SC101570

IN THE SUPREME COURT OF MISSOURI

ELIZABETH HEALEY, et al.,

Appellants,

v.

STATE OF MISSOURI, et al.,

Respondents.

From the Circuit Court of Jackson County, Missouri
The Honorable Adam L. Caine, Circuit Judge

APPELLANTS' EXHIBITS (VOLUME I)

J. Andrew Hirth
Mo. Bar No. 57807
TGH LITIGATION LLC
28 N. 8th St., Suite 200
Columbia, MO 65201
(573) 256 – 2850
(573) 213 – 2201 (fax)
Andy@TGHLitigation.com

Counsel for Appellants

Abha Khanna*
ELIAS LAW GROUP LLP
1700 Seventh Avenue, Suite 2100
Seattle, WA 98101
(206) 656-0177
akhanna@elias.law

Harleen Kaur Gambhir*
Tina Meng Morrison*
Julianna D. Astarita*
ELIAS LAW GROUP LLP
250 Massachusetts Ave. NW, Suite 400
Washington, D.C. 20001
Telephone: 202-968-4490
hgambhir@elias.law
tmengmorrison@elias.law
jastarita@elias.law
**Admitted pro hac vice*

APPELLANTS' EXHIBIT LIST

Pursuant to Missouri Supreme Court Rule 81.16(a), Appellants provide this Court with exhibits Appellants believe are "necessary to the determination of any point relied on[.] A listing and description of the exhibits deposited by Appellants are included below.

Exhibit Number	Description
	Volume I
PX 05	Elizabeth Healey Affidavit
PX 06	Giselle Anatol Affidavit
PX 07	Marques Bussey Affidavit
PX 08	Mary Sapp Affidavit
PX 09	Louie Wright Affidavit
PX 21	Dr. Stern Dec. 30 Report (Amended)
PX 22	Dr. Stern Jan. 14 Rebuttal Report
PX 23	Dr. Cervas Dec. 30 Report (Amended)
	Volume II
PX 24	Dr. Cervas Jan 14. Rebuttal Report
PX 25	Dr. Cromartie Dec. 22 Report
PX 26	Dr. Cromartie Jan. 14 Rebuttal Report
PX 27	Dr. Rodden Dec. 22 Report
PX 28	Dr. Rodden Jan. 14 Rebuttal Report
PX 30	Gov. Kehoe Aug. 29 Proclamation
PX 31	Gov. Kehoe Aug. 29 X Map Post
PX 32	Gov. Kehoe Aug. 29 X Video
PX 33	Gov. Aug. 30 MO First Map PR
PX 35	SOS May 2022 Email (EalomDep.1)
PX 36	SOS May 2022 Email (Zorich Prod.)
PX 37	SOS May 2022 Email Att. (KiefferDep.2)
PX 39	SOS Jan. 2026 Email (KiefferDep.3)
PX 40	HB 1 Bill Text
PX 41	HB 1 Map Image
	Volume III
PX 42	HB 1 Landscape Maps (District)
PX 43	HB 2909 Bill Text
PX 44	HB 2909 Map Image
PX 45	HB 2117 Joint Press Release
PX 46	HB 2117 House Committee Passage Press Release
PX 47	HB 2117 House Passage Press Release
PX 48	House Special Committee on Redistricting Meeting
PX 50	Gov. Parson HB 2902 PR
PX 84	Maps w/ Density Compilation

Volume IV	
PX 86	Cervas Alternative Maps
PX 87	Joint Stipulations
DX 101	Amended Expert Report of Dr. Trende (Jan. 13, 2026)
IX 215	Expert Report of M.V. (Trey) Hood III

PX 32 and PX 48 are video exhibits and will be delivered on a DVD to the Court. Appellants certify that the disk submitted disk submitted has been scanned for viruses and that it is virus-free.

Dated: April 22, 2026

Respectfully submitted,

/s/ J. Andrew Hirth

J. Andrew Hirth
Mo. Bar No. 57807
TGH LITIGATION LLC
28 N. 8th St., Suite 200
Columbia, MO 65201
(573) 256 – 2850
(573) 213 – 2201 (fax)
Andy@TGHLitigation.com

Abha Khanna*
ELIAS LAW GROUP LLP
1700 Seventh Avenue, Suite 2100
Seattle, WA 98101
(206) 656-0177
akhanna@elias.law

Harleen Kaur Gambhir*
Tina Meng Morrison*
Julianna D. Astarita*
ELIAS LAW GROUP LLP
250 Massachusetts Ave. NW, Suite 400
Washington, D.C. 20001
Telephone: 202-968-4490
hgambhir@elias.law
tmengmorrison@elias.law
jastarita@elias.law

Counsel for Appellants

**Admitted pro hac vice*

IN THE CIRCUIT COURT OF JACKSON COUNTY. MISSOURI
AT KANSAS CITY

TERRENCE WISE, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV29597 (LEAD CASE) Division 15
ELIZABETH HEALEY, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV31273 Division 15

AFFIDAVIT OF ELIZABETH HEALEY

I, Elizabeth Healey, am over the age of eighteen and am fully competent to make this declaration. I have personal knowledge of the facts stated herein and declare the following to be true and correct.

1. I am a U.S. citizen, a taxpayer, and I reside and am registered to vote in Kansas City, in Clay County, Missouri.

2. I am a qualified voter pursuant to Article VIII, § 2 of the Missouri Constitution.

3. Under the congressional map enacted in 2022, I reside and have voted in CD 5.

4. Under the new 2025 congressional map, I reside in CD 6.

5. I voted in the 2022 and 2024 General Elections.

PX 5

6. I intend to vote in future congressional elections, and in other elections in which I am eligible to vote.

ATTESTATION

State of ~~Missouri~~ RB Florida)
) ss
County/City of Miami-Dade,)

Before me, the undersigned authority, personally appeared Elizabeth Healey, who hereby swears on her oath or hereby affirms that she has read the foregoing affidavit and that the statements included within are true and complete to the best of her knowledge, information, and belief.

Elizabeth Healey
Signature

Subscribed and sworn to before me this 11th day of February, 2026.

Notary Public Risa Brana

Produced DRIVER LICENSE

My commission expires: 04/12/2028

RISA BRANA
Notary Public - State of Florida
Commission # HH501559
Expires on April 12, 2028
NOTARY PUBLIC STATE OF FLORIDA

Notarized remotely online using communication technology via Proof.

IN THE CIRCUIT COURT OF JACKSON COUNTY. MISSOURI
AT KANSAS CITY

TERRENCE WISE, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV29597 (LEAD CASE) Division 15
ELIZABETH HEALEY, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV31273 Division 15

AFFIDAVIT OF GISELLE ANATOL

I, Giselle Anatol, am over the age of eighteen and am fully competent to make this declaration. I have personal knowledge of the facts stated herein and declare the following to be true and correct.

1. I am a U.S. citizen, a taxpayer, and I reside and am registered to vote in Kansas City, in Jackson County, Missouri.

2. I am a qualified voter pursuant to Article VIII, § 2 of the Missouri Constitution.

3. Under the congressional map enacted in 2022, I reside and have voted in CD 5.

4. Under the new 2025 congressional map, I reside in CD 4.

5. I voted in the 2022 and 2024 General Elections.

PX 6

6. I intend to vote in future congressional elections, and in other elections in which I am eligible to vote.

ATTESTATION

State of ~~Missouri~~ Texas SJL)
) ss
County/City of Dallas,)

Before me, the undersigned authority, personally appeared Giselle Anatol, who hereby swears on her oath or hereby affirms that she has read the foregoing affidavit and that the statements included within are true and complete to the best of her knowledge, information, and belief.

Giselle Anatol
Signature

Subscribed and sworn to before me this 11th day of February, 2026.

Sa'Myca Joenisia Leonard Notary Public, State of Texas
Notary Public

My commission expires: 06/08/2029

NOTARY PUBLIC STATE OF TEXAS
Sa'Myca Joenisia Leonard
ID NUMBER
13314508-7
COMMISSION EXPIRES
June 8, 2029

Electronically signed and notarized online using the Proof platform.

IN THE CIRCUIT COURT OF JACKSON COUNTY. MISSOURI
AT KANSAS CITY

TERRENCE WISE, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV29597 (LEAD CASE) Division 15
ELIZABETH HEALEY, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV31273 Division 15

AFFIDAVIT OF MARQUES BUSSEY

I, Marques Bussey, am over the age of eighteen and am fully competent to make this declaration. I have personal knowledge of the facts stated herein and declare the following to be true and correct.

1. I am a U.S. citizen, a taxpayer, and I reside and am registered to vote in Kansas City, in Jackson County, Missouri.

2. I am a qualified voter pursuant to Article VIII, § 2 of the Missouri Constitution.

3. Under the congressional map enacted in 2022, I reside and have voted in CD 5.

4. Under the new 2025 congressional map, I reside in CD 5.

5. I voted in the 2022 and 2024 General Elections.

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7

6. I intend to vote in future congressional elections, and in other elections in which I am eligible to vote.

ATTESTATION

State of ~~Missouri~~ JJT Texas)
) ss
County/City of Travis,)

Before me, the undersigned authority, personally appeared Marques Kamil Bussey, who hereby swears on her oath or hereby affirms that she has read the foregoing affidavit and that the statements included within are true and complete to the best of her knowledge, information, and belief.

Marques Bussey
Signature

Subscribed and sworn to before me this 9th day of February, 2026.

Jennifer Jo Thomas
Notary Public

My commission expires: 09/23/2029

NOTARY PUBLIC STATE OF TEXAS
Jennifer Jo Thomas
ID NUMBER
133341819
COMMISSION EXPIRES
September 23, 2029

Electronically signed and notarized online using the Proof platform.

IN THE CIRCUIT COURT OF JACKSON COUNTY. MISSOURI
AT KANSAS CITY

TERRENCE WISE, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV29597 (LEAD CASE) Division 15
ELIZABETH HEALEY, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV31273 Division 15

AFFIDAVIT OF MARY SAPP

I, Mary Sapp, am over the age of eighteen and am fully competent to make this declaration. I have personal knowledge of the facts stated herein and declare the following to be true and correct.

1. I am a U.S. citizen, a taxpayer, and I reside and am registered to vote in Kansas City, in Jackson County, Missouri.

2. I am a qualified voter pursuant to Article VIII, § 2 of the Missouri Constitution.

3. Under the congressional map enacted in 2022, I reside and have voted in CD 5.

4. Under the new 2025 congressional map, I reside in CD 4.

5. I voted in the 2022 and 2024 General Elections.

PX
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6. I intend to vote in future congressional elections, and in other elections in which I am eligible to vote.

ATTESTATION

State of Missouri Texas Texas)
) ss
County/City of Travis,)

Before me, the undersigned authority, personally appeared Mary Sapp, who hereby swears on her oath or hereby affirms that she has read the foregoing affidavit and that the statements included within are true and complete to the best of her knowledge, information, and belief.

Mary Sapp
Signature

Subscribed and sworn to before me this 6th day of February, 2026.

Rosyline Ehirim
Notary Public

My commission expires: 12/18/2028

NOTARY PUBLIC STATE OF TEXAS
Rosyline Ehirim
ID NUMBER
132833950
COMMISSION EXPIRES
December 18, 2028

Electronically signed and notarized online using the Proof platform.

IN THE CIRCUIT COURT OF JACKSON COUNTY, MISSOURI
AT KANSAS CITY

TERRENCE WISE, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV29597 (LEAD CASE) Division 15
ELIZABETH HEALEY, et al., *Plaintiffs*, v. STATE OF MISSOURI, et al., *Defendants*.	Case No. 2516-CV31273 Division 15

AFFIDAVIT OF LOUIE WRIGHT

I, Louie Wright, am over the age of eighteen and am fully competent to make this declaration. I have personal knowledge of the facts stated herein and declare the following to be true and correct.

1. I am a U.S. citizen, a taxpayer, and I reside and am registered to vote in Kansas City, in Clay County, Missouri.

2. I am a qualified voter pursuant to Article VIII, § 2 of the Missouri Constitution.

3. Under the congressional map enacted in 2022, I reside and have voted in CD 5.

4. Under the new 2025 congressional map, I reside in CD 6.

5. I voted in the 2022 and 2024 General Elections.

PX
9

6. I intend to vote in future congressional elections, and in other elections in which I am eligible to vote.

ATTESTATION

State of Missouri)
) ss
County/City of Jackson)

Before me, the undersigned authority, personally appeared Louie Wright, who hereby swears on her oath or hereby affirms that she has read the foregoing affidavit and that the statements included within are true and complete to the best of her knowledge, information, and belief.

Signature

Subscribed and sworn to before me this 11 day of February, 2026.

Notary Public

My commission expires: 3-27-2029

VERONICA MEZA-ARELLANO
Notary Public - Notary Seal
Jackson County - State of Missouri
Commission Number 13444683
My Commission Expires Mar 27, 2029

EXPERT REPORT OF DR. ARI J. STERN

***Wise v. Missouri*, 2516-CV29597 (Circuit Court of Jackson County, Missouri)**

Amended December 30, 2025

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I. Introduction and Qualifications

1. My name is Ari Stern, Ph.D., and I am a Professor of Mathematics at Washington University in St. Louis ("WashU"). I joined the faculty of WashU in 2012, was awarded tenure in 2018, and was promoted to the rank of (full) Professor in 2024.

2. I hold a Ph.D. in Applied and Computational Mathematics from the California Institute of Technology (better known as "Caltech"), as well as an M.A. in Mathematics of Finance and a B.A. in Mathematics, both from Columbia University. Before arriving at WashU, I was a postdoctoral researcher and lecturer at the University of California, San Diego. My professional CV is attached as Appendix 5.

3. My academic research focuses on computational mathematics and geometry, specifically using geometry to develop and analyze algorithms for scientific computing and other applications. I have authored or coauthored over 30 peer-reviewed publications, which have been published in leading journals in computational mathematics (*Foundations of Computational Mathematics*, *Mathematics of Computation*, *SIAM Journal on Numerical Analysis*, *SIAM Journal on Scientific Computing*, *Numerische Mathematik*) as well as journals focusing on applications in physical, biological, and social sciences (*Multiscale Modeling and Simulation*, *European Journal of Applied Mathematics*, *Journal of Nonlinear Science*, *Computers and Chemical Engineering*, *Science Translational Medicine*, *Games and Economic Behavior*). I am an Associate Editor on the editorial boards of three journals: *Foundations of Computational Mathematics*, *International Journal of Numerical Analysis and Modeling*, and *Geometric Mechanics*. My research activities have received continuous grant support since 2011, including grants from the National Science Foundation, National Institutes of Health, and Simons Foundation.

4. Since 2017, I have been involved in applications of computational mathematics to electoral redistricting analysis, for which the algorithms have similar "geometric" ingredients to those I study in my primary line of research (e.g., both involve the splitting of large shapes into smaller ones). This work has resulted in one peer-reviewed article on computational algorithms for detecting communities of interest[1], several technical reports, testimony to state redistricting commissions, and an *amicus* brief to the Supreme Court of the United States[2].

5. I have been an active user of the open-source *GerryChain* redistricting-analysis software since it was first developed in 2018 by a team including my then-Ph.D.-student Dr. Mary Barker. I have regularly interacted with the MGGG Redistricting Lab (led by Prof. Moon Duchin at the University of Chicago), which continues to develop and maintain *GerryChain* and associated software tools. The MGGG Redistricting Lab lists me as a "key collaborator," and I have contributed algorithms, code, and data to various projects.

6. I previously served as an expert in *New York Communities for Change et al. v. County of Nassau et al.*, Case No. 602316/2024 (Sup. Ct. Nassau Cty., 2025). For that case, I performed computational redistricting analysis, submitted three expert reports, was deposed, and testified as an expert witness in court. The parties ultimately settled that case during trial.

II. Scope of Work

7. I have been asked by counsel representing the *Wise* plaintiffs in this case to analyze the Missouri FIRST Map (enacted as H.B. 1 in the September 2025 special session of the Missouri General Assembly), focusing on the region covered by the newly enacted

[1] Chambers, E., Duchin, M., Edmonds, R. A. C., Edwards, P., Matthews, J., Pizzimenti, A. E., Richardson, C., Rule, P., & Stern, A. (2022). Aggregating Community Maps. In *SIGSPATIAL '22: Proceedings of the 30th International Conference on Advances in Geographic Information Systems*, Paper No. 27, 12 pages, ACM Press, New York.
[2] Brief for Mathematicians et al. as *Amici Curiae* at 19–20, *Rucho v. Common Cause*, 139 S. Ct. 2484 (2019).

Congressional District 4 (“CD4”) and Congressional District 5 (“CD5”) and the boundary dividing these two districts.

8. Counsel informed me that the Missouri Constitution requires that Congressional districts be “as compact . . . as may be.” Mo. Const. art. III, § 45. I understand from counsel that the Missouri Supreme Court has defined compactness to mean “closely united territory,” a concept which includes but is not limited to the physical shape of a district. *Pearson v. Koster*, 367 S.W.3d 36, 48 (Mo. banc 2012). I was also informed by counsel that the Missouri Supreme Court permits some deviation from compactness to accommodate other recognized redistricting considerations, including population density, natural boundary lines, the boundaries of political subdivisions (counties, municipalities, and precincts), the historical boundary lines of prior redistricting maps, and compliance with federal law, including the Voting Rights Act. *Id.* at 50, 53.

9. For this case, I was asked to determine whether CD4 and/or CD5 could have been drawn in a more compact manner, while keeping the remaining six Congressional districts identical to those in the Missouri FIRST Map, and if so, whether compliance with recognized redistricting considerations explains why CD4 and CD5 under the Missouri FIRST Map are not as compact as they could be.

10. As part of my analysis, I was asked by counsel to examine the properties of the CD4–CD5 boundary in the Missouri FIRST Map with respect to:

a. its effect on the preservation of political subdivisions, such as counties and cities, including but not limited to Jackson County and Kansas City;

b. the compactness of the resulting two districts;

c. the two districts' preservation of prior Congressional districts as defined by their historical boundary lines, preservation of state senate districts as defined by their current boundary lines, and allocation of Black Voting Age Population (BVAP).

I was also asked to provide my opinion on whether these properties are unusual or extreme compared to other CD4–CD5 boundary lines that might have been drawn, and whether these properties are affected by any attempt to avoid placing the current incumbents of CD4 and CD5 together in the same district.

11. To conduct this analysis, I used computer software to algorithmically generate an ensemble of 100,000 alternative maps, which vary the boundary between CD4 and CD5 while leaving the other six districts in the Missouri FIRST Map unchanged. The algorithm that generates these maps uses geographic and total-population data to construct geographically admissible (e.g., contiguous) districting plans that are nearly equipopulous within a small specified tolerance. Since the algorithm does not incorporate any demographic or partisan data in constructing the maps, it is race-blind and partisan-blind. Next, I measured each of these ensemble maps with respect to the properties listed in the previous paragraph—preservation of political subunits, compactness, and other considerations such as preservation of historical boundaries and allocation of BVAP—to establish a baseline for what we might expect from alternative maps that might have been drawn. Finally, I took those same measurements of the Missouri FIRST Map and compared them to those of the ensemble to see where the Missouri FIRST Map sits in the spectrum of possible maps—and in particular, whether it resembles a typical map or is an outlier with respect to any or all of the properties listed above. Further methodological details on this ensemble analysis are provided in Section IV.

12. Since my analysis is restricted to the portion of the state covered by CD4 and CD5, geographic regions mentioned in this report should be understood to mean the portion of those regions in CD4 or CD5, excluding portions in other districts, unless specified otherwise. For example, I may simply refer to "Kansas City" to mean "the portion of Kansas City lying within CD4 or CD5," excluding the part of Kansas City that is assigned to CD6 under the Missouri FIRST Map.

13. I am compensated at the rate of $300 per hour. My compensation does not depend in any way on the results of my analyses, the opinions I provide, or the outcome of this case.

III. Summary of Opinions

14. The Missouri FIRST Map splits the population of Jackson County between CD4 and CD5 more severely than 99.79% of ensemble maps. The ensemble maps tend to draw the vast majority of the Jackson County population (excluding the portion in CD6) into a single district, while the Missouri FIRST Map cracks it nearly in half. Furthermore, even if we total the largest intact portions of *all* county populations between CD4 and CD5, without singling out Jackson County, the Missouri FIRST Map is just as extreme.

15. The Missouri FIRST Map splits the population of Kansas City between CD4 and CD5 more severely than 99.59% of ensemble maps. The ensemble maps tend to draw the vast majority of the Kansas City population (excluding the portion in CD6) into one of these districts, while the Missouri FIRST Map cracks it into two large pieces (in addition to the third large piece in CD6). Furthermore, even if we total the largest intact portions of *all* municipality populations between CD4 and CD5, without singling out Kansas City, the Missouri FIRST Map is still more extreme than 98.95% of the ensemble maps.

16. The Missouri FIRST Map splits Voting Districts ("VTDs") between CD4 and CD5 more than 100% of the ensemble maps, both by number of splits and by total population of the largest VTD pieces; the ensemble maps only split VTDs to the minimum extent needed to ensure contiguous districts. While this is partly explained by the nonzero population-balance tolerance of the ensemble maps, the ensemble also includes maps with perfect population balance that do not split *any* VTDs between CD4 and CD5, indicating that the Missouri FIRST Map splits significantly more VTDs than necessary. VTDs are official Census geographic units that "include the wide variety of small polling areas, such as election districts, precincts, or wards, that State and local governments create for the purpose of administering elections,"[3] and they are among the primary units used in redistricting.

17. Across a range of compactness measures, the Missouri FIRST Map is consistently less compact than the ensemble maps, in many cases to an extreme degree. The CD4–CD5 boundary in the Missouri FIRST Map is longer than over 97.6% of the ensemble maps, and more than twice as long as the ensemble median, indicating that CD4 and CD5 are significant outliers on compactness, even after considering natural boundaries and population density. On every one of 9 standard district-compactness metrics, the Missouri FIRST Map has a worse average CD4–CD5 compactness score than 80% or more of the ensemble maps—in several cases worse than 90% or even 99%. On 7 of the 9 metrics, *both* the CD4 and CD5 scores, not just their average, are worse in the Missouri FIRST Map than the respective ensemble medians. Taken together with the previous observations about the severe splitting of Jackson County and Kansas City, this reflects that the Missouri FIRST Map avoids drawing a compact district based around Jackson County and Kansas City to a degree that is highly unusual in the ensemble.

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[3] United States. Bureau of the Census. (1994). Geographic areas reference manual. US Department of Commerce, Economics and Statistics Administration, Bureau of the Census, at 14-1.

18. These shortcomings of the Missouri FIRST Map cannot be explained by preservation of previous Congressional districts or current state senate districts in CD4 and CD5. By the same methodology used to measure splitting of counties and municipalities, these other regions are shown to be poorly preserved by the Missouri FIRST Map compared to the ensemble.

19. These shortcomings of the Missouri FIRST Map also cannot be explained by any attempt to increase minority voting strength or to create a minority district required by the Voting Rights Act. BVAP is more cracked between CD4 and CD5 in the Missouri FIRST Map than over 97% of ensemble maps, which reflects a significantly lower-than-typical BVAP percentage in CD5 under the Missouri FIRST Map. Again, the ensemble maps used for comparison are drawn by a completely race-blind algorithm.

20. These findings do not change if one constrains the ensemble maps to keep the current CD4 and CD5 incumbents in separate districts, or to have a stricter population-equality tolerance. While the exact numbers vary slightly, the conclusions are the same.

IV. Methodology

21. Although there is sophisticated mathematics and computational science under the hood, the basic idea behind ensemble analysis is quite simple. Given a particular districting map (such as the Missouri FIRST Map), we would like to know how its properties compare to the other maps that could have been drawn. Since it is impossible to compare to every possible map, of which there are an astronomical number, we use computer algorithms to randomly generate a large sample of such maps, referred to as an *ensemble*. Then, when we measure a property of the Missouri FIRST Map, we can see where it ranks among the measurements of the ensemble maps: Does it rank somewhere in the middle, resembling a typical ensemble map, or is it among a small

percentage of ensemble maps to one extreme? For some properties, one would want an enacted map to be not just typical, but *better* than typical. In particular, if Missouri were adhering to the compactness requirement, we would expect the Missouri FIRST Map to resemble maps of *above*-average compactness in the ensemble.

A. Construction of Ensemble Maps

22. The first step in constructing an ensemble is specifying the geographic units on which the ensemble maps are to be based, where each district is to be composed of whole, unsplit units. The most basic units are 2020 Census Blocks, which are the smallest geographic units on which the Census reports data. For redistricting, one often works with larger units called VTDs, each of which consists of a collection of whole Blocks. Missouri contains 253,632 Blocks and 4,604 VTDs. Since the ensemble maps only involve changes to CD4 and CD5, I based them on geographic units constructed as follows:

a. Starting with all 2020 Census Blocks in Missouri, I selected the Blocks assigned to CD4 or CD5 in the Missouri FIRST Map. There are 67,517 of these.

b. I then combined Blocks belonging to the same contiguous piece of a VTD. (Since VTDs or portions thereof in CD4 and CD5 are not always contiguous, this step ensures that all districts in the ensemble are contiguous.) This results in 1,190 units consisting of the contiguous VTD pieces in CD4 or CD5. Block-level data, such as population, were aggregated to these units accordingly.

This construction is illustrated in Figure 1 below.

Figure 1: An illustration of the geography on which the ensemble maps are constructed. *Left*: The Missouri FIRST Map, with CD4 and CD5 highlighted. *Center*: We limit the area being redrawn to the territory covered by CD4 and CD5. *Right:* This area is divided into 1,190 units, corresponding to contiguous pieces of VTDs. The ensemble maps assign each of these units to a district without splitting them. Note that the VTDs are smaller and more numerous in densely-populated areas, particularly the Kansas City area in the northwest corner of the map.

23. The ensemble was generated using a widely used, widely studied, and widely accepted Markov Chain Monte Carlo ("MCMC") algorithm called *ReCom*[4] (for "recombination"). MCMC algorithms are similar in spirit to card shuffling: to randomly sample from the huge number of possible ways to order a deck of cards, we can simply start with any initial ordering and shuffle repeatedly. The ReCom algorithm "shuffles" a districting plan by randomly picking two adjacent districts, combining them, and then randomly splitting the combined region into two districts again, while ensuring population balance within a small specified tolerance. This step is repeated over and over again, and the ensemble is the collection of districting maps obtained in the resulting sequence.

24. Since we have restricted attention to just two districts, the ReCom algorithm always recombines and splits the same pair of districts. This makes the algorithm much simpler to understand: At each step, it randomly splits the combined region covered by CD4 and CD5.

[4] DeFord, D., Duchin, M., & Solomon, J. (2021). Recombination: A Family of Markov Chains for Redistricting. *Harvard Data Science Review*, 3(1).

I employed a "region-aware" version of ReCom that performs the random splitting in a way that avoids splitting counties.

25. The ensemble maps were constructed to satisfy the following constraints:

a. Both districts are geographically contiguous.

b. Each district's population deviates from the ideal district population of 769,364 by no more than ±1%. (Results for an additional ensemble with an even stricter population tolerance of ±0.1% are reported in Appendix 3, illustrating that minor population deviations do not significantly impact the ensemble results.)

26. Other than the preference for maps that avoid splitting counties, mentioned above, I did not introduce any artificial parameters or constraints that would cause the ensemble to prefer or require certain types of maps to others. In particular, no compactness conditions were imposed to steer the algorithm toward compact maps and away from less-compact ones.

27. The ensemble-construction algorithm uses only geographic and total-population data, so it is blind to other factors; in particular, it is partisan-blind and race-blind.

B. Description of Ensemble Analysis Software

28. I performed the ensemble analysis in this report using the open-source software library *GerryChain*[5], together with the companion software library *GerryTools*[6], which implement the core computational algorithms (e.g., ReCom) used to construct the ensembles.

29. I also wrote additional code to process the raw Census data and Block-assignment data for the Missouri FIRST Map into the formats needed for *GerryChain* and *GerryTools*—including aggregating Census Blocks into the geographic units described in paragraph 22 above—as well as code to organize and score the Missouri FIRST Map and ensemble maps, and

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[5] https://github.com/mggg/GerryChain, accessed December 20, 2025
[6] https://github.com/mggg/gerrytools, accessed December 20, 2025

to generate the tables and figures that appear in this report. This code was written in the programming language Python using open-source libraries, primarily the *Pandas* and *GeoPandas* libraries for computing with geographic data.

30. All computational analysis in this report was conducted on my personal computer.

C. Sources of Data

31. The following data were used to conduct the analysis described in this report:

a. 2020 Census TIGER/Line shapefiles, containing geographic data;

b. 2020 Census Redistricting Data (P.L. 94-171) Summary Files, containing population and demographic data;

c. Block-assignment files for VTDs, Census "Places" (including municipalities), the two preceding Congressional districting maps (116th and 118th Congress, corresponding to the 2012 and 2022 maps), and 2022 Missouri Senate districts;

d. Block-assignment files for the Missouri FIRST Map, i.e., 2025 H.B. 1 Congressional districts.

e. Census Block IDs for the CD4 and CD5 incumbents.

Items a, b, and c were downloaded directly from the United States Census. Item d was downloaded directly from the Missouri Spatial Data Information Service[7], as linked from the Missouri Office of Administration Redistricting Office[8]. Item e was obtained from the Census Geocoder service, based on home addresses provided to me by counsel.

32. For purposes of BVAP analysis, "Black" means "any part Black," which is commonly used as a metric for redistricting and can be calculated using official Census data. In

7 https://data-msdis.opendata.arcgis.com/search?tags=hb1, accessed December 20, 2025

8 https://budplan.oa.mo.gov/redistricting-office/2025-us-congressional-house-maps, accessed December 20, 2025

each Census Block, I computed BVAP by summing the 2020 VAP data columns corresponding to Black alone or in combination with other races from the P.L. 94-171 summary file.

V. Ensemble Analyses

A. Splitting of Counties and Municipalities Between CD4 and CD5

33. The CD4–CD5 boundary in the Missouri FIRST Map splits exactly one county, Jackson County. Likewise, none of the ensemble maps splits more than one county.

34. However, the *number* of splits does not tell us about the *severity* of the splitting. Some maps split off only a small portion of a county's population, leaving the vast majority of county residents together in the same district. Other maps split the county's population nearly evenly between CD4 and CD5, cracking the county in two. The latter is far more problematic from the perspective of maintaining the closely united territory that comprises a county and its residents. Cracking communities this way also dilutes the political power of residents by making *both* pieces (even the larger of the two) too small for the community to form an effective bloc in *either* district. This can be quantified by counting the population of the largest piece of each county between CD4 and CD5, i.e., how many people live in the same district as the majority of their fellow county residents. (Here and henceforth, when I refer to the "largest piece" of a county or other region, I mean the piece with the larger population between CD4 and CD5—as opposed to the largest by area or some other measurement.)

35. Table 1, below, shows that Jackson County is extremely cracked in the Missouri FIRST Map—more cracked than 99.79% of the ensemble maps. In the ensemble, the median population of the largest Jackson County piece is 701,167, which is the full population of the portion of Jackson County within these two districts. This means that the majority (in fact, about 56%) of ensemble maps do not split this portion of Jackson County at all. By contrast, in the

Missouri FIRST Map, the largest piece has a population of only 370,868; the population of Jackson County within these two districts is split about 47%–53% between CD4 and CD5, respectively. As the "Percentile" column indicates, only 0.21% of the ensemble maps keep less of this population intact between CD4 and CD5 than the State's map—meaning that the Missouri FIRST Map is more severely cracked than the remaining 99.79% of ensemble maps.

Table 1: County splitting between CD4 and CD5. The Missouri FIRST Map splits county population more severely than 99.79% of ensemble maps.

	Ensemble Median	Missouri FIRST Map	Percentile
Counties Split	1	1	50.35%
Population of Largest Jackson County Piece	701,167	370,868	0.21%
Total Population of Largest County Pieces	1,500,170	1,208,429	0.21%

36. Furthermore, this cracking of Jackson County *cannot* be explained as a trade-off for less severe county splitting overall at the expense of a single unlucky county. To test this, I totaled the largest-population pieces of *all* counties between CD4 and CD5, without singling out Jackson County or any other county for special focus. As shown in Table 1, the ensemble maps have a median total population of 1,500,170 across the largest county pieces. The combined population of CD4 and CD5 is 1,538,728—meaning that, in a typical ensemble map, about 97.5% of this population lives in the largest piece of their county. By contrast, in the Missouri FIRST Map, the total population across the largest county pieces is only 1,208,429—meaning that only about 78.5% of the population lives in the largest piece of their county. Just as when we considered Jackson County alone, the Missouri FIRST Map cracks counties in CD4 and CD5 overall more severely than all but 99.79% of the ensemble maps, with only the remaining 0.21% scoring lower (as shown in the "Percentile" column). Far from a trade-off, the extreme splitting of Jackson County drives the overall population numbers to be just as extreme.

37. The severe cracking of county population in the Missouri FIRST Map, compared with the ensemble maps, is visually striking in Figures 2 and 3 below. These plots, known as *histograms*, show the values observed in the 100,000 ensemble maps as blue bars. Each bar corresponds to a range of values on the horizontal axis—here, population values—and the height of each bar indicates what percentage of the ensemble maps have values in that range. For example, the rightmost bar in Figure 2 shows that about 60% of the ensemble maps have a Jackson County piece whose population is in the range of values between the left and right edges of the bar (from around 675,000 to the maximum of 701,167). The ensemble median is shown as a green line, and the Missouri FIRST Map value is shown as a yellow line. Both figures show the yellow line far to the left of the blue bars, indicating that it is extremely rare to observe a value this low in the ensemble.

Figure 2: Histogram showing the largest portion of Jackson County population left intact between CD4 and CD5. The Missouri FIRST Map (yellow line) is an extreme outlier compared to the ensemble maps (blue bars, median shown as green line).

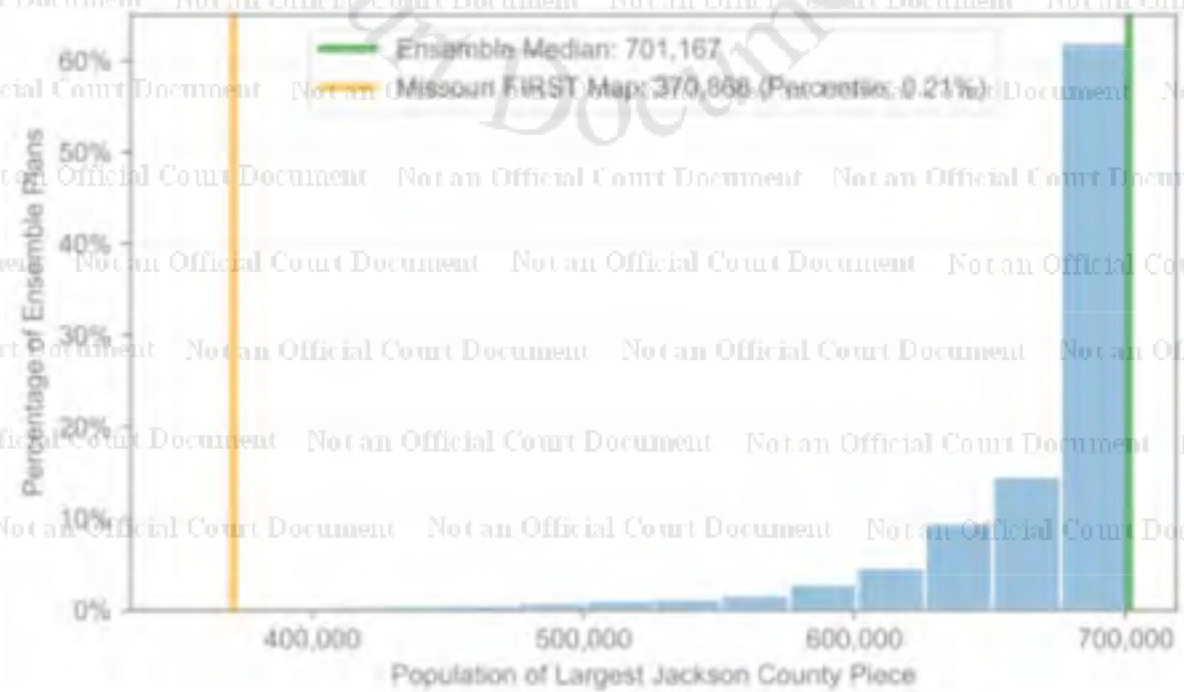
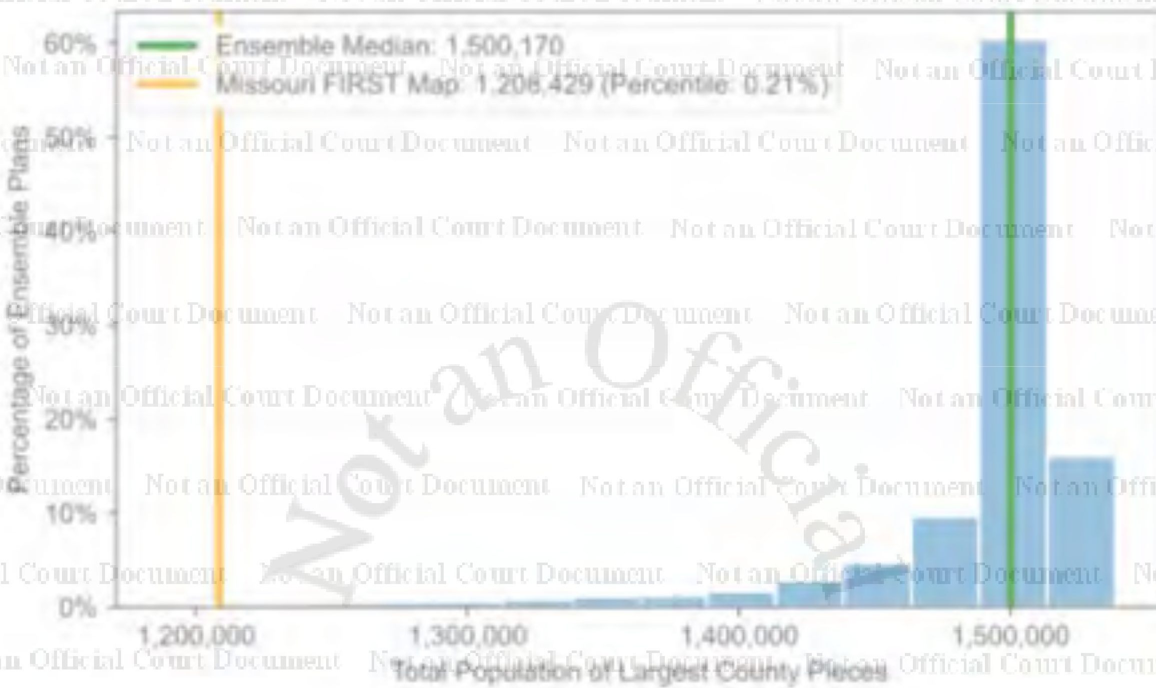


Figure 3: Histogram showing the population of the largest county pieces between CD4 and CD5, totaled over all counties.



38. Table 2, below, summarizes the results of a similar splitting analysis for municipalities[9]. The Missouri FIRST Map splits a somewhat higher-than-average number of municipalities (six) between CD4 and CD5, compared to the ensemble (four), but the *severity* of these splits—as measured by population—is far more extreme than the mere number of splits.

Table 2: Municipality splitting between CD4 and CD5. The Missouri FIRST Map splits the population of Kansas City in these two districts more severely than 99.59% of ensemble maps, and the population of municipalities overall more severely than 98.95% of ensemble maps.

	Ensemble Median	**Missouri FIRST Map**	**Percentile**
Municipalities Split	4	6	78.42%
Population of Largest Kansas City Piece	300,523	174,515	0.41%
Total Population of Largest Municipality Pieces	1,075,857	960,864	1.05%

[9] Here, a "municipality" is a Census Place whose Legal Statistical Area Description (LSAD) code indicates that it is a city, town, or village, not counting unincorporated Census Designated Places (CDPs).

39. Kansas City is more cracked between CD4 and CD5 in the Missouri FIRST Map than 99.59% of the ensemble maps; only the remaining 0.41% of the ensemble maps score lower. (This is even without accounting for the Missouri FIRST Map cracking Kansas City across a third district, CD6, which contains a comparably-sized piece of the city and is outside the scope of this analysis.) In the ensemble, the median population of the largest Kansas City piece is 300,523, which is the full population of the portion of Kansas City within these two districts. This means that the majority (in fact, about 64%) of ensemble maps have this portion of Kansas City entirely contained within a single district. By contrast, in the Missouri FIRST Map, the larger of the two pieces of Kansas City between CD4 and CD5 has a population of only 174,515, giving a roughly 42%–58% split of the Kansas City population within these two districts.

40. This cracking of Kansas City, like that of Jackson County, cannot be explained as a trade-off to achieve less severe splitting of municipalities overall; to the contrary, the extreme splitting of Kansas City drives the overall municipality-splitting numbers to be extreme as well. As shown in Table 2, the ensemble maps have a median total population of 1,075,857 across the largest pieces of all municipalities. The population of CD4 and CD5 living in municipalities is 1,087,487—meaning that a typical ensemble map places about 98.9% of this population in the largest piece of their municipality. By contrast, in the Missouri FIRST Map, the total population across the largest municipality pieces is 960,864—meaning that only about 88.4% of the municipal population lives in the largest piece of their municipality. Municipalities are more cracked between CD4 and CD5 in the Missouri FIRST Map than 98.95% of ensemble maps; only the remaining 1.05% keep less of this population intact.

41. The histograms in Figures 4 and 5, below, illustrate this severe cracking of Kansas City specifically, and of municipalities overall, between CD4 and CD5. Just as with the county-

splitting histograms, the yellow line representing the Missouri FIRST Map is far to the left of the blue bars, showing that a value this low is rarely observed among the ensemble maps.

Figure 4: Histogram showing the largest portion of Kansas City population left intact between CD4 and CD5.

