Texas Water Development Board

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TO: Board Members

THROUGH: Jeff Walker, Executive Administrator
Robert E. Mace, Ph.D., P.G., Deputy Executive Administrator, Water Science and Conservation
Les Trobman, General Counsel

FROM: Erika Mancha, Manager, Innovative Water Technologies

DATE: October 6, 2016

SUBJECT: Designation of brackish groundwater production zones.

ACTION REQUESTED

Consider designating brackish groundwater production zones in the Carrizo-Wilcox Aquifer between the Colorado River and the Rio Grande, the Gulf Coast Aquifer, the Blaine Aquifer, and the Rustler Aquifer.

BACKGROUND

In 2015, the 84th Texas Legislature passed House Bill 30, directing the Texas Water Development Board (TWDB) to conduct studies to identify and designate brackish groundwater production zones in four aquifers and to report the designations to the legislature by December 1, 2016. The four aquifers include the Carrizo-Wilcox Aquifer located between the Colorado River and the Rio Grande, the Gulf Coast Aquifer and sediments bordering that aquifer, the Blaine Aquifer, and the Rustler Aquifer. Identification and designation of brackish groundwater production zones in the remaining aquifers in the state are required to be completed before December 1, 2022.

To help undertake studies of the aquifers required to be designated by December 1, 2016, the legislature appropriated $2,000,000 to TWDB for contracts and administrative costs (House Bill 1, General Appropriations Act, 2015 Legislature, Regular Session, page IX-88, Sec. 18.30). On October 13, 2015, the Board authorized the Executive Administrator to publish a Request for Qualifications to fund contract studies for three of the four aquifers specifically named in House Bill 30 and for three additional brackish aquifers selected by the TWDB (the Trinity, Blossom, and Nacatoch aquifers). The fourth aquifer named in House Bill 30 (the Carrizo-Wilcox Aquifer) was conducted as part of an ongoing TWDB funded study. Final reports for the four House Bill 30 projects were completed and delivered by the contractors at the end of August or early September 2016. Final reports from contractors for the other three aquifer studies are due to TWDB on August 31, 2017.

For the four aquifers named in House Bill 30, contractors evaluated brackish areas in each of the aquifers for TWDB to designate as brackish groundwater production zones. As required by House Bill 30, the contractors evaluated aquifer 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 concentrations of 1,000 milligrams per liter or less.

Pursuant to House Bill 30 requirements, expressly excluded from the studies were:

- 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

In designating a brackish groundwater production zone, TWDB is required to determine the amount 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. TWDB is also required to make recommendations on reasonable monitoring to observe the effects of brackish groundwater production within the zone.

KEY ISSUES

On October 13, 2015, the Board authorized the Executive Administrator to publish a Request for Qualifications to fund contract studies for three aquifers specifically named in House Bill 30 and for three additional brackish aquifers selected by the TWDB (the Trinity, Blossom, and Nacatoch aquifers). The fourth aquifer named in House Bill 30 (the Carrizo-Wilcox Aquifer) was added to an ongoing TWDB funded study. The request for qualifications was posted on November 10, 2015, with an application due date of November 24, 2015. In response to the request, TWDB received 14 statements of qualifications and on January 6, 2016, the Board approved the Executive Administrator's recommendation to negotiate contracts for the projects. The contracts were executed between February and April 2016. Contractors began work on the projects while the contracts were still being executed.

Following Board authorization on October 13, 2015, to publish a request for qualifications, staff held a stakeholder meeting in Austin, TX, on October 26, 2015, 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. Between April and August 2016, staff held aquifer-specific stakeholder meetings to share results, solicit feedback, and request data. Details of the meetings are provided below.

- Carrizo-Wilcox Aquifer: Pleasanton, TX, November 19, 2015, and April 15, 2016
- Rustler Aquifer: Fort Stockton, TX, June 17, 2016
- Gulf Coast Aquifer: Austin, TX, June 22, 2016
- Blaine Aquifer: Quanah, TX, June 29, 2016, and Wellington, TX, August 18, 2016

We received the draft reports for the four projects on August 1, 2016. Staff reviewed the data and information and provided written comments to the contractors on or around August 15, 2016. Staff also met with the contractors several times during this period to discuss the comments, request changes, and correct errors. Contractors delivered the final reports and datasets to the TWDB within the first week of September 2016. Following receipt of the final reports, staff held a stakeholder meeting in Austin on September 9, 2016, to present the results of the studies and solicit comments.

After receiving the final reports and data, staff conducted a thorough quality control and quality check of the results and datasets to ensure that the requirements of and exclusion criteria in House Bill 30 had been properly implemented. As a result of the quality checks, several changes were made to the potential production areas that were presented in the final reports for all four aquifers. These revised areas are now recommended for designation as brackish groundwater production zones. Following Executive Administrator's approval of this board memo, the memo will be posted on the TWDB website (www.twdb.texas.gov/innovativewater/bracs/HB30.asp) and stakeholders notified via email about its availability for review and comment.

Throughout the project, stakeholders were notified of the meetings in advance via email. Emails were also sent to stakeholders informing them of the availability of draft and final contractor reports. Information pertaining to all stakeholder meetings including announcements, presentations, questions and answers, comments, and copies of contractor draft and final reports were posted on the TWDB website (www.twdb.texas.gov/innovativewater/bracs/HB30.asp) in a timely manner and stakeholders notified by email about the availability of the information.

In the process of conducting the studies, TWDB staff and project contractors encountered several challenges evaluating potential groundwater production areas and implementing House Bill 30 criteria. Several of the more important challenges and limitations are described below.

House Bill 30 excludes designation of brackish groundwater production zones in areas located in an aquifer or a geologic formation that serves as a significant source of water supply for municipal, domestic, or agricultural purposes. It also excludes areas designated or used for injection or disposal of wastewater. Therefore, identifying water wells (domestic, municipal, and agricultural) and injection wells (Class I, II, III, IV, and V) within proposed production areas is critically important in evaluating areas for designation. However, there is no single database in Texas that has a complete record of all installed water wells. Also, a vast majority of water wells are not available in the public domain, and existing datasets often are incomplete and do not contain information on current well owner, well type, or use.

House Bill 30 requires TWDB to estimate the volume of brackish groundwater that a zone is capable of producing over 30- and 50-year periods. While a calibrated groundwater model for each zone containing multiple, simultaneous well fields and regional groundwater pumping would have been desirable, because of severe time constraints, contractors were able to only conduct 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.

While analyzing Class II injection wells installed in potential production areas, staff discovered that a number of Class II injection zones are installed above, below, lateral to, or overlap with geologic stratum containing brackish groundwater. However, information needed to determine the distance that injected fluids may have traveled both laterally and vertically from these wells is lacking, necessitating staff to adopt a conservative approach (a 15-mile buffer) when recommending brackish groundwater production zones. For this reason, several areas in the Carrizo-Wilcox and Gulf Coast aquifers were not recommended for designation as brackish groundwater production zones. Additional work and interaction with staff of the Railroad Commission of Texas will be needed to further understand the implications and impact of injection activities in Texas.

The brackish groundwater production zones being recommended to the Board are representative of the aquifers and do not include every possible area that might qualify for designation. For example, for practical reasons, small well fields (one or two wells) that would have a minor impact in an area were not recommended 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 in an area.

As required by House Bill 30, stakeholders form an integral part of the brackish groundwater production zone designation process. While it would have been desirable to include every potential stakeholder in the process, the size of the study areas (for example, the Gulf Coast Aquifer study area has 56 counties) and time constraints (less than one year to complete and report on the studies), precluded contacting each and every stakeholder in the study areas. Nevertheless, staff made reasonable efforts to engage stakeholders in the process.

AREAS RECOMMENDED FOR DESIGNATION AS BRACKISH GROUNDWATER PRODUCTION ZONES

Applying the criteria listed in House Bill 30, the areas recommended for designation as brackish groundwater production zones in the four aquifers, the volumes of water that a brackish groundwater production zone can produce over 30- and 50-year periods, and reasonable monitoring to observe the effects of brackish groundwater production within the zone are described below.

Carrizo-Wilcox Aquifer between the Colorado River and the Rio Grande

Recommended brackish groundwater production zones

In the Carrizo-Wilcox Aquifer, we recommend one area for designation as a brackish groundwater production zone (Attachment A, Figure 1, CzWx1). CzWx1 is in the lower Wilcox Aquifer and contains groundwater that is slightly saline (1,000 to 3,000 milligrams per liter of total dissolved solids) to moderately saline (3,000 to 10,000 milligrams per liter of total dissolved solids).

Depth to the top of the recommended brackish groundwater production zone ranges from 1,400 feet to more than 3,000 feet below ground surface. The bottom depth of the zone ranges from 1,800 feet to more than 3,800 feet below ground surface. Approximately 140 feet of shale within

the overlying middle Wilcox geological formation constitutes a hydrogeologic barrier between the zone and the overlying Carrizo Aquifer.

Four potential areas were considered for designation as brackish groundwater production zones (Attachment A, Figure 2), but three (PPA1, PPA2, and PPA4) were removed from further consideration after TWDB staff identified water wells and Class II injection wells in these areas (Attachment A, Figure 3). Within and adjacent to PPA1, PPA2, and PPA3, Class II injection wells inject into the lower Wilcox and adjacent formations (middle Wilcox and upper Midway) while in PPA4, Class II injection wells inject into the Carrizo–upper Wilcox Formation. Staff placed a 15-mile buffer around each injection well and a 3-mile buffer around each water well. We modified the boundary of the remaining area (PPA3) after TWDB staff evaluated additional well data and geology (Attachment A, Figure 1).

Volumes of brackish groundwater in the recommended production zones
The volumes of brackish groundwater that could potentially be produced from CzWx1 over 30- and 50-year periods is presented in the table below.

Aquifer	Zone name	Annual pumpage (acre-feet/year)	30-year cumulative (million acre-feet)	50-year cumulative (million acre-feet)
Carrizo-Wilcox	CzWx1	43,000	1.29	2.15

Groundwater monitoring in the recommended production zones
Groundwater monitoring should focus on the overlying Carrizo Aquifer that contains fresh water, and on both the lower Wilcox and Carrizo aquifers in the updip areas. Monitoring in the middle Wilcox sands is recommended to determine the potential source of Carrizo Aquifer impact due to development in (1) the Carrizo Aquifer or (2) the brackish lower Wilcox Aquifer. Monitoring is not required below the lower Wilcox because there are no known fresh or brackish aquifers in that geological formation in the region.

Gulf Coast Aquifers and sediments bordering that aquifer

Recommended brackish groundwater production zones
In the Gulf Coast Aquifer, we recommend four areas for designation as brackish groundwater production zones (Attachment A, Figure 4, GCUL1, GCML1, GCLL1, and GCLL2). The areas are in the Upper Lagarto (GCUL1), Middle Lagarto (GCML1), and Lower Lagarto (GCLL1 and GCLL2) geological formations and contain groundwater that is slightly saline (1,000 to 3,000 milligrams per liter of total dissolved solids) to moderately saline (3,000 to 10,000 milligrams per liter of total dissolved solids). The overlying geological formations contain shale that can act as a hydrogeologic barrier between the areas recommended for designation and the overlying aquifers.

Twenty potential areas were considered for designation as brackish groundwater production zones (Attachment A, Figures 5-11), but 16 were removed from further consideration and four others significantly reduced in geographic area after TWDB staff identified wells in the areas and evaluated geologic parameters listed in House Bill 30 as exclusion criteria. In addition, House

Bill 30 contains a requirement that prohibits designation of zones within the Harris–Galveston Subsidence District and the Fort Bend Subsidence District.

Areas in the Lower Rio Grande Valley (Cameron, Hidalgo, Starr, and Willacy counties) were not recommended because the results from a recent TWDB study (TWDB Report 383, 2014) indicated that the region contains areas of mixed fresh and slightly saline groundwater. The region also has a substantial number of brackish groundwater and Class II injection wells.

TWDB staff evaluated Class II injection well data using 15-mile buffers over the potential production areas. The remaining portions of these areas were then evaluated for the presence of water wells (domestic, municipal, and agricultural using a 3 mile buffer), injection wells (Class I, Class III, Class IV, and Class V), and hydrogeologic barriers, in this order. The results of this analysis are presented in Figures 12 through 18 (Attachment A).

Volumes of brackish groundwater in the recommended production zones
The volumes of brackish groundwater that could potentially be produced from the zones over 30- and 50-year periods are presented in the table below.

Aquifer	Zone name	Annual pumpage (acre-feet/year)	30-year cumulative (million acre-feet)	50-year cumulative (million acre-feet)
Upper Lagarto	GCUL1	35,700	1.07	1.785
Middle Lagarto	GCML1	2,079	0.062	0.104
Lower Lagarto	GCLL1	4,992	0.15	0.25
Lower Lagarto	GCLL2	2,929	0.088	0.146

Groundwater monitoring in the recommended production zones
Groundwater monitoring should focus on the lateral and updip portions of the brackish aquifer, on the underlying aquifer, and on the overlying aquifer containing fresh and brackish water. Monitoring in permeable sands associated with shale confining units is recommended to determine the potential source of adjacent aquifer impact due to development in (1) the adjacent aquifers or (2) the brackish zone aquifer. Monitoring information is presented in the table below.

Zone name	Brackish Lagarto Aquifer	Underlying aquifer	Overlying aquifer
GCUL1	Upper Lagarto	Middle Lagarto	Lower Goliad
GCML1	Middle Lagarto	Lower Lagarto	Upper Lagarto
GCLL1	Lower Lagarto	Oakville	Middle Lagarto
GCLL2	Lower Lagarto	Oakville	Middle Lagarto

Blaine Aquifer

Recommended brackish groundwater production zones
We are not recommending an area in the Blaine Aquifer for designation as a brackish groundwater production zone (Attachment A, Figure 19).

Eight potential areas were considered (Attachment A, Figure 20), but five were excluded from further consideration after water well data received from stakeholders indicated that the Blaine Aquifer in these areas is being used to provide water for domestic or agricultural purposes. The

remaining three areas (PPA4, PPA6, and PPA8) were excluded for similar reasons after TWDB staff conducted additional evaluations (Attachment A, Figure 21).

Rustler Aquifer

Recommended brackish groundwater production zones

In the Rustler Aquifer, we recommend three areas for designation as brackish groundwater production zones (Attachment A, Figure 22, Rus1, Rus2, and Rus3). Rus1 and Rus3 will produce water from the Magenta Dolomite, Culebra Dolomite, and the limestones of the Los Medaños members of the Rustler Aquifer and Rus2 will produce water from the collapsed Rustler Aquifer. The zones contain groundwater that is slightly saline (1,000 to 3,000 milligrams per liter of total dissolved solids) to moderately saline (3,000 to 10,000 milligrams per liter of total dissolved solids).

