Memorandum

To: Kwangyul Choi; Scott McThompson

From: Chris Rilling

Date: 3 Aug 2021

Subject: Well Activity in Niobrara Basin, Colorado

Summary

The Niobrara Basin in Colorado is home to over 55,000 wells. Hot spot, cluster and point density analysis was conducted to show the concentration of wells with the basin. The analysis was conducted on both abandoned and active wells within the area to see if this type of analysis can show if activity is potentially declining or growing in an area.

Introduction

The Niobrara basin is located primarily in southeast Wyoming and northeast Colorado. This basin produces crude oil and liquid rich gases throughout five different benches. This basin has been in production since at least 1953 when oil was discovered near Lyons, CO. The Wattenberg field, a gas field, has been in production since it's discovery in 1970. Over 60 years have passed since these discoveries and as of 2020 there were over 26,000 wells in Weld County alone.

According to the USGS, as of 2007, over 1.05 billion barrels of oil and 3.67 trillion cubic feet of natural gas has been produced across the basin. The questions to be answered in this project are how many wells exist in this basin and of these how many are active and abandoned. Focus will also be on where in the basin these wells are located in an effort to see if determinations can be made on where activity is growing and/or declining within the basin. This type of analysis can be beneficial for those looking for areas of development or investment as well as income for communities within these areas.

Methods

1. Unit of Analysis: Since we know that the well count is already within the tens of thousands, the unit of analysis will be at the county level and, even though the basin extends into neighboring states, will only focus on Colorado. This is due to the desire to analyze large areas being covered by numerous point data.

2. Data and Sources: Current well data was obtained from the Colorado Oil and Gas Commission which updates their activity database daily. Boundaries for the basin was based on information obtained from the USGS. Historical data was attempted but was limited only to production amounts and not activity status which was not useable for this analysis.

3. Techniques: To best show the areas of concentration, density will be calculated for both active and abandoned wells. Hot spot analysis was conducted on both activity statuses to determine the statistical significance in an effort to see where these areas are the most significant. Due to the wide coverage area a cluster analysis was also performed.

4. Limitations: Within the oil and gas industry, nearly all data is considered proprietary. An in-depth analysis of producing formations would be helpful but data may not be available and as such only a generalized analysis is possible.

Conclusion

The first questions that were to be answered to get a feel for the data to interpret was how many wells are in the area of interest. The area of interest is a total 24,056 mi^2 over 15 counties. There was a grand total of 55002 wells in the study area (figure 1). Wells that showed a status other than active or abandoned was not used in this study since it was not known if they were in the process of becoming abandoned or were in a soak status. Active wells totaled 21,236 (figure 2) and abandoned wells totaled 5,313 (figure 3).

Looking at these figures shows that there are visible clusters shown in both the active and abandoned wells. Cluster analysis at the 95% confidence level was performed for the both (figure 4: active cluster, figure 5: abandoned cluster) which showed that there is a high concentration of wells in the north west portion of the basin. Smaller clusters are shown in east. Items of interest is the number of low-high outliers in the west cluster for both the active and abandoned wells. These are the areas that show where there is a high-high cluster. These outliers would normally need to be evaluated due to the difference of the Z-scores but due to grouping it was felt that these are statistically significant and relevant.

To further explore the statistical significance of the data hot spot analysis was conducted. Within the active wells (figure 6) the hot spot covers nearly all of Weld County at the 99% confidence. The other clustered areas showed cold spots at the 99% confidence level. The abandoned wells (figure 7) showed a little more distribution. There are three distinct hot spots and cold spots in Weld County with the bigger hot spot extending more to the south. Yuma County showed a 99% confidence of cold spots in the active wells but was 99% confidence of hot spots in abandoned wells.

A point density analysis was then performed in an attempt to see where the highest concentration of active (figure 8) and abandoned (figure 9) were located. The highest density of active wells appears to be centered in the south west portion of Weld County. Yuma County also shows some high-density areas. These areas then decrease in density moving outward as expected within both counties. The abandoned wells showed an almost complete ring around the high-density area of the active wells in Weld County. Yuma County seems to show that while the high-density areas seem to be more localized for the active wells, the high-density areas of the abandoned wells seem to be one larger group that overlaps the active well area.

As stated in the introduction, the attempt of this study was to show if areas show any type of decline or growth within the basin. Combining the results of the wells shows that while there is a higher concentration of hot/cold spot outliers within the more highly concentrated areas these wells are still significant in that they fall within the areas of interest and have either an active or abandoned status. One reason why these values may be outliers is the distance from one well to the other with a different status, but due to the number of wells in the area would be near impossible to separate on a well-by-well basis. In order to better determine if the basin activity is growing or shrinking historical data would

be needed but as this data was not available it could not be accurately determined. However, when looking at the point density analysis and seeing a ring of abandoned wells around the active wells in Weld County, one could assume that there is the possibility of the reservoir being depleted. Future analysis would be needed to compare against the historical data to verify. Within Yuma County, due to the overlap seen in the point density analysis, it is more difficult to make any type of definite determination.

The point data analysis was the best one for this type of study to answer the desired question and defines a tighter area of interest for the petroleum companies operating in the basin. Future questions to be asked, other than the verification of reservoir depletion in Weld County, is the production levels of these wells within the basin. Combined with this data, it would reinforce if the areas of interest in the point density analysis for Weld County and Yuma County are the primary areas of oil and gas production in the Niobrara Basin. Another question to be asked is if the wells located between Weld and Yuma are actually production wells, how much they produce or if they were only exploration wells.

