Texas Water Development Board

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TO: Board Members

THROUGH: Jeff Walker, Executive Administrator
John T. Dupnik, P.G., Deputy Executive Administrator, Water Science and Conservation
Todd Chenoweth, General Counsel

FROM: Erika Mancha, Manager, Innovative Water Technologies
Kevin Kluge, Director, Conservation and Innovative Water Technologies

DATE: March 14, 2019

SUBJECT: Designation of brackish groundwater production zones in four aquifers

ACTION REQUESTED

Consider designating brackish groundwater production zones in the Blossom, Lipan, Nacatoch, and Northern Trinity aquifers.

BACKGROUND

In 2015, the 84th Texas Legislature passed House Bill 30, directing the Texas Water Development Board (TWDB) to conduct studies to:

(1) identify and designate brackish groundwater production zones in the state,
(2) determine the volumes of groundwater that a brackish groundwater production zone can produce over 30-year and 50-year periods without causing significant impact to water availability or water quality,
(3) make recommendations on reasonable monitoring to observe the effects of brackish groundwater production within the zone,
(4) work with groundwater conservation districts and stakeholders in general, and
(5) provide a summary of brackish groundwater production zone designations in the biennial report due December 1 of each even-numbered year.

Further, House Bill 30 directed the TWDB to identify and designate brackish groundwater production zones in four aquifers by December 1, 2016, and in the remaining aquifers in the state by December 1, 2022.

To date, the Board has designated brackish groundwater production zones in the following aquifers: no zones in the Blaine Aquifer, one zone in the Carrizo-Wilcox Aquifer south of the Colorado River, four zones in the Gulf Coast Aquifer and bordering sediments, and three zones in the Rustler Aquifer. Summaries of each aquifer study were included in the *2016 Biennial Report on Seawater and Brackish Groundwater Desalination* and submitted to the Texas Legislature by December 1, 2016.

AREAS RECOMMENDED FOR DESIGNATION AS BRACKISH GROUNDWATER PRODUCTION ZONES

The areas recommended for designation as brackish groundwater production zones in the Blossom, Lipan, Nacatoch, and Northern Trinity aquifers are listed below.

- Blossom Aquifer
  - Areas BLSM1, BLSM2, and BLSM3 (Attachment A, Figure 1)
- Lipan Aquifer
  - No areas recommended (Attachment A, Figure 3)
- Nacatoch Aquifer
  - Areas NCTC1, NCTC2, NCTC3, NCTC4, and NCTC5 (Attachment A, Figure 5)
- Northern Trinity Aquifer–
  - Areas NTPA1 and NTPA2 (Attachment A, Figure 7)
  - Areas NTGR1, NTGR2, NTGR3, and NTGR4 (Attachment A, Figure 8)
  - Areas NTHE1, NTHE2, and NTHE3 (Attachment A, Figure 9)
  - Areas NTPE1 and NTPE2 (Attachment A, Figure 10)
  - Areas NTHO1, NTHO2, NTHO3, and NTHO4 (Attachment A, Figure 11)

For each zone, TWDB staff determined (1) hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in geologic strata, (2) volumes of brackish groundwater that a zone is capable of producing over 30- and 50-year periods without causing a significant impact to water availability or water quality in surrounding aquifers, and (3) recommendations on reasonable monitoring to observe the effects of brackish groundwater production within the zone.

The brackish groundwater production zones being recommended are representative of the aquifers and do not include every possible area that might qualify for designation. Lack of designation of such areas at this time does not preclude (1) designation of zones in these areas in the future or (2) development of the brackish resource outside of a designated zone.

RECOMMENDATION

The Executive Administrator recommends approval of areas as brackish groundwater production zones:

Attachment(s): An assessment of areas recommended for designation as brackish groundwater production zones in the Blossom, Lipan, Nacatoch, and Northern Trinity aquifers

Attachment A

An assessment of areas recommended for designation as brackish groundwater production zones in the Blossom, Lipan, Nacatoch, and Northern Trinity aquifers.

BACKGROUND

To assist the TWDB in making designations, the 84th Texas Legislature appropriated $2 million from General Revenue for contracts and administrative costs (House Bill 1, General Appropriations Act, 2015 Legislature, Regular Session, page IX-88, Sec. 18.30).

> **Sec. 18.30. Contingency for HB 30 or HB 1232**. Contingent on enactment of House Bill 30, House Bill 1232, or similar legislation relating to the study of the characteristics of aquifers in this state, by the Eighty-fourth Legislature, Regular Session, 2015, the Water Development Board is appropriated $1,849,233 in fiscal year 2016 and $150,767 in fiscal year 2017 out of the General Revenue Fund in Strategy A.2.2., Water Resources Planning. Of these amounts, $1,681,446 in fiscal year 2016 shall be used for contract costs for studies related to designating priority zones for the production of brackish groundwater in the portion of the Carrizo-Wilcox Aquifer located between the Colorado and Rio Grande Rivers, the Gulf Coast Aquifers and sediments bordering that aquifer, the Blaine Aquifer, and the Rustler Aquifer, or other appropriate aquifers as identified; and $167,787 in fiscal year 2016 and $150,767 in fiscal year 2017 shall be used for administrative costs in implementing the provisions of the legislation. In addition, the "Number of Full-Time Equivalents (FTE)" in the agency bill pattern is increased by 2.0 FTEs in fiscal year 2016 and 2.0 FTEs in fiscal year 2017. The Board shall report to the Legislature on its progress relating to the studies not later than December 1, 2016.
> Any unexpended and unencumbered balances remaining in this appropriation on August 31, 2016 are hereby appropriated for the same purpose in the fiscal year beginning September 1, 2016.

The TWDB funded seven contracts for eight aquifers or portions of an aquifer. More specifically, the TWDB funded six contracts and executed one interagency contract for a total of $1,681,446. These eight aquifers included the four aquifers specified in House Bill 30 and four additional brackish aquifers (the Blossom, Nacatoch, Queen City and Sparta, and Trinity aquifers) selected by TWDB staff because of their complexity. The interagency contract included two aquifer portions (Carrizo-Wilcox Aquifer and Queen City and Sparta aquifers). Contractors completed the four aquifers specified in House Bill 30 by September 2016 and an additional three aquifers (the Blossom, Nacatoch, and Trinity aquifers) by September 2017. The contractor has not submitted final deliverables for the Queen City and Sparta aquifers.

In the 2018-2019 biennium, the TWDB did not receive appropriations to continue implementing the requirements of House Bill 30. As a result, the TWDB is not currently able to meet the full requirements of this legislation, which include: (1) modeling and calculating production volumes for 30-year and 50-year periods in brackish groundwater production zones, and (2) completing studies by December 1, 2022. The TWDB will continue mapping and characterizing brackish aquifers with current resources at a slower pace than would have been possible with continued program funding. This scientific work is a process that first requires that brackish groundwater in an entire aquifer is analyzed, characterized, and mapped before zones within the aquifer can be delineated. It is

important that this work proceed to continue progress toward achieving the objectives of the Brackish Resources Aquifer Characterization System (BRACS) Program.

The TWDB has requested appropriations for the 2020-2021 biennium that would restore the $2 million to support the BRACS Program and work on House Bill 30. If approved, the funding would enable the TWDB to make faster progress toward meeting the House Bill 30 requirements. However, the TWDB will not be able to map brackish groundwater resources and designate zones in the remaining aquifers by the statutory deadline of December 1, 2022, even with restoration of funds. As a result, the TWDB requested a 10-year extension to finish identifying and designating zones in only brackish aquifers that meet House Bill 30 criteria by 2032.

IMPLEMENTATION PROCESS

To achieve the goals of House Bill 30, the TWDB developed the following process and plans to use the same process for future studies:

1. Contractors compiled available geologic and hydrologic information to map and characterize both the vertical and horizontal extent of the aquifer.
2. Contractors identified potential production areas and assessed the hydrologic effects of pumping in the proposed production areas.
3. TWDB staff reviewed information from the contractors and information associated with exclusions (such as existing use, water quality, injection wells, and pumping impacts) and developed brackish groundwater production zones for possible designation.
4. The Executive Administrator recommended brackish groundwater production zones to the agency's Board for approval.

More specifically, each aquifer is evaluated for areas with moderate to high availability and productivity that are separated by hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in geologic strata that have an average total dissolved solids concentration of 1,000 milligrams per liter or less. In addition, exclusion areas were also considered in the evaluation of an aquifer:

- The Edwards Aquifer located within the jurisdictional boundaries of the Edwards Aquifer Authority, the Barton Springs-Edwards Aquifer Conservation District, the Harris-Galveston Subsidence District, and the Fort Bend Subsidence District
- Aquifers, subdivisions of aquifers, or geologic strata that have an average total dissolved solids concentration of more than 1,000 milligrams per liter which serve as a significant source of water supply for municipal, domestic, or agricultural purposes
- Geologic formations that are designated or used for wastewater injection through the use of injection or disposal wells permitted under Texas Water Code Chapter 27

After receiving final reports and datasets from contractors, TWDB staff conducted a thorough review to ensure that the requirements of and exclusion criteria in House Bill 30

had been properly implemented and considered stakeholder input. These reviews required staff to modify stratigraphy, augment well data, and calculate salinity. Staff evaluated the contractor-identified potential production areas for the presence of: (1) Class I, II, III, IV, and V injection wells; (2) domestic, municipal, and agricultural water wells using a 3- to 7-mile buffer around each well; and (3) hydrogeologic barriers. If Class II (type 1, 2, and 3) injection wells were located in potential production areas, TWDB staff placed a 15-mile buffer around each well. If other injection wells (Class I, II [type 4 to 7], III, IV, and V) were located in potential production areas, TWDB staff evaluated them on case-by-case basis and determined the appropriate buffer size to place around them as needed.

TWDB staff finalized the areas and provided them to the Executive Administrator with a recommendation for the Board to designate the areas as brackish groundwater production zones. The Board memo containing the Executive Administrator's recommendation was posted on the TWDB website before the Board meeting, and stakeholders were notified via email about its availability for review and comment. If comments are received, they will be provided to the Board before the meeting.

The TWDB worked with groundwater conservation districts and stakeholders as required by House Bill 30 and made reasonable efforts to engage them. Each step of the implementation process provided ample opportunities for stakeholder review and comment. On October 26, 2015, staff held the first stakeholder meeting in Austin to explain the TWDB's approach to implementing House Bill 30, solicit feedback on key terms in the bill (for example, significant impact), and receive comments on implementation of the legislation. Throughout development of the studies, TWDB staff gave presentations at local meetings within the vicinity of each aquifer and notified stakeholders of the meetings in advance via email. Between February and November of 2017, staff held seven aquifer-specific stakeholder meetings to request data, share results, and solicit feedback. Details of the meetings are as follows:

- Blossom and Nacatoch aquifers:
  - Mount Pleasant, TX, February 8, 2017
  - Commerce, TX, April 18, 2017
  - Mount Pleasant, TX, October 25, 2017
- Lipan Aquifer:
  - San Angelo, TX, April 20, 2017
  - San Angelo, TX, May 24, 2017
- Trinity Aquifer:
  - Austin, TX, May 8, 2017
  - Waco, TX, November 1, 2017

Information pertaining to all stakeholder meetings, including announcements and presentations, were posted on the TWDB website (www.twdb.texas.gov/innovativewater/bracs/HB30.asp) in a timely manner. In addition, emails were sent to stakeholders informing them of the availability of final reports.

KEY ISSUES

In the ongoing process of conducting aquifer studies, TWDB staff and project contractors encountered the same three challenges found during the 2016 aquifer studies: (1) water well and injection well data availability, (2) groundwater model accessibility, and (3) injection well buffer applicability.

The first key challenge is that there is no single database in Texas that has complete records of all installed water wells (domestic, municipal, and agricultural) and injection wells (Class I, II, III, IV, and V). Datasets that are available are located at different agencies, have different formats, and often have incomplete information. Since House Bill 30 excludes designation of brackish groundwater production zones in specific areas, identifying water wells and injection wells within proposed production areas is critically important to the evaluation process.

