

Supplemental
Expert Demographic Report of Thomas M. Bryan

Christian Ministerial Alliance
v.
State of Arkansas

October 1, 2024

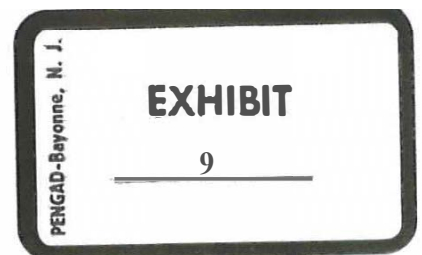


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1. I, Thomas M. Bryan, affirm the conclusions I express in this report and that these opinions are provided to a reasonable degree of professional certainty.

I. SUMMARY AND OPINIONS

2. I write this report in response to the rebuttal report of Mr. William Cooper in the matter of *CMA v. Arkansas*. I will provide an analysis of a third alternative map (“Alt3”) he has prepared that was not presented in his original report nor his rebuttal report.
3. My analysis is consistent with that performed in my supplemental report. I begin with a demographic analysis, followed by a compactness analysis, followed by a differential core retention analysis and finally a political performance analysis.

II. REPORT OVERVIEW

4. [Section III](#), provides an overview of the Cooper Report on *CMA v. Arkansas*
5. [Section IV](#), provides major demographic concepts and the demographics each plan.
6. [Section V](#), provides an analysis of the compactness of each plan.
7. [Section VI](#), provides a differential core retention analysis (or “DCRA”).
8. [Section VII](#), provides an assessment of political performance of the 2022 elections.
9. [Section VIII](#), provides references.
10. [Section IX](#), provides appendices.
11. In forming my opinions, I have considered all materials cited in my original report as well as William Cooper’s Expert Report and Rebuttal Report.
12. I reserve the right to further supplement my report and opinions.

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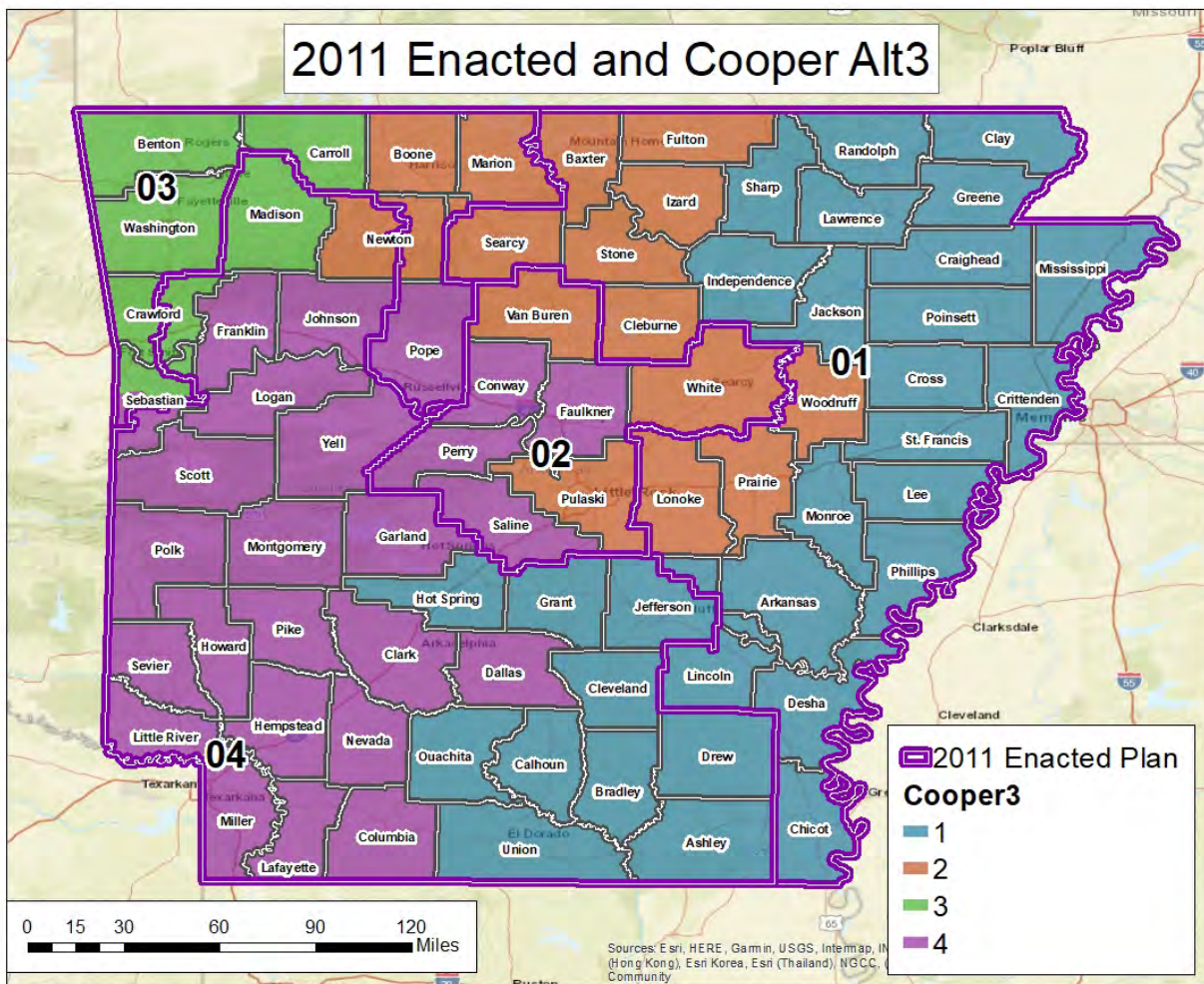
III. Cooper Report on CMA v. Arkansas