Reference

USGS, K. Higley, D., & O. Cox, D. (2007). *Oil and Gas Exploration and Development along the Front Range in the Denver Basin of Colorado, Nebraska, and Wyoming* (DDS-69-P). https://pubs.usgs.gov/dds/dds-069/dds-069-p/REPORTS/69_P_CH_2.pdf

Appendix

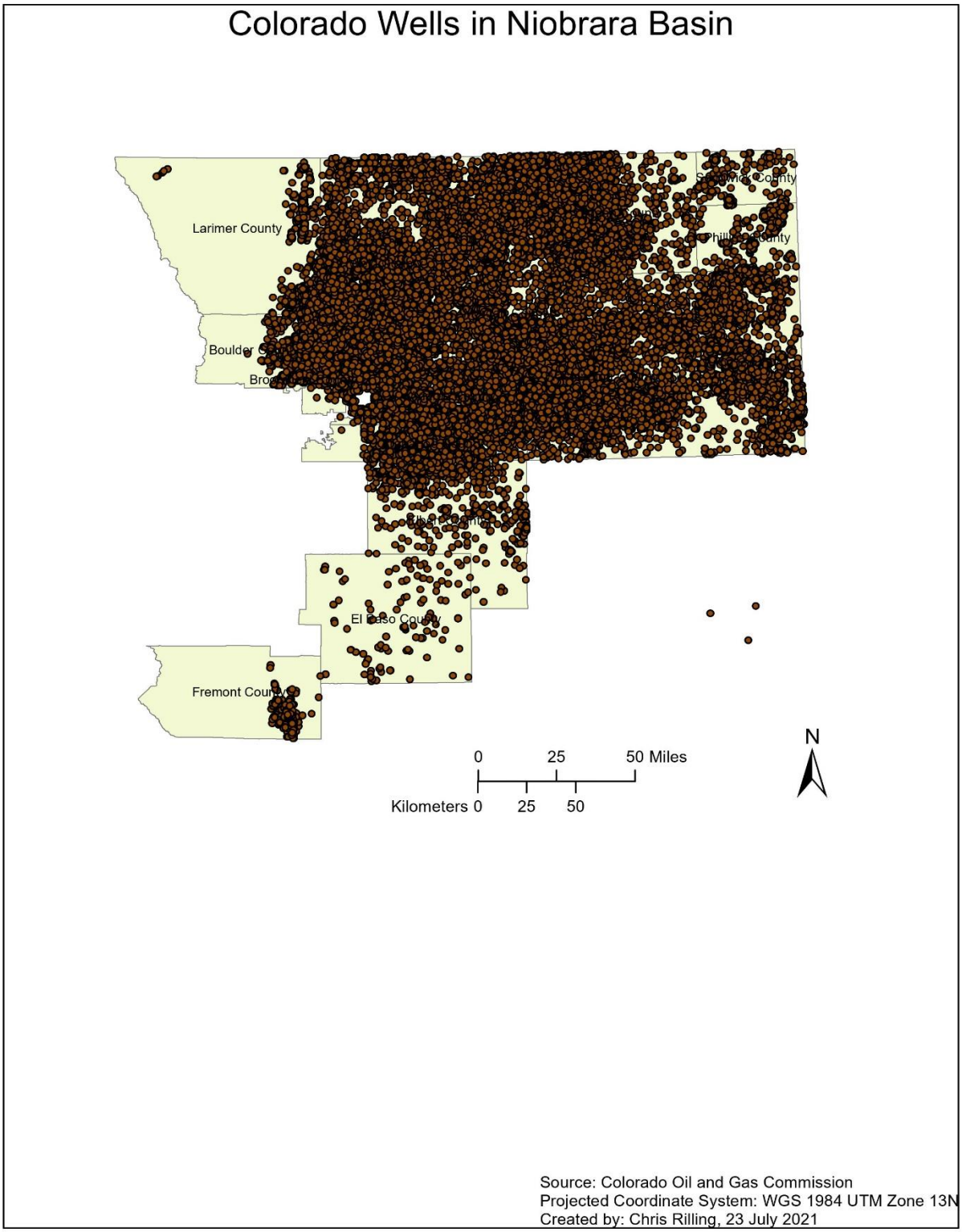

Figure 1

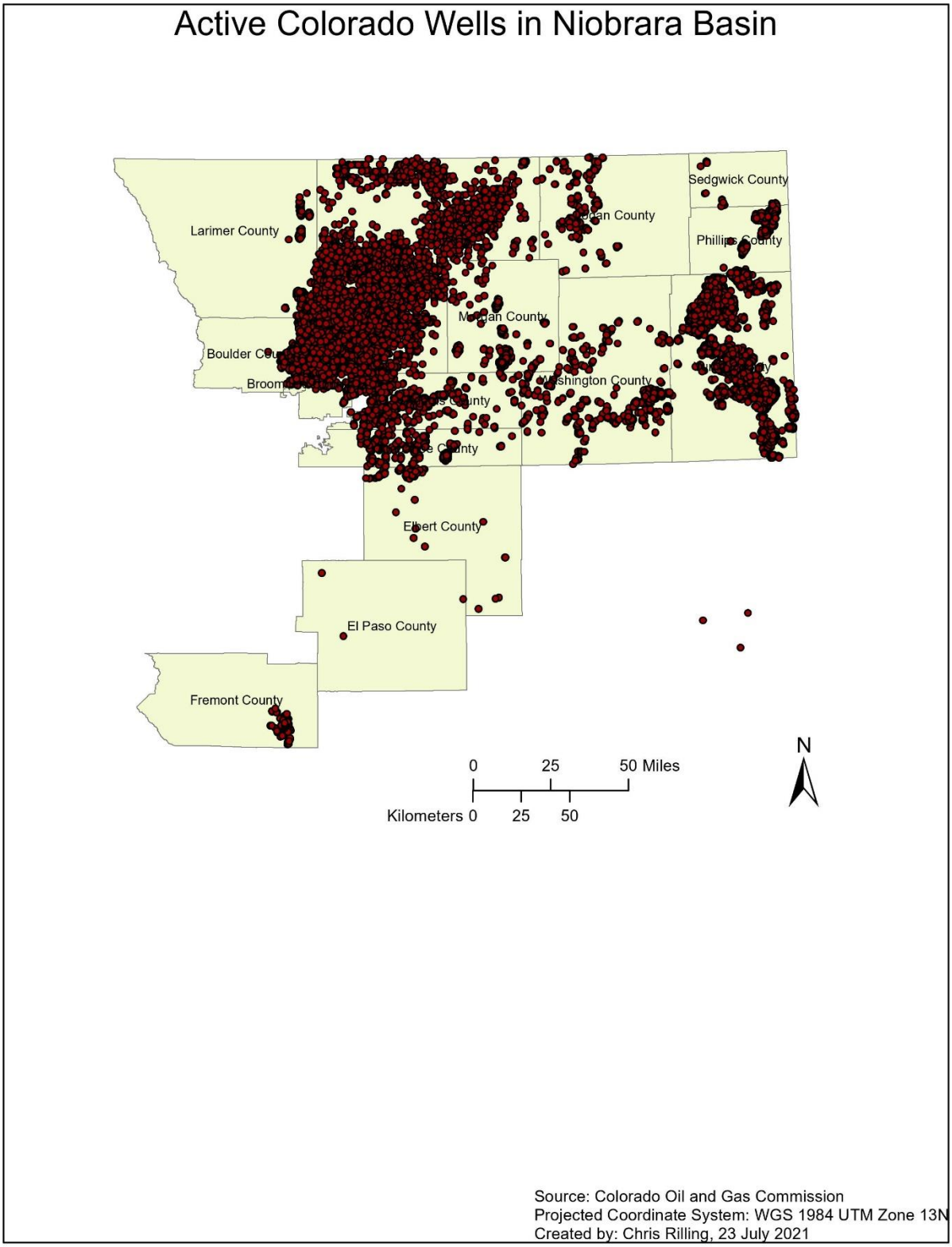
Active Colorado Wells in Niobrara Basin
Larimer County
Sedgwick County
Phillips County
Elbert County
El Paso County
Fremont County
0 25 50 Miles
Kilometers 0 25 50
N