The second challenge is that BRACS staff does not have the modeling expertise or necessary funding to create a calibrated groundwater model to estimate the volume of brackish groundwater production that will account for simultaneous well fields and regional water pumping for each zone. As a result, contractors only conducted a simple, desktop analysis of groundwater production within a zone to estimate the impact to fresh water resources. Similarly, staff used a simple analysis to determine groundwater volume based on aquifer parameters and simulated drawdown.

The third challenge is that BRACS staff does not know the distance that injected fluids may have traveled both laterally and vertically from Class II (type 1, 2,3) injection wells. Determining the distance that injected fluids travel is important, as BRACS staff discovered that several Class II injection zones are installed above, below, lateral to, or overlapping with geologic stratum containing brackish groundwater. The TWDB will continue to adopt a conservative approach to estimating the distance traveled by injected fluids and place a 15-mile buffer around Class II (type 1, 2,3) injection wells as in past studies. In the future, the TWDB may revise zone designations if the buffer is reduced.

As of July 2017, the TWDB began collaborating with the Groundwater Advisory Unit of the Railroad Commission (RRC) to discuss different aspects of their programs and to hold monthly meetings. On January 23, 2018, the RRC provided a presentation on its Underground Injection Control Permit Program, and TWDB staff learned of a recent project completed by the RRC that is relevant to the BRACS Program. The State of Texas Aquifer Exemption Project involved researching and verifying records for about 62,500 Class II injection well permits that allow injection into Underground Sources of Drinking Water (groundwater less than 10,000 milligram per liter of total dissolved solids). On February 27, 2018, the TWDB requested and subsequently obtained the report for the State of Texas Aquifer Exemption Project, the RRC's internal searchable database of injection wells, and the geographic information system files and metadata developed for this project. TWDB staff will use this data when evaluating brackish groundwater production zones for future studies. Staff from both agencies met an additional three times (March 3, April 23, June 27) on the same topic and will continue discussions.

It is essential that TWBD staff have a thorough understanding of the Class II injection well data and methodology so they can accurately use the data when evaluating and delineating brackish groundwater production zones. It is also important for RRC staff to understand the requirements of House Bill 30 and to learn how the TWDB uses their information to support the BRACS Program. Key topics for continued discussion include: (1) the methodology the RRC applies to determine the geologic separation between the federally-designated Underground Source of Drinking Water and top of the injection zone, and (2) specific injection wells that may not be within mapped aquifer exemption boundaries.

AREAS RECOMMENDED FOR DESIGNATION AS BRACKISH GROUNDWATER PRODUCTION ZONES

The areas recommended for designation as brackish groundwater production zones in the Blossom, Lipan, Nacatoch, and Northern Trinity aquifers are described below. For each zone, TWDB staff determined (1) hydrogeologic barriers sufficient to prevent significant impacts to water availability or water quality in geologic strata, (2) volumes of brackish groundwater that a zone is capable of producing over 30- and 50-year periods without causing a significant impact to water availability or water quality in surrounding aquifers, and (3) recommendations on reasonable monitoring to observe the effects of brackish groundwater production within the zone.

The brackish groundwater production zones being recommended are representative of the aquifers and do not include every possible area that might qualify for designation. Lack of designation of such areas at this time does not preclude (1) designation of zones in these areas in the future or (2) development of the brackish resource outside of a designated zone.

BLOSSOM AQUIFER

Recommended brackish groundwater production zones

In the Blossom Aquifer, TWDB staff recommends three areas for designation as brackish groundwater production zones (Attachment A, Figure 1, BLSM1, BLSM2, and BLSM3). The recommended zones are located within the Blossom Sand geological formation. Zones BLSM1 and BLSM3 contain moderately saline groundwater (3,000 to 9,999 milligrams per liter total dissolved solids). Zone BLSM2 contains a small amount of slightly saline groundwater (1,000 to 2,999 milligrams per liter of total dissolved solids), but the majority is moderately saline groundwater). For each recommended zone, the minimum, maximum, and average top surface depth and thickness were calculated (Table 1).

Table 1. Parameters of brackish groundwater production zones in the Blossom Aquifer.

Zone name	Measured in feet					
	Minimum top depth	Maximum top depth	Average depth	Minimum thickness	Maximum thickness	Average thickness
BLSM1	115	370	234	98	180	129
BLSM2	0	746	381	224	385	288
BLSM3	339	666	488	268	345	289

Interlayered clays, marls, and chalk that overlie the Blossom Sand constitute a significant hydrologic barrier to prevent impact on fresh water wells completed more than 200 feet from the top of the Blossom Sand within the brackish groundwater production zones. The locations of the zones are sufficiently downdip of the fresh portion of the Blossom Aquifer that potential impacts on fresh groundwater resources are minimal under most of the pumping scenarios analyzed.

To act as a horizontal-distance hydrogeologic barrier to jurisdictions and existing use, a 3-mile buffer was applied to the freshwater line, the state line, and 86 known municipal, domestic, and agricultural water wells. No Class I, III, IV, or V injection wells were found injecting into the Blossom Sand within the study area. Less than 15 miles downdip of the potential production areas, 13 Class II (type 1, 2, and 3) injection wells were found in the Blossom Sand. These injection wells were determined to have hydrogeologic separation from the aquifer by the Mexia-Talco Fault Zone and therefore were not used to exclude areas from brackish groundwater production zone recommendations. Based on the contractor's modeling of pumping 100 acre-feet per year for 50 years, drawdown expected at the nearest receptor well was between 5 and 15 feet, which was determined not to be significant. After considering all criteria above (Attachment A, Figure 2), three brackish groundwater production zones are recommended.

Volumes of brackish groundwater in the recommended production zones

The volumes of brackish groundwater that could potentially be produced from BLSM1, BLSM2, and BLSM3 over 30- and 50-year periods were calculated based on the contractor's modeling (Table 2).

Table 2: Volumes of brackish groundwater that a zone can produce over 30- and 50-year periods without causing significant impact.

Aquifer	Zone name	Annual pumpage (acre-feet/year)	30-year cumulative (acre-feet)	50-year cumulative (acre-feet)
Blossom	BLSM1	100	3,000	5,000
Blossom	BLSM2	100	3,000	5,000
Blossom	BLSM3	100	3,000	5,000

Groundwater monitoring in the recommended production zones

In general, groundwater monitoring in the Blossom Aquifer should focus on the various aquifers overlying the Blossom Aquifer. Monitoring in wells completed in these aquifers

would ensure that the interlayered clays, marls, and chalk overlying the Blossom Sand provide an adequate hydrologic barrier. Freshwater resources of the Blossom Aquifer, updip from the zones, should also be monitored to ensure that significant impact from potential production of brackish groundwater is prevented. Monitoring is not required below the Blossom Sand geological formation because there are no known fresh or brackish aquifers that would be impacted by pumping in the zones. Future wellfields in the brackish zones should include monitor wells to track water levels and water quality during production.

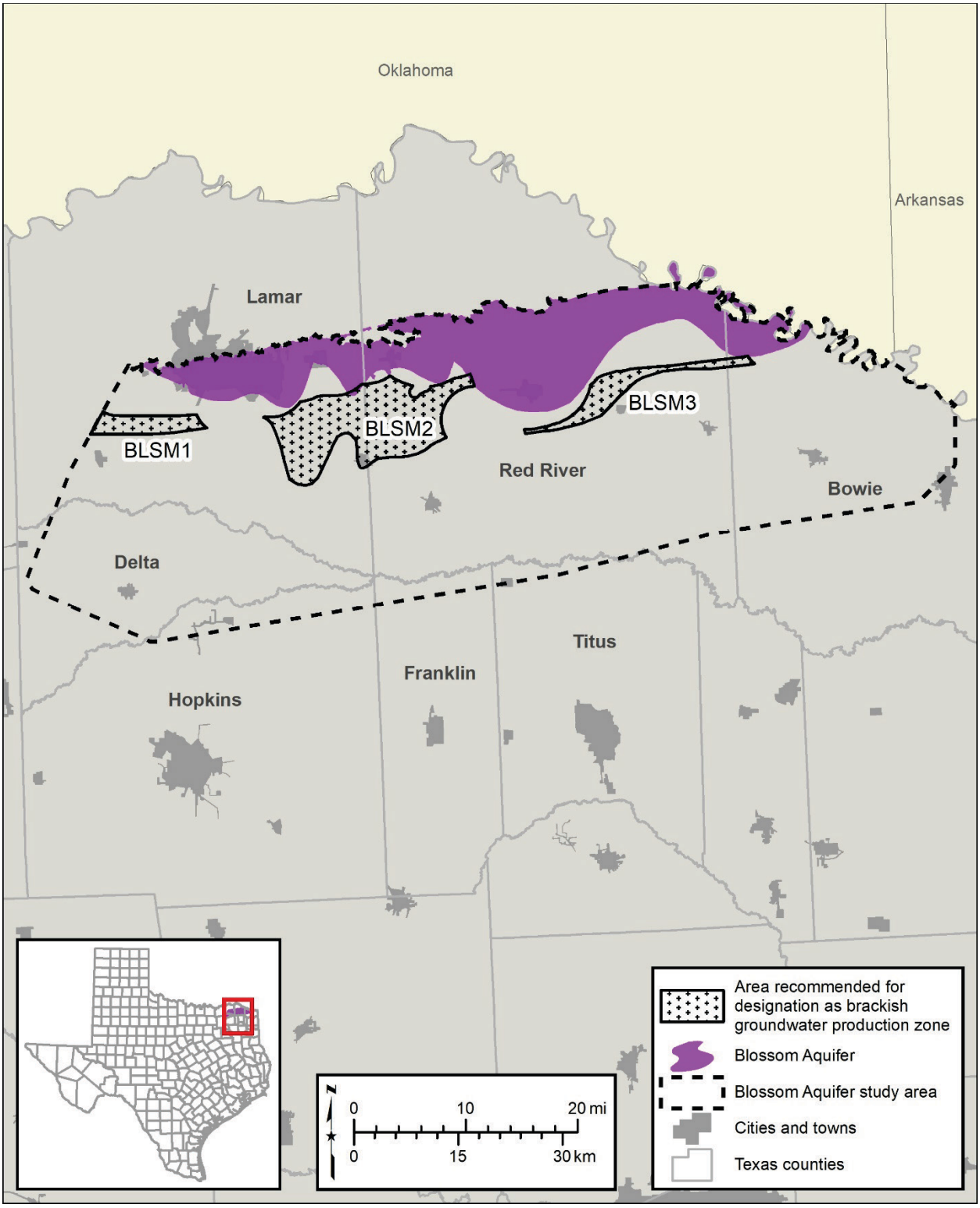

Figure 1. **Three recommended brackish groundwater production zones (BLSM 1, BLSM2, and BLSM3) in the Blossom Aquifer study area. The Blossom Aquifer includes both outcrop and subcrop and is defined by the TWDB as a minor aquifer.**

