EXPERT REPORT OF JOWEI CHEN, Ph.D.

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I am an Associate Professor in the Department of Political Science at the University of Michigan, Ann Arbor. I am also a Research Associate Professor at the Center for Political Studies of the Institute for Social Research at the University of Michigan and a Research Associate at the Spatial Social Science Laboratory at Stanford University. In 2007, I received a M.S. in Statistics from Stanford University, and in 2009, I received a Ph.D. in political science from Stanford University. I have published academic papers on legislative districting and political geography in several political science journals, including *The American Journal of Political Science* and *The American Political Science Review*, and *Election Law Journal*. My academic areas of expertise include legislative elections, spatial statistics, geographic information systems (GIS) data, redistricting, racial politics, legislatures, and political geography. I have unique expertise in the use of computer simulations of legislative districting and to study questions related to political geography and redistricting.

I have provided expert reports in the following redistricting court cases: The League of Women Voters of Florida et al. v. Ken Detzner et al. (Fla. 2d Judicial Cir. Leon Cnty. 2012); Rene Romo et al. v. Ken Detzner et al. (Fla. 2d Judicial Cir. Leon Cnty. 2013); Missouri National Association for the Advancement of Colored People v. Ferguson-Florissant School District and St. Louis County Board of Election Commissioners (E.D. Mo. 2014); Raleigh Wake Citizens Association et al. v. Wake County Board of Elections (E.D.N.C. 2015); Corrine Brown et al. v. Ken Detzner et al. (N.D. Fla. 2015); City of Greensboro et al. v. Guilford County Board of Elections, (M.D.N.C. 2015); Common Cause et al. v. Robert A. Rucho et al. (M.D.N.C. 2016); The League of Women Voters of Pennsylvania et al. v. Commonwealth of Pennsylvania et al. (No. 261 M.D. 2017); Georgia State Conference of the NAACP et al v. The State of Georgia et al. (N.D. Ga. 2017); The League of Women Voters of Michigan et al. v. Ruth Johnson et al. (E.D. Mich. 2017). I have testified at trial in the following cases: Raleigh Wake Citizens Association et al. v. Wake County Board of Elections (E.D.N.C. 2015); City of Greensboro et al. v. Guilford County Board of Elections (M.D.N.C. 2015); Common Cause et al. v. Robert A. Rucho et al. (M.D.N.C. 2016); The League of Women Voters of Pennsylvania et al. v. Commonwealth of Pennsylvania et al. (No. 261 M.D. 2017). I am being compensated $500 per hour for my work in this case.

I was asked by plaintiffs' counsel to perform the following five tasks:

1) Construct a 'Chen Composite Measure' for the purpose of measuring the Republican vote share of Wisconsin Assembly districts. Construct the measure by using all 2004-2010 statewide election results, as listed in the column headings of Exhibit 464 ("EXH 464.xlsx"), and applying a uniform swing such that the average Republican vote share of the 99 Assembly Districts in the Act 43 plan is identical to the 48.58% average Republican vote share across the 99 Assembly Districts, as reported in Exhibit 172 ("EXH 172.pdf").

2) Generate a large number of computer-simulated districting plans for Wisconsin's Assembly districts with the following characteristics: A) The same or lower magnitude of population deviations as the Act 43 Assembly map; B) Fewer split counties than the Act 43 map; C) Fewer split municipalities than the Act 43 map; D) At least as many majority-African-American and majority-Hispanic districts as the Act 43 map; E) Fewer paired incumbents than the Act 43 map.

3) Among these computer-simulated plans, identify only those plans with an Efficiency Gap between -0.5% and +0.5%, with districts' partisanship measured using the Chen Composite Measure. Among the computer-simulated plans with an Efficiency Gap between -0.5% and +0.5%, identify the most compact plan, as measured by average Reock score.

4) Describe the characteristics of this identified computer-simulated plan and compare it to the enacted Act 43 plan.

5) Identify the districts in the computer-simulated plan and the enacted Act 43 plan in which each of 31 plaintiffs resides.

1. Constructing the 'Chen Composite Measure' of District-Level Republican Vote Share

Plaintiffs' counsel informed me that the drafters of the Act 43 map used all 13 of Wisconsin's 2004-2010 statewide elections in measuring the partisanship of Assembly districts, as listed in the column headings of Exhibit 464 ("EXH 464.xlsx"). Plaintiffs' counsel also informed me that Exhibit 172 ("EXH 172.pdf") reports the Act 43 drafters' measure of partisanship for each of the 99 Assembly districts in a near-final version of the Act 43 map. Specifically, plaintiffs' counsel informed me the "Final Map" referenced in Exhibit 172 is identical to the Assembly plan currently in use for all but four districts: Assembly Districts 8 and 9 (which were adjusted after the *Baldus* litigation) and Assembly Districts 98 and 99 (which were adjusted after the "Final Map" was created but before Act 43 was enacted).