13. I received a copy of Mr. Cooper's rebuttal expert report on September 24, 2024.

A. Cooper Alt3 Plan

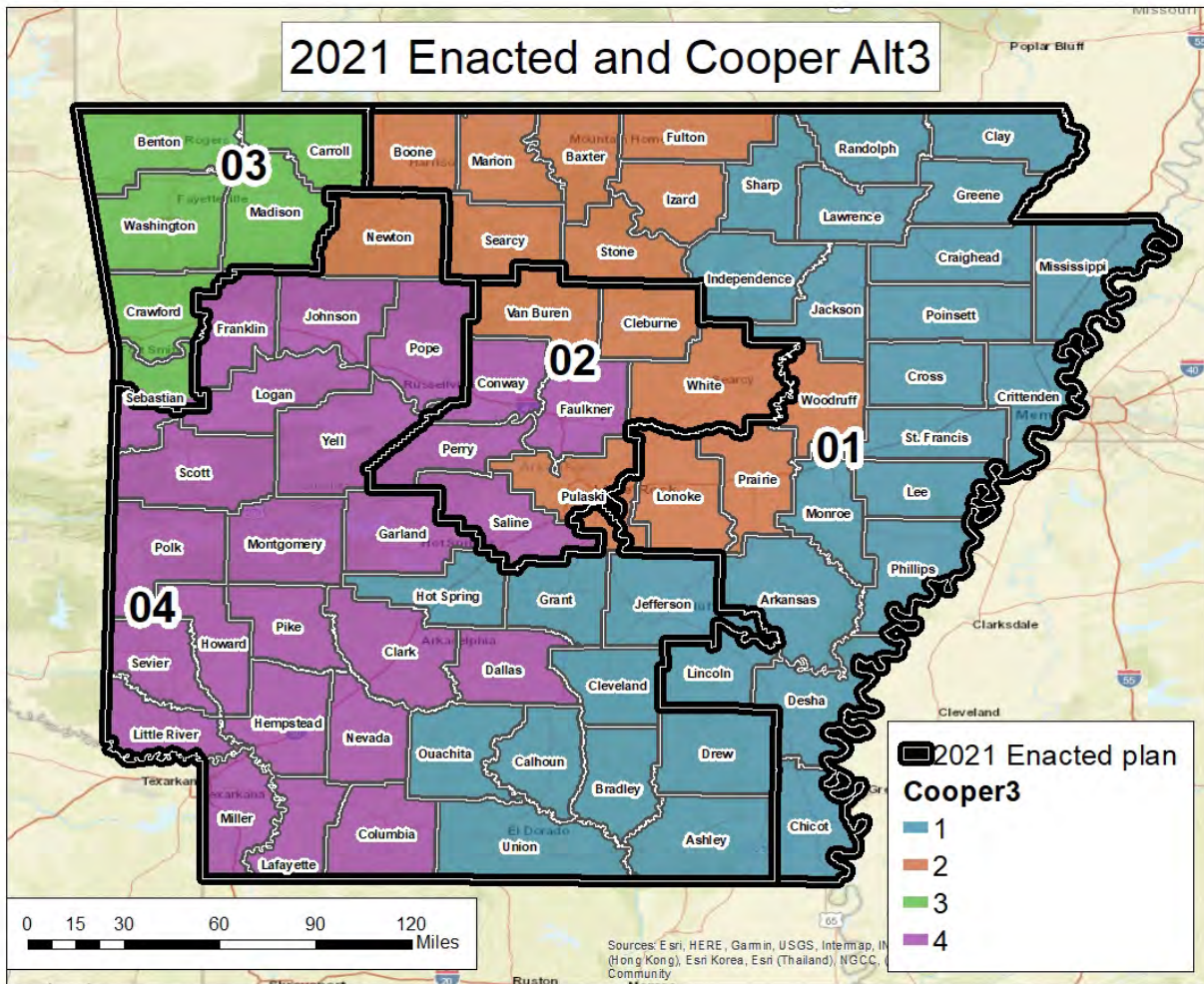
14. Next, I present illustrations of Cooper's Alt3 plan, compared with Arkansas's 2011 and 2021 Enacted plans, for reference.