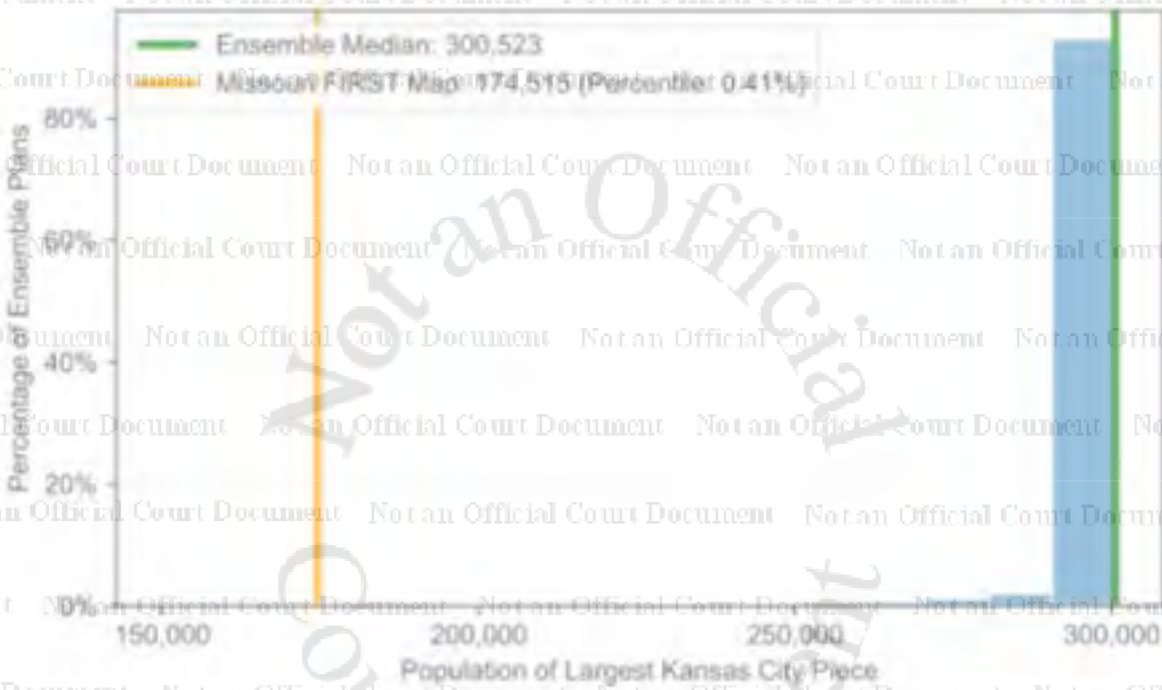


Figure 5: Histogram showing the population of the largest municipality pieces between CD4 and CD5, totaled over all municipalities.

42. The Missouri FIRST Map splits VTDs between CD4 and CD5 more than 100% of the ensemble maps, both by number of splits and by total population of the largest VTD pieces, as shown below in Table 3 and in Figures 6 and 7. As previously described in paragraph 22, the ensemble maps only split VTDs to the minimum extent needed to ensure contiguous districts.

Table 3: VTD splitting between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
VTDs Split	0	18	100.00%
Total Population of Largest VTD Pieces	1,538,728	1,534,476	0.00%

Figure 6: Histogram showing the number of VTDs split between CD4 and CD5.

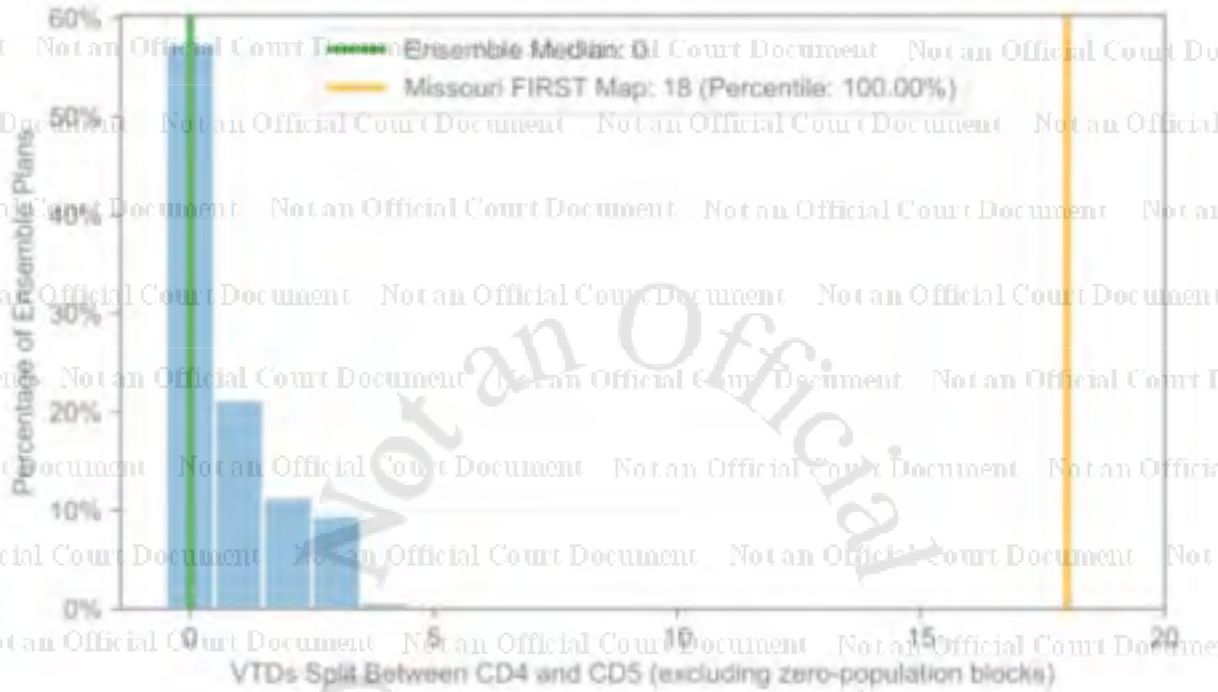
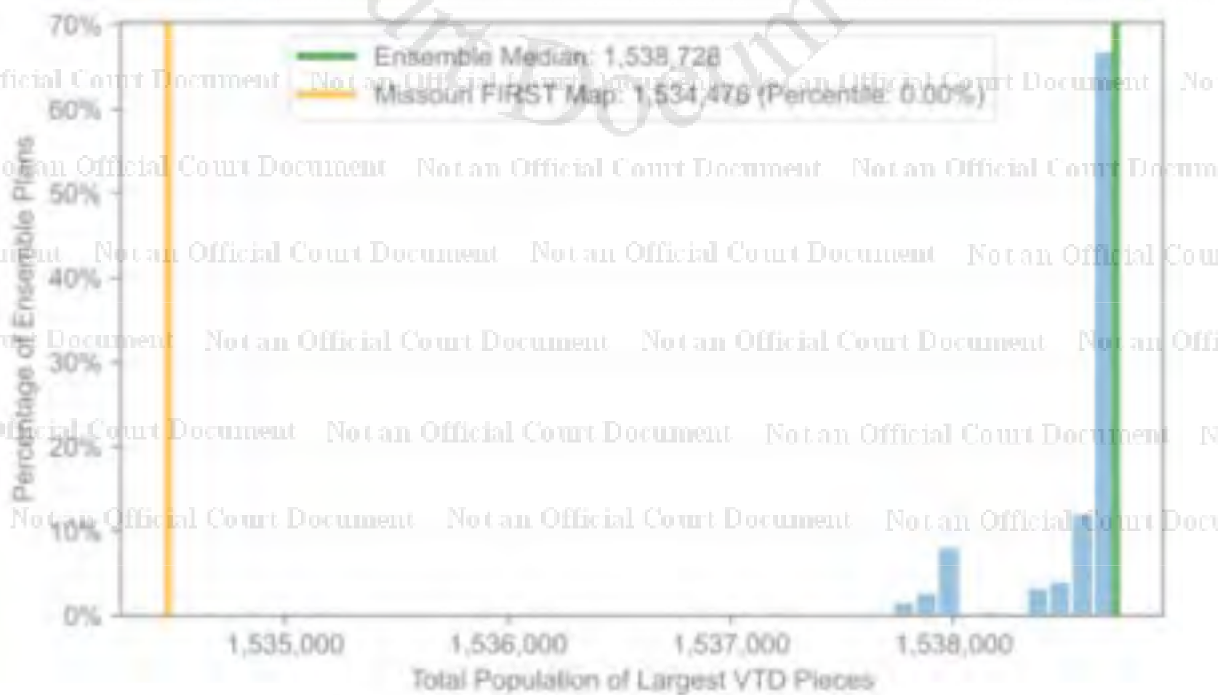


Figure 7: Histogram showing the population of the largest VTD pieces between CD4 and CD5, totaled over all VTDs.



43. To be sure, this is partly because the ensemble maps allow a ±1% tolerance in population: for any particular ensemble map, one would need to make small Block-level adjustments in order to achieve perfect population balance, and this adjustment might introduce VTD splits. However, this ensemble, together with the ±0.1% population tolerance ensemble discussed in Appendix 3, includes maps with perfect population balance that do not split *any* VTDs between CD4 and CD5. Examples of these maps are shown in Appendix 4.

B. Compactness Metrics

44. There are numerous metrics for quantifying "compactness" of districts and districting maps—but across a wide variety of standard metrics, the Missouri FIRST Map stands out as remarkably and consistently less compact in CD4 and CD5 compared to the ensemble.

45. One hallmark of compact plans is that they tend to have relatively short boundaries. A circle has the shortest boundary among all shapes enclosing a given area and is often considered an ideal of compactness, while—on the other hand—long, snaking boundaries have been a traditional signature of gerrymandering. Since the outer boundary of the CD4–CD5 region is held fixed in the ensemble maps, the only boundary line that changes between maps is the interior boundary separating CD4 from CD5.

46. There are two main ways to measure the size of the CD4–CD5 boundary. The first, and simplest, is to measure its length in miles. A second, subtler approach is to count what are called "cut edges" between Census Blocks. The terminology comes from mathematics—but in plain English, a "cut edge" corresponds to a pair of adjacent Blocks that lie on opposite sides of the boundary. The number of cut edges counts how many adjacent pairs of Blocks are divided by the boundary, one placed into CD4 and its neighbor into CD5. There are important interpretive benefits of looking at cut edges:

a. Many compactness metrics are based on the notion that there is an "ideal shape" (such as a circle or square) for all districts, regardless of constraints imposed by natural geography, political subunits, and how population is distributed. Of course, this is not true: a twisting, winding boundary could be carving up population in a very unnatural way, or it could be innocuously following a natural boundary, like a river, that has an irregular geometric shape. Census Blocks typically follow these natural boundaries, so the cut edges metric incorporates these geographic and population factors that other metrics omit.

b. Boundary length in miles does not account for population density. A mile of boundary can separate many more people in a densely-populated city than it can in a sparsely-populated area. For example, changing a relatively short segment of the district boundary in Kansas City can have a greater effect on the district's population than a much longer segment in a rural county. The cut edges metric accounts for this, since Census Blocks are more numerous and denser in areas of denser population (as previously shown in Figure 1 for VTDs).

47. However we measure the CD4–CD5 boundary—whether by length in miles or cut edges—the Missouri FIRST Map scores as much less compact than the ensemble maps. Indeed, it both stretches halfway across the state *and* carves through densely populated areas. As Table 4 shows, below, the CD4–CD5 boundary is longer in miles than 97.69% of the ensemble maps, and over twice as long as the ensemble median. Likewise, the Missouri FIRST Map cuts more edges along the CD4–CD5 boundary than 97.63% of the ensemble maps, and over twice as many edges as the ensemble median. This is also apparent from the histograms in Figures 8 and 9, below.

Table 4: Size of the boundary between CD4 and CD5, as measured by length in miles and by cut edges. On both metrics, the Missouri FIRST Map is less compact than over 97.6% of ensemble maps, having a CD4–CD5 boundary over twice the size of the ensemble median.

	Ensemble Median	Missouri FIRST Map	Percentile
Length in Miles	130.17	273.37	97.69%
Cut Edges	333	792	97.63%

Figure 8: Histogram showing the length in miles of the CD4–CD5 boundary.

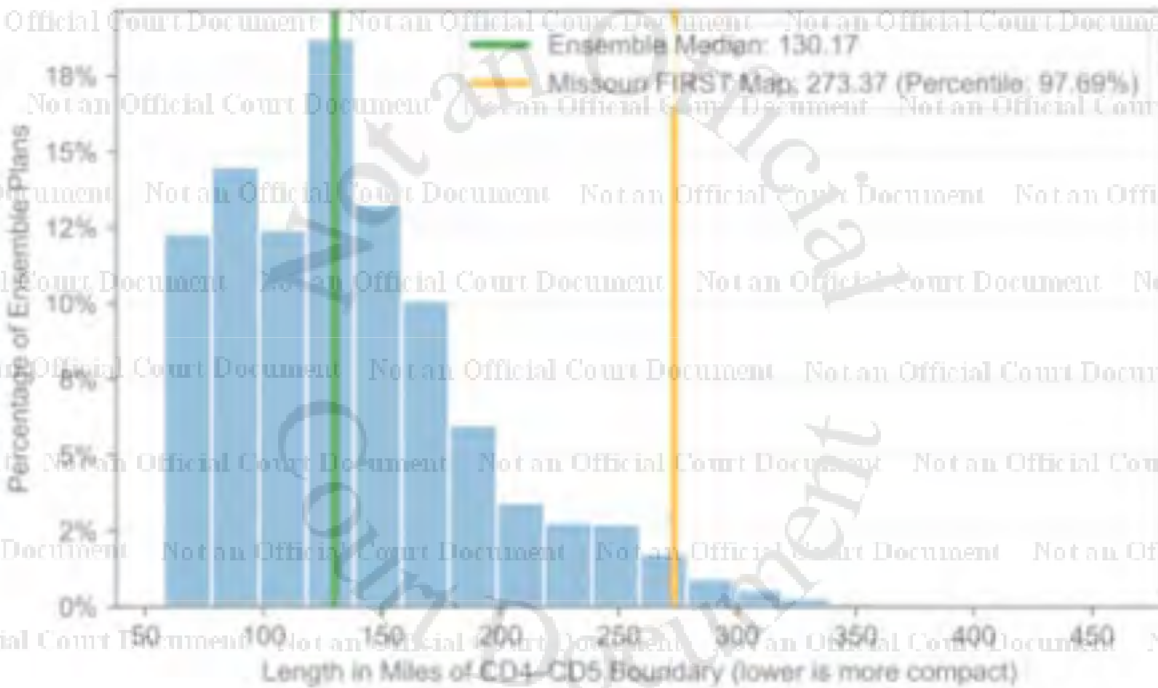
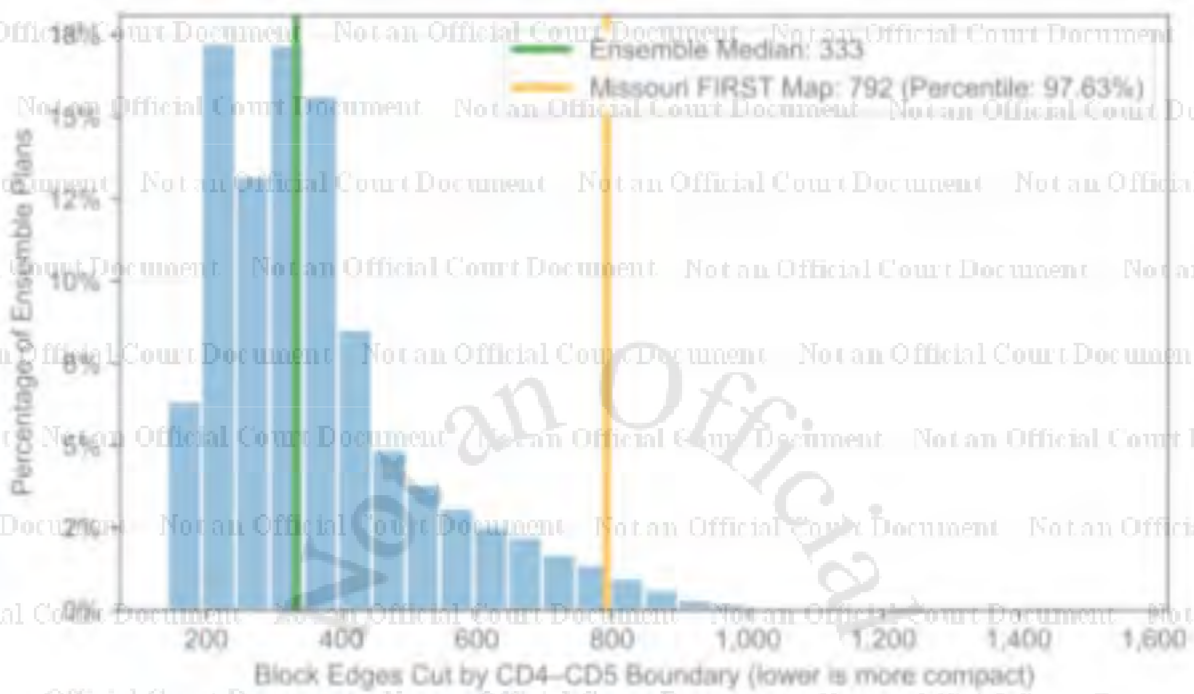


Figure 9: Histogram showing the number of cut edges along the CD4–CD5 boundary.



48. In addition to boundary length and cut edges, we consider 9 standard metrics for measuring the compactness of individual districts. With these metrics, each district gets its own compactness score, so we will have two numbers for each map rather than just one. However, since the districts vary from map to map in the ensemble, it is not necessarily meaningful to say which score corresponds to "CD4" and which corresponds to "CD5." Instead, for each map, we will consider the *minimum* of the two scores, the *maximum* of the two scores, and the *average* of the two scores. The 9 metrics are:

a. Reock,

b. (Alternate) Schwartzberg,

c. Polsby–Popper,

d. Population Polygon,

e. Area/Convex Hull,

f. Population Circle,

g. Ehrenburg,

h. Perimeter,

i. Length-Width.

This is the full list of district-by-district compactness metrics reported in a September 10, 2025, memo on the Missouri FIRST Map[10], showing scores computed using the software *Maptitude*. Figure 10 contains a visual guide to these scores and a brief description of the idea behind each.[11]

49. Note that *Maptitude* distinguishes between two versions of the Schwartzberg score, which it calls "Schwartzberg" and "Alternate Schwartzberg." The original metric proposed by Schwartzberg in 1966 used a rough approximation to district perimeter, since it was not feasible at the time to compute perimeter precisely.[12] The Schwartzberg metric using the true perimeter is what *Maptitude* calls "Alternate Schwartzberg," and this is the version I compute.

[10] Adam Kincaid, *Memo to Representative Dirk Deaton, HB 1 Sponsor, re: The Missouri First Map* (Sept. 10, 2025).
[11] For these 9 metrics, minor variations in the scores may arise from differences in the underlying map projection or in the software used to calculate those scores. Those variations, to the extent they exist, do not affect the conclusions I present here.
[12] Duchin, M. (2022). Explainer: Compactness, by the Numbers. In *Political Geometry*, eds. Duchin, M., and Walch, O., Birkhäuser/Springer, Cham, at p. 30.

Figure 10: A visual guide to the 9 standard district-by-district compactness metrics, illustrated with CD5 of the Missouri FIRST Map shown in blue. *From left to right*: Reock compares the area of the district to that of the smallest circle enclosing it; Population Circle compares these shapes' populations rather than areas. Area/Convex Hull compares the area of the district to that of its "convex hull," which contains all straight-line paths between points in the district; Population Polygon compares these shapes' populations rather than areas. Ehrenburg compares the area of the district to that of the largest circle contained inside it. Polsby–Popper compares the area of the district to that of the circle with the same perimeter; Schwartzberg compares the perimeter of the district to that of the circle with the same area. Finally, Length-Width simply measures the difference between the length and width of a rectangle enclosing the district.

50. For some of these compactness scores, a higher score means better compactness; for others, a lower score means better compactness. To avoid confusion, I will present the ensemble analysis of all the higher-is-better scores first, followed by the lower-is-better scores.

51. Table 5, below, shows the results of the ensemble analysis for the 6 higher-is-better compactness scores, where the three rows for each score correspond to the minimum, average, and maximum score between the two districts. The percentile column is shaded red whenever the Missouri FIRST Map is less compact than the ensemble median and green whenever it is more compact. Only one cell of 18 is shaded green; in the remaining 17 red cells, the percentiles range from 0.13% to 27.01%, meaning that the Missouri FIRST Map is less compact than 72.99% of ensemble maps at best, and less compact than 99.87% of them at worst. For *all six* metrics, the average score of CD4 and CD5 is less compact in the Missouri FIRST Map than 81.35% of ensemble maps at best, and less compact than 99.82% of them at worst.

Table 5: Compactness metrics for which higher scores indicate greater compactness.

		Ensemble Median	Missouri FIRST Map	Percentile
Reock	min	0.39	0.35	27.01%
	avg	0.47	0.39	1.39%
	max	0.56	0.43	0.50%
Polsby–Popper	min	0.30	0.20	5.53%
	avg	0.32	0.27	6.04%
	max	0.36	0.33	24.51%
Population Polygon	min	0.62	0.60	22.72%
	avg	0.77	0.62	0.25%
	max	0.92	0.63	0.13%
Area/Convex Hull	min	0.78	0.70	16.80%
	avg	0.81	0.76	18.65%
	max	0.84	0.82	25.27%
Population Circle	min	0.29	0.35	92.23%
	avg	0.53	0.38	0.18%
	max	0.76	0.40	0.47%
Ehrenburg	min	0.35	0.25	15.65%
	avg	0.43	0.37	13.20%
	max	0.52	0.49	19.94%

52. On several of these measures, the Missouri FIRST Map ranks as extremely non-compact by comparison to the ensemble maps. In particular:

a. On Reock, the most compact district in the Missouri FIRST Map (CD4) scores worse than the most compact district in 99.50% of ensemble maps. The average Reock compactness of CD4 and CD5 is worse than 98.61% of ensemble maps.

b. On Population Polygon, the most compact district in the Missouri FIRST Map (CD4) scores worse than the most compact district in 99.87% of ensemble maps, and the average score is worse than 99.75% of ensemble maps.

c. On Population Circle, the most compact district in the Missouri FIRST Map (CD5) scores worse than the most compact district in 99.53% of ensemble maps, and the average score is worse than 99.82% of the ensemble maps.

53. The lone green cell reflects a trade-off between moderately better Population Circle compactness in CD4 at the expense of vastly worse compactness in CD5 and on average. Specifically, the Population Circle compactness score for the Missouri FIRST Map is about 20% better than the ensemble median in one district, but the ensemble median is about *90%* better in the other. This poor trade-off has an intuitive explanation: For maps where CD5 is a compact district based around Jackson County and Kansas City, the small circle around CD5 will contain very little of the CD4 population, but the huge circle around CD4 will contain all of the CD5 population and more.

54. On Polsby–Popper, the least compact district in the Missouri FIRST Map, CD5, scores worse than 94.47% of ensemble maps, and the average score is worse than 93.96% of ensemble maps. (The most compact district, CD4, is "only" worse than 75.49% of ensemble maps.) This is well below the vast majority of ensemble maps, albeit not as extreme an outlier as some of the other compactness scores.

55. Table 6, below, shows the results of the ensemble analysis for the three lower-is-better compactness scores. As above, the percentile column is shaded red whenever the Missouri FIRST Map is less compact than the ensemble median, and green whenever it is more compact. Again, all but one of the cells is red, corresponding to worse compactness of CD4 and CD5 in the Missouri FIRST Map than 75.50% to 99.35% of the ensemble maps. For all three metrics, the average compactness of CD4 and CD5 is worse than 89.34% or more of ensemble maps.

Table 6: Compactness metrics for which lower scores indicate greater compactness.

		Ensemble Median	Missouri FIRST Map	Percentile
(Alternate) Schwartzberg	min	1.67	1.74	75.50%
	avg	1.76	1.98	94.68%
	max	1.83	2.22	94.48%
Perimeter in Miles	min	242.09	628.75	99.35%
	avg	529.76	672.96	97.69%
	max	805.30	717.16	3.63%
Length-Width in Miles	min	0.33	11.80	92.77%
	avg	12.28	30.88	89.34%
	max	24.23	49.95	78.04%

56. On perimeter, the more compact district in the Missouri FIRST Map (CD4) is worse than 99.35% of the ensemble maps, and the average perimeter is worse than 97.69% of ensemble maps. (This is the same 97.69% previously encountered for the length of the CD4–CD5 boundary.) The lone green cell again reflects a trade-off, where one district's perimeter is shorter in the Missouri FIRST Map, at the expense of a much longer perimeter in the other district and on average. Specifically, in the Missouri FIRST Map, one district has a perimeter about 88 miles shorter than the corresponding ensemble median, but the other has a perimeter about *387 miles longer* than the corresponding ensemble median. Again, this poor trade-off has an intuitive explanation: A compact CD5 based around Jackson County and Kansas City would have a much shorter perimeter than either district in the Missouri FIRST Map, while the corresponding CD4 would have a longer perimeter.

57. On (Alternate) Schwartzberg, the least compact district in the Missouri FIRST Map, CD5, scores worse than 94.48% of ensemble maps, and the average score is worse than 94.68% of ensemble maps. (The most compact district, CD4, is "only" worse than 75.50% of ensemble maps.) This is essentially what we observed for Polsby–Popper, due to a mathematical relationship between the Schwartzberg and Polsby–Popper scores.

58. Histograms visualizing the CD4–CD5-average compactness scores for these 9 metrics are included in Appendix 1.

C. Splitting of Previous Congressional Districts and State Senate Districts Between CD4 and CD5

59. To analyze how the Missouri FIRST Map preserves or splits previous Congressional districts and current state senate districts between CD4 and CD5, I employed the same methodology used above to analyze splitting of counties, municipalities, and VTDs. As before, only the portions of a state senate district that are within CD4 or CD5 of the Missouri FIRST Map are considered. I analyze the preservation of previous Congressional districts, because, as mentioned above, I understand historical boundary lines to be a relevant districting consideration articulated by the Missouri Supreme Court. I also analyze the current state senate districts, because the Kincaid memo, *see supra* note 9, identified adherence to state senate district boundary lines as a potential justification for the Missouri FIRST Map.

60. Table 7, below, shows that the Missouri FIRST Map splits the population of 2012 Congressional districts between CD4 and CD5 more severely than 98.71% of ensemble maps, with only the remaining 1.29% of the ensemble maps preserving less population (as indicated in the "Percentile" column). For 2022 Congressional districts, the splitting is more severe than 98.85% of ensemble maps, with only the remaining 1.15% maps preserving less population. The histograms in Figures 11–14, below, illustrate the number and severity of these splits.

Table 7: Splitting of 2012 and 2022 Congressional districts between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
2012 Congressional Districts Split	2	4	99.75%
Total Population of Largest District Pieces	1,412,696	1,007,069	1.29%
2022 Congressional Districts Split	2	3	82.76%
Total Population of Largest District Pieces	1,374,550	1,006,066	1.15%

Figure 11: Histogram showing the number of 2012 Congressional districts split between CD4 and CD5.

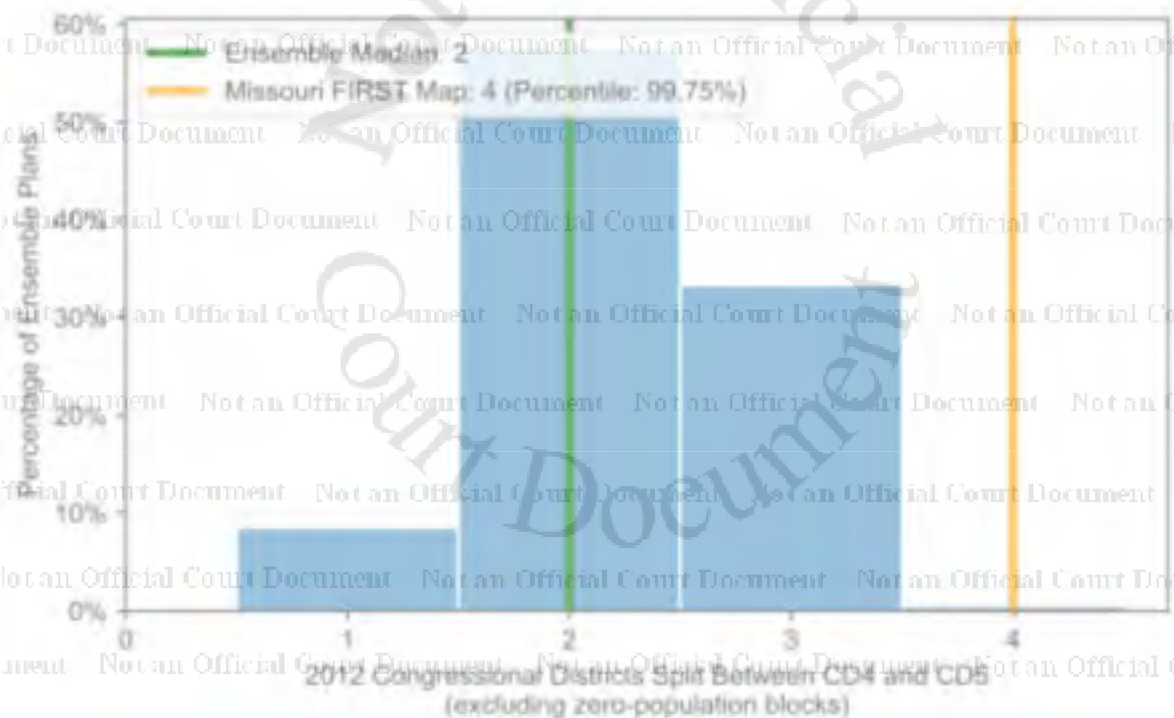


Figure 12: Histogram showing the population of the largest 2012 Congressional district pieces between CD4 and CD5, totaled over all districts.

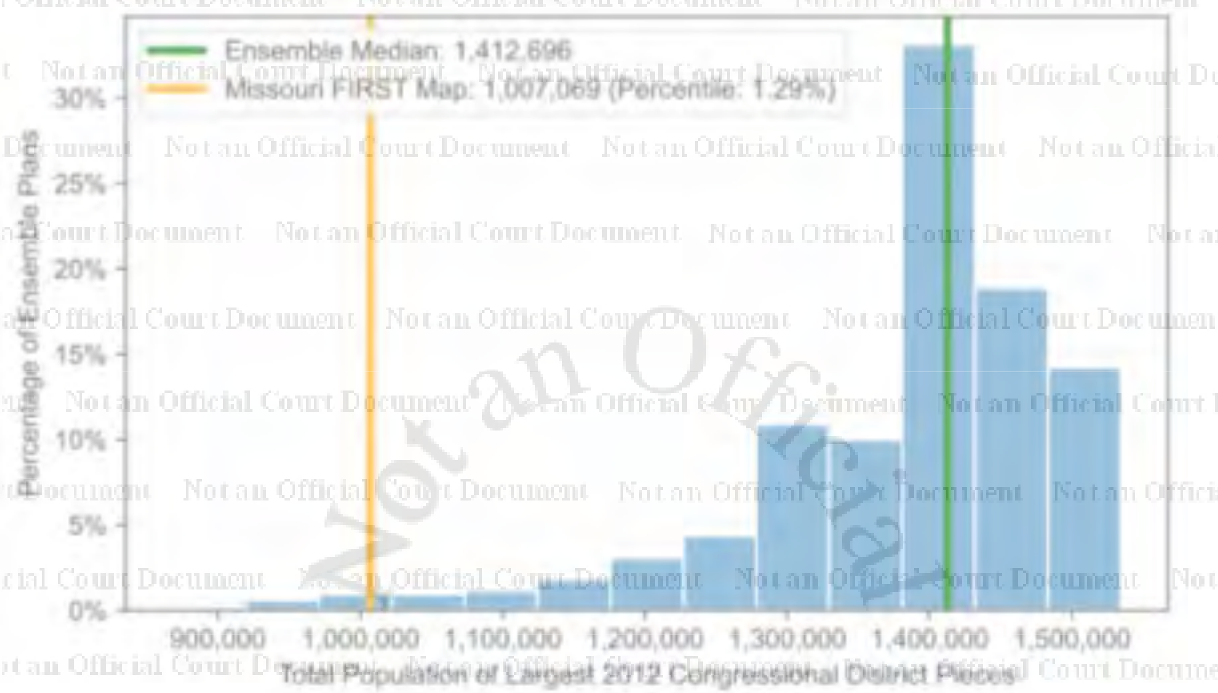


Figure 13: Histogram showing the number of 2022 Congressional districts split between CD4 and CD5.

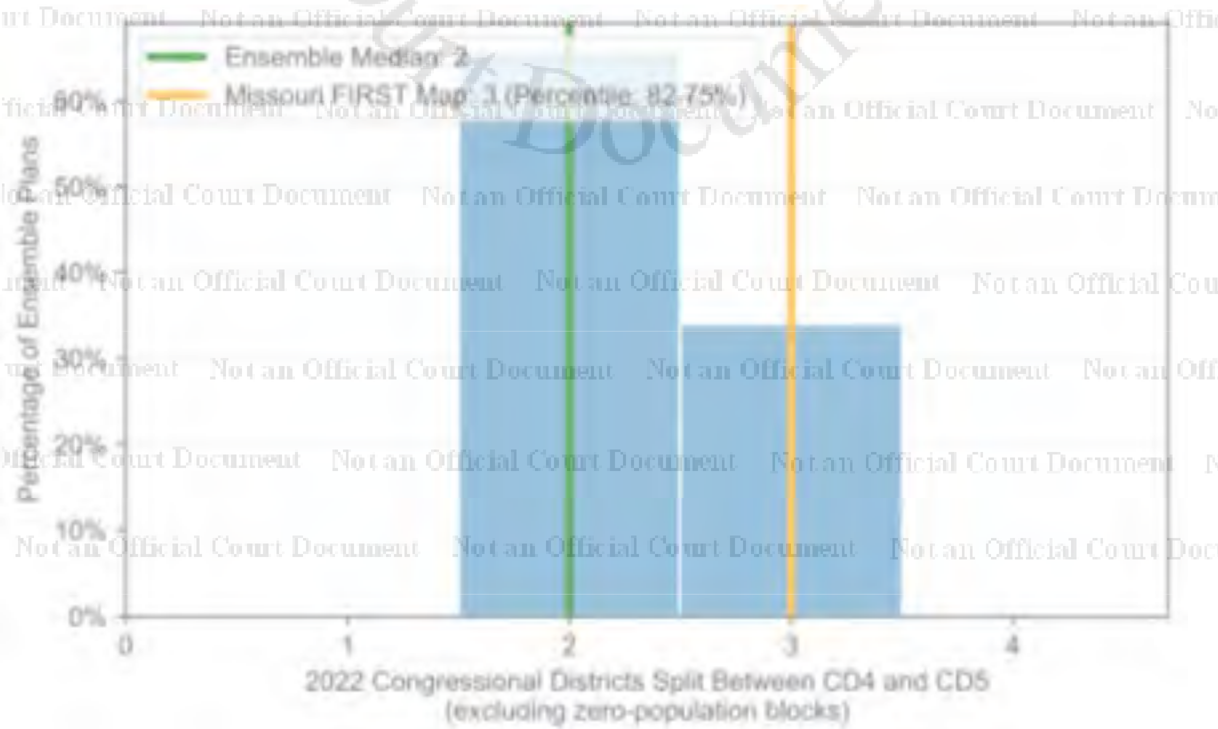
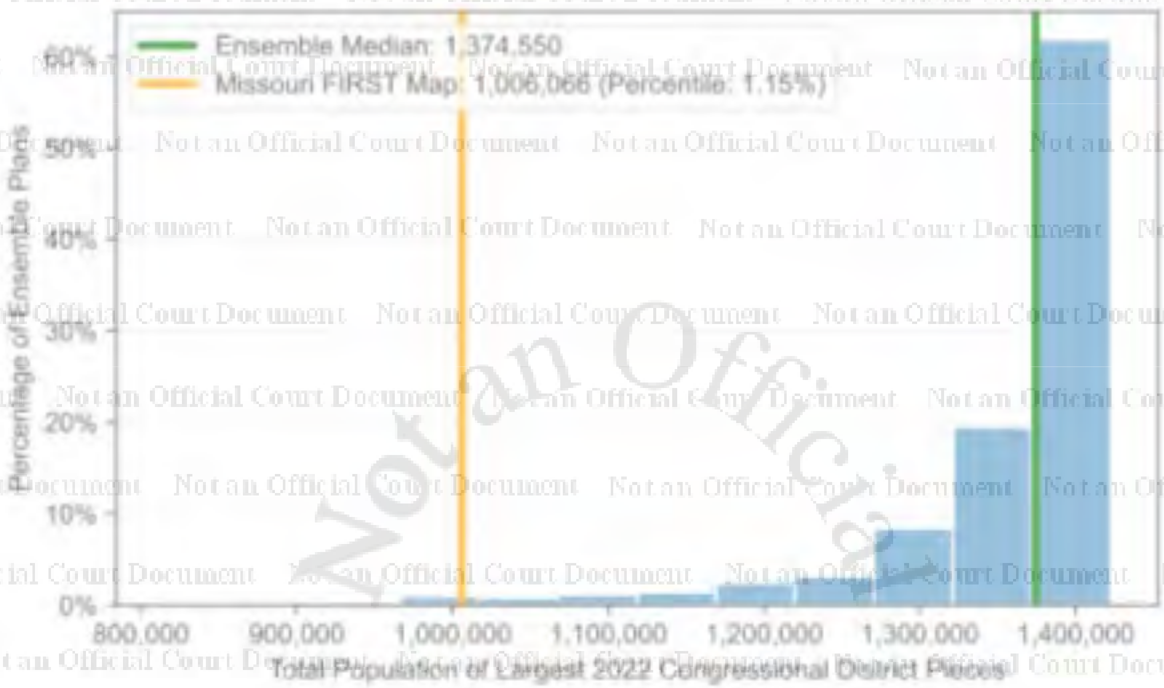


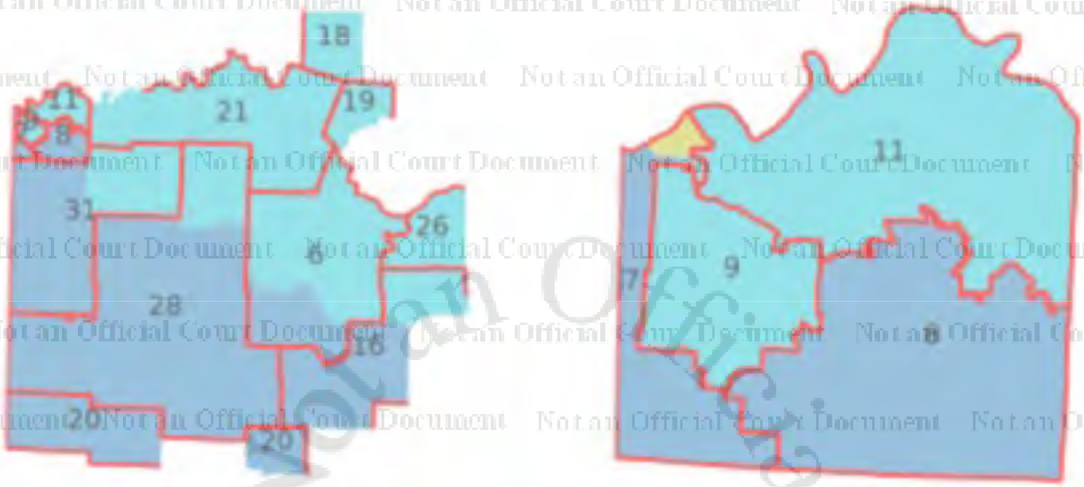
Figure 14: Histogram showing the population of the largest 2022 Congressional district pieces between CD4 and CD5, totaled over all districts.



61. Next, we analyze the splitting of state senate districts between CD4 and CD5 of the Missouri FIRST Map. Because the Kincaid memo indicated that "align[ing] closely with the existing Missouri Senate Map" was considered in "the split of Jackson County," *id.* at p. 4, I examine whether this stated priority to respect state senate districts is supported by the data.

62. For context, Figure 15 below overlays the current state senate district ("SD") lines and numbers over CD4 and CD5 of the Missouri FIRST Map, as well as a detailed view of Jackson County (including the portion in CD6). In addition to the splitting between CD4 and CD5 of SD6, SD16, SD28, and SD31 clearly visible at left, the Jackson County detail at right shows a *three-way* split of SD7 between CD4, CD5, and CD6. Other senate districts are seen to be split with neighboring Congressional districts in the Missouri FIRST Map, which in particular leaves two disconnected pieces of SD20 in CD4.

Figure 15: The Missouri FIRST Map compared with state senate district boundaries (in red) and district numbers. *Left*: Detail of the area covered by CD4 and CD5. *Right*: Detail of Jackson County, with portion of CD6 shown in green. Note the three-way split of SD7.



63. As Table 8, Figure 16, and Figure 17 show below, the Missouri FIRST Map splits state senate districts between CD4 and CD5 a greater number of times, and more severely, than about 90% of ensemble maps. While not as extreme an outlier as the splitting of Jackson County and Kansas City, the Missouri FIRST Map is still worse in this regard than the vast majority of alternative maps in the ensemble—and thus it does not resemble a map for which "align[ing] closely with the existing Missouri Senate Map" was indeed a priority.

Table 8: Splitting of Missouri Senate districts between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
State Senate Districts Split	2	5	93.11%
Total Population of Largest State Senate District Pieces	1,464,752	1,382,297	10.88%

Figure 16: Histogram showing the number of Missouri Senate districts split between CD4 and CD5.