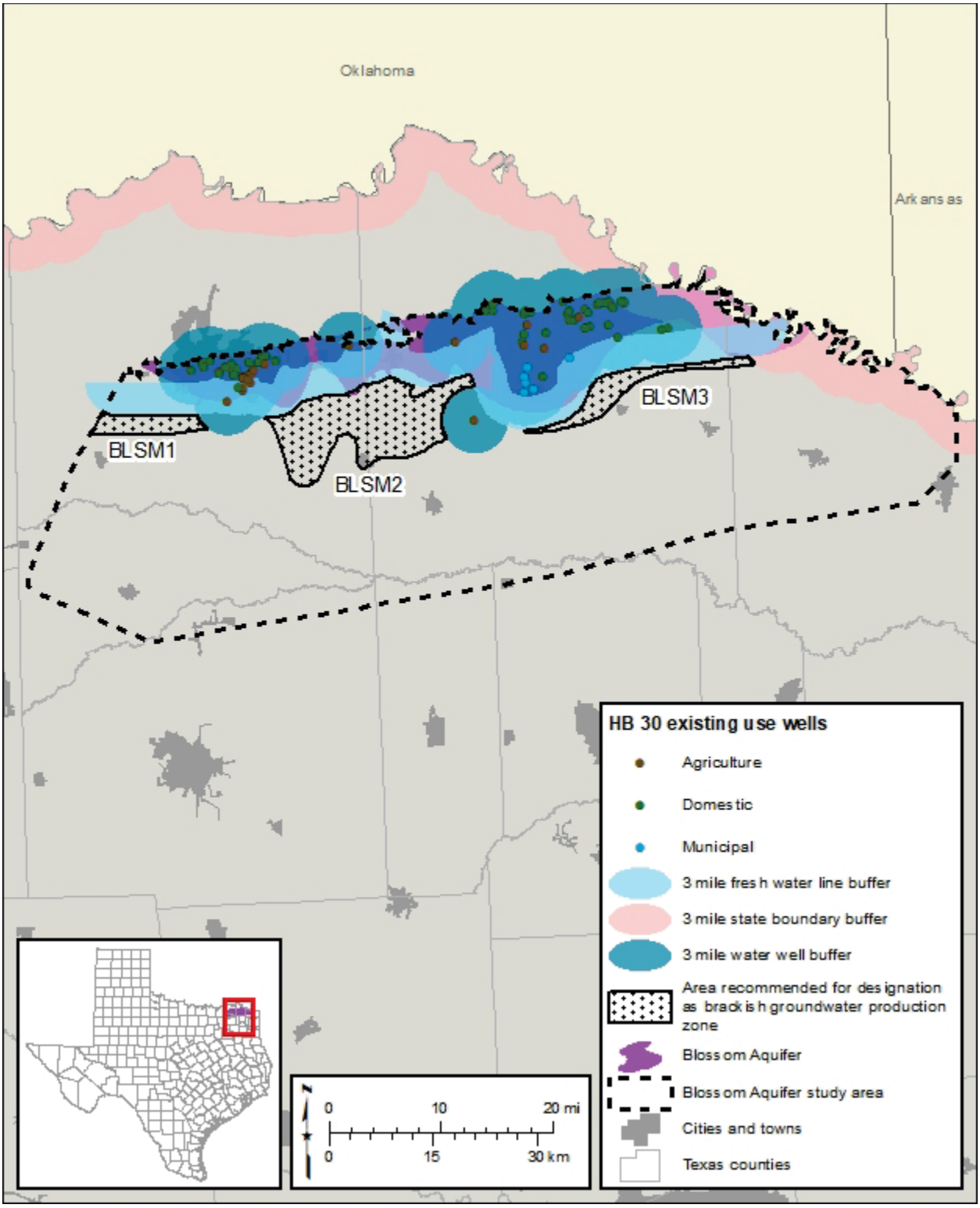

Figure 2. **Blossom Aquifer study area showing existing water wells (municipal, domestic, and agricultural) used to exclude areas from being recommended as Blossom Aquifer brackish groundwater production zones. A three-mile buffer was applied to existing water wells, the fresh water line, and the state boundary. There are no injection wells affecting the designation of the brackish groundwater production zones.**

LIPAN AQUIFER

TWDB staff is not recommending an area in the Lipan Aquifer for designation as a brackish groundwater production zone because the aquifer did not meet two House Bill 30 requirements (Attachment A, Figure 3). The first was that hydrogeologic barriers do not exist between the brackish Permian units and the overlying Quaternary and Neogene sediments where fresh water occurs. A confining caliche layer is believed to occur within the sediments, but it is discontinuous and only occurs locally. The second was that the Lipan Aquifer serves as a significant water source for municipal, domestic, and agricultural purposes and the groundwater has an average total dissolved solids concentration greater than 1,000 milligrams per liter (Attachment A, Figure 4).

TWDB staff did not develop groundwater monitoring recommendations for brackish groundwater production zones because no zones are recommended in the aquifer. However, as new wells are drilled in the Lipan Aquifer area, obtaining water quality information using discrete interval sampling methods from deeper brackish water formations would be helpful. In brackish water intervals that appear to contain significant groundwater, pump test data would greatly enhance knowledge of the hydraulic properties of these formations.

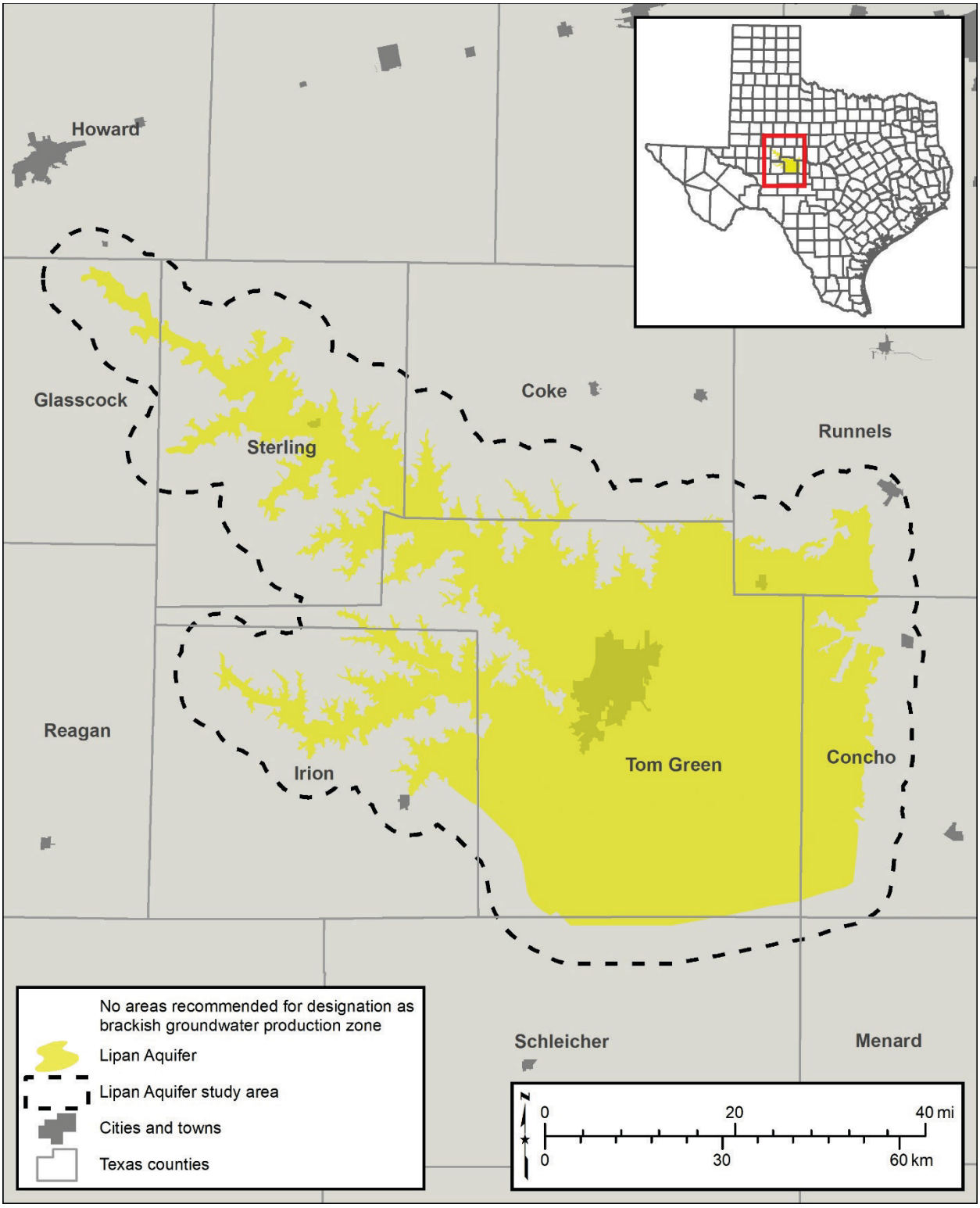

Figure 3. **The Lipan Aquifer study area. No areas are recommended for designation as brackish groundwater production zones.**

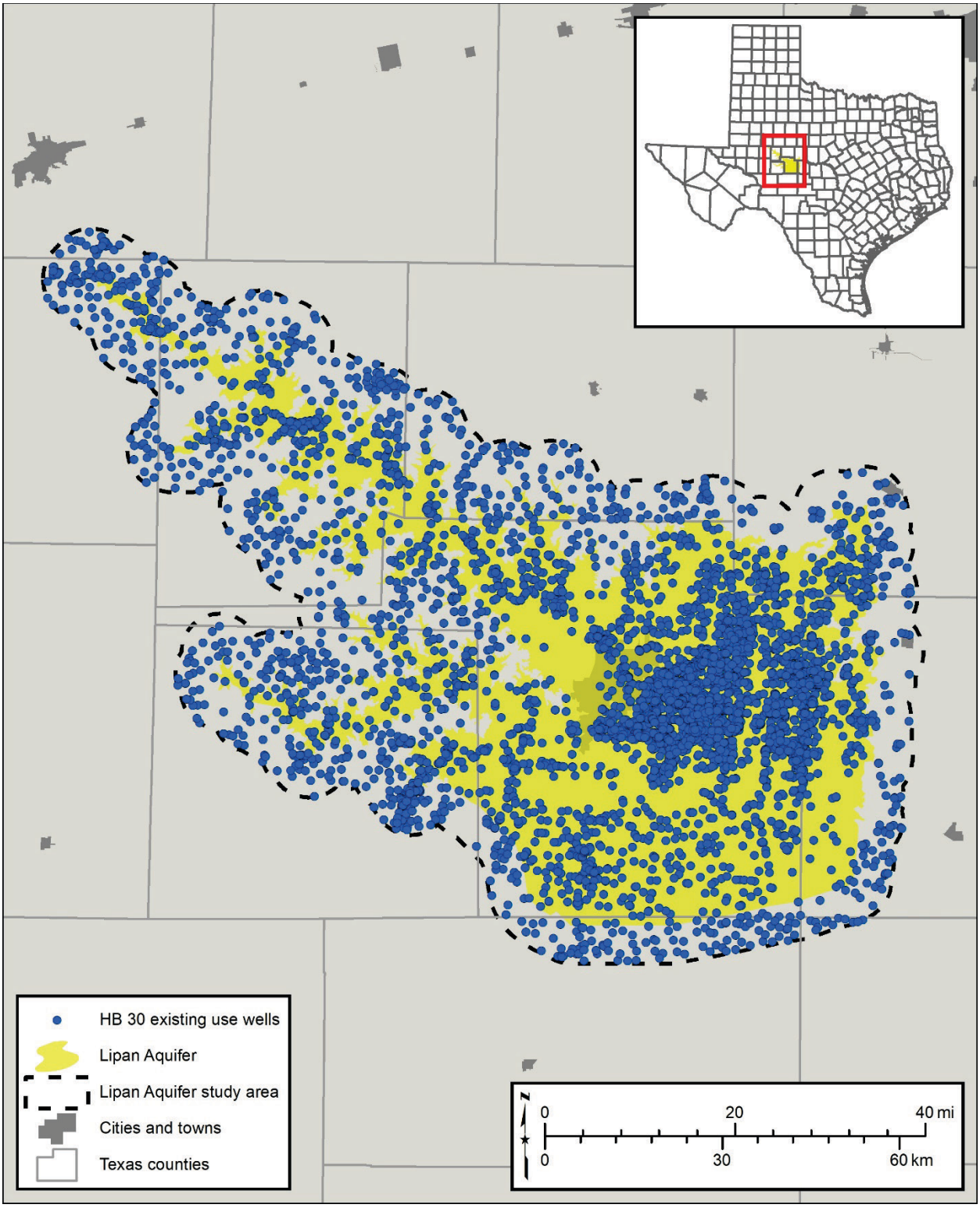

Figure 4. **Lipan Aquifer study area showing existing water wells (municipal, domestic, and agricultural) used to exclude areas from being recommended as brackish groundwater production zones.**

NACATOCH AQUIFER

Recommended brackish groundwater production zones

In the Nacatoch Aquifer, TWDB staff recommends five areas for designation as brackish groundwater production zones (Attachment A, Figure 5, NCTC1, NCTC2, NCTC3, NCTC4, and NCTC5). The recommended zones are located within sands of the Nacatoch Aquifer and contain moderately saline groundwater (3,000 to 9,999 milligrams per liter total dissolved solids) with a small part of NCTC3 that has slightly saline groundwater (1,000 to 2,999 milligrams per liter total dissolved solids). For each recommended zone, the minimum, maximum, and average top surface depth and thickness were calculated (Table 3).