Hydrogeologic barriers in each zone include structural geological boundaries such as faults, the Dewey Lake Formation which is present above the Rustler Aquifer, and the Salado Formation which is present below the aquifer. Additionally, hydraulic distance barriers apply to zones Rus1 and Rus3 and distance from existing use.

Five areas were considered (Attachment A, Figure 23, PPA1, PPA2, PPA3, PPA4, and PPA5), but two were removed (PPA2 and PPA5) from further consideration after TWDB staff identified additional water wells or Class II injection wells in the areas (Attachment A, Figure 24). The boundaries of the remaining three areas were modified following evaluation of additional well data and geology by TWDB staff (Attachment A, Figure 22).

Volumes of brackish groundwater in the recommended production zones

The volumes of brackish groundwater that could be potentially produced from the three zones over 30- and 50-year periods is presented in the table below.

Aquifer	Zone name	Annual pumpage (acre-feet/year)	30-year cumulative (million acre-feet)	50-year cumulative (million acre-feet)
Rustler	Rus1	2,513	0.075	0.126
	Rus2	522	0.016	0.026
	Rus3	12,645	0.379	0.632

Groundwater monitoring in the recommended production zones

Parts of brackish groundwater production zone Rus1 in the Rustler Aquifer are overlain by one, none, or both the Pecos Valley and Edwards-Trinity (Plateau) aquifers. Minor aquifers in the area that may be adjacent to the Rustler Aquifer include the Capitan Reef Complex Aquifer to the southwest, the Igneous Aquifer to the south, and the Dockum Aquifer to the east. Groundwater monitoring should focus on those aquifers, where present, and on areas near existing use. Monitoring in permeable strata within adjacent confining units is recommended to determine the potential source of adjacent aquifer impact due to development in (1) the adjacent aquifer or (2) the brackish Rustler Aquifer. Monitoring is not required below the Rustler Aquifer because there are no known fresh or brackish aquifers in the region.

All of brackish groundwater production zone Rus2 in the Rustler Aquifer is overlain by the Edwards-Trinity (Plateau) Aquifer. The only minor aquifer in the area that may be adjacent to the Rustler Aquifer is the Igneous Aquifer to the west. The Tessey Limestone is not a TWDB-designated major or minor aquifer in Texas but is used for water supply in the area and could be located hydrogeologically adjacent to the Rustler Aquifer east of brackish groundwater production zone Rus2. Groundwater monitoring should focus on those aquifers and the Tessey Limestone, where present, and on areas near existing use. Monitoring in permeable strata within adjacent confining units is recommended to determine the potential source of adjacent aquifer impact due to development in (1) the adjacent aquifer or (2) the brackish Rustler Aquifer. Monitoring is not required below the Rustler Aquifer because there are no known fresh or brackish aquifers in the region.

Parts of brackish groundwater production zone Rus3 for the Rustler Aquifer are overlain by either or both the Pecos Valley and the Edwards-Trinity (Plateau) aquifers. Minor aquifers in the area that may be adjacent to the Rustler Aquifer are the Dockum Aquifer which overlies most of the zone and the Igneous Aquifer which is present in the southwest corner. Groundwater monitoring should focus on those aquifers, where present, and on areas near existing use. Monitoring in permeable strata within adjacent confining units is recommended to determine the potential source of adjacent aquifer impact due to development in (1) the adjacent aquifer or (2) the brackish Rustler Aquifer. Monitoring is not required below the Rustler Aquifer because there are no known fresh or brackish aquifers in the region.

RECOMMENDATION

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

- Carrizo-Wilcox Aquifer between the Colorado River and the Rio Grande – Area CzWx1 (Attachment A, Figure 1)
- Gulf Coast Aquifer and sediments bordering that aquifer – Areas GCUL1, GCML1, GCLL1, and GCLL2 (Attachment A, Figure 4).
- Blaine Aquifer – No areas recommended (Attachment A, Figure 19)
- Rustler Aquifer – Areas Rus1, Rus2, and Rus3 (Attachment A, Figure 22)

This recommendation has been reviewed by legal counsel and is in compliance with applicable statutes and Board rules.

Attachment A: Maps of potential production areas and areas recommended for designation as brackish groundwater production zones in the Carrizo-Wilcox, Gulf Coast, Blaine, and Rustler aquifers

Attachment A

Maps of potential production areas and areas recommended for designation as brackish groundwater production zones in the Carrizo-Wilcox, Gulf Coast, Blaine, and Rustler aquifers.

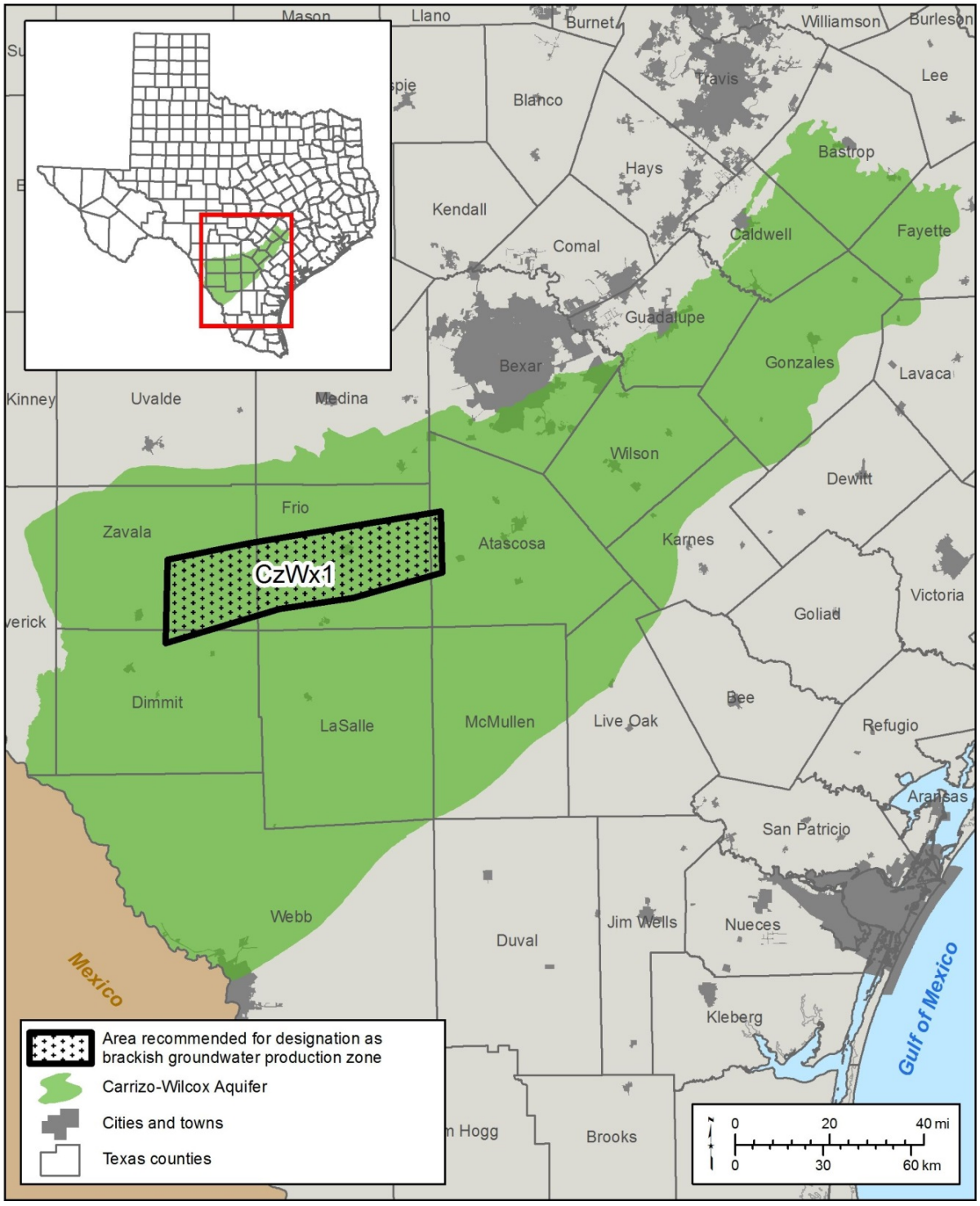

Figure 1. Carrizo-Wilcox Aquifer located between the Colorado River and the Rio Grande showing one potential production area (CzWx1) within the lower Wilcox Formation recommended for designation as a brackish groundwater production zone. The area contains groundwater that is slightly saline (1,000 to 3,000 milligrams per liter of total dissolved solids) to moderately saline (3,000 to 10,000 milligrams per liter of total dissolved solids).

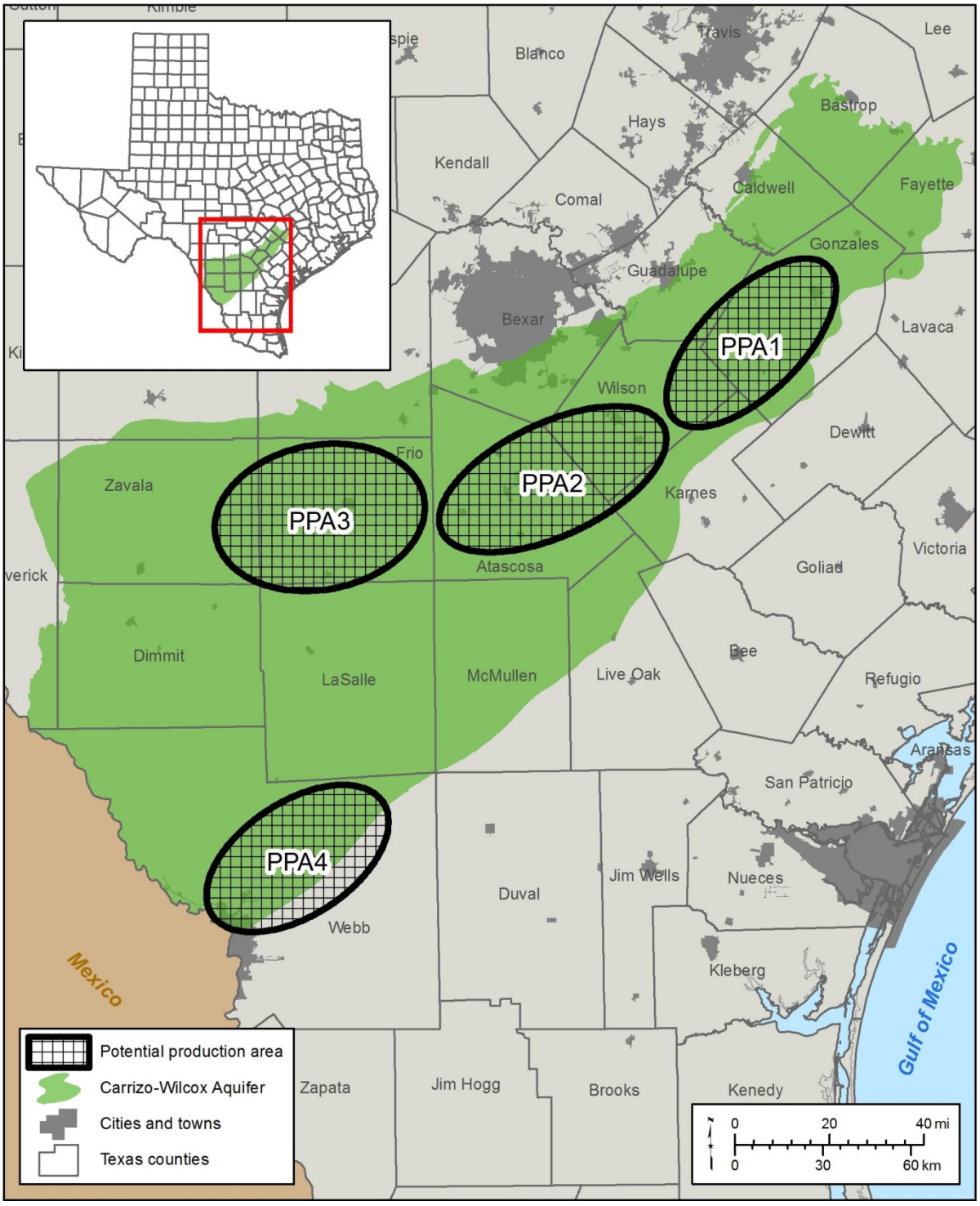

Figure 2. Carrizo-Wilcox Aquifer located between the Colorado River and the Rio Grande showing four potential production areas (PPA1, PPA2, and PPA3 in the lower Wilcox Formation, and PPA4 in the Carrizo-upper Wilcox Formation).

