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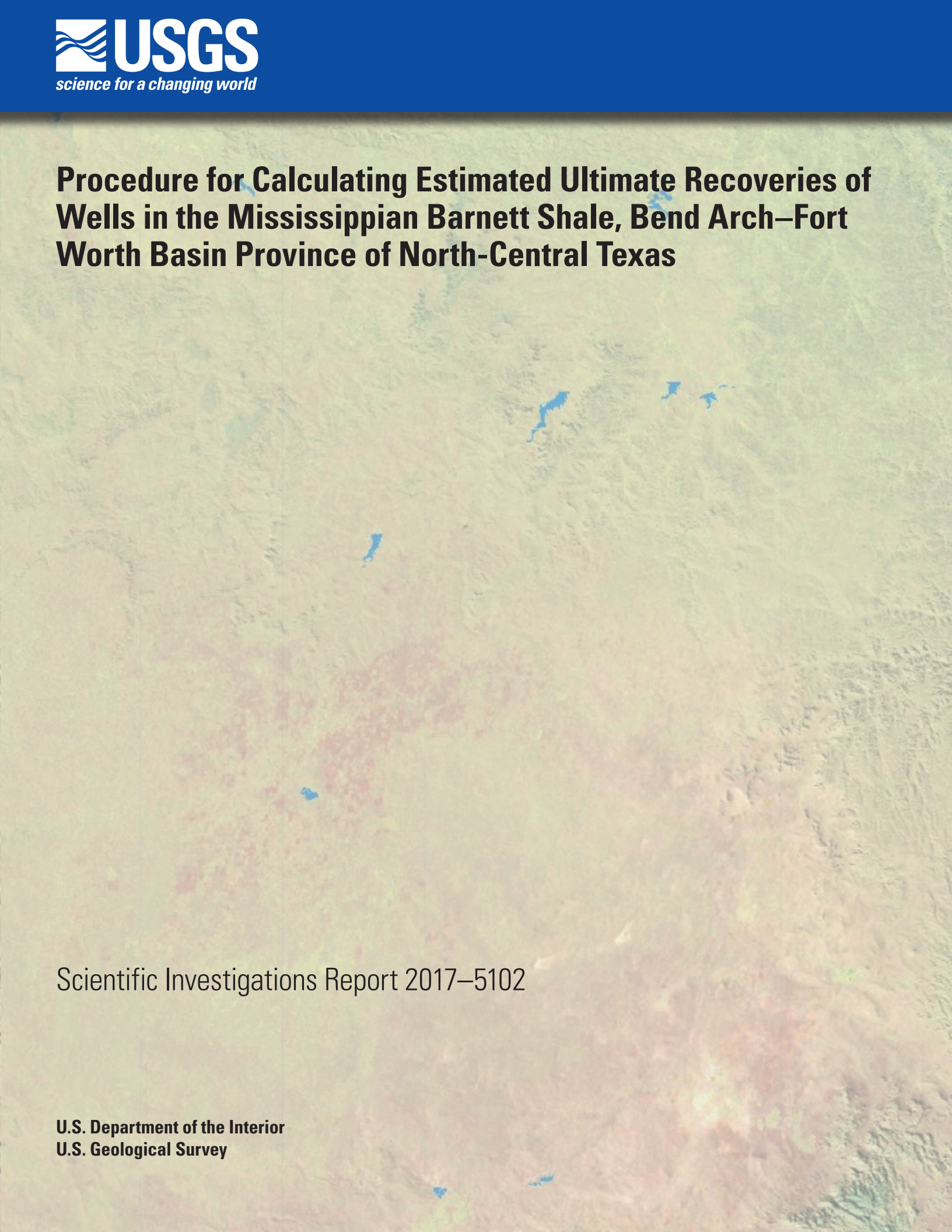
Procedure for Calculating Estimated Ultimate Recoveries of Wells in the Mississippian Barnett Shale, Bend Arch–Fort Worth Basin Province of North-Central Texas