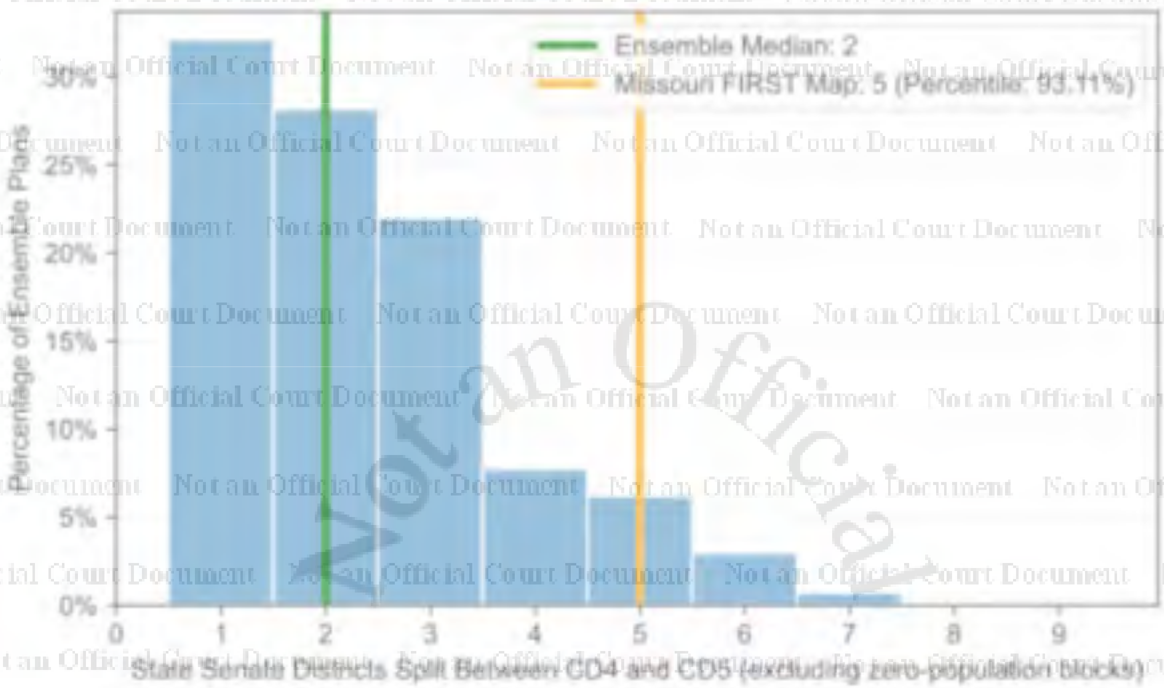
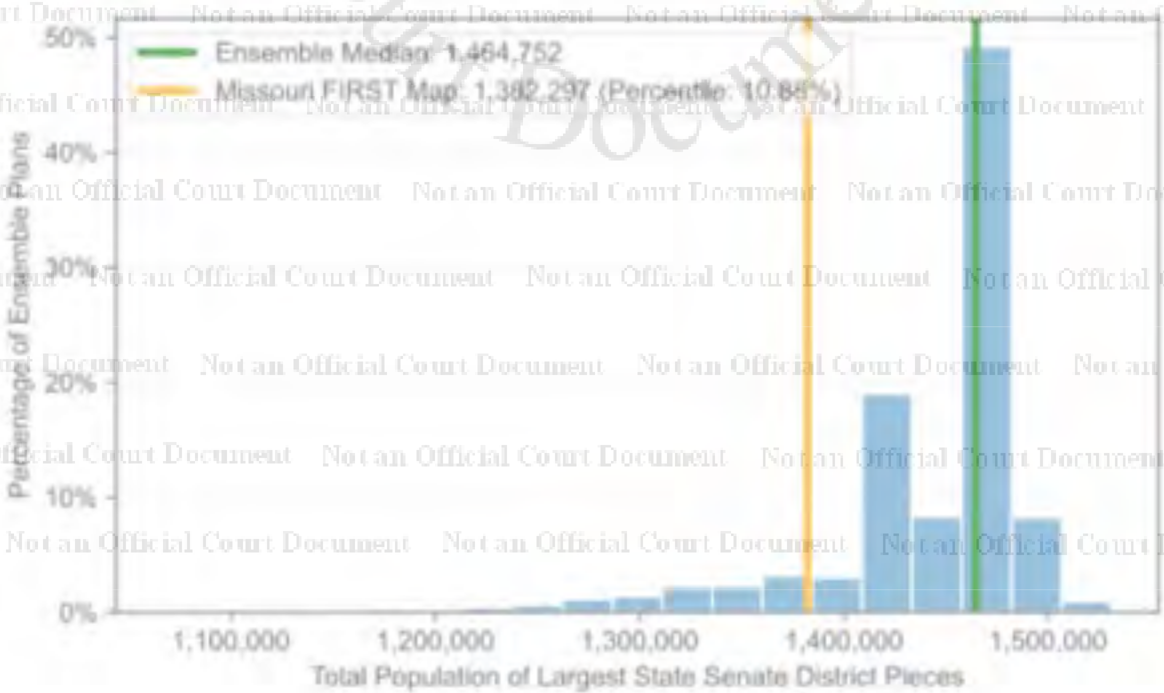


Figure 17: Histogram showing the population of the largest Missouri Senate district pieces between CD4 and CD5, totaled over all districts.



D. Allocation of Black Voting Age Population

64. Black voters make up a minority of CD4 and CD5, both before and after the enactment of the Missouri FIRST Map. The BVAP for CD4 went from 5.01% to 7.64% of VAP under the Missouri FIRST Map, and the BVAP for CD5 dropped from 22.45% to 17.97%. For that reason and those discussed below, compliance with federal law, such as any requirement to create a majority-Black district under the Voting Rights Act, does not explain why CD4 and CD5 in the Missouri FIRST Map are non-compact.

65. Notably, BVAP is more cracked between CD4 and CD5 of the Missouri FIRST Map than 97.31% of the ensemble maps, as shown in Table 8, below. (Note that the percentiles in the table add to 100%, because the sum of BVAP between the two districts is the same in every map, i.e.: the total BVAP in the area covered by the two districts.)

Table 9: BVAP in the lower-BVAP district (CD4 in the Missouri FIRST Map) and higher-BVAP district (CD5 in the Missouri FIRST Map). BVAP is significantly lower in the higher-BVAP district and higher in the lower-BVAP district compared to the ensemble plans.

	Ensemble Median	Missouri FIRST Map	Percentile
BVAP: Lower of CD4 and CD5	25,444	45,836	97.31%
BVAP: Higher of CD4 and CD5	126,168	105,776	2.69%

66. These results show that the Missouri FIRST Map's distribution of Black voters is an extreme outlier compared to the ensemble maps, which were created without employing any racial data or preference. Whereas the ensemble median has 126,168 Black voting-age residents in the higher-BVAP district, the Missouri FIRST Map has only 105,776 Black voting-age residents.

67. The histograms in Figures 18 and **19** clearly illustrate this lower-than-typical BVAP in the higher-BVAP district, which is CD5 in the Missouri FIRST Map, compared with the

ensemble maps. The usual green line marks the ensemble median, while the yellow line indicates that the Missouri FIRST Map is a clear outlier.

Figure 18: Histogram showing BVAP in the larger-BVAP district between CD4 and CD5.

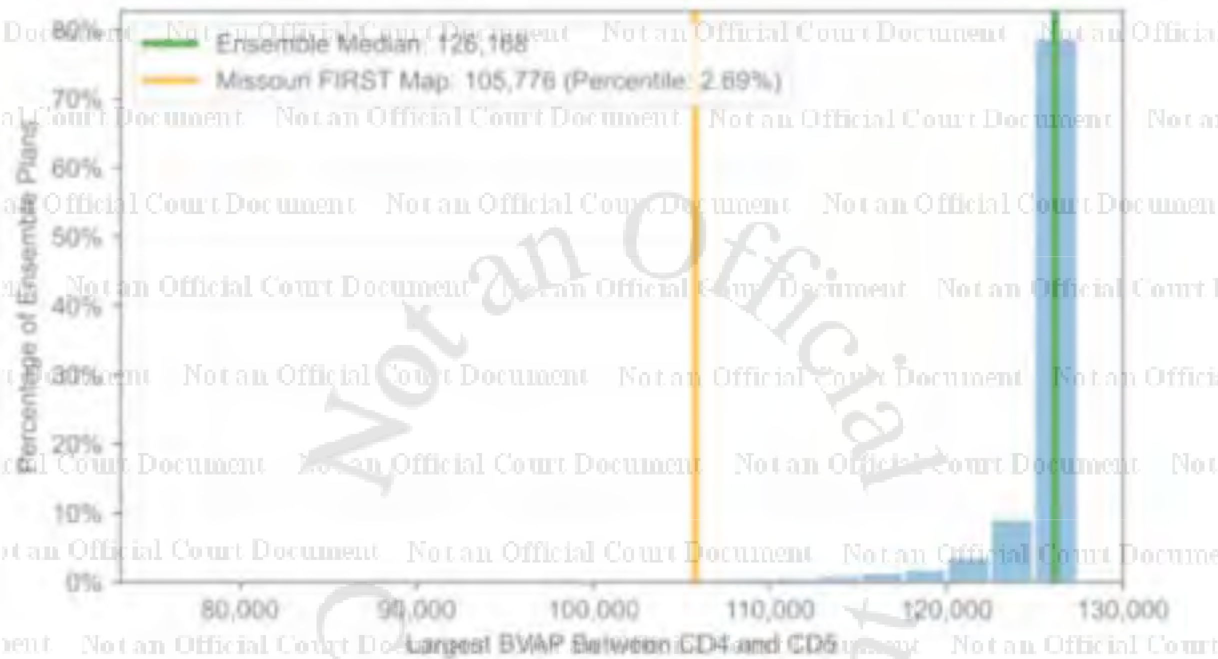
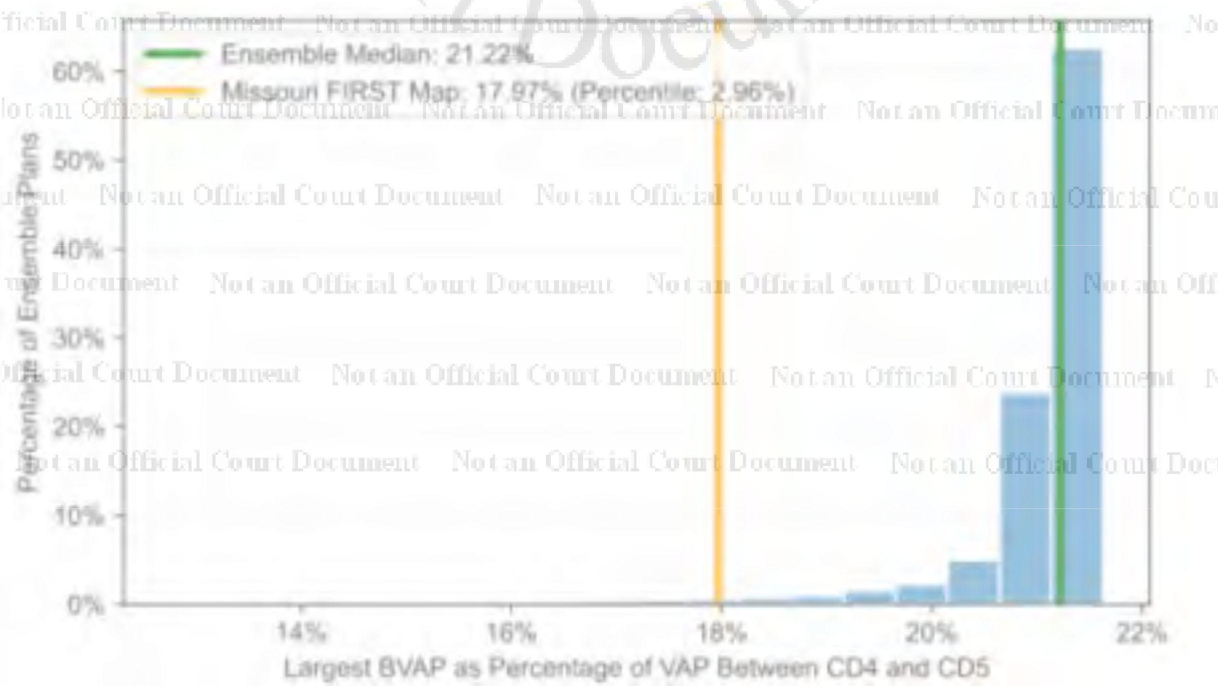


Figure 19: Histogram showing BVAP as a percentage of VAP in the larger-BVAP district between CD4 and CD5.



E. Effects of Incumbency Constraints and Population Equality on the Conclusions of the Preceding Analyses

68. The preceding analyses are based on the ensemble of 100,000 maps constructed as described in Section IV.A. This construction does not impose any constraints on the properties of the ensemble maps with respect to the current CD4 and CD5 incumbents, and it allows for these districts' populations to deviate by ±1% from perfect population balance. To determine whether each of these factors has an effect on the conclusions above, I conducted two additional sets of ensemble analyses: one using only the ensemble maps that place the current CD4 and CD5 incumbents into separate districts, and the other using a new ensemble of 100,000 maps that tightens the population tolerance to ±0.1% but otherwise employs the same methodology.

69. For these alternative ensembles, the exact numbers (scores, percentiles, etc.) vary slightly, but the top-line results and conclusions are unchanged from those above. I will briefly summarize these analyses here; numerical tables appear in Appendix 2 for the incumbency-constrained ensemble and in Appendix 3 for the stricter-population-balance ensemble.

70. To perform the incumbency-constrained ensemble analysis, I selected only those maps from the original ensemble placing the current CD4 and CD5 incumbents into separate districts, and discarded those that place them in the same district. This is no different than if one were to impose the constraint at the time of construction: the algorithm would simply discard any maps it drew that violated the constraint, which is the same as discarding them after the fact. About two-thirds of the original ensemble maps place the CD4 and CD5 incumbents in the same district, which is unsurprising since both reside in the greater Kansas City area; discarding these leaves an ensemble of 33,439 maps satisfying the incumbency constraint.

71. The results of the incumbency-constrained ensemble analysis, supported by the numerical tables in Appendix 2, are summarized as follows:

a. The Missouri FIRST Map cracks the population of Jackson County and counties overall more severely than about 99.9% of incumbency-constrained ensemble maps, and the population of Kansas City and cities overall more severely than over 99% of incumbency-constrained ensemble maps.

b. The Missouri FIRST Map splits more VTDs and cracks VTD population more severely than all 100% of the incumbency-constrained ensemble maps.

c. The Missouri FIRST Map CD4–CD5 boundary is longer than over 98% of the incumbency-constrained ensemble maps, whether measured in miles or cut edges.

d. On the compactness metrics where the Missouri FIRST Map previously appeared most extreme—less compact than over 99% of original ensemble maps—it is just as extreme or worse by comparison with the incumbency-constrained ensemble. Some of the metrics where the Missouri FIRST Map appeared only moderately non-compact have moved closer to the ensemble median. Two of the scores that were below the original ensemble median are very close to the median of the incumbency-constrained ensemble, and the corresponding table cells are colored yellow. As before, the remaining cells are colored red when they are below the ensemble median and green when they are above the ensemble median.

e. The Missouri FIRST Map cracks the population of previous Congressional districts more severely than over 99% of the incumbency-constrained ensemble, and the population of state senate districts more severely than over 90% of the incumbency-constrained ensemble.

f. The Missouri FIRST Map cracks BVAP more severely than 95.65% of the incumbency-constrained ensemble maps.

The top-line conclusions about the original ensemble therefore remain true for the ensemble of incumbency-constrained maps.

72. The stricter-population-balance ensemble analysis can be summarized much more briefly: The numerical tables in Appendix 3 are very close to those for the original ensemble, generally differing by only a small fraction. The top-line conclusions about the original ensemble therefore remain true for the alternative ensemble satisfying stronger population equality.

73. In short, neither incumbency protection nor a more stringent population equality threshold affects my conclusion that CD4 and CD5 under the Missouri FIRST Map are extremely non-compact in a manner that cannot be explained by recognized redistricting principles.

* * *

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge. I reserve the right to revise, update, or supplement my opinions as new information becomes available to me.

Date: December 30, 2025

Dr. Ari J. Stern

APPENDIX 1: DISTRICT-AVERAGE COMPACTNESS HISTOGRAMS

Figure 20: Histogram showing the average Reock score between CD4 and CD5.

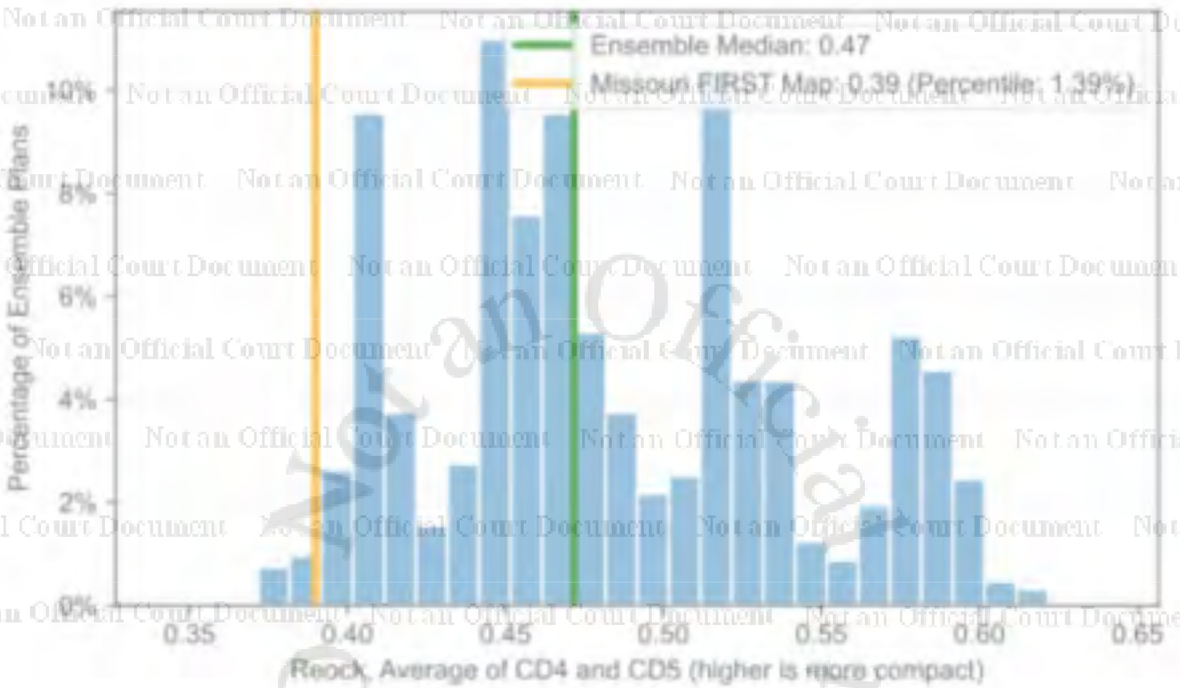


Figure 21: Histogram showing the average Polsby–Popper score between CD4 and CD5.

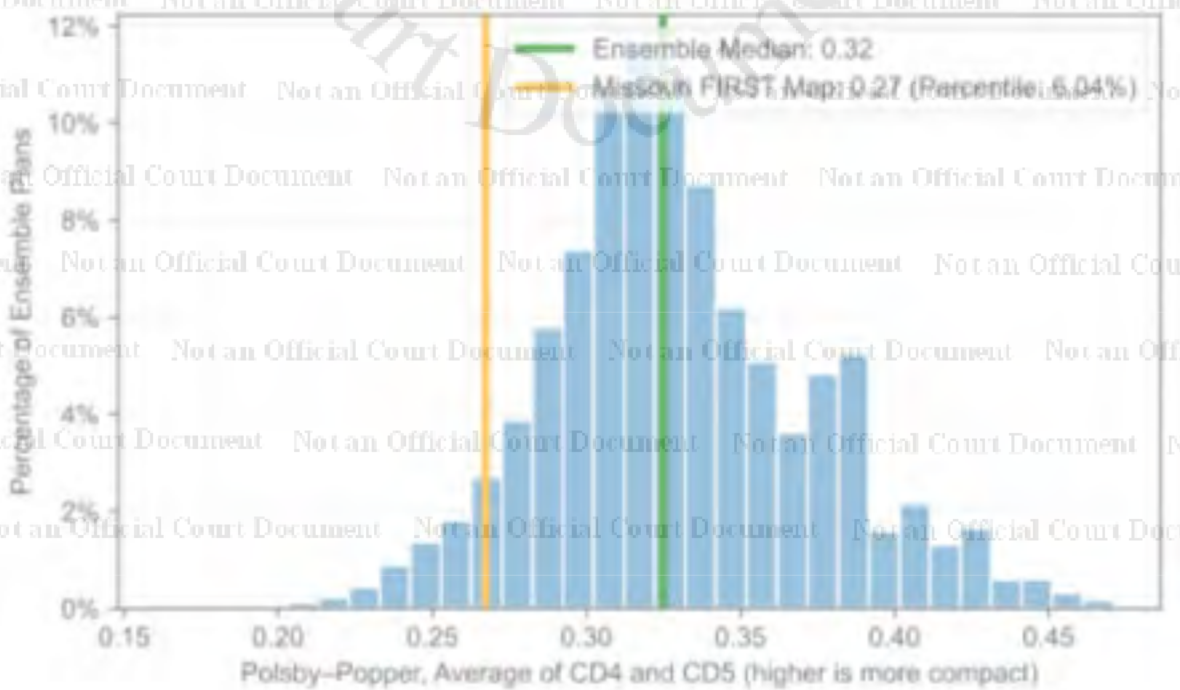


Figure 22: Histogram showing the average Population Polygon score between CD4 and CD5.

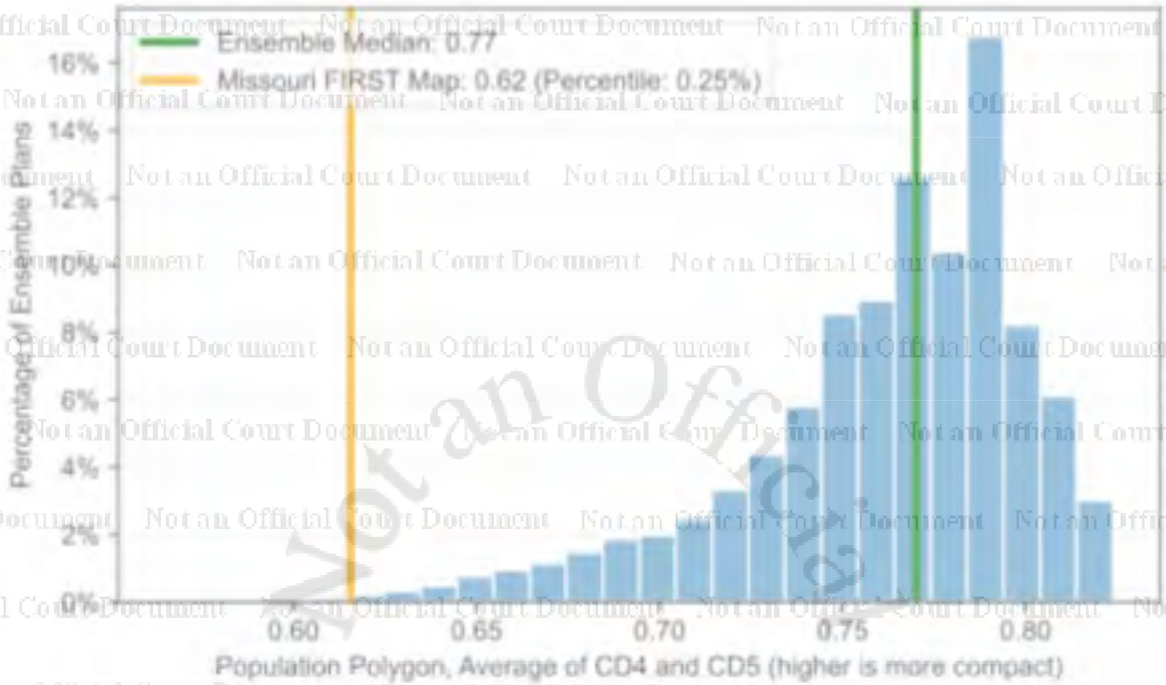


Figure 23: Histogram showing the average Area/Convex Hull score between CD4 and CD5.

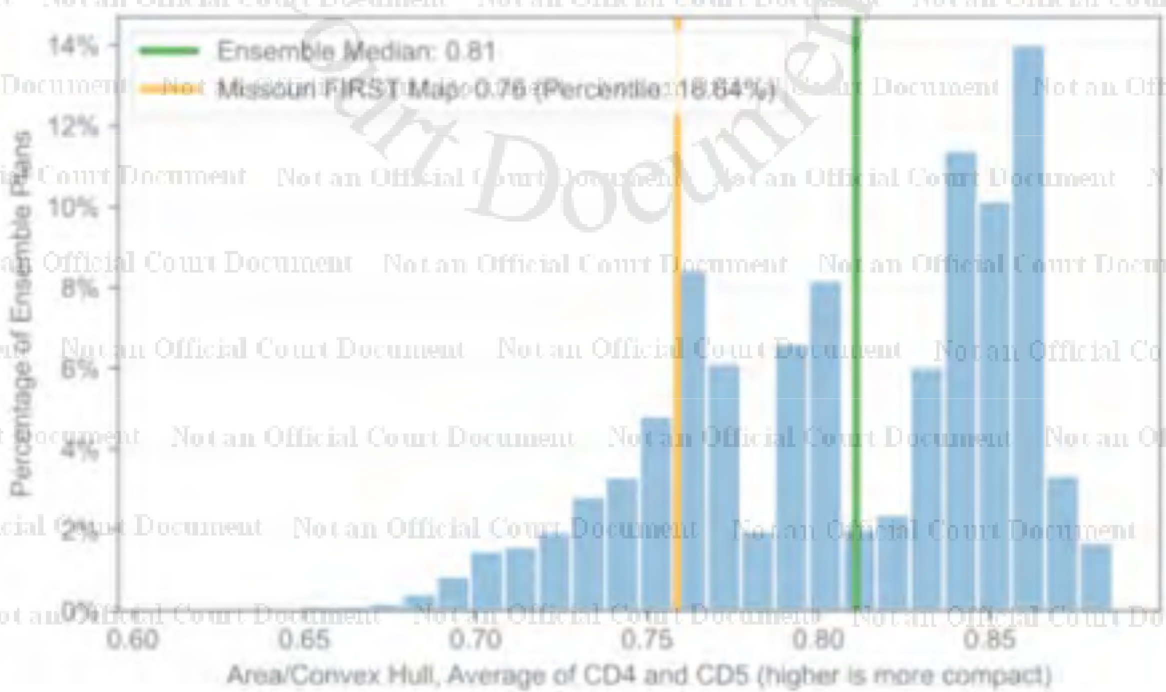


Figure 24: Histogram showing the average Population Circle score between CD4 and CD5.

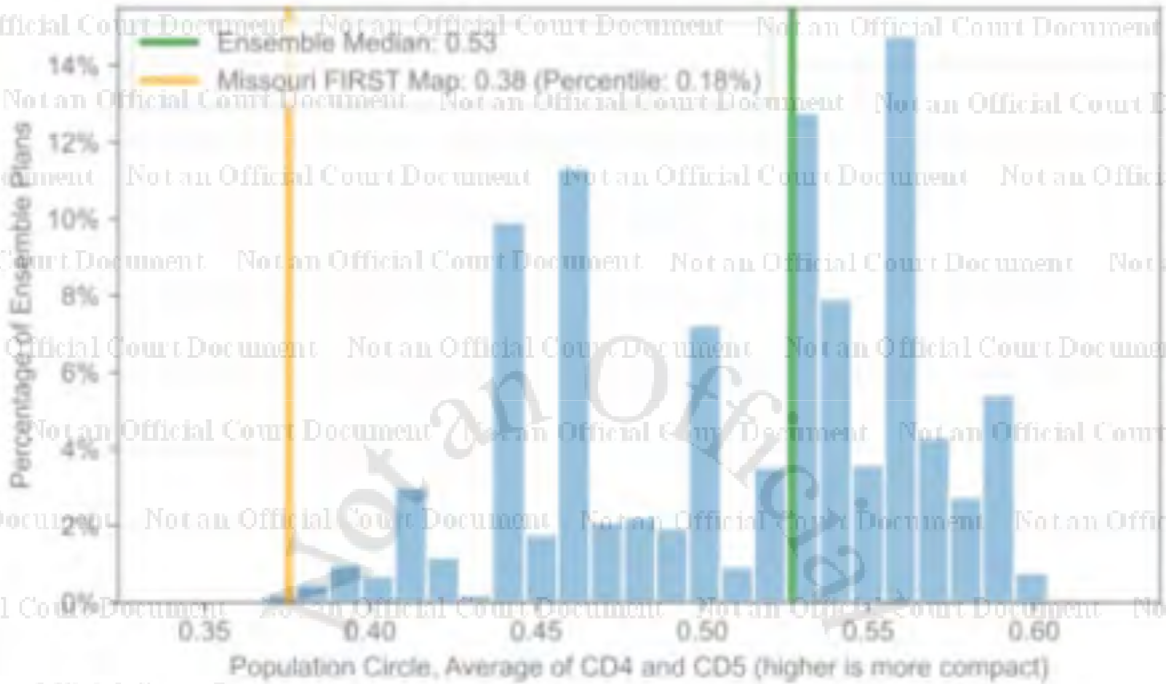


Figure 25: Histogram showing the average Ehrenburg score between CD4 and CD5.

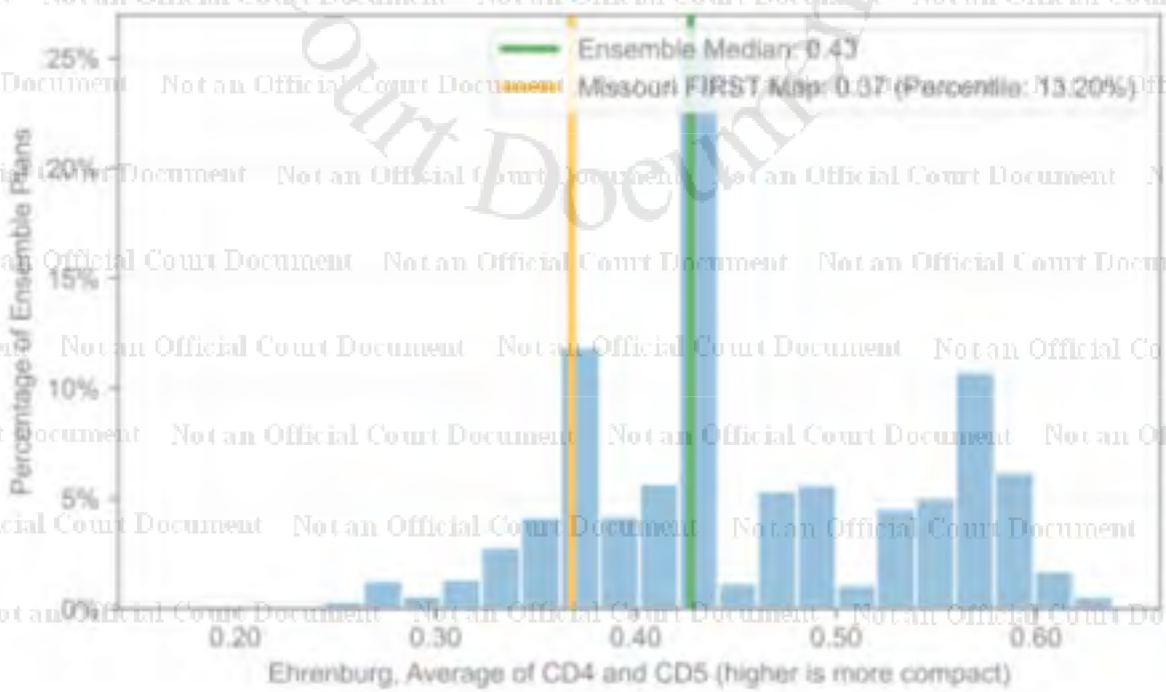


Figure 26: Histogram showing the average (Alternate) Schwartzberg score between CD4 and CD5.

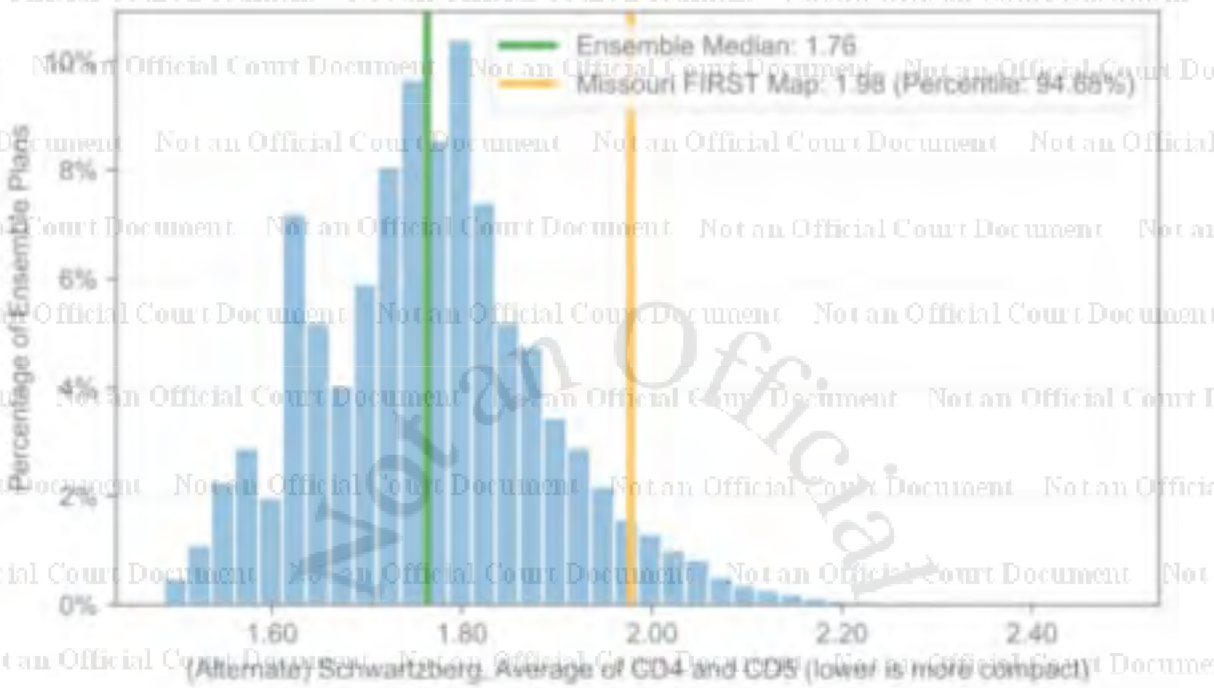


Figure 27: Histogram showing the average perimeter length between CD4 and CD5.

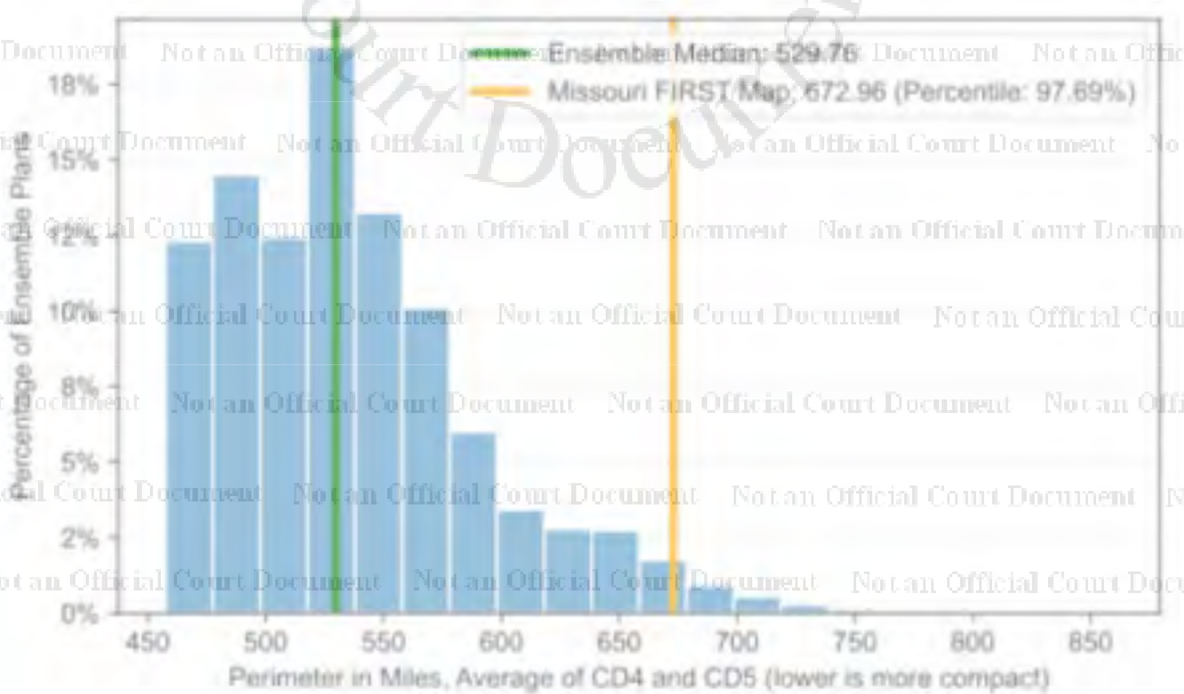
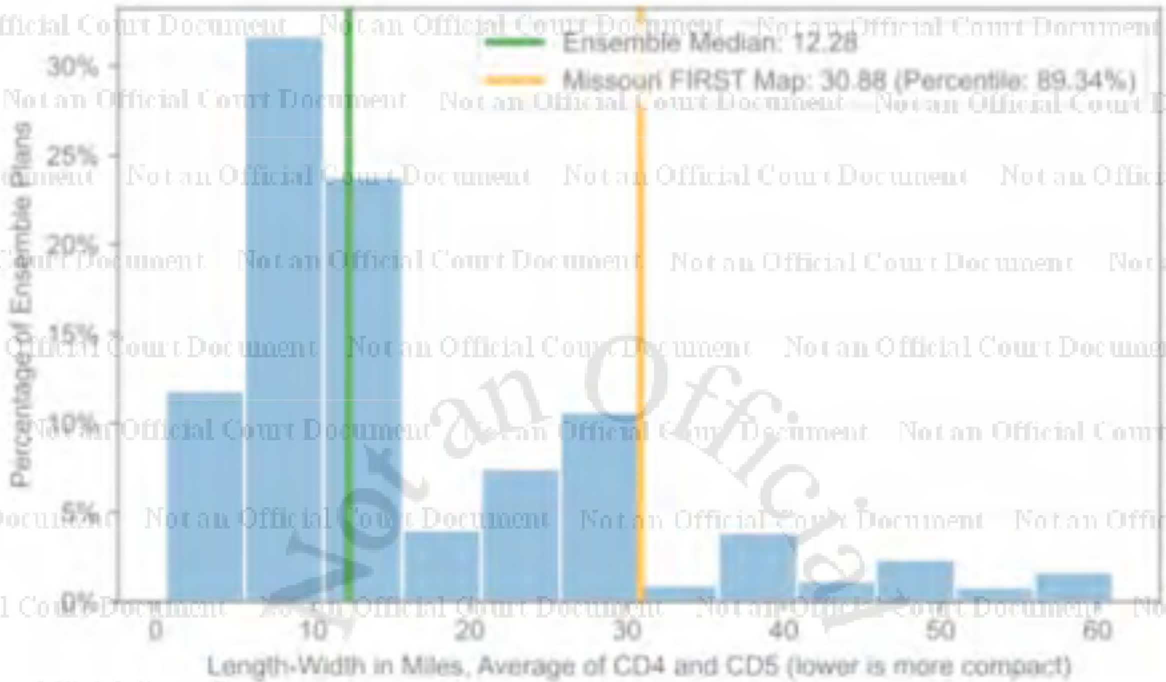


Figure 28: Histogram showing the average Length-Width score between CD4 and CD5.



APPENDIX 2: RESULTS FOR INCUMBENCY-CONSTRAINED ENSEMBLE MAPS

Table 10: County splitting between CD4 and CD5.

	Ensemble Median	Missouri FIRST Map	Percentile
Counties Split	1	1	51.04%
Population of Largest Jackson County Piece	701,167	370,868	0.11%
Total Population of Largest County Pieces	1,506,196	1,208,429	0.11%

Table 11: Municipality splitting between CD4 and CD5.

	Ensemble Median	Missouri FIRST Map	Percentile
Municipalities Split	6	6	55.24%
Population of Largest Kansas City Piece	300,419	174,515	0.28%
Total Population of Largest Municipality Pieces	1,075,487	960,864	0.97%

Table 12: VTD splitting between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
VTDs Split	0	18	100.00%
Total Population of Largest VTD Pieces	1,538,728	1,534,476	0.00%

Table 13: Size of the CD4–CD5 boundary, as measured by length in miles and by cut edges.

	Ensemble Median	Missouri FIRST Map	Percentile
Length in Miles	140.14	273.37	98.35%
Cut Edges	353	792	98.58%

Table 14: Compactness metrics for which higher scores indicate greater compactness..

		Ensemble Median	Missouri FIRST Map	Percentile
Reock	min	0.34	0.35	52.93%
	avg	0.44	0.39	3.67%
	max	0.54	0.43	0.19%
Polsby–Popper	min	0.28	0.20	9.95%
	avg	0.32	0.27	7.64%
	max	0.36	0.33	22.13%
Population Polygon	min	0.62	0.60	18.36%
	avg	0.76	0.62	0.22%
	max	0.90	0.63	0.13%
Area/Convex Hull	min	0.74	0.70	29.90%
	avg	0.77	0.76	31.53%
	max	0.82	0.82	49.63%
Population Circle	min	0.29	0.35	91.24%
	avg	0.46	0.38	0.09%
	max	0.63	0.40	0.39%
Ehrenburg	min	0.32	0.25	29.82%
	avg	0.42	0.37	26.80%
	max	0.51	0.49	41.22%

Table 15: Compactness metrics for which lower scores indicate greater compactness.

		Ensemble Median	Missouri FIRST Map	Percentile
(Alternate) Schwartzberg	min	1.67	1.74	77.87%
	avg	1.80	1.98	92.67%
	max	1.90	2.22	90.05%
Perimeter in Miles	min	270.85	628.75	99.31%
	avg	539.73	672.96	98.35%
	max	795.53	717.16	9.38%
Length-Width in Miles	min	0.33	11.80	87.89%
	avg	12.51	30.88	85.77%
	max	24.68	49.95	75.71%

Table 16: Splitting of 2012 and 2022 Congressional districts between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
2012 Congressional Districts Split	2	4	99.68%
Total Population of Largest District Pieces	1,450,191	1,007,069	0.35%
2022 Congressional Districts Split	2	3	80.34%
Total Population of Largest District Pieces	1,375,064	1,006,066	0.54%

Table 17: Splitting of Missouri Senate districts between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
State Senate Districts Split	2	5	92.80%
Total Population of Largest State Senate District Pieces	1,468,500	1,382,297	9.09%

Table 18: BVAP in the lower-BVAP district (CD4 in the Missouri FIRST Map) and higher-BVAP district (CD5 in the Missouri FIRST Map).

