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DRAFT FOR REVIEW

Emissions Impacts by Freight Mode

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Transportation Air Quality Policy Analysis

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CHAPTER 1: INTRODUCTION

The overall goal of this task is to investigate the air quality implications of freight corridors in Texas and identify and catalog applicable emissions mitigation strategies. The study also identifies a set of criteria to classify Texas highways according to their significance to freight movement.

Freight movement characteristics are an indicator of an economy's growth and productive capacity. It is a crucial factor in facilitating domestic and international trade. With rapid expansion in urban complexes and the age of globalized trading, efficient and reliable movement of freight goods is vital. As high volumes of freight are moving in corridors across the country, any inefficiency in the transportation system would result in loss of precious time and money.

Not only does freight transportation contribute to the economy by adding jobs to millions of people, improvements in freight productivity helps a country maintain its competitive position in the world economy. It benefits an economy by stimulating demand for goods and increases the value of goods by moving them to locations where they worth more.

In the U.S., over 15 billion tons of goods, valued at over $9 trillion, were moved in 1998 according to the Federal Highway Administration (FHWA). By 2020, the U.S. transportation system is expected to handle about 23 billion tons of cargo valued at nearly $30 trillion.[1] The growing nature of the freight industry demands the support of a robust transportation network that best serves the ever-expanding pattern of trade and population.

Freight moves throughout the U.S. on 985,000 miles of federal–aid highways, 141,000 miles of railroads, 11,000 miles of inland waterways, and 1.6 million miles of pipelines.[2] It is expected that by 2035, freight volume will double within the U.S. while international freight volume will triple. As the industry expands to sustain a burgeoning economy, on the flipside it is associated with problems of corridor congestion and delays, which have direct environmental and health consequences.

According to the FHWA[3] trucks are the major freight mode in Texas. In 2002, almost 1 billion tons of freight with an estimated value of $866 billion were moved by trucks in Texas. This amounts to about 46 percent of all freight moved in Texas in 2002. The share of truck freight is expected to increase to 52 percent by 2035, with an anticipated 2.3 billion tons of cargo valued at nearly $3.2 trillion.

The majority of freight in the U.S. is moved by diesel-powered trucks and locomotives, which are major sources of greenhouse gases (GHG) emissions as well as other emissions that are directly or indirectly harmful to human health, including oxides of nitrogen (NO_x), volatile organic compounds (VOC), and particulate matter (PM). Thus, the air quality impact of freight

[1] http://ops.fhwa.dot.gov/freight/publications/fhwaop03004/today.htm.
[2] http://www.sametroplan.org/Plans/MTP/Mobility2035/8%20Freight%20significantly%20revised.pdf .
[3] FHWA, Freight Shipments To, From, and Within Texas, http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/state_info/faf2/pdfs/tx.pdf.

movement is a significant issue, both in terms of climate change/GHG emissions and the emissions of other harmful pollutants.

Improving air quality in Texas' urban areas is considered a priority since it can improve the health and quality of life for the public and prevent the loss of federal highway funds that are essential to the state's transportation system. Diesel exhaust from freight trucks is a primary source of $PM_{2.5}$, air toxic contaminants, and NO_x emissions. Transportation sources account for nearly 30% of total GHG emissions in the U.S., one-third of which is emitted from freight transportation.[4, 5] Freight emissions have grown by more than 50% since 1990. Approximately half of mobile source NO_x emissions and 27% of all NO_x emissions at the national level are emitted from freight sources. Additionally, 36% of mobile PM_{10} emissions come from freight modes of transport. Considering the bursting growth in the freight sector, this would lead to detrimental impacts on the health of people as well as the environment unless firm measures are taken to counter this problem.

Freight in Texas is largely moved by surface modes of transport, particularly by trucks (Figure 1). In 2002, nearly 54% of total freight tonnage moving within Texas was transported by trucks. It is estimated that this dependence on trucks will only increase to 58% by 2035.[6] Whereas, railroads accounted for a mere 7% of freight moved in the state in 2002 and this figure is not projected to change in the next 30 years.[7] While considering the value of goods moved, a staggering 74% of the net value was moved on the road and only 2% on rail.

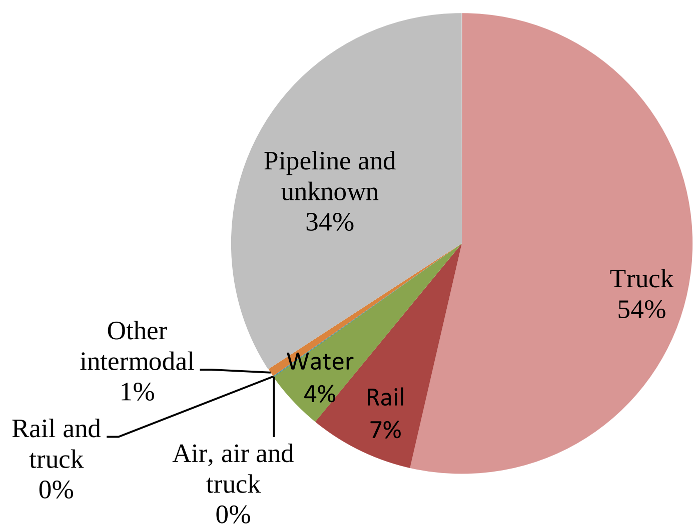

Figure 1. Freight Tonnage Distribution by Mode.

[4] http://www.ops.fhwa.dot.gov/publications/fhwahop10024/index.htm.
[5] http://www.epa.gov/otaq/climate/basicinfo.htm.
[6] http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/state_info/faf2/tx.htm.
[7] http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/state_info/faf2/tx.htm.

In Texas, Interstate Highway (IH)-35 and U.S. 59 are the two high-priority corridors with respect to freight activity and trade.[8] The Port of Laredo serves as a major national gateway connecting the U.S. with Mexico. Laredo is one of seven rail ports-of-entry on the U.S.-Mexico international border and is the largest rail freight gateway in the U.S. This corridor spans from the Port of Laredo through San Antonio, Austin, Dallas/Fort Worth (DFW) and the Texas border. IH-35 corridor is selected to serve as a case-study for the purpose of this project.

The purpose of this study is to create an analytical approach by which the air quality implications of major freight corridors of the state can be studied, with a view to reduce environmental impacts. Corridors by definition are the most congested parts of the surface freight transportation system and thus require specific attention in an environmental assessment of freight movement. A few studies have examined air quality impacts of freight movement on a corridor, but there has not been an attempt to examine this impact from a performance-monitoring perspective. The research team addressed the overall project goals through the following steps:

- conducting a comprehensive literature review of the environmental impacts of freight movement, the applicability of performance measurement, data needs and availability, and other relevant topics;
- developing an approach to assess air quality and GHG emissions from freight movement at the corridor level; and
- applying this methodology to a case study of a major freight corridor, IH-35, to determine the air quality impact of rail and truck movement.

This study is intended to fill a void in the current understanding of air quality impacts of surface freight transportation at the corridor level. Together, these resources provided a context for determining issues, opportunities, and challenges related to conducting a corridor-level air quality analysis of freight movement. The following sections of this report cover the background and literature review, the case study findings, and a review of conclusions relating to freight movement and air quality impact analyses.

[8] http://www.cityoflaredo.com/city-planning/Departments/MPO/MTPFinal/ch05.pdf.

CHAPTER 2: FREIGHT AND AIR QUALITY

This chapter covers the air pollutants associated with the freight transportation sector and an overview of the health and environmental impacts of the pollutants. Additionally, the section includes a discussion of global climate change implications and some of the tools and methods used to estimate emissions from surface freight movement. Pollutants that are associated with freight movement are divided into two general categories — criteria pollutants and GHGs.

Of the five major freight transportation modes — rail, truck, air, waterways, and pipeline — trucks have consistently proven to be the most popular option for shippers in the U.S. In 2008, according to the FHWA,[9] 67% of domestic freight tonnage was moved by trucks, compared to 10% by rail and 3% by water.

There are 20,000 freight locomotives in use throughout the country.[10] Though rail engines are a significant source of NO_x and PM, the rail mode has an emissions impact of one-third as much as the trucking mode and is capable of carrying tonnage equal to 125 trucks. However, the rail industry is bound by the most primitive of regulations.[11] Marine vessels are also a major source of diesel particulate pollution, especially in the coastal regions. The lax standards on vessels and the poor quality of the bunker fuel used in ships is a cause for poor environmental performance of these modes.

For the purpose of this study, researchers will consider only the rail and truck transport modes, which are the most dominant both in terms of tonnage moved as well as fuel used. The other modes, though important, will not be addressed in this report due to their relatively lesser impacts on emissions and due to the defined scope of this study. Additionally, there is conclusive literature on the comparative emissions impacts of different modes for freight transport, which suggests that road transport via trucks is the least sustainable, followed next by rail. [12, 13]

Criteria Pollutant Emissions

Trucks and locomotives that are powered by diesel engines move the majority of freight in the U.S. Diesel engines are a major source of ozone precursors (NO_x and VOC) and PM emissions. Ground-level ozone can trigger a variety of health problems including a variety of respiratory illnesses and is associated with other adverse environmental impacts such as crop and ecosystem damages. Exposure to PM emissions is also linked to serious health conditions such as aggravated asthma, having difficulty breathing, heart attacks, and premature death. PM is also a major contributor to haze formation that reduces visibility and creates unsafe conditions for airplanes and other modes of transportation. In the U.S., NO_x, CO, and VOC are one of six

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[9] FHWA, http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/09factsfigures/table2_1.htm.
[10] Palaniappan, M., Prakash, S., and Bailey, D. *Paying With Our Health: The Real Cost of Freight Transport in California.* The Pacific Institute, November 2006.
[11] FHWA freight and air quality handbook.
[12] Air Quality Impacts of Intercity Freight, Vol. 1, Report No. FHWA-PD-97-051, U.S. Department of Transportation, March 1997.
[13] Air Quality Impacts of Intercity Freight, Vol. 2, Report No. FHWA-PD-97-051, U.S. Department of Transportation, March 1997.

criteria pollutants and are regulated based on standards set by the U.S. Environmental Protection Agency (EPA).

GHG Emissions and Inventories

Freight transportation is also a major contributor of carbon dioxide (CO_2) emissions. CO_2 is the most prevalent GHG, which contributes to global climate change. Unlike the previously mentioned criteria pollutants that can be reduced by emissions reduction technologies, GHG emissions cannot be reduced easily using the currently available technology. Although the federal government does not regulate CO_2 emissions from freight movement activities, transportation is seen as a possible source of significant GHG reductions in the coming years.

GHG emissions quantification, also known as GHG emissions inventories, is often the first step to taking action on GHG emissions. Inventories are often used in regulatory settings to providing a sense of scale to emissions and are often the foundation for action plans in setting quantifiable goals and targets. Besides the EPA, which creates an annual national GHG emissions inventory, at least 40 states in the U.S. have also developed GHG emissions inventories. Some states have also developed GHG action plans and some others have specifically addressed transportation-related CO_2 emissions in their state environmental regulations or state energy plans.

CHAPTER 3: EMISSIONS MITIGATION OPTIONS

There is a wide variety of options available to transportation agencies and freight operators to reduce emissions from freight operations. These options are generally divided in to two categories:

- technological strategies; and
- operational strategies.

Technological strategies include using cleaner fuels, increasing engine efficiency, and installing idle-reduction equipment. Operational improvements such as mandatory idling restrictions and using fiscal instruments to bring about economic efficiency are other strategies to indirectly reduce freight transport emissions. A modal shift from truck to rail or barge would cause a significant reduction in GHG emissions. Great environmental and economic benefit can be realized if a combination of modes is chosen to optimize freight shipping.

The most common approach mentioned by the FHWA is the 3R principle of emissions reduction — Replacement, Repower, and Retrofit. The following provides a brief summary of these principles.

Replacement

Selectively replacing older freight equipment can sometimes prove to be the most cost-effective way to reduce the emissions of a fleet. In this way, older and outdated equipment, resulting in high emissions, is retired from service before it would otherwise be retired. Newer equipment designed to meet tighter emissions standards is purchased to replace the retired equipment, sometimes in conjunction with retrofit devices or alternative fuels. These programs are sometimes called “scrappage” or “fleet renewal” programs. Such programs often include procedures to ensure that the retired equipment is destroyed in order to prevent re-sale and continued use. Fleet owners often benefit from improved fuel economy and performance, as well as lower maintenance costs.

Repower

Repowering involves replacing an existing engine with a new engine. Repowering is a useful strategy to reduce emissions usually when the equipment has a longer life than the engine. It enables the vehicle to comply with newer and more stringent emission standards, often also improving fuel economy and lowering maintenance costs. Repowering can also include converting diesel-powered equipment (such as port cranes) to electrical power.

Retrofit or Add-On Options

Retrofitting involves introducing an after-treatment device to remove emissions from the engine exhaust. In some cases, retrofits can eliminate up to 90% of pollutant emissions. Many of the effective after-treatment devices require the use of ultra-low sulfur diesel (ULSD). Some of the better-known diesel retrofitting, after-treatment devices are Diesel Oxidation catalysts, Diesel particulate filters, and Selective Catalytic Reduction (SCR) Technologies. Diesel pollution consists primarily of PM and NO_x, and, in this aspect, these devices can cause substantial reduction in emissions.

The following provide a brief summary of the retrofit options.

Diesel Particulate Filter (DPF)

DPFs are designed to collect PMr in the exhaust stream and can be installed in both new and used vehicles. One mandate is that the filters must be used in conjunction with low sulfur diesel fuel. The high temperature of the exhaust heats the ceramic structure and allows the particles inside to break down into less harmful components. DPFs can reduce PM emissions by 50% to 90%, but do not affect NO_x emissions.

Exhaust Catalysts

SCR – SCR is a technology for controlling NO_x emissions that uses a catalyst to convert NO_x to nitrogen and water. An SCR system can be used in conjunction with a DPF to achieve much greater particulate reduction. Installed downstream of a DPF, the SCR system injects diesel exhaust into the hot exhaust gases, which then travel through a catalyst where they are converted to nitrogen and water and emitted through the tailpipe. Although these systems are most frequently found in industrial applications such as utility boilers, they have successfully been applied to marine diesel engines, locomotives, and even automobiles. SCR systems can reduce NO_x by an estimated 65% while significantly slashing hydrocarbon (HC) and CO emissions.[14]

DOC – Diesel oxidation catalysts (DOCs) use a chemical process to break down the pollutants found in diesel exhaust, converting them into less harmful compounds. These devices can reduce PM emissions by 20% and CO pollutants by up to 40%. Unlike DPFs, DOCs do not require the use of low-sulfur fuel. DOC technology only works on the soluble organic fraction of diesel PM emissions, which is why the overall emissions reduction is limited. DOCs are suitable for truck and rail applications as well as some marine applications, but the technology is not yet fully developed for the largest marine engines.

NO_X Catalysts – Some DPF technologies have been coupled with NO_x catalysts to control NO_x emissions. A NO_x catalyst is installed downstream from the DPF. Since the PM already is removed from the exhaust gases, the catalyst can work without becoming clogged by the soot.

[14] U.S. EPA. *Emerging Technology List,* http://www.epa.gov/otaq/diesel/prgemerglist.htm, accessed May 2009.

Lean NO_x catalysts have been shown to reduce NO_x emissions by 10% to 20%. NO_x absorbers can eliminate more than 70% of NO_x, but require the use of ULSD.[15] Other types of catalysts that can be used are three-way catalysts and two-way catalysts.

Exhaust Gas Recirculation – Exhaust gas recirculation (EGR) is a NO_x emissions reduction technique used by gasoline and diesel engines, wherein the exhaust gases are injected back into the combustion chamber. This process results in a reduction in the net amount of NO_x released through tailpipe emissions.

Fuel Strategies

Clean fuels are becoming more widely accepted as alternatives to fossil fuels. They can be used in freight transport with little or no modification to the equipment. Compressed Natural Gas (CNG), Ethanol, Emulsified diesel, fuel additives, and the use of catalysts contribute to lesser vehicular emissions. The following discusses a few of the strategies.

Bio Fuels

Biodiesel is a renewable alternative fuel that is clean burning and can be produced from a wide range of vegetable oils and animal fats. It contains no petroleum, but can be blended at any level with petroleum diesel to create a biodiesel blend. With little or no modifications, it can be used in compression-ignition engines. A popular blend of biodiesel that also has commercial applications is the B20 biodiesel. It contains 20% pure biodiesel and 80% petroleum. Though the tailpipe emissions from B20 biodiesel are similar to its standard petroleum derived diesel counterpart, it promises a lower life-cycle carbon foot print.

Natural Gas

Natural gas, in the form of CNG or liquefied natural gas (LNG), can be used to power on and off-road engines. Existing diesel engines can sometimes be converted to run on natural gas, or the existing engine can be replaced with a natural gas engine. Though CNG and LNG have a fossil fuel base, an advantage is that it can be processed from renewable sources such as landfill gas. CNG emits 70% to 90% less PM than conventional diesel.[16]

Fuel Additives

Fuel additives are also known as Fuel-Borne Catalysts (FBCs). FBCs are usually metallic chemicals added to diesel fuel to improve combustion and thereby reduce PM emissions. These additives can reduce oxidation temperatures for PM, so that a DPF would not have to reach as high a temperature to burn off soot in the exhaust.[17]

[15] http://www.fhwa.dot.gov/environment/freightaq/chapter4.htm.
[16] http://epa.gov/cleandiesel/documents/420f03015.pdf .
[17] Freight and air quality Handbook, http://www.ops.fhwa.dot.gov/publications/fhwahop10024/sect3.htm.

Engine Efficiency Strategies

The fuel economy of the vehicle can be improved by modifying the vehicle structure. Methods to maximize engine efficiency are aerodynamic improvements, low-rolling resistance tires, rail track lubricants, lightweight vehicles and low-viscosity lubricants.