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U.S. Geological Survey

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
	Volume	
barrel (bbl; petroleum, 1 barrel=42 gal)	0.1590	cubic meter (m^3)
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)

Abbreviations

AU	assessment unit
EUR	estimated ultimate recovery
ft^3/bbl	cubic feet of gas per barrel of oil
MBO	thousand barrels of oil
MMBO	million barrels of oil
MMcf	million cubic feet
USGS	U.S. Geological Survey

Procedure for Calculating Estimated Ultimate Recoveries of Wells in the Mississippian Barnett Shale, Bend Arch–Fort Worth Basin Province of North-Central Texas

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Abstract

In 2015, the U.S. Geological Survey published an assessment of technically recoverable continuous oil and gas resources of the Mississippian Barnett Shale in the Bend Arch–Fort Worth Basin Province of north-central Texas. Of the two assessment units involved in the overall assessment, one included a roughly equal number of oil wells and gas wells as classified by the U.S. Geological Survey's standard of gas wells having production greater than or equal to 20,000 cubic feet of gas per barrel of oil and oil wells having production less than 20,000 cubic feet of gas per barrel of oil. As a result, estimated ultimate recoveries (EURs) were calculated for both oil wells and gas wells in one of the assessment units. Generally, only gas EURs or only oil EURs are calculated for an assessment unit. These EURs were calculated with data from IHS Markit™ using DeclinePlus software in the Harmony interface and were a major component of the quantitative resource assessment. The calculated mean EURs ranged from 235 to 2,078 million cubic feet of gas and 21 to 39 thousand barrels of oil for various subsets of wells.

Introduction

In 2015, the U.S. Geological Survey (USGS) published an assessment of technically recoverable continuous oil and gas resources of the Mississippian Barnett Shale in the Bend Arch–Fort Worth Basin Province of north-central Texas (Marra and others, 2015). Continuous resources for this assessment include shale oil and shale gas. The calculation of estimated ultimate recoveries (EURs) for oil and gas wells is a major component of the USGS assessment methodology for continuous resources (Charpentier and Cook, 2012). This report outlines the procedure used to calculate EURs that were subsequently utilized in the quantitative assessment. The EURs were calculated for wells in the Barnett Continuous Gas Assessment Unit (AU) and the Barnett Mixed Continuous Gas and Oil AU (fig. 1). The Western Barnett Continuous Oil AU was not quantitatively assessed and so has no associated EURs.

Procedure

A resource assessment was performed on a previously identified formation of interest, the Mississippian Barnett Shale in the Bend Arch–Fort Worth Basin Province of north-central