	Ensemble Median	Missouri FIRST Map	Percentile
BVAP: Lower of CD4 and CD5	25,708	45,836	95.65%
BVAP: Higher of CD4 and CD5	125,904	105,776	4.36%

APPENDIX 3: RESULTS FOR A STRICTER-POPULATION-BALANCE ENSEMBLE

Table 19: County splitting between CD4 and CD5.

	Ensemble Median	Missouri FIRST Map	Percentile
Counties Split	1	1	50.00%
Population of Largest Jackson County Piece	701,167	370,868	0.20%
Total Population of Largest County Pieces	1,498,890	1,208,429	0.20%

Table 20: Municipality splitting between CD4 and CD5.

	Ensemble Median	Missouri FIRST Map	Percentile
Municipalities Split	4	6	78.46%
Population of Largest Kansas City Piece	300,523	174,515	0.46%
Total Population of Largest Municipality Pieces	1,075,501	960,864	1.25%

Table 21: VTD splitting between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
VTDs Split	0	18	100.00%
Total Population of Largest VTD Pieces	1,538,728	1,534,476	0.00%

Table 22: Size of the CD4–CD5 boundary, as measured by length in miles and by cut edges.

	Ensemble Median	Missouri FIRST Map	Percentile
Length in Miles	131.60	273.37	97.46%
Cut Edges	340.00	792.00	97.35%

Table 23: Compactness metrics for which higher scores indicate greater compactness.

		Ensemble Median	Missouri FIRST Map	Percentile
Reock	min	0.40	0.35	23.57%
	avg	0.48	0.39	1.18%
	max	0.56	0.43	0.58%
Polsby–Popper	min	0.30	0.20	6.13%
	avg	0.33	0.27	6.47%
	max	0.36	0.33	25.25%
Population Polygon	min	0.61	0.60	23.95%
	avg	0.77	0.62	0.29%
	max	0.92	0.63	0.17%
Area/Convex Hull	min	0.79	0.70	17.41%
	avg	0.83	0.76	20.22%
	max	0.85	0.82	23.76%
Population Circle	min	0.29	0.35	91.29%
	avg	0.53	0.38	0.20%
	max	0.77	0.40	0.52%
Ehrenburg	min	0.40	0.25	13.63%
	avg	0.43	0.37	13.90%
	max	0.52	0.49	21.59%

Table 24: Compactness metrics for which lower scores indicate greater compactness.

		Ensemble Median	Missouri FIRST Map	Percentile
(Alternate) Schwartzberg	min	1.67	1.74	74.75%
	avg	1.76	1.98	94.33%
	max	1.83	2.22	93.87%
Perimeter in Miles	min	237.84	628.75	99.27%
	avg	531.19	672.96	97.46%
	max	805.61	717.16	4.15%
Length-Width in Miles	min	0.33	11.80	91.77%
	avg	12.00	30.88	88.42%
	max	23.23	49.95	79.69%

Table 25: Splitting of 2012 and 2022 Congressional districts between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
2012 Congressional Districts Split	2	4	99.72%
Total Population of Largest District Pieces	1,414,145	1,007,069	1.42%
2022 Congressional Districts Split	2	3	81.38%
Total Population of Largest District Pieces	1,379,157	1,006,066	1.39%

Table 26: Splitting of Missouri Senate districts between CD4 and CD5.

	Ensemble Median	Missouri First Map	Percentile
State Senate Districts Split	2	5	92.34%
Total Population of Largest State Senate District Pieces	1,470,037	1,382,297	12.03%

Table 27: BVAP in the lower-BVAP district (CD4 in the Missouri FIRST Map) and higher-BVAP district (CD5 in the Missouri FIRST Map).

	Ensemble Median	Missouri FIRST Map	Percentile
BVAP: Lower of CD4 and CD5	25,376	45,836	96.83%
BVAP: Higher of CD4 and CD5	126,236	105,776	3.17%

APPENDIX 4: ALTERNATIVE MAPS OBSERVED IN THE ENSEMBLES

Among the 100,000 maps in the ensemble with stronger population balance (±0.1%) are 30 maps that are, by chance, *exactly* population-balanced between CD4 and CD5. Of these, 11 maps also satisfy the incumbency condition, drawing the current CD4 and CD5 incumbents into separate districts. (Other maps in the ensemble that have some population deviation can be easily adjusted to achieve perfectly equal population without significantly affecting compactness or other relevant properties, as demonstrated by the adjustments made to several of my ensemble maps in a report produced by a different Plaintiffs' expert.)

This appendix presents the five most compact of these 11 maps as measured by cut edges; the maps are numbered as they occur in the ensemble and listed in order. The first of these, Map #12064, also happens to appear in the original ensemble with ±1% population tolerance. Since the maps are taken from the stricter-population-balance ensemble, the medians and percentiles stated in this appendix will also be relative to that ensemble, as presented in Appendix 3, rather than the original ensemble presented in the body of the report.

Some notes on the properties of these five maps:

a. Compared with the Missouri FIRST Map, these maps (like all the ensemble maps) vary only the CD4–CD5 boundary and leave the other six districts unchanged.

b. Four of the maps (all but #85776) split only Jackson County between CD4 and CD5, introducing no new split counties and thus keeping the three-way split of Jackson County between CD4, CD5, and CD6. Map #85776 splits a small portion of Cass County. All five maps are far superior to the Missouri FIRST Map in preservation of intact county population.

c. Four of the maps (all but #88159) split 7 municipalities between CD4 and CD5, more than the 6 splits in the Missouri FIRST Map. However, these splits are far less severe and preserve much more of the population of municipalities than the Missouri FIRST Map. For instance, the four maps that split Kansas City only split off between 170 and 6,424 Kansas City residents, compared to over 126,000 in the Missouri FIRST Map. In fact, the four maps splitting 7 municipalities preserve more of the total municipal population than Map #88159, which only has 3 municipality splits.

d. Four of the maps (all but #85776) split *zero* VTDs. Map #85776 splits two VTDs and about 900 people, whereas the Missouri FIRST Map splits 18 VTDs and over 4,000 people.

e. In all five maps, the length of the CD4–CD5 boundary is about half the size as in the Missouri FIRST Map, whether measured by miles or by cut edges.

f. Across the 9 district-by-district compactness metrics, the five maps generally compare favorably, without exhibiting the consistent and occasionally extreme non-compactness of the Missouri FIRST Map. Three of the maps (#12064, #26709, and #58210) have *all* of the compactness scores between the 10th and 90th percentiles, and a fourth (#85776) has only one score outside this range (minimum Population Polygon, 92.37%). Of the five, only Map #88159 has any significant compactness outliers compared to the ensemble.

g. All five maps far better preserve the historical Congressional district lines and current Missouri Senate district lines than does the Missouri FIRST Map.

h. BVAP is much less cracked in these five ensemble maps, compared with the Missouri FIRST Map. Of the five, Map #26709 has the lowest CD5 BVAP with 119,416—compared with only 105,776 in the Missouri FIRST Map CD5.

These maps further illustrate that the extreme non-compactness of the Missouri FIRST Map is not necessary to achieve perfect population balance, to separate incumbents, to achieve BVAP representation, to prevent splitting of political or historical boundaries, or to meet any of the other criteria on which these maps outperform the Missouri FIRST Map.

Figure 29: Map #12064

Figure 30: Map #26709

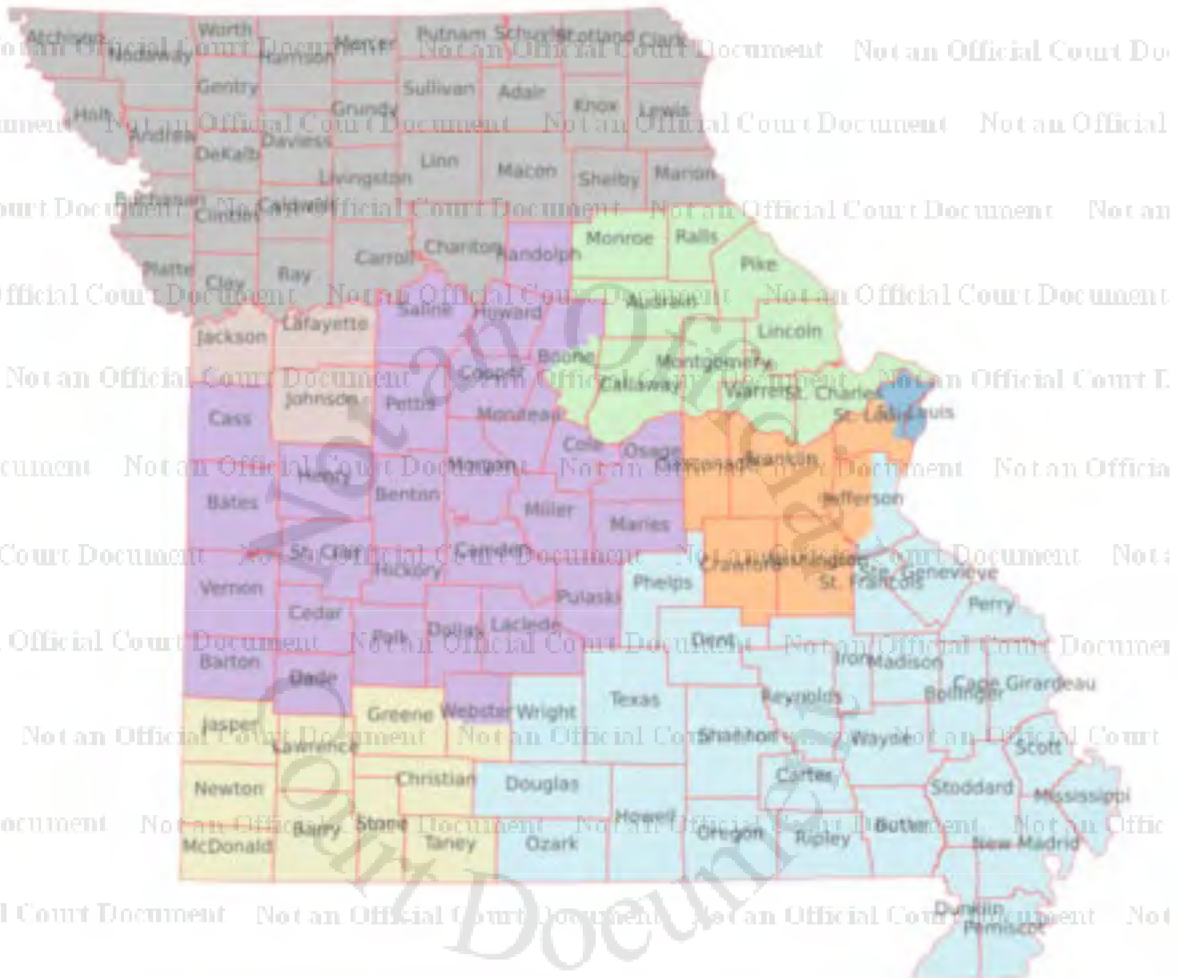


Figure 31: Map #58210

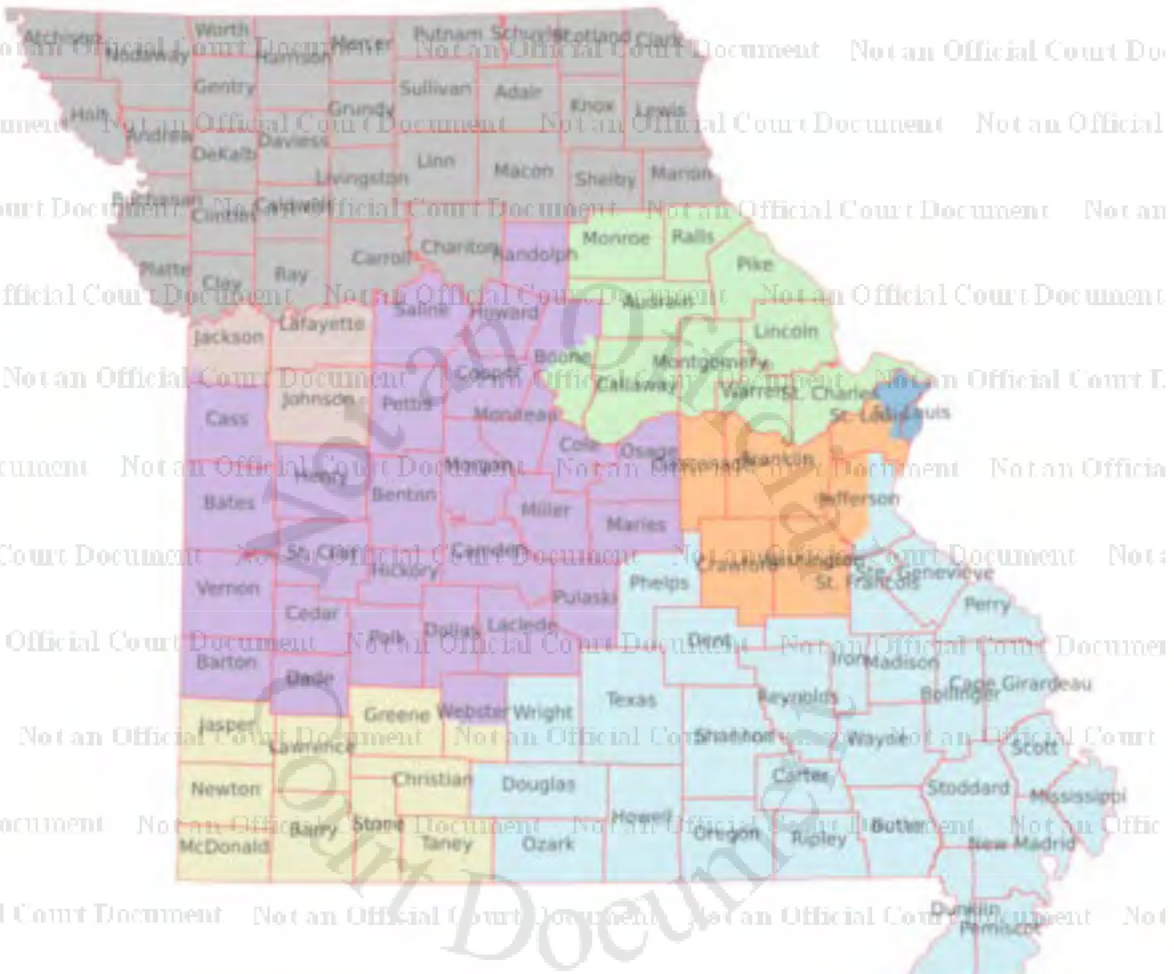


Figure 32: Map #85776

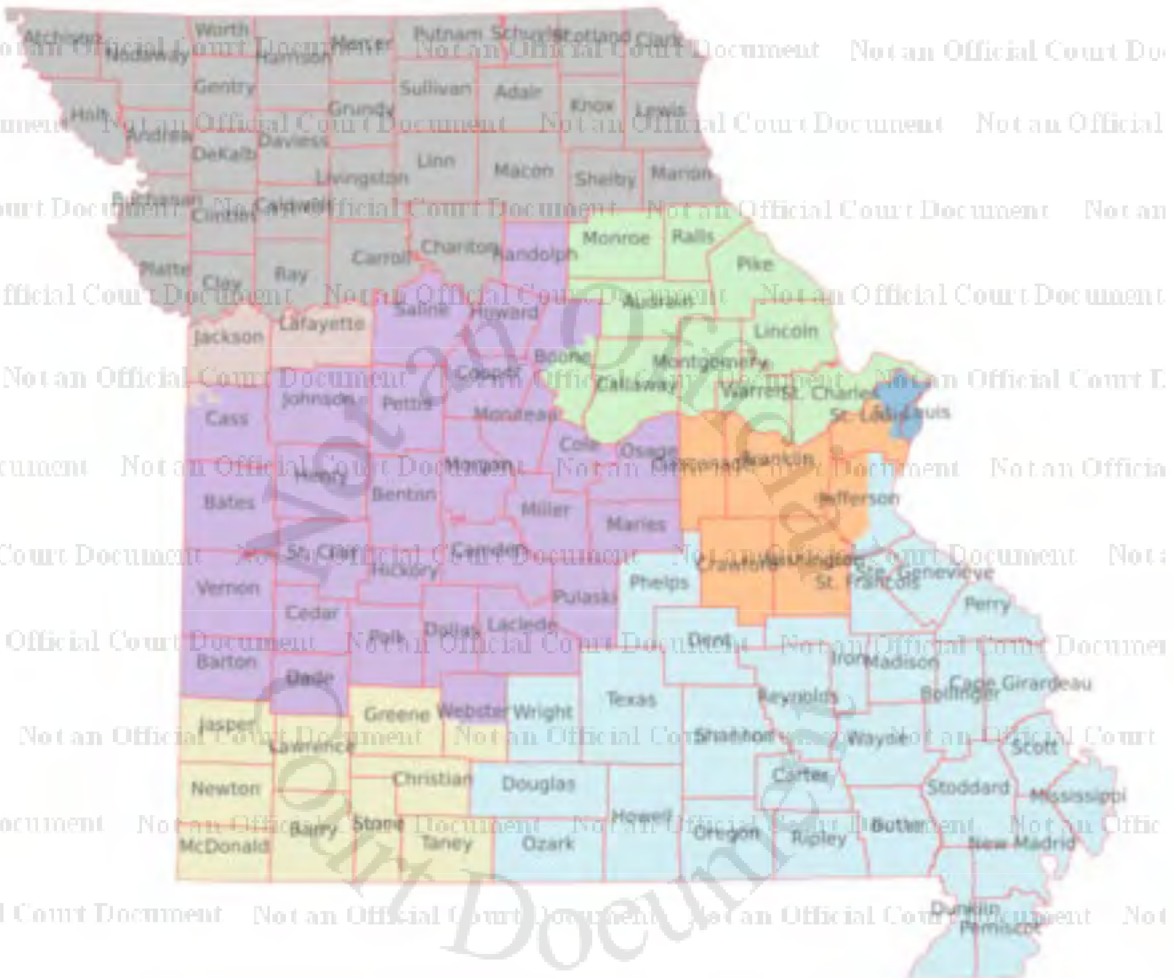
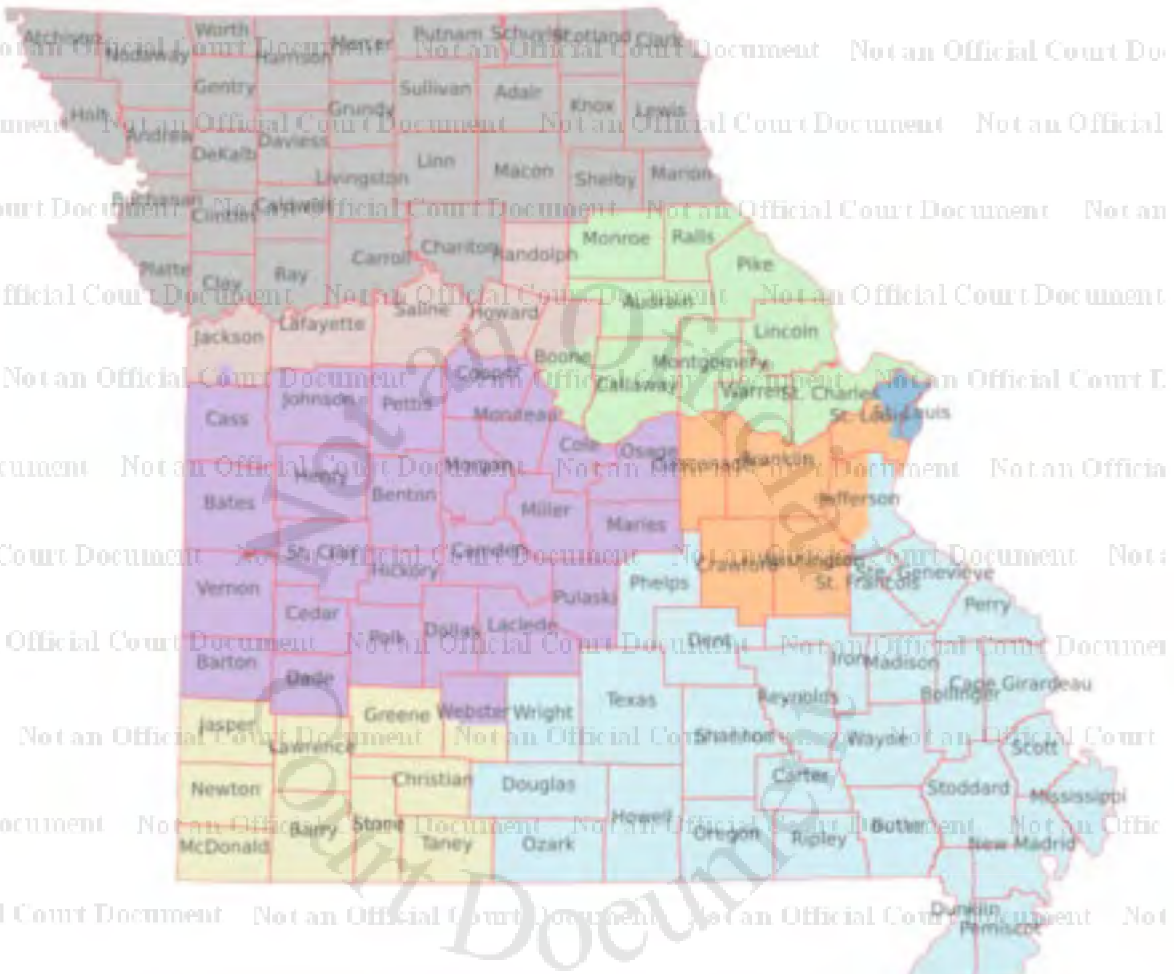


Figure 33: Map #88159



		Ensemble Median	Missouri FIRST Map	12064	26709	58210	85776	88159
Counties Split	Value	1	1	1	1	1	1	1
	Percentile	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%	50.00%
Population of Largest Jackson County Piece	Value	701,167	370,868	682,367	682,367	682,367	701,167	645,150
	Percentile	73.56%	0.20%	43.99%	43.99%	43.99%	73.56%	20.61%
Total Population of Largest County Pieces	Value	1,498,890	1,208,429	1,519,928	1,519,928	1,519,928	1,503,515	1,482,711
	Percentile	49.90%	0.20%	90.07%	90.07%	90.07%	77.35%	20.61%
Municipalities Split	Value	4	6	7	7	7	7	3
	Percentile	45.89%	78.46%	90.71%	90.71%	90.71%	90.71%	27.08%
Population of Largest Kansas City Piece	Value	300,523	174,515	299,153	294,099	295,601	300,523	300,353
	Percentile	66.60%	0.46%	13.77%	9.46%	10.18%	66.60%	16.38%
Total Population of Largest Municipality Pieces	Value	1,075,501	960,864	1,074,346	1,065,487	1,067,242	1,069,244	1,039,033
	Percentile	50.00%	1.25%	47.12%	31.34%	34.59%	37.28%	11.68%
VTDs Split	Value	0	18	0	0	0	2	0
	Percentile	30.49%	100.00%	30.49%	30.49%	30.49%	84.82%	30.49%
Total Population of Largest VTD Pieces	Value	1,538,728	1,534,476	1,538,728	1,538,728	1,538,728	1,537,832	1,538,728
	Percentile	69.51%	0.00%	69.51%	69.51%	69.51%	1.70%	69.51%

		Ensemble Median	Missouri FIRST Map	12064	26709	58210	85776	88159
Length in Miles	Value	131.60	273.37	140.88	151.35	141.83	124.85	159.8
	Percentile	50.00%	97.46%	57.58%	65.02%	58.70%	43.96%	69.55%
Cut Edges	Value	340	792	369	432	366	356	425
	Percentile	49.86%	97.35%	59.35%	74.25%	58.48%	55.11%	73.22%

Minimum Compactness Score (higher is more compact)		Ensemble Median	Missouri FIRST Map	12064	26709	58210	85776	88159
Reock	Value	0.40	0.35	0.50	0.50	0.50	0.32	0.22
	Percentile	50.05%	23.57%	74.53%	75.25%	72.46%	15.72%	1.26%
Polsby–Popper	Value	0.30	0.20	0.31	0.30	0.31	0.26	0.17
	Percentile	50.00%	6.13%	62.42%	55.77%	61.60%	21.77%	1.56%
Population Polygon	Value	0.61	0.60	0.58	0.58	0.56	0.67	0.78
	Percentile	50.03%	23.95%	18.42%	20.05%	10.72%	92.37%	99.88%
Area/Convex Hull	Value	0.79	0.70	0.79	0.79	0.79	0.75	0.66
	Percentile	50.00%	17.41%	51.92%	52.91%	50.35%	30.24%	7.47%
Population Circle	Value	0.29	0.35	0.29	0.29	0.29	0.29	0.39
	Percentile	49.99%	91.29%	38.08%	38.08%	38.08%	38.08%	95.85%
Ehrenburg	Value	0.40	0.25	0.40	0.40	0.40	0.32	0.17
	Percentile	50.00%	13.63%	54.67%	55.33%	52.68%	27.18%	1.13%

Average Compactness Score (higher is more compact)		Ensemble Median	Missouri FIRST Map	12064	26709	58210	85776	88159
Reock	Value	0.48	0.39	0.52	0.52	0.52	0.44	0.40
	Percentile	50.02%	1.18%	68.90%	69.75%	66.68%	20.11%	2.33%
Polsby–Popper	Value	0.33	0.27	0.35	0.33	0.35	0.30	0.33
	Percentile	50.07%	6.47%	71.18%	54.49%	70.40%	24.22%	57.04%
Population Polygon	Value	0.77	0.62	0.74	0.73	0.73	0.80	0.80
	Percentile	49.92%	0.29%	23.20%	19.75%	18.84%	88.99%	89.10%
Area/Convex Hull	Value	0.83	0.76	0.81	0.80	0.80	0.79	0.77
	Percentile	50.00%	20.22%	45.02%	40.41%	43.68%	34.00%	26.51%
Population Circle	Value	0.53	0.38	0.50	0.50	0.50	0.46	0.42
	Percentile	50.00%	0.20%	35.33%	35.33%	35.33%	18.33%	6.84%
Ehrenburg	Value	0.43	0.37	0.43	0.42	0.43	0.42	0.36
	Percentile	50.00%	13.90%	39.52%	37.39%	41.86%	32.84%	12.19%

Maximum Compactness Score (higher is more compact)		**Ensemble Median**	**Missouri FIRST Map**	**12064**	**26709**	**58210**	**85776**	**88159**
Reock	Value	0.56	0.43	0.54	0.54	0.54	0.56	0.57
	Percentile	49.99%	0.58%	20.65%	19.89%	23.16%	47.37%	60.46%
Polsby–Popper	Value	0.36	0.33	0.39	0.35	0.39	0.34	0.49
	Percentile	49.96%	25.25%	67.80%	47.59%	66.34%	35.87%	91.11%
Population Polygon	Value	0.92	0.63	0.90	0.88	0.90	0.92	0.81
	Percentile	50.00%	0.17%	30.72%	21.77%	31.77%	47.69%	9.15%
Area/Convex Hull	Value	0.85	0.82	0.82	0.81	0.82	0.84	0.88
	Percentile	49.98%	23.76%	27.80%	22.95%	26.37%	40.72%	75.31%
Population Circle	Value	0.77	0.40	0.71	0.71	0.71	0.63	0.45
	Percentile	50.07%	0.52%	39.19%	39.19%	39.19%	18.96%	2.02%
Ehrenburg	Value	0.52	0.49	0.45	0.45	0.45	0.52	0.56
	Percentile	49.84%	21.59%	15.17%	14.24%	16.57%	51.07%	63.88%

Minimum Compactness Score (lower is more compact)		**Ensemble Median**	**Missouri FIRST Map**	**12064**	**26709**	**58210**	**85776**	**88159**
(Alternate) Schwartzberg	Value	1.67	1.74	1.60	1.68	1.60	1.70	1.43
	Percentile	50.04%	74.75%	32.20%	52.42%	33.66%	64.13%	8.89%
Perimeter in Miles	Value	237.84	628.75	257.17	270.65	258.11	251.66	488.32
	Percentile	50.00%	99.27%	58.21%	64.26%	58.81%	55.31%	93.77%
Length-Width in Miles	Value	0.33	11.80	0.33	0.33	0.33	0.33	37.33
	Percentile	43.75%	91.77%	43.75%	43.75%	43.75%	43.75%	97.47%

Average Compactness Score (lower is more compact)		**Ensemble Median**	**Missouri FIRST Map**	**12064**	**26709**	**58210**	**85776**	**88159**
(Alternate) Schwartzberg	Value	1.76	1.98	1.70	1.75	1.70	1.84	1.91
	Percentile	50.00%	94.33%	28.04%	44.06%	29.79%	74.60%	87.85%
Perimeter in Miles	Value	531.19	672.96	540.48	550.94	541.42	524.45	559.39
	Percentile	50.00%	97.46%	57.58%	65.02%	58.70%	43.96%	69.55%
Length-Width in Miles	Value	12.00	30.88	5.32	5.35	5.32	11.62	59.40
	Percentile	50.02%	88.42%	13.38%	15.80%	13.38%	48.93%	99.67%

Maximum Compactness Score (lower is more compact)		**Ensemble Median**	**Missouri FIRST Map**	**12064**	**26709**	**58210**	**85776**	**88159**
(Alternate) Schwartzberg	Value	1.83	2.22	1.80	1.82	1.80	1.97	2.40
	Percentile	50.00%	93.87%	37.58%	44.23%	38.40%	78.23%	98.44%
Perimeter in Miles	Value	805.61	717.16	823.78	831.23	824.72	797.23	630.45
	Percentile	49.53%	4.15%	64.05%	69.61%	65.13%	35.79%	0.58%
Length-Width in Miles	Value	23.23	49.95	10.30	10.36	10.30	22.91	81.48
	Percentile	50.03%	79.69%	13.39%	15.81%	13.39%	49.14%	98.44%

		Ensemble Median	Missouri FIRST Map	12064	26709	58210	85776	88159
2012 Congressional Districts Split	Value	2	4	2	2	2	2	3
	Percentile	34.76%	99.72%	34.76%	34.76%	34.76%	34.76%	81.67%
Total Population of Largest District Pieces	Value	1,414,145	1,007,069	1,442,582	1,442,582	1,442,582	1,480,182	1,414,814
	Percentile	49.63%	1.42%	75.96%	75.96%	75.96%	85.32%	65.96%
2022 Congressional Districts Split	Value	2	3	3	3	3	2	3
	Percentile	31.57%	81.38%	81.38%	81.38%	81.38%	31.57%	81.38%
Total Population of Largest District Pieces	Value	1,379,157	1,006,066	1,341,965	1,341,965	1,341,965	1,379,565	1,305,550
	Percentile	49.95%	1.39%	27.94%	27.94%	27.94%	65.36%	17.27%
State Senate Districts Split	Value	2	5	3	4	3	2	3
	Percentile	45.80%	92.34%	68.72%	84.50%	68.72%	45.80%	68.72%
Total Population of Largest State Senate District Pieces	Value	1,470,037	1,382,297	1,432,931	1,432,931	1,432,931	1,470,531	1,465,608
	Percentile	49.86%	12.03%	40.39%	40.39%	40.39%	64.10%	45.59%

		Ensemble Median	Missouri FIRST Map	12064	26709	58210	85776	88159
BVAP: Lower of CD4 and CD5	Value	25,376	45,836	30,351	32,196	29,055	25,080	26,924
	Percentile	50.00%	96.83%	88.88%	90.80%	86.04%	42.96%	78.64%
BVAP: Higher of CD4 and CD5	Value	126,236	105,776	121,261	119,416	122,557	126,532	124,688
	Percentile	50.01%	3.17%	11.12%	9.20%	13.96%	57.04%	21.36%

APPENDIX 5: Curriculum Vitae of Dr. Ari J. Stern

Ari Stern

Department of Mathematics
Washington University in St. Louis
One Brookings Drive, Campus Box 1146
St. Louis, MO 63130-4899, USA
stern@wustl.edu
www.math.wustl.edu/~astern

Curriculum Vitae

prepared December 22, 2025

Academic Positions

2024– **Professor**, *Washington University in St. Louis*
Department of Mathematics

2018–2024 **Associate Professor**, *Washington University in St. Louis*
Department of Mathematics

2012–2018 **Assistant Professor**, *Washington University in St. Louis*
Department of Mathematics

2009–2012 **Postdoctoral Scholar and Lecturer**, *University of California, San Diego*
Department of Mathematics

Education

2009 **Ph.D.**, *California Institute of Technology*
Applied and Computational Mathematics
Thesis: *Geometric discretization of Lagrangian mechanics and field theories*
Advisors: Jerrold E. Marsden and Mathieu Desbrun

2002 **M.A.**, *Columbia University*
Mathematics of Finance

2001 **B.A.**, *Columbia University*
Mathematics

Publications and Preprints

[36] A. Stern and E. Zampa, *Multisymplecticity in finite element exterior calculus*, Found. Comput. Math. (2025). doi:10.1007/s10208-025-09720-y.

[35] A. Stern and M. Viviani, *Quadratic projectable Runge–Kutta methods* (2024), in review. arXiv:2411.12634 [math.NA].

[34] A. Stern and S. Suri, *Functional equivariance and modified vector fields*, J. Comput. Dyn. **11** (2024), 409–426. doi:10.3934/jcd.2023010.

[33] M. Barker, S. Cao, and A. Stern, *A nonconforming primal hybrid finite element method for the two-dimensional vector Laplacian*, SMAI J. Comput. Math. **10** (2024), 85–106. doi:10.5802/smai-jcm.107.

[32] R. I. McLachlan and A. Stern, *Functional equivariance and conservation laws in numerical integration*, Found. Comput. Math. **24** (2024), 149–177. doi:10.1007/s10208-022-09590-8.

[31] J. Hu and A. Stern, *Hamiltonian mechanics and Lie algebroid connections*, J. Nonlin. Sci. **34** (2024), Paper No. 9, 23 pages. doi:10.1007/s00332-023-09986-y.

[30] G. Awanou, M. Fabien, J. Guzmán, and A. Stern, *Hybridization and postprocessing in finite element exterior calculus*, Math. Comp. **92** (2023), 79–115. doi:10.1090/mcom/3743.

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cognition in Alzheimer's disease, Science Translational Medicine **8** (2016), 338ra66. doi:10.1126/scitranslmed.aaf2362.

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Grants

2025–2030 *Structure-Preserving Numerical Methods for Hamiltonian PDEs*
Simons Foundation, Grant No. SFI-MPS-TSM-00014348
Role: PI
Award Amount: $42,000

2022–2025 *Structure-Preserving Hybrid Finite Element Methods*
National Science Foundation, Grant No. DMS-2208551
Role: PI
Award Amount: $237,648

2019–2023 *Hybrid Finite Element Methods for Geometric PDEs*
National Science Foundation, Grant No. DMS-1913272
Role: PI
Award Amount: $212,640

2018–2023 *Imaging Tauopathy in the Dominantly Inherited Alzheimer Network (DIAN)*
National Institutes of Health, Grant No. 5R01AG05255003
Role: Personnel
Award Amount: $3,583,474

2013–2018 *Collaborative Research in Geometric Numerical Analysis*
Simons Foundation, Grant No. 279968
Role: PI
Award Amount: $35,000

2011–2013 AMS–Simons Travel Grant
American Mathematical Society and Simons Foundation
Role: PI
Award Amount: $4,000

Visiting Positions

Jul–Dec 2019 University of Cambridge, Isaac Newton Institute for Mathematical Sciences

Jun–Aug 2014 Massey University, Palmerston North, New Zealand

Sep–Dec 2009 CSIC (Spanish National Research Council), Madrid

Fellowships

Mar 2016 & Jul 2012 US Junior Oberwolfach Fellowship
Mathematisches Forschungsinstitut Oberwolfach, NSF Grant No. DMS-1049268
Role: Travel Support Recipient

2009–2011 Center for Theoretical Biological Physics Postdoctoral Fellowship
University of California, San Diego
Role: Postdoctoral Fellow

Sep–Dec 2009 SIMUMAT Visiting Research Fellowship
CSIC (Spanish National Research Council), Madrid, Spain
Role: Visiting Postdoctoral Fellow

2003–2007 Gordon and Betty Moore Foundation Fellowship
California Institute of Technology
Role: Graduate Fellow

2000–2001 VIGRE Undergraduate Research Fellowship
Columbia University, NSF Grant No. 9810750
Role: Undergraduate Fellow

Awards and Honors

2009 W. P. Carey & Co., Inc., Prize in Applied Mathematics
California Institute of Technology
"For an outstanding doctoral dissertation in applied mathematics or pure mathematics"

2008 Everhart Distinguished Graduate Lecture Award
California Institute of Technology

2001 John Dash Van Buren, Jr., Prize in Mathematics
Columbia University

2000 Professor Van Amringe Mathematical Prize
Columbia University

Professional Talks

Plenary Addresses

Dec 2, 2024 Lie–Størmer Colloquium, Tromsø
Jul 25, 2022 SciCADE Conference, Reykjavik
Jun 30, 2022 *Acta Numerica* 30th Anniversary Conference, Będlewo
Sep 10, 2021 NUMDIFF Conference, Halle
Mar 28, 2014 Mathematical Association of America (MAA) Missouri Section Meeting, St. Louis
Jan 12, 2010 Fourth International Young Researchers' Workshop on Geometry, Mechanics, and Control, Ghent

Invited Research Talks

Oct 19, 2025 AMS Fall Central Sectional Meeting, St. Louis
Jun 27, 2025 Delft University of Technology
Apr 29, 2025 Saint Louis University
Mar 19, 2025 Workshop on Geometric Mechanics Formulations for Continuum Mechanics, Banff International Research Station (BIRS)
Mar 7, 2025 SIAM Conference on Computational Science and Engineering (CSE25), Fort Worth
Oct 5, 2024 SIAM Central States Section Meeting, Kansas City
Jul 8, 2024 SIAM Annual Meeting, Spokane
Jun 13, 2024 University of Cambridge
Jun 10, 2024 Imperial College London
Jun 6, 2024 University of Oxford
Apr 14, 2024 Midwest Numerical Analysis Day, Iowa City

Jan 16, 2024	Workshop on Numerical Analysis and PDEs (WONAPDE), Concepción
Nov 17, 2023	Portland State University
Oct 24, 2023	Columbia University
Aug 24, 2023	International Congress on Industrial and Applied Mathematics (ICIAM), Tokyo
Jun 13, 2023	Foundations of Computational Mathematics (FoCM), Paris
Apr 15, 2023	AMS Spring Central Sectional Meeting, Cincinnati
Mar 1, 2023	SIAM Conference on Computational Science and Engineering (CSE23), Amsterdam
Oct 1, 2022	SIAM Central States Section Meeting, Stillwater
Jul 15, 2022	SIAM Annual Meeting, Pittsburgh
Jun 22, 2022	Workshop on Hilbert Complexes: Analysis, Applications, & Discretizations, Oberwolfach
Jun 13, 2022	Canadian Applied and Industrial Mathematics Society Annual Meeting
Jun 9, 2022	Seminario Internacional: Geometría Diferencial y Física Matemática, virtual
May 24, 2022	University of California, San Diego
May 5, 2022	University of Notre Dame
Apr 9, 2022	Finite Element Circus, University of Florida
Oct 2, 2021	SIAM Central States Section Meeting, virtual
Sep 18, 2021	SIAM Southeastern Atlantic Section Meeting, Auburn
Sep 15, 2021	Firedrake '21, virtual
Apr 1, 2021	Geometric Numerical Integration Workshop, Oberwolfach, virtual
Mar 19, 2021	University of Warwick, virtual
Mar 4, 2021	SIAM Conference on Computational Science and Engineering (CSE21), virtual
Nov 7, 2020	Finite Element Circus, virtual
Nov 3, 2020	Imperial College London, virtual
Oct 30, 2020	Brown University, virtual
Sep 30, 2020	University of Tennessee, virtual
Jul 7, 2020	International Conference on Mathematical Neuroscience (ICMNS), virtual
Jun 18, 2020	Foundations of Computational Mathematics (FoCM), virtual
Feb 17, 2020	Princeton University
Dec 12, 2019	Karlsruhe Institute of Technology
Nov 11, 2019	University of Oxford
Nov 8, 2019	Imperial College London
Oct 14, 2019	International Centre for Mathematical Sciences, Edinburgh
Sep 30, 2019	University of Cambridge
Aug 20, 2019	Imperial College London
Aug 14, 2019	University of Cambridge
Jul 22, 2019	SciCADE, Innsbruck
Apr 4, 2019	University of Iowa
Mar 23, 2019	Finite Element Circus, Purdue
Jan 25, 2019	Missouri University of Science and Technology
Nov 2, 2018	University of Missouri–St. Louis
Oct 21, 2018	AMS Fall Central Sectional Meeting, Ann Arbor