Figure III.A.1: 2011 Enacted and Cooper Alt3 Plan



Sources: 2020 U.S. Census TIGER, 2020 U.S. Census PL94-171 P2, BGD calculations, built with 2020 VTDs.

Note: the exact split of Sebastian County under Alt3 is unclear from Cooper's map shown in his *Figure 1*. I have done my best to replicate Alt3 faithfully here.

Figure III.A.2: 2021 Enacted and Cooper Alt3 Plan

Sources: 2020 U.S. Census TIGER, Cooper Expert Report

Note: the exact split of Sebastian County under Alt3 is unclear from Cooper's map shown in his *Figure 1*. I have done my best to replicate Alt3 faithfully here.

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IV. DEMOGRAPHIC ANALYSIS

15. In this section I assess the total population, voting age population (VAP) and citizen voting age population (CVAP) for the 2011 and 2021 Enacted Plans, and Cooper's Alt3 plan for Arkansas's D2.

A. Demographics of 2011 Enacted Plan

16. [Table IV.A.1](#) shows the 2020 population and by race and ethnicity for the 2011 Enacted Plan in D2. The Any Part Black (APB) population makes up 24.4% of the total population, 22.6% of the VAP and 23.4% of CVAP.

Table IV.A.1: 2011 Enacted Plan D2

Population	Total	WNH	APB	Hispanic		% WNH	% APB	% HISP
Total	769,391	487,210	188,021	53,622		63.3%	24.4%	7.0%
VAP	593,620	393,757	134,409	34,272		66.3%	22.6%	5.8%
CVAP	577,490	411,131	134,915	15,991		71.2%	23.4%	2.8%

Sources: 2020 U.S. Census PL94-171 P1, P2, P3 and P4, 2018-2022 American Community Survey, BGD calculations

17. [Table IV.A.2](#) shows the 2020 population and by race and ethnicity for the 2021 Enacted Plan in D2. The Any Part Black (APB) population makes up 22.1% of the total population, 20.3% of the VAP and 20.6% of CVAP.

Table IV.A.2: 2021 Enacted Plan D2

Population	Total	WNH	APB	Hispanic		% WNH	% APB	% HISP
Total	752,710	498,838	166,319	46,673		66.3%	22.1%	6.2%
VAP	582,706	402,756	118,487	30,008		69.1%	20.3%	5.1%
CVAP	566,916	419,664	117,047	14,651		74.0%	20.6%	2.6%

Sources: 2020 U.S. Census PL94-171 P1, P2, P3 and P4, 2018-2022 American Community Survey, BGD calculations

18. [Table IV.A.3](#) shows the 2020 population and by race and ethnicity for the Cooper's Alt1 Plan in D2. The Any Part Black (APB) population makes up 25.0% of the total population, 23.1% of the VAP and 23.9% of CVAP.