Idle Reduction Technologies

The EPA estimates that idling long-haul trucks consume 960 million gallons of diesel fuel and emit 10.9 million tons of CO_2, 180,000 tons of NO_x, and 5000 tons of PM annually.[18] Idling is most extensive when trucks are parked at truck stops or other roadside rest areas, often to allow the driver to sleep. Drivers tend to idle for extended periods to heat or cool the cab, to run vehicle electrical appliances, to keep the engine warm during winters, or simply out of habit. Using a heavy-duty truck engine to provide temperature control or electricity is grossly inefficient and causes unnecessary fuel consumption and pollutant emissions. Idle reduction (IR) technologies can be used to reduce emissions caused by extended idling. Following are the available IR technologies.

Internal Combustion Auxiliary Power Units

Auxiliary power units (APUs) are portable, truck-mounted systems that can provide climate control and power for trucks without idling. These systems generally consist of a small internal combustion engine equipped with a generator and heat-recovery system to provide electricity and heat. An electrically powered air-conditioner unit is normally installed in the sleeper for air-conditioning, although some systems use the truck's air-conditioning system. Because of the engine's smaller size, operating a diesel-fueled auxiliary power system uses only a fraction of the fuel that would be used by idling the vehicle's primary engine.

Fuel Operated Heaters

Direct-fired heaters (DFHs) are small, lightweight devices usually installed in the tool or luggage compartment. DFHs produce heat from the combustion of a small amount of diesel fuel in an auxiliary burner. DFH is the simplest of APUs. These systems can be used to heat up both the cab and the engine. DFHs do not provide air conditioning, power for appliances, or charge for the truck's batteries.

Thermal Storage Systems

A Thermal Storage Cooling (TSC) unit consists of a phase-changing material that stores cooling energy transferred from the vehicle air conditioning system while the vehicle is operating. TSCs can only provide cooling to the cab. A small amount of electrical power is required to operate the fans. A TSC system stores energy in cold storage as the truck is driven, and then provides air conditioning when the truck is not running. The stored energy can be used later for cab or sleeper berth cooling during periods of rest. Such systems only provide cooling, but can be paired with a fuel-fired heater for a complete heating and cooling package.

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[18] H. Christopher Frey, Po-Yao Kuo and Charles Villa, Effects of Idle Reduction Technologies on Real World Fuel Use and Exhaust Emissions of Idling Long-Haul Trucks, *Environ. Sci. Technol.*, 2009**,** *43* (17), pp 6875–6881.

Stationary Idle Reduction Options

Truck stop electrification (TSE) can be installed at truck stops, service plazas, or rest areas to provide electric power, cooling and heating, and other services to a truck parking area. Truckers park, connect their trucks to a convenient power source, and use electricity. TSE allows truckers, without idling their engines, to operate on-board systems – sleeper cab heating and cooling, microwave ovens, refrigerators, televisions, telephones, personal computers, and other small appliances – while parked. Different from other idle reduction technologies, TSE provides "plug-in" power to operate accessory loads in the truck cab without running the engine at idle.

Activity Reduction Strategies

Apart from vehicular improvements and the installation of cleaner technologies, the nature of freight operational practices also impacts the pollutant emissions associated with freight transport. Optimization of freight modal use and reduction in freight activity are methods of building a transportation structure that is overall more sustainable. Emissions reduction can be maximized by adopting policies that push for cleaner vehicular and non-vehicular practices. The role of stringent policies and regulations is critical as it helps implement and enforce the use of cleaner freight technologies and practices. Fiscal instruments like emissions trading and carbon taxes have the potential to maximize emissions reduction by associating monetary benefits with sustainable freight practices.

Intermodalism describes an approach to planning, building, and operating the transportation system that emphasizes optimal use of transportation resources and connections between modes. In an intermodal transportation network, trains, trucks, ships, and aircraft are connected in a seamless system that is efficient and flexible, and meets the needs of the nation's consumers, carriers, and shippers.[19] New intermodal partnerships among rail, truck, and ocean carriers offer enhanced mobility by shifting traffic from congested highways to the private sector rail or marine shipping network, and environmental benefits by employing the cleanest possible technologies that improve air quality. Policies and programs fostering intermodal development would aid in the growth of a truly sustainable freight transportation system.

In Seattle, BNSF Railway installed four electric wide-span, rail-mounted gantry cranes at the Seattle International Gateway (SIG) intermodal facility. The cranes' wide footprints allow them to span three tracks, stack containers, and load and unload both trucks and railcars. The cranes produce zero onsite emissions and have increased throughput by 30% at the facility. Along the Gulf, SeaBridge freight, a coastal shipping service between Port Manatee, Florida and Brownsville, Texas avoids an average of 1,386 miles of congested highways. Compared to trucking, one SeaBridge barge has the capacity to remove 400,000 truck highway miles on a single one-way voyage.[20]

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[19] FHWA, http://ops.fhwa.dot.gov/freight/freight_analysis/freight_story/responses.htm (November 2009).
[20] http://t4america.org/blog/2010/03/17/speeding-up-cleaning-up-freight-movement-in-the-u-s/.

Avoiding unnecessary idling is a very effective way of reducing truck emissions. In Texas, the Texas Commission on Environmental Quality (TCEQ) adopted vehicle idling restrictions in 2004. This rule places idling limits on gasoline and diesel-powered engines in motor vehicles in any locality that signs a Memorandum of Agreement with the TCEQ. This rule prohibits any person in the affected locality from permitting the primary propulsion engine of a heavy-duty motor vehicle to idle for more than five consecutive minutes when the vehicle is not in motion unless the driver is using the engine to heat or cool his sleeper berth while taking a federally-mandated rest break. [21]

In efforts to reduce GHG, diesel PM, and NO_x emissions in California, the California Air Resources Board (CARB) staff is investigating opportunities to reduce idling emissions from cargo handling equipment used at ports and intermodal rail yards. The CARB approved a regulatory measure in 2005 to reduce emissions of toxics and criteria pollutants by limiting idling of new and in-use sleeper-berth equipped diesel trucks. The regulation consists of new engine and in-use truck requirements and emissions performance requirements for technologies used as alternatives to idling the truck's main engine.[22]

Market-based mechanisms are gaining attention worldwide as a means to regulate GHG emissions. While there has been activity to target stationary sources, the largest GHG emitters, such a concept is yet to gain momentum as a practical solution in the transportation sector, much less for freight modes.

Market-based mechanisms that limit GHG emissions can be divided into two types: quantity control (e.g., cap-and-trade) and price control (e.g., carbon tax or fee). The carbon tax and a cap-and-trade program would essentially produce similar effects: both are estimated to increase the price of fossil fuels, which would ultimately be borne by consumers, particularly households. While the main disadvantage with the carbon tax is that it would yield uncertain emissions control, the cap-and-trade program would lead to uncertain pricing. Many questions have to be answered regarding the rate of carbon tax and the amount of emissions to be capped before it can serve as an effective strategy to maximize emissions reduction from the freight transportation sector. Some argue that the potential for irreversible climate change impacts necessitates the emissions certainty that is only available with a quantity-based instrument (i.e., cap-and-trade).[23]

Table 1 shows a summary of the available freight emissions mitigation options.

[21] TCEQ, http://www.tceq.state.tx.us/implementation/air/sip.
[22] California Air Resources Board, http://www.arb.ca.gov/cc .
[23] Congressional Research Service. *Carbon Tax and Greenhouse Gas Control: Options and Considerations for Congress*. February 2009. http://assets.opencrs.com/rpts/R40242_20090223.pdf. Accessed November 2009.

Table 1. Freight Emission Mitigation Strategies.

Strategy	Applications in Truck and Railroads
Vehicular Improvements	• Auto-tire inflation systems • Low-rolling resistance tires • Aerodynamic improvements • Low-viscosity lubricants • Lighter tractors and trailers • Track lubricants • Low friction bearings • Lightweight cars
Idle Reduction Technologies	• Bunker heaters • Auxiliary power units • Automatic shut down/start up systems • Truck stop electrification
Retrofit and Replacement Strategies	• Diesel oxidation catalysts • Diesel particulate filters • Selective catalytic reduction systems • Engine upgrades and replacements • Exhaust gas recirculation • Fuel additives • Hybrid rail yard switches
Fuel Strategies	• Biodiesel, low sulfur diesel • Compressed natural gas • Electrification
Activity Reduction	• Improved trucking logistics to maximize loads • Intermodal shift • Double stacked trains
Economic Options	• Carbon taxes, emissions trading • Incentive programs for freights • Policies and regulations such as anti-idling restrictions

CHAPTER 4: EMISSIONS REDUCTION PROGRAMS

Freight-related environmental issues are an integral component in transportation planning, both at the federal as well as state level. There exist several initiatives to encourage cleaner ways of freight movement. Following is a list of freight related programs currently in place.

National Programs

SmartWay Transport Partnership[24]

The SmartWay programs were launched by the EPA to promote healthy partnerships among government, business, and consumers to protect the environment, reduce fuel consumption, and improve air quality. Business partners include shippers, truck and rail carriers, logistics companies, and truck stops. In a nutshell, the program benefits to the private sector include cost savings, business-to-business advantage, environment achievement, and public and peer recognition.[25]

National Clean Diesel Campaign

The National Clean Diesel Campaign (NCDC) program consists of four components under which funding is provided to reduce emissions from existing diesel engines through various strategies, and encourages existing fleet owners to adopt cleaner technologies.[26]

Congestion Mitigation and Air Quality Improvement Program

The Congestion Mitigation and Air Quality Improvement (CMAQ) Program is jointly administered by the FHWA and the Federal Transit Administration. Under this program, states, Metropolitan Planning Organizations (MPOs), and transport agencies are funded to invest in surface transportation projects that result in better air quality and reduced congestion. Several inter-modal projects have been successfully completed under this program. In one such project, the Columbia Slough Intermodal Expansion Bridge in Portland, Oregon was constructed for railroads to directly access a deep-water port facility, eliminating truck trips. The estimated truck emissions reductions were 52 kg/day of VOC, 241 kg/day of CO, and 364 kg/day of NO_x. In New York, the Red Hook Container barge was purchased to ship freight containers via the Hudson River rather than on the highways, removing 54,000 trucks trips from New York and New Jersey streets annually. The estimated emissions reductions were 12 kg/day of VOC, 48 kg/day of CO, and 53 kg/day of NO_x.[27]

Diesel Emissions Reduction Act

The Diesel Emissions Reduction Act (DERA) is a voluntary national and state-level grant and loan program to reduce emissions from existing diesel engines through clean diesel retrofits. Several states, including California, Texas, North Carolina, Tennessee, and New York, are

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[24] EPA, http://www.epa.gov/smartwaylogistics/basic-information/index.htm.
[25] US Environmental Protection Agency, *www.epa.gov/**smartway**/ (November 16, 2009).*
[26] US Environmental Protection Agency. National Clean Diesel Campaign. http://www.epa.gov/otaq/diesel/index.htm. (March 2009).
[27] CMAQ Improvement Program, http://www.fhwa.dot.gov/environment/cmaqpgs/ (November 2009).

showing interest in developing statewide diesel retrofit programs due to growing air quality concerns and a lack of federal funding.[28]

21st Century Truck Partnership

The U.S. Department of Energy (DOE) initiated this program to develop a freight and passenger transport system that is least polluting and that reduces dependence on foreign oil. It aims to do so by promoting research and encouraging the deployment of energy-saving technologies.[29]

A concerted effort is now being initiated to address idling emissions from long-haul trucks and locomotives. The U.S. Department of Transportation (U.S. DOT) and the EPA have formed a partnership to work with state transportation and environmental agencies, and MPO's to accelerate the implementation of TSE projects on routes heavily traveled by long-haul trucks. The U.S. DOT and EPA are currently working with TSE manufacturers, truck stop operators, trucking fleets, to identify appropriate locations and assist in jointly funding projects. Efforts are also being made to promote the use of on-board idle-reduction technologies for long-haul trucks and locomotives.

In addition to the billions being invested toward this research by private industry, the government is also increasing research such as the FreedomCar Program to examine the infrastructural technologies needed to produce pollutant-free vehicles such as hydrogen fuel-cell vehicles.[30]

As per the Florida 2006 Energy Plan,[31] a *Hydrogen FCV (Fuel Cell Vehicle) Demonstration Program* was begun. Under this program, fuel-cell vehicles were evaluated under real-world conditions for three years. The *Zero Emission Vehicle (ZEV) Program* is a key element of the California's plan to attain health-based standards and meet the GHG reduction goals.

State Programs

Port of Los Angeles and Port of Long Beach

The Ports of Los Angeles and Long Beach have begun a clean-truck program that aims to reduce truck-related emissions by 80% by 2012. Since inception, the program has purged the roads of more than 2,000 polluting trucks, with more than 5,500 clean trucks in operation today. Under this program, all trucks not meeting 2007 Federal Clean Truck Emission Standards will be banned from the ports. This program is part of the Clean Air Action Plan, which targets major air polluting sources in the two ports – trucks, trains, ships, cargo handling units, and harbor craft.

The Ports of Los Angeles and Long Beach also enacted the "PierPASS Offpeak" Program in 2005. It was intended to create incentives to shift traffic to off-peak hours.

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[28] http://www.deq.state.la.us/portal/tabid/2949/Default.aspx (November 2009).
[29] http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/21centurytruck/index.html (November 2009).
[30] AASHTO, http://www.transportation1.org/RealSolutions/strategythree.html (As of November 2009).
[31] The National Association of Regional Councils, Integrating Air Quality and Transportation Planning: A Resource Compendium, U.S. Department of Transportation, Federal Highway Administration, (2009) pp 108.

Mississippi Multimodal Transportation Improvement Program

The Mississippi Legislature created the Mississippi Multimodal Transportation Improvement Program to provide funds for non-highway transportation projects. The program funded 19 port projects, 29 airport projects, 8 rail projects, and 35 transit projects.

North Central Texas Clean Vehicle Program

The North Central Texas Council of Governments (NCTCOG) plans to develop a Clean Fleet Vehicle Policy, a Clean Vehicle Technology Project, and a Smart Way Upgrade Kit Demonstration. These programs will target fuel savings, truck idle-reduction and emissions control. NCTCOG is also currently working on a Diesel Vehicle Idling Reduction Program and the Regulated Fleet Program.

Northwestern Indiana Regional Planning Commission

The Northwestern Indiana Regional Planning Commission (NIRPC) began a diesel emissions and Truck Stop Electrification pilot project that involved the installation of 50 in-cab service modules for diesel trucks, enabling trucks to shut down their engines, rather than idle in highly populated areas along a major truck corridor.

There are various state and national freight programs that freight operators and the industry in general can use to move toward a more sustainable transportation practice.

CHAPTER 5: ESTIMATION OF FREIGHT EMISSIONS

The objective of the study was to quantify the pollutant emissions from surface freight transportation modes along the Texas corridors. This chapter will discuss issues related to this effort including freight corridor identification and classification, emissions estimation methodologies, required data and data sources, and the case study results. The case study demonstrates the proposed methodologies by applying them to a selected freight corridor in Texas. Two analysis years are considered for this purpose – 2010 and 2035.

Corridor Selection and Classification

A freight corridor is a linear system of freight transport infrastructure and related services connecting centers of economic activity and bounded by transport gateways which provide access to sources and destinations outside the corridor.[32] A freight corridor can be classified based on many parameters – freight volume, length of corridor, mobility, and access. While these parameters for classification may provide useful insight, there is limited information regarding corridors differentiated on the basis of mobility, access, and length.

A Freight Corridor classification aims to fulfill the following purposes.[33]

- Identify the state's important freight corridors and performance problems.
- Prioritize freight corridors based on their ability to support regional and national economy.
- Provide detailed information to transportation agencies at all levels about state freight corridors.
- Produce weighted 'Freight Value' factors that transportation project managers, engineers and planners may use within their existing evaluation process or as a stand-alone when considering improvements to transportation facilities.

Washington State Department of Transportation has used a freight corridor classification based on average annual gross truck tonnage. Freight corridors designated as Strategic Freight Corridors are those routes that carry an average of four million or more gross tons by truck annually. Similarly, roadways at the state, city, and county levels are also classified.[34]

For the purpose of this study, the research team will be adopting a classification based on freight volume. Such a designation of the Corridors of Freight Significance (COFS), based on the particular freight mode of travel traffic volumes is applicable across all modes and all transportation systems (see Table 2).

Based on the classification used in the Kansas City region, the three corridors are classified as:

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[32] http://www.mcli.co.za/18Nov04/NEELESH_NCPM_MCLI.pdf

[33] http://www.wstc.wa.gov/agendasminutes/agendas/2008/July15/July15_BP11a_FreightCorridorFolioJuly2008.pdf

[34] http://www.wsdot.wa.gov/Freight/FGTS/default.htm

1. **Corridors of National Significance –** Corridors that provide service across many state lines, long-distance travel and access to international ports of entry.
2. **Corridors of Regional Significance –** Corridors that provide supplementary service for regional travel and direct access to freight-related activities such as manufacturing, distribution, and intermodalism.
3. **Corridors of Local Significance –** Corridors that provide connecting links to higher level facilities, as well as providing direct access to freight-related facilities found in industrially zoned areas.[35]

Table 2. Criteria or Designation of Corridors of Freight Significance.

		2010		2035	
Corridor Class	**Freight AADT**	**Centerline Miles**	**Percentage**	**Centerline Miles**	**Percentage**
National Corridor	> 4000	3130	25.65%	4154	39.87%
Regional Corridor	1000 - 3999	5695	46.68%	3794	36.41%
Local Corridor	500 - 999	3376	27.67%	2472	23.72%
Total		**12201**		**10420**	

Based on the above classification, Figure 2 and Figure 3 show the Texas freight corridors for the years 2010 and 2035. Figure 4 shows a separate classification based on whether the route is a national or a state route.