Oct 6, 2018	SIAM TX-LA Sectional Meeting, Baton Rouge
July 25, 2018	World Congress on Computational Mechanics, New York
Apr 5, 2018	Symmetry and Computations Workshop, CIRM, Marseille
Dec 11, 2017	University of Illinois, Urbana–Champaign
Sep 30, 2017	SIAM Central States Section Meeting, Fort Collins
Jul 11, 2017	Foundations of Computational Mathematics (FoCM), Barcelona
Jun 12, 2017	Workshop on Connections in Geometric Numerical Integration and Structure-Preserving Discretization, Banff International Research Station (BIRS)
Dec 4, 2016	Canadian Mathematical Society Winter Meeting, Niagara Falls
Nov 21, 2016	California Institute of Technology
Nov 16, 2016	University of California, Riverside
Oct 2, 2016	SIAM Central States Section Meeting, Little Rock
Aug 23, 2016	University of Bergen, Norway
Apr 11, 2015	SIAM Central States Section Meeting, Rolla
Mar 9, 2015	University of Illinois, Urbana–Champaign
Dec 17, 2014	Foundations of Computational Mathematics (FoCM), Montevideo
Dec 9, 2014	Penn State
Oct 30, 2014	Wesleyan University
Jul 10, 2014	Massey University, Palmerston North, New Zealand
May 19, 2014	California Institute of Technology
Jan 9, 2014	Australian National University
Oct 28, 2013	IMA Workshop on Modern Applications of Homology and Cohomology, Minneapolis
Oct 19, 2013	AMS Fall Central Sectional Meeting, St. Louis
Oct 17, 2013	University of Chicago
Mar 11, 2013	CRM–McGill Applied Mathematics Seminar, Montreal
Jan 11, 2013	Joint Mathematics Meetings, San Diego
Jul 27, 2012	Conference on Geometry, Symmetry, Dynamics, and Control: the Legacy of Jerry Marsden, Fields Institute, Toronto
Jul 12, 2012	Discrete Differential Geometry Workshop, Oberwolfach
Jan 27, 2012	University of Wisconsin, Madison
Dec 14, 2011	Washington University in St. Louis
Nov 14, 2011	SIAM Conference on Analysis of Partial Differential Equations (PD11), San Diego
Oct 29, 2011	"Gone Fishing" Poisson Geometry Meeting, St. Louis
Sep 2, 2011	University of California, Berkeley
Jul 27, 2011	US National Congress on Computational Mechanics (USNCCM), Minneapolis
Jul 21, 2011	International Congress on Industrial and Applied Mathematics (ICIAM), Vancouver
Jul 4, 2011	Foundations of Computational Mathematics (FoCM), Budapest
May 6, 2011	Penn State
Mar 24, 2011	Geometric Numerical Integration Workshop, Oberwolfach
Feb 18, 2011	University of Wisconsin, Madison
Jan 25, 2011	University of Maryland, College Park

Jun 1, 2010	Dynamical Systems and Partial Differential Equations (DSPDEs'10), Barcelona
Apr 27, 2010	Sixth Structured Integrators Workshop, San Diego
Apr 8, 2010	Massey University, Palmerston North, New Zealand
Nov 20, 2009	Universidad Complutense de Madrid
Nov 6, 2009	Universidad de La Laguna, Canary Islands, Spain
Sep 17, 2009	Real Academia de Ciencias (Royal Academy of Sciences), Madrid
Aug 28, 2009	University of Notre Dame
May 7, 2009	Fifth Structured Integrators Workshop, California Institute of Technology
Apr 9, 2009	University of California, San Diego
Nov 21, 2008	University of Cambridge
Jul 3, 2008	Progress in Electromagnetics Research Symposium (PIERS), Cambridge
Jun 17, 2008	University of California, San Diego
Apr 2, 2008	Everhart Lecture Series, California Institute of Technology
Mar 22, 2008	Pacific Coast Gravity Meeting (PCGM), University of California, Santa Barbara
Oct 11, 2007	University of Southern California
Aug 13, 2007	Workshop on Geometric Mechanics, Banff International Research Station (BIRS)
Jun 14, 2007 Jun 21, 2007 Aug 2, 2007	Three-Part Lecture Series on Geometric Discretization of Classical Physics, TAPIR Numerical Relativity Seminar, California Institute of Technology.
Apr 30, 2007	Third Structured Integrators Workshop, University of Southern California
Nov 13, 2006	Workshop on Geometry and Computer Graphics, Columbia University
Jul 30, 2006	Discrete Differential Geometry: An Applied Introduction, SIGGRAPH, Los Angeles

Research Supervision

Postdoctoral Advisor

2020–2022 Shuhao Cao
Current Position: Tenure-Track Assistant Professor, University of Missouri–Kansas City

2016–2019 Yakov Berchenko-Kogan
Current Position: Tenure-Track Assistant Professor, Florida Institute of Technology

Ph.D. Advisor

2024– Marston Xue

2023– Calvin Reedy

2021–2025 Sanah Suri
Thesis: *Functional Equivariance and Backward Error Analysis*
Current Position: Postdoctoral Fellow, University of California, Davis

2018–2022 Mary Barker
Thesis: *A Nonconforming Finite Element Method for the 2D Vector Laplacian*
Current Position: Teaching Assistant Professor, University of Minnesota Duluth

Undergraduate Research Advisor

2021–2022 Aidan Kelley (jointly co-advised with Xiang Tang)

2020–2021 Jiawei Hu

2016–2017 Zhengdao Chen

2015–2016 Alexander Tettenhorst
2013–2014 Evan Miller

Ph.D. Thesis Committee Member

2025– Swarup Dhar
2025 Boris Andrews (University of Oxford)
2025 Ty Easley
2024 Eric Pasewark
2023 Kiprian Berbatov (University of Manchester)
2023 Yanjie Zhong
2022 Bowei Zhao
2022 Joshua Covey
2020 Luis Garcia German
2016 Benjamin Passer
2015 Casey Boyett
2015 Matthew Wallace
2013 Kelly Bickel
2013 Timothy Chumley

Teaching Experience

Washington University in St. Louis

Spring 2025 MATH 450, *Numerical Methods for Differential Equations*
Fall 2024 MATH 449, *Numerical Applied Mathematics*
Spring 2024 MATH 5052, *Measure Theory & Functional Analysis II*
Fall 2023 MATH 5051, *Measure Theory & Functional Analysis I*
Spring 2023 MATH 4121, *Introduction to Lebesgue Integration*
Fall 2022 MATH 4111, *Introduction to Analysis*
Spring 2022 MATH 5052, *Measure Theory & Functional Analysis II*
Fall 2021 MATH 5051, *Measure Theory & Functional Analysis I*
Spring 2021 MATH 204, *Honors Mathematics II*
Fall 2020 MATH 203, *Honors Mathematics I*
MATH 598, *Mathematical Professional Development*
Spring 2020 MATH 308, *Mathematics for the Physical Sciences*
MATH 450, *Numerical Methods for Differential Equations*
Spring 2019 MATH 233, *Calculus III*
Fall 2018 MATH 547, *Geometric Mechanics*
Spring 2018 MATH 450, *Numerical Methods for Differential Equations*
Fall 2017 MATH 449, *Numerical Applied Mathematics*
MATH 456, *Topics in Financial Mathematics*
Spring 2017 MATH 217, *Differential Equations*
Spring 2016 MATH 450, *Numerical Methods for Differential Equations*
Fall 2015 MATH 449, *Numerical Applied Mathematics*

MATH 456, *Topics in Financial Mathematics*
Spring 2015 MATH 131, *Calculus I*
MATH 450, *Numerical Methods for Differential Equations*
Fall 2014 MATH 449, *Numerical Applied Mathematics*
Spring 2014 MATH 515, *Partial Differential Equations*
Fall 2013 MATH 456, *Topics in Financial Mathematics*
Spring 2013 MATH 5052, *Measure Theory & Functional Analysis II*
Fall 2012 MATH 5051, *Measure Theory & Functional Analysis I*

University of California, San Diego

Spring 2012 MATH 10B, *Calculus II*
Winter 2012 MATH 142B, *Introduction to Analysis II*
Fall 2011 MATH 142A, *Introduction to Analysis I*
Spring 2011 MATH 20E, *Vector Calculus*
Winter 2011 MATH 20F, *Linear Algebra*
Fall 2010 MATH 10A, *Calculus I*

Academic Service

Departmental Service

2023– Director of Undergraduate Studies
Spring 2022 Interim Director of Undergraduate Studies
2021– Undergraduate Committee (Chair, Spring 2022 and 2023–)
2018–2019
2012–2015
2022– Executive Committee
2018–2019
2020– Computing Committee (Chair, 2014–2015 and 2020–2025)
2016–2019
2012–2015
2021–2022 Building Committee
2020–2021 Flexible Teaching and Seminars Committee (Chair)
2019–2021 Tenure-Track Search Committee (Chair, 2020–2021)
2019–2020 Postdoc Search Committee (Chair, 2015–2016 and 2019–2020)
2014–2016
2015–2019 Web Site Committee (Chair)
2013–2014 Math Club, Faculty Supervisor
2013–2015 Calculus Committee

School and University Service

2024–2025 "Literacies for Life and Career" Pilot Instructor
2023–2024 Academic Integrity Working Group on Grade Penalties
2017–2018 Advisory Group on IT Resources for Teaching and Learning

Other WashU Service

2022 Mathematical Contest in Modeling, Faculty Advisor

Workshops Organized

2027 *Structure Preserving Methods for Computational Geometric Mechanics*
Oberwolfach

2026 *Geometric Integration and Computational Mechanics*
FoCM'26, Vienna

2025 *Numerical PDEs and Geometry*
AMS Fall Central Sectional Meeting, St. Louis

2025 *DEC/FEEC: Discrete and Finite Element Exterior Calculus*
SIAM CSE25, Fort Worth

2023 *Exterior Calculus in Numerical Computing, Modeling, and Simulation*
SIAM CSE23, Amsterdam

2019 *Geometry and Structure Preservation in Numerical Differential Equations*
SciCADE, Innsbruck

Editorial Boards

2025– Associate Editor, *Foundations of Computational Mathematics*
2023– Associate Editor, *Geometric Mechanics*
2022– Associate Editor *International Journal of Numerical Analysis and Modeling*
2020–2023 Associate Editor, *Journal of Geometric Mechanics*

Peer Review

Acta Applicandae Mathematicae (Springer)
Advances in Computational Mathematics (Springer)
Applied Mathematics and Computation (Elsevier)
Applied Mathematics Letters (Elsevier)
Applied Numerical Mathematics (Elsevier)
BIT Numerical Mathematics (Springer)
Chinese Physics Letters (IOP)
Communications in Computational Physics (Global Science Press)
Communications in Mathematical Sciences (International Press)
Comptes Rendus Mecanique (Elsevier)
Computational and Applied Mathematics (Springer)
Computers and Mathematics with Applications (Elsevier)
Discrete and Continuous Dynamical Systems (AIMS)
Foundations of Computational Mathematics (Springer)
Games and Economic Behavior (Elsevier)
Geoscientific Model Development (Copernicus/EGU)
IMA Journal of Numerical Analysis (Oxford)
International Journal of Numerical Analysis and Modeling (Global Science Press)
Journal of Computational Dynamics (AIMS)
Journal of Computational Mathematics (Global Science Press)
Journal of Computational Physics (Elsevier)

Journal of the European Mathematical Society (EMS)
Journal of Geometric Mechanics (AIMS)
Journal of Nonlinear Science (Springer)
Journal of Physics A: Mathematical and Theoretical (IOP)
Mathematics of Computation (AMS)
Numerical Algorithms (Springer)
Numerische Mathematik (Springer)
Physics Letters A (Elsevier)
Proceedings of the London Mathematical Society (LMS/Wiley)
SIAM Journal on Applied Algebra and Geometry (SIAM)
SIAM Journal on Numerical Analysis (SIAM)
SIAM Journal on Scientific Computing (SIAM)
SMAI Journal of Computational Mathematics (SMAI)
Zeitschrift für Angewandte Mathematik und Physik (Birkhäuser)

Grant Review Panels

National Science Foundation
Simons Foundation

Professional Memberships

American Mathematical Society (AMS)
Society for Industrial and Applied Mathematics (SIAM)

Public Service Work on Mathematics of Redistricting

2017– Collaboration with MGGG Redistricting Lab (PI: Moon Duchin, Tufts)

2022 Public Testimony, Missouri House & Senate Independent Bipartisan Citizens Commissions and Missouri Judicial Redistricting Commission

2021–2022 Member of OPEN-Maps Faculty Working Group

2019 *Amicus Curiae*, *Rucho v. Common Cause*, Supreme Court of the United States

REBUTTAL EXPERT REPORT OF DR. ARI J. STERN

***Wise v. Missouri*, 2516-CV29597 (Circuit Court of Jackson County, Missouri)**

January 14, 2026

PX
22

I. Scope of Engagement

1. I have been asked by counsel to evaluate and respond to the Expert Report of Sean P. Trende, Ph.D. (the "Trende Report") and the Expert Report of M.V. Hood III (the "Hood Report"), with regard to the Missouri Congressional districts enacted in 2025 as H.B. 1 (the "Missouri FIRST Map"). In this response, I will also be referring to the contents of the Expert Report of Dr. Ari J. Stern (as amended on December 30, 2025) (the "Stern Report"), in which I previously presented my own analysis of the Missouri FIRST Map.

2. My qualifications and compensation are unchanged since the Stern Report. As before, my compensation does not depend in any way on the results of my analyses, the opinions I provide, or the outcome of this case.

II. Summary of Opinions

3. The Missouri FIRST Map is an extreme departure from historical Congressional maps in splitting the populations of Jackson County and of Kansas City. Maps going back decades kept over 87% of the Jackson County population and over 73% of the Kansas City population intact in a single district, CD5. The Missouri FIRST Map keeps under 52% of the Jackson County population and under 41% of the Kansas City population intact—and furthermore, places the largest intact populations of Jackson County and of Kansas City into separate districts.

4. The Trende Report and Hood Report compare the shapes of districts between different decades, different electoral offices, and different geographical regions, without regard for differences in natural boundaries, political subdivision boundaries, and other recognized redistricting criteria. These comparisons are incomplete at best and invalid at worst—especially so for Dr. Trende's comparison between the shapes of Congressional districts and those of

Missouri Senate and Missouri House districts, which differ in a variety of ways, including their number, size, population, and geography.

5. The ensemble used in the Stern Report contains a wide variety of both compact and non-compact maps, and is sufficiently diverse to include maps that resemble the Missouri FIRST Map. The algorithm I employ does not overweight compactness, nor does it have an adjustable compactness parameter as Dr. Trende claims. Nor do the conclusions of the Stern Report depend solely on the *proportion* of compact and non-compact maps in the ensemble; they also depend on the *magnitude* of compactness (and other) differences observed. Moreover, one may accept these conclusions without accepting Dr. Trende's straw-man standard that "requires the *most* compact map to be selected" (Trende Report at p. 27, emphasis original).

6. Additional ensemble analysis shows that the Missouri FIRST Map is extreme in the number of different counties it combines into CD5. Specifically, it combines portions of 15 different counties in CD5, compared to an ensemble median of 3, with less than 0.5% of ensemble maps being more extreme than this. The maps in the ensemble are much more likely to create a district that combines Jackson County only with neighboring counties, and much less likely to combine Jackson County with far-flung rural counties across the state. This rebuts Dr. Trende's claim that the ensemble "make[s] similar choices" to the Missouri FIRST Map in combining urban and rural counties in this manner (Trende Report at p. 30).

III. Extreme Splitting of Jackson County and Kansas City Compared to Previous Maps

7. The Trende and Hood Reports both employ an overly simplistic approach to measuring county and municipal splitting that understates the extreme splitting in the Missouri FIRST Map, especially in Jackson County and Kansas City. For instance, they note *whether* a county is split, and sometimes the *number* of splits—but fail to distinguish between splits that

keep the vast majority of the county population intact, versus those that fracture the population into much smaller pieces. As I emphasized in my previous report, "The latter is far more problematic from the perspective of maintaining the closely united territory that comprises a county and its residents." (Stern Report at p. 12).

8. Dr. Trende asserts: "The split of Jackson County is also not entirely *sui generis*. It was split three ways in the 2022 map…. [It] was also split three ways in 1992 and 2002." (Trende Report at p. 21). Although the *number* of splits has precedent in these historical maps, the severe cracking of Jackson County population by these splits is in fact "*sui generis*."

9. Table 1 shows the percentage of Jackson County population in each of CD4, CD5, and CD6, based on Census total population data for the 1992, 2002, 2012, and 2022 Congressional districts (103rd, 108th, 113th, and 118th Congresses, respectively), alongside the same data for the Missouri FIRST Map districts enacted in 2025. I make this comparison going back to 1992, since this is the range of time mentioned in Dr. Trende's claim above.

10. From 1992 until the adoption of the Missouri FIRST Map, between 87–90% of the population of Jackson County was assigned to CD5, keeping this portion of the county population intact. Even in those maps with a three-way split of Jackson County, only a small fraction of the county population was split off into CD4 and/or CD6. The Missouri FIRST Map is an extreme departure from the precedent set by these historical boundary lines, with less than 52% of the Jackson County population assigned to CD5 and over 46% assigned to CD4. In other words: historical maps going back decades have consistently kept nearly 90% of the Jackson County population intact, while the Missouri FIRST Map keeps less than 52% intact.

Table 1: Percentage of Jackson County population in each Congressional district by year.

District	1992	2002	2012	2022	2025
4	3.87%	2.89%	–	10.83%	46.05%
5	89.88%	88.36%	88.20%	87.32%	51.71%
6	6.26%	8.76%	11.80%	1.85%	2.24%

11. Likewise, Table 2 shows the percentage of Kansas City population in each of CD4, CD5, and CD6 by year, revealing a similarly extreme departure from the historical maps. From 1992 until the adoption of the Missouri FIRST Map, between 73%–84% of the population of Kansas City was assigned to CD5, keeping a majority of the population intact, with virtually all of the remainder assigned to CD6. By dramatic contrast, the Missouri FIRST Map cracks the Kansas City population into three comparably-sized pieces, with no district containing a majority of the population. The largest intact portion of population plunges by more than half from 2022 (83.55% of the population in CD5) to 2025 (40.85% of the population in CD6). Among the previous maps where Kansas City was split three ways, only a negligible number of residents was assigned to CD4: 42 persons in 1992, 197 in 2012, and 104 in 2022. The Missouri FIRST Map splits off 126,008 Kansas City residents into CD4, an over-thousandfold increase.

Table 2: Percentage of Kansas City population in each Congressional district by year.

District	1992	2002	2012	2022	2025
4	0.01%	–	0.04%	0.02%	24.80%
5	78.41%	73.13%	74.99%	83.55%	34.35%
6	21.58%	26.87%	24.97%	16.43%	40.85%

12. In the 1992, 2002, 2012, and 2022 Congressional districts, as shown above, the vast majority of the Jackson County population was kept intact in a single district, and likewise for the Kansas City population. In fact, these (overlapping) populations were kept intact in the *same* district, CD5, maintaining the closely united territory both within and between Jackson

County and Kansas City. In the Missouri FIRST Map, not only are the largest intact portions of Jackson County population and Kansas City population each reduced, but these largest portions are in *separate* districts. Specifically, the largest portion of Jackson County population (51.71%) is in CD5, which has only 34.35% of the Kansas City population; the largest portion of Kansas City population (40.85%) is in CD6, which has only 2.24% of the Jackson County population. Thus, the Missouri FIRST Map vastly reduces the extent to which the districts maintain the historical unity of Jackson County and Kansas City in their Congressional representation.

IV. Response to Compactness Comparisons Between Different Geographies and Maps

13. Compactness is highly context-dependent and cannot be reduced to a single score or threshold. A shape that is acceptable for a district in one part of the state may be unacceptable for a district in another part of the state due to differences in natural geographic boundaries, political subdivision boundaries (such as counties, municipalities, VTDs, and the boundary of the state itself), historical district boundaries, population density, and geographic distribution. Even within a particular part of the state, a district shape might be considered sufficiently compact if it maintains "closely united territory" and meets other recognized redistricting criteria, but insufficiently compact if it fails to do so. Comparing compactness scores between districts, without this context, is incomplete at best and invalid at worst.

14. The Trende Report and Hood Report both rely on such questionable comparisons. As an example of comparing district shapes covering different geographical areas, Dr. Trende compares CD5 in the Missouri FIRST Map to CD6 in the same map, as well as to CD2, CD3, CD4, and CD6 in previous maps (Trende Report at pp. 17–18). Prof. Hood also compares CD4 and CD6 in the Missouri FIRST Map to CD8 in the same map (Hood Report at pp. 6–7), and he groups completely different districts into a "zone of similarity" based on their compactness

scores alone (Hood Report at pp. 8–9). Yet, one cannot conclude—as they do—that if the challenged districts score similarly on some compactness metrics to other districts, in this or previous maps, then that alone is sufficient to judge the districts comparably compact without any additional context.

15. Even more questionable is Dr. Trende's comparison between the shapes of Congressional districts and those of Missouri Senate and Missouri House districts, which he applies to CD5 in the Missouri FIRST Map (Trende Report at p. 18). In addition to covering different geographic regions across the state, Missouri Senate and (especially) Missouri House districts are far smaller and more numerous than Congressional districts—making it hard to see how such a comparison could illuminate anything about the Congressional map in question.

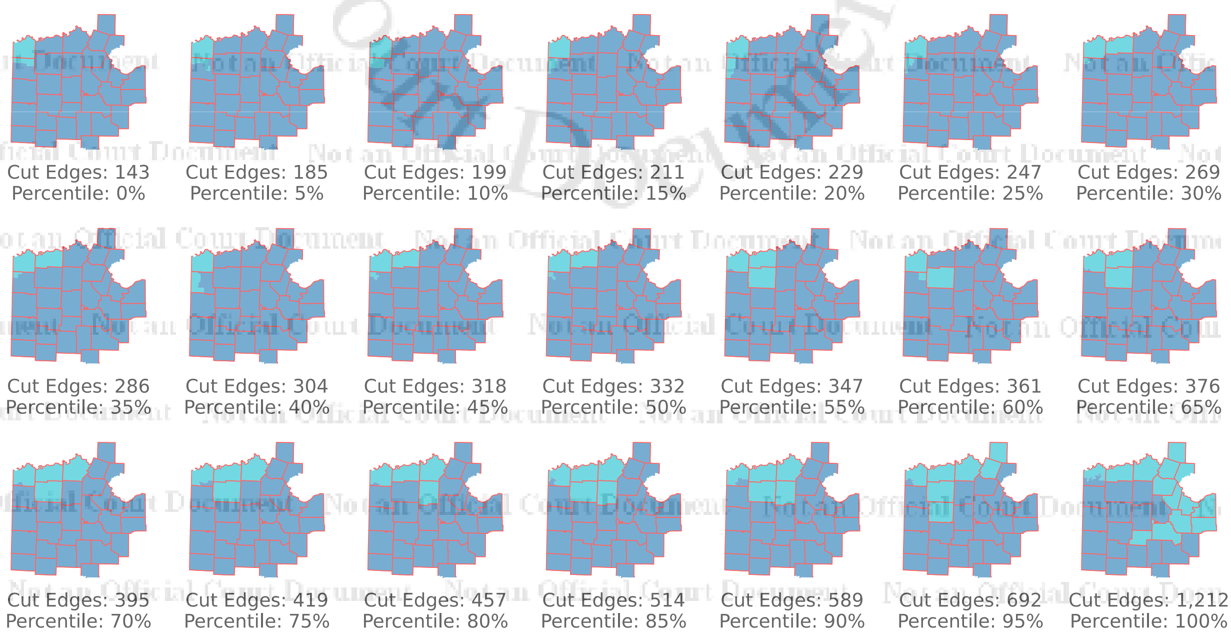
V. Response to Dr. Trende's Claims About Compactness of the Ensemble Maps

16. The Stern Report is based on an ensemble of 100,000 alternative maps that change only the CD4–CD5 boundary in the Missouri FIRST Map, while leaving the other 6 districts untouched. Dr. Trende criticizes the ensemble methodology on the grounds that this ensemble might not contain sufficiently many "conceptually different maps" (Trende Report at pp. 27–28), and that the ReCom algorithm producing these maps might naturally *overweight* compactness to such a degree that the ensemble reflects only a narrow range of compactness possibilities among "the universe of plans that are available to the map drawer." (Trende Report at p. 29). In this section, I respond to these criticisms.

17. Within the region covered by CD4 and CD5, the ensemble contains a wide variety of maps across the spectrum of compactness. Figure 1 illustrates the wide range of compactness observed in the ensemble maps according to the number of cut edges along the CD4–CD5

boundary.[1] The most compact maps with the fewest cut edges, starting in the top left, contain a district based tightly around Jackson County (shown in light blue). As the number of cut edges increases, compactness decreases, with the light blue district expanding further into neighboring counties. Eventually, in the least compact maps shown in the bottom row—and especially the bottom right—the districts sprawl and snake across numerous counties. For comparison, the Missouri FIRST Map cuts 792 edges along the CD4–CD5 boundary (percentile: 97.63%), placing it in between the least compact of the two maps in the bottom right of this figure (Stern Report at p. 22). Indeed, CD4 and CD5 in the Missouri FIRST Map visually resemble the districts in these last two maps more closely than the others.

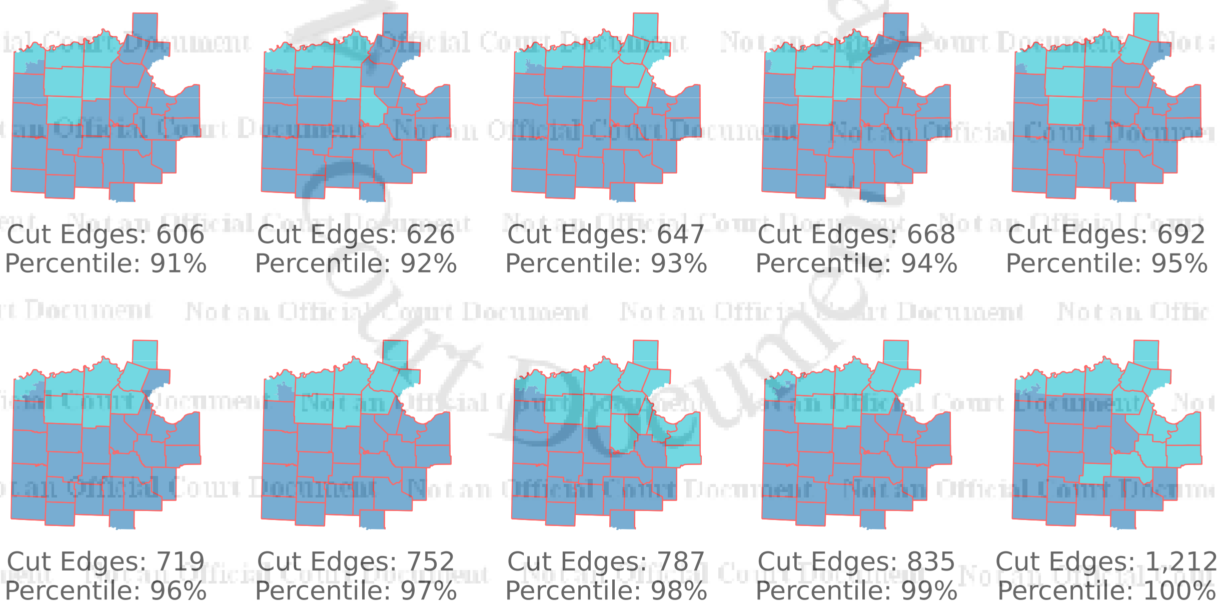
Figure 1: A sample of maps across the compactness range observed in the ensemble, according to the number of cut edges along the CD4–CD5 boundary, from the 0th percentile (fewest cut edges, most compact) in the top left to the 100th percentile (most cut edges, least compact) in the bottom right. Only the region covering CD4 and CD5 in the Missouri FIRST Map is shown, since the ensemble does not make changes to any other districts. County lines are shown in red.



[1] This metric, and its usefulness in measuring compactness, are described in paragraph 46 of the Stern Report.

18. Figure 2 focuses on the least compact 10% of maps in the ensemble, according to the cut edges metric, this time showing a sample map at every whole-number percentile level rather than every five. Again, we see considerable variety and range among these non-compact maps, which become less compact as the number of cut edges and percentile rank increase. CD4 and CD5 in the Missouri FIRST Map bear a close visual resemblance to the 98th percentile ensemble map shown here, which has a similar number of cut edges.[2] Clearly, the range of compactness is sufficiently broad to include maps as non-compact as the Missouri FIRST Map.

Figure 2: A sample of maps from the 91st–100th percentile in cut edges along the CD4–CD5 boundary, representing the least compact 10% of ensemble maps according to this metric.



19. Dr. Trende suggests that the ensemble may be giving excess weight to compactness (Trende Report at pp. 28–30), but it is impossible to overweight one redistricting factor without underweighting another, where there is some trade-off between the two. If the ensemble truly overweighted compactness, we would expect to see better compactness among

[2] More precisely, this "98th percentile" map has a percentile score of 97.51%, rounded to the nearest whole-number percentile for display in the figure, which is slightly more compact than the Missouri FIRST Map at 97.63%.

the ensemble maps, but at the expense of *worse* performance on some other recognized redistricting criteria for which deviations from compactness are permissible. Yet, the Stern Report demonstrates that this is not the case: the Missouri FIRST Map is worse than the ensemble on compactness *and* other criteria that might explain deviations from compactness. These criteria include preservation of counties, municipalities, and VTDs; preservation of previous Congressional districts and current Missouri Senate districts; and allocation of Black Voting Age Population between CD4 and CD5.

20. Dr. Trende correctly notes that the ReCom algorithm used in *Gerrychain* has a natural preference for compact maps: it "does not *enforce* compactness, but it tends to avoid extreme or pathological district shapes." (Trende Report at p. 29, emphasis original). However, some context is needed to understand what this means and its bearing on the maps in question. Figure 3, reproduced from the original paper introducing ReCom,[3] shows what maps look like when produced by an algorithm that does not have this preference. The map shown at center, produced by an earlier algorithm called Flip that does not share ReCom's compactness properties, looks noisy and fractured—almost like television static. There is no meaningful sense in which such a map should be considered "available to the map drawer" (Trende Report at p. 29) in a redistricting context. Yet, perhaps counterintuitively, there is a far larger variety of such wild-looking maps than ordinary-looking maps resembling those a human map drawer might produce, so if one were to simply pick maps out of a hat uniformly, nearly all of them would contain extremely unusual districts like the Flip example below (DeFord, Duchin, and Solomon at p. 7). *These* are the "extreme or pathological" maps that ReCom naturally avoids, and by reducing their likelihood of being drawn, the ensemble actually better resembles the

[3] DeFord, D., Duchin, M., & Solomon, J. (2021). Recombination: A Family of Markov Chains for Redistricting. *Harvard Data Science Review*, *3*(1).

options available to a map drawer. As shown above, ReCom is plenty capable of drawing maps that resemble the Missouri FIRST Map.

Figure 3: A comparison between the pathological maps produced by the non-compactness-favoring Flip algorithm (center) and the more ordinary-looking maps produced by ReCom (right). Reproduced from DeFord, Duchin, and Solomon, Figure 1.

(a) Initial Partition (b) 1,000,000 Flip steps (c) 100 ReCom steps

21. Dr. Trende's statements about the compactness of ReCom ensembles (Trende Report at pp. 28–30) rely on work characterizing the original version of the algorithm, which draws maps using random spanning trees without regard to county lines. My ensemble does not use this plain-vanilla ReCom algorithm; it uses a "region-aware" variant of ReCom configured to avoid splitting counties. This means that it does not simply prefer geometrically compact plans in the spanning-tree sense; it gives additional weight to plans that keep counties together. There are surely geometrically-compact maps that split several counties between CD4 and CD5; the fact that the ensemble contains *no* such maps clearly shows that this factor is given sufficient weight, and that the algorithm is not simply valuing compactness above all. Indeed, my ensemble matches the Missouri FIRST Map in splitting only one county between CD4 and CD5 (Stern Report at p. 12), showing that the avoidance of county splits was weighed appropriately.

22. Dr. Trende states that "one *may* adjust the compactness parameter in ReCom upward or downward, so as to favor more- or less- compact districts." (Trende Report at p. 30,

emphasis original). This is incorrect: there is no such parameter. While there has been some recent research on so-called "Metropolized" variants of ReCom[4] that can target a more- or less-compact distribution of maps than the natural one, these variants essentially work by drawing ReCom maps as usual, then keeping or discarding them according to their compactness score. This is not part of the ReCom algorithm itself, however: it is an extra processing step that "weeds out" maps according to their compactness in order to hit an externally-imposed target. I do no such weeding-out and impose no such target. Interpreted literally, Dr. Trende's statement is false. Interpreted charitably, through the lens of recent research, it merely says that the Missouri FIRST Map might look better if I deliberately threw away the ensemble maps that make it look bad.[5]

23. Furthermore, the conclusions in the Stern Report are not based solely on the *proportion* of ensemble maps that outperform the Missouri FIRST Map on compactness (and population splitting, and other factors), but on the *magnitude* of this outperformance. For example, the CD4–CD5 boundary in the Missouri FIRST Map is over twice as long as the ensemble median, whether measured in miles or in cut edges (Stern Report at pp. 21–22). If one were to adjust the *relative* proportion of compact and non-compact maps, it would change the percentile scores—but it would not make the CD4–CD5 boundary in the Missouri FIRST Map any shorter in an *absolute* sense. There would still be many thousands of maps that are more compact in this regard than the Missouri FIRST Map by at least a factor of two.

24. Finally, Dr. Trende frequently resorts to a straw-man argument against a compactness standard no one is advancing: that the State is obligated to find *the* most compact map possible out of "millions or even billions of maps," and to change it the moment "more

[4] Autry, E., Carter, D., Herschlag, G. J., Hunter, Z., & Mattingly, J. C. (2023). Metropolized forest recombination for Monte Carlo sampling of graph partitions. *SIAM Journal on Applied Mathematics, 83*(4), 1366-1391.

[5] Calibrating an ensemble to match the enacted map's compactness *can* be useful for analyzing other properties of the map, such as race or partisanship, but is not useful if one is interested in analyzing compactness itself.

simulations and exploration … discover a more compact map" (Trende Report at p. 17); that "the Missouri Constitution requires the *most* compact map to be selected" (Trende Report at p. 27, emphasis original); that "to demonstrate that it is possible to generate a map that is even *more* compact than the Enacted Map" is invalidating (Trende Report at p. 27). Again, no one to my knowledge is making these claims—I certainly am not. The ensemble analysis does not merely show that a more compact map exists: it shows that there is an *abundance* of maps that are *substantially* more compact (both geometrically and in the "closely united territory" sense), and which also outperform the Missouri FIRST Map (often dramatically) on recognized redistricting criteria that would permit deviations from compactness. Within the ensemble, it is not merely possible to do better than the Missouri FIRST Map; it is difficult to do worse.

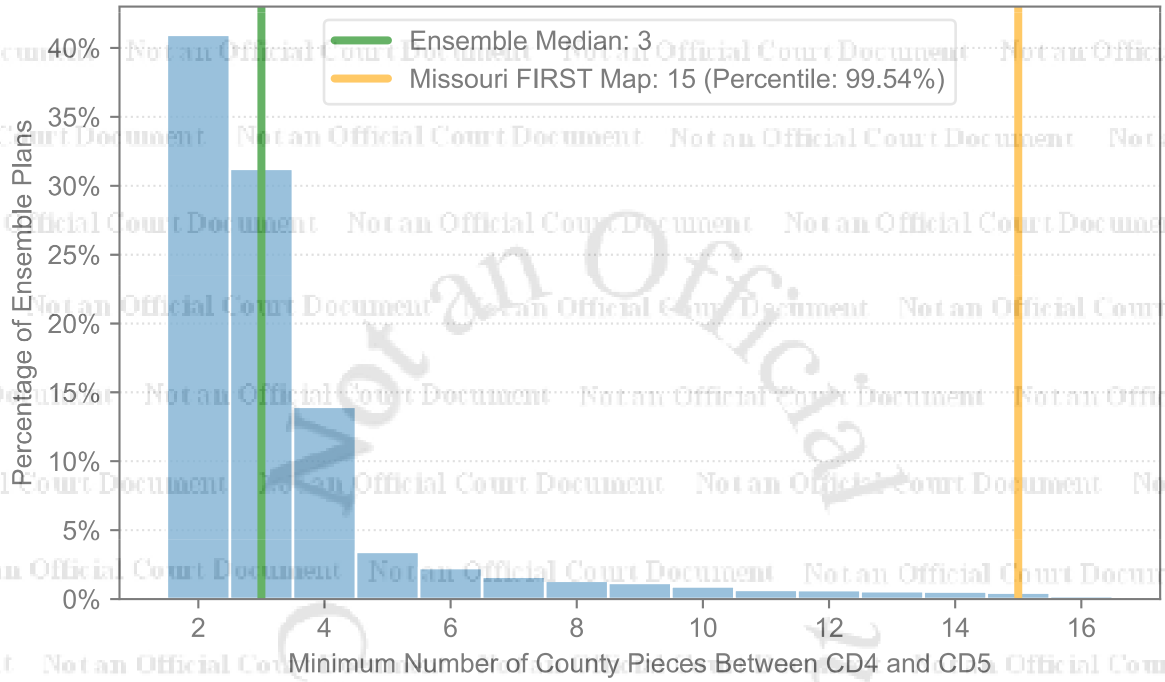
VI. Ensemble Analysis of Districts Combining Many Different Counties

25. Dr. Trende uses my ensemble to challenge a claim in Dr. Cromartie's report about "districts combining very different types of counties and extending into different metropolitan areas…. Dr. Stern demonstrates that even a computer drawing blindly to such considerations can make similar choices." (Trende Report at p. 30). As evidence, he points to one of my demonstration maps in which CD5 contains parts of 6 different counties. Setting aside the apparent contradiction between this statement of Dr. Trende's, and his previous claim that the ensemble maps are too laser-focused on compactness and thus insufficiently diverse, I will use ensemble analysis to examine the degree to which the Missouri FIRST Map is extreme in its combining of Jackson County with many different counties. As in the Stern Report, I will confine my attention to the region covered by CD4 and CD5, since that is the geography on which the ensemble is constructed.

26. For context, the Missouri FIRST Map contains 32 "county pieces" between CD4 and CD5: (i) two pieces of Jackson County, one in each district; (ii) pieces of two counties (Boone and Webster) that are not split between CD4 and CD5 but are split with other districts in the map; and (iii) 28 whole counties that are not split at all and lie entirely within CD4 or CD5. Of these 32 county pieces, there are 17 in CD4 and 15 in CD5 of the Missouri FIRST Map. By comparison, my demonstration map that Dr. Trende cites has 26 county pieces in CD4, with only 6 in CD5 (Stern Report at p. 57). In other words, the Missouri FIRST Map combines parts of more than twice as many counties in CD5 compared with my demonstration map. If these are "similar choices" in kind, then they are hardly similar in magnitude.

27. Figure 4 contains a histogram showing the number of county pieces in whichever district contains fewer of them, which would typically be labeled CD5. The ensemble median is only three counties, typically Jackson County and neighboring counties; over 40% of ensemble maps have just two, Jackson County and Cass County. *That* is the typical result of "a computer drawing blindly" (Trende Report at p. 30), i.e., without expressly distinguishing between rural and metro counties. Compared to the ensemble, the Missouri FIRST Map is especially extreme with 15 county pieces in CD5, corresponding to a percentile rank of 99.54%. Less than 0.5% of the ensemble maps are more extreme than this with a perfect 16–16 split of the 32 county pieces.

Figure 4: Histogram of the number of county pieces in whichever of the districts has fewer. In the ensemble, this typically consists only of Jackson County and neighboring counties, forming a compact district based around Jackson County and the Kansas City metro area. In the Missouri FIRST Map, CD5 combines Jackson County with 14 other counties across a sprawling territory.



VII. Response to Dr. Trende's Claims About Splitting of Missouri Senate Districts

28. My previous report showed that the Missouri FIRST Map "splits state senate districts between CD4 and CD5 a greater number of times, and more severely, than about 90% of ensemble maps … and thus it does not resemble a map for which 'align[ing] closely with the existing Missouri Senate Map' was indeed a priority." (Stern Report at p. 33). Indeed, the supposed goal of following Missouri Senate district lines appears to have been applied selectively in splitting Jackson County, but not elsewhere along the CD4–CD5 boundary.

29. Dr. Trende explains this selective following of Missouri Senate district lines within Jackson County, but not outside it, as follows:

> While the 2022 Map might split fewer districts *outside* of Jackson County, rural Missouri has large state senate districts that sprawl multiple counties; keeping

counties whole will often be at odds with avoiding senate district splits. (Trende Report at p. 31, emphasis original).

This last point is false, as the results in my previous report show. The ensemble maps avoid splitting counties along the CD4–CD5 boundary to the same extent the Missouri FIRST Map does—i.e., no more than one county split between CD4 and CD5—*and* 90% of them split fewer Missouri Senate districts (Stern Report at pp. 33–34). This is incompatible with the two factors being "at odds" (Trende Report at p. 31).

VIII. Additional Responses to the Hood Report

30. Prof. Hood mischaracterizes a law review article by Pildes and Niemi,[6] stating:

> There is also at least one academic article of note that suggests a cutoff point by which a district may be judged to be non-compact…. On two measures of compactness, Reock and Polsby-Popper, these scholars suggest numerical values whereby a district might be judged to be non-compact. For the Reock measure this value is less than .16 and for the Polsby-Popper measure this value is less than .06…. Using these specific metrics there is no evidence to categorize the challenged congressional districts as being non-compact. (Hood Report at p. 8).

In fact, Pildes and Niemi explicitly and repeatedly caution against such a misinterpretation and misuse of their work. These cutoffs are not a proposed legal standard, but merely a threshold for inclusion in a short table "listing the congressional districts whose [Reock] or [Polsby–Popper] score (or both) is relatively low. *In choosing the cutoff points used in Table 3, we do not imply that all districts below those points, or only those districts, are vulnerable …. The cutoff points in Table 3 are somewhat arbitrary*." (Pildes and Niemi at p. 564, emphasis added). They later repeat

[6] Pildes, R. H., & Niemi, R. G. (1993). Expressive Harms, "Bizarre Districts," and Voting Rights: Evaluating Election-District Appearances After Shaw v. Reno. *Michigan Law Review*, *92*(3), 483–587.

this statement about arbitrariness and adopt different cutoffs for a subsequent table (*id.* at p. 568). Elsewhere, Pildes and Niemi emphasize that "there is no bright line between compact and noncompact districts" and that comparisons between scores must be evaluated with additional context, including geographic differences (*id.* at p. 563 n.223).

31. The Hood Report employs three compactness metrics: Reock, Polsby–Popper, and (Alternate) Schwartzberg. However, it should be noted that the latter two scores measure the exact same relationship between a district's area and its perimeter: "Schwartzberg and Polsby–Popper assessments must rank districts from best to worst in precisely the same way."[7] (This is the "mathematical relationship between the Schwartzberg and Polsby–Popper scores" alluded to on p. 28 of the Stern Report.) As a (literal) reflection of this relationship, note that Figure 3 in the Hood Report is basically just Figure 2 turned upside down. Using both Polsby–Popper and Schwartzberg provides no additional analytical power over using just one of them, so the Hood Report really contains only two independent compactness metrics rather than three.