Table IV.A.3: Cooper's Alt1 Plan D2

Population	Total	WNH	APB	Hispanic		% WNH	% APB	% HISP
Total	752,901	472,275	187,854	53,093		62.7%	25.0%	7.1%
VAP	580,289	381,551	134,314	33,951		65.8%	23.1%	5.9%
CVAP	564,071	398,467	134,787	15,718		70.6%	23.9%	2.8%

Sources: 2020 U.S. Census PL94-171 P1, P2, P3 and P4, 2018-2022 American Community Survey, BGD calculations

19. [Table IV.A.4](#) shows the 2020 population and by race and ethnicity for Cooper's Alt2 Plan in D2. The Any Part Black (APB) population makes up 24.0% of the total population, 22.3% of the VAP and 22.9% of CVAP.

Table IV.A.4: Cooper's Alt2 Plan D2

Population	Total	WNH	APB	Hispanic		% WNH	% APB	% HISP
Total	752,455	483,064	180,379	49,027		64.2%	24.0%	6.5%
VAP	581,465	389,851	129,445	31,458		67.0%	22.3%	5.4%
CVAP	566,120	405,281	129,638	15,760		71.6%	22.9%	2.8%

Sources: 2020 U.S. Census PL94-171 P1, P2, P3 and P4, 2018-2022 American Community Survey, BGD calculations

20. [Table IV.A.5](#) shows the 2020 population and by race and ethnicity for the 2011 Enacted Plan in D2. The Any Part Black (APB) population makes up 22.0% of the total population, 20.3% of the VAP and 21.1% of CVAP.

Table IV.A.5: Cooper's Alt3 Plan D2

Population	Total	WNH	APB	Hispanic		% WNH	% APB	% HISP
Total	753,910	502,907	166,175	45,019		66.7%	22.0%	6.0%
VAP	587,695	408,411	119,594	28,863		69.5%	20.3%	4.9%
CVAP	572,445	421,272	120,711	15,311		73.6%	21.1%	2.7%

Sources: 2020 U.S. Census PL94-171 P1, P2, P3 and P4, 2018-2022 American Community Survey, BGD calculations

V. GEOGRAPHIC COMPACTNESS

A. 2011 Enacted Plan Compactness

21. [Table V.A.1](#) shows the compactness scores by district, by method under the 2011 Enacted Plan.

Table V.A.1 Compactness Scores of 2011 Enacted Plan

District	Polsby-Popper	Reock	Convex_Hull	Schwartzberg
1	0.13	0.37	0.71	2.80
2	0.24	0.46	0.71	2.02
3	0.14	0.33	0.52	2.67
4	0.28	0.41	0.80	1.88
All	0.20	0.39	0.68	2.34

Source: Calculations by BGD.

B. 2021 Enacted Plan Compactness

22. [Table V.B.1](#) shows the compactness scores by district, by method under the 2021 Enacted Plan.

Table V.B.1 Compactness Scores of 2021 Enacted Plan

District	Polsby-Popper	Reock	Convex_Hull	Schwartzberg
1	0.12	0.34	0.68	2.87
2	0.27	0.49	0.77	1.94
3	0.43	0.44	0.83	1.52
4	0.26	0.48	0.80	1.95
All	0.27	0.44	0.77	2.07

Source: Calculations by BGD.

C. Cooper Alt1 Plan Compactness

23. [Table V.C.1](#) shows the compactness scores by district, by method under the Cooper Alt1 Plan.

Table V.C.1 Compactness Scores of Cooper Alt1 Plan

District	Polsby-Popper	Reock	Convex_Hull	Schwartzberg
1	0.18	0.50	0.81	2.36
2	0.24	0.40	0.72	2.03
3	0.47	0.58	0.90	1.47
4	0.19	0.45	0.69	2.31
All	0.27	0.48	0.78	2.04

Source: Calculations by BGD.

D. Cooper Alt2 Plan Compactness

24. [Table V.D.1](#) shows the compactness scores by district, by method under the Cooper Alt2 Plan.

Table V.D.1 Compactness Scores of Cooper Alt2 Plan

District	Polsby-Popper	Reock	Convex_Hull	Schwartzberg
1	0.13	0.33	0.64	2.79
2	0.23	0.47	0.72	2.08
3	0.26	0.28	0.64	1.95
4	0.20	0.39	0.79	2.22
All	0.21	0.37	0.70	2.26

Source: BGD Calculations

E. Cooper Alt3 Plan Compactness

25. [Table V.E.1](#) shows the compactness scores by district, by method under the Cooper Alt3 Plan.