Table 3. Parameters of brackish groundwater production zones in the Nacatoch Aquifer.

Zone name	Measured in feet					
	Minimum top depth	Maximum top depth	Average depth	Minimum thickness	Maximum thickness	Average thickness
NCTC1	132	746	433	227	326	263
NCTC2	248	545	414	274	362	322
NCTC3	235	1,326	795	329	474	398
NCTC4	341	1,246	938	370	485	442
NCTC5	907	1,149	1,039	410	443	423

The interbedded sand and clay that overlie and underlie the Nacatoch Sand geological formation act as a significant hydrogeologic barrier to isolate fresh groundwater in other aquifers. The Mexia-Talco fault zone consists primarily of strike-oriented normal faults that formed grabens and disrupt the basinward dip of the Nacatoch Aquifer layers. The faulting generally causes the normal downdip flow of groundwater to be halted or diverted, thus limiting the downdip extent of fresh water in the aquifer and providing an additional barrier against the interaction between the fresh and brackish parts of the Nacatoch Aquifer.

To act as a horizontal-distance hydrogeologic barrier to existing use, a 3-mile buffer was applied to the freshwater line, the state line, and 784 known water wells. Existing water wells include 94 agricultural wells, 572 domestic wells, and 118 municipal wells. No Class I or IV injection wells were found within 15 miles of the study area. There are 529 Class II (type 1, 2, and 3) injection wells injecting into the Nacatoch Aquifer, and a 15-mile buffer was applied to all wells. Three Class II (type 5, 6, and 7) injection wells for liquid petroleum gas are located in the study area, but these were not buffered since injection fluid is restricted to reservoir storage. Five Class III injection wells for brine mining were found in a salt dome in Van Zandt County, but these were not buffered since injection fluids are restricted to the mining activity as opposed to waste disposal. There are 19 Class V injection wells for heat flow and shallow aquifer remediation within 15 miles of the study area, but these were not buffered since they are shallow and do not pose an injection problem. Based on the TWDB's Theis modeling of pumping 200 acre-feet per year for 50 years, the drawdown expected at the nearest receptor well was between 24 and 43 feet,

which was determined not to be significant. After considering all criteria above (Attachment A, Figure 6), five brackish groundwater production zones are recommended.

Volumes of brackish groundwater in the recommended production zones

The volumes of brackish groundwater that could potentially be produced from NCTC1, NCTC2, NCTC3, NCTC4, and NCTC5 over 30- and 50-year periods were calculated based on the TWDB's Theis modeling (Table 4).

Table 4: Volumes of brackish groundwater that a zone can produce over 30- and 50-year periods without causing significant impact.

Aquifer	Zone name	Annual pumpage (acre-feet/year)	30-year cumulative (acre-feet)	50-year cumulative (acre-feet)
Nacatoch	NCTC1	200	6,000	10,000
Nacatoch	NCTC2	165	4,950	8,250
Nacatoch	NCTC3	400	12,000	20,000
Nacatoch	NCTC4	200	6,000	10,000
Nacatoch	NCTC5	200	6,000	10,000

Groundwater monitoring in the recommended production zones

In general, groundwater monitoring in the Nacatoch Aquifer should focus on the various aquifers overlying the Nacatoch Aquifer. Monitoring in wells completed in these aquifers would ensure that the marine clay in the upper Navarro Group overlying the Nacatoch sand provides an adequate hydrologic barrier. Freshwater resources of the Nacatoch Aquifer, updip from the zones, should also be monitored to ensure that significant impact caused by the production of brackish groundwater is prevented. Monitoring is not required below the basal sand unit of the Nacatoch Aquifer because there are no known fresh or brackish aquifers that would be impacted by pumping in these zones. Future wellfields in the brackish zones should include monitor wells to track water levels and water quality during production.

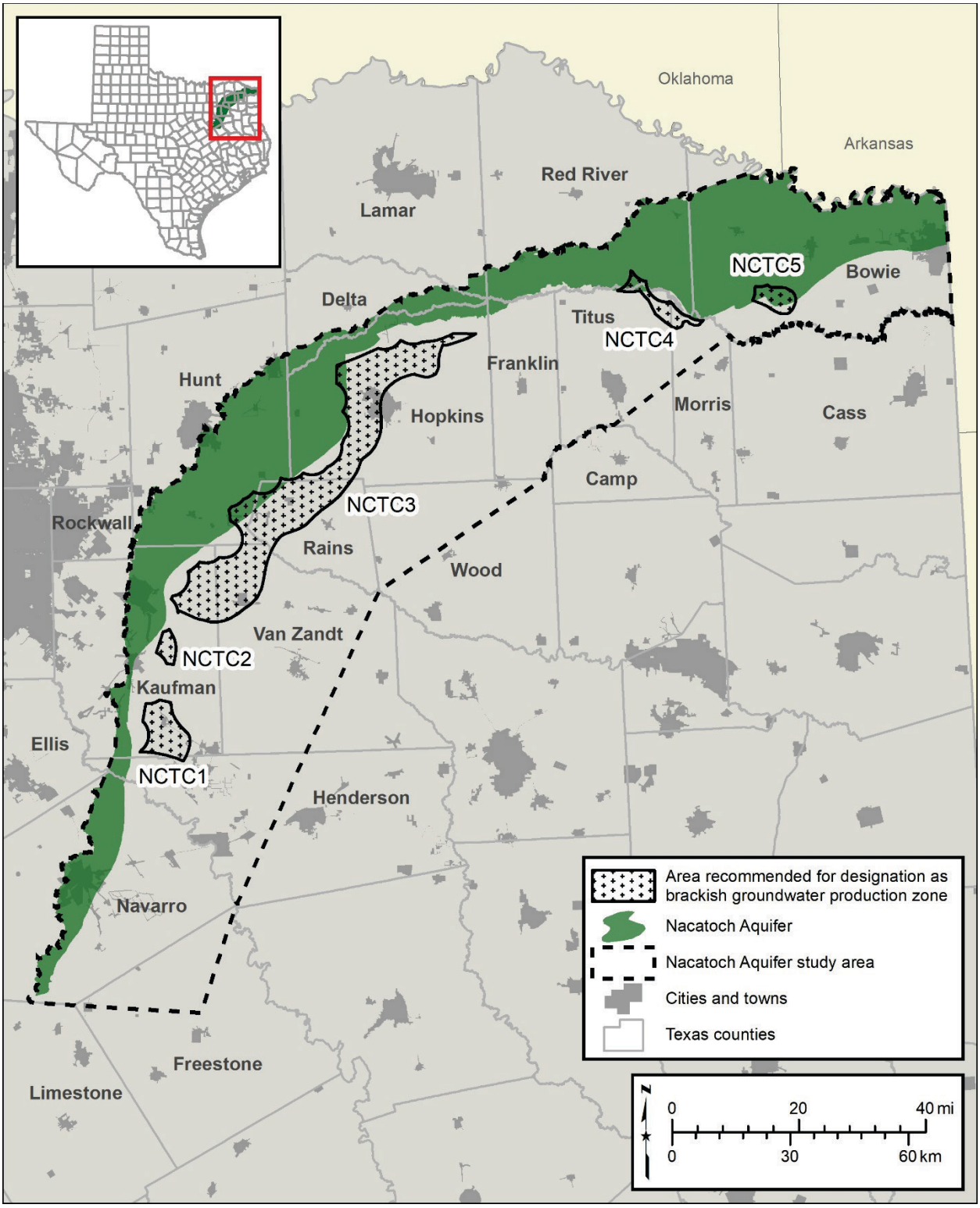

Figure 5. **Five recommend brackish groundwater production zones (NCTC1, NCTC2, NCTC3, NCTC4, and NCTC5) in the Nacatoch Aquifer study area. The Nacatoch Aquifer includes both outcrop and subcrop and is defined by the TWDB as a minor aquifer.**

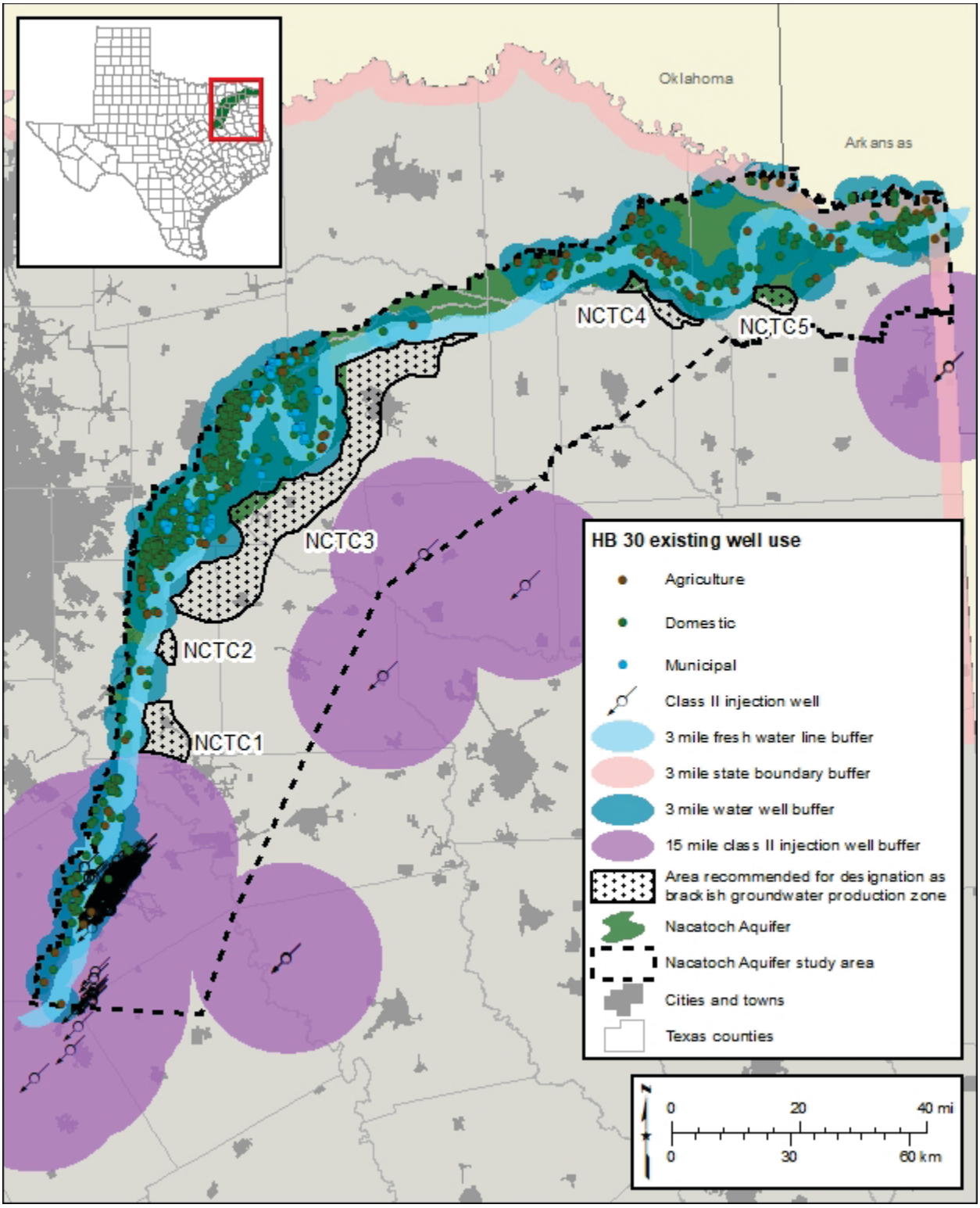

Figure 6. **Nacatoch Aquifer study area showing existing water wells (municipal, domestic, and agricultural) used to exclude areas from being recommended as Nacatoch Aquifer brackish groundwater production zones. A three-mile buffer was applied to existing water wells, the fresh water line, and the state boundary. A 15-mile buffer was placed around all Class II injection wells.**