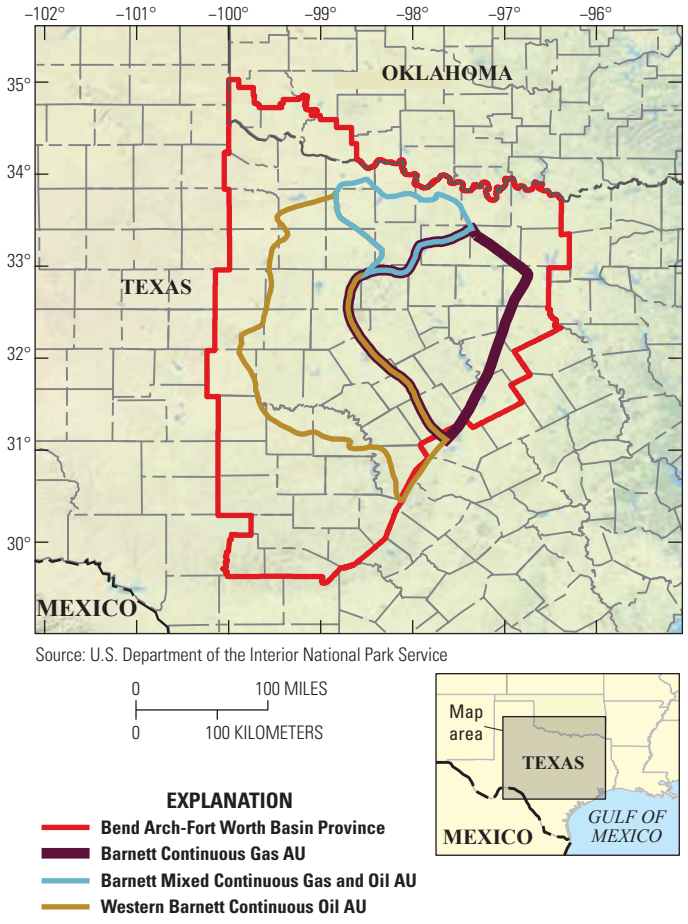

Figure 1. Map of north-central Texas with assessment unit (AU) boundaries for the Mississippian Barnett Shale in the Bend Arch–Fort Worth Basin Province. The Western Barnett Continuous Oil AU was not quantitatively assessed. (Modified from Marra and others, 2015)

Texas. The lead geologist defined AU boundaries based on a variety of geologic concerns, such as depth, lithology, and thermal maturity of source rocks. Wells within this formation were queried, and a map of the wells in each AU was created. There were separate groups of wells for each AU. The wells were further grouped into sweet spots and non-sweet spots within an AU. A "sweet spot" is a defined area in an AU with relatively better production characteristics than the overall AU area (Schmoker, 2003). These production characteristics include higher drilling success rates and greater EURs.

Next, monthly production data were extracted from the IHS Markit™ database, current as of August 2015 (IHS Markit, 2015). This is a proprietary database to which the USGS subscribes. Along with the production data, other ancillary data such as well orientation and production start dates were concurrently extracted to aid in organization and application of the final EURs. For example, this was useful in comparing EURs from horizontal and vertical wells.

EURs were calculated using the IHS Markit DeclinePlus software, which is run on the Harmony interface (IHS Markit Energy Group, 2013). The DeclinePlus software is equipped to calculate decline curves using four different methods: (1) traditional decline (such as Arps), (2) multi-segment decline, (3) Duong, and (4) stretched exponential. For the assessment of continuous oil and gas resources, the USGS uses the stretched exponential method because it is considered a mathematical construct for use on continuous resources (Valkó, 2009). The stretched exponential method is also used because traditional Arps decline methods are based on flow and other assumptions that are commonly invalid for wells in continuous accumulations (Anderson and others, 2010). In addition, the multi-segment method is a simple extension of traditional decline, and Duong tends to give erratic results.

The EUR for each well was modeled on a 30-year time frame specific to the product, oil or gas, to which the well is assigned using the last 50 percent of the available production data points. The USGS uses a cutoff of 20,000 cubic feet of gas per barrel of oil (ft^3/bbl) to define a well as either an oil well (less than 20,000 ft^3/bbl) or a gas well (greater than or equal to 20,000 ft^3/bbl) (Schmoker and Klett, 2005). For