Emissions Estimation Methodologies

The methodology used for emissions estimation was different for truck and railroads due to the variation in the data availability.

Estimation of Truck Freight Emissions

Emission factors required for the analysis of freight and non-freight truck categories were obtained from the EPA's MOVES model. The study discusses the emissions of the following pollutants: NOx, THC (total hydrocarbons), CO, PM_{10}, and CO_2. Since the corridor crosses urban areas, two average operating speeds were assumed for the analysis – 55 mph for urban areas and 65 mph for rural areas – and the emissions rates were considered to vary accordingly. While these assumptions fail to explicitly include the impact of extended idling and local congestion, they produce results at the required resolution for a corridor study. The classification of the areas as urban and rural was determined from the Freight Analysis Framework (FAF) Geographic Information System (GIS) dataset.

[35] http://www.marc.org/2040/documents/draftplan/8.0_GoodsMovement.pdf.

Detailed emissions rates in grams per mile (g/mi) for these two speeds were obtained for all model years using the following assumptions:

- Analysis years: 2010 and 2035;
- Default ambient conditions; and
- All trucks in this analysis are powered by ULSD fuel with a maximum 15 parts per million (ppm) sulfur content.

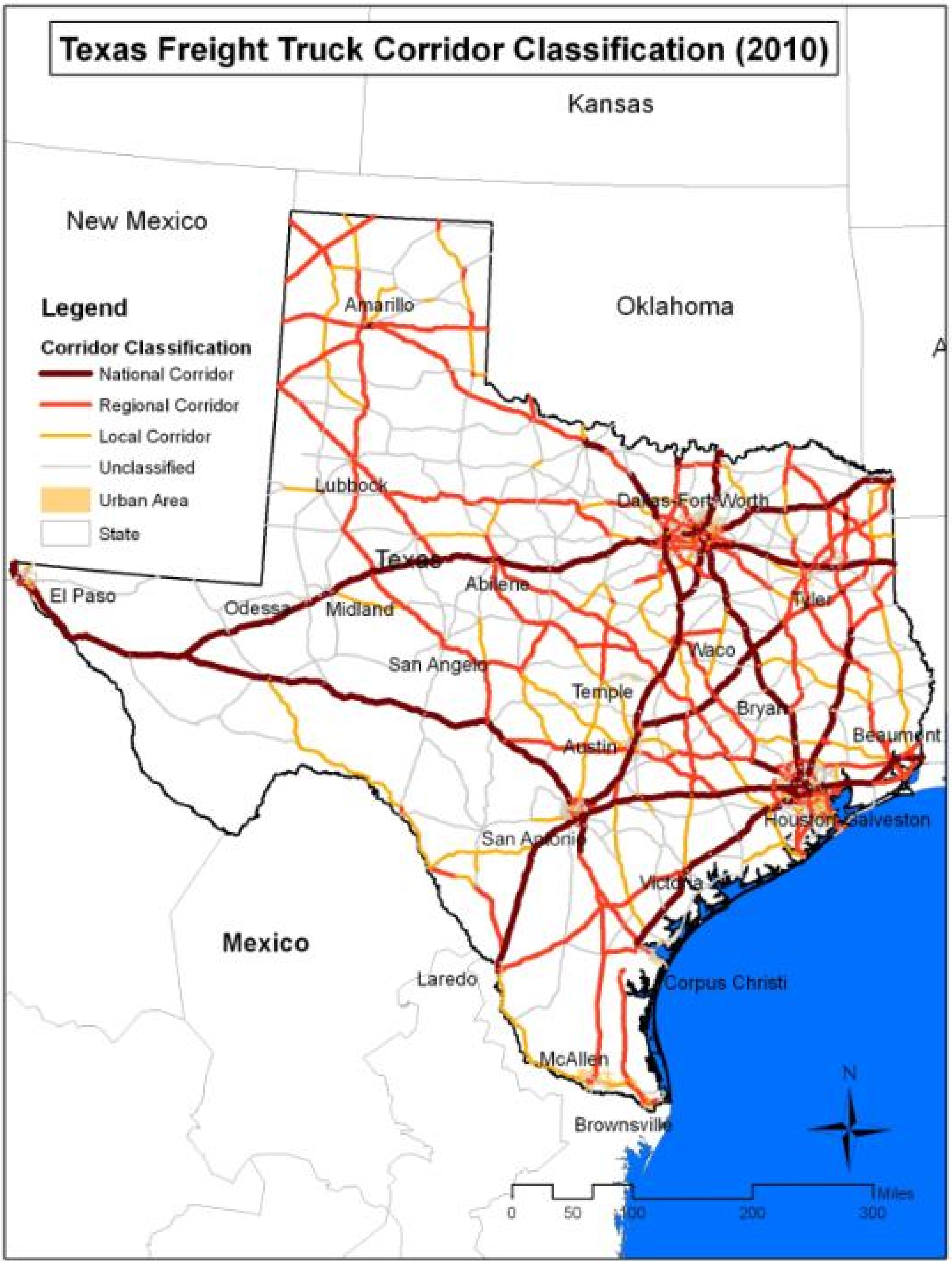

Figure 2. Texas Freight Truck Corridor in 2010

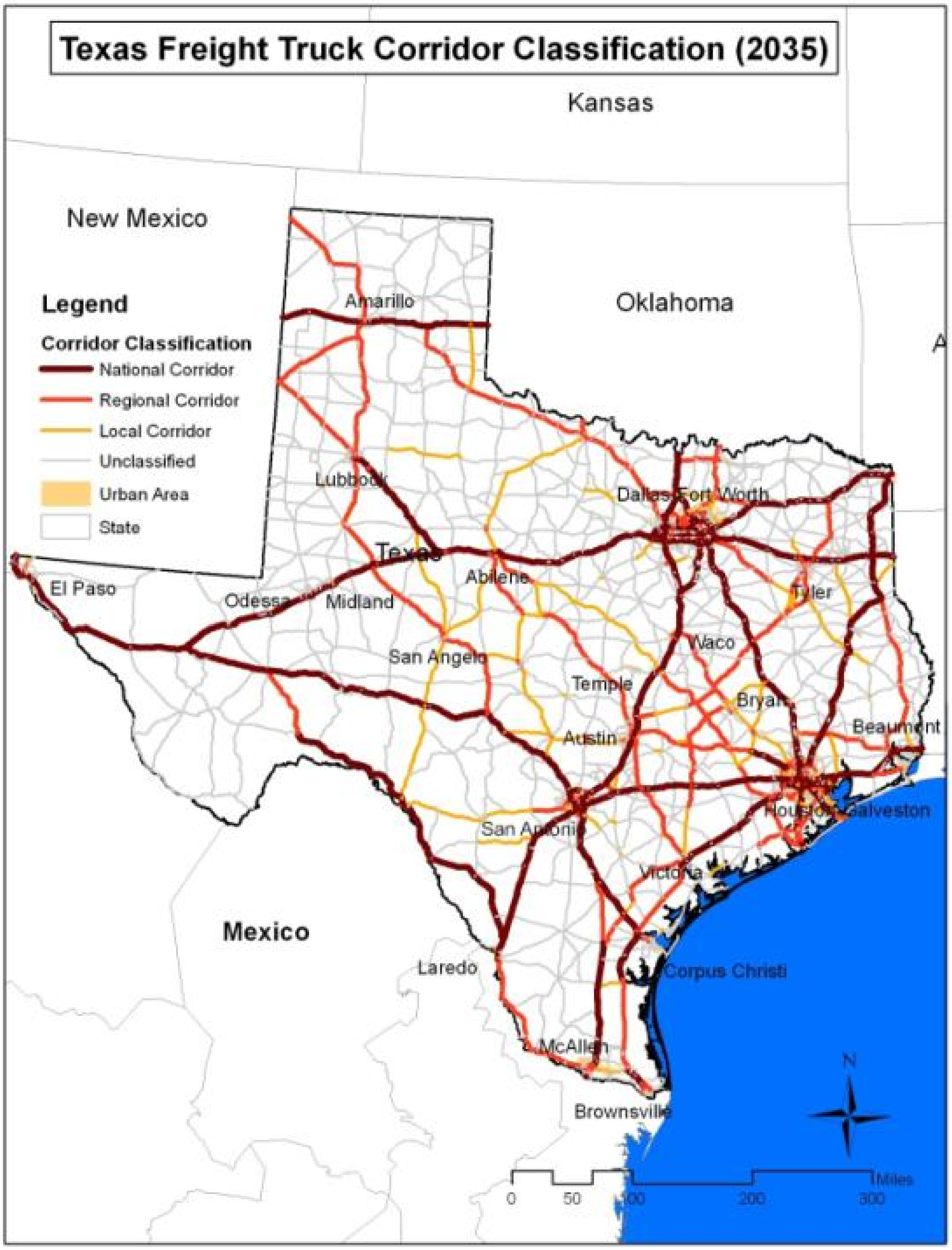

Figure 3. Texas Freight Truck Corridor in 2035

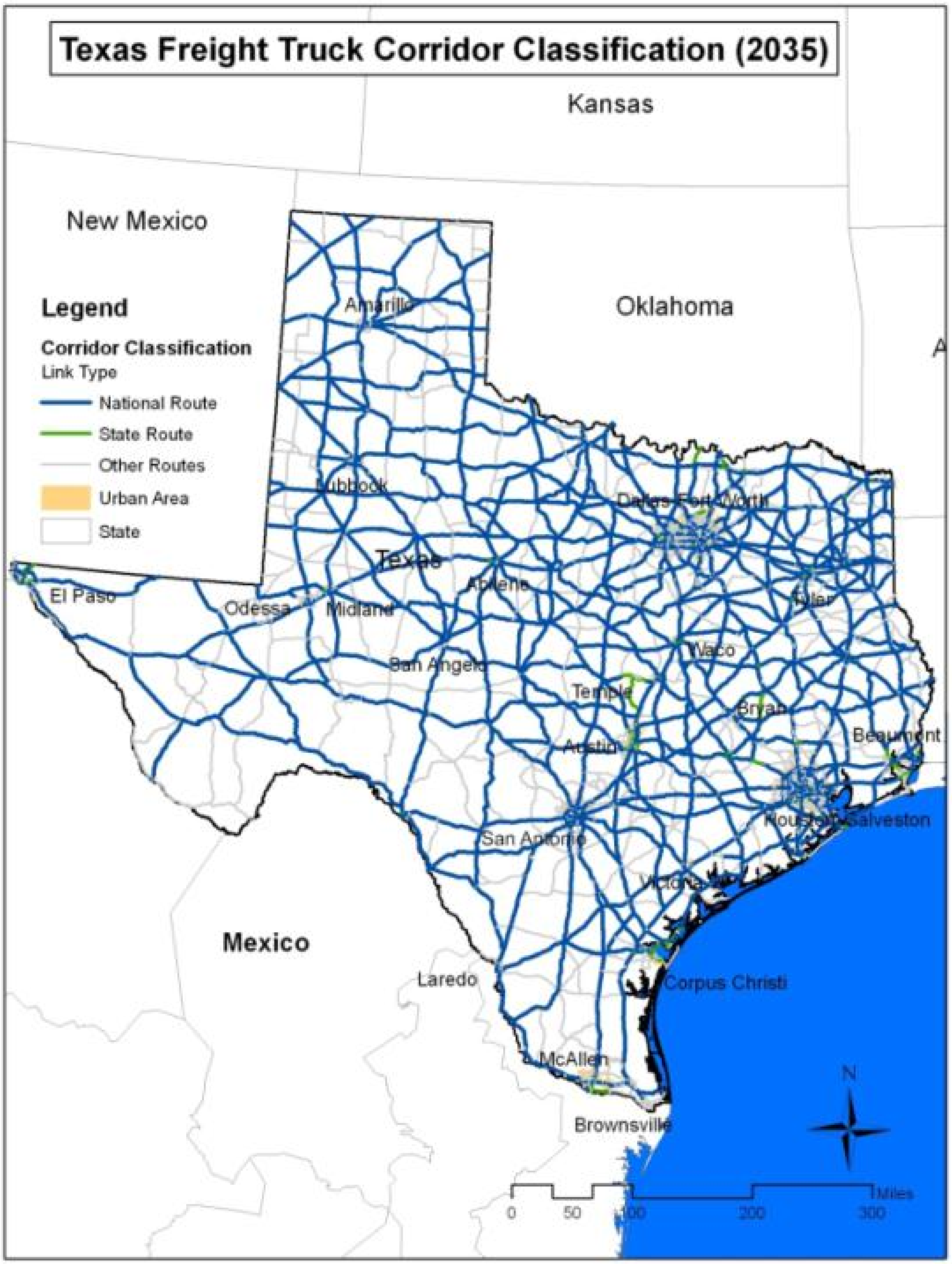

Figure 4. Texas Freight Truck Corridor in 2035

Figure 5 shows the methodology for estimating emissions from the truck modes. After the detailed emissions rates were obtained from the MOVES model, these were aggregated to obtain a set of average fleet emissions rates for the truck fleet operating on the defined Texas freight corridors. The emissions rates were weighted based on the age distribution and corresponding estimated annual driven miles to obtain aggregate emissions rates. These aggregate rates were applied to the freight VMT values to obtain total emissions per mile for each section of the corridor. The results were transformed into GIS map formats for analysis.

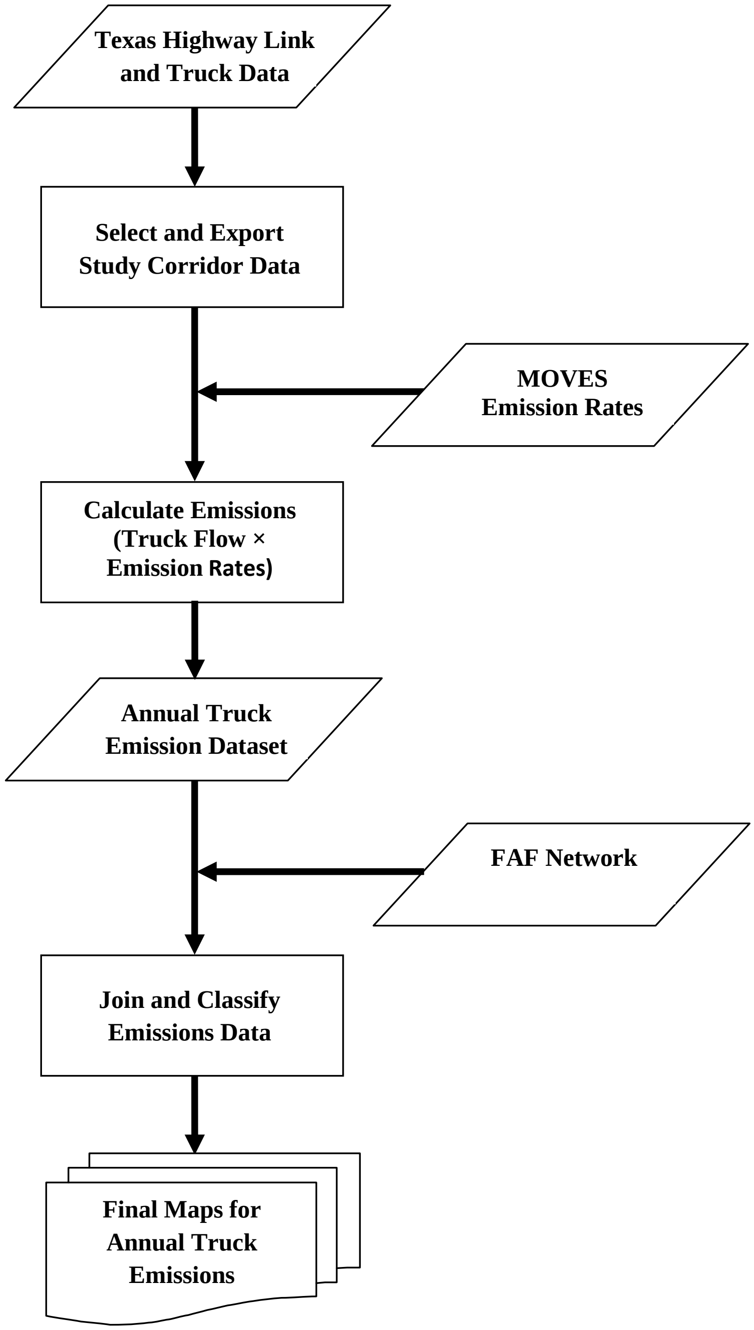

Figure 5. Analysis Process for Annual Truck Emissions Calculations along Texas Corridors.

Estimation of Freight Rail Emissions

The standard method for estimating the emissions of rail locomotives is based on fuel consumption. The emissions rates are expressed in grams of pollutants per gallon of fuel burned in the engine. The EPA standards for rail locomotives requires a 59% reduction in NO_x for engines built in 2005 and later, compared to pre-2002 levels. The standards also required 40 percent lower HC and PM emissions for locomotives than their pre-2002 level. Current EPA standards do not include provisions for future CO and CO_2 emissions as reflected in their corresponding future rates in Table 4. The base year emissions rates were obtained from the FHWA website.[36] For the future year case (2035), it is assumed that all the in-service locomotive engines will be in compliant with the previously discussed standards. Figure 6 shows the methodology for estimating emissions from the rail mode.