Northern Trinity Aquifer

Recommended brackish groundwater production zones

In the Northern Trinity Aquifer study area, TWDB staff recommends 15 areas for designation as brackish groundwater production zones with 2 to 4 zones designated for each of the 5 hydrostratigraphic units that define the Northern Trinity Aquifer. There are two zones in the Paluxy unit (Attachment A, Figure 7, NTPA1 and NTPA2), four zones in the Glen Rose unit (Attachment A, Figure 8, NTGR1, NTGR2, NTGR3, and NTGR4), three zones in the Hensell unit (Attachment A, Figure 9, NTHE1, NTHE2, and NTHE3), two zones in the Pearsall unit (Attachment A, Figure 10, NTPE1 and NTPE2), and four zones in the Hosston unit (Attachment A, Figure 11, NTHO1, NTHO2, NTHO3, and NTHO4). These recommended zones contain groundwater that is slightly to moderately saline (1,000 to 9,999 milligrams per liter of total dissolved solids). For each recommended zone, the maximum, minimum, and average top surface depth and thickness were calculated (Table 5).

Table 5. Parameters of brackish groundwater production zones in the Northern Trinity Aquifer.

Zone Name	Measured in feet					
	Minimum top depth	Maximum top depth	Average depth	Minimum thickness	Maximum thickness	Average thickness
NTPA1	998	3,992	2,476	109	465	393
NTPA2	716	4,916	2,698	53	405	185
NTGR1	1,420	4,063	2,654	248	869	538
NTGR2	1,214	4,687	3,001	363	1,010	716
NTGR3	1,120	3,996	2,505	539	946	783
NTGR4	1,032	6,614	3,056	411	1,269	934
NTHE1	1,676	4,729	3,387	57	133	96
NTHE2	1,496	4,071	2,795	66	113	89
NTHE3	1,132	5,577	3,326	30	169	72
NTPE1	1,316	4,541	3,046	57	494	250
NTPE2	1,155	5,669	3,070	81	610	260
NTHO1	1,655	5,946	4,092	61	1,089	453
NTHO2	1,398	6,645	3,721	56	913	415
NTHO3	2,114	6,404	4,189	194	1,170	605
NTHO4	1,707	8,116	4,289	205	1,670	1,050

The overlying geological formations contain shale that can act as a hydrogeologic barrier between the areas recommended for designation and the overlying aquifers. Hydrogeologic barriers in each brackish groundwater production zone in the study area include structural geological boundaries such as faults, the Fredericksburg Group that is present above the Trinity Aquifer, and the Pre-Cretaceous formations that are present below the aquifer. Within the Trinity Group there are significant vertical flow barriers formed by the Pearsall shale, Hammett shale, and massive limestone beds interspersed throughout that isolate the five hydrostratigraphic units.

TWDB staff evaluated Class II (type 1, 2, and 3) injection well data and found one well injecting into the Paluxy Formation of the Northern Trinity Aquifer. A 15-mile buffer was applied to account for injected fluids that may have traveled both laterally and vertically from this well. Remaining areas were then evaluated for the presence of water wells (domestic, municipal, and agricultural), injection wells (Class I, Class III, Class IV, and Class V), and hydrogeologic barriers, in this order. For existing water wells, buffers ranging between 3 and 7 miles were applied and based upon modeled drawdown effects (Attachment A, Figures 12 to 16).

Volumes of brackish groundwater in the recommended production zones

The volumes of brackish groundwater that could potentially be produced from modeled single-well well fields in the zones over 30- and 50-year periods were calculated (Table 6).

Table 6: Volumes of brackish groundwater that a zone can produce over 30- and 50-year periods without causing significant impact.

Hydrostratigraphic unit	Zone name	Annual pumpage (acre-feet per year)	30-year cumulative (acre-feet)	50-year cumulative (acre-feet)
Paluxy	NTPA1	1,000	30,000	50,000
	NTPA2	380	11,400	19,000
Glen Rose	NTGR1	725	21,750	36,250
	NTGR2	315	9,450	15,750
	NTGR3	600	18,000	30,000
	NTGR4	780	23,400	39,000
Hensell	NTHE1	375	11,250	18,750
	NTHE2	350	10,500	17,500
	NTHE3	117	3,510	5,850
Pearsall	NTPE1	1,400	42,000	70,000
	NTPE2	1,600	48,000	80,000
Hosston	NTHO1	975	29,250	48,750
	NTHO2	3,950	118,500	197,500
	NTHO3	3,550	106,500	177,500
	NTHO4	1,165	34,950	58,250

Groundwater monitoring in the recommended production zones

In general, groundwater monitoring should focus on the overlying and laterally adjacent aquifers that contain fresh water or existing use. Monitoring in hydrogeologic barriers is recommended to determine the potential source of impacts to fresh water or existing use due to development in surrounding aquifers or the Trinity Aquifer. Monitoring is not required below the Trinity Aquifer because there are no known fresh or brackish aquifers in the underlying Pre-Cretaceous formations in this area. Future wellfields in the brackish

zones should include monitor wells to track water levels and water quality during production.

The northern extension of the Edwards (Balcones Fault Zone) Aquifer extends into the southern portion of the study area and overlies the Trinity Aquifer. Over 200 feet of non-water bearing sediment of the lower Fredericksburg Group separate the Edwards Aquifer from the water bearing units in the Trinity Aquifer. In Williamson and Bell counties there is the potential that the Edwards Aquifer may, as a result of faulting, be adjacent to porous units of the Trinity Aquifer. Therefore, monitoring water levels in the Edwards Aquifer should be considered with development of the Glen Rose formation in zone NTGR4.

TWDB staff did not review the occurrence and effect that faults might have upon the juxtaposition of water bearing formations in detail. When developing brackish groundwater in the vicinity of large offset faults, monitoring in the shallower water bearing units on the downthrown side is recommended.

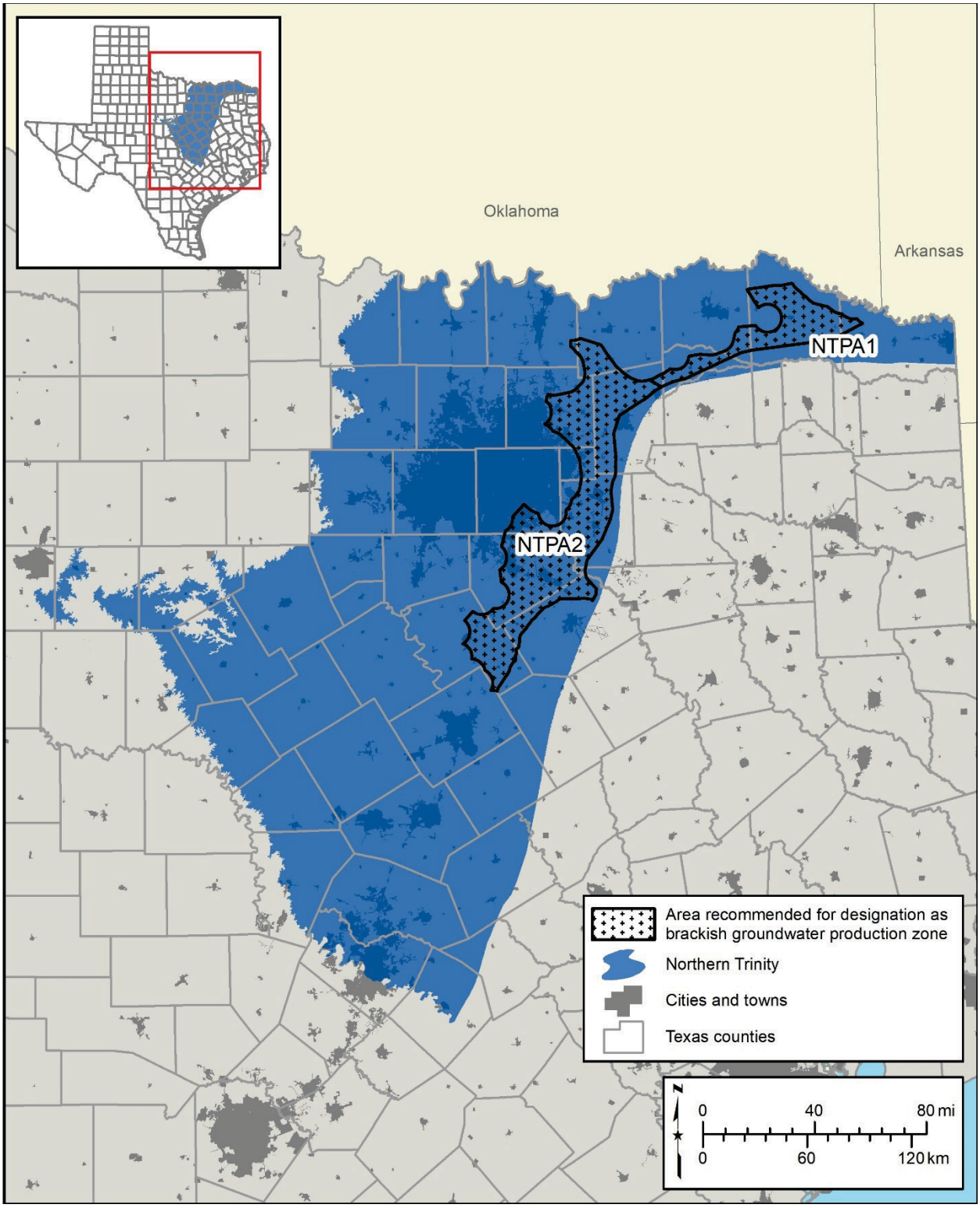

Figure 7. **Two recommended brackish groundwater production zones (NTPA1 and NTPA2) in the Paluxy Formation of the Northern Trinity Aquifer study area.**

