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A Total Maximum Daily Load for Atrazine in Aquilla Reservoir

For Segment 1254

Prepared by the:
TSSWCB TMDL Team and
TNRCC Strategic Assessment Division, TMDL Team

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Introduction

Section 303(d) of the federal Clean Water Act (CWA) requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. For each listed water body that does not meet a standard, states must develop a total maximum daily load (TMDL) for each pollutant that has been identified as contributing to the impairment of water quality in that water body. The Texas Natural Resource Conservation Commission (TNRCC) is responsible for ensuring that TMDLs are developed for impaired surface waters in Texas.

In simple terms, a TMDL is a quantitative plan that determines the amount of a particular pollutant that a water body can receive and still attain and maintain its applicable water quality standards. In other words, TMDLs are the best possible estimates of the assimilative capacity of the water body for a pollutant under consideration. A TMDL is commonly expressed as a load, with units of mass per unit of time, but may be also be expressed in other ways. TMDLs must also estimate how much the pollutant load needs to be reduced from current levels in order to achieve water quality standards.

The Total Maximum Daily Load Program, a major component of Texas' statewide watershed management approach, addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in or bordering the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses (such as drinking water, recreation, support of aquatic life, or fishing) of impaired or threatened water bodies.

The ultimate goal of this TMDL is to reduce the running annual average atrazine concentration to a level reliably and consistently below the Safe Drinking Water Act maximum contaminant level (MCL), allowing the beneficial uses to be restored to the water body.

Section 303(d) of the CWA and the U.S. Environmental Protection Agency's (EPA) implementing regulations (40 Code of Federal Regulations, Section 130) describe the statutory and regulatory requirements for acceptable TMDLs. The TNRCC guidance document, *Developing Total Maximum Daily Load Projects in Texas* (GI-250), further refines the process for Texas. Following all these guidelines, this TMDL document has been prepared and is composed of six elements which are summarized in the following sections:

- Problem Definition
- Endpoint Identification
- Source Analysis

- Linkage Between Sources and Receiving Water
- Margin of Safety
- Pollutant Load Allocation

This TMDL document was prepared by:

- the Texas State Soil and Water Conservation Board (TSSWCB) TMDL Team
- the TMDL Team in the Strategic Assessment Division of the Texas Natural Resource Conservation Commission.

The Texas State Soil and Water Conservation Board approved the TMDL document on September 20, 2001. It was adopted by the Texas Natural Resource Conservation Commission on June 14, 2002. Upon adoption, the TMDL became part of the state Water Quality Management Plan. The TNRCC and TSSWCB will use this TMDL document as a tool for managing and abating atrazine in the Aquilla Reservoir Watershed.

Background Information

Aquilla Reservoir is a watershed of the Brazos River and lies within Hill County and Johnson County in the state of Texas (HUC 12060202). The Texas state segment number for Aquilla is 1254. The watershed drains approximately 255 square miles, or 163,000 acres, and is characterized by Blackland Prairies and Cross Timbers eco-regions. Soil progresses from west to east from Gasil and Konsil sandy loams to Houston black clay (Heiden and Altoga) respectively. The watershed is divided into six main tributaries: Little Aquilla Creek, Aquilla Creek, Rocky Branch, Jack's Branch, Hackberry Creek, and Two-Mile Creek. All of these tributaries are unclassified water bodies (see Figure 1).

The Aquilla Reservoir dam was constructed by the U.S. Army Corps of Engineers in 1983 with a projected lifespan of 100 years. The Aquilla Water Supply District uses the reservoir as a drinking water source. The City of Cleburne will also be using the reservoir as a drinking water source by April of 2002. The reservoir currently supplies approximately 14,633 people with drinking water and with the addition of Cleburne, that figure will increase to approximately 26,670. The reservoir covers an area varying from 3,280 acres (or 45,962 acre feet) at a conservation pool elevation of 537.5 feet to 7,000 acres (or 132,662 acre feet) at a flood pool elevation of 556.0 feet. Currently, the Texas Parks and Wildlife Department is leasing a portion of the reservoir from the U.S. Army Corps of Engineers and is providing hunting leases for the area. The area is also being managed to increase waterfowl habitat.

Stakeholder contributions to the TMDL project are achieved through a 24 member Watershed Steering Committee. Members of the Steering Committee represent the general public, agriculture, Aquilla Water Supply District, and state and federal agencies. An agricultural subcommittee was formed to encourage awareness of best management practices and survey management practices in 1999. A Surface Water Protection Committee was formed from various government agencies and private interest groups to act as an advisory group for the TMDL. The committee continues to meet quarterly to address statewide pesticide pollution abatement.