32. Finally, Prof. Hood makes a small error about my methodology when he states: "Professor Stern's expert report … also relies on Maptitude" (Hood Report at p. 5 n.9). Although my choice of compactness metrics was informed by those included in the *Maptitude* reports appearing in the Kincaid Memo,[8] I did not use the *Maptitude* software for any of my analysis. All of the compactness metrics appearing in the Stern Report were calculated using my own Python code, employing the *GeoPandas* geospatial-computing library.

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[7] Duchin, M. (2022). Explainer: Compactness, by the Numbers. In *Political Geometry*, eds. Duchin, M., & Walch, O., Birkhäuser/Springer, Cham, at p. 30.
[8] Adam Kincaid, *Memo to Representative Dirk Deaton, HB 1 Sponsor, re: The Missouri First Map* (Sept. 10, 2025).

* * *

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge. I reserve the right to revise, update, or supplement my opinions as new information becomes available to me.

Date: January 14, 2026

Dr. Ari J. Stern

Expert Report of Dr. Jonathan Cervas

Wise v. State, 2516-CV29597 (Circuit Court of Jackson County, Missouri)

Monday, December 22, 2025 (amended December 30, 2025)

I. Executive Summary

My name is Jonathan Cervas. I am an Assistant Teaching Professor at Carnegie Mellon University, where I teach courses in constitutional law, American politics, quantitative methods, and voting rights and representation. I was asked by counsel for the Plaintiffs in *Wise v. State* to analyze the congressional map enacted by the Missouri legislature in H.B. 1 (the "2025 Map").

Counsel informed me that Article III, Section 45 of the Missouri Constitution requires that congressional districts be "as compact . . . as may be." I was also informed that the Missouri Supreme Court has defined compactness to mean "closely united territory," which includes, but is not limited to, an assessment of the district's physical size and shape. *Pearson v. Koster*, 367 S.W.3d 36, 48 (Mo. banc 2012). I was informed that the Missouri Supreme Court has understood the compactness requirement to allow minimal or practical deviation from compactness necessary to comply with the constitutional requirements for congressional redistricting in the Article III, Section 45 of the Missouri Constitution, to comply with or resolve potential violations of the federal Voting Rights Act of 1965 or U.S. Constitution, or to abide by a set of redistricting factors recognized by Missouri courts (political subdivision boundaries, including counties, cities, and precincts; population density; natural boundary lines; and historical boundary lines of prior redistricting maps).

First, I was asked by counsel to determine whether the 2025 Map's reconfiguration of Congressional Districts (CDs) 4 and 5 is compact and whether the reduction in compactness of CDs 4 and 5 was a minimal or practical deviation necessary to comply with any of these other requirements or recognized factors. To answer these questions, I compare the 2025 Map to the 2022 Map and a set of eight alternative maps that I drew to satisfy all constitutional requirements and abide by recognized redistricting factors while avoiding the 2025 Map's departures from compactness in CDs 4 and 5. I conclude that CDs 4 and 5 in the 2025 Map are less compact than their counterparts in the 2022 Map and my alternative maps. The 2022 Map and my eight alternative maps show that such a reduction in the compactness of CDs 4 and 5 was not necessary to comply with any legal requirement or recognized redistricting factor in Missouri. My alternative maps demonstrate that the legislature could have *increased* the compactness of CDs 4 and 5 while achieving its apparent goals and complying with the relevant factors Missouri courts have recognized.

Second, Plaintiffs' counsel asked me to adjust three maps produced by another expert who used a computer algorithm to draw maps, in order to bring them into compliance with the constitutional requirement that district populations be equal. Equalizing population for such maps is a trivial task that requires minimal alteration of each simulated map, and does not meaningfully change their characteristics, including their levels of compactness.

Third, I was asked to determine whether the text of H.B. 1 clearly assigns each area of Missouri to a single congressional district in the 2025 Map. I found that it does not because the text double assigns a noncontiguous geographic area labeled "KC 811" to both CDs 4 and 5. This has the effect of making both districts malapportioned and CD 5 noncontiguous.

II. Qualifications

I am an Assistant Teaching Professor at Carnegie Mellon University (CMU). I currently teach courses for the Carnegie Mellon Institute for Strategy and Technology, which houses the university's undergraduate and master's degree-granting political science programs. I am also an uncompensated Research Associate of the non-profit Electoral Innovation Lab, which is affiliated with the non-partisan Princeton Gerrymandering Project at Princeton University.

I teach a wide range of courses at CMU, including U.S. Constitutional Law; the American Politics Graduate Seminar (also offered to undergraduates as Advanced Topics in American Politics); Regression Analysis for Political Science II (graduate); American Political Divides and Great Debates; Democracy's Data; and Representation and Voting Rights (formerly Representation and Redistricting).

Several of these courses emphasize applied analysis of democratic institutions and electoral systems. In Representation and Voting Rights, students learn how to design legally compliant legislative maps and rigorously evaluate them using statutory and constitutional criteria. In Democracy's Data, coursework focuses on hands-on quantitative analysis, including the evaluation of redistricting plans, surname analysis, racial polarization analysis, and related methods central to contemporary voting rights research.

I received my undergraduate degree at the University of Nevada Las Vegas and my graduate degrees at the University of California Irvine. My 2020 doctoral dissertation is titled "A Quantitative Assessment of the Electoral College, 1790-2020." As my curriculum vitae, attached as Appendix C, shows, I've published eleven peer-reviewed scholarly articles on topics related to political institutions, elections, redistricting, and voting rules. My work has been published in journals that specialize in political science, geography, economics, and law. These include the *Proceedings of the National Academy of Arts and Sciences*, *Presidential Studies Quarterly*, *Social Science Quarterly*, *Political Geography*, *Public Choice*, *Election Law Journal*, *Stanford Journal of Civil Rights & Civil Liberties*, and *PS: Political Science and Politics*. I have been invited to give talks to Princeton University, the University of Houston, and the National Conference of State Legislatures, and others. As part of my service commitment to the discipline of political science, I have served as a referee for the *American Journal of Political Science*, *Political Geography*, *Election Law Journal*, *Public Choice*, and *Political Research Quarterly*.

I have applied experience in redistricting, including recent work for state courts and redistricting commissions. In *Clarke v. Wisconsin Elections Commission* (Wisc. 2024), the Wisconsin Supreme Court appointed me and Dr. Bernard Grofman as co-consultants to assist in evaluating remedial State Senate and Assembly plans. Dr. Grofman and I evaluated the parties' proposed remedial redistricting plans and produced a report with recommendations to the court. The state later enacted one of the plans we evaluated.

In *Harkenrider v. Hochul* (N.Y. 2022), Justice Patrick McAllister of a New York Supreme Court (trial court) retained me as "special master to prepare and draw a new neutral, non-partisan Congressional map" upon ruling that the state's enacted plan was unconstitutional. In affirming that ruling, the New York Court of Appeals expanded my scope of work to include drawing a new, neutral redistricting plan for the State Senate. I prepared the congressional and senatorial maps, both of which were approved by the court and implemented in the 2022 election cycle.

In 2021, I was retained by the bipartisan Pennsylvania Legislative Reapportionment Commission to provide consulting services related to the Pennsylvania State House and Senate districts for elections held between 2022 and 2030. My work supported multiple aspects of the reapportionment process, including the development and evaluation of the legislative maps. The commission adopted the final maps by a bipartisan vote, and the Pennsylvania Supreme Court unanimously affirmed the plan in March 2022.

I have also assisted court-appointed special masters in federal redistricting matters, including *Wright v. Sumter County Board of Elections and Registration* (M.D. Ga. 2020), *Bethune-Hill v. Virginia State Board of Elections* (E.D. Va. 2019), and *Navajo Nation v. San Juan County, Utah* (D. Utah 2018).

I have also served as an expert witness in voting rights and redistricting litigation. In *New York Communities for Change v. Nassau County* (N.Y. 2025, Index No. 602316/2024), I served as an expert witness for the plaintiffs in challenge to Nassau County's redistricting map under the John R. Lewis Voting Rights Act of New York and the New York Municipal Home Rule Law. I produced two expert reports, was deposed, and provided testimony at trial. In *Wygant v. Lee* (Tenn. 2023, No. 22-0287-IV), I served as an expert witness for the plaintiffs in a case challenging the redistricting maps for the Tennessee General Assembly. I prepared an expert report, including alternative redistricting maps, was deposed, and testified at trial.

I am being compensated at a rate of $300 per hour. The opinions in this report are my own, and my compensation does not depend on the results of my analyses, the opinions I provide, or the outcome of the case.

III. Data Relied Upon

The primary data source I used for this report and analysis comes from the U.S. Census Bureau. I downloaded population data from the Census Bureau's Application Programming Interface (API) (which allows for data to be downloaded directly into statistical software). I also downloaded geographic data from the Census's "Tiger/Line" website. For my analysis of the 2025 Map, I re-created the district lines by identifying the VTD and Blocks listed in H.B. 1, and after it became available, downloaded the shapefile of the 2025 Map posted on the website of the Missouri

Office of Administration, Division of Budget & Planning.[1] The 2022 Map is available as part of the Tiger/Line dataset. I used other geographic data also obtained from Tiger/Line, including the VTD, Places, and Urban Areas geographies. I obtained an estimated list of addresses for incumbent members of Congress from counsel, which I identified where they lived using the Census Bureau's GeoCoder API.

I used Dave's Redistricting Application (DRA) as the source for the compactness scores reported in this report. DRA is a popular free, open-source web application for drawing and assessing redistricting maps. I have used this software to report these numbers in cases where I served as Special Master or Court Consultant. I computed other metrics, such as political subdivision splits and core retention, using the R statistical software. I created map images using the website mapshaper.org. I did not rely upon or reference any partisan or political data in assessing or drawing any maps.

IV. Compactness

The 2025 Map significantly reconfigures the districts that include the Kansas City area (CDs 4, 5, and 6), and most substantially alters CDs 4 and 5. This new configuration renders CDs 4 and 5 less compact than they were in the 2022 Map and far less compact than other lawful alternative maps the Legislature could have drawn. My comparative analysis of these maps shows that the 2025 Map's departure from compactness was not a minimal or practical deviation necessary to comply with any constitutional requirements, to adhere to recognized redistricting factors, or to comply with federal law. The Legislature could have achieved all these objectives without making CDs 4 and 5 less compact. Therefore, I conclude that CDs 4 and 5 in the 2025 Map are not as compact "as may be."

I begin with a comparison of the 2025 Map to the 2022 Map and the eight alternative maps I developed. **Figure 1** below provides a visual comparison of the boundaries of the 2025 Map, the 2022 Map, and my eight alternative maps. Full-page images of each map are found in Appendix A. Table 1 compares the 2025 Map, the 2022 Map, and my alternative illustrative maps along various features and metrics corresponding to constitutional requirements and recognized redistricting factors.

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[1] https://budplan.oa.mo.gov/redistricting-office/2025-us-congressional-house-maps

Figure 1 – Boundary Lines of 2022 Map, 2025 Map, and Alternative Maps

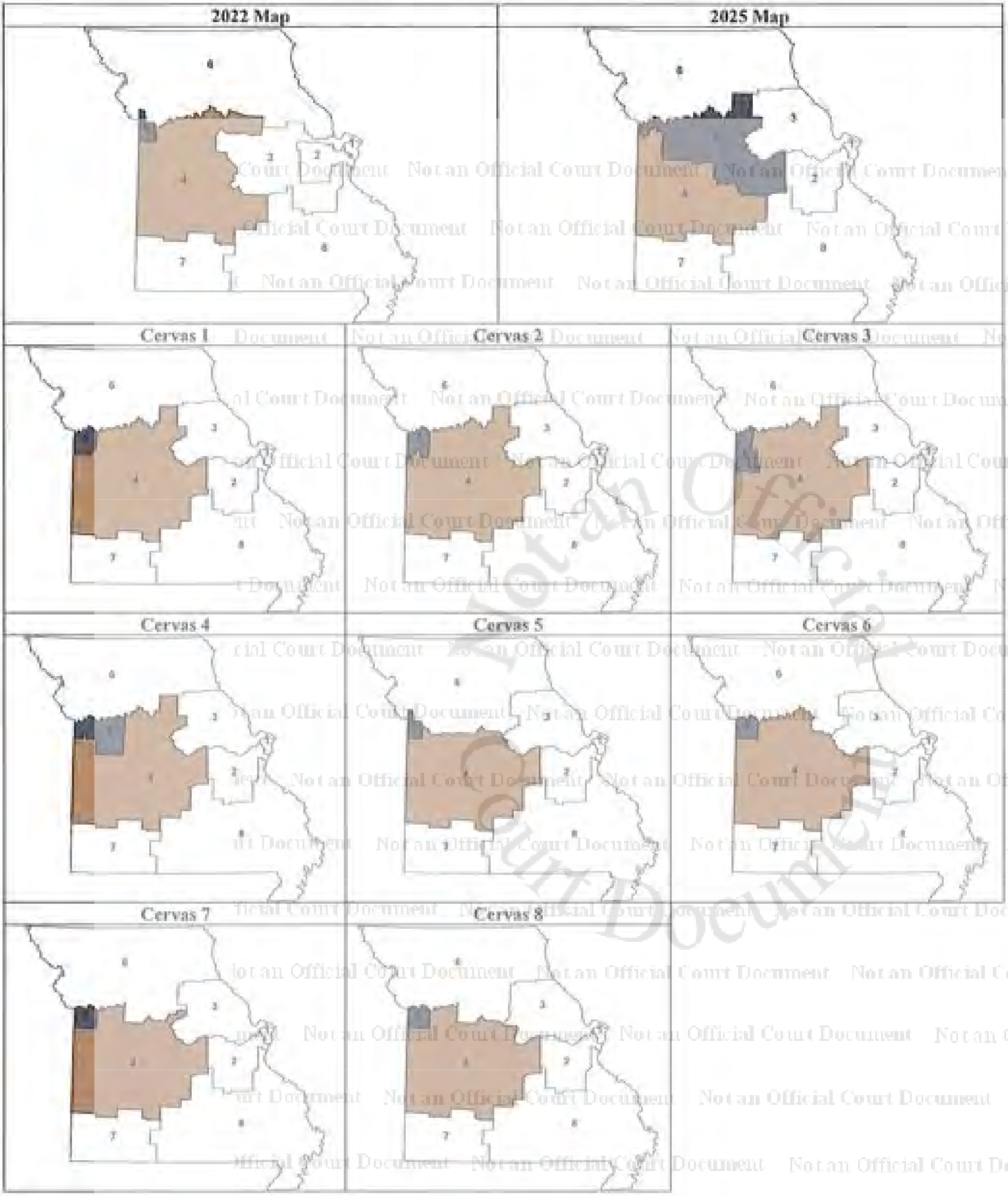

Table 1 – Metrics for 2022 Map, 2025 Map, and Alternative Maps

	2022 Map	2025 Map	Cervas 1	Cervas 2	Cervas 3	Cervas 4	Cervas 5	Cervas 6	Cervas 7	Cervas 8
Districts Altered from 2025 Map	—	—	4, 5	4, 5	4, 5	4, 5	4, 5, 6	4, 5, 6	4, 5, 6	3, 4, 5, 6
Compactness										
Reock (Map)	0.42	0.41	0.48	0.47	0.46	0.45	0.45	0.48	0.48	0.48
CD 4, 5 avg.	0.46	0.34	0.60	0.56	0.53	0.48	0.46	0.59	0.59	0.59
Polsby-Popper (Map)	0.31	0.35	0.40	0.38	0.38	0.37	0.39	0.42	0.41	0.42
CDs 4, 5 avg.	0.35	0.26	0.47	0.38	0.35	0.35	0.43	0.54	0.49	0.53
Equally Populated Districts	Y	N*	Y	Y	Y	Y	Y	Y	Y	Y
Contiguous Districts	Y	N*	Y	Y	Y	Y	Y	Y	Y	Y
Political Subdivision Splits										
# of Total County Splits	10	7	7	7	7	7	8	7	7	7
# of Counties Split	9	5	6	6	5	5	6	6	5	5
# of Total Municipal Splits	33	14	9	11	10	13	17	12	14	14
# of Municipalities Split	31	13	9	11	10	12	15	11	13	13
# of Precincts (VTDs) Split	43	42	26	28	33	25	32	26	26	25
Historical District Boundaries										
Core Preservation with 2012 Map (%)	80.7	72.6	78.4	78.4	77.4	78.9	78.3	79.4	79.8	79.8
Core Preservation with 2022 Map (%)	—	76.9	83.0	83.0	83.0	82.4	86.7	85.0	85.0	84.4

* H.B. 1's text enacting the 2025 Map does not technically define CDs 4 and 5 to be equally populated or define CD 5 to be contiguous because it assigns the noncontiguous geographic areas labeled "KC 811" to both districts. *See* Sec. VI. For the sake of this compactness analysis, I assume the 2025 Map reflects the shapefile available on the website of the Missouri Office of Administration, Division of Budget & Planning (https://budplan.oa.mo.gov/redistricting-office-2025-us-congressional-house-maps), which assigns the areas labeled "KC 811" to CDs 4 and 5 in a way that makes both districts equally populated and contiguous.

I begin with a summary of my alternative maps. It is important to note that I did not draw any alternative maps from scratch. Instead, I always used the 2025 Map as my starting point and tried to maximally preserve the lines the Legislature adopted in 2025 to give deference to its goals while improving compactness.[2] I made no changes to CDs 1, 2, 4, 7, or 8 in any map; this means 100% of the legislature's choices in these districts are reflected in all of my eight alternative maps.

The first four alternative maps modify only CDs 4 and 5. In Map 1, CD 5 is drawn as a compact district (square in shape), encompassing nearly all of Jackson County (excluding the small portion retained in untouched CD 6) and the northern part of Cass County. Map 2 is a variant of Map 1 in which CD 5 remains compact and includes the same portion of Jackson County but adjusts the Cass County configuration—excluding the Lake Winnebago area—to avoid pairing two incumbent congressmembers in CD 5.[3] Map 3 draws CD 5 as a compact district including western Jackson County (except the small part retained in CD 6) and all of Cass County.[4] Map 4 draws CD 5 to include nearly all of Jackson County (except the small part retained in CD 6) along with all of adjacent Lafayette and Johnson Counties. In all four of these maps, CD 4 unites the remaining compact territory comprising rural western Missouri.

The next three alternative maps modify CDs 4, 5, and 6 to produce districts that are more compact than the 2025 Map's districts. In Map 5, CD 5 is restored to its exact compact 2022 configuration, with CDs 4 and 6 redrawn into new more compact districts. Maps 6 and 7 each configure CD 5 as a small, compact square centered on all of Jackson County and a small portion of Clay County to the north. These maps differ only in which additional county is split to accommodate that configuration: Map 6 splits a small portion of Cooper County instead of splitting Jackson County twice (as the 2025 Map does). Map 6 also uses the Missouri River, a natural boundary, to nearly fully delineate the boundary between CDs 4 and 6. Map 7 splits Boone County twice rather than splitting Jackson County twice. Finally, Map 8 is a variant of Map 7 that also splits Boone County twice, while making minor adjustments to CD 3 to further improve compactness.

A. The 2025 Map's Compactness

Next, I assess the compactness of the 2025 Map, namely CDs 4 and 5, as compared to the 2022 Map and the alternative maps.

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[2] This is the general framework for creating remedial maps for courts, consistent with my experience.

[3] I received estimated incumbent addresses from Plaintiffs' counsel. There is no requirement that members of Congress reside in their districts. I nevertheless include compact alternative configurations of CDs 4 and 5 that avoid pairing incumbents, to the extent the legislature sought to do so.

[4] Incumbents who represent CDs 4 and 5 would both live in this version of CD 4.

I evaluate compactness using two quantitative measures recognized in academic literature and relied upon by courts: the Reock and Polsby-Popper scores. I have applied these measures in redistricting analyses for courts in New York and Wisconsin and have reported these metrics in my peer-reviewed academic work.

There are, of course, a wide range of mathematical measures of compactness that may be informative. I focus on Reock and Polby-Popper in this report because they are often used in the social sciences and because they capture different features of district shape.[5] Reock compares the area of a district to the smallest circle that can fully contain it, measuring how spread out the district is and penalizing districts that are elongated or sprawling. Polsby-Popper compares the area of a district to the length of its boundary, capturing the "smoothness" of boundaries and penalizing districts with more irregular boundaries. The Polsby-Popper score can needlessly penalize districts that follow the boundaries of inherently irregular features like river boundaries. Both scores range from 0 to 1, where 1 is most compact. Neither measure fully characterizes compactness standing alone, so they are most informative when considered together as part of a holistic assessment, including visual inspection.

There is also an important qualitative component to assessing compactness. This can be thought of as whether a district is "reasonably configured". This involves visually assessing the size, shape, and regularity of the district given natural boundaries, political subdivisions, and other territorial boundaries. Though my analysis of these factors is set out in more detail in the next section, that analysis informed my opinion here about whether CDs 4 and 5 depart from principles of compactness.

When assessing CDs 4 and 5 in the 2025 Map on both quantitative and qualitative measures, both are less compact than their counterparts in the 2022 Map and the alternative illustrative maps. Table 2 provides the Reock and Polsby-Popper scores map wide and for every district in the 2022 Map, 2025 Map, and my alternative maps. For the alternative maps, the districts altered from the 2025 Map are shaded light grey. A green up arrow (▲) indicates an increase in the relevant score compared to the 2025 Map, an equal sign (=) indicates no change, and a red down arrow (▼) indicates a decrease.

[5] Minor variation in mathematical scores that rely on district shape or perimeter can arise from differences in the underlying map projection or boundary shapefiles. These differences are unlikely to affect the overall conclusions, especially when paired with visual inspection, like I do here.

Table 2 – District-Level Reock & Polsby-Popper Scores

Reock	2022 Map	2025 Map	Cervas 1	Cervas 2	Cervas 3	Cervas 4	Cervas 5	Cervas 6	Cervas 7	Cervas 8
Mapwide Avg.	0.42	0.41	0.48 ▲	0.47 ▲	0.46 ▲	0.45 ▲	0.45 ▲	0.48 ▲	0.48 ▲	0.48 ▲
1	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
2	0.41	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
3	0.30	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36 =
4	0.51	0.39	0.56 ▲	0.56 ▲	0.55 ▲	0.52 ▲	0.49 ▲	0.53 ▲	0.52 ▲	0.52 ▲
5	0.42	0.29	0.63 ▲	0.56 ▲	0.52 ▲	0.45 ▲	0.42 ▲	0.65 ▲	0.65 ▲	0.65 ▲
6	0.25	0.28	0.28	0.28	0.28	0.28	0.33 ▲	0.30 ▲	0.31 ▲	0.31 ▲
7	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
8	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42

Polsby-Popper	2022 Map	2025 Map	Cervas 1	Cervas 2	Cervas 3	Cervas 4	Cervas 5	Cervas 6	Cervas 7	Cervas 8
Mapwide Avg.	0.31	0.35	0.40 ▲	0.38 ▲	0.38 ▲	0.37 ▲	0.39 ▲	0.42 ▲	0.41 ▲	0.42 ▲
1	0.31	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
2	0.29	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
3	0.15	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.36 ▲
4	0.30	0.33	0.37 ▲	0.35 ▲	0.32 ▼	0.32 ▼	0.47 ▲	0.45 ▲	0.36 ▲	0.43 ▲
5	0.40	0.20	0.57 ▲	0.41 ▲	0.38 ▲	0.38 ▲	0.40 ▲	0.62 ▲	0.62 ▲	0.62 ▲
6	0.28	0.32	0.32	0.32	0.32	0.32	0.32 =	0.29 ▼	0.32 =	0.33 ▲
7	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
8	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26

Compared to the 2022 Map, the average compactness of CDs 4 and 5 together dropped in the 2025 Map. As shown in **Table 2**, the 2025 Map reduced CD 5's Reock score from 0.51 to 0.39 and its Polsby-Popper score from 0.42 to 0.29. As for CD 4, the 2025 Map increased its Polsby-Popper score from 0.30 to 0.33 but significantly decreased its Reock score from 0.40 to 0.20. These measures confirm what is clear from looking at the maps. CD 5 went from a small, reasonably configured and regularly shaped district centered on Kansas City's urban core in 2022 to one in 2025 that begins in the central part of the state in Osage and Maries Counties, collects rural western Missouri and parts of Columbia before heading west until it snakes into Jackson County and urban Kansas City. CD 4 went from a district uniting rural western Missouri in 2022 to one in 2025 that splits this rural area in half and goes deep into urban Kansas City with a narrow tentacle. The 2025 Map made CDs 4 and 5 less compact than the 2022 Map.

The 2025 Map's CDs 4 and 5 are also far less compact than those in the alternative maps. **Figures 2 and 3** below display plots for both Polsby-Popper and Reock scores at the district level for each of my eight alternative maps, and the 2025 and 2022 baseline Maps (generated from the data in Table 2). The scores for each district are shown as gray circles. I symbolize CD 4 as a orange square and CD 5 as a blue diamond so that it is easy to identify where the districts rank in each of the plans. To compare the 2025 Map with the alternatives, I have added horizonal lines to show the 2025 CDs 4 and 5 scores.

These figures show that CDs 4 and 5 are always more compact or about as compact than they are in the 2025 Map. The Reock scores for CDs 4 and 5 in my eight alternative maps are all higher than those of the 2025 Map. The Polsby-Popper scores for CD 5 in all eight of my alternative maps are significantly higher than those of CD 5 in the 2025 Map. The Polsby-Popper scores for CD 4 are also higher than those of CD 4 in the 2025 Map in six of eight plans, and similar to the 2025 plan in the two other alternatives, Maps 3 and 4. It is noteworthy that increased compactness in CDs 4 and 5 is associated with an increase in the plan wide averages. The alternative plans all show how it's possible to increase or maintain the compactness of CDs 4 and 5 while also increasing the overall average compactness across all districts.

Figure 2 – Plot of District-Level Reock Scores by Map

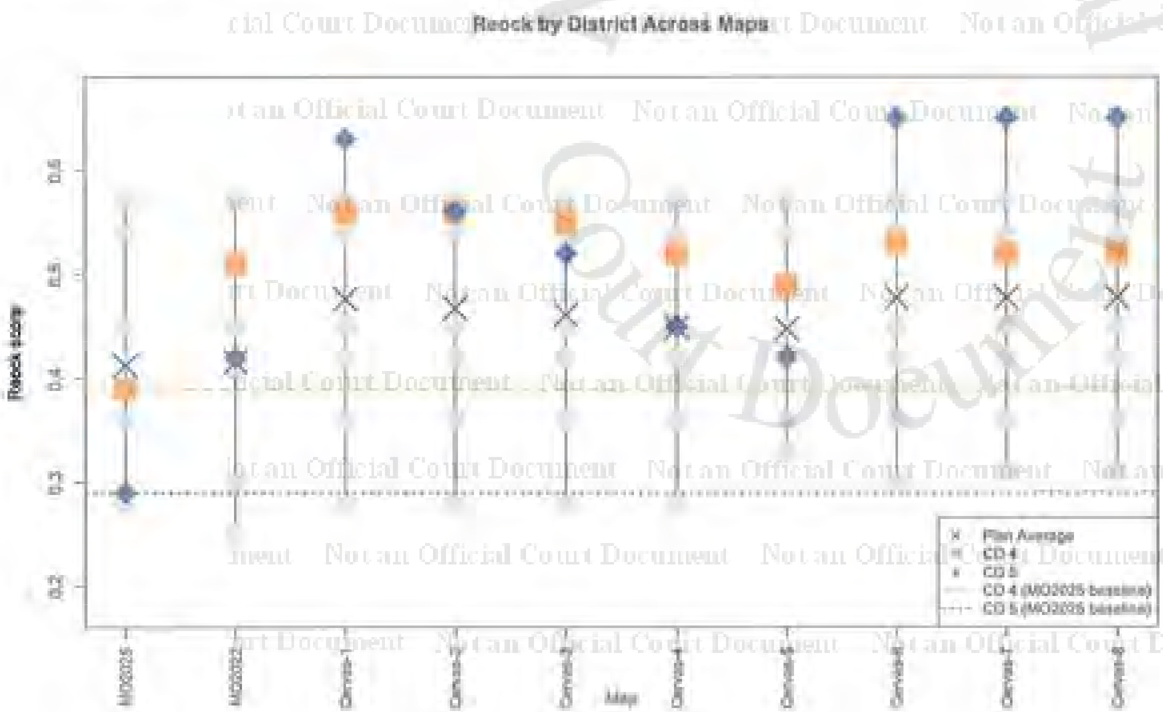
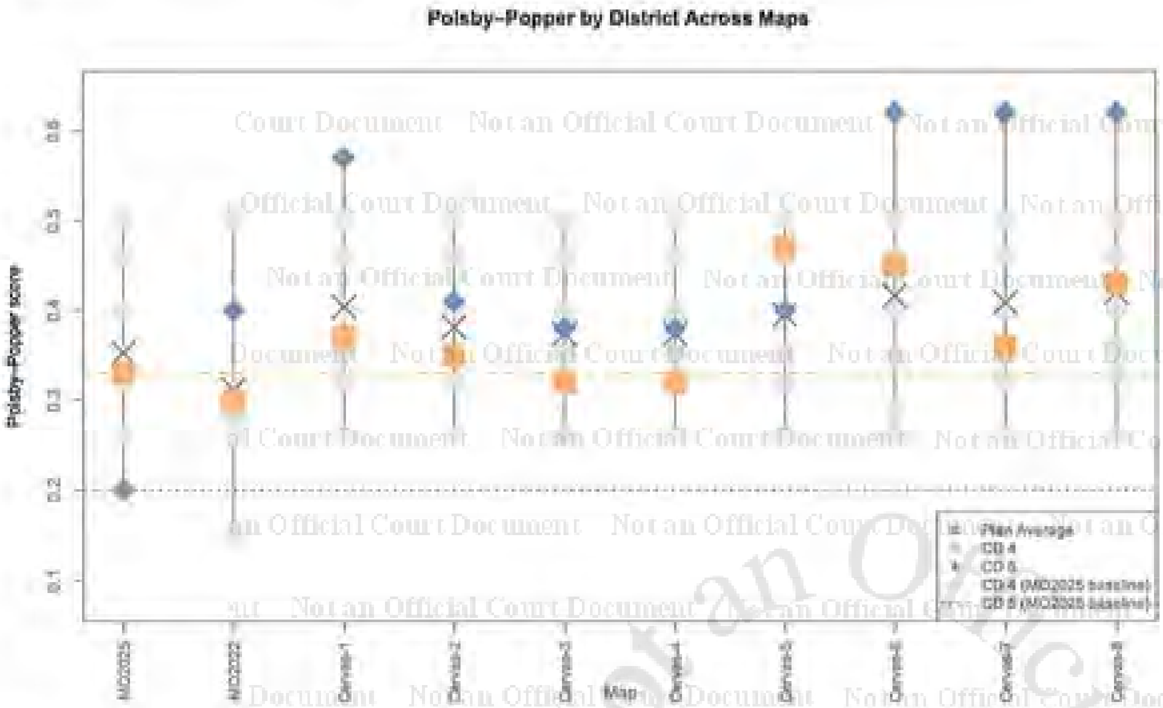


Figure 3 – Plot of District Level Polsby-Popper Scores by Map



The visual (inter-ocular) test corroborates what the data above demonstrates. In every alternative map, CD 5 is a relatively small compact district that includes the urban core of Jackson County and extends no farther than the immediately surrounding counties, while CD 4 is a compact rural district uniting rural areas in western Missouri. The 2025 Map departs from this compact configuration.

I conclude that the configuration of CDs 4 and 5 in the 2025 Map is not as compact as may be.

B. Whether the 2025 Map's Non-Compact CDs 4 and 5 Were Necessary to Comply with Constitutional Requirements, Federal Law, and Recognized Factors

Next, I assess whether the reduction in compactness of CDs 4 and 5 was a minimal or practical deviation necessary to achieve compliance with constitutional requirements, federal law, or other redistricting factors recognized by Missouri courts. For the reasons explained below, I conclude that it was not.

1. Equal Population

The Missouri and federal constitutions require congressional districts to be equally populated. There was no new census that happened between the passage of the 2022 Map and the 2025

Map, so the relevant population data is the 2020 decennial census. Missouri's 2020 census population was 6,154,913. Equal population among eight congressional districts requires seven districts to contain exactly 769,364 people and one district to contain exactly 769,365 people. The 2022 Map and all eight of my more compact alternative maps comply with this requirement. These maps show that the 2025 Map did not need to make CDs 4 and 5 less compact to comply with the equal population requirement.

2. Contiguity

The same is true of contiguity, which is also required by the Missouri Constitution. A district is generally considered contiguous if it is composed of adjacent territory. The 2022 Map is contiguous, as are all my more compact alternative maps. These maps show that it was not necessary to make CDs 4 and 5 in the 2025 Map less compact to comply with the contiguity requirement.

3. Compactness of Other Districts

Reducing the compactness of CDs 4 and 5 in the 2025 Map was not necessary to improve the compactness of other districts or the map as a whole. In my alternative Maps 1-4, only CDs 4 and 5 were modified, while all other districts remained unchanged from the legislature's preferred 2025 configuration. To the extent the legislature improved the compactness of those other districts in the 2025 Map, alternative Maps 1-4 show that the legislature could have increased (or at least avoided meaningfully decreasing) the compactness of CDs 4 and 5 while making its desired changes to all the other districts. Nor was any reduction in CD 5's compactness required to improve CD 4's compactness and vice versa. The alternative maps show that both districts can be made more compact simultaneously.

4. Federal Voting Rights Act of 1965

In the Governor's proclamation calling the General Assembly into special session, the Governor stated that "the State of Missouri's current congressional district map may be vulnerable to a legal challenge under the Voting Rights Act and the Fourteenth Amendment, due to a lack of compactness in certain districts."[6] It is unclear what was meant by this statement. I am not aware of any VRA analysis conducted by the legislature in redrawing the 2025 Map, nor did the legislature identify a particular district in the 2022 Map that it thought violated the VRA or was predominantly drawn based on race without sufficient justification under the Fourteenth Amendment.

[6] https://governor.mo.gov/proclamations/governor-kehoe-convenes-second-extraordinary-session-first-regular-session-one.

I understand that State officials have since indicated that this statement refers to St. Louis-based CD 1. However, this explanation does not align with the changes made to the map. For each district in the 2025 Map, I calculated the core retention rate, or the percentage of a previous district's population that remains within the new district's boundaries (see below for additional discussion). CD 1 had the highest level of core retention between the 2022 Map and the 2025 Map of all the districts that were altered. This means of all the districts changed, the legislature made the *fewest* changes to CD 1. Its demographic characteristics are also nearly the same as before. In any event, those minimal changes the legislature viewed as necessary in CD 1 could have been made without reducing the compactness of CDs 4 and 5 on the opposite side of the state, as all eight of my alternative maps (which do not alter the 2025 Map's version of CD 1) demonstrate. As a result, any changes made to CD 1 cannot explain the legislature's reduction in the compactness of CDs 4 and 5.

5. Political Subdivisions Boundaries: County Splits

One redistricting factor recognized by Missouri courts is respect for political subdivision boundaries, including counties. This is evaluated with two related but distinct measures: the number of counties that are split and the total number of county splits. The "number of counties split" counts only the number of counties divided between two or more congressional districts, regardless of how many times a county is divided. The "total number of county splits" counts every time a county is divided between districts. For example, a county divided between two districts has one county split, a county divided between three districts has two total county splits, and so on. I have explained to courts in prior engagements that the total number of county splits is the more informative metric because it reflects the actual number of times counties are crossed by district lines, and it cannot be manipulated by dividing just one county into many pieces.

The 2025 Map reduces county splits compared to the 2022 Map. Under the 2022 Map, nine counties were split, resulting in a total of 10 county splits. Under the 2025 Map, five counties are split between two districts, two of which (Jackson County and St. Louis County) are split among three districts, resulting in 5 counties split and a total of 7 county splits.

This reduction in the number of county splits does not require reducing the compactness of CDs 4 and 5. As shown in **Table 1** above, seven of my alternative maps—including Maps 1, 2, 3, 4, 6, 7, and 8—also achieve seven total county splits, matching the 2025 Map while drawing CDs 4 and 5 substantially more compact.[7] These maps show that the legislature could have achieved the same reduction in county splits without sacrificing compactness in CDs 4 and 5.

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[7] Only one alternative map, Map 5, has an additional county split, exceeding that of the 2025 Map. This is because Map 5 redraws CD 5 precisely as it appeared in the 2022 Map, which splits both Jackson and Clay Counties to keep more of the Kansas City urban area in a single district. These splits are in addition to the county splits that result

If the legislature's main objective were instead to minimize the number of counties split, that goal also cannot explain the less compact configuration of CDs 4 and 5 in the 2025 Map. My alternative Maps 3, 4, 7, and 8 reduce the number of counties split to five, equal to the 2025 Map, without sacrificing the compactness of CDs 4 and 5.

6. Political Subdivision Boundaries: Municipal Splits

Respect for municipal boundaries is another relevant redistricting consideration. I evaluate this factor by counting the number of municipalities[8] whose populations are split among multiple congressional districts.[9] As for counties, I include the number of municipalities that are split, as well as the total number of municipal splits.

My analysis shows that the substantial reduction in compactness of CDs 4 and 5 cannot be explained by and does not necessitate the number of municipalities split and the total number of municipal splits in the 2025 Map. The 2025 Map splits 13 municipalities and has a total of 14 municipal splits. As shown in **Table 1** above, seven of my alternative maps split as many or fewer municipalities and include as many or fewer total municipal splits than the 2025 Map while drawing CDs 4 and 5 to be far more compact.

7. Political Subdivision Boundaries: Precinct/VTD Splits

Avoiding precinct, or voting tabulation district (VTD), splits is also a relevant redistricting consideration. VTDs are analogous to "precincts"; they are the smallest units of geography created for purposes of election administration. As shown in **Table 1** above, all eight of my alternative maps split far fewer VTDs[10] (at least 9 less) while drawing CDs 4 and 5 to be far more compact than in the 2025 Plan. Thus, the legislature's reduction in compactness of those districts cannot be explained by an effort to avoid splitting VTDs.

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from the districts I left unchanged. My other alternative maps show that these additional splits can easily be eliminated.

[8] I use the term "municipalities" here as a catch-all for all legally incorporated cities, towns, and villages in Missouri. I determine where municipalities are located based on the Census Bureau's Places shapefile. I excluded census designated places (CDPs).

[9] Cities do not always align with counties or voting tabulation districts (VTDs). Some cities cross county boundaries, and others include small census blocks with no population. For this reason, I count a municipality as "split" only when its resident population is divided between two or more districts. If no people are affected by the split, I do not include it in my total. These zero-population splits do not affect representation and can often be adjusted without practical consequence. Regardless of the method used, however, the alternative maps perform as well as or better than the 2025 Map on this measure.

[10] See the previous footnote above about counting county and municipal splits with no resident population. The same method for counting applies for VTDs.

8. Population Density

Another factor that may be considered in drawing congressional districts is population density. But the 2025 Map's reduction in the compactness of CDs 4 and 5 cannot be explained by the legislature's attentiveness to population density because the 2025 Map disregards obvious population density patterns in western Missouri.

One common way to visualize population density is a dot density map, like the ones shown in **Figures 4** and 5 below. Each dot represents 100 people. Urbanized areas have a pattern of higher density, while rural areas exhibit lower density. **Figure 4** shows a dot density map with the boundaries of 2022 Map. It shows that the 2022 Map took population density into account by keeping areas with comparable population density patterns together in a district. **Figure 5** shows the same dot density map layered under the 2025 Map. It shows that the 2025 Map does not recognize population density patterns at all; it pairs dense urban areas with low-density rural areas, creating districts with large disparities in population density distribution.