Table V.E.1 Compactness Scores of Cooper Alt3 Plan

District	Polsby-Popper	Reock	Convex_Hull	Schwartzberg
1	0.13	0.33	0.64	2.78
2	0.26	0.45	0.69	1.98
3	0.43	0.44	0.84	1.52
4	0.22	0.54	0.80	2.11
All	0.26	0.44	0.74	2.10

Source: BGD Calculations

F. D2 Compactness Comparison by Plan

26. [Table V.F.1](#) shows the compactness scores by district, by method for Arkansas's D2.

27. [Table V.F.2](#) shows the compactness scores on average for all districts, by method for Arkansas's districts.

Table V.F.1 Comparison of Compactness Scores for D2

D2	Polsby-Popper	Reock	Convex_Hull	Schwartzberg
Enacted Plan 2011	0.24	0.46	0.71	2.02
Enacted Plan 2021	0.27	0.49	0.77	1.94
Cooper Alt1	0.24	0.40	0.72	2.03
Cooper Alt2	0.23	0.47	0.72	2.08
Cooper Alt3	0.26	0.45	0.69	1.98
Enacted 2011 v. 2021	0.02	0.03	0.06	-0.08
Enacted 2011 v. Alt1	0.00	-0.07	0.01	0.01
Enacted 2011 v. Alt2	-0.01	0.01	0.01	0.06
Enacted 2011 v. Alt3	0.01	-0.02	-0.02	-0.04

Source: BGD Calculations

Note: Higher Polsby-Popper, Reock and Convex Hull scores are better, while lower Schwartzberg scores are better.

Table V.F.2 Comparison of Compactness Scores for All Districts

Total	Polsby-Popper	Reock	Convex_Hull	Schwartzberg
Enacted Plan 2011	0.20	0.39	0.68	2.34
Enacted Plan 2021	0.27	0.44	0.77	2.07
Cooper Alt1	0.27	0.48	0.78	2.04
Cooper Alt2	0.21	0.37	0.70	2.26
Cooper Alt3	0.26	0.44	0.74	2.10
Enacted 2011 v. 2021	0.07	0.04	0.08	-0.27
Enacted 2011 v. Alt1	0.07	0.09	0.09	-0.30
Enacted 2011 v. Alt2	0.01	-0.02	0.01	-0.08
Enacted 2011 v. Alt3	0.06	0.05	0.06	-0.25

Source: BGD Calculations

Note: Higher Polsby-Popper, Reock and Convex Hull scores are better, while lower Schwartzberg scores are better.

28. Cooper lists his “DRA Compactness” scores (higher is better) as 41 for the 2011 Enacted Plan and 59 for the 2021 Enacted Plan (see Cooper Expert Report, Figure 22) 59 for Alt1 (see Cooper Expert Report, Figure 25), 43 for Alt2 (see Cooper Expert Report, Figure 28) and 62 for Alt3 (see Cooper Rebuttal Report, Figure 3).

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VI. DIFFERENTIAL CORE RETENTION

29. [Table VI.1](#) shows the overall core retention by plan, and by race and ethnicity. [Table VI.2](#) shows the difference in core retention by race and ethnicity from the 2021 Enacted Plan.

Table VI.1: Overall Core Retention by Plan

Plan	Total	WNH	APB	Hispanic
2021 Enacted	92.2%	91.5%	94.5%	93.0%
Alt 1	87.6%	88.0%	87.2%	86.6%
Alt 2	80.4%	78.6%	81.7%	88.2%
Alt 3	70.6%	67.3%	75.0%	83.8%

Source: Calculations by BGD.

Table VI.2: Change in Core Retention between 2021 Enacted and Cooper Alt1, Alt2 and Alt3 Plans

Plan	Total	WNH	APB	Hispanic
Alt 1	-4.7%	-3.5%	-7.4%	-6.4%
Alt 2	-11.9%	-12.9%	-12.8%	-4.9%
Alt 3	-21.6%	-24.1%	-19.6%	-9.2%

Source: Calculations by BGD.

Table VI.3: Alt3 Core Retention by District

Alt3	Total	WNH	BNH	HISP
D1	72.1%	66.7%	93.2%	77.3%
D2	63.9%	56.0%	83.3%	69.3%
D3	84.8%	81.4%	90.5%	93.9%
D4	59.4%	62.4%	41.7%	76.0%
Total	70.6%	67.3%	75.0%	83.8%

Source: Calculations by BGD.