Water quality data has been collected by different groups within the watershed. Aquilla Water Supply District, and Novartis have been collecting samples for analysis of atrazine concentrations from the reservoir since 1998. Additional water quality data, including atrazine concentration, has been collected by Blackland Research and Extension Center from the reservoir and its tributaries.

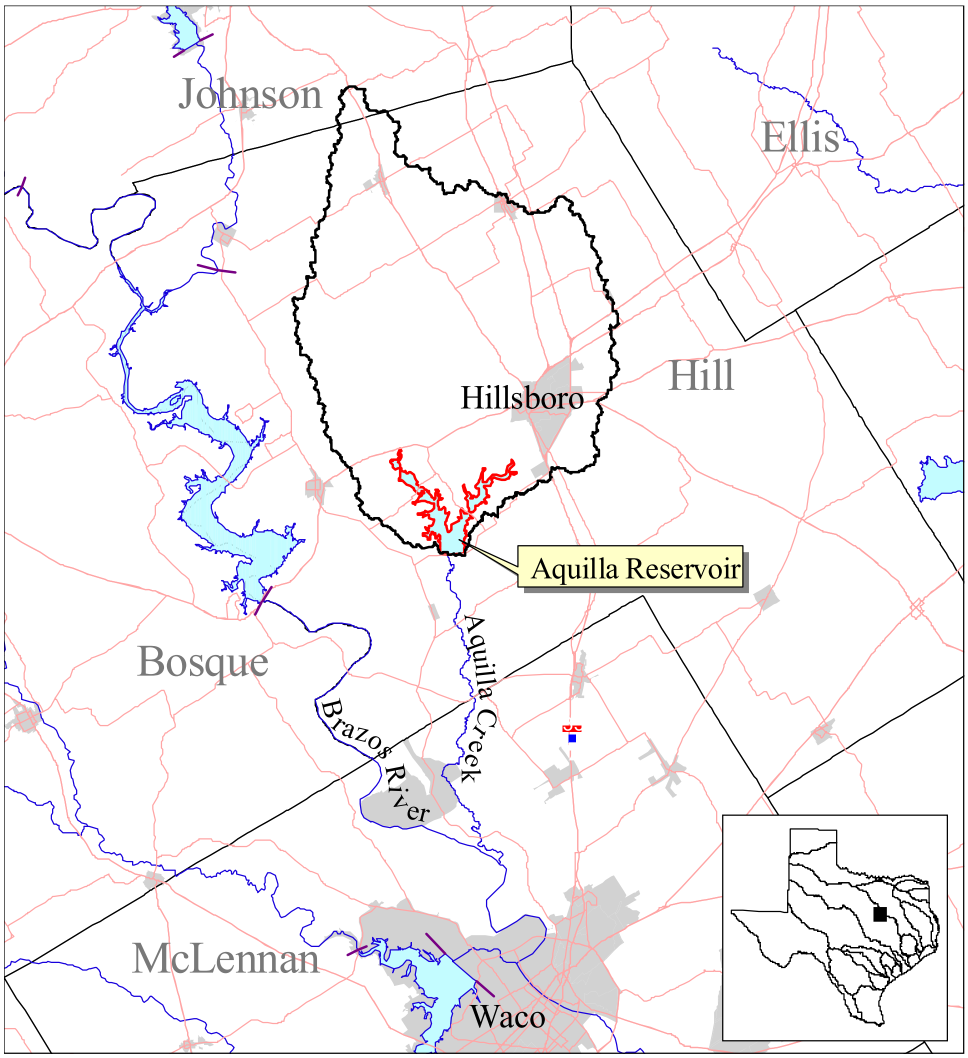

Figure 1. TMDL Project Area

Problem Definition

Aquilla Reservoir has been determined by the TNRCC to have the following uses: public water supply, fish consumption, contact recreation, and aquatic life. Aquilla Reservoir was listed on the State of Texas 1998 Clean Water Act Section 303(d) List for failure to support the public water supply use. Language from the 1998 List reads:

> "Atrazine concentrations in finished drinking water violate the Maximum Contaminant Level for primary drinking water standards. Origin of the contamination is source water and represents a failure of the water body to support the public water supply use."