Figure 4 – Population Density, 2022 Map

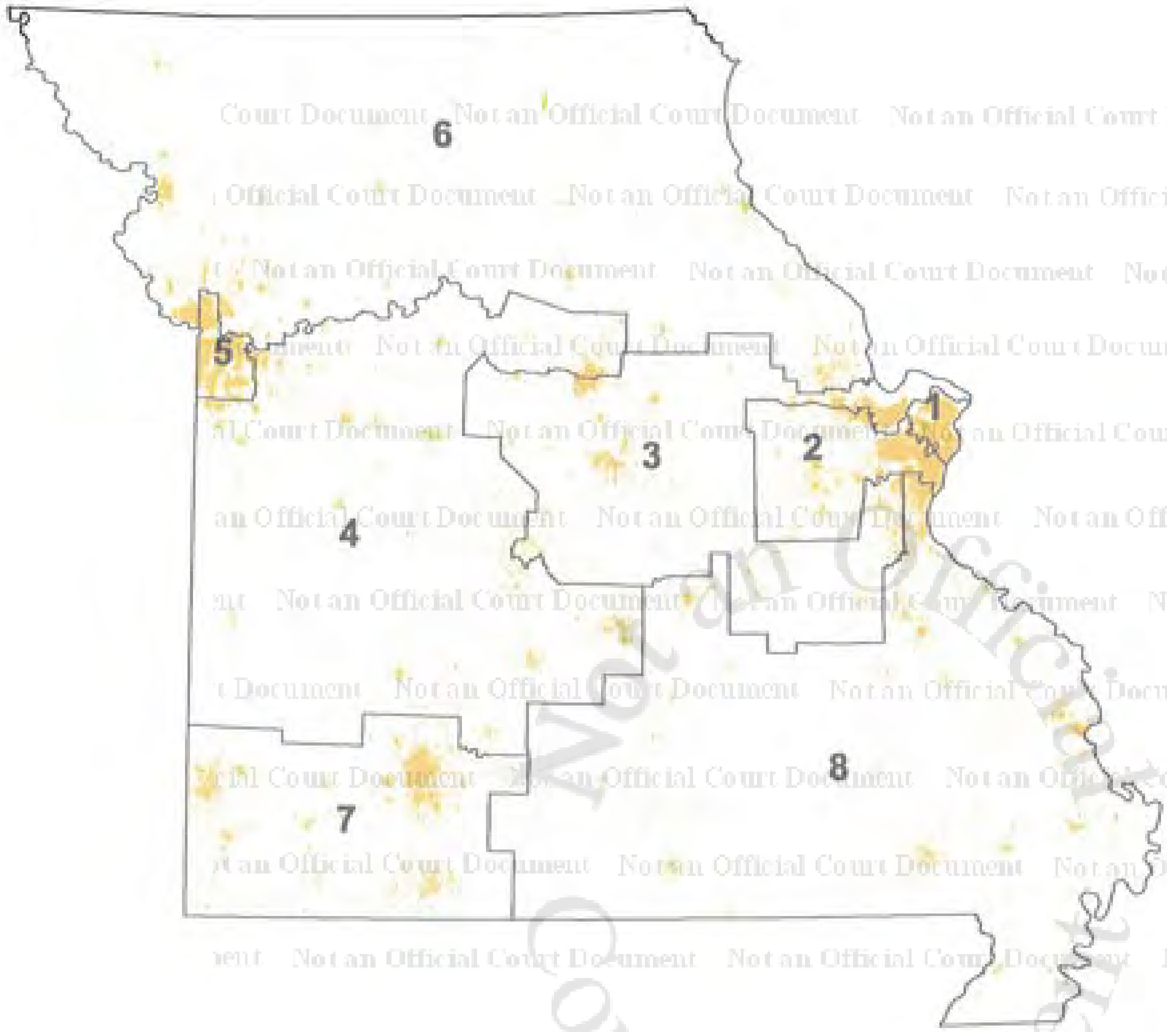
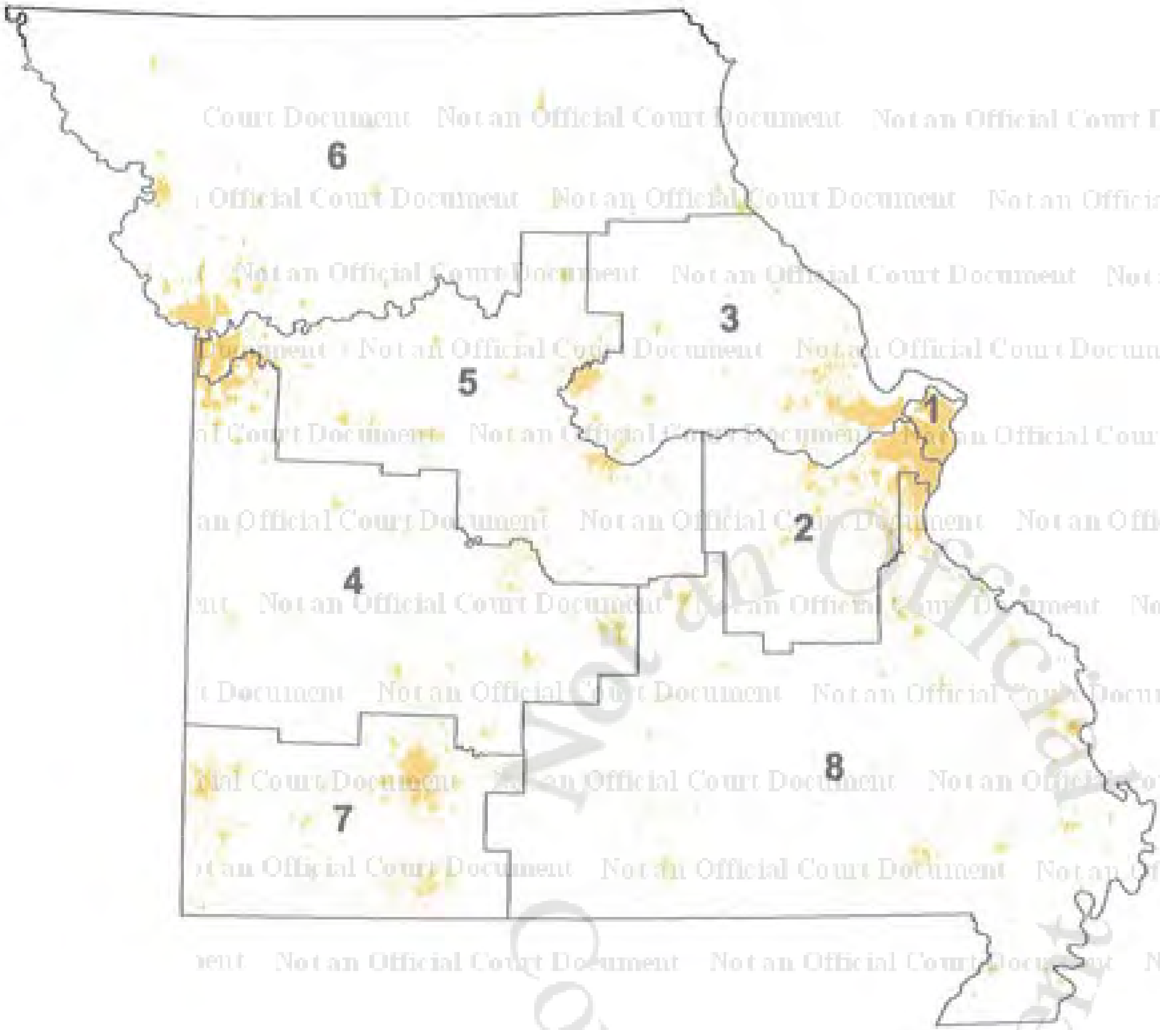


Figure 5 – Population Density, 2025 Map



Another way to assess whether districts account for population density patterns is to determine what percentage of a district population lies within an urban area, and what percentage lies in a rural area. The US Census identifies each block as either "Urban" or "Rural," based on the density of housing units.[11]

Table 3 below provides the percentage of the population in each district that lives in an urban area across the 2012, 2022, and 2025 Maps, as well as my alternative maps. It shows that CD 5 was an urban district in 2012 and 2022 but no longer in the 2025 Map. In 2022, for example, 98.7% of CD 5 residents lived in an urban area. In 2025, CD 5's urban population shrank to just 67%, not much more than the urban population of CD 4. My alternative maps maintain CD 5 as an urban district.

Table 3 – Percentage of District Population Who Live in an Urban Area

District	2012 Map	2022 Map	2025 Map	Cervas 1	Cervas 2	Cervas 3	Cervas 4	Cervas 5	Cervas 6	Cervas 7	Cervas 8
1	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6	99.6
2	98.4	87.3	77.6	77.6	77.6	77.6	77.6	77.6	77.6	77.6	77.6
3	61.4	64.8	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.4	74.1
4	48	46.7	63.8	35.8	36.3	37	41.3	44	41.1	40.4	40.6
5	91.4	98.7	67	95.1	94.6	93.9	89.5	98.7	96	96	96
6	61.4	51	65.6	65.6	65.6	65.6	65.6	53.7	59.5	60.1	60.3
7	62	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5
8	33.3	45	45	45	45	45	45	45	45	45	45

Figure 6 below overlays the 2022 Map's CD 4 and 5 boundaries on a map of the Census-designated urban areas in Missouri. **Figure 7** overlays the 2025 Map's CD 4 and 5 boundaries on the same urban area map. The same pattern emerges from this data: while the 2022 Map kept alike areas together, the 2025 Map cuts through urban areas, splitting closely united urban areas with rural areas in other parts of the state.

[11] See https://www2.census.gov/geo/pdfs/reference/ua/Census_UA_2020FAQs_Feb2023.pdf ("Urban areas represent densely developed territory, and encompass residential, commercial, and other nonresidential urban land uses"; "Urban areas are defined primarily based on housing unit density measured at the census block level.").

Figure 6 – Census-defined Urban Areas, 2022 Map

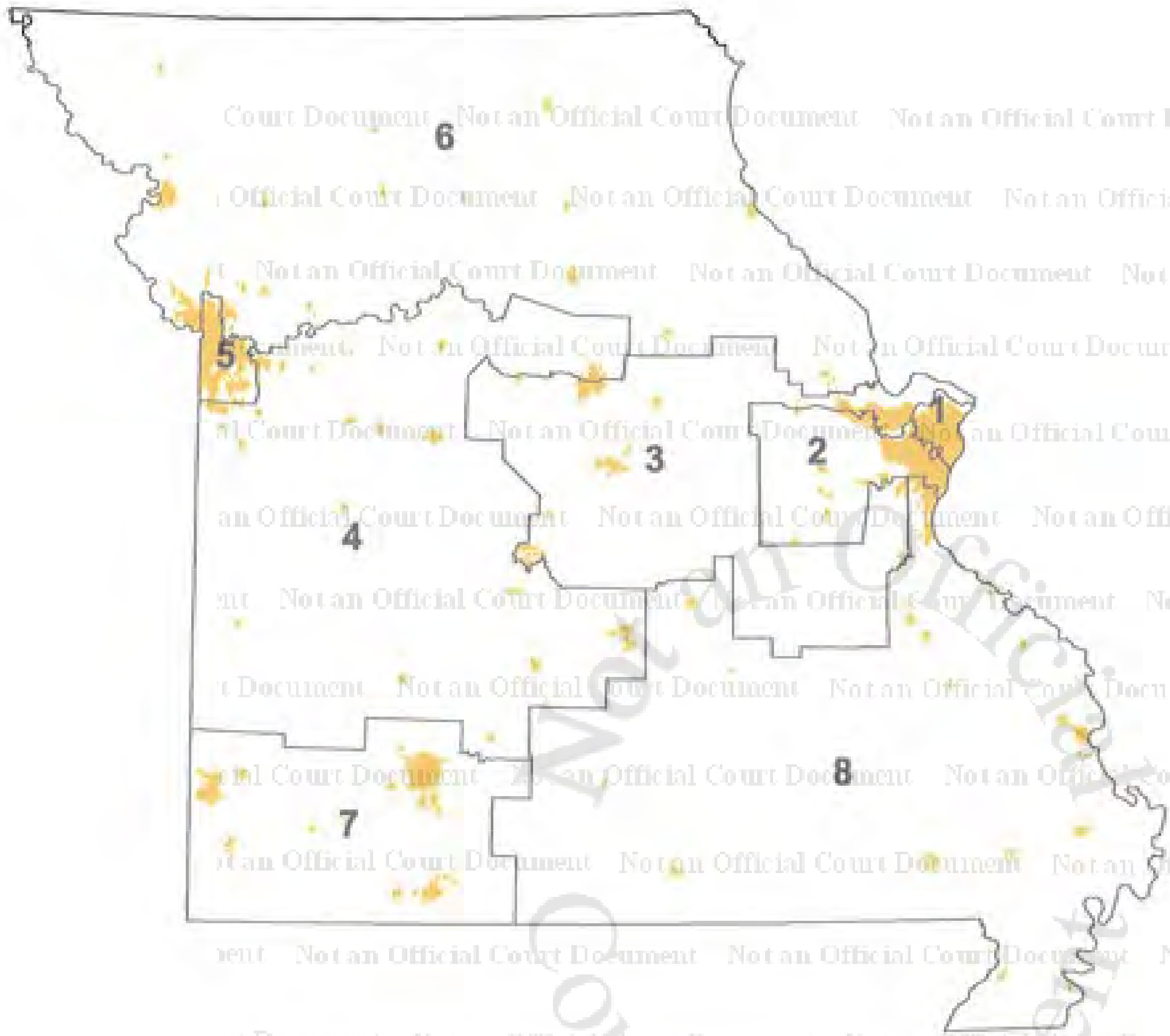
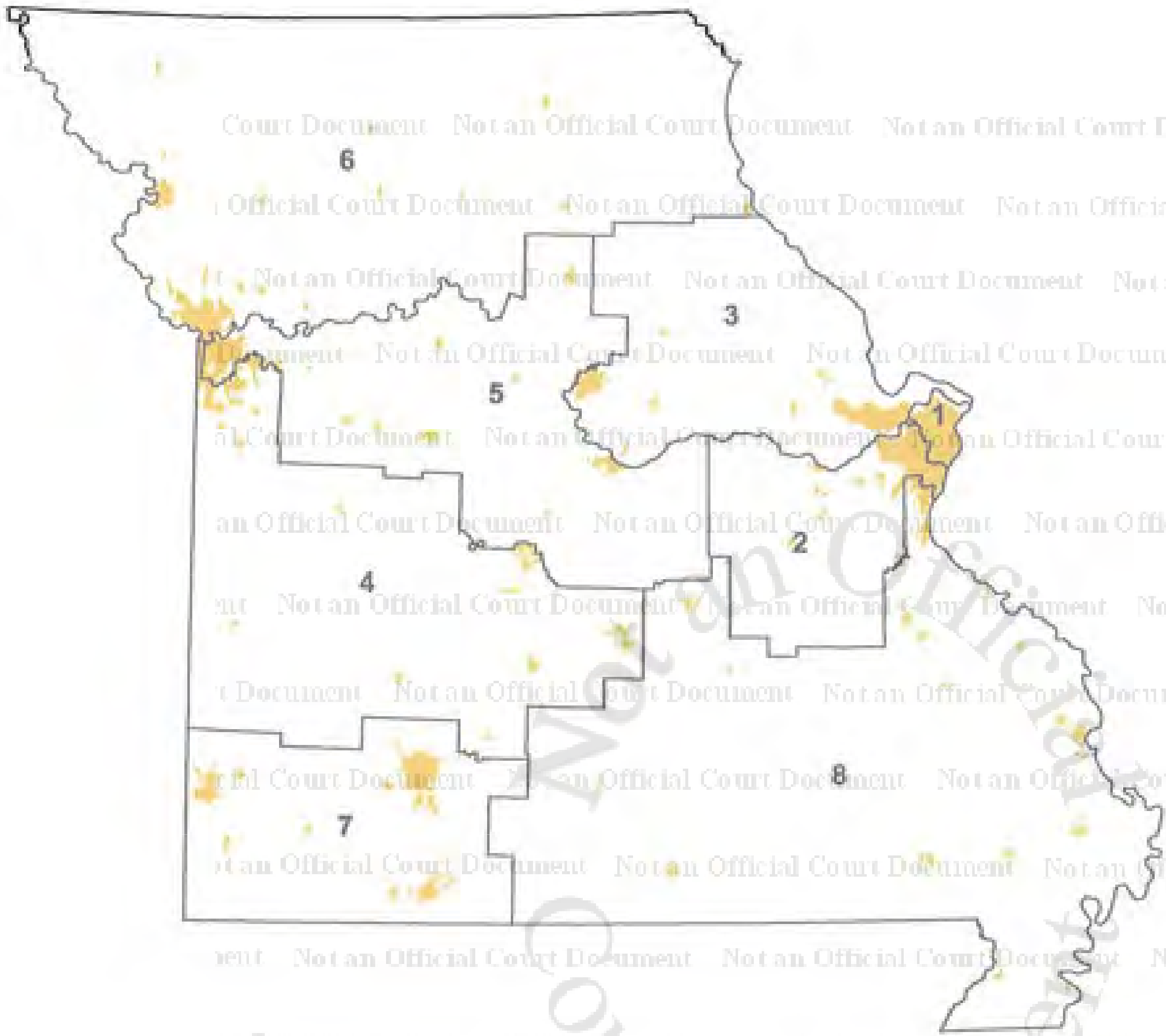


Figure 7 – Census-defined Urban Areas, 2025 Map



9. Natural Boundary Lines

The 2025 Map noticeably uses the Missouri River as a boundary between CDs 2 and 3, CDs 3 and 5, and CDs 5 and 6. But using the river as a natural district boundary does not necessitate the 2025 Map's substantial reduction in compactness of CDs 4 and 5. For example, my alternative Map 6 uses *more* of the Missouri River as a natural district boundary while making CDs 4 and 5 also more compact.

Figure 8 – 2025 Map and Cervas 6 (CD 6 River Boundary Highlighted)

2025 Map *Cervas 6*

10. Historical Boundary Lines

Another recognized redistricting factor is the extent to which a map respects historical boundary lines. This factor can be understood and measured by the core retention rate with previous congressional maps. As I note above, the core retention rate is the percentage of a previous district's population that remains within the new district's boundaries.

The most recent congressional map before the 2025 Map was the 2022 Map. Table 4 shows the 2025 Map's rate of core retention with 2022 Map for each district. It shows that the 2025 Map makes substantial changes to CDs 4 and 5, more than any other districts, in apparent disregard for those historical boundaries. Keep in mind that no population changes necessitated the 2025 redistricting. Both plans need to use the 2020 decennial census population numbers to satisfy 'one person, one vote' requirements.

Table 4 – Core Retention with 2022 Map

District	2025 Map	Cervas 1	Cervas 2	Cervas 3	Cervas 4	Cervas 5	Cervas 6	Cervas 7	Cervas 8
Map wide	76.9	83.0	83.0	83.0	82.4	86.7	85.0	85.0	84.4
1	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9	93.9
2	77.3	77.3	77.3	77.3	77.3	77.3	77.3	77.3	77.3
3	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	58
4	61.9	74	74	73.5	71.6	78.1	78.2	77.3	75.1
5	42.7	79.3	79.3	79.3	76.9	100	88.1	88.1	88.1
6	79.3	79.3	79.3	79.3	79.3	84.3	82.5	82.5	82.5
7	100	100	100	100	100	100	100	100	100
8	100	100	100	100	100	100	100	100	100

I also compare the 2025 and 2022 Maps' core retention with the prior decade's congressional map (the "2012 Map"). Although some changes are necessary to account for population growth and decline each decade, historical boundary lines and core retention are common considerations in drawing redistricting maps. Table 5 below shows the map wide and district-level core retention numbers between the 2022 and 2012 maps and between the 2025 and 2012 maps. It shows that the 2025 Map departs from the historical boundaries of CD 4 and 5 to a greater degree than the 2022 Map. It also shows that the most significant changes to the district cores were in CDs 4 and 5 and retain far less of the district cores than my alternative maps.

Table 5 – Core Retention with 2012 Map

District	2022 Map	2025 Map	Cervas 1	Cervas 2	Cervas 3	Cervas 4	Cervas 5	Cervas 6	Cervas 7	Cervas 8
Map wide	80.7	72.6	78.4	78.4	77.4	79.0	78.3	79.4	79.8	79.8
1	96.9	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7	97.7
2	70.5	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7	66.7
3	55.6	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5
4	75.8	49	68.3	68.3	63.2	70.1	68.3	68.3	71.3	71.3
5	82.7	51.4	77.9	77.9	74.4	79.7	82.7	86	86	86
6	81.5	83.4	83.4	83.4	83.4	83.4	77.5	82.9	82.9	82.9
7	96	96	96	96	96	96	96	96	96	96
8	89.1	89.1	89.1	89.1	89.1	89.1	89.1	89.1	89.1	89.1

Any reduction in the compactness of CDs 4 and 5 cannot be explained by an effort to pay respect to historical boundaries.

V. Equalizing Population of Simulated Maps

Plaintiffs' counsel asked me to adjust three maps produced by another expert using a computer algorithm. The algorithm is designed to produce maps which create districts nearly equal in population but may deviate slightly as they avoid splitting precincts. I adjust three of these maps to equalize the population of each district in the maps. I was provided the block assignment file for each map.

After making the population corrections to these three maps, each of the adjusted versions meet the requirements of equal population and contiguity. The impact on compactness and other metrics is either none or marginal. Images of the maps as provided to me and as adjusted are in Appendix B.

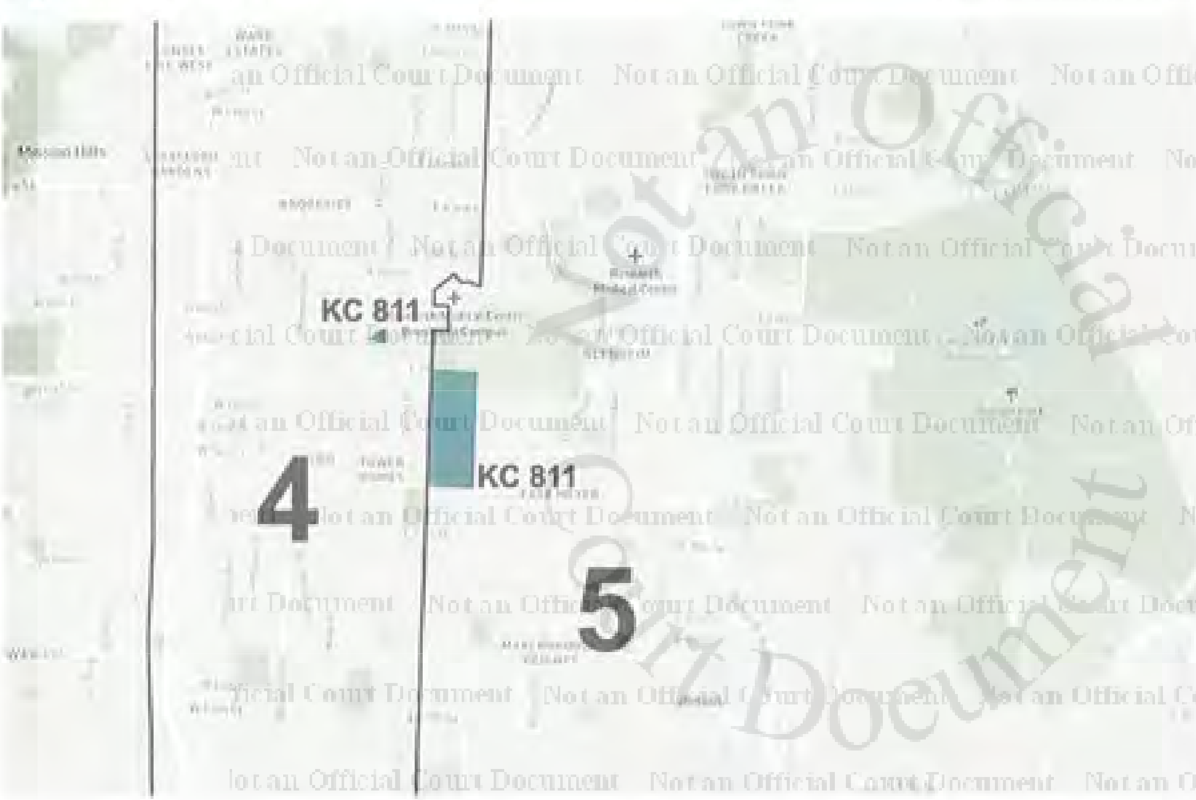
Table 6 – Simulation Map Metrics

Metric	map11029	Adjusted	map11163	Adjusted	map71871	Adjusted
Reock	0.43	0.43	0.46	0.46	0.45	0.45
Polsby-Popper	0.36	0.37	0.39	0.38	0.37	0.37
# of County Splits	7	7	7	7	7	7
# of Counties Split	6	6	6	6	5	5
# of Municipal Splits	14	15	12	12	14	14
# of Municipalities Split	14	14	12	12	13	13
# of Precincts Split	27	26	24	25	24	25
Core Retention ('12)	79.5%	79.5%	78.5%	78.4%	79.0%	78.9%

VI. H.B. 1's Legislative Text

Finally, I was asked to assess whether H.B. 1's legislative text provides clear guidance, as a technical matter, about which voting tabulation districts (VTDs) should be assigned to each district in the 2025 Map. When I reviewed the bill text prior to the state's release of a shapefile for the 2025 Map, I found that the bill's text does not provide clear guidance as to how to assign VTDs to congressional districts. Namely, H.B. 1's text assigns two VTDs, both named by the Census Bureau as "KC 811," to *both* CDs 4 and 5. *See* H.B. 1 at page 76 & 112.[12] As shown in Figure 9 below, these VTDs (depicted in teal) are not adjacent. The smaller VTD to the west has a population of 32, and the larger VTD to the east has a population of 843.

Figure 9 – KC 811 VTDs



In this circumstance, H.B. 1 should have either uniquely identified the VTDs or specified which census blocks comprising the VTDs belong in CD 4 and which belong in CD 5. Census blocks

[12] Available at: https://documents.house.mo.gov/billtracking/bills254/hlrbillspdf/7334H.01I.pdf.

are the smallest geographic unit at which census population is reported. Instead, H.B. 1 assigns every block in both KC 811 VTDs to *both* districts, leaving it to election officials' discretion where the voters who live in these VTDs will ultimately be assigned.

The double assignment of population in the VTDs named KC 811 renders both CDs 4 and 5 in the 2025 Map malapportioned. If the VTDs are assigned to CD 4, it has 843 more people than the ideal population of 769,364 and CD 5 has 843 too few people. If the VTDs are assigned to CD 5, then CD 5 has 32 people too many and CD 4 has 32 people too few.

Because these KC 811 VTDs are not contiguous, their assignment to CD 5 also renders CD 5 noncontiguous, as shown in Figure 9 above.

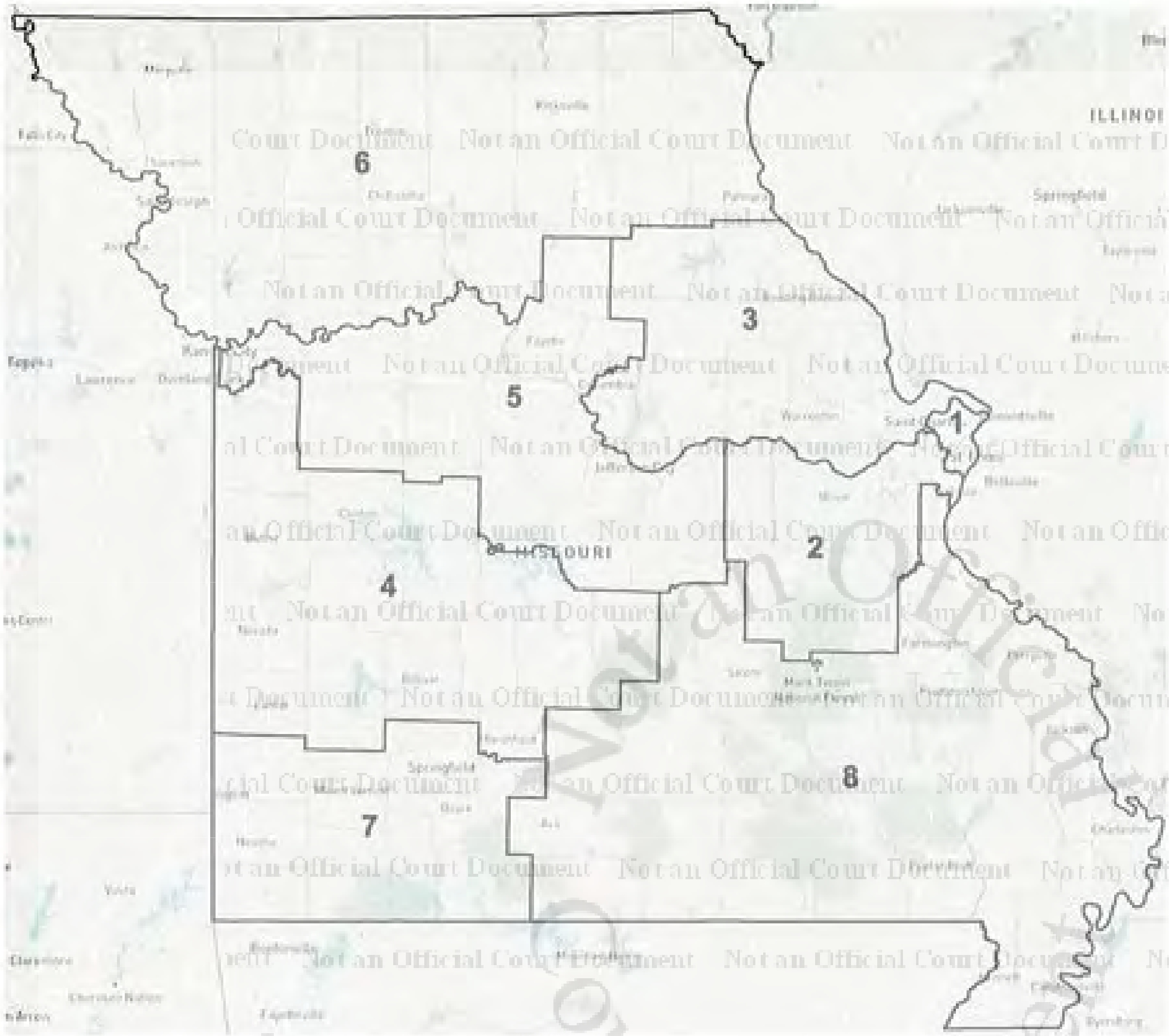
* * *

I declare under penalty of perjury that the foregoing is true and correct to the best of my knowledge. I reserve the right to revise, update, or supplement my opinions as new information becomes available to me.