From this exhibit, I determined that the Exhibit 172 measure of partisanship has an average Republican vote share of 48.58% across the 99 Assembly Districts in the "Final Map" referenced in this Exhibit. In Table 1, the fourth column lists these district-level Republican vote shares, as taken from Exhibit 172, and represents the information I used to calculate this average Republican vote share of 48.58% across the 99 Assembly Districts.

Plaintiffs' counsel then asked me to construct a composite measure of partisanship having both of these aforementioned characteristics: Specifically, I was instructed to construct a composite measure of partisanship by using all 2004-2010 statewide election results and applying a uniform swing such that the average Republican vote share of the 99 Assembly Districts in the Act 43 plan is identical to the 48.58% average Republican vote share across the 99 Assembly Districts, as reported in Exhibit 172.

I constructed this composite measure of partisanship using ward-level election data from Wisconsin's 2004-2010 elections, downloaded in a zipped file ("20022010_WI_Election_Data_with_2017_Wards.zip") from Wisconsin's Legislative Technology Services Bureau website.[1] I summed up the total number of votes cast in favor of Republican candidates and Democratic candidates during all 2004-2010 statewide elections within each ward. For each Act 43 Assembly District, I then calculated the Republican share of the two-party votes cast in all 2004-2010 statewide elections. These raw Republican vote shares for all Act 43 districts are reported in the second column of Table 1. Across all 99 Assembly Districts in the Act 43 map, the average district-level Republican vote share in the 2004-2010 statewide elections is 46.78%, as reported at the bottom of Table 1.

I then adjusted this raw Republican vote share by a uniform swing in order to match the 48.58% average Republican vote share across the 99 Assembly Districts, as reported in Exhibit 172 (and reproduced in the fourth column of Table 1). The difference between 48.58% (the district-level average from Exhibit 172) and 46.78% (the district-level average raw Republican share in the 2004-2010 statewide elections) is +1.8%. Thus, I applied a uniform swing of +1.8% to each district's raw Republican share in the 2004-2010 statewide elections in order to arrive at a resulting partisan measure whose district-level average across the 99 Act 43 districts is 48.58%. This resulting uniform-swing-adjusted partisan measure is reported in the third column of Table 1 and is hereinafter referred to as the 'Chen Composite Measure.'

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[1] Downloaded from: https://data-ltsb.opendata.arcgis.com/datasets/2002-2010-wi-election-data-with-2017-wards

The Chen Composite Measure closely mimics the Act 43 drafters' measure of partisanship, as reported in Exhibit 172, in three important ways. First, at the level of the Act 43 Assembly Districts, the statistical correlation between the Chen Composite Measure and the Exhibit 172 partisanship measure is over 0.99, indicating a near-perfect correlation between the two measures. Second, both measures agree about which Act 43 Assembly Districts favor Republicans versus Democrats: The 59 districts with over 50% Republican vote share as measured by the Exhibit 172 partisanship measure are also the same 59 districts that have over 50% Republican vote share using the Chen Composite Measure. Similarly, the 40 districts that are under 50% Republican vote share in Exhibit 172 also all have under 50% Republican vote share using the Chen Composite Measure. Finally, the Chen Composite Measure has, by design, exactly the same average score across the 99 Act 43 Assembly Districts as the Exhibit 172 partisanship measure has across the 99 "Final Map" districts listed in Exhibit 172.

Figure 1 provides a visual comparison of the Chen Composite Measure and the Exhibit 172 partisanship measure. In this Figure, each Assembly District's partisanship, as measured by Exhibit 172, is shown along the vertical axis. Each Assembly District's Republican vote share, as measured by the Chen Composite Measure, is shown along the horizontal axis. Figure 1 makes visually clear that among Wisconsin's 99 Assembly districts, all but four districts have an Exhibit 172 partisanship measure virtually identical to their Chen Composite Measure. The four districts for which the Exhibit 172 partisanship measure is not virtually identical to the Chen Composite Measure are Assembly Districts 8, 9, 98, and 99. As explained earlier, plaintiffs' counsel informed me that the boundaries of these four districts were adjusted after the creation of Exhibit 172. Therefore, the correlation between the Chen Composite Measure and the Exhibit 172 partisanship measure would be even higher, but for the changing of these four districts' boundaries.