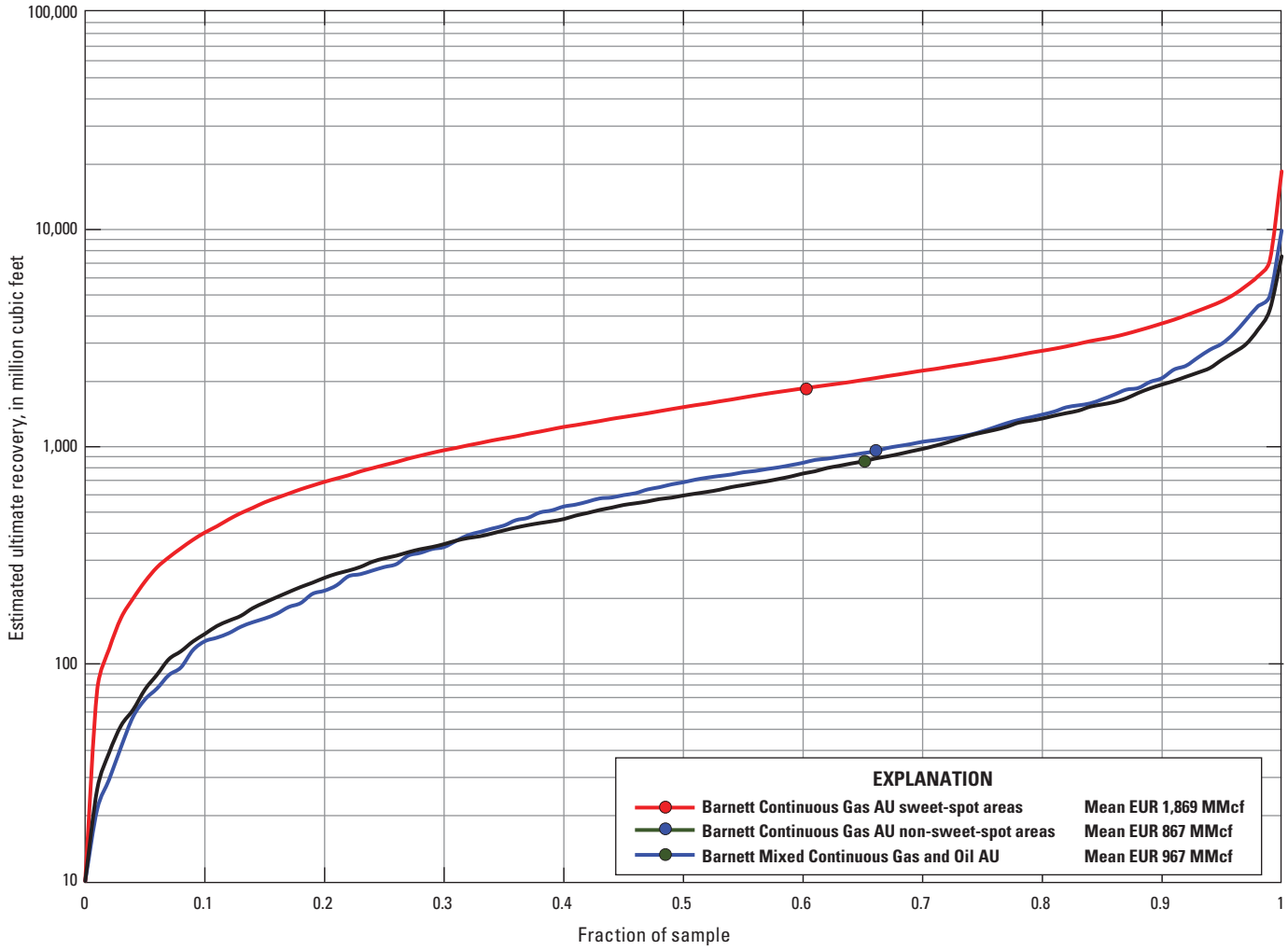

Figure 2. Estimated ultimate recovery (EUR) distributions for gas wells in the Barnett Continuous Gas and the Barnett Mixed Continuous Gas and Oil Assessment Units (AUs). (MMcf, million cubic feet)

comparison, 60-year EURs were also run with the 30-year EURs; the comparison showed minimal differences. As such, the 30-year time frame was used for this study.

Wells with less than 18 months of production were removed from the analysis because data from early production are commonly erratic and an accurate trend cannot be modeled for these early-stage wells. For the Barnett Shale, the number of wells with less than 18 months of production is small compared to the total dataset available for these AUs. In addition, wells with less than 18 months of production data since they reached maximum production were removed from the analysis. This is to help ensure the production profile has a shape suitable for production forecasting.

Any wells with EURs of less than 20 million cubic feet (MMcf) of gas or 2 thousand barrels of oil (MBO) were also removed from the analysis. If a well is loaded into the DeclinePlus software with no production data, the software will calculate a fixed EUR value. The value is around 20 MMcf of gas or 20 MBO, but varies based on the program settings. Wells with these fixed values were removed from the analysis. Finally, wells on the high end of the range of EURs were investigated, and wells with production profile shapes not suitable for production forecasting were removed from the analysis. The wells that were removed from the analysis for any of these reasons were considered nonproducers and were subsequently used in the success ratio portion of the overall assessment rather than in consideration for the distribution of EURs.