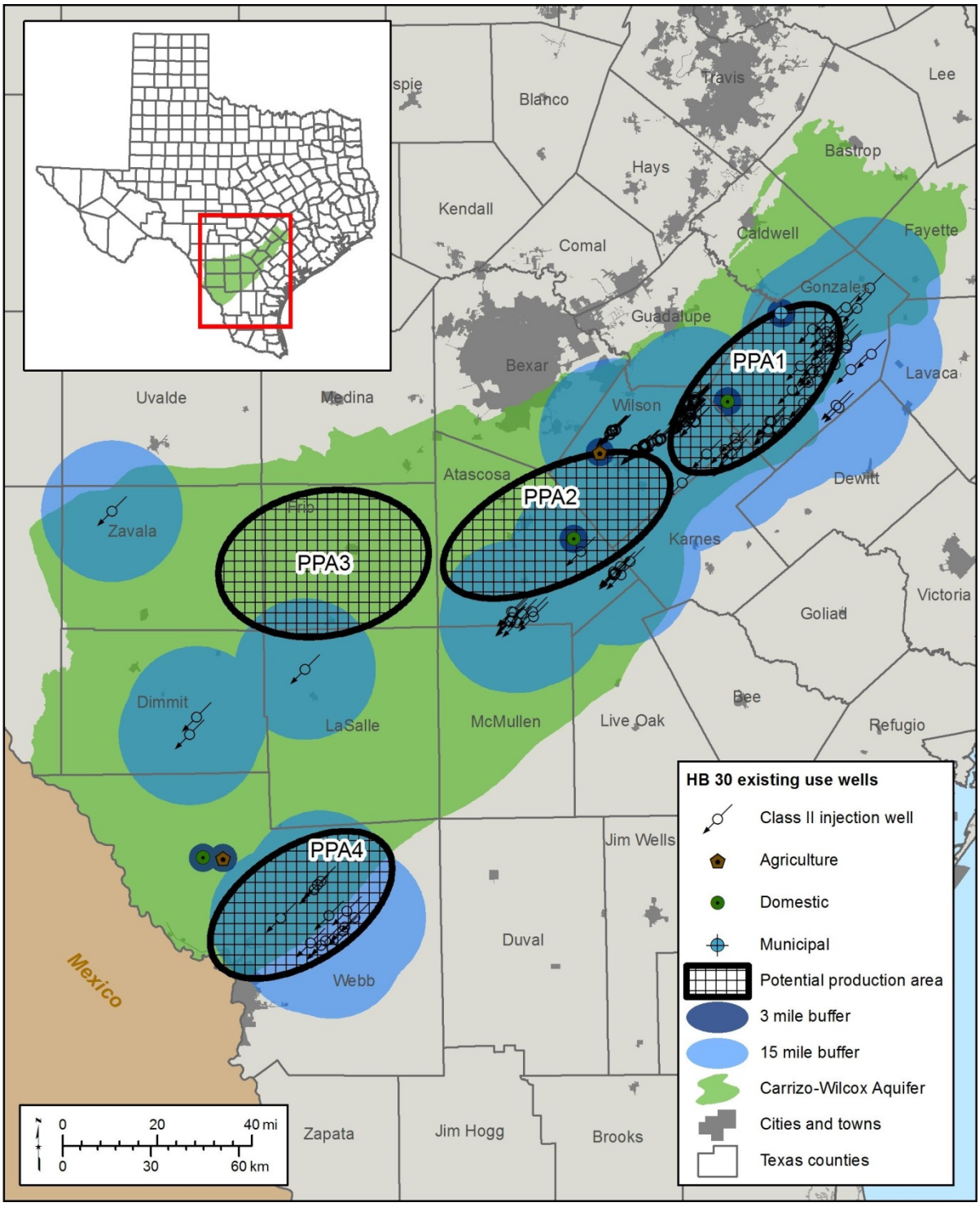

Figure 3. Carrizo-Wilcox Aquifer located between the Colorado River and the Rio Grande showing wells used to exclude areas from being recommended as brackish groundwater production zones. The wells include water wells (municipal, domestic, and agricultural) and injection wells (Class II). A three mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. Water wells that do not meet House Bill 30 exclusion criteria are not shown.

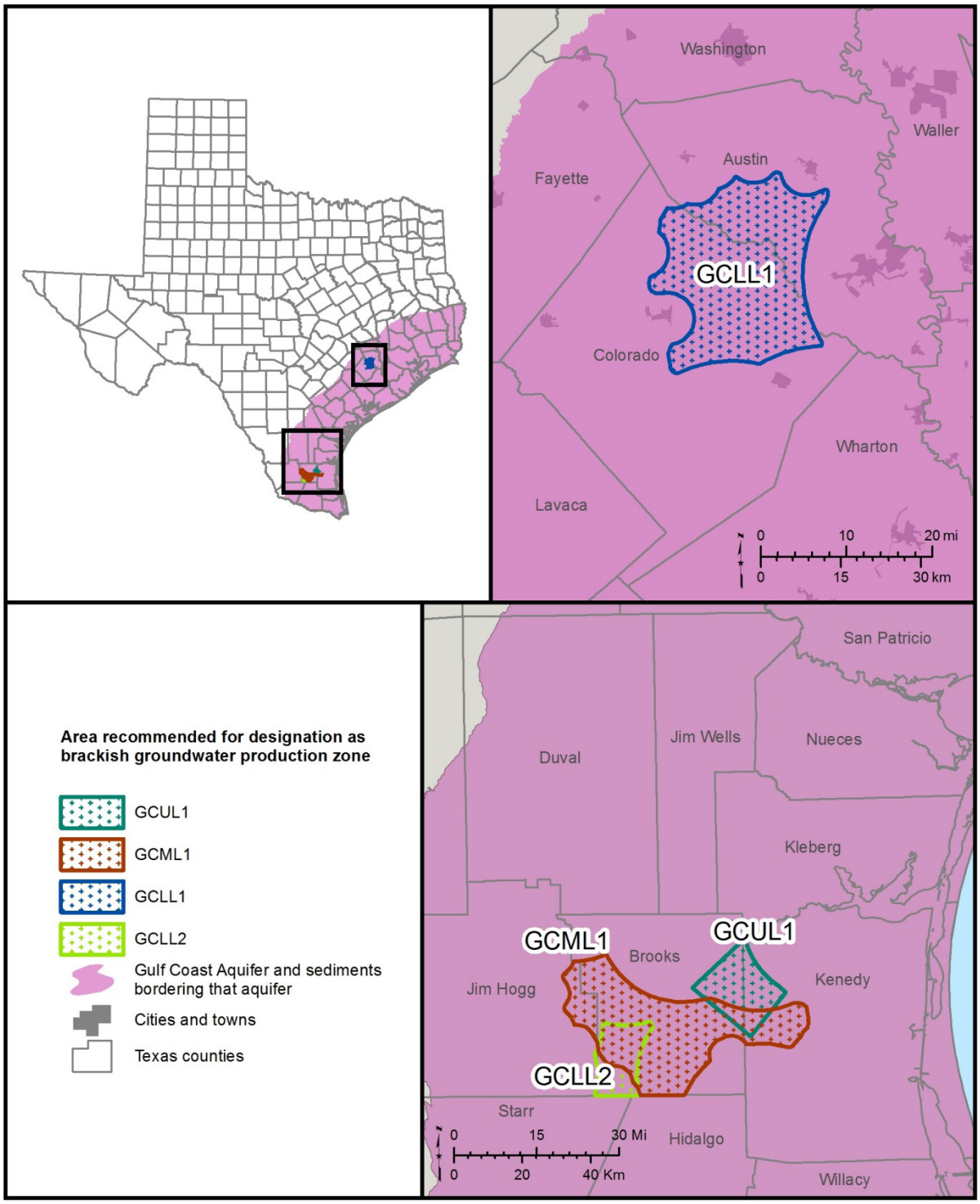

Figure 4. Gulf Coast Aquifer, sediments bordering that aquifer, and four potential production areas (GCUL1, GCML1, GCLL1, and GCLL2) recommended for designation as brackish groundwater production zones. The areas contain groundwater that is slightly saline (1,000 to 3,000 milligrams per liter of total dissolved solids) to moderately saline (3,000 to 10,000 milligrams per liter of total dissolved solids).

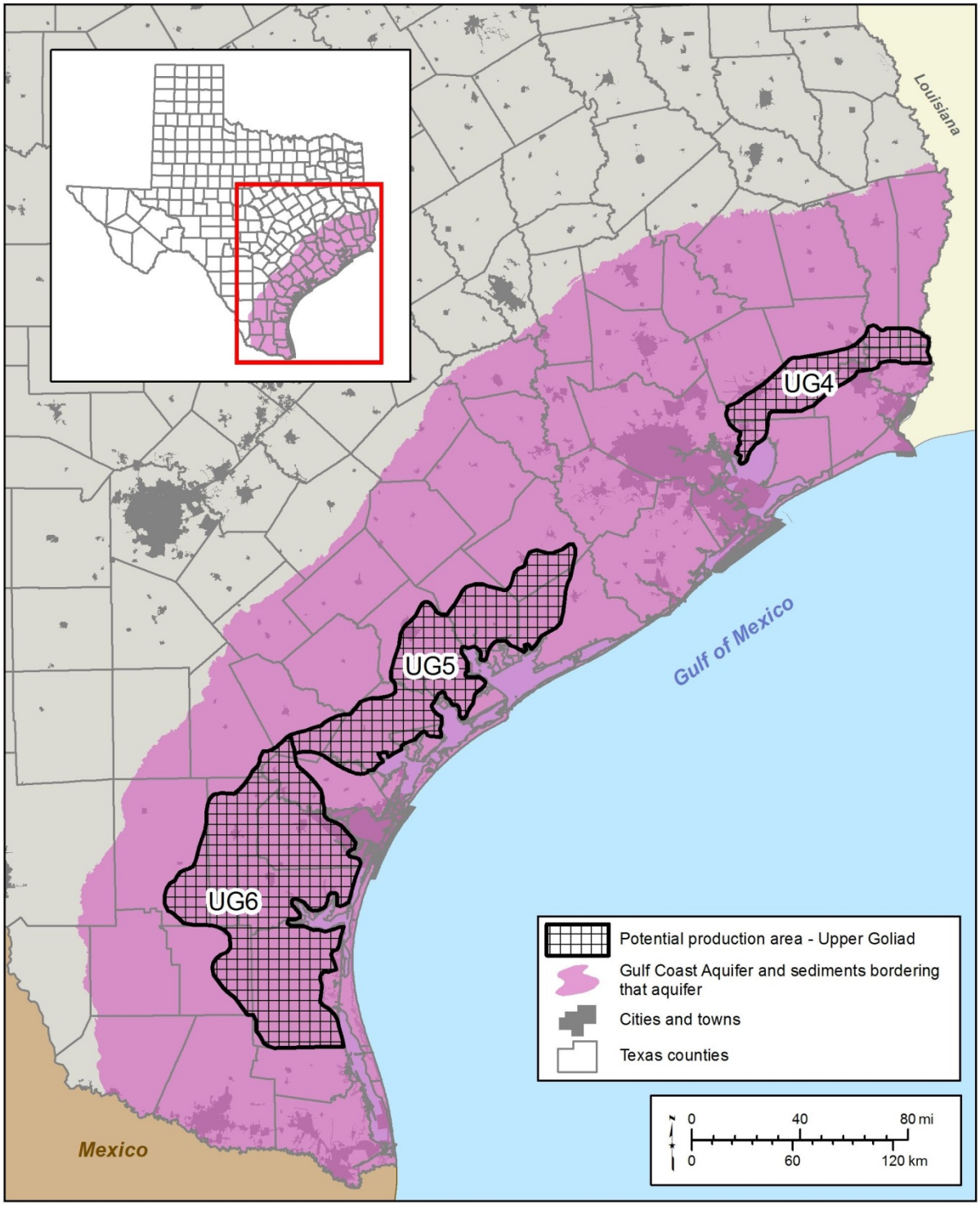

Figure 5. Gulf Coast Aquifer, sediments bordering that aquifer, and three potential production areas (UG4, UG5, and UG6) located in the Upper Goliad Formation.

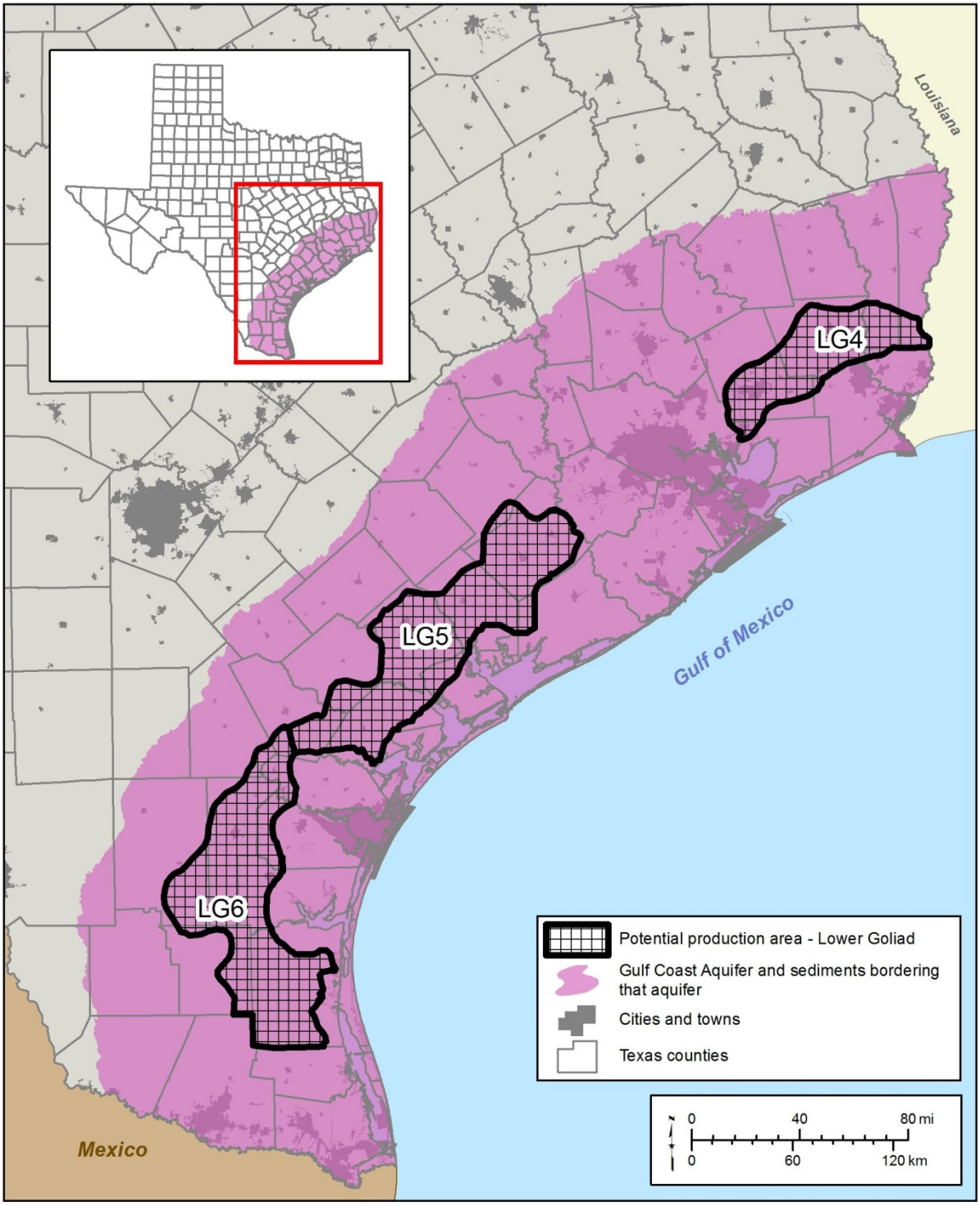

Figure 6. Gulf Coast Aquifer, sediments bordering that aquifer, and three potential production areas (LG4, LG5, and LG6) located in the Lower Goliad Formation.