As outlined in 30 TAC §290.104(c)(1), the TNRCC has established a MCL of 0.003 mg/l for atrazine in treated drinking water. For surface water systems, compliance with the MCL is based on a running annual average from quarterly sampling using EPA certified laboratories and methods for drinking water. Aquilla Reservoir was assessed as not supporting its designated use as a public drinking water supply when samples of finished drinking water from Aquilla Water Supply District, I.D. 1090068, violated the MCL for atrazine in 1998. The running annual average for the second quarter of 1997 through the first quarter of 1998 was 0.004 mg/l (see Table 1). After the MCL violation, the TNRCC listed Aquilla Reservoir on the 1998 303(d) list as impaired for atrazine, and assigned the reservoir a high priority for TMDL development. Subsequently, Aquilla Water Supply District began additional treatment to remove atrazine and has had no additional MCL violations or finished drinking water samples exceeding 50% of the MCL to date.

Table 1. Running Annual Average for Finished Drinking Water Supplies

Quarter	Sample Collection Date	Concentration (mg/l)	Quarter Average (mg/l)
2nd Quarter 1997	4/30/97	0.0089	**0.0097**
	5/15/97	0.0105	
3rd Quarter 1997	9/24/97	0.00085	**0.00085**
4th Quarter 1997	12/4/97	0.00093	**0.00093**
1st Quarter 1998	2/3/98	0.0054	**0.0054**
Running Annual Average			**0.004**

Endpoint Identification

Aquilla Reservoir was originally assessed as not supporting its designated use as a public drinking water supply when samples of finished drinking water from Aquilla Water Supply District, I.D. 1090068, violated the MCL for atrazine. Subsequently, Aquilla Water Supply District began additional treatment processes to remove atrazine from the finished drinking water. As previously stated, the TNRCC has established a MCL of

0.003 mg/l for atrazine in treated drinking water. For surface water systems, compliance with the MCL is based on a running annual average from quarterly sampling using EPA certified laboratories and methods for drinking water. In accordance with the Texas Surface Water Quality Standards [30 TAC §307.6(d)(8)], the endpoint of this TMDL will be an atrazine concentration of 0.003 mg/l, which is the numeric equivalent of the drinking water MCL. The running annual average will be based on monthly sampling of ambient water from the reservoir.

Source Analysis

The Aquilla Reservoir watershed drains approximately 255 square miles or 163,000 acres. Approximately 21 % of the acres are pasture, hay and grassland, approximately 60% of the acres are used for row crops and small grains, approximately 13% of the acres are deciduous and evergreen forest, and approximately 6% of the acres are commercial, industrial, transportation, residential, and urban.

Atrazine has been widely used since the 1960s for selective control of broadleaf weeds in corn and grain sorghum. Within the Aquilla Reservoir watershed, the application of atrazine to corn and grain sorghum (milo) occurs between late fall and early spring, and encompasses roughly 63,600 acres. This application mainly controls henbit, pigweed, ryegrass, sunflowers, and cocklebmenurs. Atrazine is an inexpensive, effective herbicide for these weeds. No alternative herbicide is as economically viable. The application of weed and feed products to urban lawns occurs periodically for the control of dandelions, annual bluegrass, henbit, various spurges, and other broadleaves. Pesticide law prohibits the application of atrazine to pasture or hay land, and this use of the product is assumed not to occur. No known point sources of atrazine occur within the watershed and point source discharges of atrazine are assumed not to occur.

Linkage Between Sources and Receiving Waters

Atrazine transport and fate are difficult to quantify and model. However, a general understanding of the chemical’s properties may aid in establishing a link between sources and receiving waters.

Once atrazine is applied, it is absorbed by plant roots and also through foliage. The chemical is translocated upward and accumulates in the growing tips and the new leaves of the plant. In susceptible broadleaf plant species, atrazine inhibits photosynthesis. In tolerant plants, such as corn and sorghum, it is metabolized.

Atrazine that is not absorbed by plants begins to degrade in soil and water by chemical hydrolysis, and biodegradation. This produces hydroxyatrazine. The rate at which degradation occurs is affected by several factors; sunlight, temperature, pH, and the abundance of water and organic matter. Sunlight may break down atrazine to a small degree, and a small amount of atrazine may volatilize (evaporate) at high temperature. However, sunlight and volatilization of atrazine are not usually significant methods of transport within an ecosystem. These methods of transport may become more significant if aerial application of atrazine is made to a field. However, a 1999 survey of producers in the Aquilla Watershed found that 100% of the producers do not use aerial application of atrazine.

Temperature acts as a catalyst to chemical hydrolysis. Higher temperatures cause atrazine to be degraded more rapidly. Therefore, cooler fall applications of the herbicide can be expected to reside longer than warm springtime applications. The 1999 survey of producers found that a large amount of atrazine was applied during cooler months.