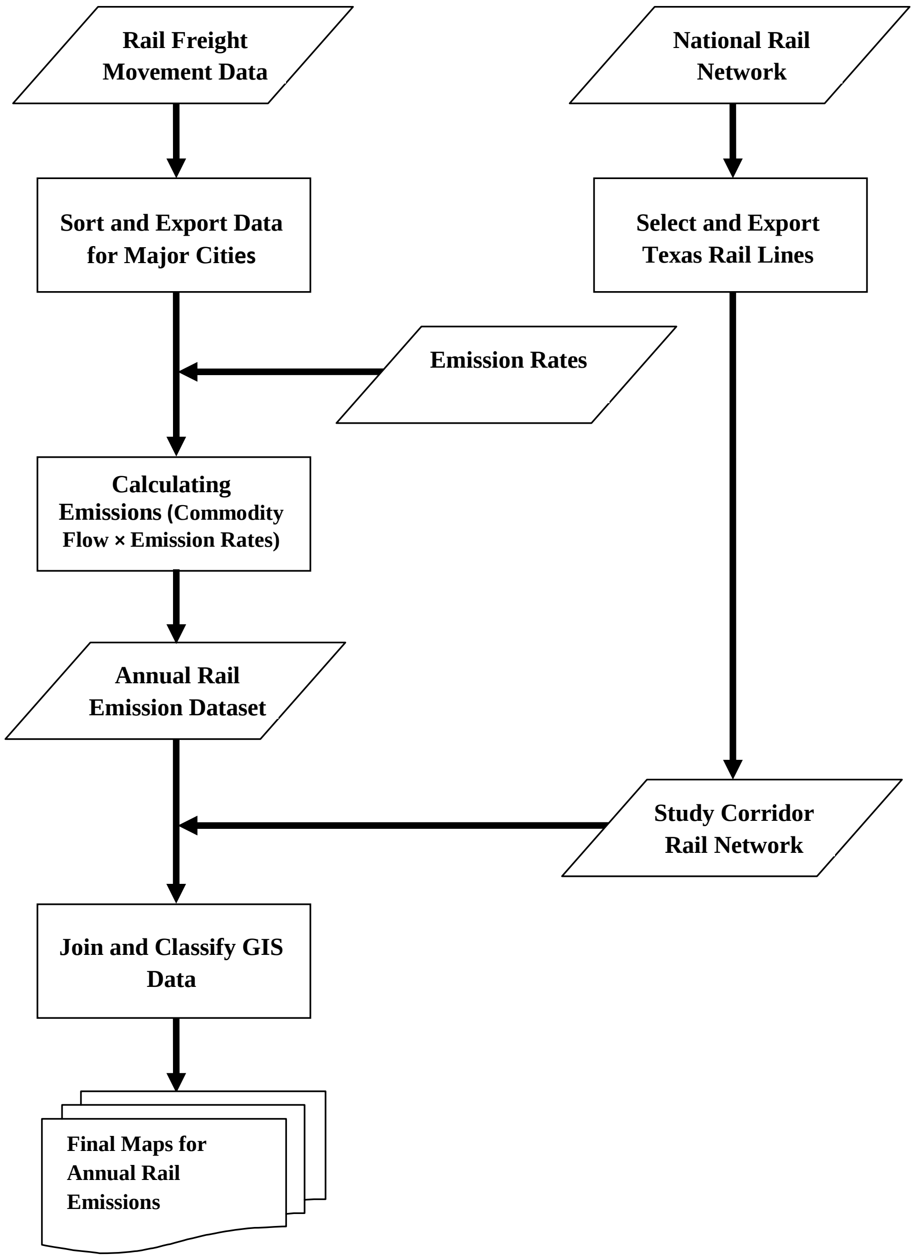

Figure 6. Analysis Process for Annual Rail Emissions along Texas Corridors.

[36] FHWA. National Freight Transportation Trends and Emissions, http://www.fhwa.dot.gov/environment/freightaq/chapter2.htm#s2_3.

Data Sources

The major data source for truck and rail freight movement used in this effort was the FHWA's Freight Analysis Framework (FAF and FAF^2). The highway and railway network information in FAF are available in the form of GIS datasets. FAF contains the two following major datasets:[37]

- highway link and truck data, and
- commodity origin-destination data.

The highway link and truck dataset contains length and freight and non-freight truck volumes for each specific highway link. The database also includes additional information such as section capacity, congested speed, and estimated delays for each link of a highway. Rail freight movement data among major cities in the U.S. were obtained from FAF and FAF^2 Commodity Origin-Destination Data.

Two analysis years were selected for this purpose – the year 2010 was selected as the base case, and the year 2035 was selected for the future case. The selection of the base and future case years was largely based on data availability. The research team began with identifying the key characteristics of truck and rail emissions estimation methodologies. In general, quantifying the air quality impacts of freight activities requires information on freight movements and emissions rates per unit of activity; however, the estimation methods for each mode demands different data. Most significantly, the available data on truck freight movement and emissions rates are significantly more detailed and accurate. Table 3 shows the major data required for corridor level air quality analysis of freight movement by truck and rail.

Table 3. Data Required for Corridor Level Air Quality of Freight Movement.

Truck	**Rail**
Freight Activity - Annual vehicle-mile traveled of each link (VMT) for trucks estimated from annual volume - Annual truck and volumes at ports of entry - Speed profile for trucks crossing the ports of entry into the U.S.	Freight Activity - Annual ton-mile commodity flow between each major origin-destination pair
Emission Rates - Aggregated exhaust emissions rates based on vehicle registration data and MOVES model - Portable Emissions Measurement System measurements	Emission Rates - Exhaust emissions rates based on national average rates

[37] FHWA, FAF^2 Highway Link and Truck Data and Documentation: 2002 and 2035, Freight Analysis Framework, http://www.ops.fhwa.dot.gov/freight/freight_analysis/faf/faf2_high.htm.

Case Study: IH-35 from Laredo to the Red River

Since the focus of this study was to investigate the air quality impacts of freight movement at a corridor level in Texas, the aim was to develop an approach where the air quality and GHG emissions impacts could be evaluated. The specific purpose of the task described in this section was to perform an analysis for the selected freight corridor, the IH-35 corridor from the U.S.-Mexico border at Laredo to the northern border of the state where IH-35 crosses the Red River, to estimate the GHG and pollutant emissions caused by freight movement.

Truck and rail freight movement data were collected for the selected corridor. The highway corridor runs through San Antonio, Austin, Waco, and the Dallas-Fort Worth metropolitan areas. This highway corridor and the paralleling rail facilities represent a very important transportation lane for the movement of freight in North America.

As discussed previously, two analysis years were selected for this case study – the year 2010 (base case) was selected as the base case, and the year 2035 (future case) was selected for the future case. The selection of the base and future case years was largely based on data availability. The research team began with identifying the required key parameters of truck and rail freight movement as discussed in previous sections.

Emissions of CO_2, CO, THC, PM_{10} and NO_x were calculated for all the links of the study corridor. Figure 7 through Figure 10 show the results of the CO_2 emissions analysis in GIS map format. The maps show main features of the corridor, including the urban areas. The levels of emissions are indicated through color coding, with darker shades representing sections with higher levels of emissions. Note that the maps for rail emissions have a wider band representing the corridor; this is indicative of the presence of parallel rail facilities that are sometimes shifted away from the highway itself, and do not indicate the relative level of emissions. The CO_2 results are shown for both base (2010) and future year (2035). The results for the remainder of the pollutants are presented in Appendix A.

Table 4 summarizes the total annual amount of pollutants for the base and future cases for truck and rail freight along the corridor. These results do not include Laredo trans-border short-haul (drayage) freight activity. The base case results indicate that trucks emit higher amounts of all pollutants. However, the share emissions contributed by rail locomotives increase in the future case except for a few pollutants such as CO_2. Trucks emit over 200 times as much CO_2 as freight locomotives overall in the base case, while in 2035 trucks are shown to emit about 90 times more CO_2 than freight locomotives. CO_2 is the direct result of fuel combustion and the fuel consumption would therefore follow the same trend. Due to limitations in the setup of available data, it is unclear what proportion of the relative reduction in truck emissions and increase in rail emissions can be attributed to modal shifts, to technological improvements, and overall the increase in freight, respectively. Future detailed research can help in providing more insight into these issues.

Overall, the results indicate that emissions reduction strategies used on trucks will result in a considerable reduction of criteria pollutants (CO, NO_x, and PM). The rail emissions, however, generally increase for the future case. This is because of looser emissions standards expected for locomotives when compared to trucks and the long compliance/implementation periods for those standards.

Table 4. Total Annual Amount of Emissions Due to Freight Movement on the IH-35 Corridor.

		Annual Emissions				
	Year	CO_2 (kt)	CO (metric ton)	NOx (metric ton)	THC (metric ton)	PM (metric ton)
Truck	2010	2,941	3,335	13,756	551	485.34
	2035	5,696	775	3,164	155	61.16
Rail	2010	12.44	33.80	202	11.35	7.03
	2035	62.52	169.88	634	39.80	25.30

Note that future emissions estimates for the criteria pollutants depend heavily on future engine standards, emissions reduction technologies, and their market penetration. It is expected that diesel will still be the main energy source for truck and rail freight activities and the advance in technology will marginally improve the fuel efficiency as it is modeled in current version of EPA's MOVES model. Therefore, pollutant emissions' future estimates are considered fairly reliable and accurate.

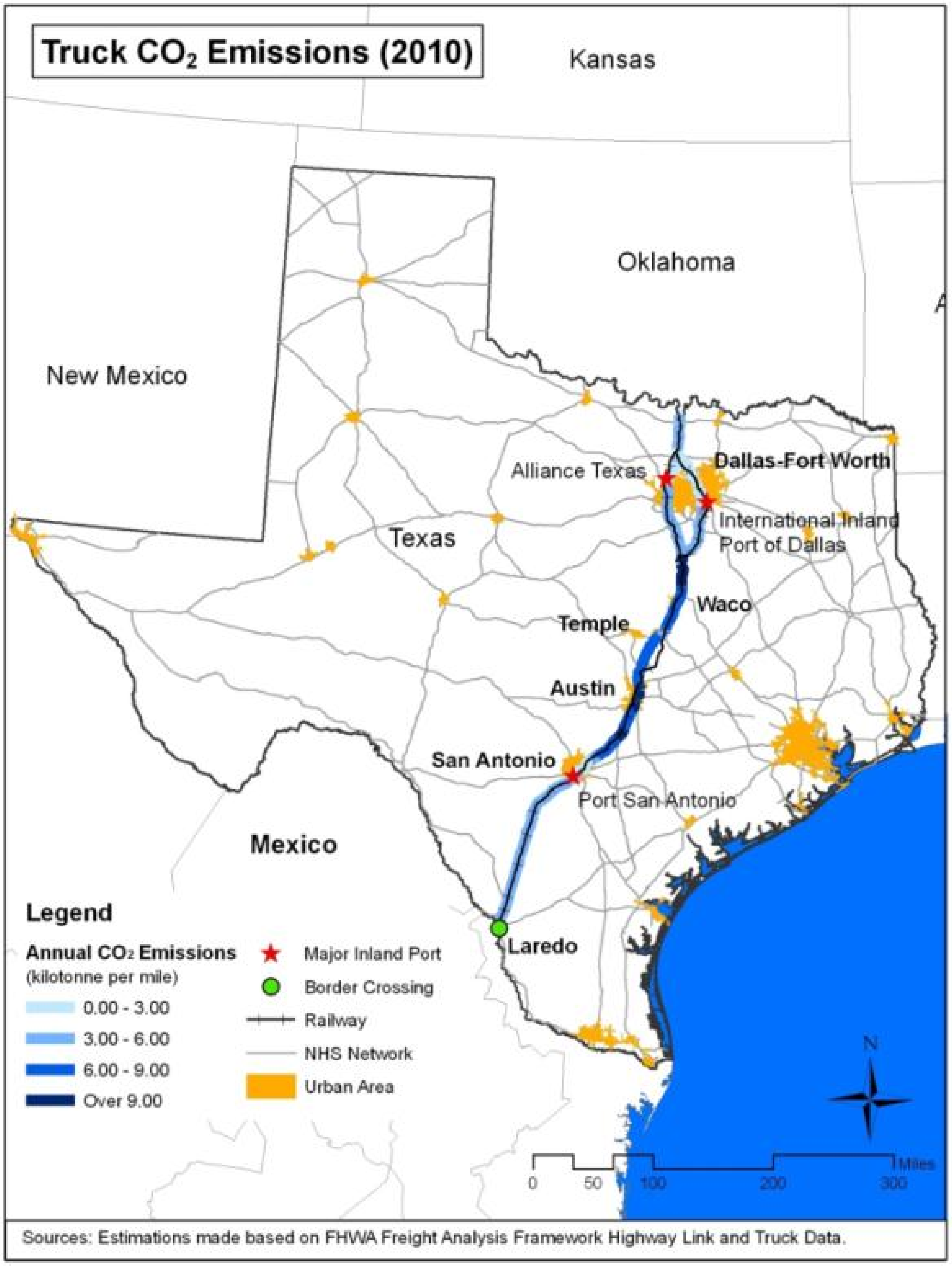

Figure 7. Estimated CO_2 Emissions from Trucks along the Corridor in 2010.

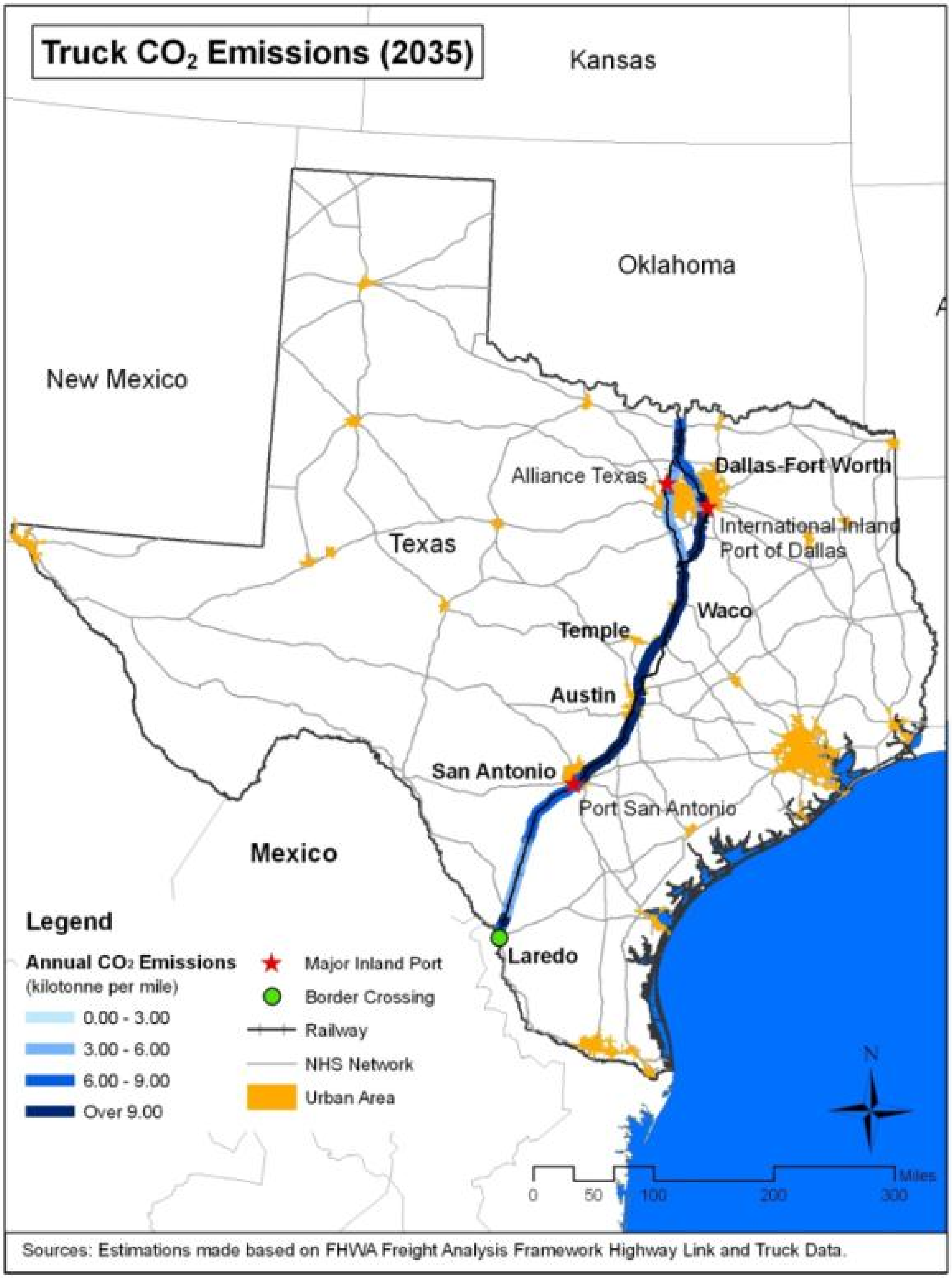

Figure 8. Estimated CO_2 Emissions from Trucks along the Corridor in 2035.