Source: Colorado Oil and Gas Commission
Projected Coordinate System: WGS 1984 UTM Zone 13N
Created by: Chris Rilling, 23 July 2021

Figure 2

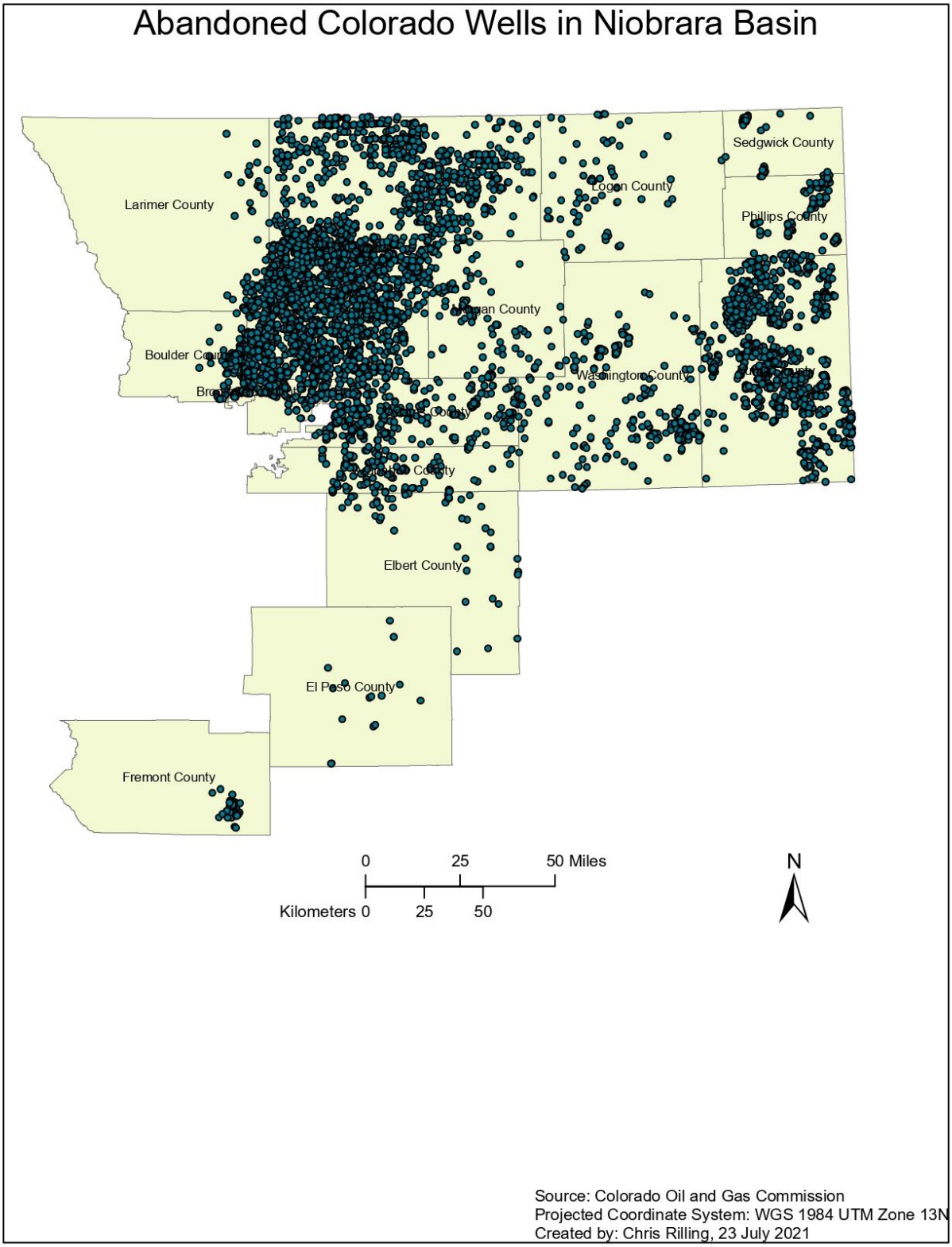
Abandoned Colorado Wells in Niobrara Basin
Larimer County
Logan County
Sedgwick County
Phillips County
Boulder County
Washington County
Elbert County
El Paso County
Fremont County
0 25 50 Miles
Kilometers 0 25 50
N
Source: Colorado Oil and Gas Commission
Projected Coordinate System: WGS 1984 UTM Zone 13N
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Figure 3