The abundance of water and organic matter has a large impact on atrazine transport and fate characteristics. Under moist and warm conditions, the half-life of atrazine in topsoil is approximately two months. In subsurface soils, or in water, atrazine's half-life is generally longer, sometimes exceeding six months. The presence of organic material increases the rate of hydrolysis, and acts as a catalyst to the biodegradation of atrazine by boosting populations of soil microbes. Atrazine is moderately to highly mobile in soils with low clay or organic matter content. Atrazine transport should not correlate closely with sediment transport, despite its moderate solubility in water, because it does not adsorb strongly to soil particles.

Although most creek bed soils may be characterized as Tinn-Pursley moderately alkaline loams and clays, soils vary across the watershed and are summarized by Table 2. Houston-Black-Heiden-Altoga soils are deep, nearly level to gently sloping, moderately alkaline clay soils. Gasil-Konsil-Crosstell soils are deep, nearly level to strongly sloping, mildly alkaline to slightly acid loamy soils. Hydrolysis is rapid in acidic or basic environments, but is slower at neutral pHs. Atrazine solubility also increases with increasing pH.

Table 2. Aquilla Reservoir Watershed Soil Types and Land Uses

Subwatershed Name	**Predominant Soil**	**Predominant Landuse**
Hackberry Creek	Houston Black-Heiden-Altoga	Cropland
Aquilla Creek	Houston Black-Heiden-Altoga and Gasil-Konsil-Crosstell	Cropland
Jack's Branch	Houston Black- Heiden-Altoga	Cropland
Two Mile Creek	Houston Black-Heiden-Altoga	Cropland

Identification of primary sources of atrazine runoff is a function of the subwatersheds' proportion of cropland and soil type. Land use coverage analysis indicates large percentages of cropland in the subwatersheds of Hackberry Creek, Jack's Branch and Aquilla Creek. Moderate cropland acreage is found in the Two Mile Creek and Little Aquilla Creek subwatersheds. Two Mile Creek subwatershed cropland is used primarily for cotton production, which has no atrazine use. Very little cropland exists in the Upper

Aquilla Creek subwatershed. The majority of the residential land use is within Hillsboro, Texas and is located in the subwatershed of Pecan Creek, a secondary tributary of Hackberry Creek. Based on this information, known soil properties and proximity, one may assume the majority of atrazine loading is occurring in Aquilla Creek, Hackberry Creek, and Jack's Branch subwatersheds.

Margin of Safety

A margin of safety (MOS) is required in a TMDL to account for uncertainty about the pollutant load and its association with water quality. This TMDL has an implicit margin of safety embodied in the endpoint identification. By defining the endpoint in the same units as the impairment, concentration in mg/l, at a geographic point within the drinking water source, the TMDL assures that successfully meeting the endpoint will also eliminate the impairment. An endpoint defined in terms of loading would contain a higher level of uncertainty, due to the undefined and highly variable linkage between watershed loading and water body concentration, and may necessitate a higher margin of safety.

There is very little uncertainty associated with the pollutant load allocation as described below using units of percent. The sources of atrazine are known with a high degree of certainty. The responsibility for controlling atrazine loading can be distributed between source categories with a high degree of certainty. Consequently, this TMDL has an implicit margin of safety.

Pollutant Load Allocation

The endpoint for this TMDL is defined as a concentration, specifically a running annual average concentration in Aquilla Reservoir not to exceed 0.003 mg/L of atrazine (the MCL). The amount of loading that can be allowed while meeting the concentration target would vary substantially year-to-year, or even day-to-day, as a function of rainfall amount, runoff rate, timing of recent atrazine applications, reservoir volume, duration of atrazine within the sediment and water column, and hydraulic residence time in the reservoir. There is minimal utility in attempting to define a precise target for loading when concentration is really the important and controlling metric. However, using the data set resulting in the 1998 MCL violation, albeit limited, suggests that a load reduction of approximately twenty five percent would have resulted in attainment of the standard.

Responsibility for reducing loading to the extent that the concentration target will be met can be allocated. All atrazine loading originates from non-point sources associated with human activities. There are no natural background sources. There are no point source discharges, nor are any anticipated. Therefore, none of the responsibility for reducing or controlling atrazine loading is allocated to the waste load allocation (WLA) and all of the responsibility is allocated to the load allocation (LA). Units of percent can be used to quantify the standard TMDL equation:

LA	+	WLA	=	TMDL
100 %	+	0 %	=	100 %

This equation describes both the allocation of allowable loading, and the allocation of responsibility for reducing loading to the extent necessary to achieve the endpoint.