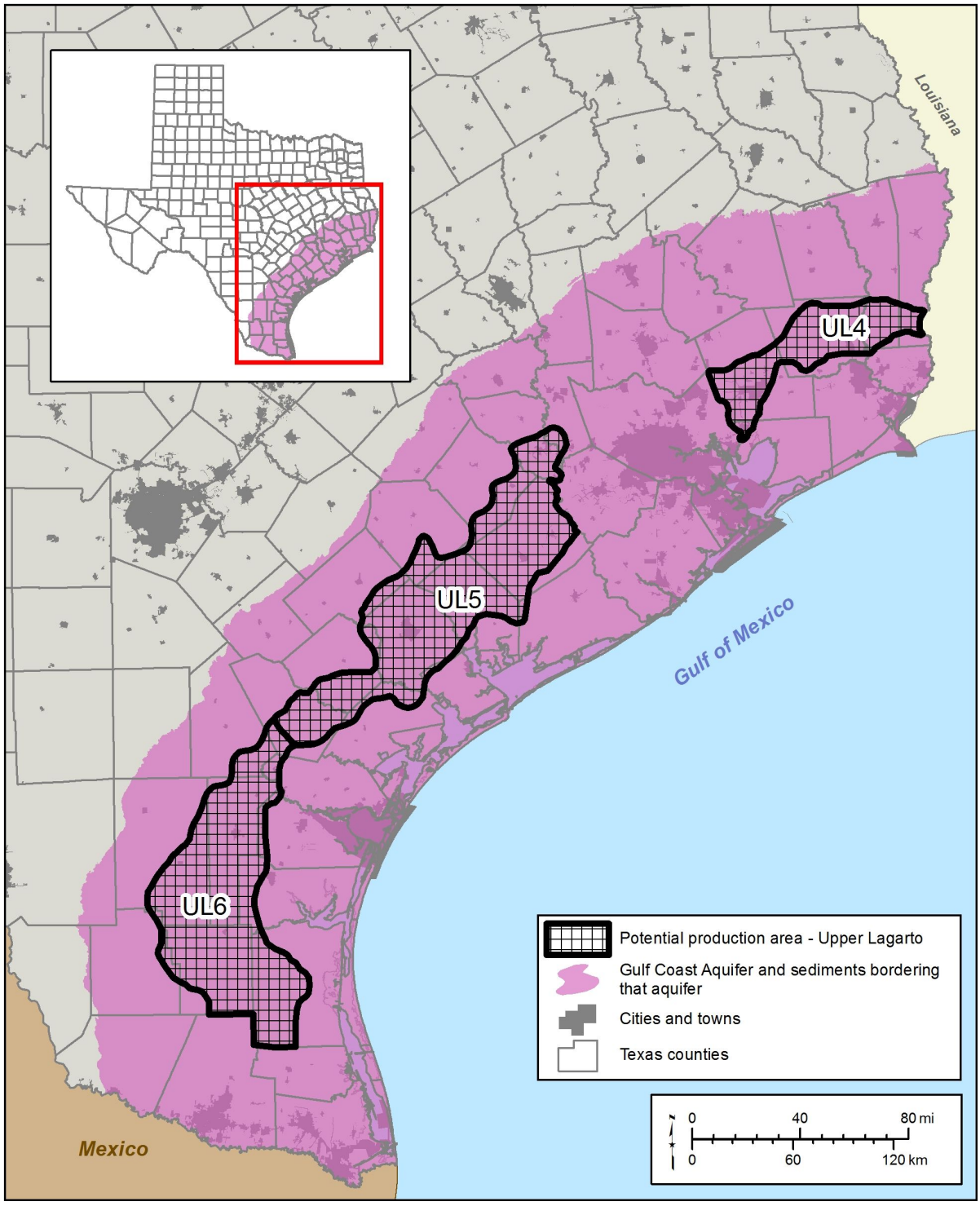

Figure 7. Gulf Coast Aquifer, sediments bordering that aquifer, and three potential production areas (UL4, UL5, and UL6) located in the Upper Lagarto Formation.

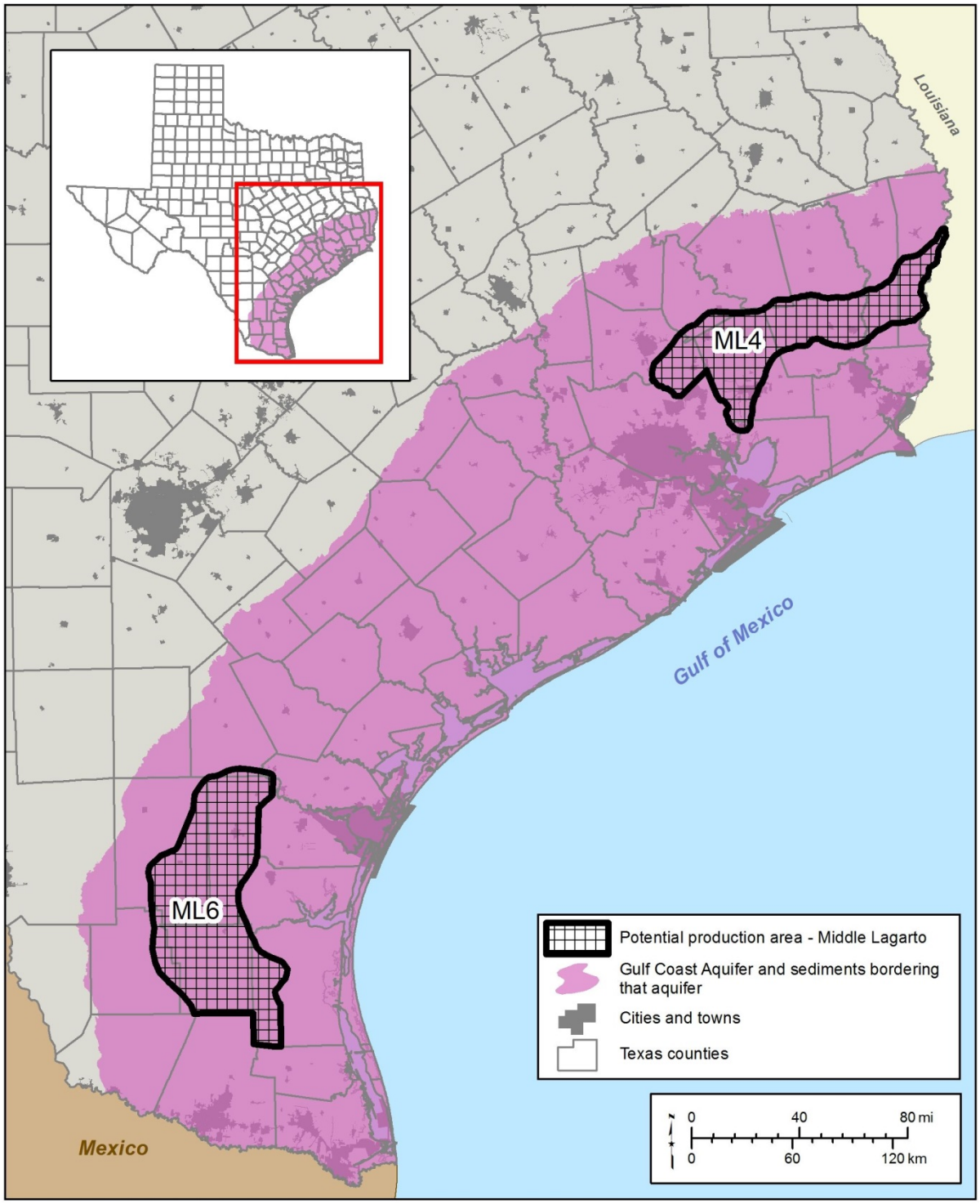

Figure 8. Gulf Coast Aquifer, sediments bordering that aquifer, and two potential production areas (ML4 and ML6) located in the Middle Lagarto Formation.

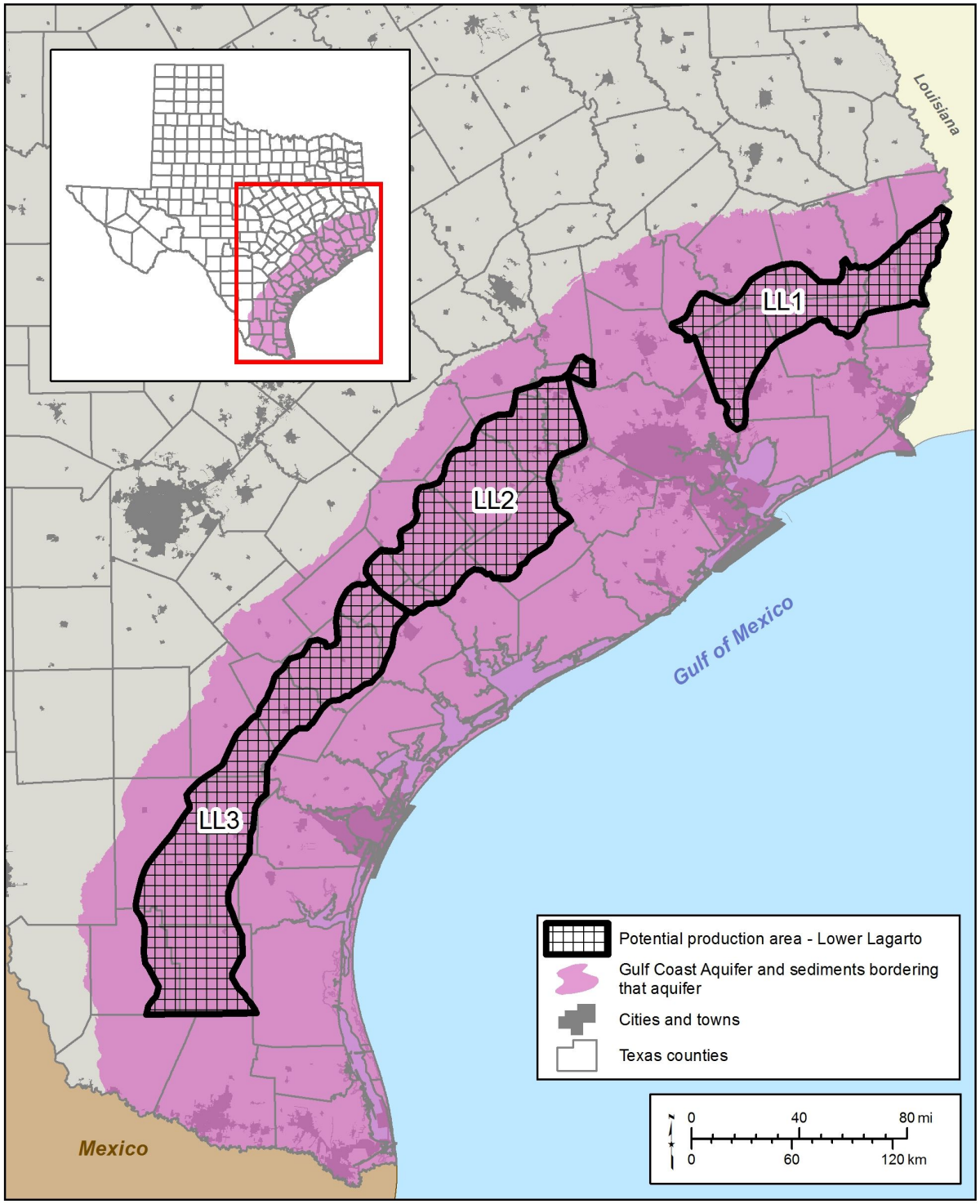

Figure 9. Gulf Coast Aquifer, sediments bordering that aquifer, and three potential production areas (LL1, LL2, and LL3) located in the Lower Lagarto Formation.

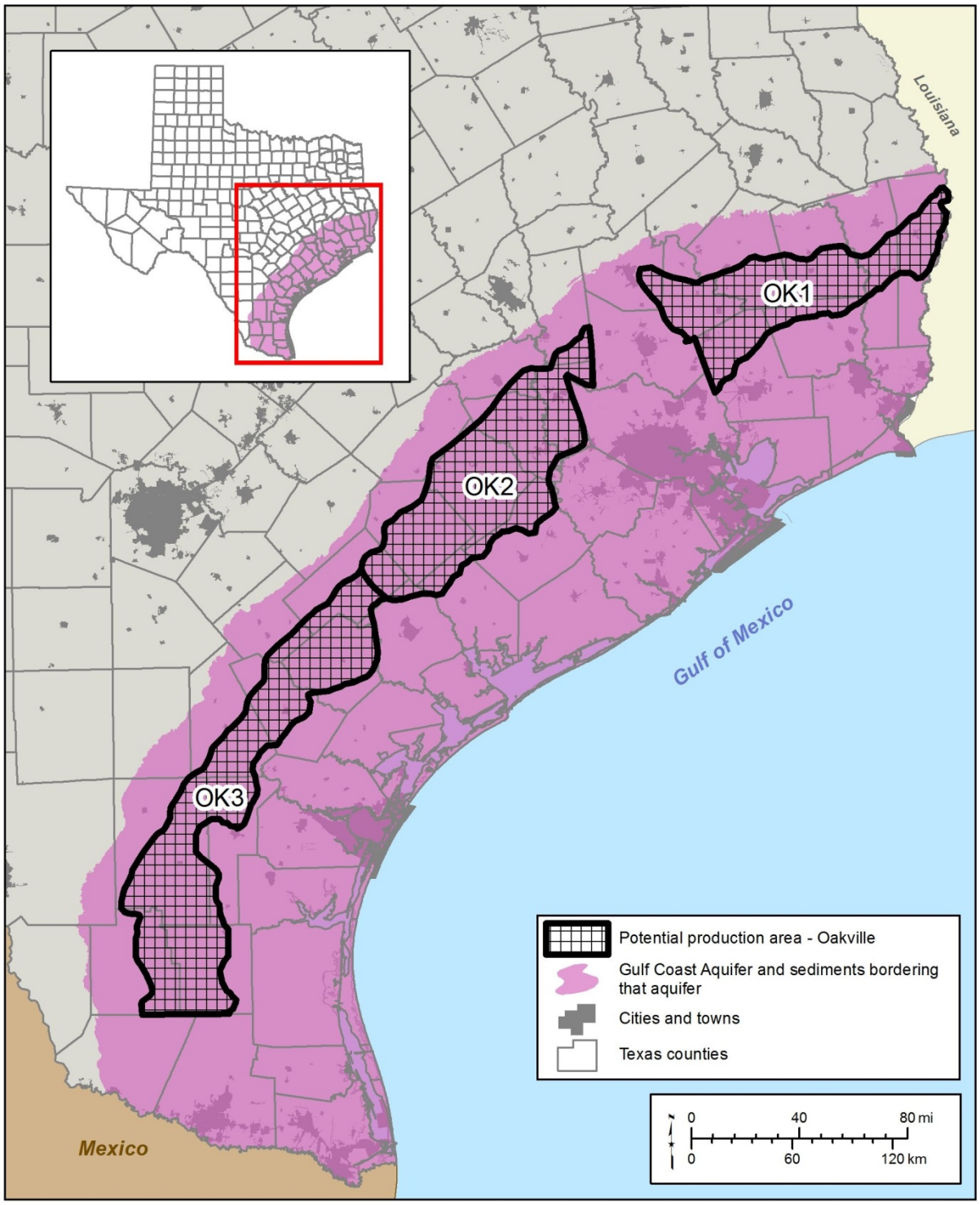

Figure 10. Gulf Coast Aquifer, sediments bordering that aquifer, and three potential production areas (OK1, OK2, and OK3) located in the Oakville Formation.