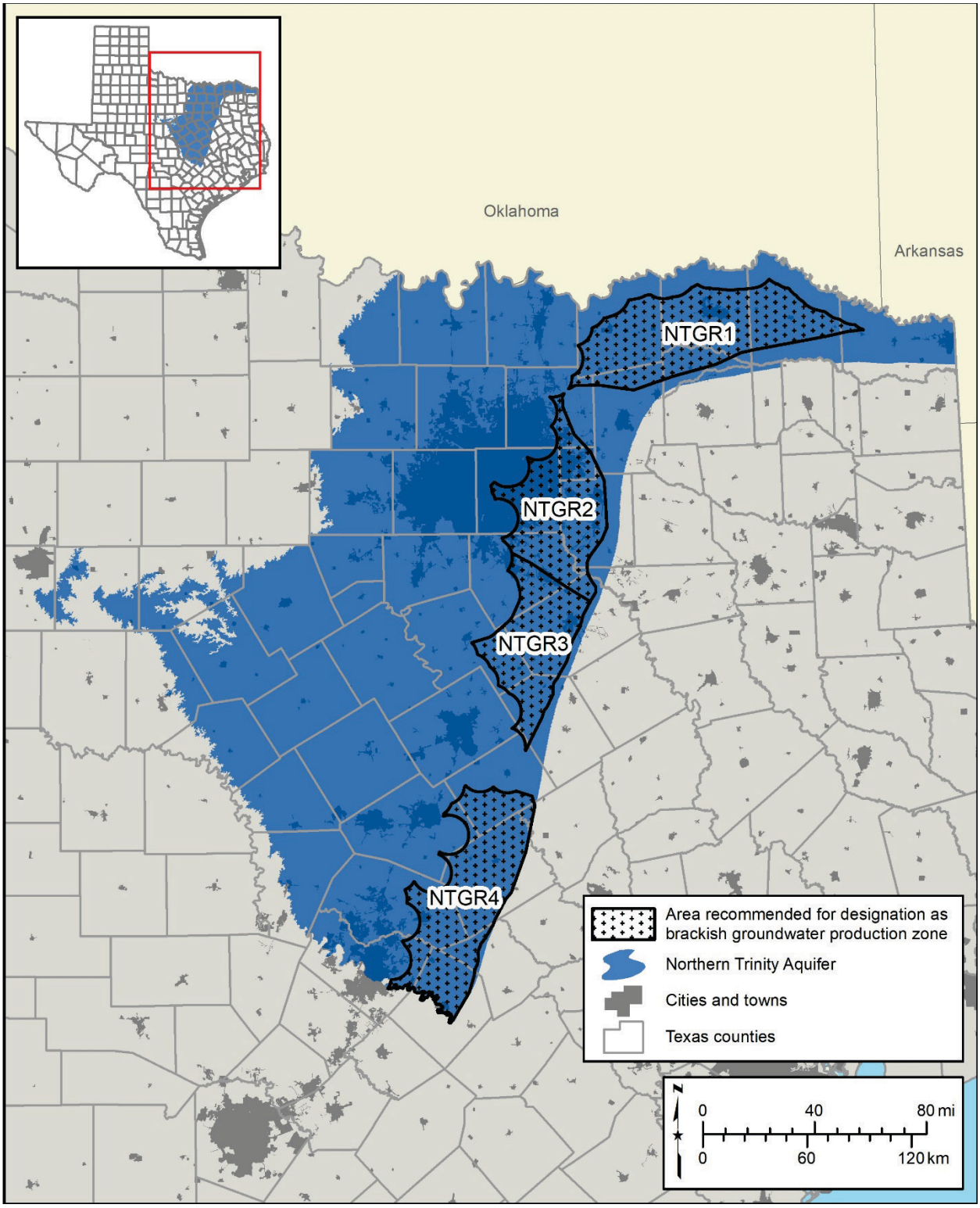

Figure 8. **Four recommended brackish groundwater production zones (NTGR1, NTGR2, NTGR3, and NTGR4) in the Glen Rose Formation of the Northern Trinity Aquifer study area.**

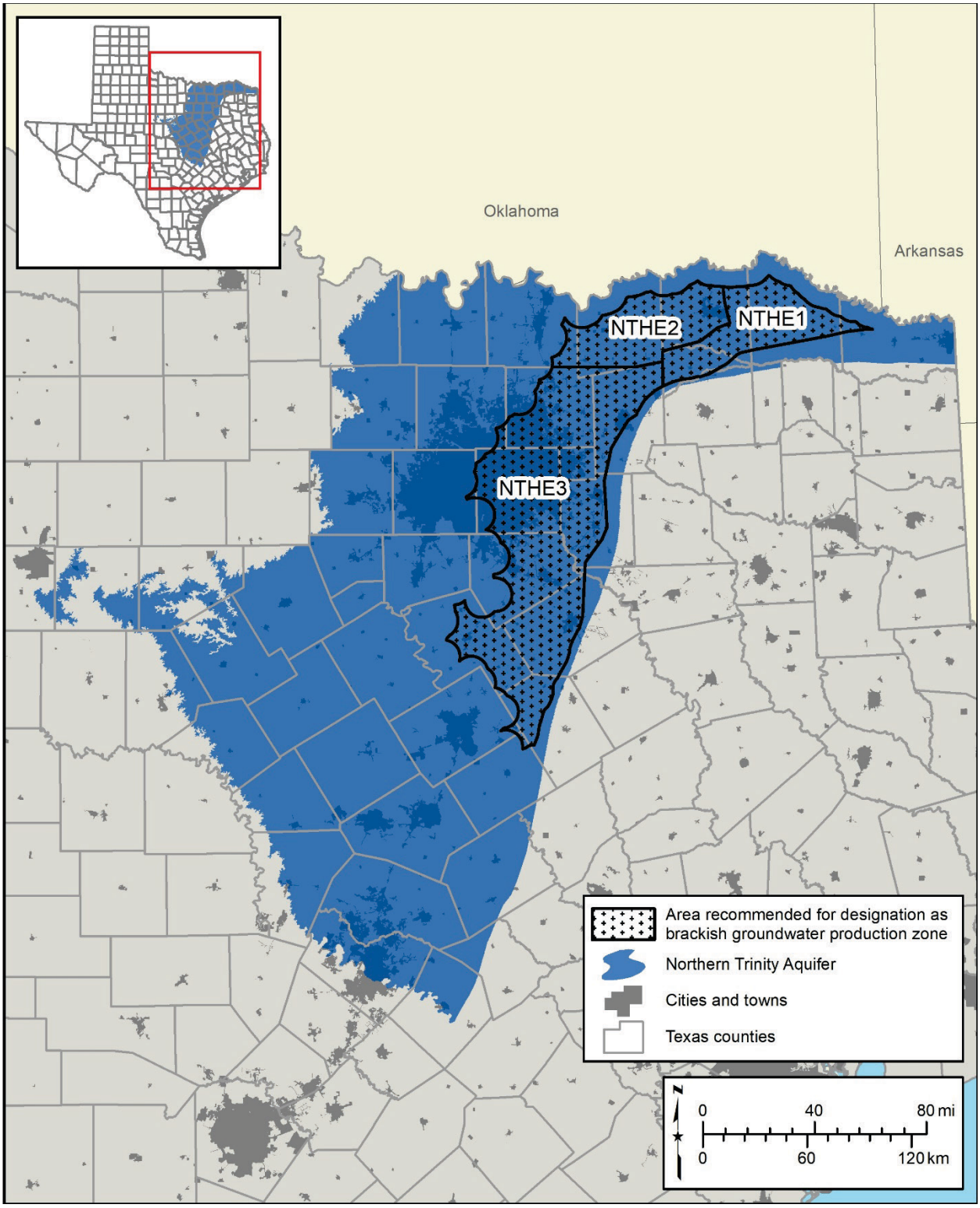

Figure 9. **Three recommended brackish groundwater production zones (NTHE1, NTHE2, and NTHE3) in the Hensell Formation of the Northern Trinity Aquifer study area.**

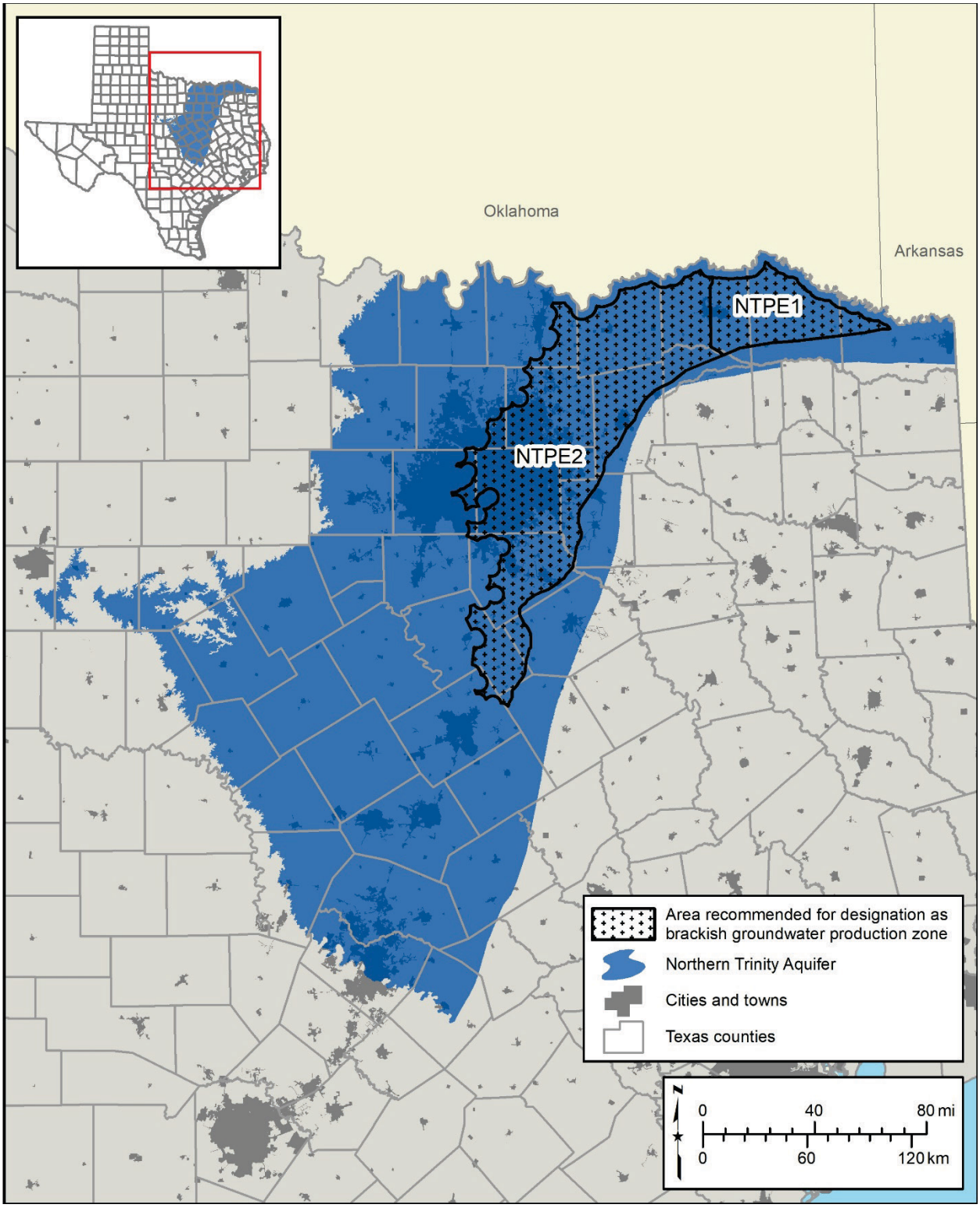

Figure 10. **Two recommended brackish groundwater production zones (NTPE1 and NTPE2) in the Pearsall Formation of the Northern Trinity Aquifer study area.**