30. [Appendix B.1](#) shows the 2020 Census total population, by race and ethnicity for the 2011 Enacted Plan, and how those populations were retained and moved in the Cooper Alt3 Plan.

VII. Political Performance

31. Here I analyze the political performance of the 2021 Enacted plan and compare it to that of Cooper's Alt1, Alt2 and Alt3 plans using the major races in the 2022 Election. Cooper's analysis of the 2020 presidential race under Alt3 is correct for D2, with Trump winning 58.3% (dividing Trump votes by Trump + Biden votes).

A. 2022 Election

32. The results of the 2022 election allow us to see the political impact of the changes that were made to D2 in the 2021 Enacted Plan. Here I examine the 2022 senate, congressional, governor, attorney general (AG) and secretary of state (SOS) races by congressional district.

33. In [Table VII.A.1](#) and [Figure VII.A.1](#) we see the results of the 2022 political races for D2 by plan. [Table VII.A.2](#) shows the difference of each plan from the 2011 Enacted Plan.

Table VII.A.1 2022 Republican Performance in D2 by Plan

2022 Race D2 Results	2011 Enacted	2021 Enacted	Cooper Alt1	Cooper Alt2	Cooper Alt3
Senate	57.2%	59.1%	56.6%	58.1%	61.4%
Congressional	58.1%	60.0%	57.6%	59.4%	63.0%
Governor	53.5%	55.5%	52.9%	54.6%	58.2%
Attorney General	59.5%	61.5%	58.9%	60.5%	63.5%
Secretary of State	58.6%	60.6%	58.0%	59.5%	62.7%

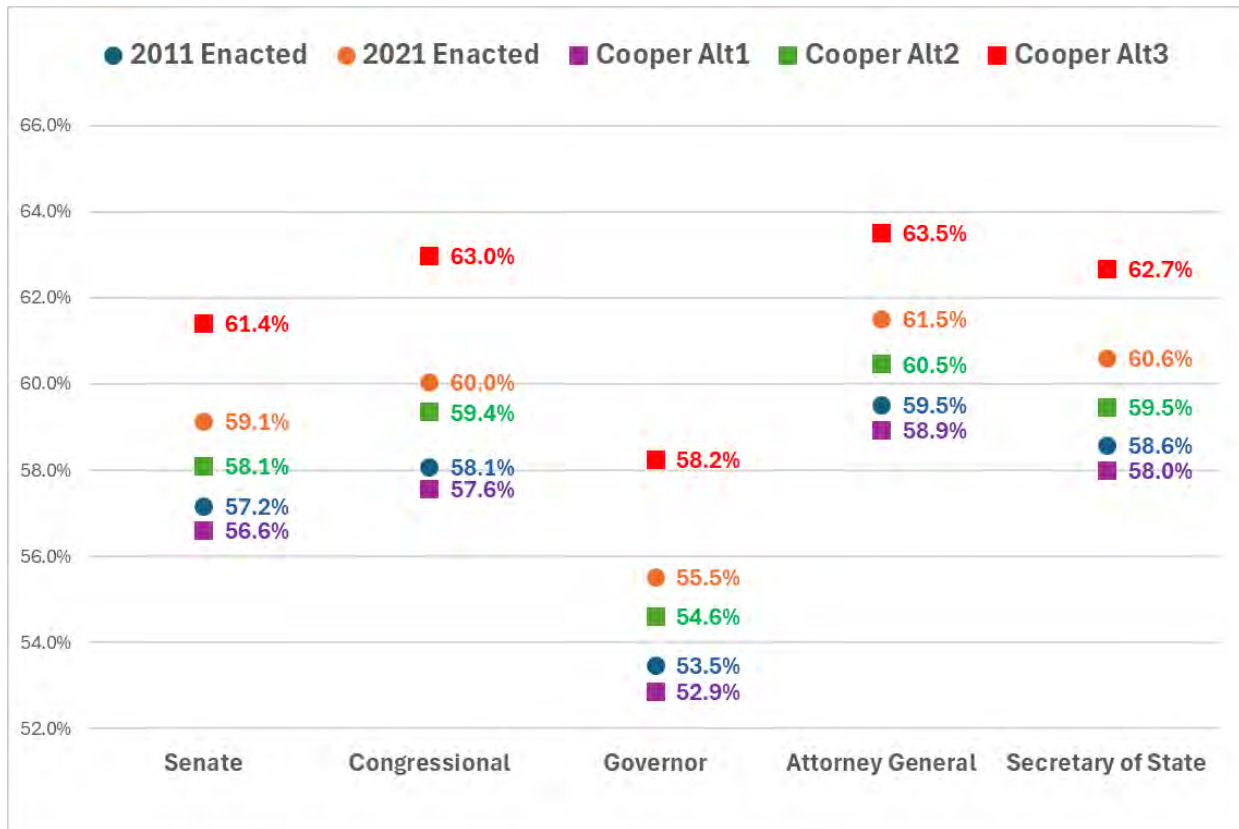
Source: Arkansas Secretary of State, BGD Calculations. See also:

https://ballotpedia.org/Arkansas%27_2nd_Congressional_District_election,_2022#General_election_race_ratings for more information on the 2022 congressional race in D2.

Table VII.A.2 2022 Political Performance Difference from 2011 Enacted Plan in D2 by Plan

2022 Race	2021 Enacted	Cooper Alt1	Cooper Alt2	Cooper Alt2
Senate	2.0%	-0.6%	0.9%	4.3%
Congressional	2.0%	-0.5%	1.3%	4.9%
Governor	2.0%	-0.6%	1.1%	4.8%
Attorney General	2.0%	-0.6%	1.0%	4.0%
Secretary of State	2.0%	-0.6%	0.9%	4.1%

Source: Arkansas Secretary of State, BGD Calculations. Note – numbers may not foot due to rounding.

Figure VII.A.1 2022 Republican Performance in D2 by Plan

Source: Arkansas Secretary of State, BGD Calculations. Note – numbers may not foot due to rounding.

Submitted: October 1, 2024

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VIII. REFERENCES

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IX. APPENDICES

Appendix A: Compactness Measures

Appendix B: Differential Core Retention for Alt3

Appendix C: Terms and Definitions

Appendix A: Compactness

The Reock compactness score (Reock, 1961) is computed by dividing the area of the district by the area of the smallest circle that would completely enclose it. Since the circle encloses the district, its area cannot be less than that of the district, and so the Reock compactness score will always be a number between 0 and 1 (which may be expressed as a percentage). The Reock Score (R) is the ratio of the area of the district (A_D) to the area of a minimum bounding circle (A_{MBC}) that encloses the district's geometry.

(Reock score)
$$R = \frac{A_D}{A_{MBC}}$$

The Area/Convex Hull test computes the ratio of is the ratio of the area of the district A_D to the area of the convex hull of the district (A_{MCP} - the minimum convex polygon which completely contains the district). This measure is always between 0 and 1, with 1 being the most compact.

(Convex Hull score)
$$CH = \frac{A_D}{A_{MCP}}$$

The Polsby-Popper (PP) measure is the ratio of the area of the district (A_D) to the area of a circle whose circumference is equal to the perimeter of the district (P_D). The factor 4π ensures that the resulting score takes a value between 0 and 1 - with 1 being entirely circular and the most compact.

(Polsby-Popper score)
$$PP(D) := \frac{4\pi A_D}{P_D^2},$$

Reock: Area of district relative to area of smallest circle that contains it.



Convex-Hull: Area of district relative to area of smallest convex polygon containing it.



Polsby-Popper: Area of district relative to area of circle with same circumference as the district perimeter.



The Schwartzberg test (Schwartzberg, 1966) is a perimeter-based measure that compares a simplified version of each district to a circle, which is considered to be the most compact shape possible. Taking the square root of the inverse Polsby-Popper score gives the Schwartzberg score (Belotti, 2023) which notably results in an identical ranking of geographies. Unlike other measures, the scale of Schwartzberg values is *above* 1, with *lower* values approaching 1 being most compact.

$$(\text{Schwartzberg score}) \quad PP(D)^{-1/2} := \frac{P_D}{\sqrt{4\pi A_D}},$$

Schwartzberg: Ratio of district to a circle with the same area as the district.