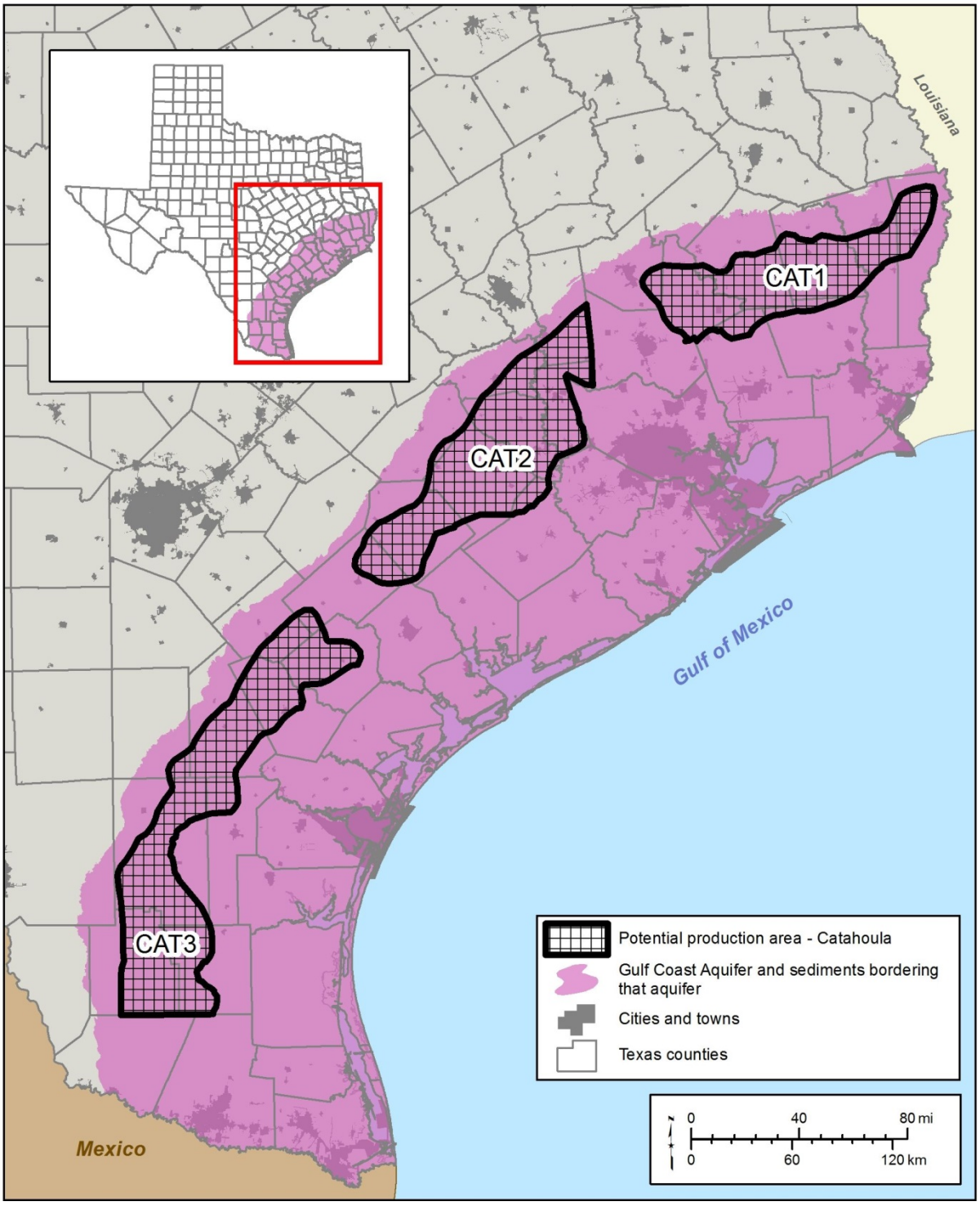

Figure 11. Gulf Coast Aquifer, sediments bordering that aquifer, and three potential production areas (CAT1, CAT2, and CAT3) located in the Catahoula Formation.

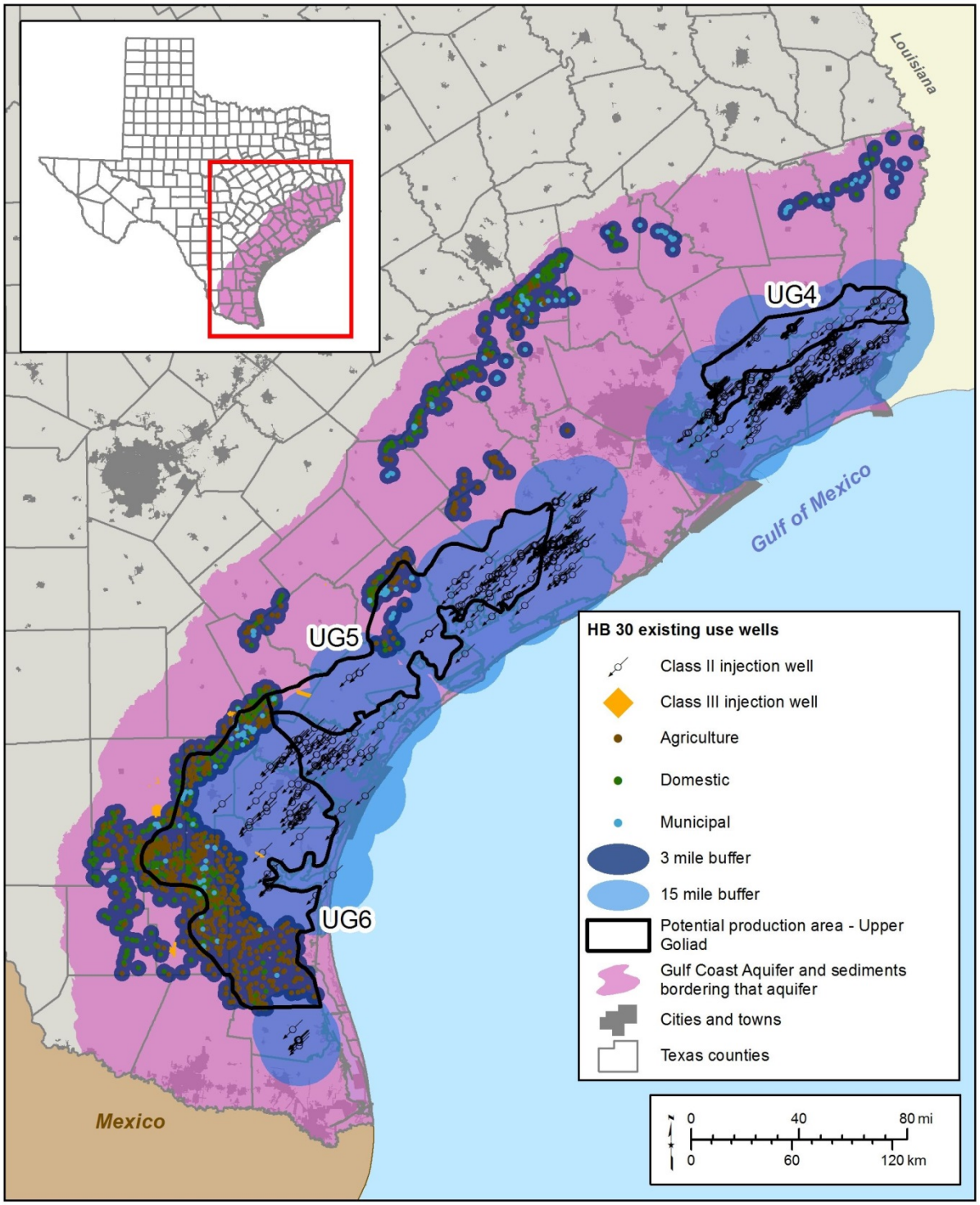

Figure 12. Upper Goliad Formation showing potential production areas. Wells used to exclude areas from designation as brackish groundwater production zones include water wells (municipal, domestic, and agricultural) and injection wells (Class II). A three-mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. Water well and hydrogeologic barrier evaluations were only performed in areas not covered by a Class II injection well buffer. Water wells that do not meet House Bill 30 exclusion criteria are not shown. Class III injection well aquifer exemption areas in the Goliad Formation are excluded from zone designation.

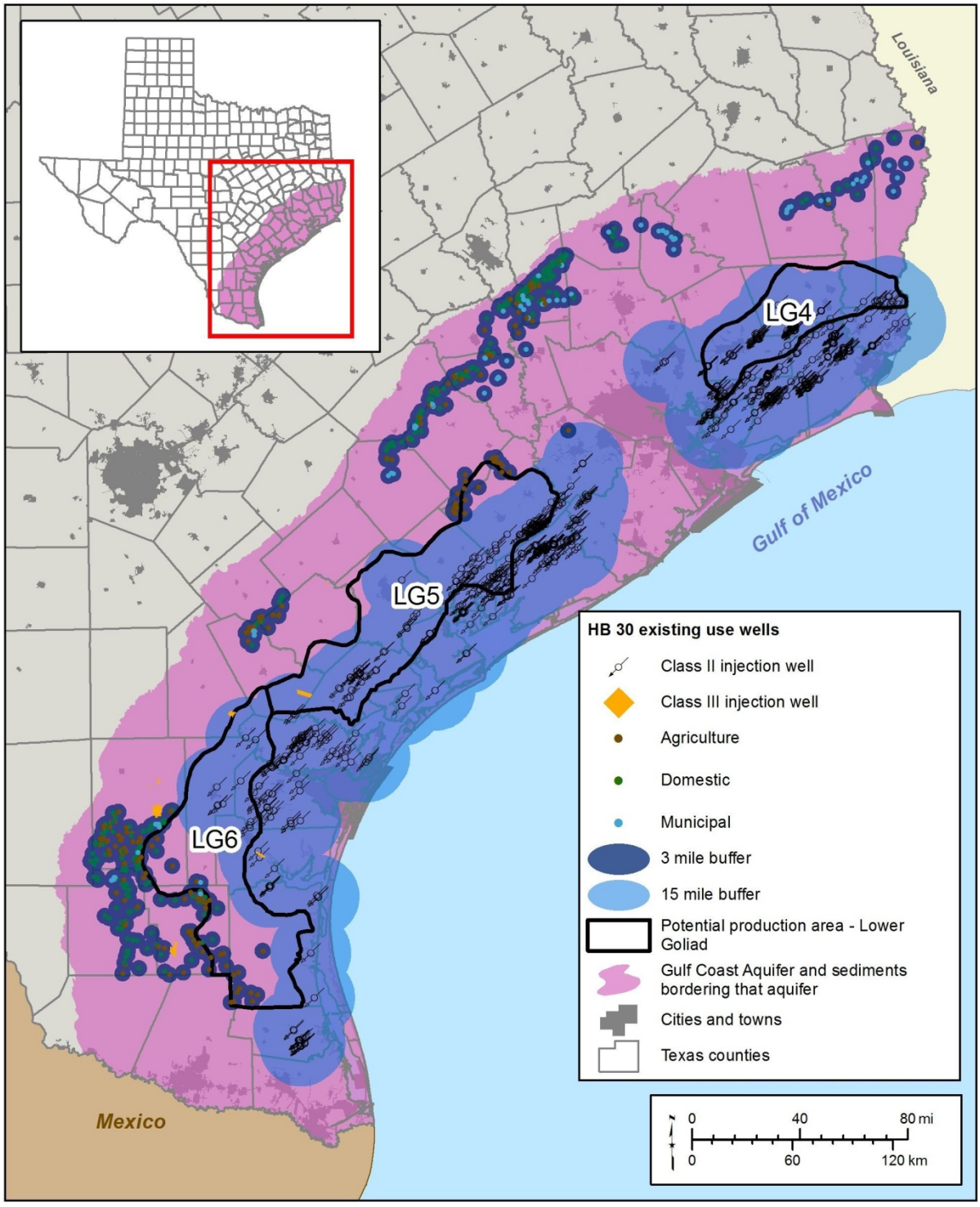

Figure 13. Lower Goliad Formation showing potential production areas. Wells used to exclude areas from designation as brackish groundwater production zones include water wells (municipal, domestic, and agricultural) and injection wells (Class II). A three-mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. Water well and hydrogeologic barrier evaluations were only performed in regions not covered by a Class II injection well buffer. Water wells that do not meet House Bill 30 exclusion criteria are not shown. Class III injection well aquifer exemption areas in the Goliad Formation are excluded from zone designation.