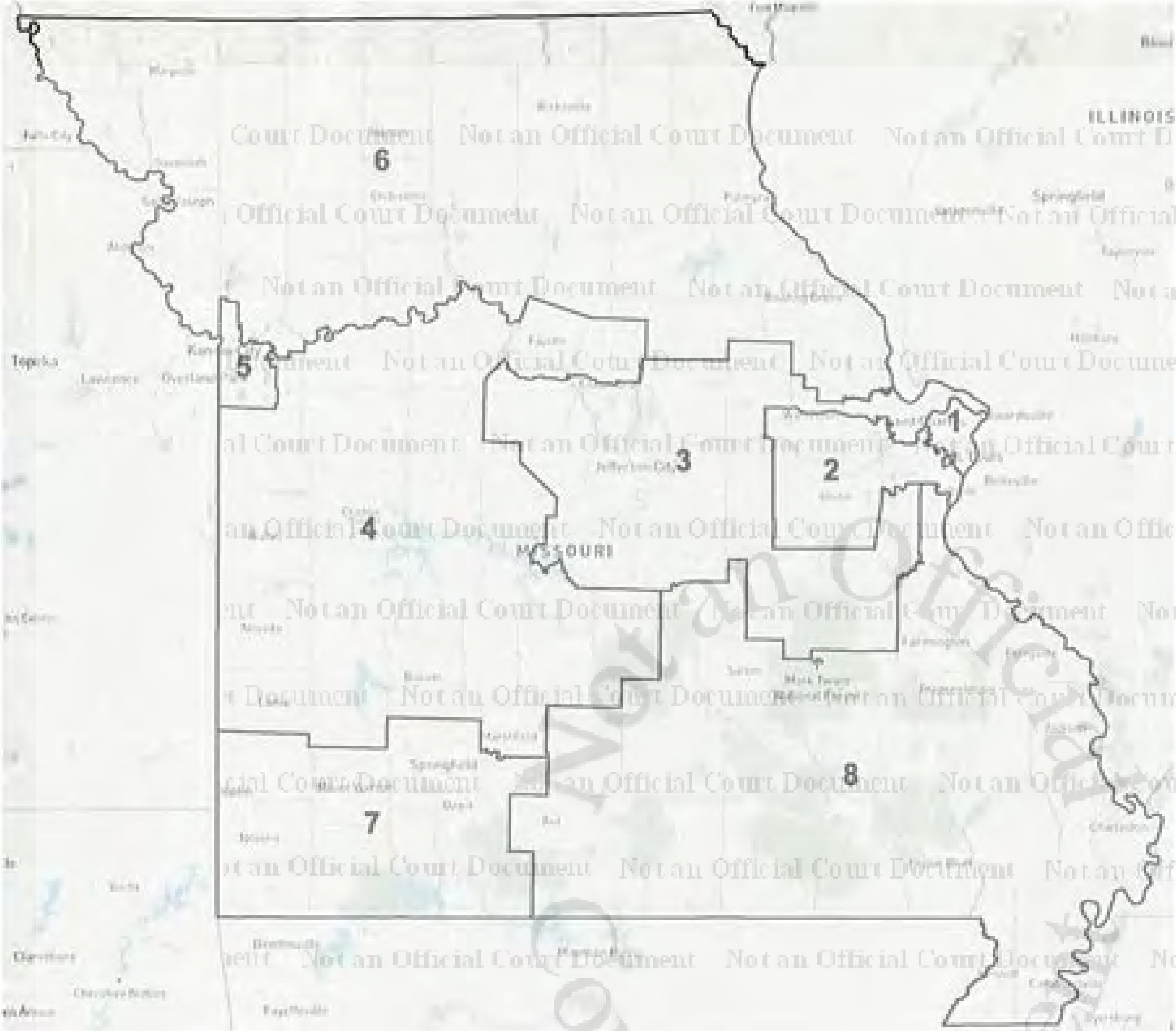
Dr. Jonathan Cervas

APPENDIX A

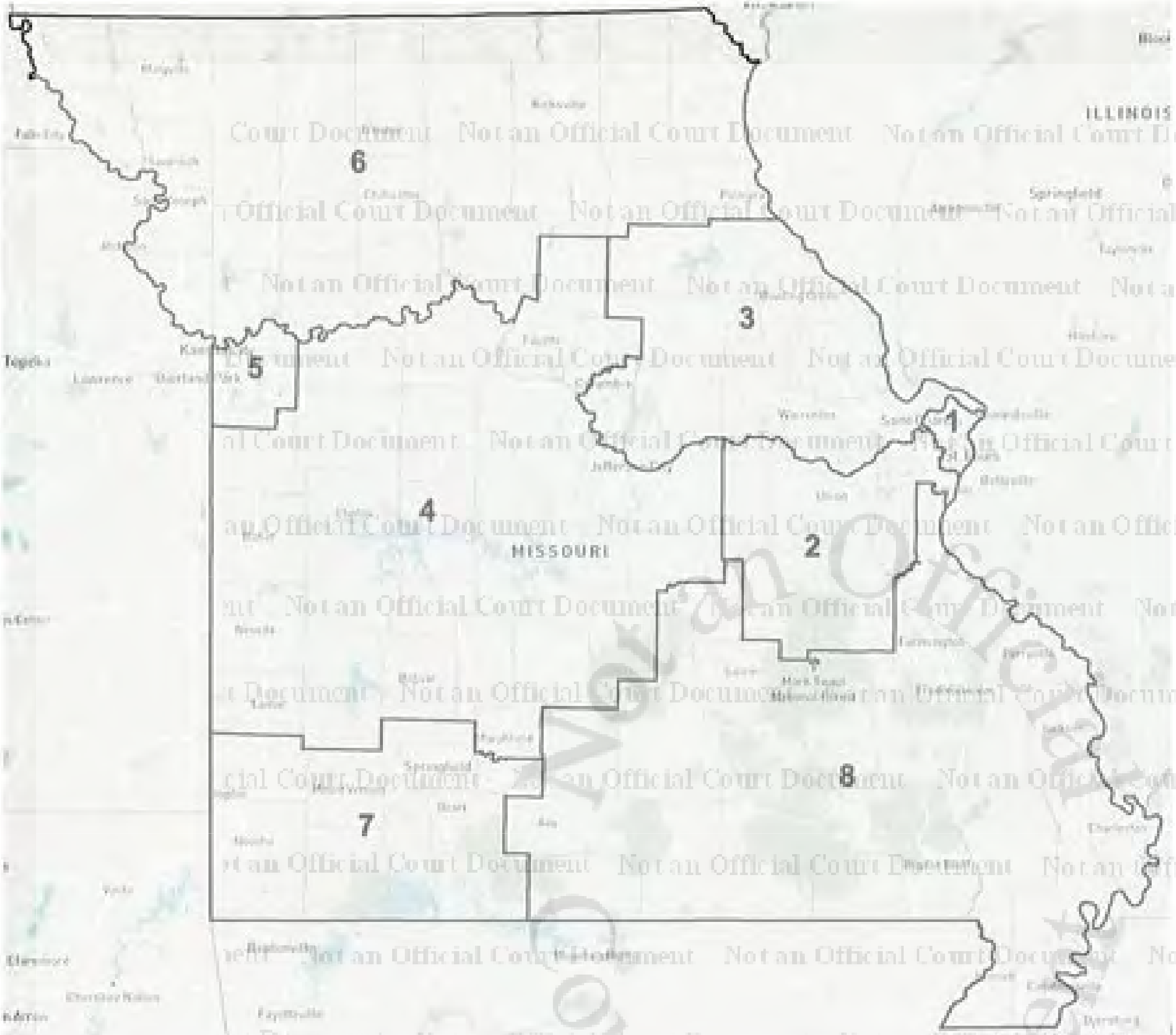
2025 Map



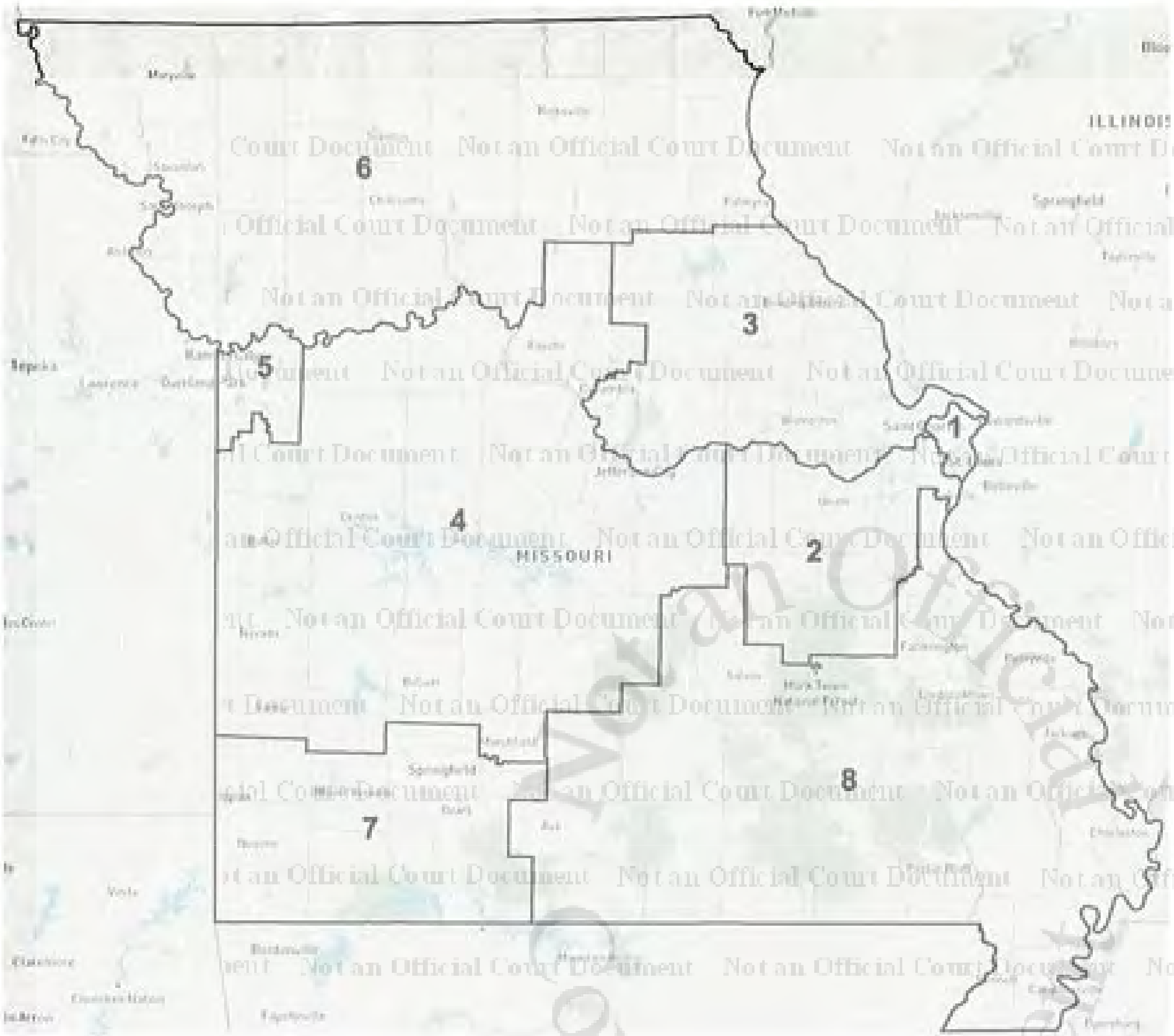
2022 Map



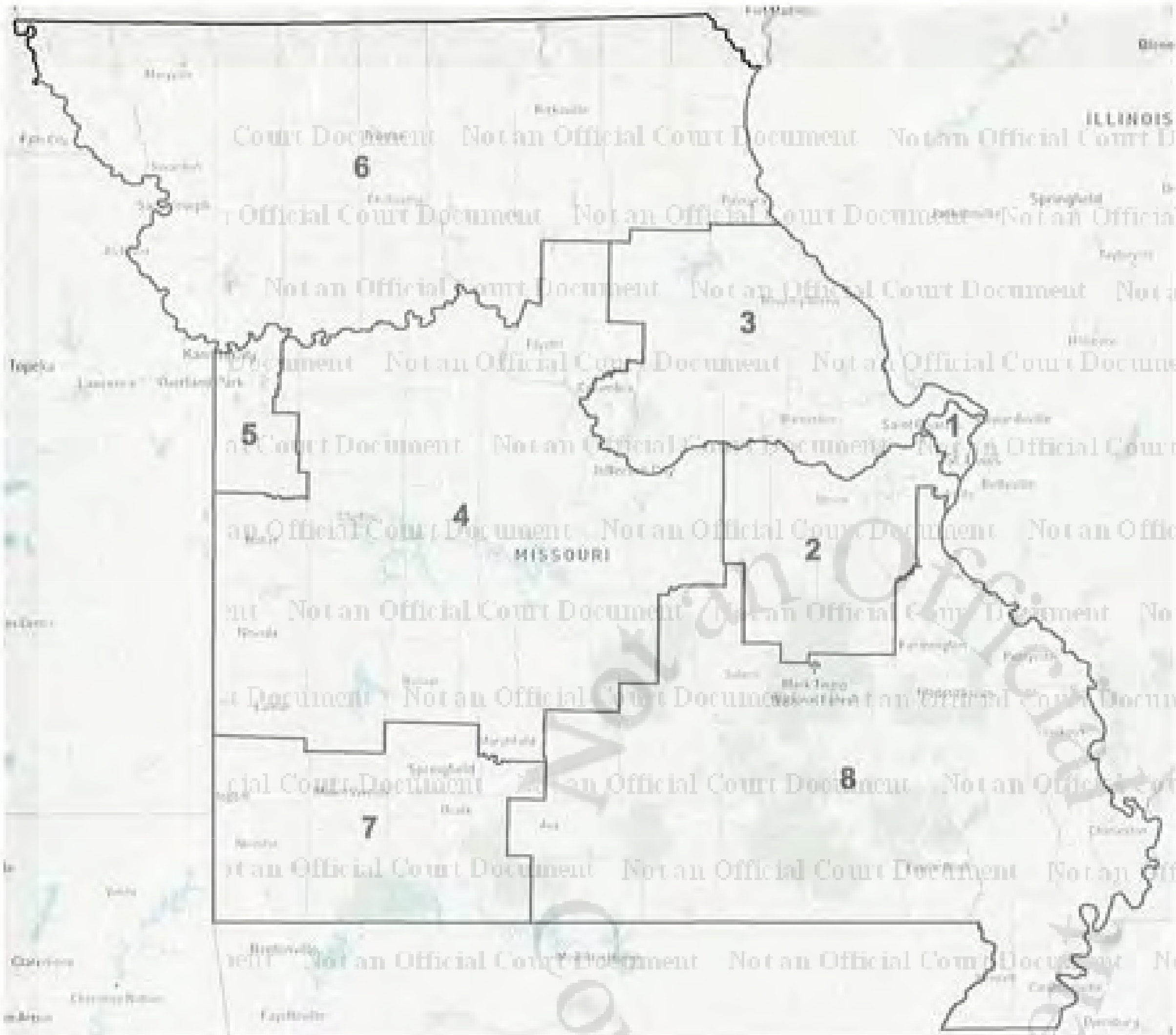
Cervas 1



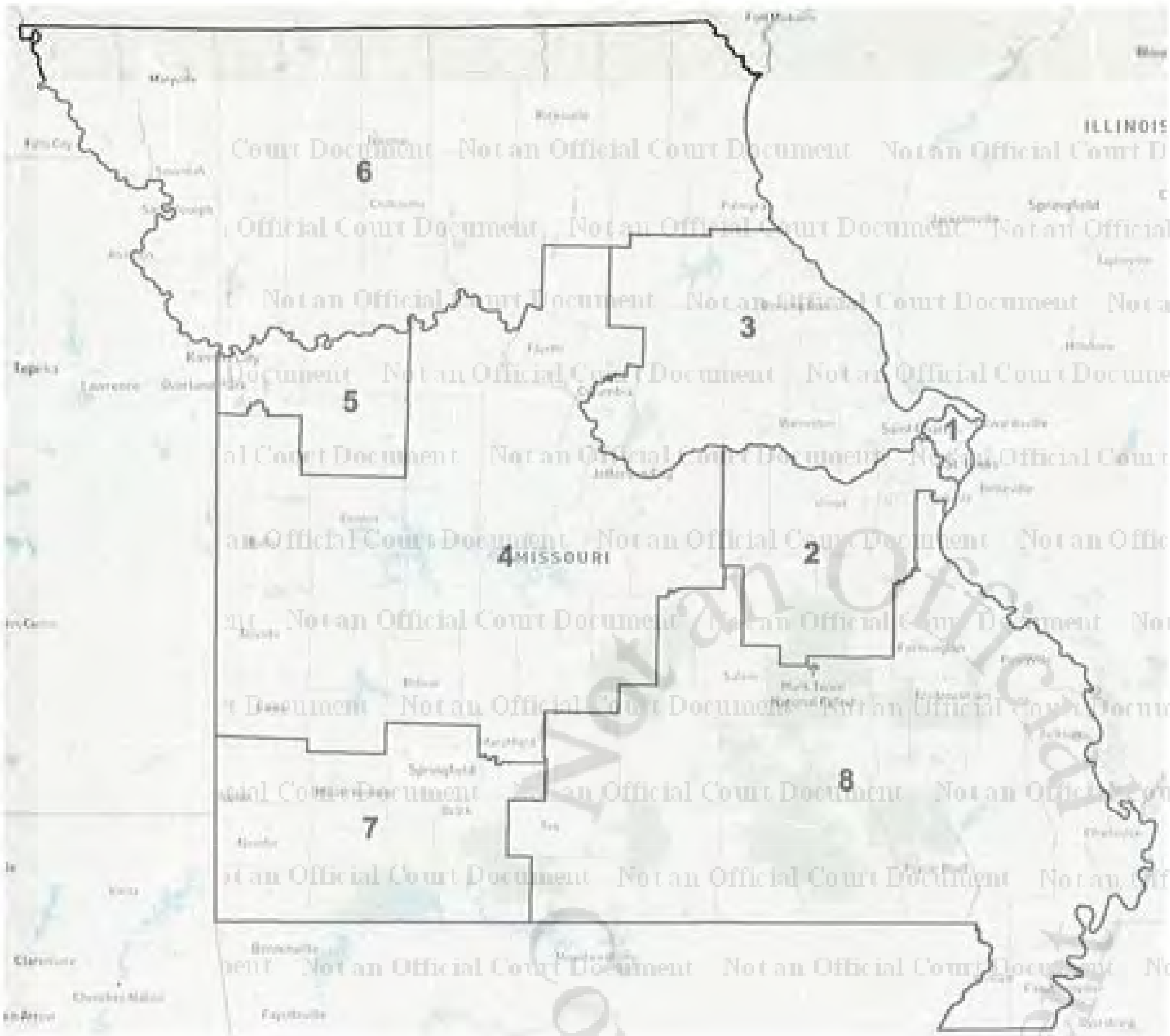
Cervas 2



Cervas 3

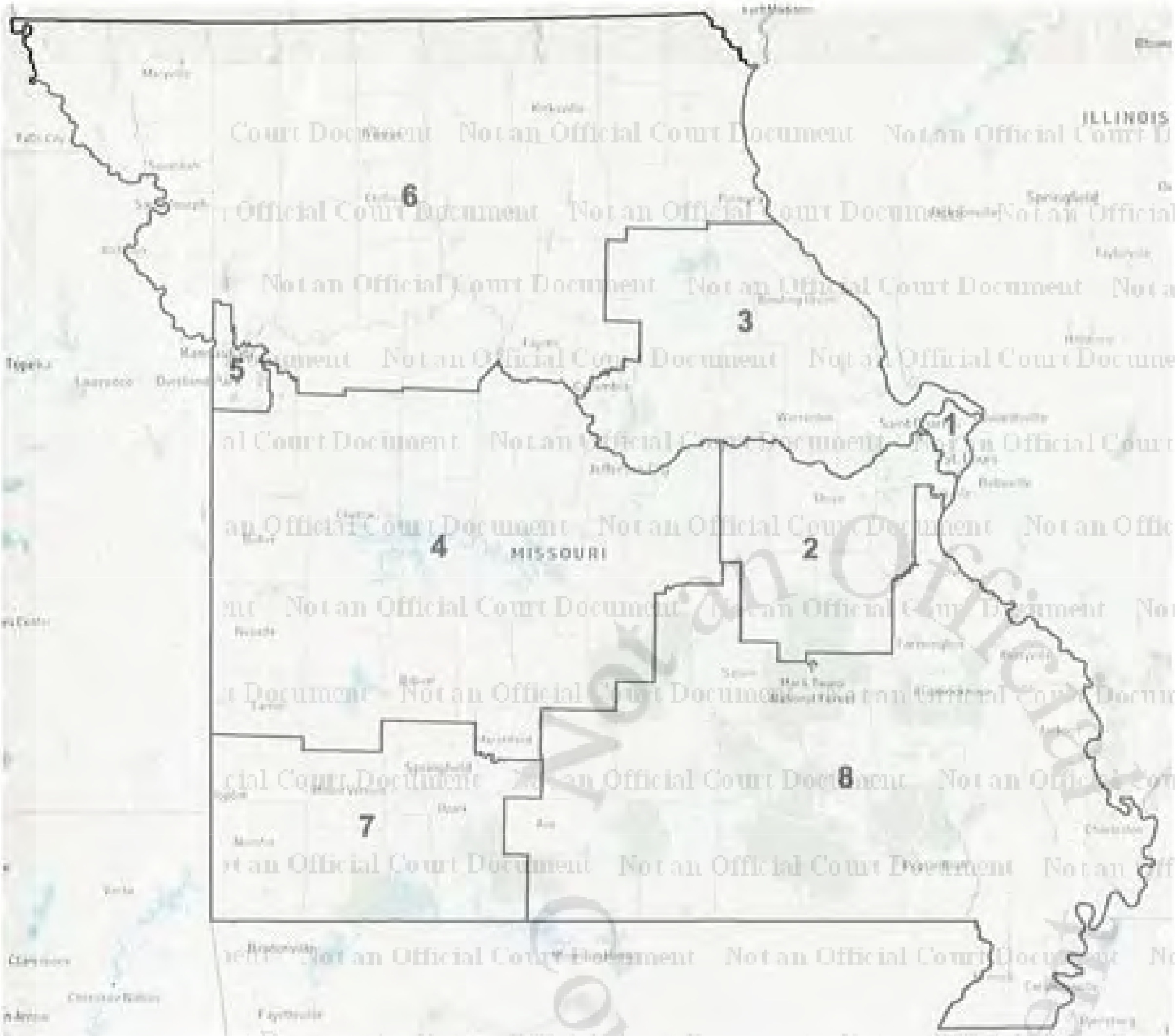


Cervas 4

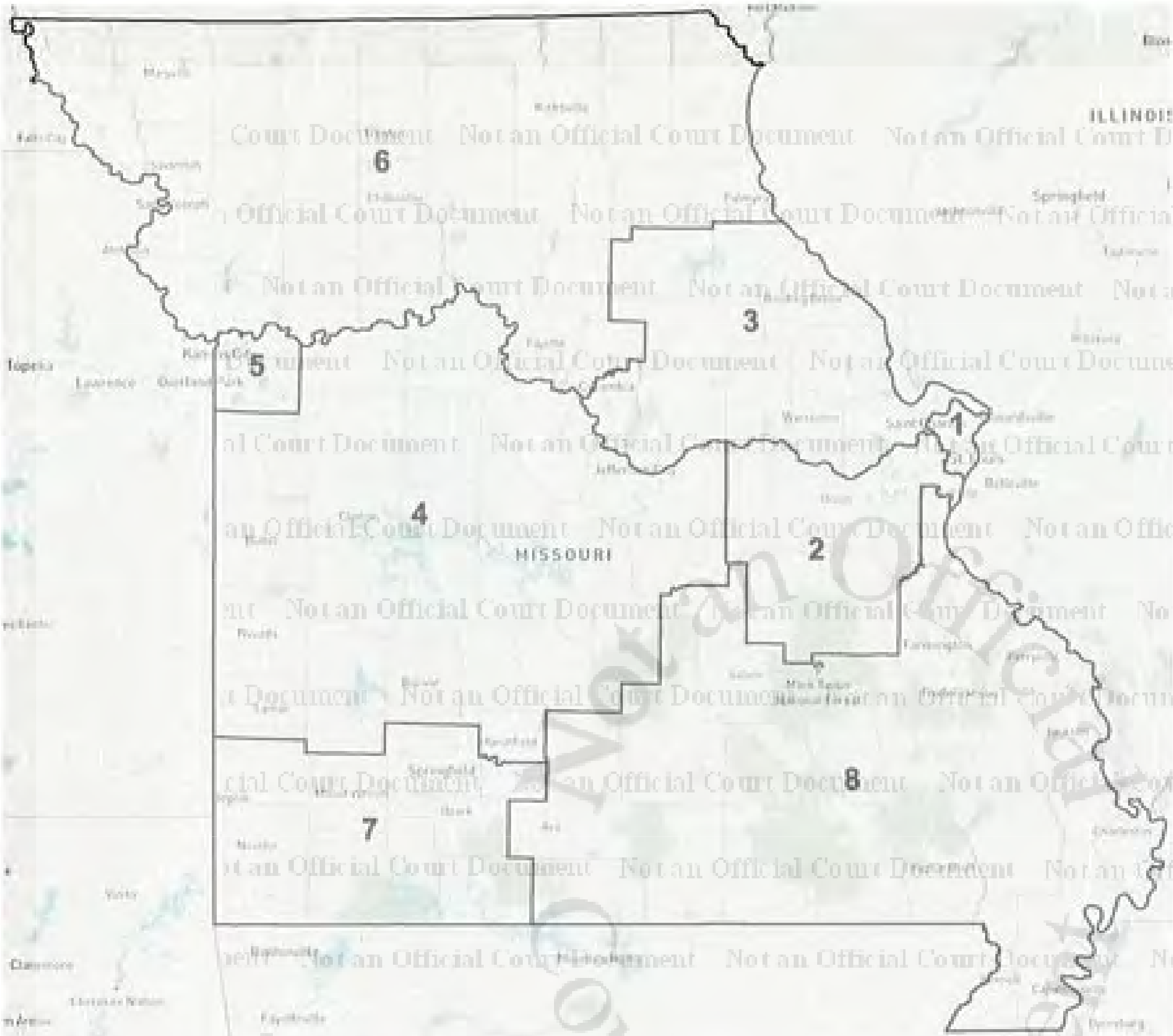


Electronically Filed - SUPREME COURT OF MISSOURI - April 22, 2026 - 10:37 AM

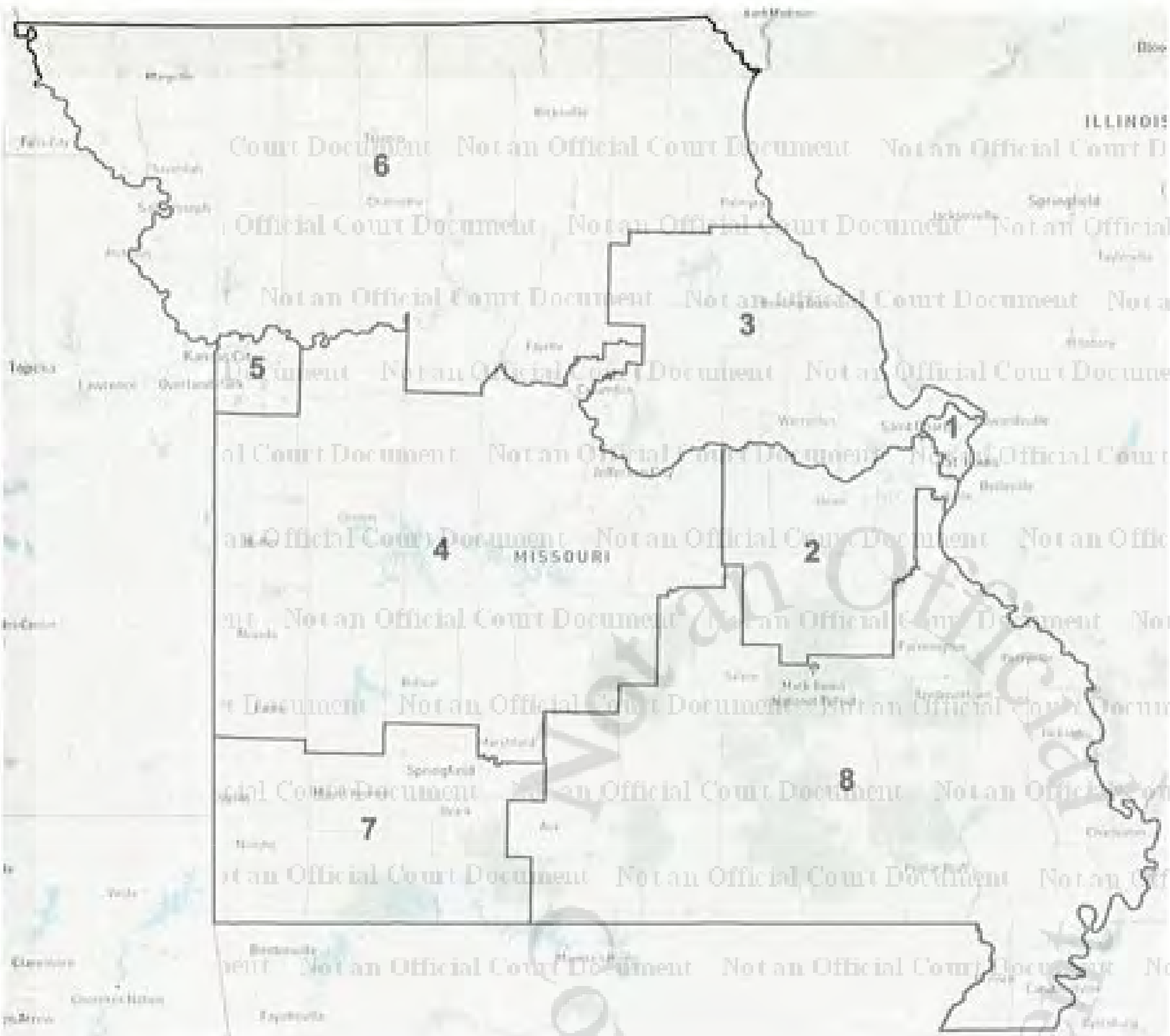
Cervas 5



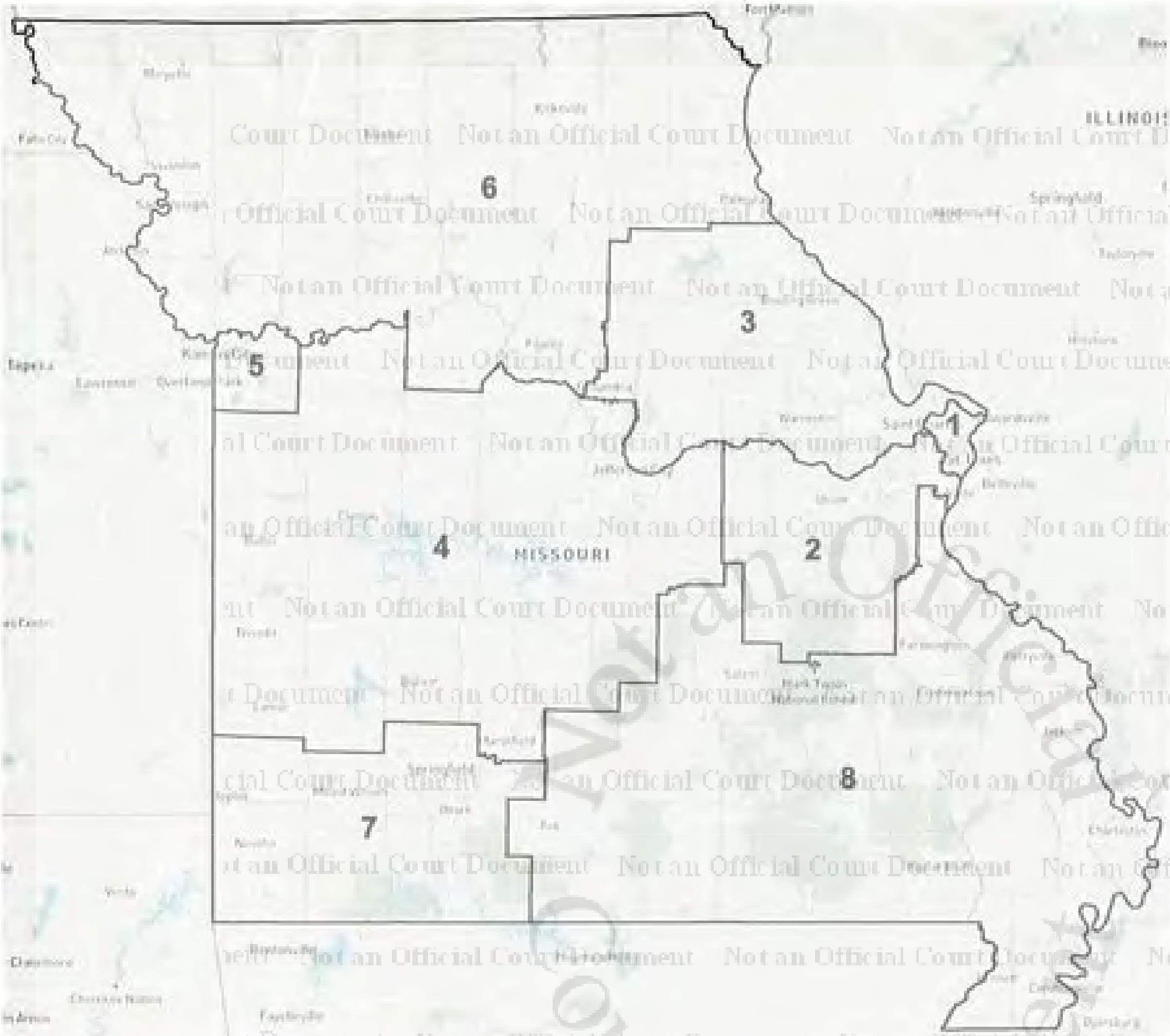
Cervas 6



Cervas 7

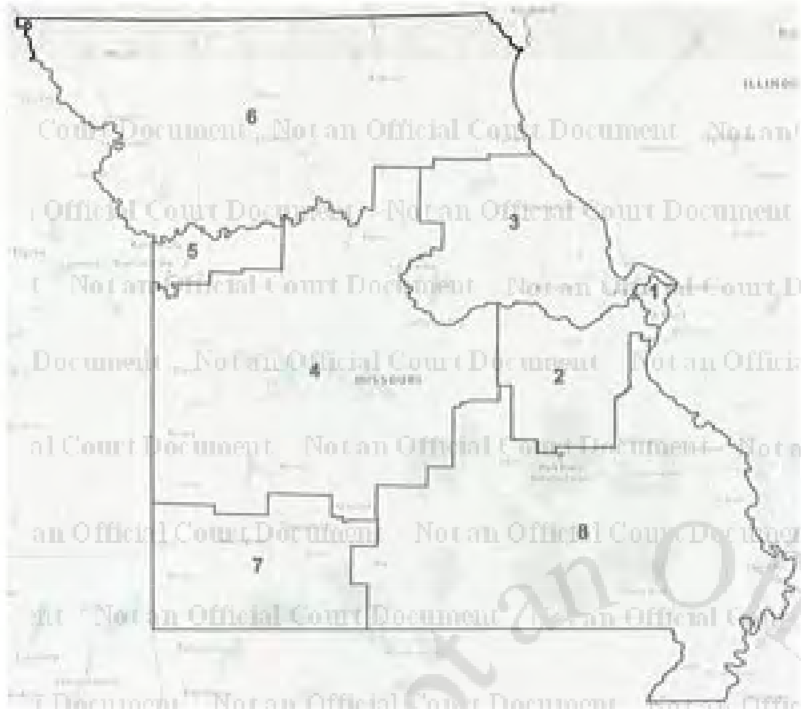


Cervas 8

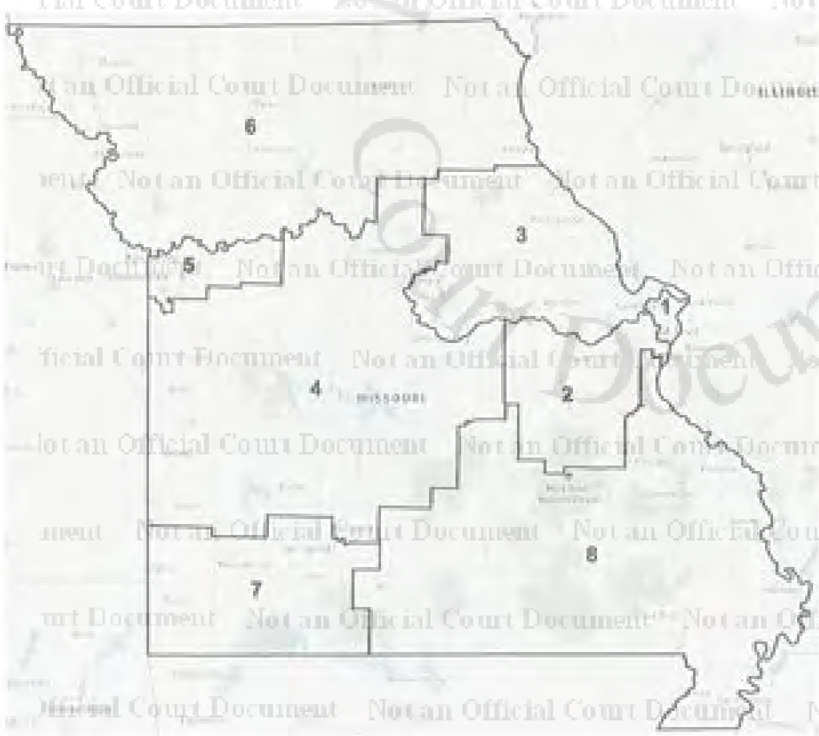


APPENDIX B

Simulated Map 11029

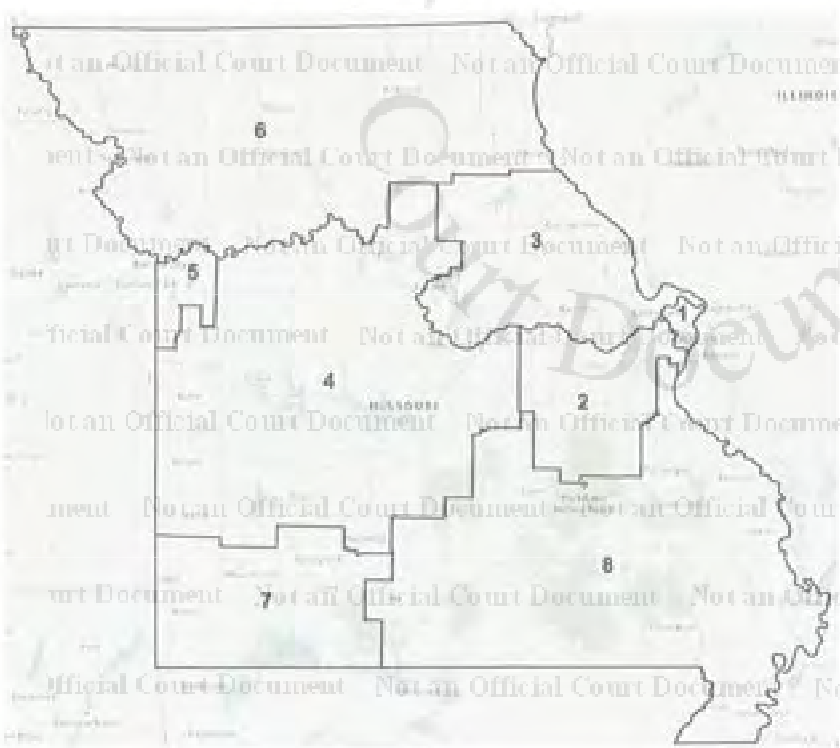


Adjusted Simulated Map 11029

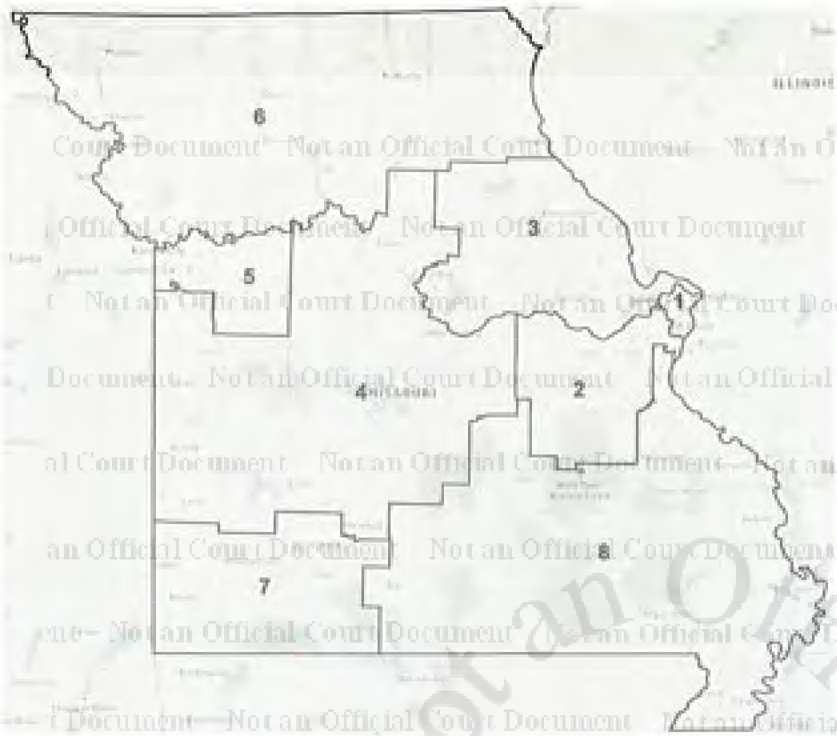


Simulated Map 11163

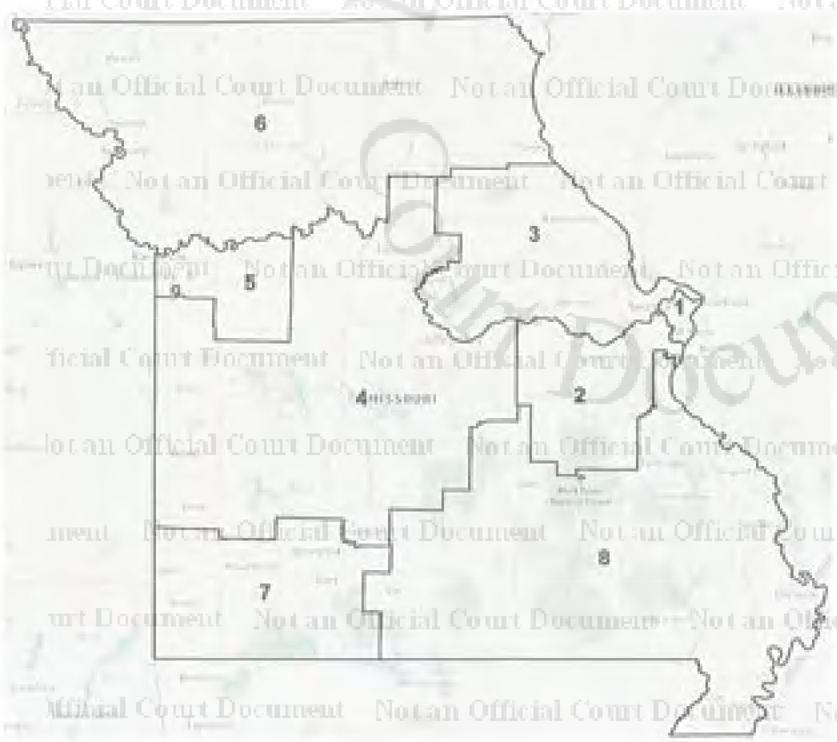
Adjusted Simulated Map 11163



Simulated Map 71871



Adjusted Simulated Map 71871



APPENDIX C

Jonathan Robert Cervas

Curriculum Vitae
Revised December 2025

Carnegie Mellon University
5000 Forbes Avenue
Posner Hall 374
Pittsburgh, PA 15213

Email: cervas@cmu.edu
Website: jonathancervas.com
Github: jcervas
Google Scholar: Jonathan Cervas

Employment

Carnegie Mellon University
– *Assistant Teaching Professor* — 2024–Present
– *Post-Doctoral Fellow* — 2020–2024

Education

University of California, Irvine
– **Ph.D., Political Science, August 2020**
– Dissertation Committee: Bernard Grofman (Chair), Michael Tesler, Carole Uhlaner
– Dissertation: *A Quantitative Assessment of the U.S. Electoral College, 1790–2020*
– Fields: American Politics, Political Methodology, Comparative Politics

- **M.A., Political Science, December 2018**

University of Nevada, Las Vegas
– **B.A., Political Science, 2007**

Additional Training

- Workshop on Research Design for Causal Inference, **Northwestern University**, 2017
- Inter-university Consortium for Political and Social Research (ICPSR), **University of Michigan**, 2016

Publications

2025

- *Partisan Gerrymandering.* Bernard Grofman & Jonathan Cervas, Partisan Gerrymandering, in Elgar Encyclopedia of Public Choice 476 (Richard Jong-A-Pin & Christian Bjørnskov eds., 2025), https://www.elgaronline.com/view/book/9781802207750/chapter68.xml. Read Online]

2024

- *Statistical Fallacies in Claims about 'Massive and Widespread Fraud' in the 2020 Presidential Election.* Bernard Grofman and **Jonathan Cervas**. *Statistics and Public Policy*, 11(1). Read Online
- *Partisan Gerrymandering Cases in State Supreme Courts in the 2020s Redistricting Round.* **Jonathan Cervas**, Bernard Grofman, Scott Matsuda, and Justine Kawa. *Albany Law Review* (forthcoming). Read Online

2023

- *The Role of State Courts In Constraining Partisan Gerrymandering in Congressional Elections.* **Jonathan Cervas**, Bernard Grofman, and Scott Matsuda. *University of New Hampshire Law Review*, 21:2, 421. Read Online

2022

- *Using Folded Seats-Votes Curves to Compare Partisan Bias in the 2020 Presidential Election with Other 21st Century Elections.* **Jonathan Cervas** and Bernard Grofman. *Presidential Studies Quarterly*. Read Online
- *Turning Communities of Interest into a Rigorous Standard for Fair Districting.* Wang, Chen, Ober, Grofman, Barnes, and **Cervas**. *Stanford J. of Civil Rights & Civil Liberties*, 18, 101. Read Online
- *Why Donald Trump Should be a Fervent Advocate of Using Rank-Choice Voting in 2024.* **Jonathan Cervas** and Bernard Grofman. *PS: Political Science & Politics*, 55(1). Read Online

2021

- *A Systems Framework for Remedying Distortions in U.S. Democracy.* Wang, **Cervas**, Grofman, and Lipsitz. *PNAS*, 118(50), e2102154118. Read Online
- *The Unanticipated Effect of Covid-19 on House Apportionments.* **Jonathan Cervas** and Bernard Grofman. *Social Science Quarterly*, 102(5), 2432-2434. Read Online

2020

- *ZIP Codes as Geographic Bases of Representation.* Grofman and **Cervas**. *Election Law Journal*. Read Online
- *Legal, Political Science and Economics Approaches to Measuring Malapportionment.* **Jonathan Cervas** and Grofman. *Social Science Quarterly*, 101(6), 2238-2256. Read Online
- *Tools for Identifying Partisan Gerrymandering: Pennsylvania Case Study.* **Jonathan Cervas** and Grofman. *Political Geography*, 76, 102069. Read Online

2019

- *Are Presidential Inversions Inevitable?* **Jonathan Cervas** and Grofman. *Social Science Quarterly*, 100(4), 1322-1342. Read Online

2018

- *Can State Courts Cure Partisan Gerrymandering? Lessons from League of Women Voters v. Pennsylvania.* Grofman and **Cervas**. *Election Law Journal* 17(4), 264-285. Read Online

2017

- *Why Noncompetitive States Matter: The Electoral College 1868-2016.* **Jonathan Cervas** and Grofman. *Public Choice*, 173(3-4), 251-265. Read Online

Other Publications

2024

- *Report of the Court-Appointed Co-Consultants in re Clarke v. Wisconsin Elections Commission* (Case Number 2023Ap1399-Oa, 2023 WI 79). [Read Online]

2023

- *Memo in Support of Grofman/Cervas/Griggy Remedial Proposals.* U.S. District Court for the Northern District of Alabama, Southern Division. [Read Online]
- *Brief Of Amici Curiae Dr. Jonathan Cervas, Paul Mitchell, Dr. Samuel S.-H. Wang, Roderick Kennedy, Election Reformers Network, Common Cause New Mexico, and League Of Women Voters New Mexico In Support Of Neither Party.* State of New Mexico, County of Lea, Fifth Judicial District Court. Cervas, Jonathan et al. [Read Online]

2022

- *Report of the Special Master (Harkinrider v. Hochel).* **Jonathan Cervas**. [Read Online]

2021

- *Fracking: A Contiguity-Related Redistricting Metric.* **Jonathan Cervas** and Bernard Grofman. *Election Law Blog.* [Read Online]
- *Trump the Wrestler and the 2024 Grudge Match.* Bernard Grofman and **Jonathan Cervas**. [Read Online]
- *The GOP Scared Latinos from the Census. Now That May Cost the Party Red Seats.* Sam Wang and **Jonathan Cervas**. *Washington Post.* [Read Online]
- *Great Lobster and a More Equitable Voting System Exists in Maine.* Anjali Akula, **Jonathan Cervas**, and Elsie Goren. *Medium.com "3Streams"*. [Read Online]

2020

- *Amicus Curiae with Princeton Electoral Innovation Lab.* [Read Online]
- *How Likely is Trump to Lose the Popular Vote but Win the Electoral College?* **Jonathan Cervas** and Bernard Grofman. *Medium.com "3Streams"*. [Read Online]
- *These Are the Political Consequences of Excluding Undocumented Immigrants from Apportionment.* Angela Ocampo and **Jonathan Cervas**. *Medium.com "3Streams"*. [Read Online]

2018

- *Pennsylvania Has to Draw New Congressional Districts but Getting Rid of Gerrymandering Will Be Harder Than You Think.* Bernard Grofman and **Jonathan Cervas**. *The Washington Post*. [Read Online]

Work Experience

Special Master
- *Harkenrider v. Hochul* (2022), New York Congressional and Senate Districts. Court Opinion

Court/Legislative Consultant
- Wisconsin Supreme Court (*Clarke v. Wisconsin Elections Commission*), 2023–2024.
- Pennsylvania Reapportionment Commission, 2021–2022.

Assistant to the Special Master
- *Wright v. Sumter County Board of Elections*, 2019–2020. Court Opinion
- *Bethune-Hill v. Virginia State Board of Elections*, 2018–2019. Court Opinion
- *Navajo Nation v. San Juan County, UT*, 2017. Court Opinion

Expert Witness
- *New York Communities for Change v. County of Nassau* (2024)
- *Moore v. Lee*, Tennessee Chancery Court (2022). Reports 1, 2, 3, 4, 5.

Consultant
- Town of Newburgh, NY (2024)
- Town of Cheektowaga, NY (2024)

Invited Talks

2025

- What's the Story with Redistricting? – Heinz School of Public Policy, Policy and Politics Group, September 24, 2025.
- *Mid-decade Redistricting* — New York Law School, Hosted by Jeff Wice, September 17, 2025.
- *Disinformation and the Fight for Democracy* — University of Pittsburgh, Hosted by Ralph L. Bangs, July 15, 2025.

- *Partisan & Racial Gerrymandering and the Voting Rights Act* — New York Law School, Hosted by Jeff Wice, February 19, 2025.
- *Gerrymandering and the Voting Rights Act: A Threat to Democracy?* — University of Pittsburgh, Hosted by Ralph L. Bangs, February 11, 2025.
- *Build a 2030 Redistricting Checklist* — National Conference of State Legislatures, NCSL Annual Summit, Louisville, KY, August 7, 2024.
- *NY Redistricting Conference: What Happened and What's Next?* — Keynote Speaker, New York Law School, June 18, 2024. [Website] [Keynote Remarks]

2024

- *When Third Parties Matter* — Niskanen Center, Hosted by Matt Grossman, May 29, 2024. [Website]
- *Elections and Voting* — Sacramento State University, Hosted by Hallee Caron, March 25, 2024.
- *Elections Redistricting and Voting Rights* — New York Law School, Hosted by Jeff Wice, February 21, 2024.
- *The Issues Shaping Attitudes Around the Election* — New York University School of Journalism, Hosted by Eliza Griswold and SpotlightPA, February 19, 2024.

2023

- *Redistricting* — Carnegie Mellon University Osher Class, Hosted by Randy Weinberg, October 23, 2023.
- *Power to the People* at "A Path Towards Equality" — Hosted by SpotlightPA, October 11, 2023. [Website]
- *Elections Redistricting and Voting Rights* — New York Law School, Hosted by Jeff Wice, October 4, 2023.
- *Federal Appellate Advocacy* — University of Pittsburgh School of Law, Hosted by Hon. D. Michael Fisher, September 26, 2023.
- *Pennsylvania Redistricting: Lessons Learned and Next Steps for Reform* — Hosted by Common Cause PA, League of Women Voters PA, NAACP PA, Committee of Seventy, FairDistricts PA, and Pennsylvania Voice, May 31, 2023.
- *Voting Rights and Election Law* — Touro Law School, Hosted by Judge Phil Solages, May 4, 2023.
- *Remapping Democracy: Redistricting, Race, and Fair Elections in a Changing Legal Environment* — Government Law Review at Albany Law School, March 6, 2023. [Website]

2022

- *Representation, Race, Redistricting* — CUNY Graduate School, Hosted by Keena Lipsitz and John Mollenkopf, November 17, 2022.

- *Voting Rights and Redistricting: Reshaping American Democracy* — New York Law School, Hosted by Jeff Wice, October 20, 2022.
- *Democracy Threatened: Will Your Vote Count?* — Great Issues Forum at Redeemer, October 12, 2022.
- *Contemporary Issues in Election Law* — New Hampshire Law School, Hosted by Kyle Kopko, October 7, 2022. [Website]
- *Voting Rights and Election Law* — Hofstra Law School, Hosted by Judge Phil Solages, September 12, 2022.
- *Measuring Compactness* — Pennsylvania Redistricting with Geographers: Communities of Interest Criteria and Beyond, American Association of Geographers. [Slides]

2021

- *Voting Rights and Elections* — University of Texas at Austin, Hosted by Beto O'Rourke, Spring 2021.
- *Tools for Identifying a Partisan Gerrymander* — Princeton University Wintersession.

2019

- *2019 NCSL Capital Forum (Legislative Options for Redistricting Post-conference)* — National Conference of State Legislatures.
- *Redrawing the Virginia Legislative Map: The Bethune-Hill Racial Gerrymandering Case* — Princeton University.

2018

- *Triple Play: Election 2018, Census 2020, and Redistricting 2021* — University of Houston, Hobby School.

2016

- *Representation of Non-Eligible Resident Populations in Legislative Bodies* — Center for the Study of Democracy Graduate Student Conference, UC Irvine.

2015

- *Asymmetry in State Grant Distribution: Why Proximity to the State Capital Matters* — Western Political Science Association, San Diego, California.

Service to the University

- Democracy Day, Co-Chair (2025)

- Faculty Senate, CMIST Representative (2025)
- Democracy Day, Committee Member (2024)
- *Bridging the Divide: Understanding and Addressing Political Polarization in America* (2024). Website

Service to the Discipline

Referee: *American Journal of Political Science, Political Geography, Election Law Journal, Public Choice, Political Research Quarterly*

References

Bernard Grofman, UC Irvine
Distinguished Professor of Political Science
Fellow, American Academy of Arts and Sciences
Email: bgrofman@uci.edu

Mark Nordenberg, University of Pittsburgh
Chancellor Emeritus, University of Pittsburgh
Dean Emeritus, Pitt Law School
Email: norden@pitt.edu

Carole Jean Uhlaner, UC Irvine
Professor of Political Science
Email: cuhlaner@uci.edu

Richard L. Hasen, UCLA Law School
Chancellor's Professor of Law and Political Science
Email: rhasen@uci.edu