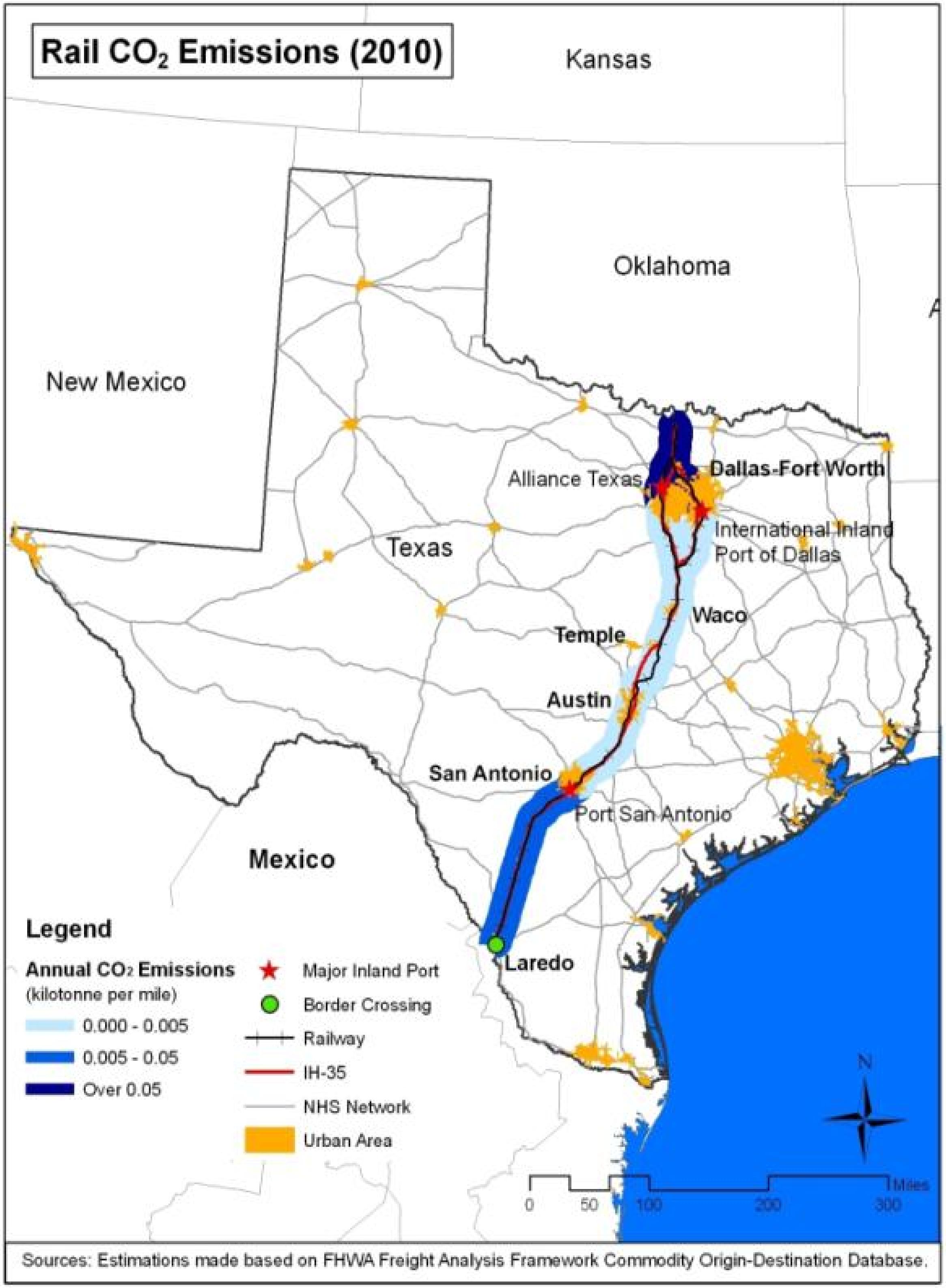

Figure 9. Estimated CO_2 Emissions from Freight Railroad along the Corridor in 2010.

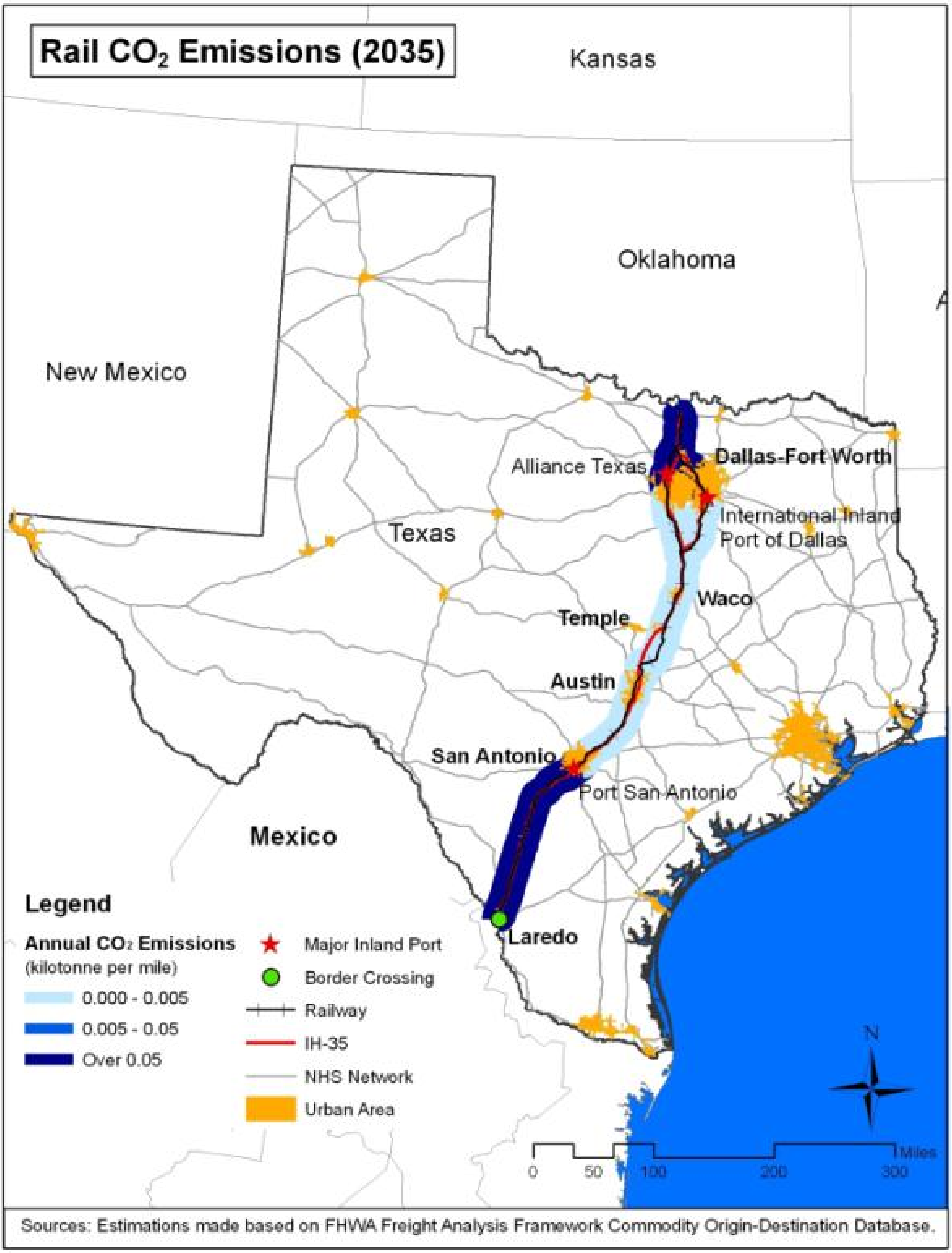

Figure 10. Estimated CO_2 Emissions from Freight Railroad along the Corridor in 2035.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

This research investigated the issues related air quality and GHG emissions impacts on major freight corridors in Texas. The following are the main findings and implications of this research.

- Texas has many major truck and rail corridors carrying large truck and rail volumes causing significant greenhouse gas emissions. In addition, Texas has ports of entry along the US-Mexico border through which large volumes of freight is moved. Border congestion and border-crossing delays are another source of greenhouse gas emissions.
- An analytical methodology based on publicly available data and emissions models was proposed to assess the emissions impact associated with freight movement by rail and truck along a major freight corridor. Background information on data requirements and data availability were also assembled and presented.
- A case study of the IH-35 corridor from Laredo to the Red River was conducted to demonstrate the proposed methodology. The case study used two scenarios: base case for 2010 and a future case for 2035. The results demonstrated how the methodology can be used to determine track emissions of different pollutants for different scenarios.
- The research team also discussed mitigation strategies that can be used to reduce greenhouse gas and criteria pollutant emissions.
- The research provides the basis for assessing the air quality impacts of freight and the use of performance measurement to track progress towards achieving goals.
- While many emission reduction strategies have been discussed to reduce emissions from freight transport modes, a detailed examination of the Texas corridors is expected to give a better insight of the effectiveness of specific reduction strategies.
- The following are some techniques that can reduce truck emissions:
    - Several highly congested zones were identified along the test corridor. Delays at these zones can be reduced by promoting scheduled appointment systems for pickups and drop offs to reduce wait times.
    - Emissions from idling can be minimized by installing idling reduction equipment in the trucks such as auxiliary power units (APUs) or providing stationary idling reduction strategies such as truck stop electrification (TSE).
    - Freight use can be optimized by reducing empty mileage of trucks.
    - Drivers can be trained to adopt eco-friendly driving practices.
    - Several clean vehicle and fuel technology options can be pursued.

APPENDIX A

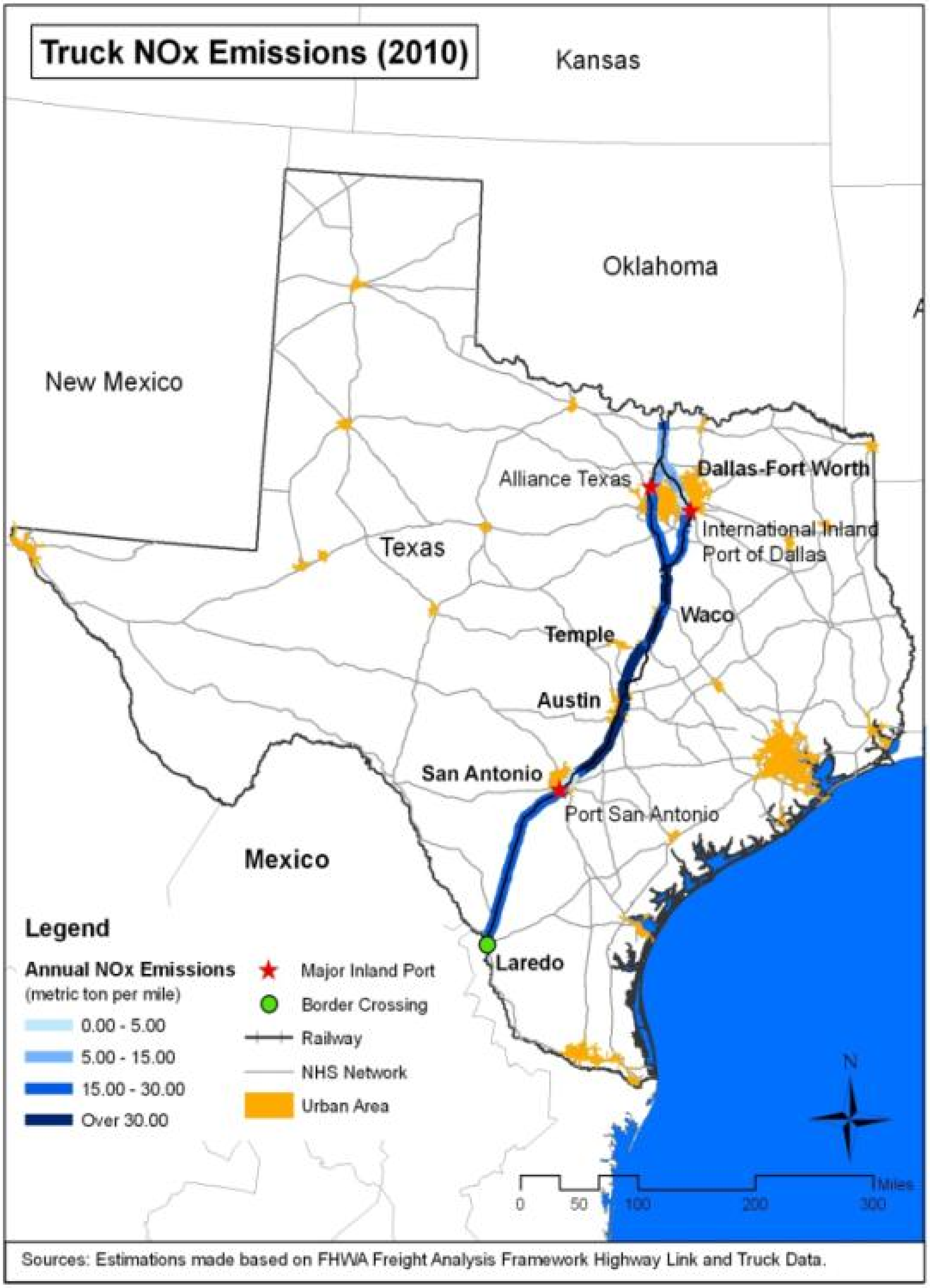

Figure A.1. Estimated NO_x Emissions from Trucks along the Corridor in 2010.

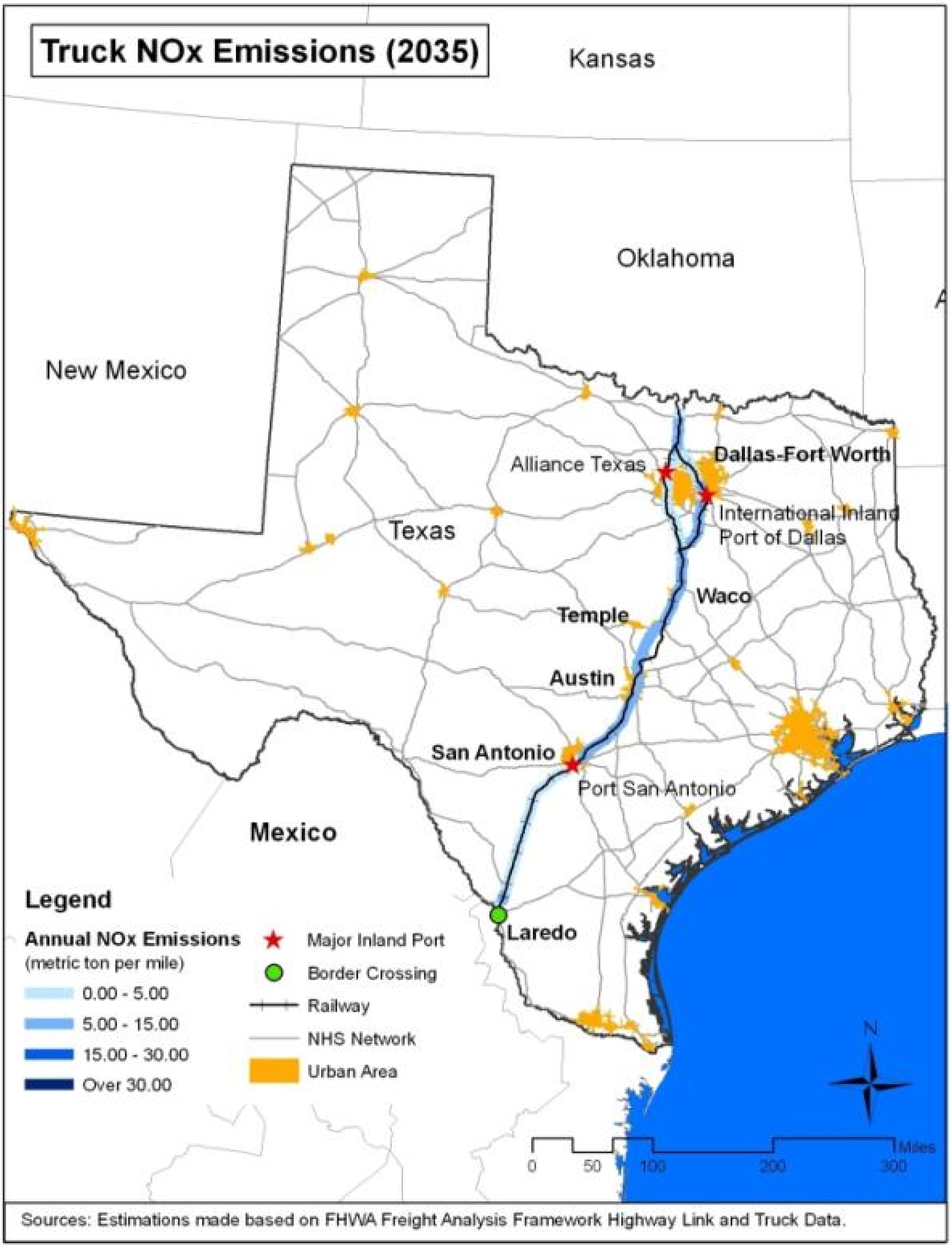

Figure A.2. Estimated NO_x Emissions from Trucks along the Corridor in 2035

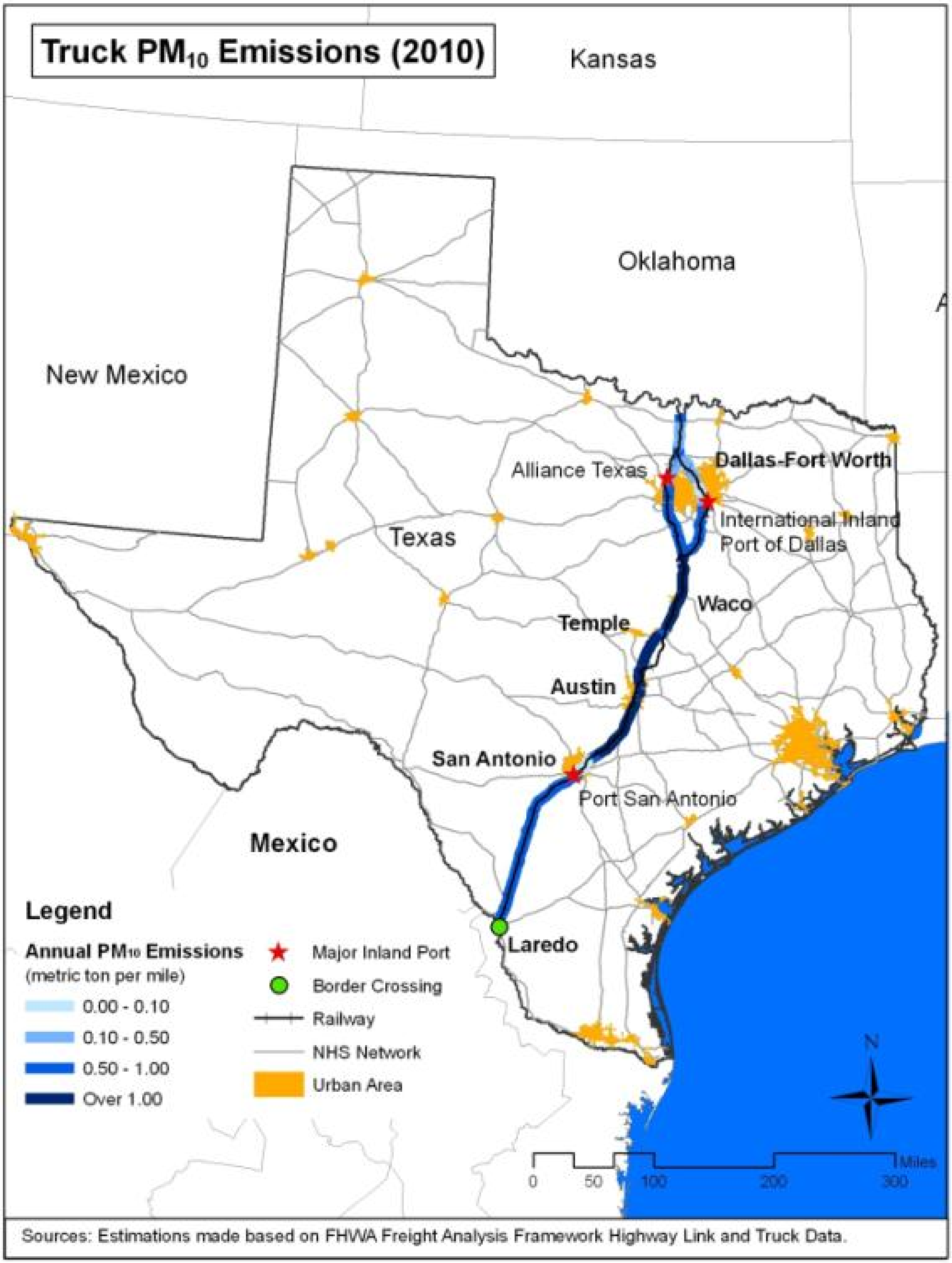

Figure A.3. Estimated PM_{10} Emissions from Trucks along the Corridor in 2010.