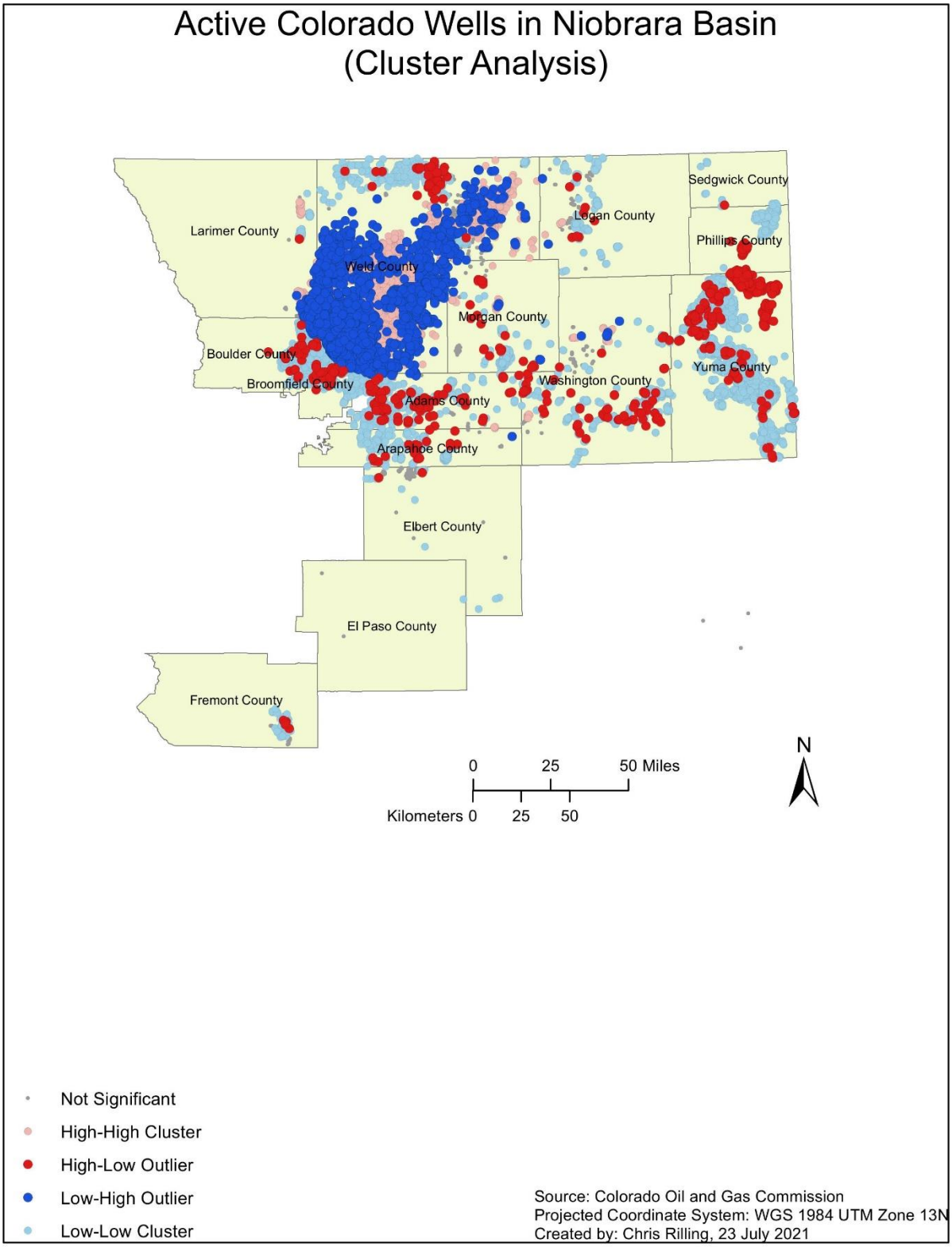
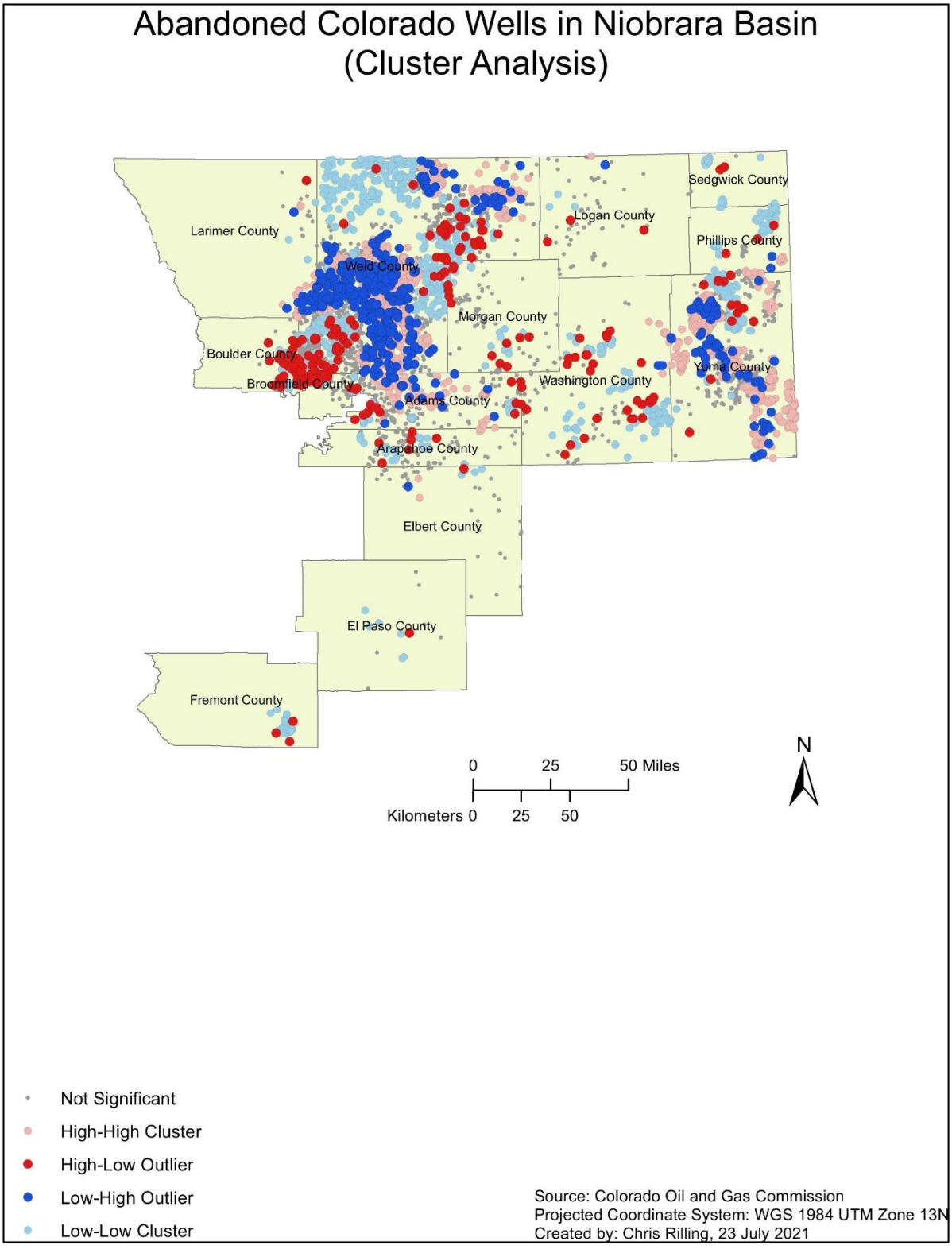