The procedure outlined above results in an EUR for each well and a distribution of EURs for each AU. If geologic sweet spots were defined, additional EUR distributions were provided for areas representing sweet spots and non-sweet spots. The mean of each EUR distribution is critical and used in the assessment process. The EUR distributions for the Barnett Continuous Gas AU and the Barnett Mixed Continuous Gas and Oil AU (for gas only) are shown in figure 2. The EUR distributions for the Barnett Continuous Gas AU sweet-spot and non-sweet-spot areas are depicted on the plot. The EUR distribution for oil wells in the Barnett Mixed Continuous Gas and Oil AU is shown in figure 3.

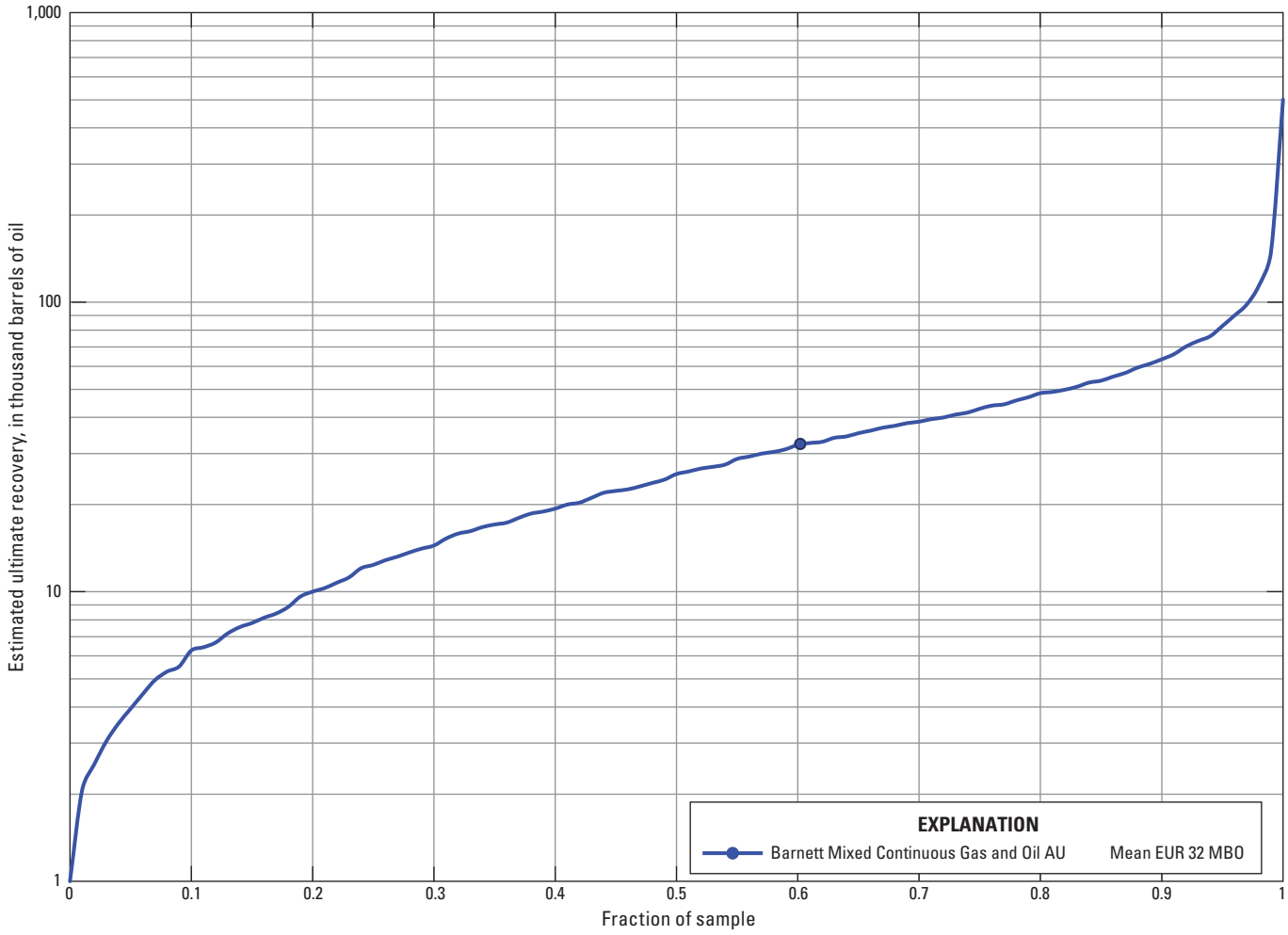

Figure 3. Estimated ultimate recovery (EUR) distribution for oil wells in the Barnett Mixed Continuous Gas and Oil Assessment Unit (AU). (MBO, thousand barrels of oil)

Procedure Modified for Barnett Mixed Continuous Gas and Oil Assessment Unit

As mentioned above, the USGS assigns wells to an AU as either gas or oil using a 20,000 ft^3/bbl definition. In most USGS assessments, well and AU types are clearly defined. However, in the case of the Barnett Shale, one AU had approximately 50 percent of its wells below 20,000 ft^3/bbl and the other 50 percent above 20,000 ft^3/bbl. As a result, the AU had a nearly equal number of oil and gas wells. This means the AU could not be strictly defined as an oil AU or a gas AU. For this reason, the resource assessment methodology and the EUR calculation procedure were slightly modified to accommodate both oil and gas wells.

First, each well was categorized as an oil or gas well using the 20,000 ft^3/bbl definition. As stated previously, gas wells have production of greater than or equal to 20,000 ft^3/bbl and oil wells have production of less than 20,000 ft^3/bbl. A range of EURs and a mean EUR were calculated for each product type, and these values were reported for use in the geologically based assessment of resources.

Results

The Barnett Continuous Gas AU was subdivided into geologic sweet-spot and non-sweet-spot areas. The mean gas EUR ranges from 867 MMcf in the non-sweet spot to 1,869 MMcf in the sweet spot. This mean consists of all wells in the area, including horizontal and vertical wells. The mean EUR for gas wells in the Barnett Mixed Continuous Gas and Oil AU is 967 MMcf, similar to the non-sweet spot of the Barnett Continuous Gas AU. The mean EUR for the oil wells in the Barnett Mixed Continuous Gas and Oil AU is 32 MBO.

A comparison analysis was performed on the vertical and the horizontal wells. As expected, because of the greater