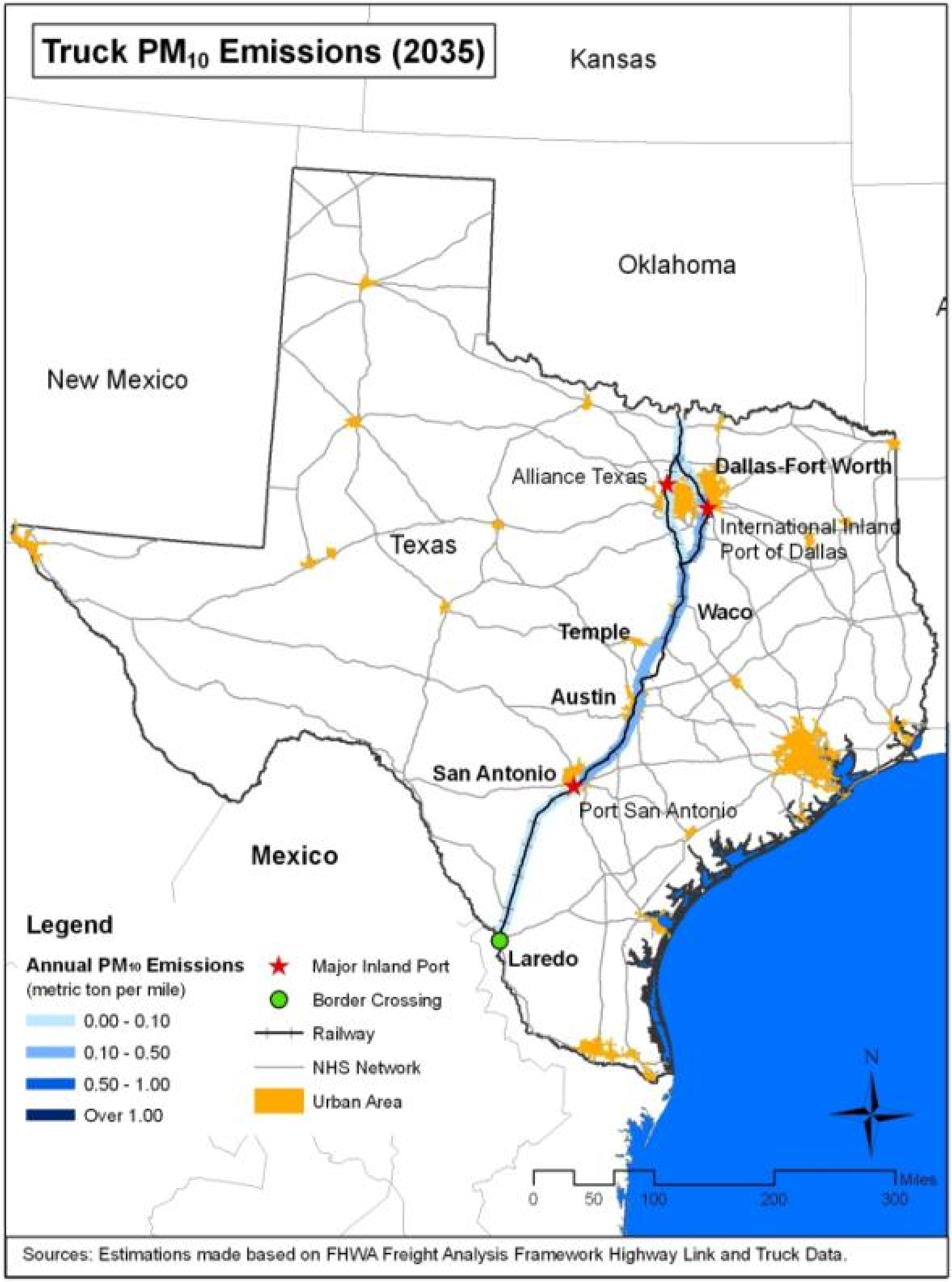

Figure A.4. Estimated PM_{10} Emissions from Trucks along the Corridor in 2035.

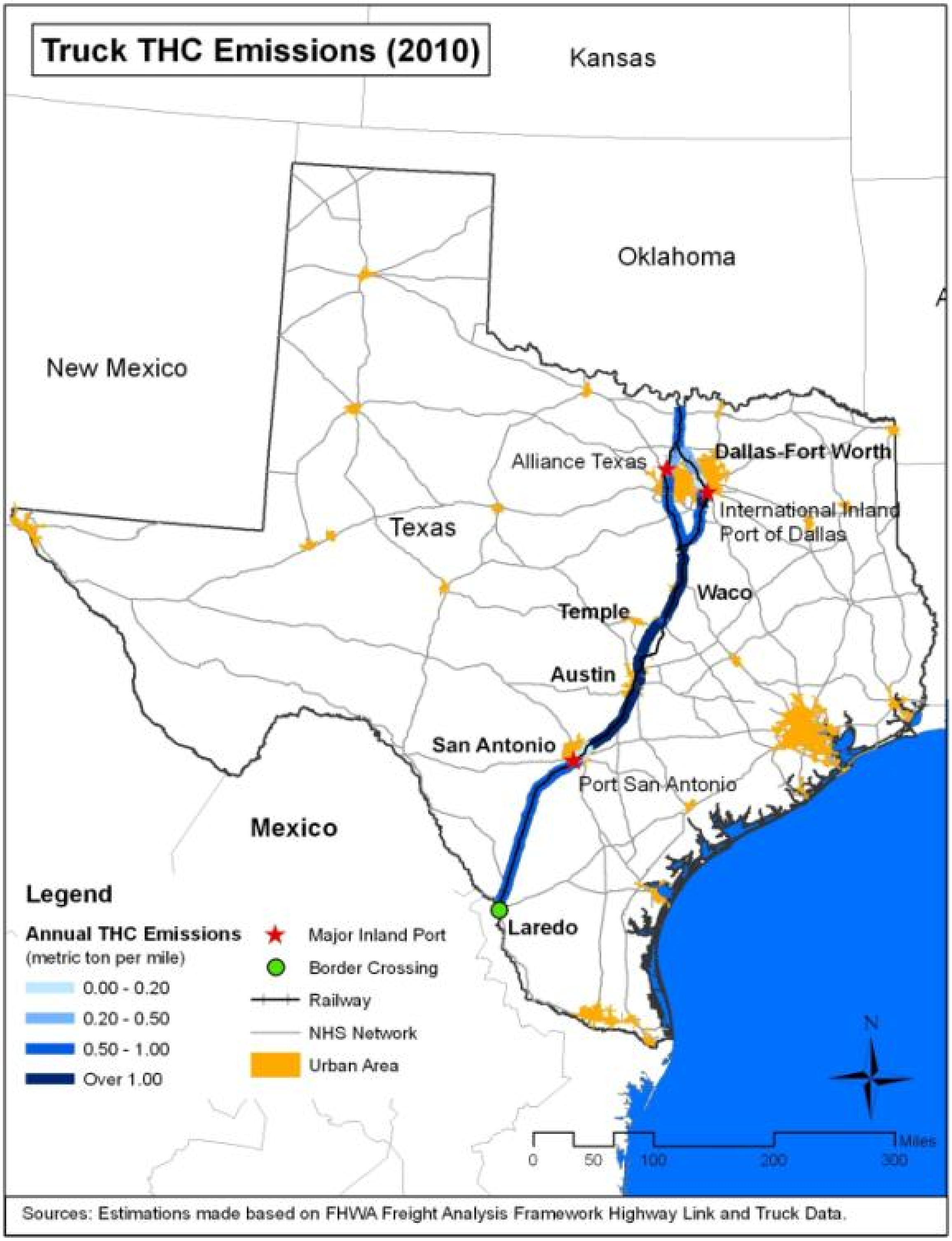

Figure A.5. Estimated THC Emissions from Trucks along the Corridor in 2010.

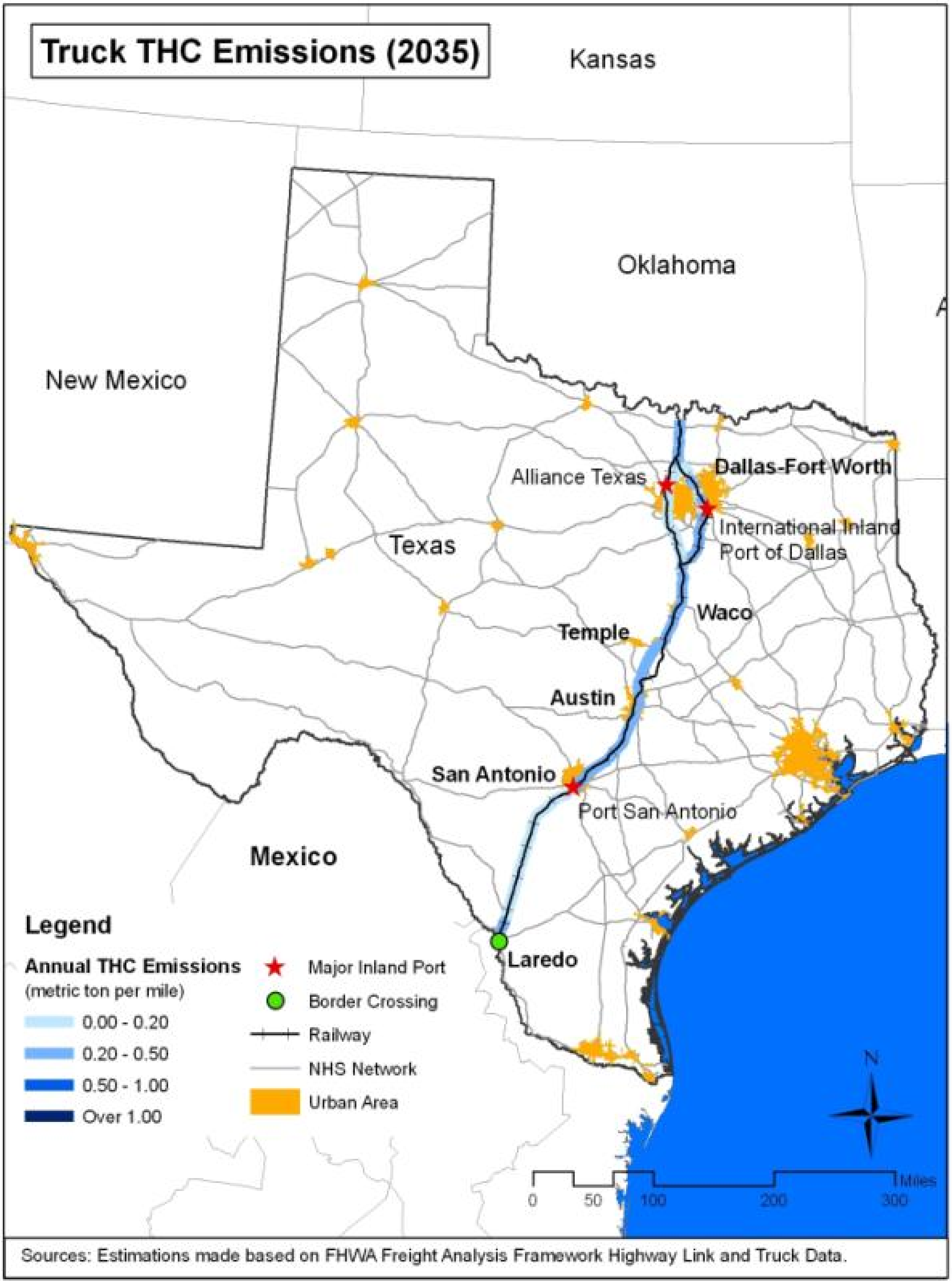

Figure A.6. Estimated THC Emissions from Trucks along the Corridor in 2035.

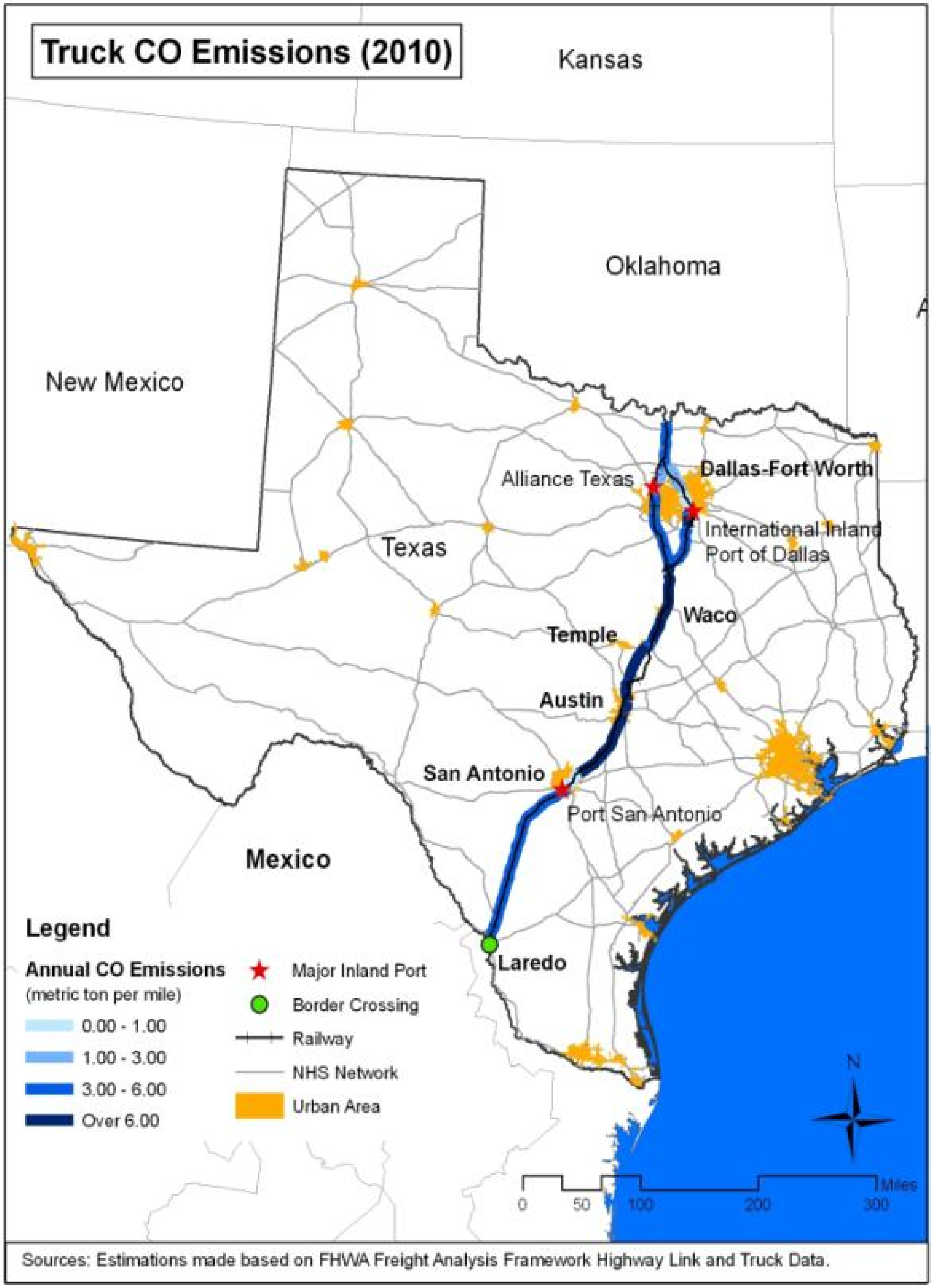

Figure A.7. Estimated CO Emissions from Trucks along the Corridor in 2010.