The endpoint for this TMDL is defined as a concentration; specifically, a running annual average concentration in Aquilla Reservoir not to exceed 0.003 mg/L of atrazine (the MCL). The amount of loading that can be allowed while meeting the established concentration target will vary substantially year-to-year, or even day-to-day, as a function of rainfall amount, runoff rate, timing of recent atrazine applications, reservoir volume, duration of atrazine within the sediment and water column, and hydraulic residence time in the reservoir.

Due to the factors described above and to additional watershed-specific factors, defining a precise target for loading of atrazine into Aquilla Reservoir would be a complicated and resource-intensive task. While state-of-the-art watershed modeling could reduce the margin of error (MOE) in these types of loading estimates, MOEs in excess of 25% are not uncommon. Although very limited in its utility, a general loading estimate based on simple mass balance and simplifying assumptions can provide an average annual loading estimate of atrazine into Aquilla Reservoir. However, it should be stressed that a general loading estimate derived from a simple mass balance equation with assumptions designed to simplify the loading calculation is likely to contain a MOE of sufficient magnitude to render the load estimate unsuitable for use as a basis for regulatory action.

Assuming a steady state loading of a conservative substance (no decay) in a completely mixed system, the upper bound first estimate of the steady state response to the atrazine loading into Aquilla Reservoir would be given by Equation 1 (shown below).

Equation 1.

$$\bar{s} = \frac{W}{Q}$$

Where:

$\bar{s}$ = equilibrium concentration (TMDL endpoint concentration) in the reservoir (0.003 mg/l)

W = estimated steady state loading into the reservoir (141.71 lbs/yr)

Q = average flow from the reservoir (24 cfs annual average)

Rearranging Equation 1 to solve for loading (W) yields Equation 2 (following).

Equation 2. $W = \bar{s} * Q$

$$W =$$

$$(24\text{cfs}) * (0.003\text{mg}/\text{l}) * \frac{(1699.01\ \text{l}/\text{min})}{1\ \text{cfs}} * (525600\ \text{min}/\text{Yr}) * (2.204\text{E-}6\ \text{mg}/\text{lb})$$

$$= 141.71\ \text{lb}/\text{Yr}$$

Based on the simple analysis presented above, the maximum allowable load of atrazine into Aquilla Reservoir is 141.71 lbs/yr.

The flow value used in the calculation presented above was derived using the annual average of observed mean daily discharge measurements (period of record 1979-1992) from USGS Gage Number 08093360 (Aquilla Creek above Aquilla, TX) and the current annual average of daily production of municipal drinking water from the Aquilla Water Supply District. It should be pointed out that the principle water right in the reservoir, currently held by the Brazos River Authority, authorizes the diversion of 13,896 acre-ft per year, approximately five times the amount accounting for municipal use in the calculation above.

Of the many assumptions made in the analysis, the following two are likely to cause the greatest amount of error in the load estimate:

1. Steady state loading
2. Complete, instantaneous mixing

Atrazine loading into Aquilla Reservoir is almost exclusively a nonpoint source, event-based occurrence that bears little resemblance to a steady state loading scenario. Furthermore, unlike rivers and streams, lakes and reservoirs are known to develop seasonal depth stratification that often prevents the mixing of upper and lower layers. It is conceivable that these two factors, alone or in combination, could cause the concentration of atrazine in reservoir water to exceed the endpoint concentration specified in the TMDL while the annual loading estimated above is not exceeded. In contrast, other factors such as reservoir volume and timing (seasonality) of the loading event(s) may allow a much greater amount of atrazine than the amount estimated above to enter the reservoir without exceeding the TMDL criteria.

No watershed model was developed for this TMDL for atrazine for Aquilla Reservoir. Therefore, no season-specific analyses were performed. Season-specific loading scenarios would be expected to vary due to seasonal differences in rainfall, the timing of atrazine application (winter and spring), and atrazine degradation (as related to temperature and sunlight).

However, season-specific analyses are not necessary, since in all cases, even the critical season(s), compliance with the water quality standard (the TMDL endpoint) is a function of the annual loading necessary in order to maintain an annual average concentration less than the standard. The TNRCC has established an MCL of 0.003 mg/l for atrazine in treated drinking water. For surface water systems, compliance with the MCL is based on a running annual average from quarterly sampling using EPA certified laboratories and methods for drinking water. Furthermore, the surface water quality monitoring planned as a followup to the TMDL calls for monthly sampling, which would be more likely than the quarterly sampling to capture peak runoff events.