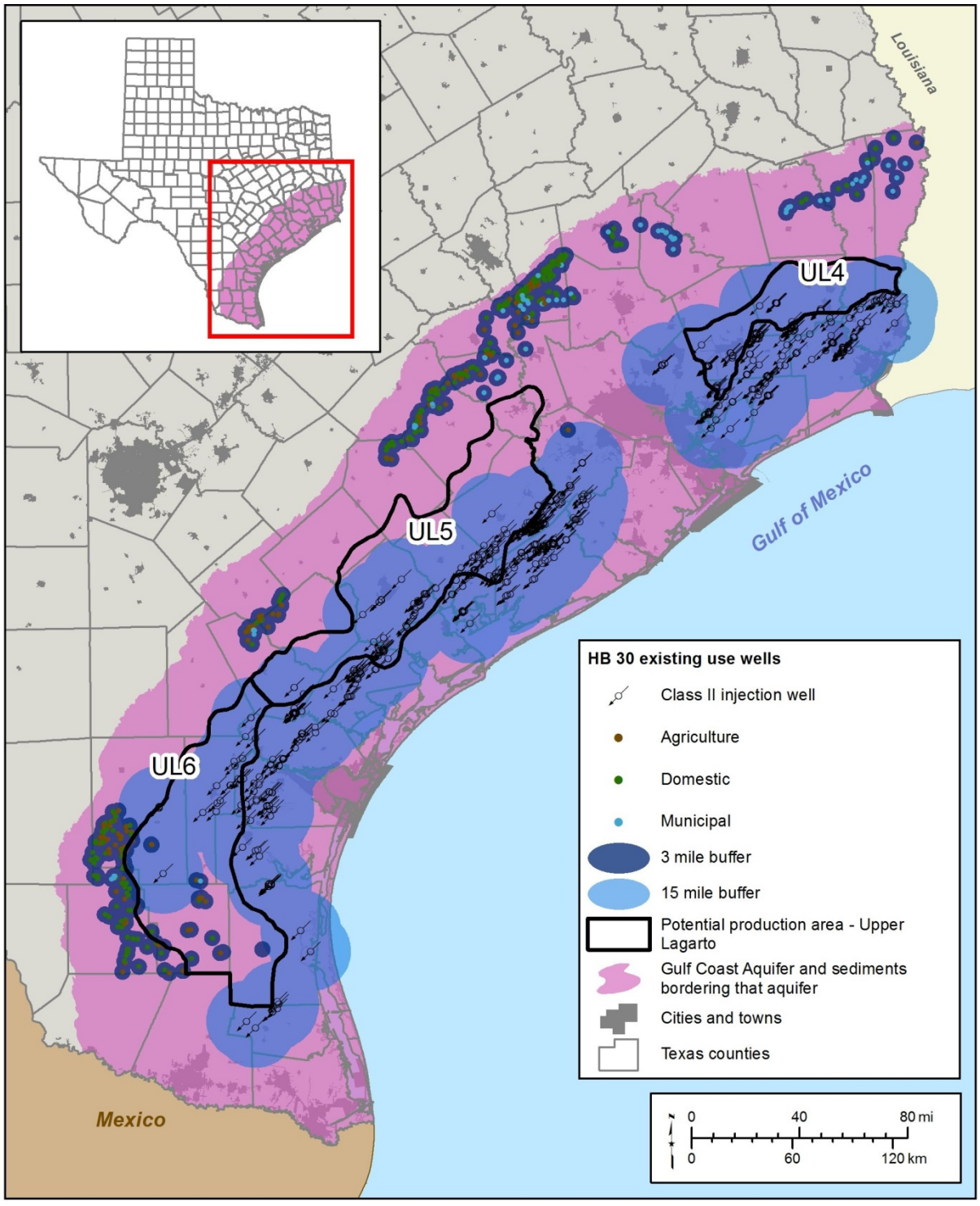

Figure 14. Upper Lagarto Formation showing potential production areas. Wells used to exclude areas from recommendation for designation as brackish groundwater production zones include water wells (municipal, domestic, and agricultural) and injection wells (Class II). A three-mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. Water well and hydrogeologic barrier evaluations were only performed in areas not covered by a Class II injection well buffer. Water wells that do not meet House Bill 30 exclusion criteria are not shown.

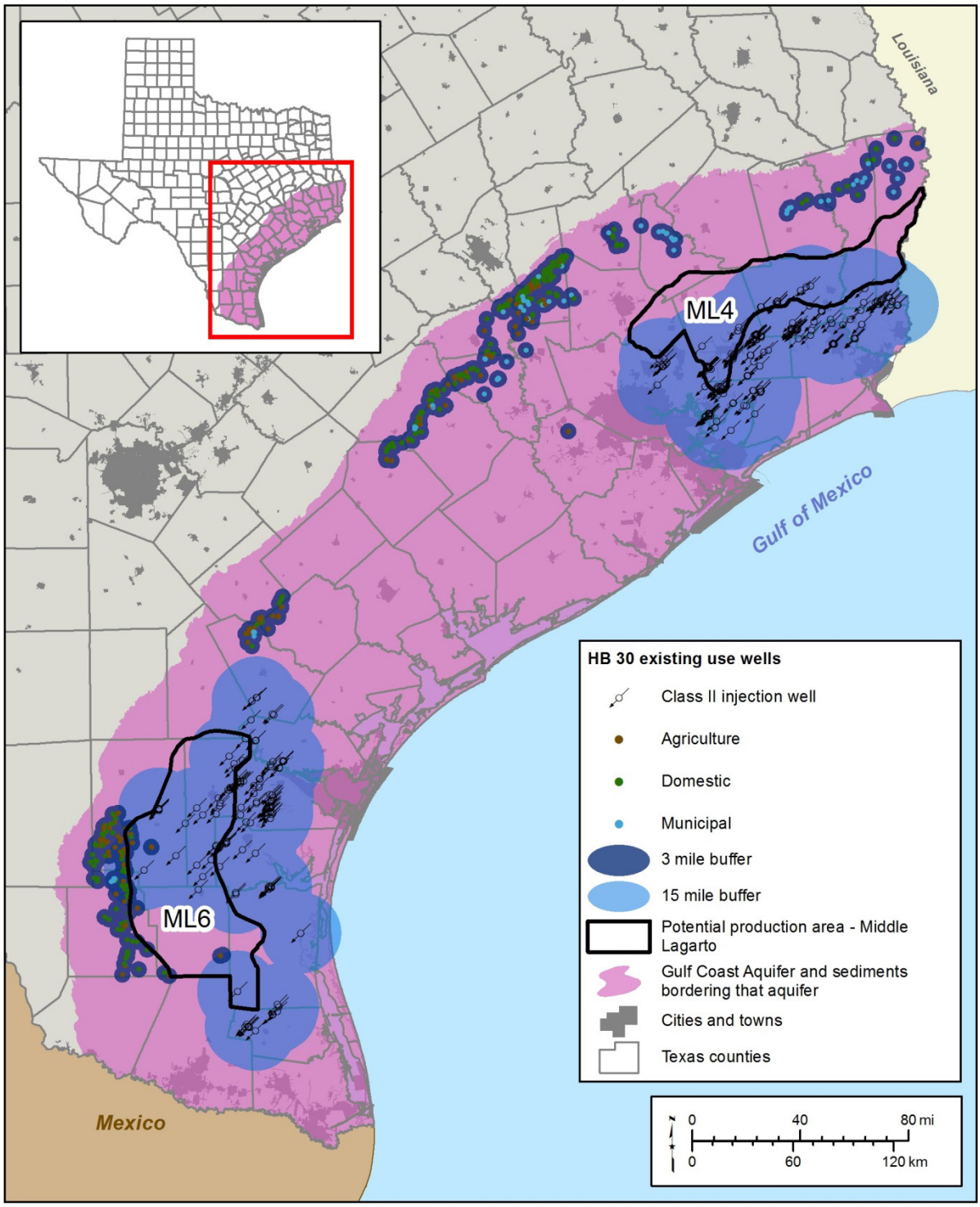

Figure 15. Middle Lagarto Formation showing potential production areas. Wells used to exclude areas from designation as brackish groundwater production zones include water wells (municipal, domestic, and agricultural) and injection wells (Class II). A three-mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. Water well and hydrogeologic barrier evaluations were only performed in areas not covered by a Class II injection well buffer. Water wells that do not meet House Bill 30 exclusion criteria are not shown.

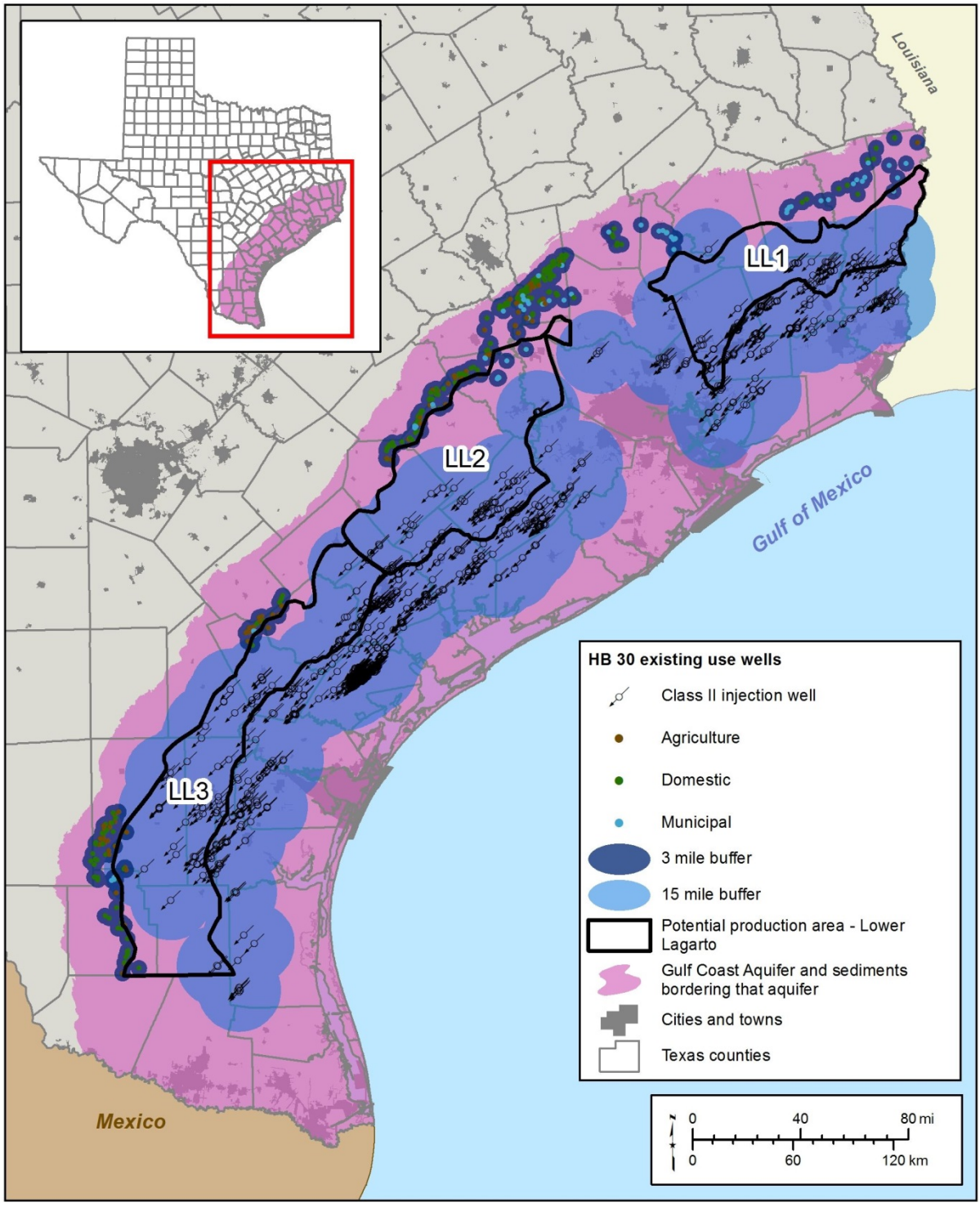

Figure 16. Lower Lagarto Formation showing potential production areas. Wells used to exclude areas from designation as brackish groundwater production zones include water wells (municipal, domestic, and agricultural) and injection wells (Class II). A three-mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. Water well and hydrogeologic barrier evaluations were only performed in areas not covered by a Class II injection well buffer. Water wells that do not meet House Bill 30 exclusion criteria are not shown.

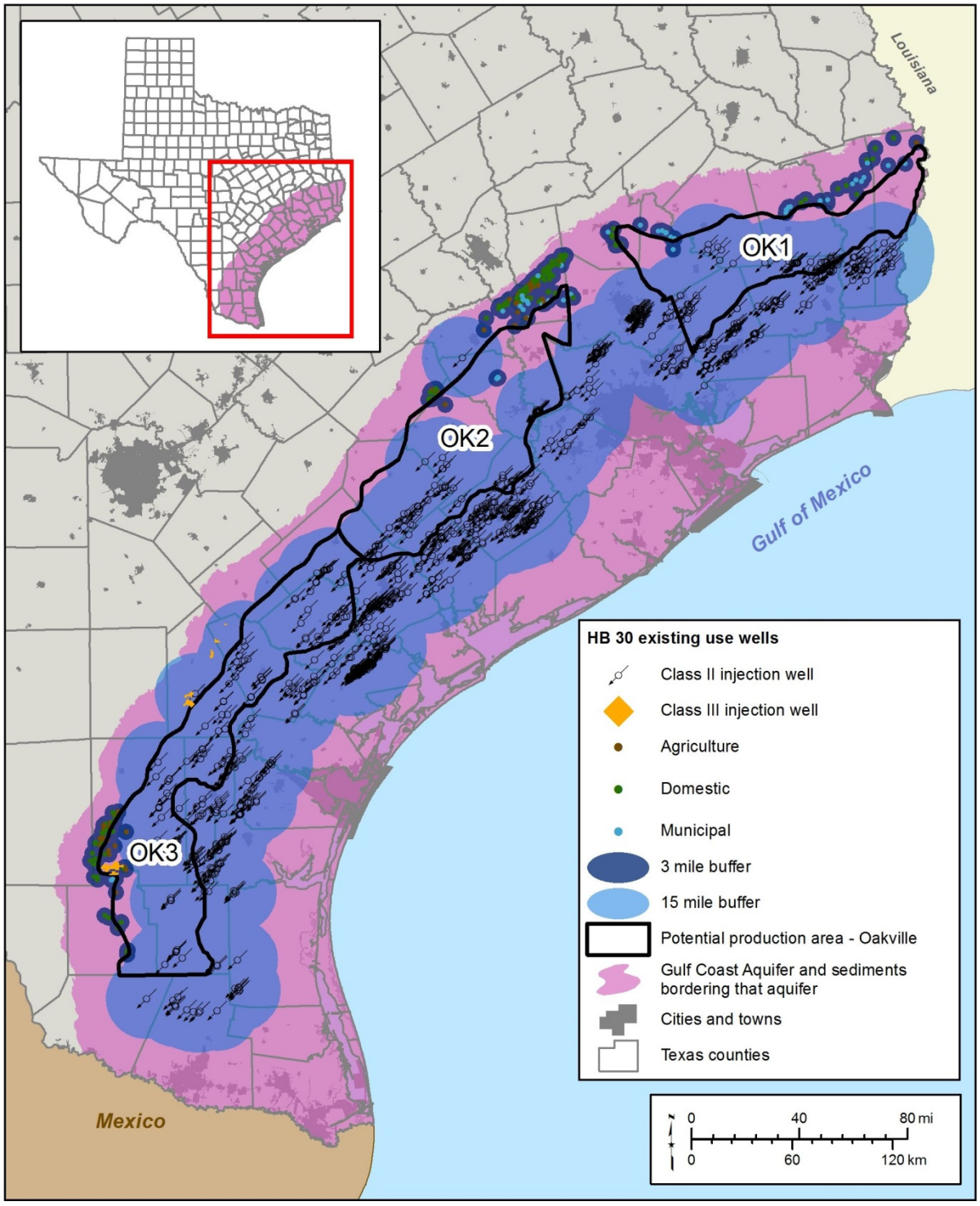

Figure 17. Oakville Formation showing potential production areas. Wells used to exclude areas from designation as brackish groundwater production zones include water wells (municipal, domestic, and agricultural) and injection wells (Class II). A three-mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. Water well and hydrogeologic barrier evaluations were only performed in areas not covered by a Class II injection well buffer. Water wells that do not meet House Bill 30 exclusion criteria are not shown. Class III injection well aquifer exemption areas in the Oakville Formation are excluded from zone designation.