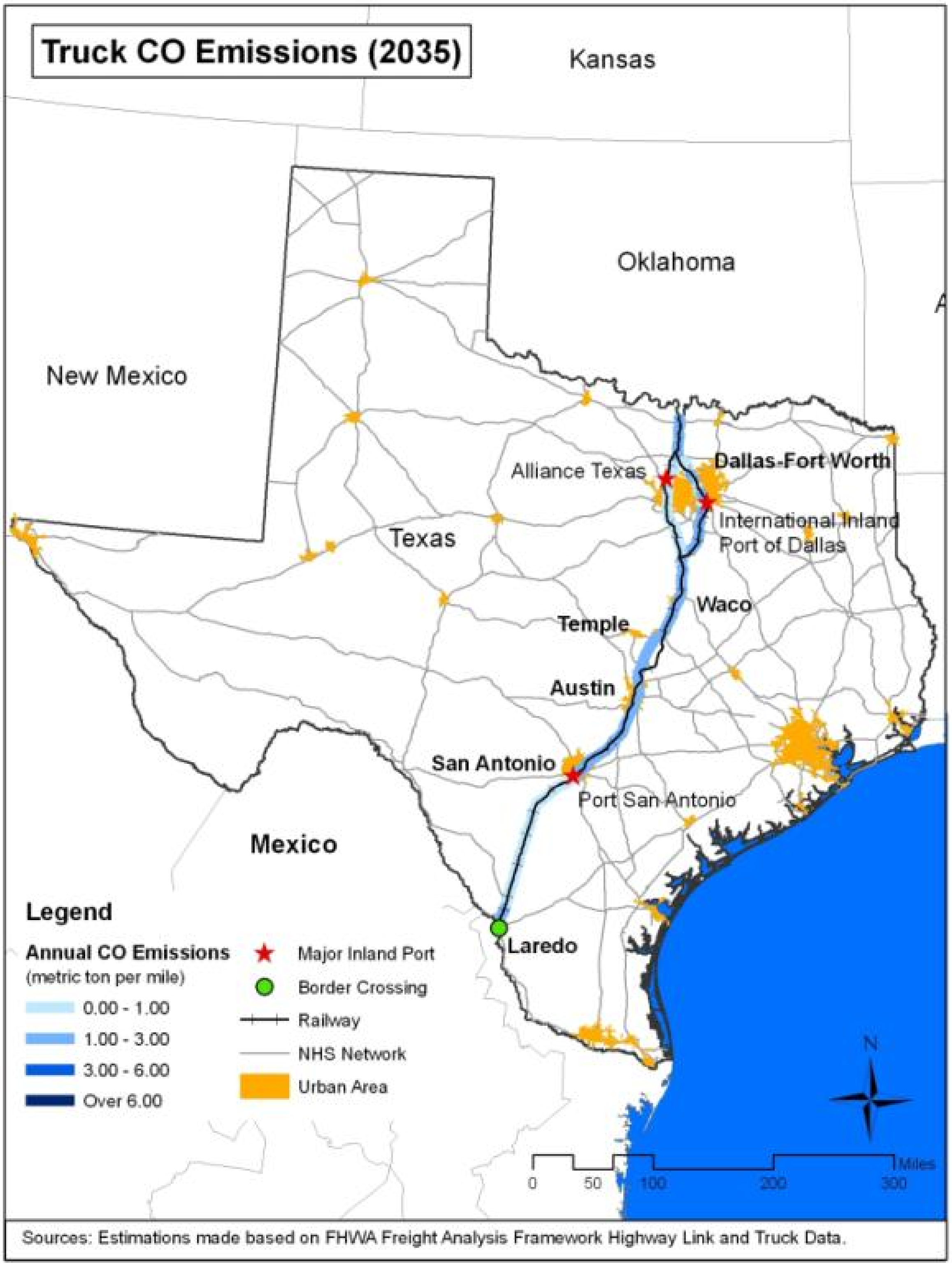

Figure A.8. Estimated CO Emissions from Trucks along the Corridor in 2035.

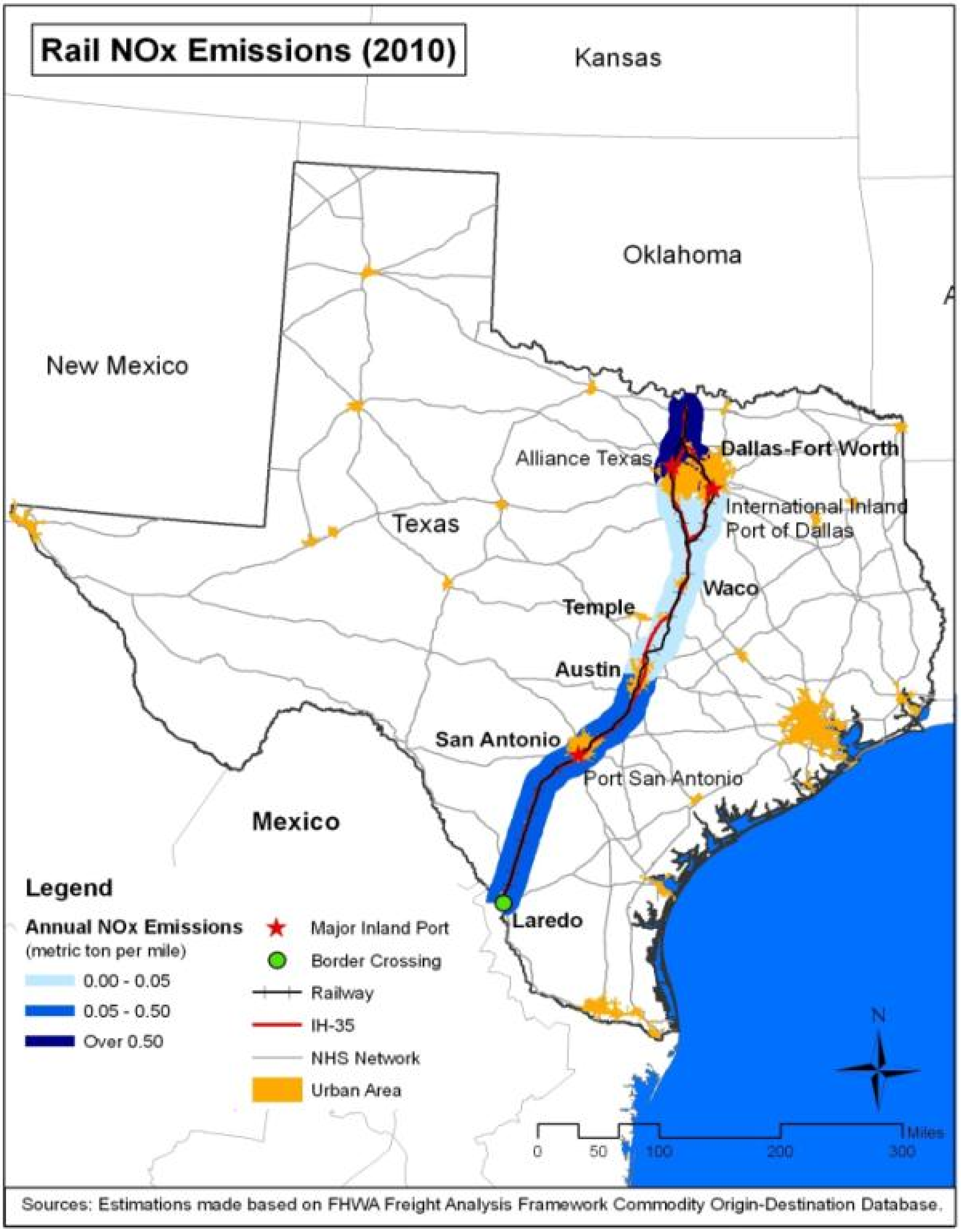

Figure A.9. Estimated NO_x Emissions from Freight Railroads along the Corridor in 2010.

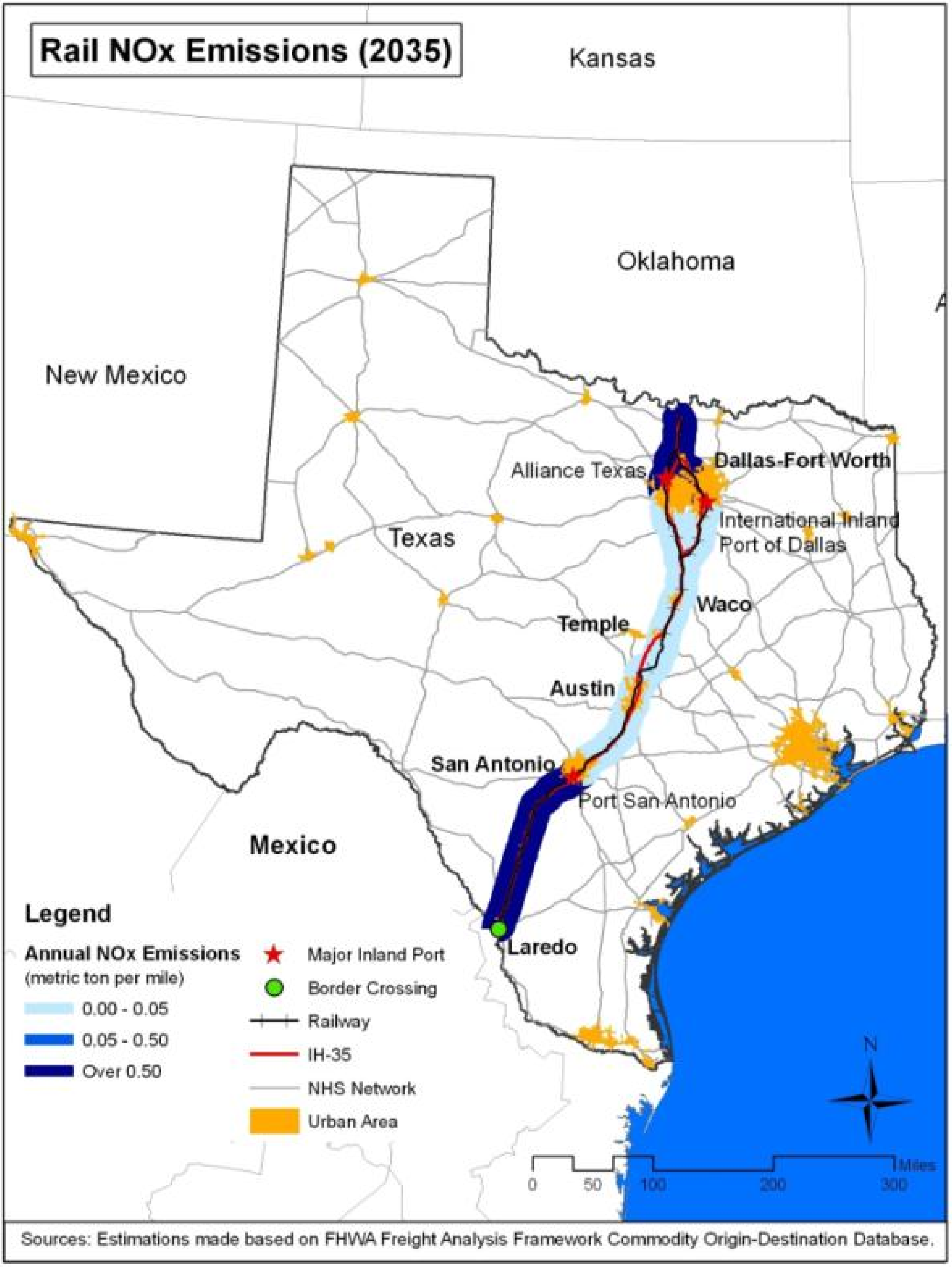

Figure A.10. Estimated NO_x Emissions from Freight Railroads along the Corridor in 2035.

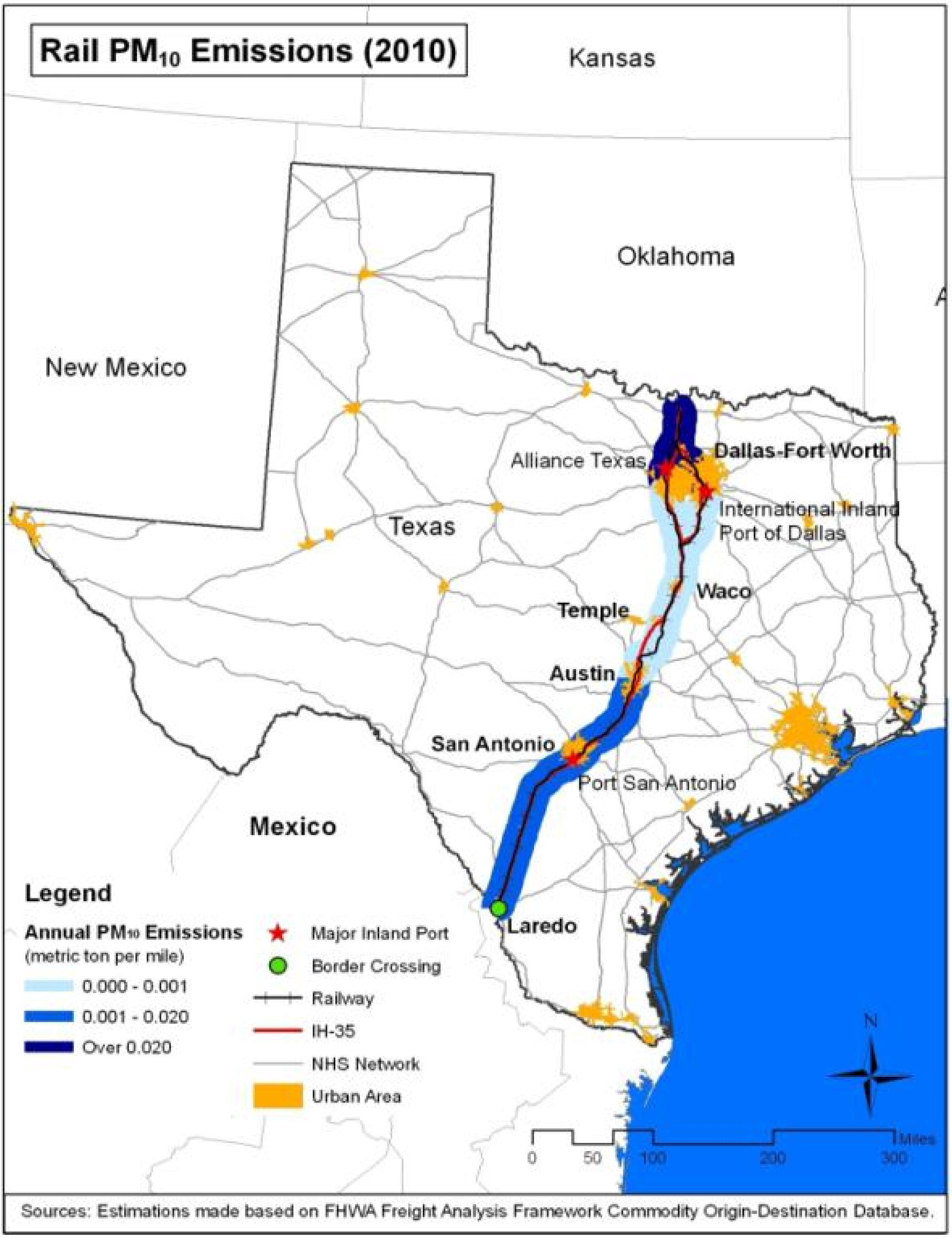

Figure A.11. Estimated PM10 Emissions from Freight Railroads along the Corridor in 2010.