2. Generating Computer-Simulated Assembly Districting Plans

Plaintiffs' counsel asked me to generate a large number of computer-simulated districting plans for Wisconsin's Assembly districts with the following characteristics: A) The same or lower magnitude of population deviations as the Act 43 Assembly map; B) Fewer split counties than the Act 43 plan; C) Fewer split municipalities than the Act 43 plan; D) At least as many majority-African-American and majority-Hispanic districts as the Act 43 map; E) Fewer paired incumbents than the Act 43 map. More specifically, plaintiffs' counsel instructed me to hold frozen Assembly Districts 8 and 9 from the Act 43 map (using the boundaries of these two districts as adjusted after the *Baldus* litigation). Holding these two districts frozen has the effect of matching the Act 43 map's creation of one majority-Hispanic district.

Table 2 describes the characteristics of the Act 43 Assembly map along these various aforementioned criteria. Below, I describe how the computer simulation algorithm implements these criteria:

1) Geographic Contiguity: The computer simulation algorithm I use for this report requires districts to be contiguous by land, with no point contiguity. In other words, a district that combines two areas is considered contiguous only if those two areas share a common border of non-zero length. Even when a ward contains geographically non-contiguous fragments, the district in which the ward lies is nevertheless required to be contiguous. Where offshore islands exist, these islands are considered to be contiguous with the mainland portions of their respective wards.

2) Equal Population: As of the 2010 Census, Wisconsin has a total statewide population of 5,686,986, so each of the state's 99 Assembly districts has an ideal district population of 57,444.3. In the Act 43 map, Assembly District 8, with a population of 57,196, deviates from this ideal district population by 248.3, which is the largest deviation among all districts in the Act 43 map. Therefore, I program the computer-simulated districting algorithm to require that all simulated districts have a population deviation of less than 248.3.

3) Minimizing Split Counties: After ensuring district contiguity and compliance with the equal population threshold, the simulation algorithm then seeks to minimize the number of counties split in each simulated districting plan. As Table 2 reports, the Act 43 map splits apart 58 of Wisconsin's 72 counties. Table 6 lists these 58 split counties in the Act 43 map. Thus, the simulation algorithm intentionally produces plans that split fewer than 58 total counties.

4) Minimizing Split Municipalities: The simulation algorithm also seeks to minimize the number of municipalities split in each simulated districting plan. As Table 2 reports, the Act 43 map splits apart 67 of Wisconsin's municipalities, which include cities, towns, and villages. Table 5 lists these 67 split municipalities in the Act 43 map. Thus, the simulation algorithm intentionally produces plans that split fewer than 67 total municipalities.

5) Majority-Minority Assembly Districts: The simulation algorithm requires plans to contain six districts with at least 50% African-American VAP, matching the Act 43 map's number of majority-African-American districts. In calculating the Black Voting Age Population of each district, I include only individuals who identify as single-race African-American. Additionally, Assembly Districts 8 and 9 from the Act 43 map are frozen in every simulated plan, thus producing one district in each plan (District 8) with a majority-Hispanic VAP.

6) Avoiding Paired Incumbents: Plaintiffs' counsel provided me with a list of all 96 incumbent Assembly members as of the November 2012 election; the remaining three districts (Assembly districts 60, 83, and 94) contained no incumbent as of 2012. I geocoded the residential addresses of each incumbent to identify the district in which each incumbent resides in the Act 43 map and the computer-simulated maps.

As reported in Table 2, the Act 43 map contains 22 incumbents who were placed into a district containing multiple incumbents; the remaining 74 incumbents were the only incumbents in their respective districts. Therefore, I programmed the simulation algorithm to guarantee that fewer than 22 incumbents were paired, or placed into a district with multiple incumbents. Table 9 identifies the 22 paired (or "Not Protected") incumbents and the 74 non-paired (or "Protected") incumbents under the Act 43 plan.

The Computer Simulation Algorithm: The simulation algorithm proceeds as follows: First, the algorithm begins with a set of base geographies to be used as building blocks for constructing a simulated plan. In creating Assembly districting plans, I primarily use ward boundaries as the building blocks; however, I split up non-contiguous portions of single wards into separate building blocks in order to avoid creating non-contiguous Assembly districts. Specifically, in constructing this set of base geographies, I used Wisconsin's 2012 ward-level shapefile, which I downloaded in a zipped file (named "2012_wi_precincts.zip") from Wisconsin's Legislative Technology Services Bureau website.[2] This shapefile, produced by the Wisconsin LTSB, uses the Wisconsin Transverse Mercator projected coordinate system.[3] Thus, all subsequent calculations of district compactness of computer-simulated plans in this expert report are also based on this same projected coordinate system.