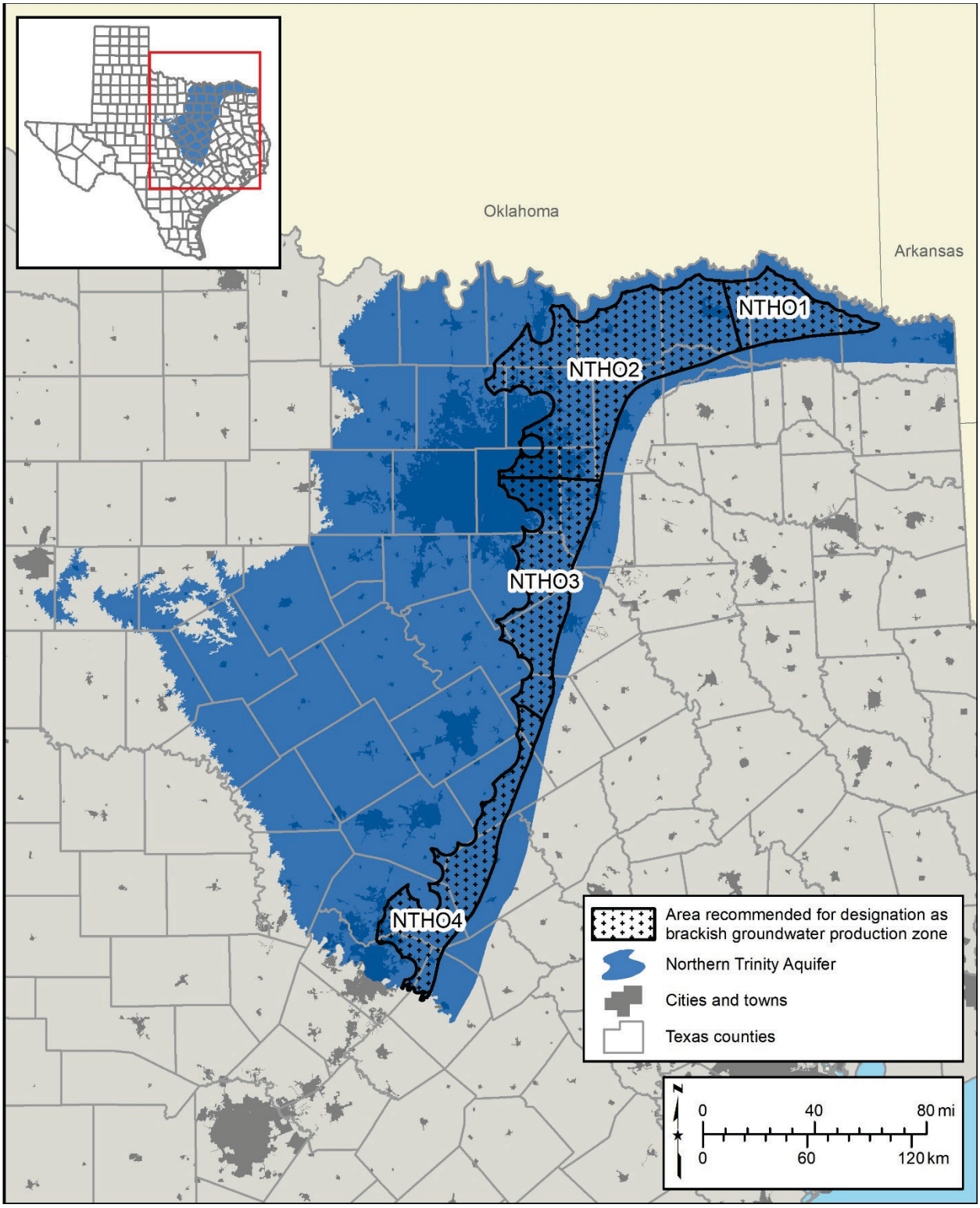

Figure 11. **Four recommended brackish groundwater production zones (NTHO1, NTHO2, NTHO3, and NTHO4) in the Hosston Formation of the Northern Trinity Aquifer study area.**

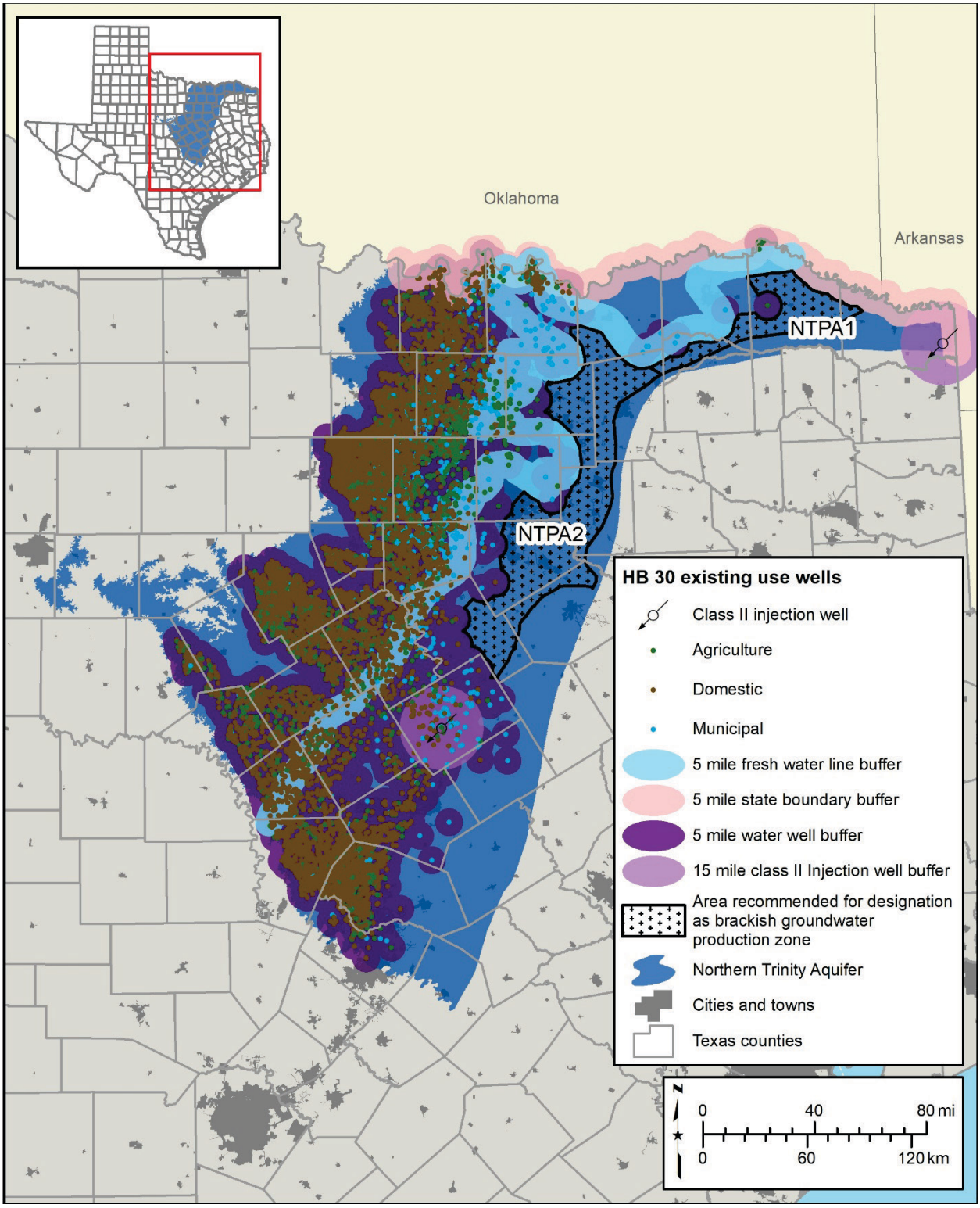

Figure 12. **Northern Trinity Aquifer study area showing existing water wells (municipal, domestic, and agricultural) used to exclude areas from being recommended as Paluxy Formation brackish groundwater production zones (NTPA1, NTPA2). A five-mile buffer was applied to existing water wells, the fresh water line, and the state boundary. There are no injection wells affecting the designation of the brackish groundwater production zone.**

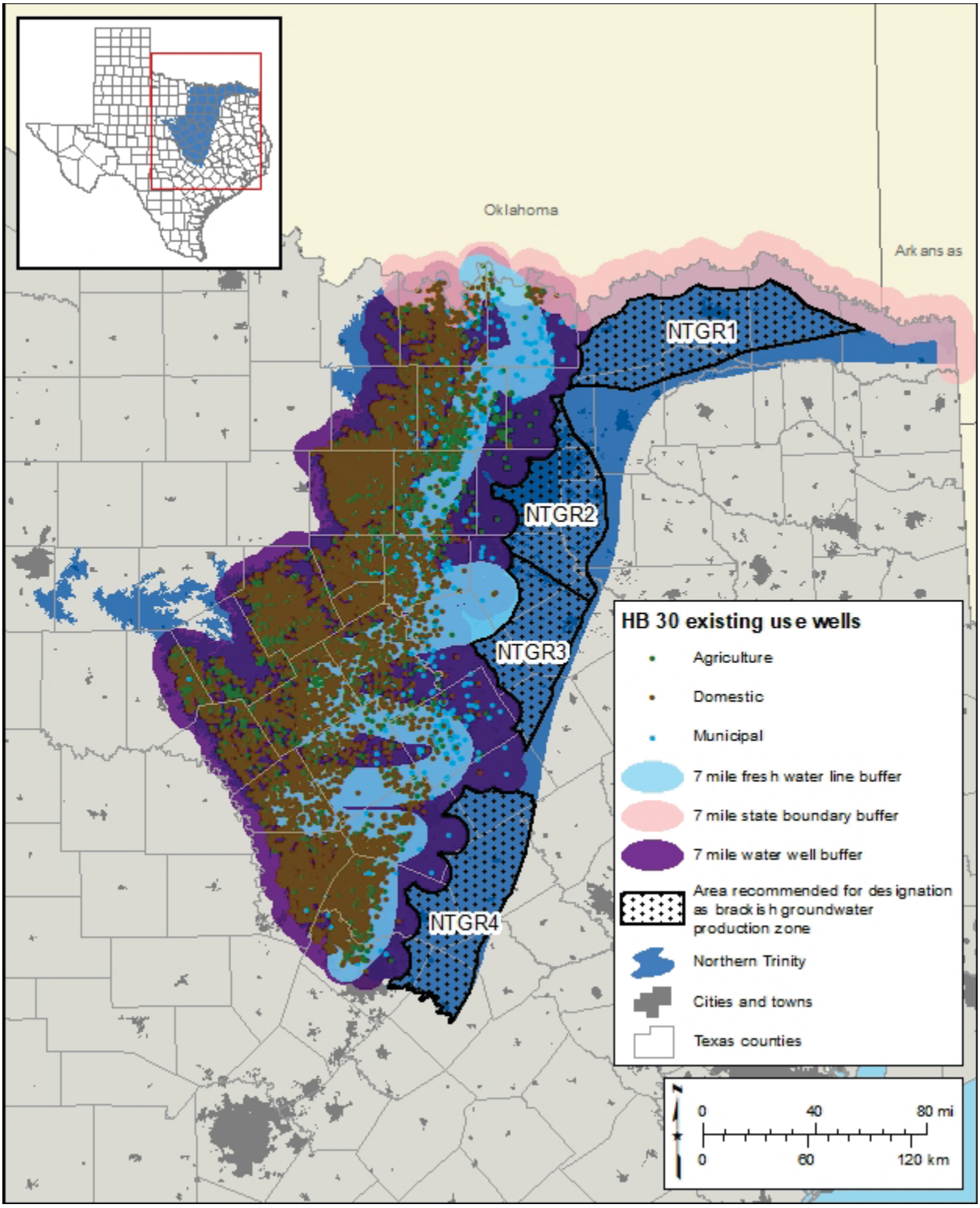

Figure 13. **Northern Trinity Aquifer study area showing existing wells (municipal, domestic, and agricultural) used to exclude areas from being recommended as Glen Rose Formation brackish groundwater production zones (NTGR1, NTGR2, NTGR3, NTGR4). A seven-mile buffer was applied to existing wells, the fresh water line, and the state boundary. There are no injection wells affecting the designation of the brackish groundwater production zone.**