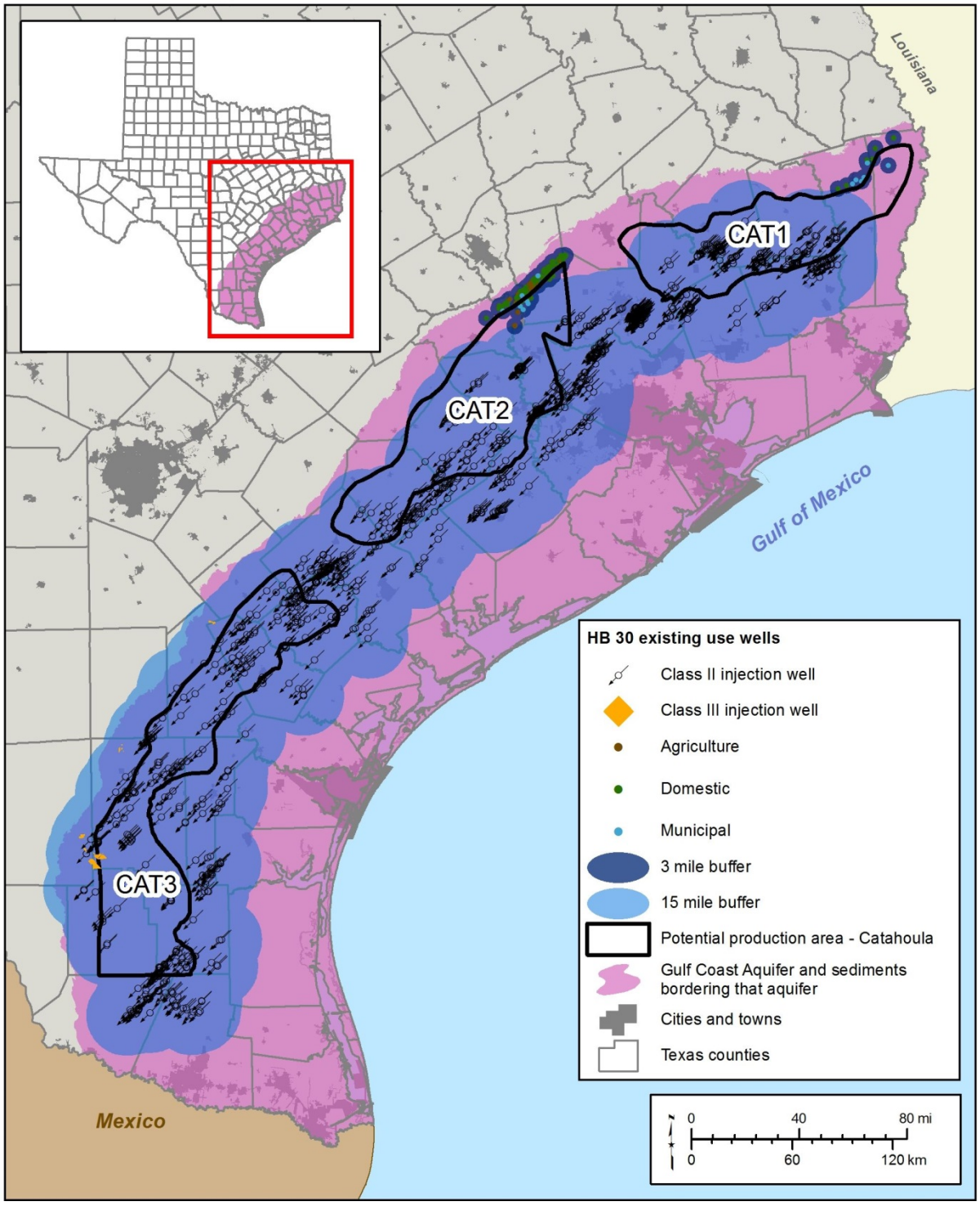

Figure 18. Catahoula Formation showing potential production areas. Wells used to exclude areas from designation as brackish groundwater production zones include water wells (municipal, domestic, and agricultural) and injection wells (Class II). A three-mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. Water well and hydrogeologic barrier evaluations were only performed in areas not covered by a Class II injection well buffer. Water wells that do not meet House Bill 30 exclusion criteria are not shown. Class III injection well aquifer exemption areas in the Catahoula Formation are excluded from zone designation.

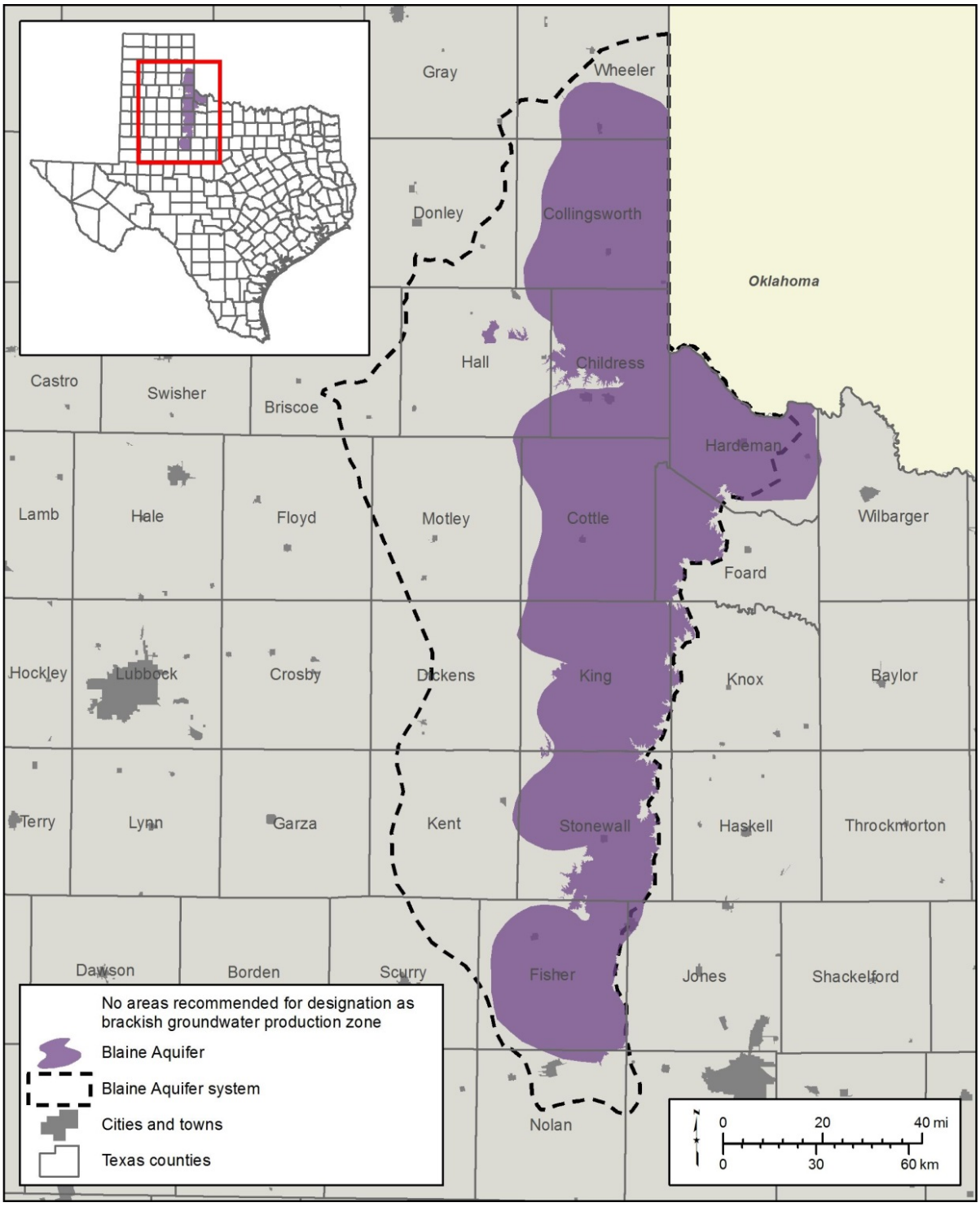

Figure 19. Blaine Aquifer. No areas are recommended for designation as brackish groundwater production zones.

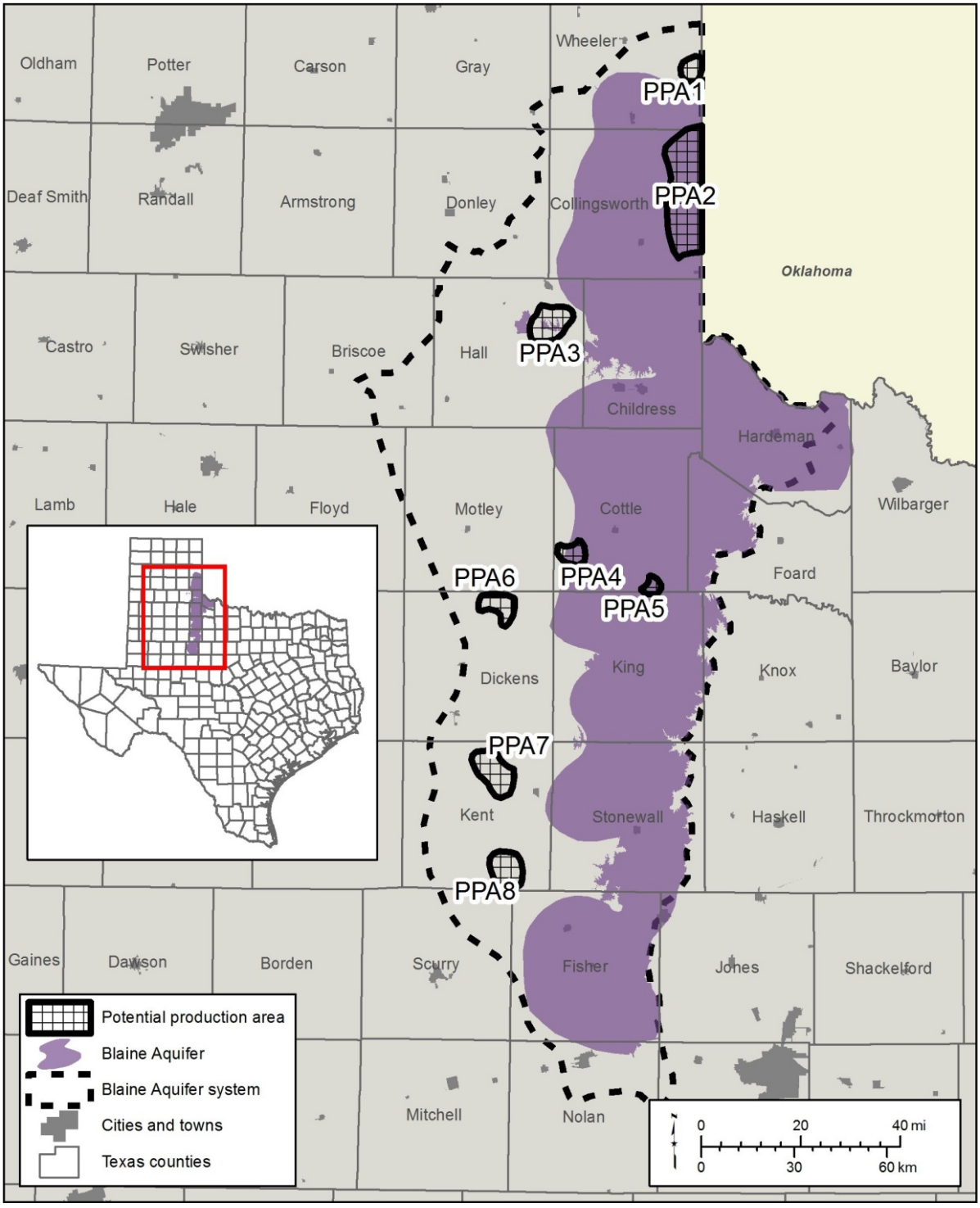

Figure 20. Blaine Aquifer showing eight potential production areas (PPA1, PPA2, PPA3, PPA4, PPA5, PPA6, PPA7, and PPA8). The areas were selected based on the potential for moderate to high productivity within the Blaine Aquifer and the lack of exclusion wells. Areas PPA1, PPA2, PPA3, PPA5, and PPA7 were removed from further consideration after additional well data were obtained and assessed.