Active Colorado Wells in Niobrara Basin
(Cluster Analysis)
Larimer County
Weld County
Logan County
Sedgwick County
Phillips County
Morgan County
Boulder County
Broomfield County
Adams County
Arapahoe County
Washington County
Yuma County
Elbert County
El Paso County
Fremont County
0 25 50 Miles
Kilometers 0 25 50
N
Not Significant
High-High Cluster
High-Low Outlier
Low-High Outlier
Low-Low Cluster
Source: Colorado Oil and Gas Commission
Projected Coordinate System: WGS 1984 UTM Zone 13N
Created by: Chris Rilling, 23 July 2021

Figure 4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0 25 50 Miles
Kilometers 0 25 50
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High-High Cluster
High-Low Outlier
Low-High Outlier
Low-Low Cluster
Source: Colorado Oil and Gas Commission
Projected Coordinate System: WGS 1984 UTM Zone 13N
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Figure 5

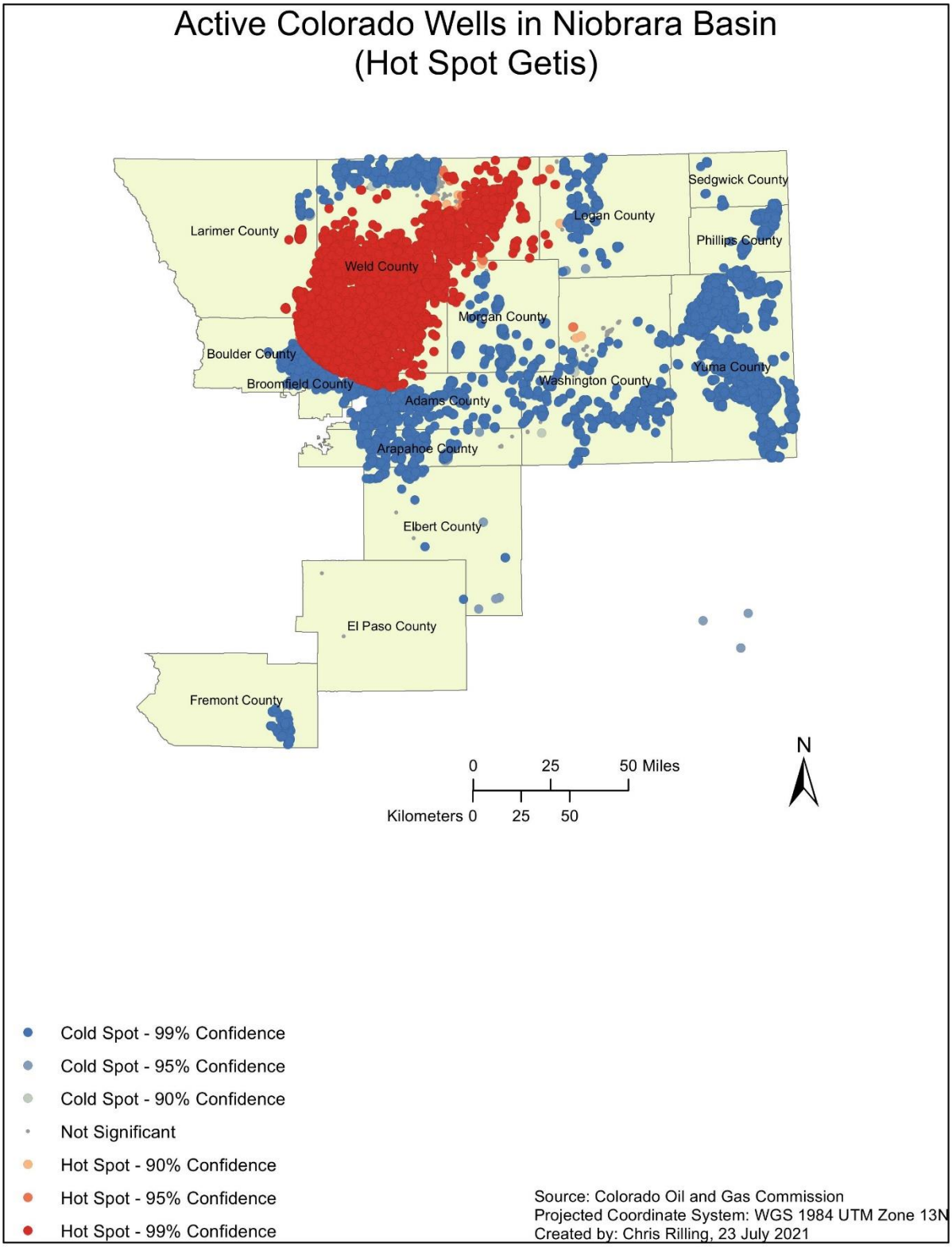
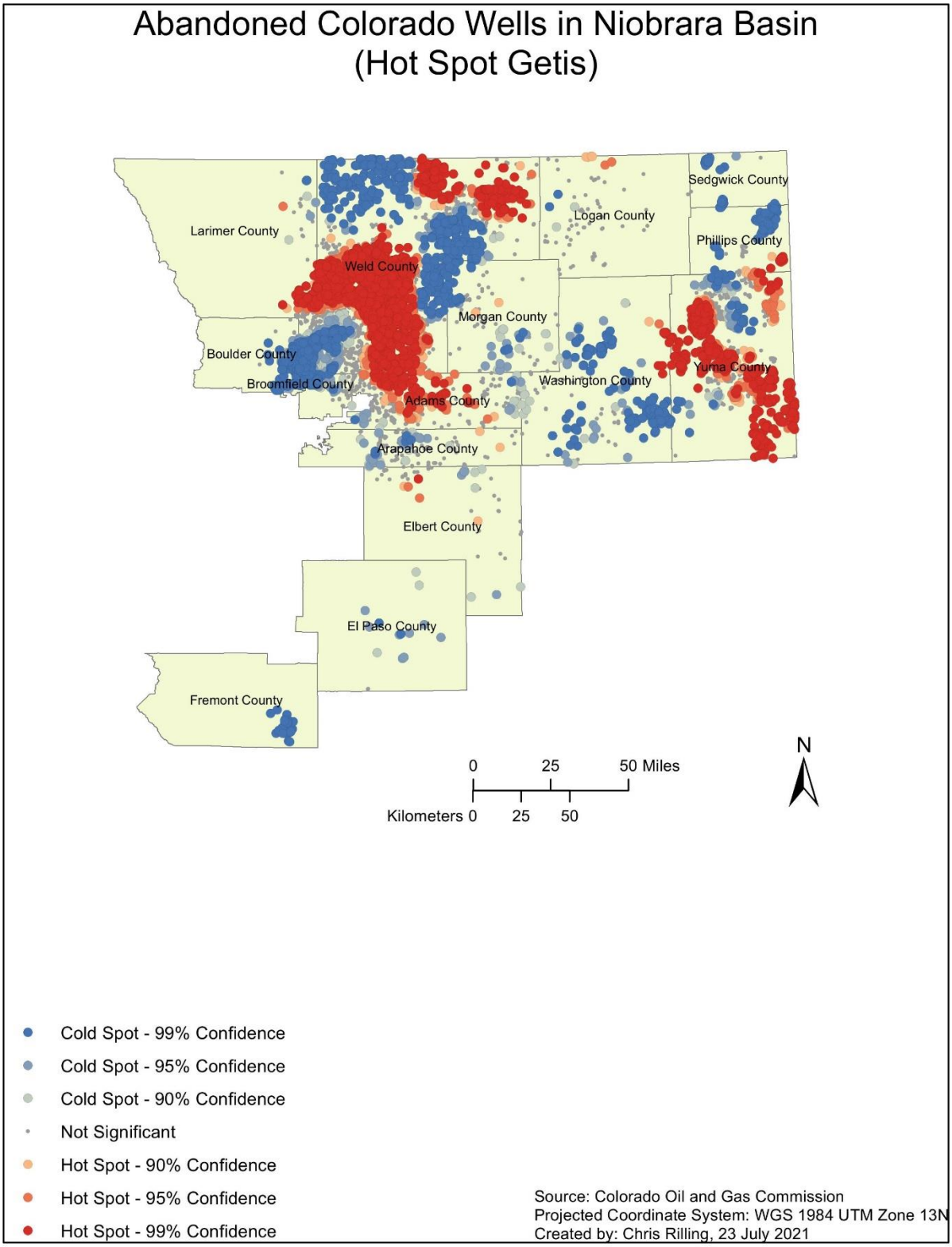