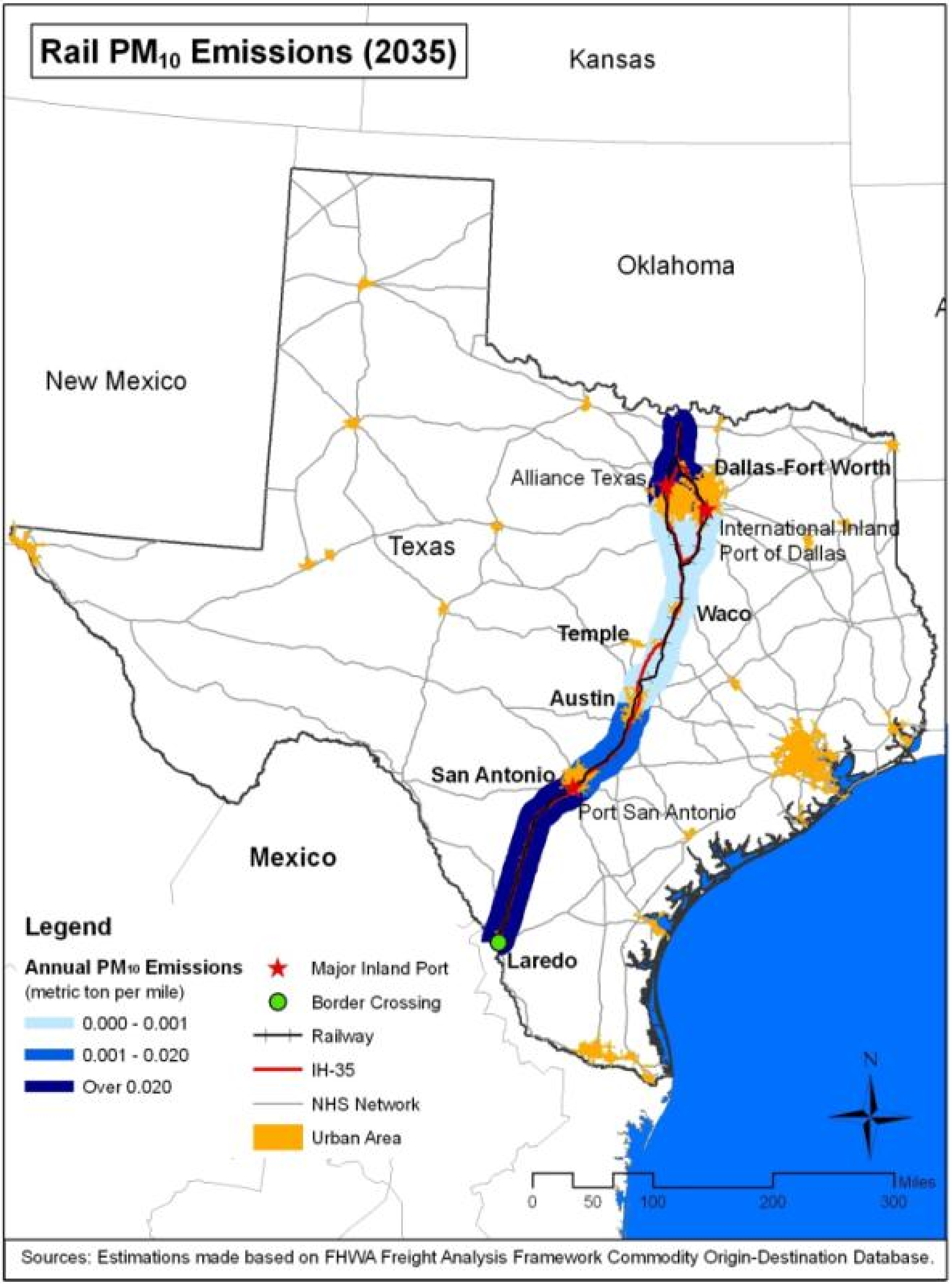

Figure A12. Estimated PM_{10} Emissions from Freight Railroads along the Corridor in 2035.

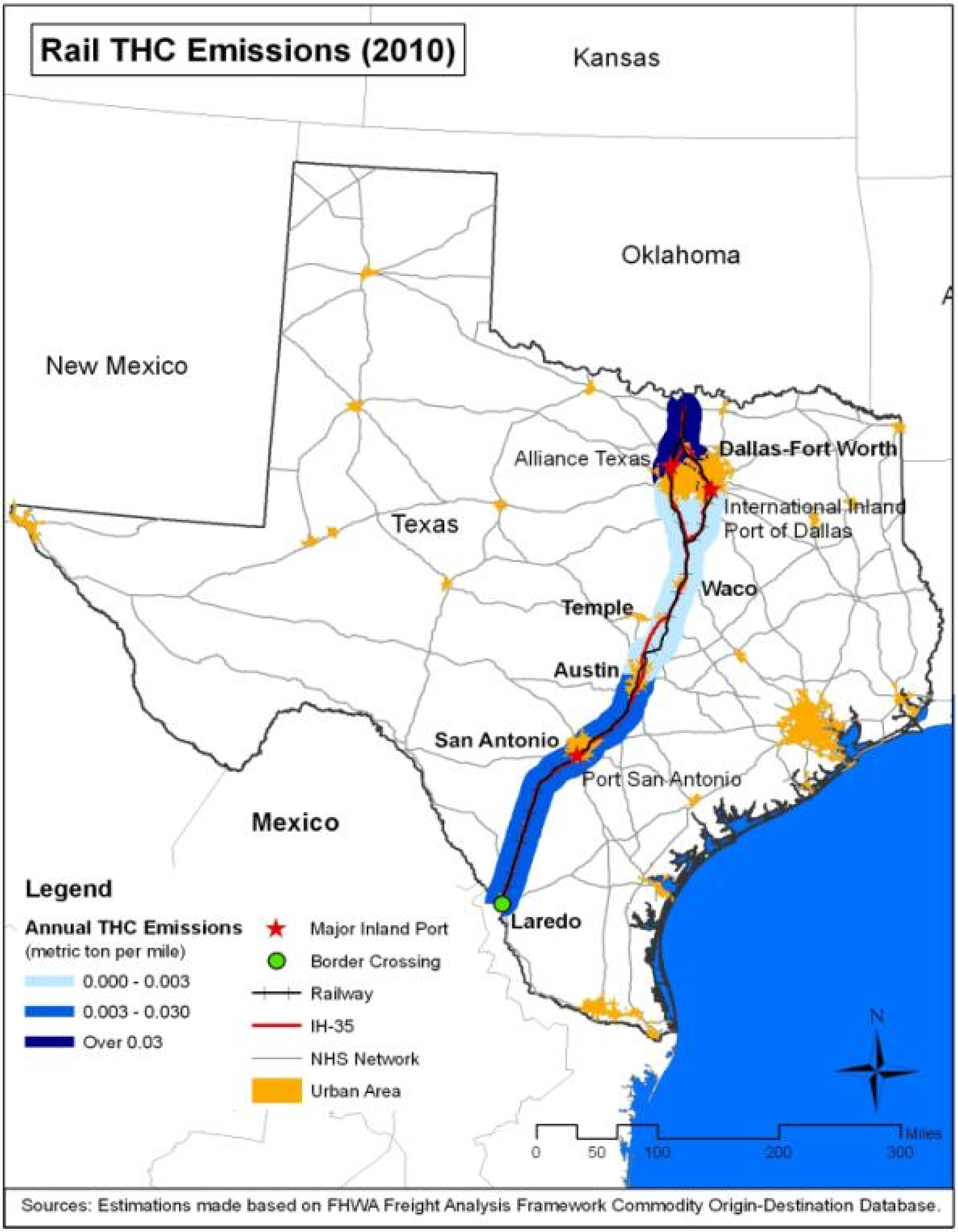

Figure A.13. Estimated THC Emissions from Freight Railroads along the Corridor in 2010.

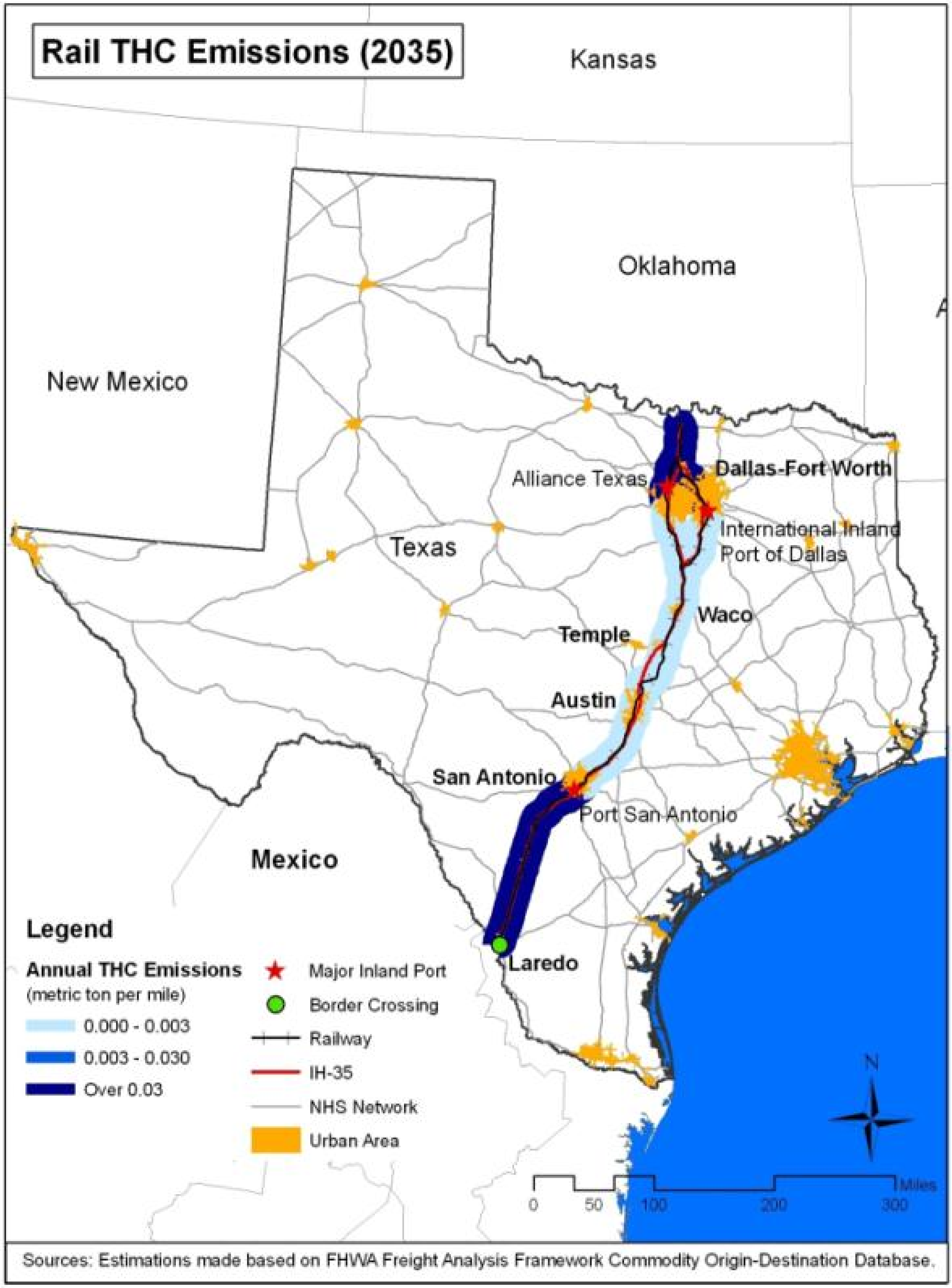

Figure A.14. Estimated THC Emissions from Freight Railroads along the Corridor in 2035.

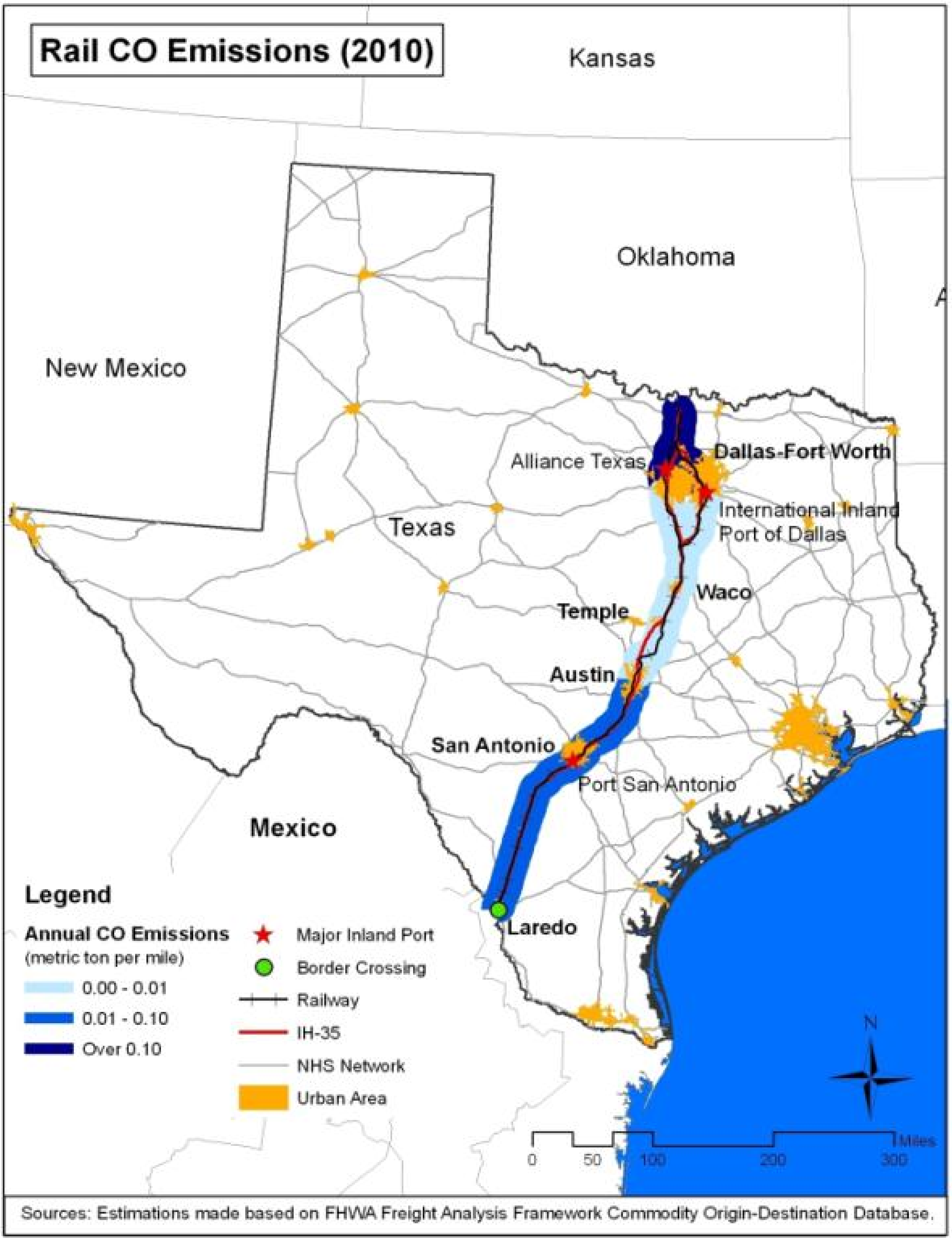

Figure A.15. Estimated CO Emissions from Freight Railroads along the Corridor in 2010.

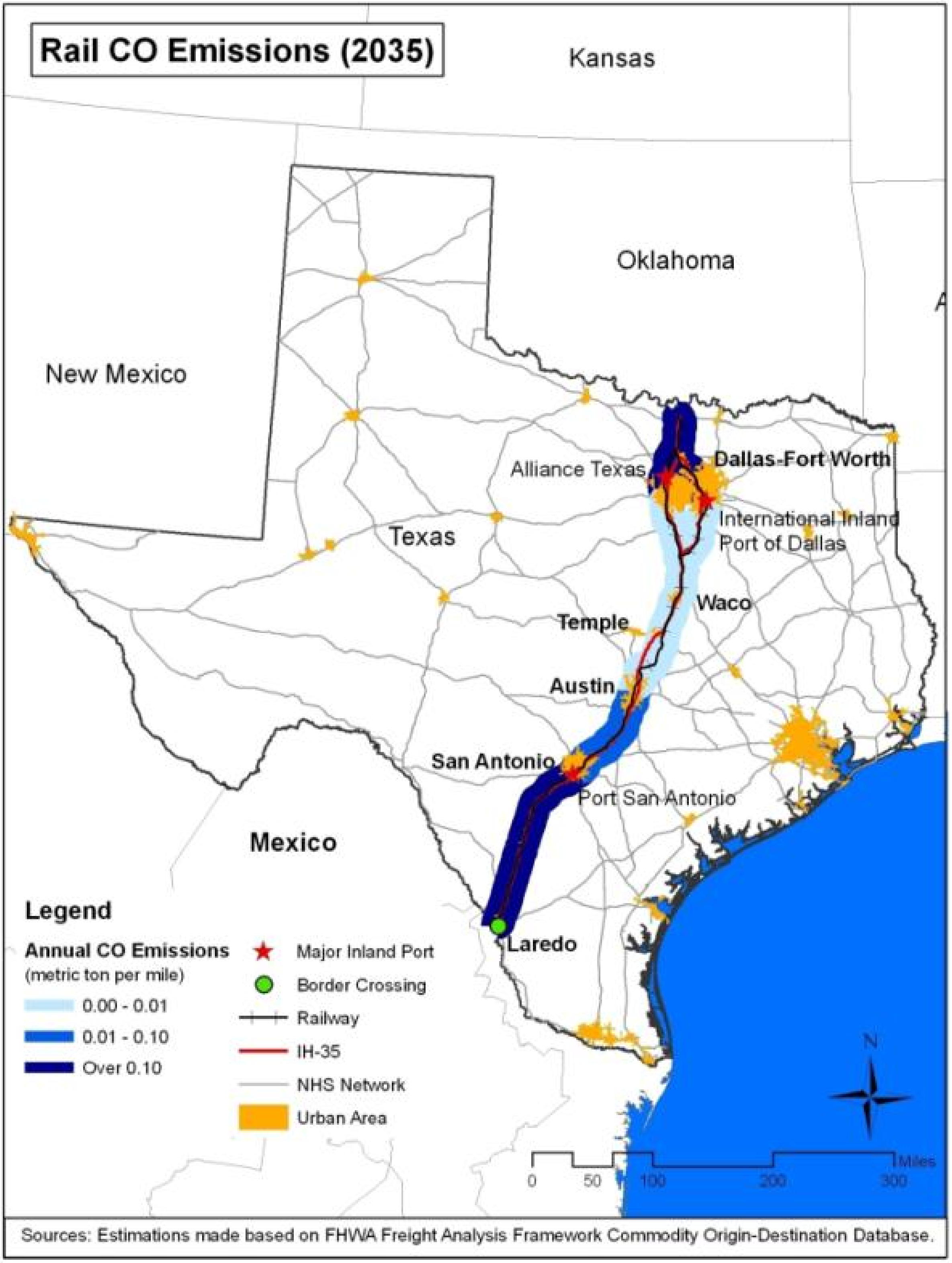

Figure A.16. Estimated CO Emissions from Freight Railroads along the Corridor in 2035.