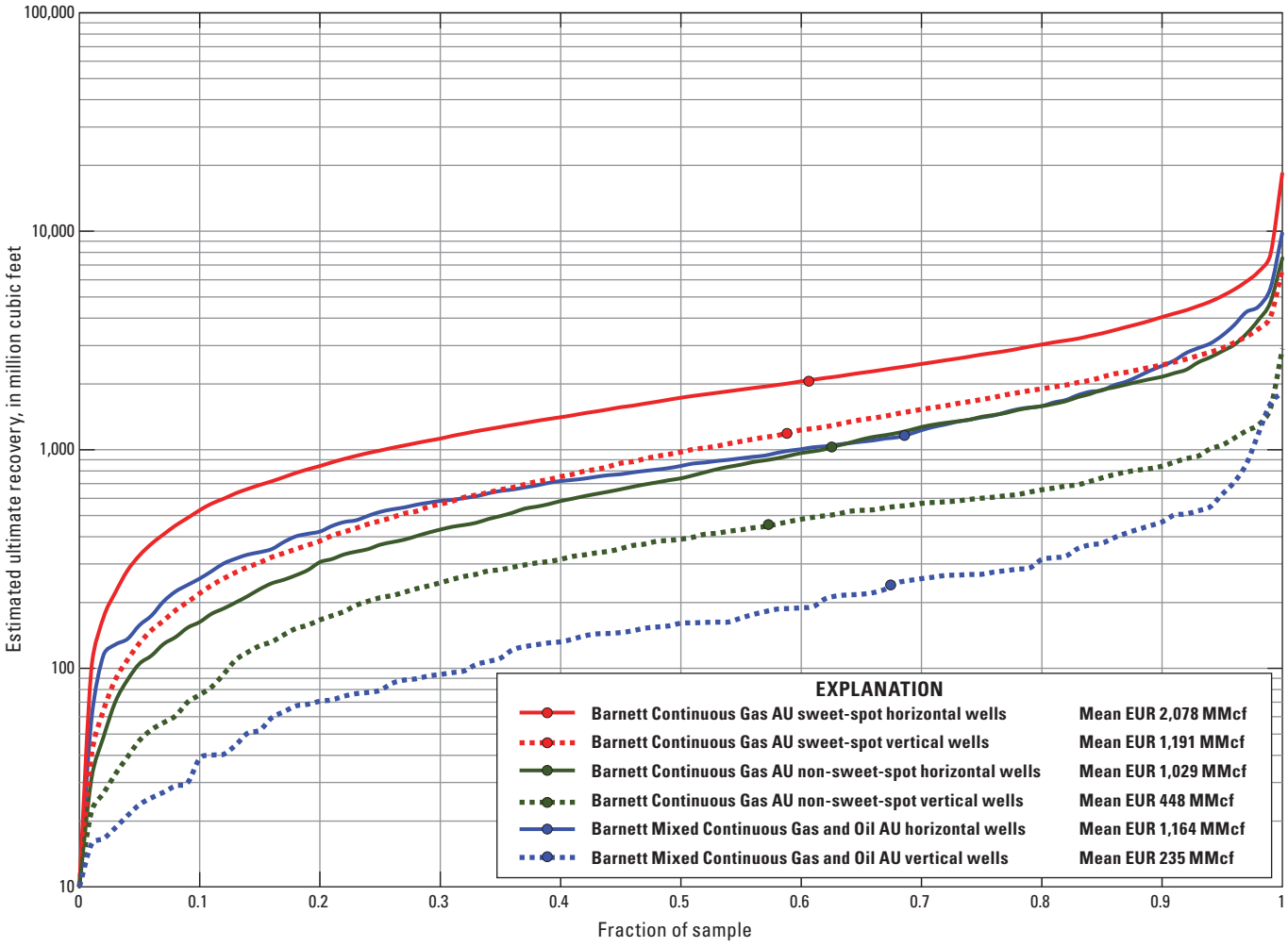

Figure 4. Estimated ultimate recovery (EUR) distributions for gas wells in the Barnett Continuous Gas and the Barnett Mixed Continuous Gas and Oil Assessment Units (AUs) showing the differences between horizontal and vertical wells. (MMcf, million cubic feet)