Active Colorado Wells in Niobrara Basin
(Hot Spot Getis)
Larimer County
Weld County
Logan County
Sedgwick County
Phillips County
Morgan County
Boulder County
Broomfield County
Adams County
Arapahoe County
Washington County
Yuma County
Elbert County
El Paso County
Fremont County
0 25 50 Miles
Kilometers 0 25 50
N
Cold Spot - 99% Confidence
Cold Spot - 95% Confidence
Cold Spot - 90% Confidence
Not Significant
Hot Spot - 90% Confidence
Hot Spot - 95% Confidence
Hot Spot - 99% Confidence
Source: Colorado Oil and Gas Commission
Projected Coordinate System: WGS 1984 UTM Zone 13N
Created by: Chris Rilling, 23 July 2021

Figure 6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Phillips County
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Broomfield County
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Washington County
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Elbert County
El Paso County
Fremont County
0 25 50 Miles
Kilometers 0 25 50
N
Cold Spot - 99% Confidence
Cold Spot - 95% Confidence
Cold Spot - 90% Confidence
Not Significant
Hot Spot - 90% Confidence
Hot Spot - 95% Confidence
Hot Spot - 99% Confidence
Source: Colorado Oil and Gas Commission
Projected Coordinate System: WGS 1984 UTM Zone 13N
Created by: Chris Rilling, 23 July 2021

