activities under the control of the CAFO operator;
- Discharges of manure and/or wastewater due to pipe breakage or equipment failure.

*Discharge is allowed due to overflow through the emergency spillway of the lagoon or other uncovered storage structure when the overflow is caused by storm events that exceed the defined design storm event. Only that portion of storm water flow, which exceeds the design storm event may be discharged.

Stormwater discharges from land application areas that have received manure as fertilizer are authorized under this permit. Storm water that comes from land application sites is exempt from effluent limits. The reason storm water discharges are not subject to discharge limits is because the federal definition of a point source contains a specific exclusion for agricultural storm water. This exclusion was further clarified when the U.S. Environmental Protection Agency (USEPA) promulgated the revised CAFO Regulations on February 12, 2003. The clarification stated that if the process waste is applied at agronomic rates, the storm water runoff from land application sites is not subject to effluent limitations. This determination by the USEPA was later upheld by the Second Circuit Court's ruling in *Waterkeeper Alliance, Inc. et. al. v. U.S. Environmental Protection Agency*, 399 F.3d 486 (2nd Cir. 2005). Since the State of Missouri has not enacted any laws that would differ from the EPA's determination or the subsequent court ruling, the storm water runoff from land application sites is exempt from effluent limitations and is considered a non-point source not subject to permit requirements.

PROPOSED DISCHARGE LIMITATIONS, MONITORING, AND TREATMENT REQUIREMENTS
Please see Section A & B of this draft Permit attached to this fact sheet

RATIONALE FOR PROPOSED DISCHARGE LIMITATIONS, MONITORING AND TREATMENT REQUIREMENTS:

Effluent parameters and limitations contained in this Missouri State Operating Permits are obtained from Technology Based Effluent Limits (TBEL), Missouri's Effluent Regulations [10 CSR 20-7.015], Missouri's Water Quality Standards [10 CSR 20-7.031], previous Missouri State Operating Permits, and from Permit Applications. When CAFOs actively operate and maintain properly designed manure and wastewater storage structures they will prevent most, if not all overflows and discharges. Because of this, the department has established Best Management Practices (BMPs) to insure proper operation and maintenance of the production area and to prevent unauthorized discharges. Because of the uncertainty that is involved in determining if runoff or overflow of process waste has led to a discharge, as well as the substantial variation of the volume and nature of the pollutants of the discharge, numeric effluent limitation guidelines to control discharges are considered infeasible. Conversely, effluent limitations in the form of BMPs are particularly suited for the regulation of CAFOs. Controlling discharges to surface water is largely associated with controlling runoff and controlling overflows from manure storage structures. Runoff from CAFOs can be highly intermittent and is usually characterized by very high flows, due to precipitation, occurring over relatively short time intervals.

Along with BMPs, proper nutrient management planning and mandated recordkeeping requirements in dealing with the CAFOs manure storage structures and land application is required under this permit. These requirements will ensure that CAFOs apply manure, litter, and other process wastewaters at rates, and in a manner consistent with appropriate agricultural utilization of nutrients. Limits on the rate at which manure or litter can be applied and certain other constraints on application practices, such as setbacks, and application methods are widely demonstrated as achievable and are being imposed through this permit.

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ANTIDEGRADATION ISSUES:
As there shall be no-discharge of process wastewater during dry weather conditions the terms and conditions proposed in this draft permit will maintain and protect the designated uses of the various receiving stream(s) as well as the level of water quality necessary to protect said water uses. With proper implementation of Best Management Practices (BMPs) and the NMTS at both the CAFO production area(s) and land application site(s) as well as other minimum standards, protection of water quality will be provided for a particular water body where the water quality exceeds levels necessary to protect fish and wildlife propagation and recreation on and in the water. This also includes special protection of waters designated as outstanding natural resource waters. Antidegradation plans are adopted by each State to minimize adverse effects on water.

ANTI-BACKSLIDING:
A provision in the Federal Regulations [CWA §303(d)(4); CWA §402(c); CFR §122.44(l)] requires a reissued permit to be as stringent as the previous permit with some exceptions.

☒ - All limits in this Factsheet are at least as protective as those previously established; therefore, backsliding does not apply.

☐ - Backsliding proposed in this Factsheet for the reissuance of this permit conform to the anti-backsliding provisions of Section 402(o) of the Clean Water Act, and 40 § CFR 122.44.

COMPLIANCE AND ENFORCEMENT:
Action taken by the department to resolve violations of the Missouri Clean Water Law, its implementing regulations, and/or any terms and condition of an operating permit.

Applicable ☐;

Not Applicable ☒; The permittee/facility is not under enforcement action and is considered to be in compliance with the Missouri Clean Water Law, its implementing regulations, and/or any terms and condition of an operating permit.

The Public Notice period for this operating permit was from July 9, 2010 to August 8, 2010.

Date of Factsheet: 10-07-2010