The Polsby-Popper and Schwartzberg ratios place high importance on district perimeter. One criticism of perimeter-related scores is that they suffer from the Coastline Paradox in which boundary lengths are not well-defined and depend on the choice of map projection and the “size of your ruler” (Bar-Natan et al. 2020, Barnes and Solomon 2021). Another criticism can be summarized with the slogan “land does not vote; people do”. In 2010, 47% of all census blocks were uninhabited (Freeman 2014); reassigning these blocks to different districts can significantly change the Polsby-Popper score, but the districts would function the same.

This is precisely why it is important to use multiple compactness scores (in this case the Polsby-Popper, Schwartzberg, Reock and Convex Hull measures) and let the reader judge which one is a better fit based on the geography of the district and method of calculation each score uses. A higher score means more compact, but the scores using different measures cannot be directly compared to each other.

Appendix B.1: Differential Core Retention of Total, White, non-Hispanic, Any Part Black and Hispanic Populations between the 2011 and Alt3 Plan

2011 Enacted District	Alt 3 District	Total	WNH	APB	Hispanic
1	1	516,193	349,030	126,545	21,924
	2	200,192	173,906	9,179	6,424
1 Total		716,385	522,936	135,724	28,348
2	2	491,743	272,675	156,597	37,153
	4	277,648	214,535	31,424	16,469
2 Total		769,391	487,210	188,021	53,622
3	2	58,260	52,903	376	1,391
	3	711,327	473,955	31,334	122,314
	4	69,560	55,242	2,921	6,604
3 Total		839,147	582,100	34,631	130,309
4	1	236,681	140,874	79,695	9,006
	2	3,715	3,423	23	51
	3	38,411	32,887	488	1,654
	4	407,794	294,120	57,386	33,857
4 Total		686,601	471,304	137,592	44,568
Grand Total		3,011,524	2,063,550	495,968	256,847

Alt 3	Total	WNH	APB	Hispanic
D1 Retained	516,193	349,030	126,545	21,924
D1 Moved	200,192	173,906	9,179	6,424
D1 Total	716,385	522,936	135,724	28,348
D1 Core Retention	72.1%	66.7%	93.2%	77.3%
D2 Retained	491,743	272,675	156,597	37,153
D2 Moved	277,648	214,535	31,424	16,469
D2 Total	769,391	487,210	188,021	53,622
D2 Core Retention	63.9%	56.0%	83.3%	69.3%
D3 Retained	711,327	473,955	31,334	122,314
D3 Moved	127,820	108,145	3,297	7,995
D3 Total	839,147	582,100	34,631	130,309
D3 Core Retention	84.8%	81.4%	90.5%	93.9%
D4 Retained	407,794	294,120	57,386	33,857
D4 Moved	278,807	177,184	80,206	10,711
D4 Total	686,601	471,304	137,592	44,568
D4 Core Retention	59.4%	62.4%	41.7%	76.0%
Total Retained	2,127,057	1,389,780	371,862	215,248
Total Moved	884,467	673,770	124,106	41,599
Total	3,011,524	2,063,550	495,968	256,847
Total Core Retention	70.6%	67.3%	75.0%	83.8%

Sources: 2020 U.S. Census PL94-171 P1 and P2, BGD Calculations

Appendix C: Terms and Definitions

Term	Description
ACS	American Community Survey. See: https://www.census.gov/programs-surveys/acs
APB	Any Part Black population – defined as Black or African American alone or in combination, including Hispanic.
CPS	Current Population Survey. See: https://www.census.gov/programs-surveys/cps.html
CES	Cooperative Election Study. See: https://cces.gov.harvard.edu/
CVAP	Citizen Voting Age Population. See: https://www.census.gov/programs-surveys/decennial-census/about/voting-rights/cvap.2019.html
DCRA	Differential Core Retention Analysis - which measures how many total VAP were retained in each district when the new plan was drawn (the “core”) and how many VAP by race and ethnicity were retained (the “differential”) by district.
VAP	Voting Age Population, 18+. See: https://www.census.gov/topics/public-sector/voting/about/faqs.html
VEP	Voting Eligible Population, typically CVAP less ineligible voters such as felons and those mentally incapacitated. See: https://electionlab.mit.edu/research/voter-turnout
VRA	Voting Rights Act of 1965 See: https://www.archives.gov/milestone-documents/voting-rights-act
VTD	Voting Tabulation District, comparable with precincts.