Figure 7

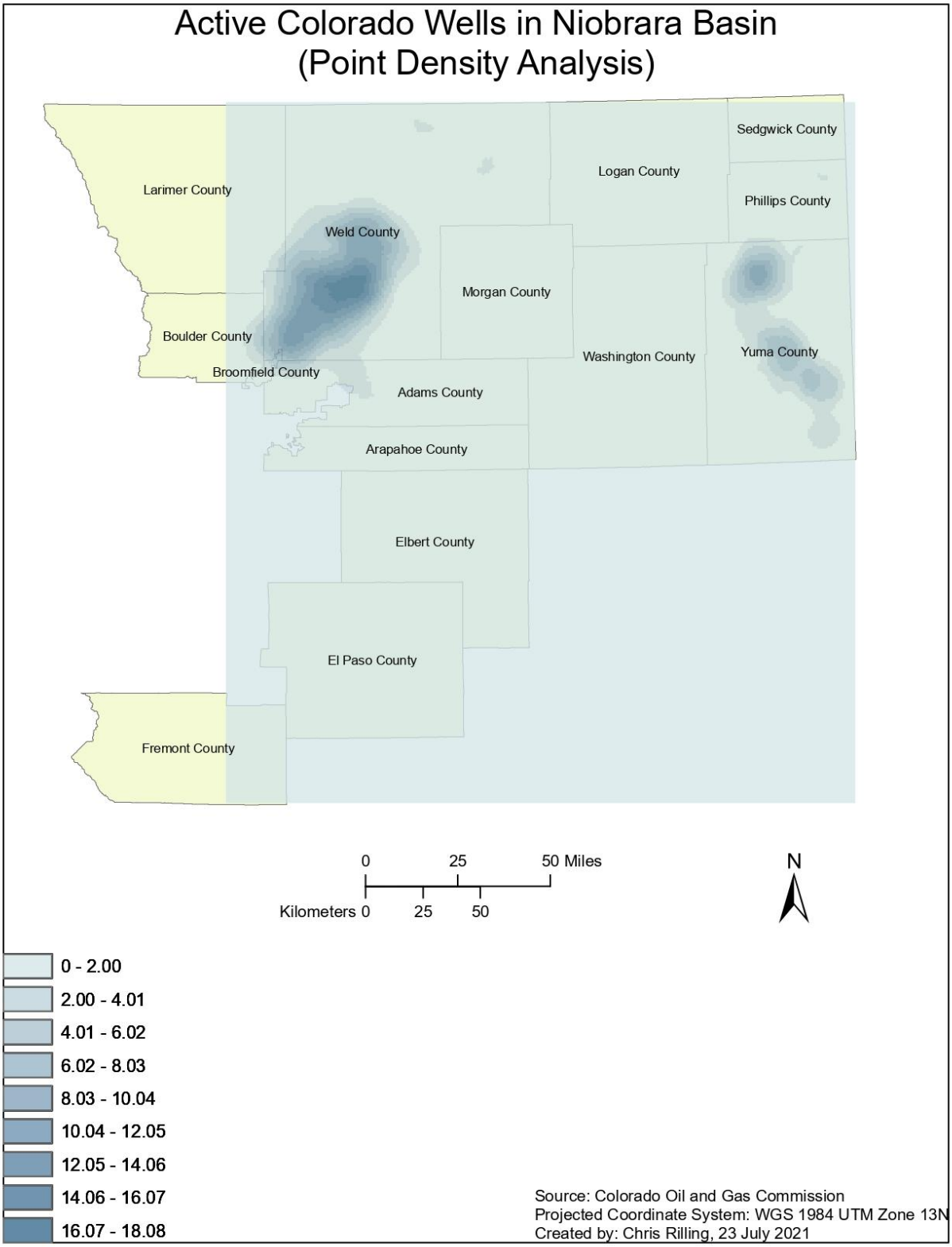
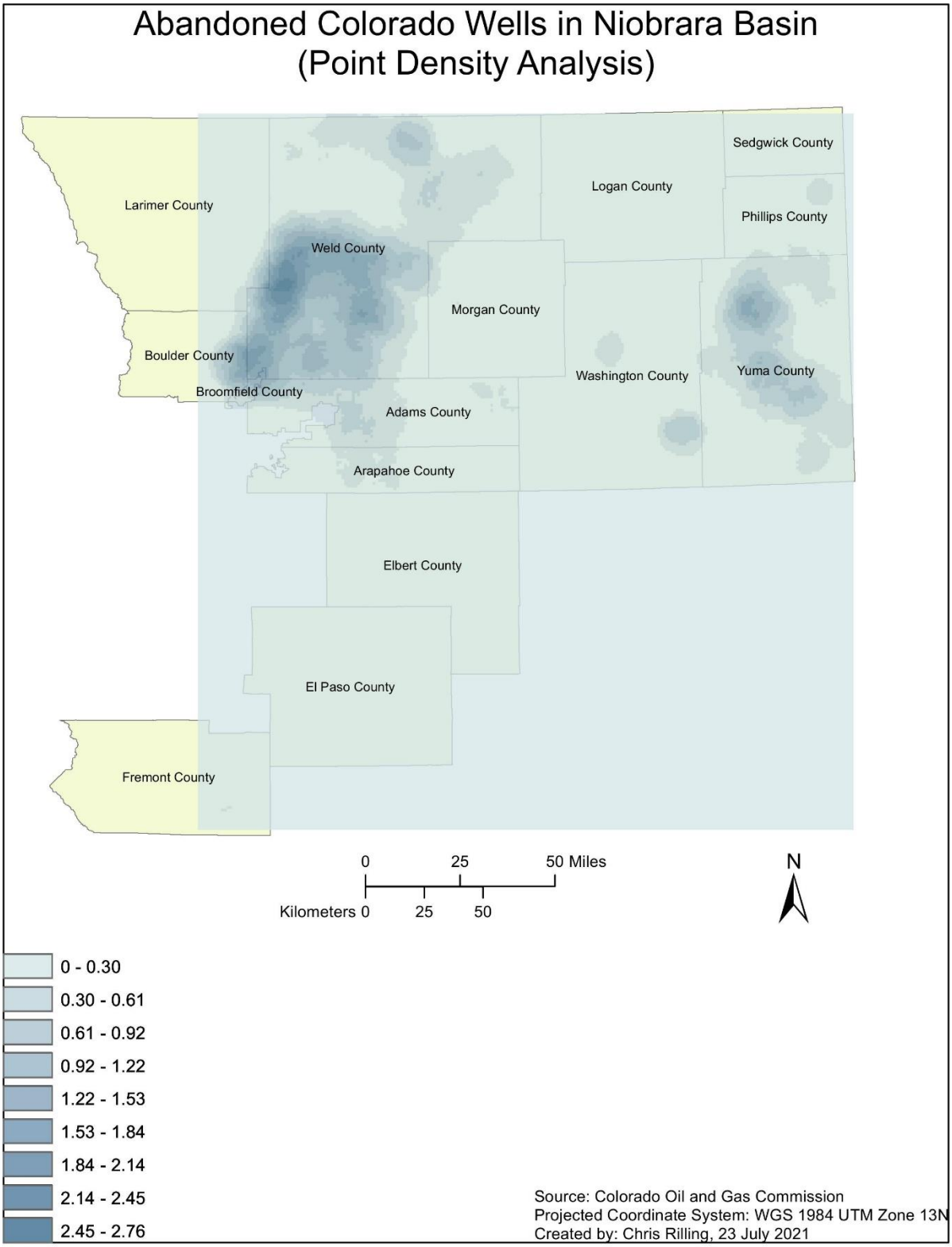

Active Colorado Wells in Niobrara Basin
(Point Density Analysis)
Sedgwick County
Logan County
Larimer County
Phillips County
Weld County
Morgan County
Boulder County
Washington County
Yuma County
Broomfield County
Adams County
Arapahoe County
Elbert County
El Paso County
Fremont County
0 25 50 Miles
Kilometers 0 25 50
N
0 - 2.00
2.00 - 4.01
4.01 - 6.02
6.02 - 8.03
8.03 - 10.04
10.04 - 12.05
12.05 - 14.06
14.06 - 16.07
16.07 - 18.08
Source: Colorado Oil and Gas Commission
Projected Coordinate System: WGS 1984 UTM Zone 13N
Created by: Chris Rilling, 23 July 2021

Figure 8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Washington County
Yuma County
Broomfield County
Adams County
Arapahoe County
Elbert County
El Paso County
Fremont County
0
25
50 Miles
Kilometers 0
25
50
N
0 - 0.30
0.30 - 0.61
0.61 - 0.92
0.92 - 1.22
1.22 - 1.53
1.53 - 1.84
1.84 - 2.14
2.14 - 2.45
2.45 - 2.76
Source: Colorado Oil and Gas Commission
Projected Coordinate System: WGS 1984 UTM Zone 13N
Created by: Chris Rilling, 23 July 2021

Figure 9