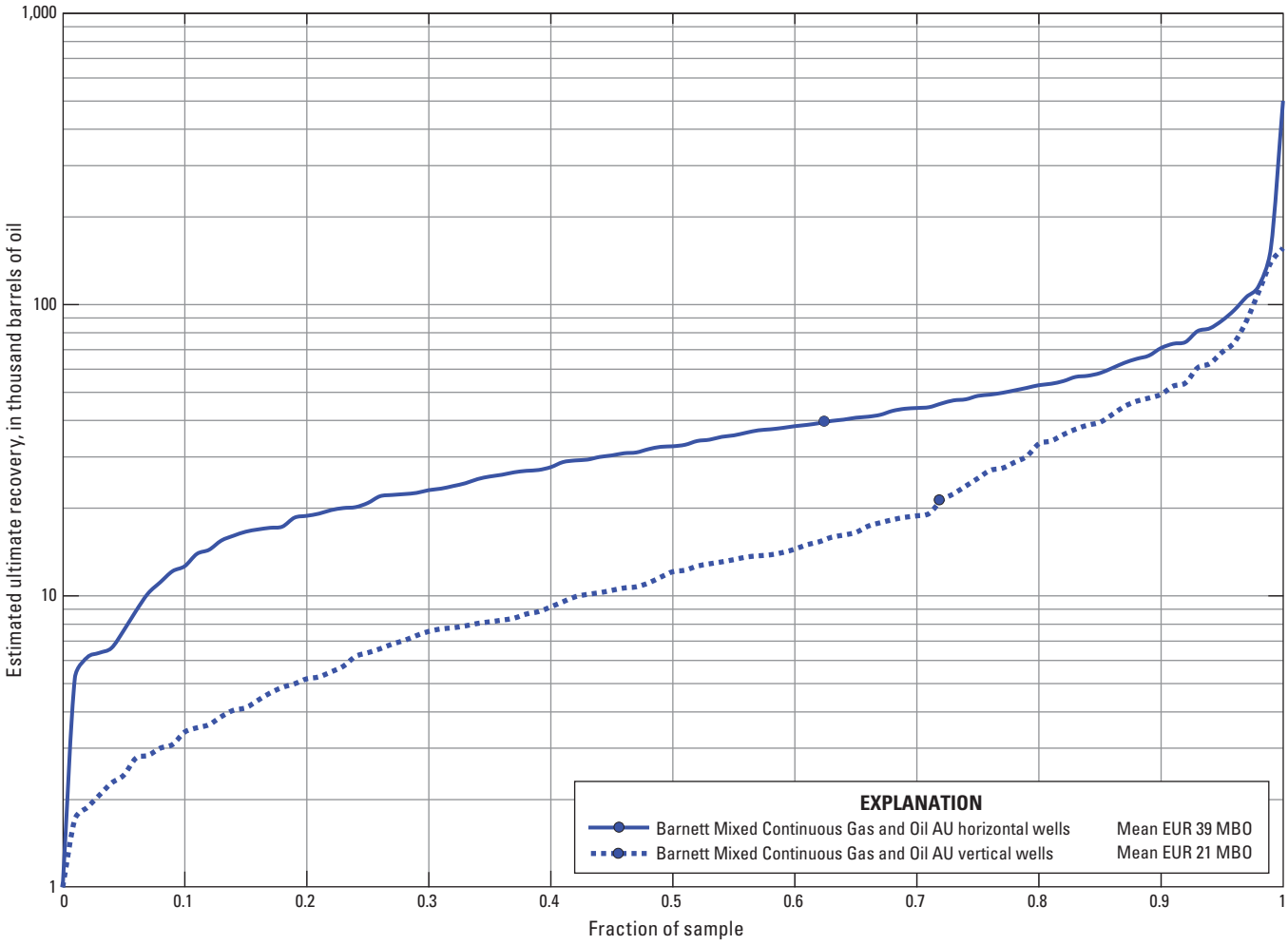

Figure 5. Estimated ultimate recovery (EUR) distributions for oil wells in the Barnett Mixed Continuous Gas and Oil Assessment Unit (AU) showing the differences between horizontal and vertical wells. (MBO, thousand barrels of oil)

reservoir contact and drainage area of horizontal wells, the mean EUR for horizontal wells is greater than the mean EUR for vertical wells. This can be observed in figure 4 for gas wells and figure 5 for oil wells. The difference is especially apparent in the gas wells of the Barnett Mixed Continuous Gas and Oil AU.

The EUR means and ranges are helpful in calculating overall well productivity and were used to build EUR probability distributions for the USGS 2015 assessment.

Summary

This report outlines the steps taken to calculate estimated ultimate recoveries for continuous assessment units in the Mississippian Barnett Shale within the Bend Arch–Fort Worth Basin Province of north-central Texas. The procedure was modified from that used for estimated ultimate recovery calculations for other U.S. Geological Survey assessments in order to deal with the unique situation of the Barnett Mixed Continuous Gas and Oil Assessment Unit. The final calculated values of ranges and means of estimated ultimate recoveries in the assessment units were useful as guides for a geologically based resource assessment of Marra and others (2015).

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