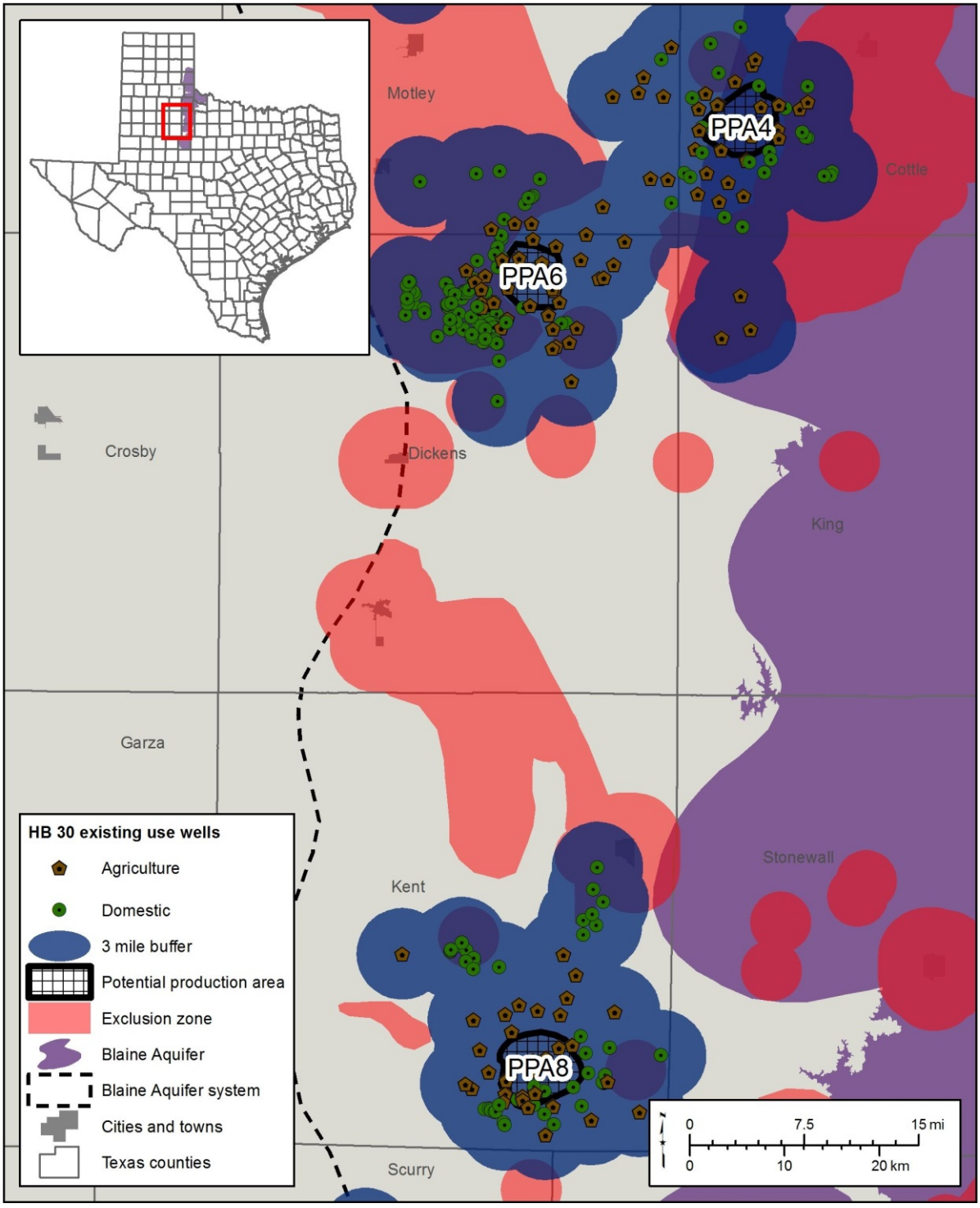

Figure 21. Blaine Aquifer showing water wells used to exclude areas from the remaining potential production areas (PPA4, PPA6, and PPA8). The wells included water wells (domestic, and agricultural). A three-mile buffer was placed around each water well. The area labeled "Exclusion zone" was based on initial data evaluation.

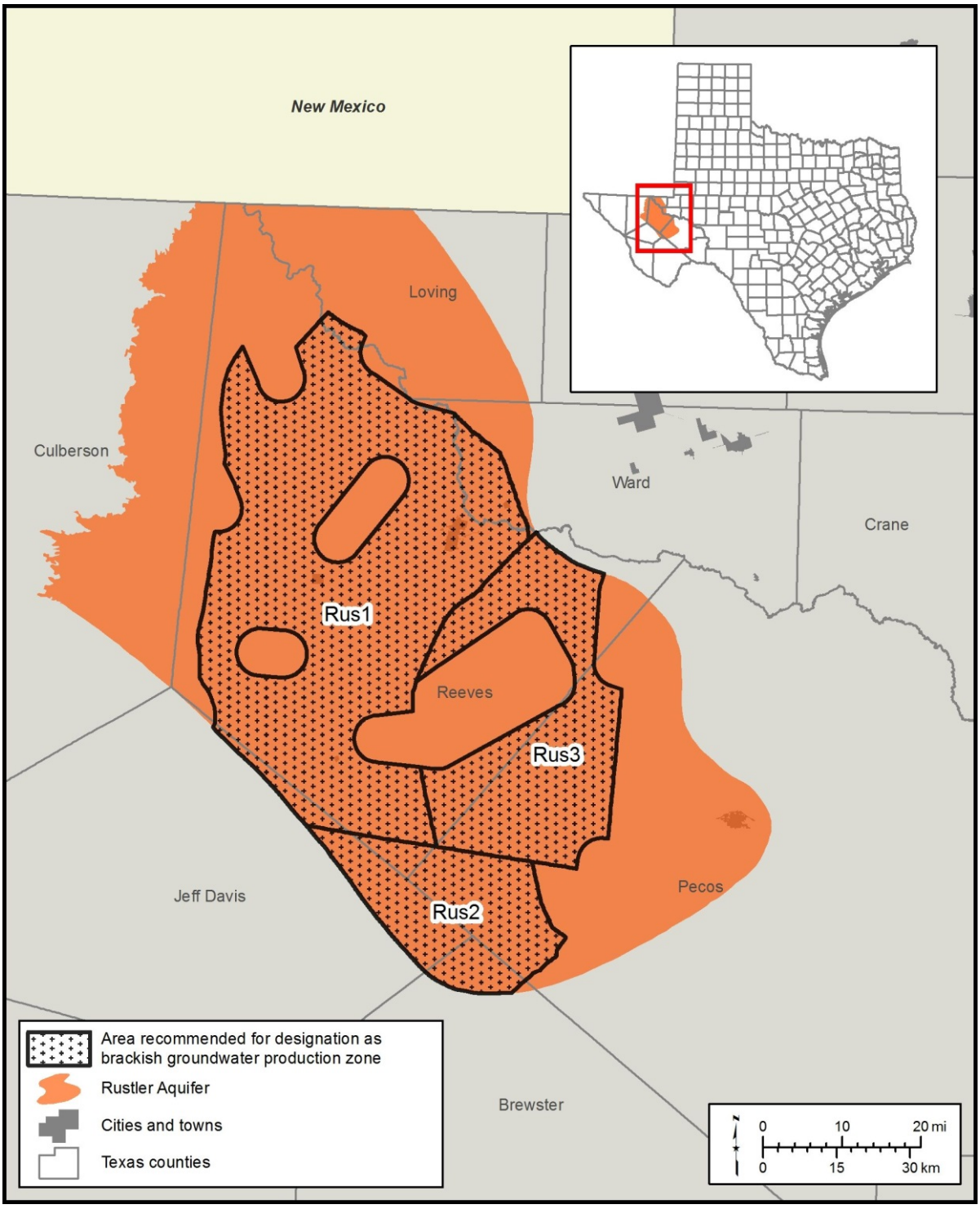

Figure 22. Rustler Aquifer showing three potential production areas (Rus 1, Rus 2, and Rus 3) recommended for designation as brackish groundwater production zones. The areas contain groundwater that is slightly saline (1,000 to 3,000 milligrams per liter of total dissolved solids) to moderately saline (3,000 to 10,000 milligrams per liter of total dissolved solids).

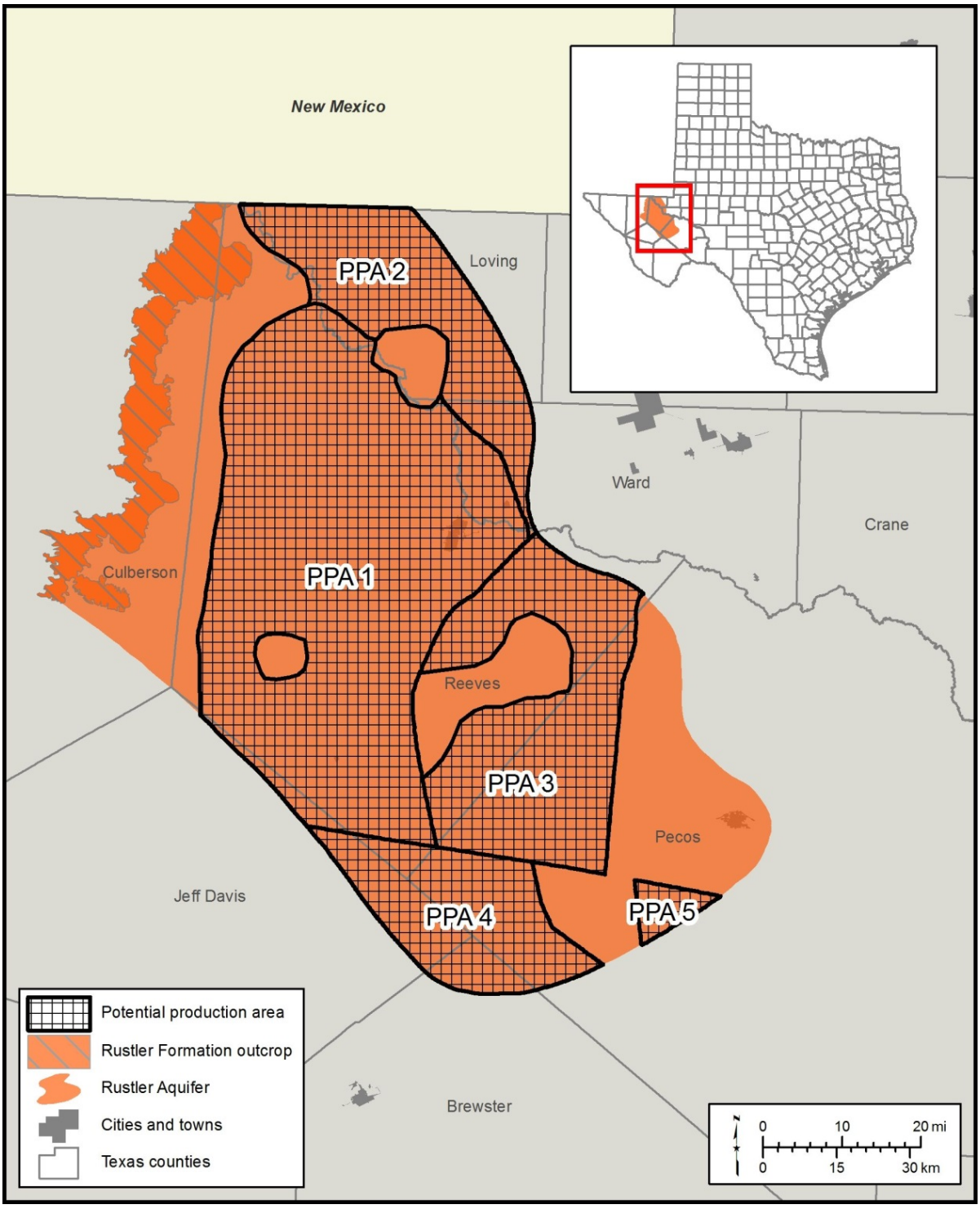

Figure 23. Rustler Aquifer showing five potential production areas (PPA1, PPA2, PPA3, PPA4, and PPA5). Areas not covered by a potential production area were excluded based on the presence of the Rustler outcrop, existing water wells, Class II injection wells, or anticipated low aquifer productivity.

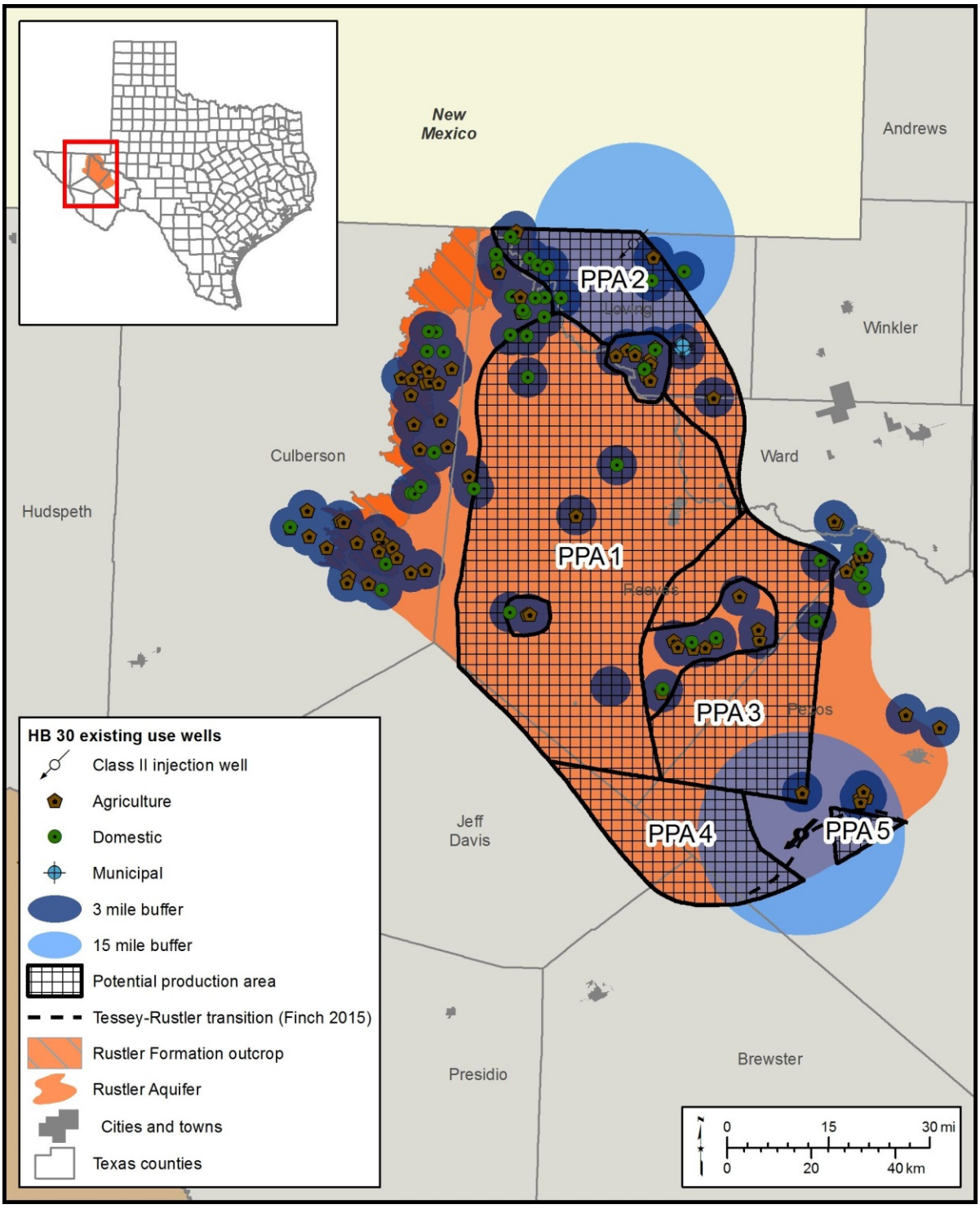

Figure 24. Rustler Aquifer showing wells used to exclude areas from designation as brackish groundwater production zones. The wells include water wells (municipal, domestic, and agricultural) and injection wells (Class II and III). A three-mile buffer was placed around each water well and a 15-mile buffer around each Class II injection well. The southern part of area PPA4 was trimmed to reflect the lack of a hydrogeologic barrier between the Rustler Formation and the transition into the Tessey Limestone. Water wells that do not meet House Bill 30 exclusion criteria are not shown.