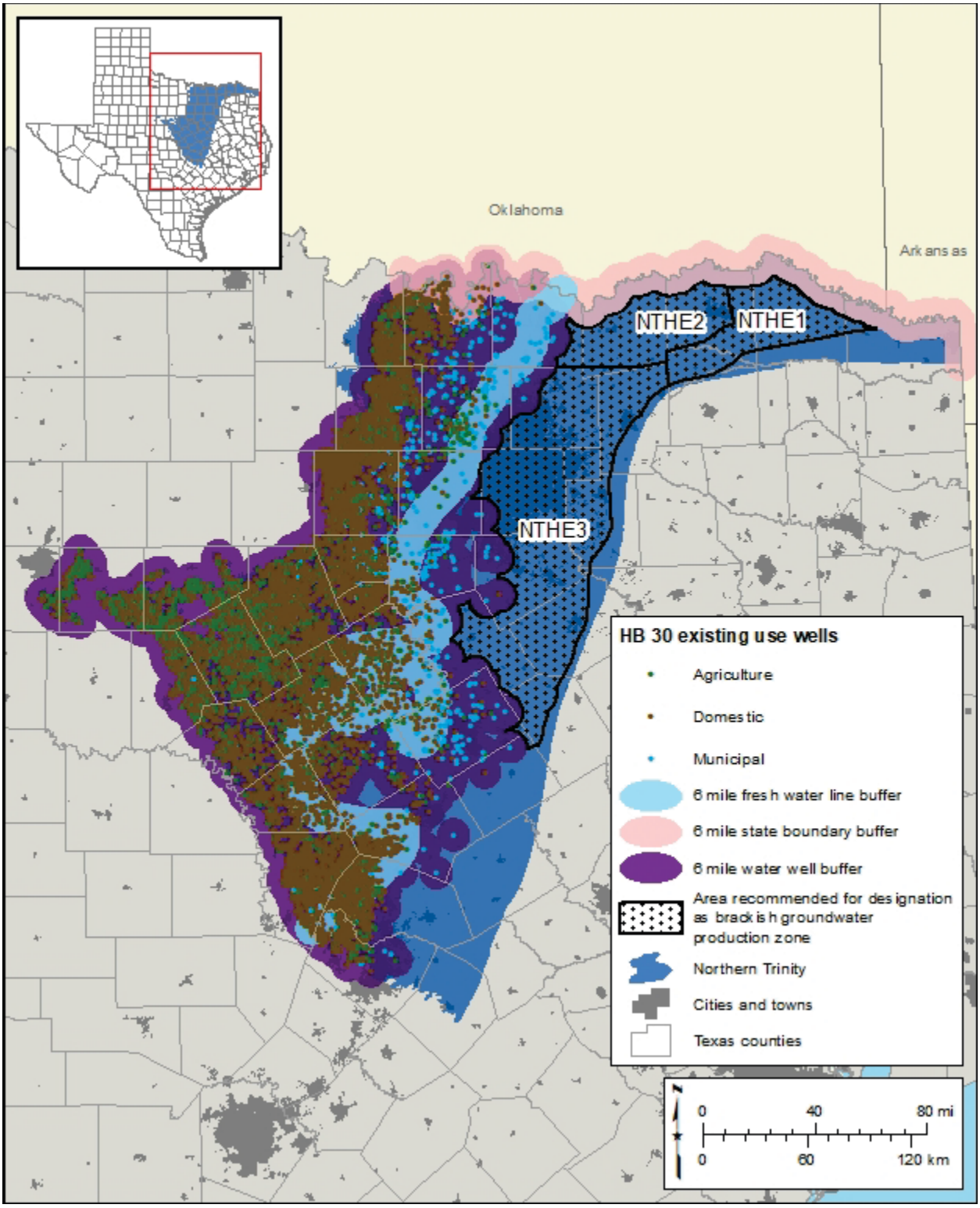

Figure 14 **Northern Trinity Aquifer study area showing existing water wells (municipal, domestic, and agricultural) used to exclude areas from being recommended as Hensell Formation brackish groundwater production zones (NTHE1, NTHE2, NTHE3). A six-mile buffer was applied to existing water wells, the fresh water line, and the state boundary. There are no injection wells affecting the designation of the brackish groundwater production zone.**

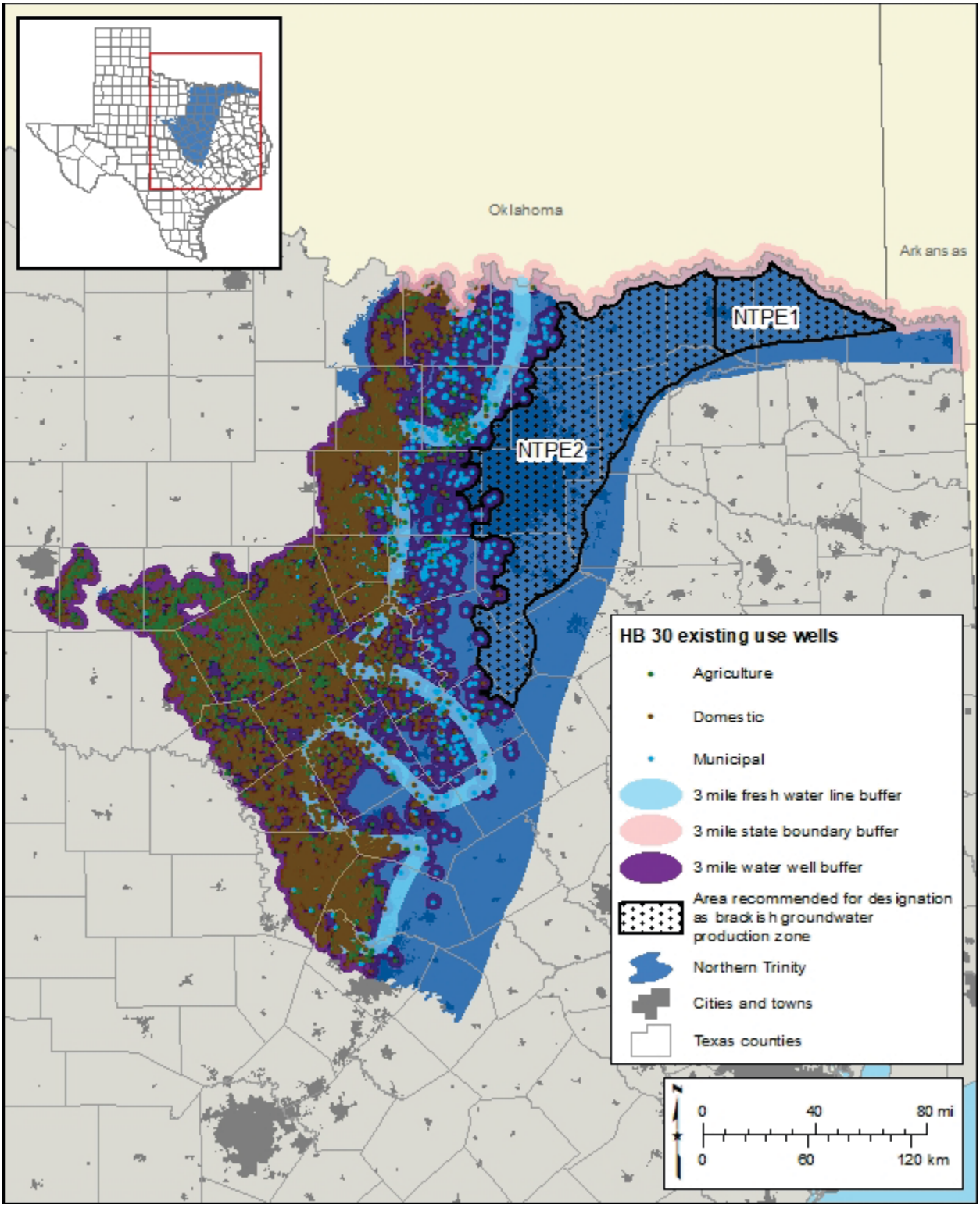

Figure 15. **Northern Trinity Aquifer study area showing existing water wells (municipal, domestic, and agricultural) used to exclude areas from being recommended as Pearsall Formation brackish groundwater production zones (NTPE1, NTPE2). A three-mile buffer was applied to existing water wells, the fresh water line, and the state boundary. There are no injection wells affecting the designation of the brackish groundwater production zone.**

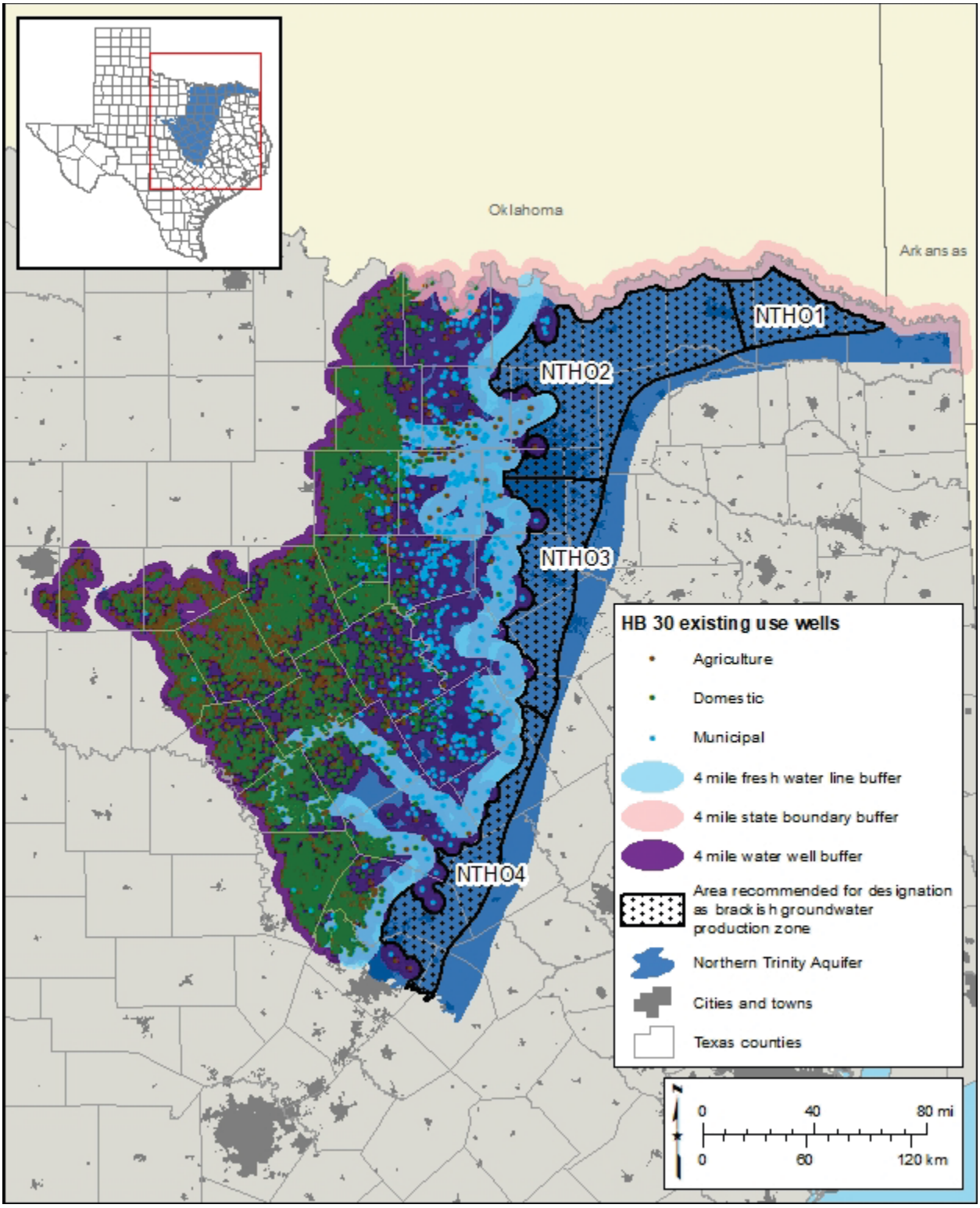

Figure 16. **Northern Trinity Aquifer study area showing existing water wells (municipal, domestic, and agricultural) used to exclude areas from being recommended as Hosston Formation brackish groundwater production zones (NTHO1, NTHO2, NTHO3, NTHO4). A four-mile buffer was applied to existing water wells, the fresh water line, and the state boundary. There are no injection wells affecting the designation of the brackish groundwater production zone.**