Second, the algorithm randomly divides up these geographies into an initial plan consisting of 97 simulated districts and two frozen districts (Assembly Districts 8 and 9 from the Act 43 map, as adjusted after the *Baldus* litigation). These 97 simulated districts are constructed in the following manner: First, the non-frozen portions of Wisconsin are randomly divided into two contiguous

[2] I downloaded the "2012_wi_precincts.zip" file on February 16, 2016. Although the file is no longer available on the Wisconsin LTSB website, a copy remains available on the following external URL: https://github.com/aaron-strauss/precinct-shapefiles/tree/master/wi

[3] Described at: https://epsg.io/3071

groups: One group consisting of 48/97ths of the total population, and the second group consisting of 49/97ths of the total population. Next, the 48/97ths group is randomly divided into two sub-groups, each consisting of 24/97ths of the total population. Meanwhile, the 49/97ths group is randomly divided into two subgroups, one consisting of 24/97ths and the second consisting of 25/97ths of the total population. These iterative sub-divisions continue until the non-frozen portions of Wisconsin are divided into 97 contiguous, equally-populated sub-groups.

Third, the computer then employs three Markov chain Monte Carlo (MCMC) algorithms to pursue various redistricting criteria. First, the algorithm evaluates a large number of randomly-proposed, iterative changes to the various boundaries between the districts; in each iteration, a proposed change is accepted only if the total number of majority-African-American districts does not decrease. These random, iterative changes continue until the districting map achieves a total of six majority-African-American VAP districts. The second MCMC algorithm considers yet more randomly-proposed, iterative changes to the district boundaries; proposed changes are accepted only if the number of paired incumbents does not increase and the number of majority-African-American VAP districts does not decrease. This second set of MCMC iterations continues until the number of paired incumbents falls below 22, which is the number of paired incumbents in the Act 43 map. Finally, the third MCMC algorithm accepts randomly-proposed, iterative changes to district boundaries only if the number of paired incumbents does not increase, the number of majority-African-American VAP districts does not decrease, and the total number of split county and municipality fragments does not increase. This third set of MCMC iterations continues until the plan contains significantly fewer than the 58 split counties and 67 split municipalities observed in the enacted Act 43 map. By considering and selectively implementing a large number of random iterative changes to the districts' boundaries, the algorithm thus gradually decreases the number of split counties, split municipalities, and paired incumbents in the plan, while matching the Act 43 map's six majority-African-American districts. These iterative changes result in a plan in which county and municipality boundaries are generally followed, except when splitting counties and municipalities is necessary for achieving one of the other aforementioned districting criteria.

In total, I conducted this entire simulation algorithm enough times to produce 9,452 separate districting plans. In the following section, I describe how I calculated certain characteristics of these simulated plans and identified one plan using a set of objective criteria.

3. Selecting a Single Simulated Assembly Plan

I was instructed by plaintiffs' counsel to identify, among the 9,452 computer-simulated plans, only those plans whose Efficiency Gap rounds to zero - that is, plans with an Efficiency Gap between -0.5% and +0.5%, with districts' partisanship measured using the Chen Composite Measure. I was further instructed to identify, among the computer-simulated plans with an Efficiency Gap between -0.5% and +0.5%, the most compact plan, as measured by average Reock score.

For each computer-simulated plan, I calculated each district's partisanship using the Chen Composite Measure by using the 2004-2010 statewide election votes and applying the same uniform swing described in the first section of this report. I then calculated the Efficiency Gap of each computer-simulated plan using the Chen Composite Measure to characterize each district's Republican vote share.

The Efficiency Gap is a commonly-used measure of a districting plan's partisan bias. To calculate the Efficiency Gap of each computer-simulated plan, I first calculated the number of Republican and Democratic voters within each district using the Chen Composite Measure, multiplied by the total number of two-party votes cast in statewide elections during 2004-2010. I then calculated each districting plan's Efficiency Gap using the method outlined in *Partisan Gerrymandering and the Efficiency Gap*[4]. Districts are classified as Democratic victories if, across these statewide elections, the sum total of Democratic votes in the district during these elections exceeds the sum total of Republican votes; otherwise, the district is classified as Republican. For each party, I then calculate the total sum of surplus votes in districts the party won and lost votes in districts where the party lost. Specifically, in a district lost by a given party, all of the party's votes are considered lost votes; in a district won by a party, only the party's votes exceeding the 50% threshold necessary for victory are considered surplus votes. A party's total wasted votes for an entire districting plan is the sum of its surplus votes in districts won by the party and its lost votes in districts lost by the party. The Efficiency Gap is then calculated as total wasted Democratic votes minus total wasted Republican votes, divided by the total number of two-party votes cast statewide across all 13 elections. Thus, a positive Efficiency Gap indicates more wasted Democratic than Republican votes, while a negative Efficiency Gap indicates more wasted Republican than Democratic votes.

[4] Nicholas O. Stephanopoulos & Eric M. McGhee, *Partisan Gerrymandering and the Efficiency Gap*, 82 University of Chicago Law Review 831 (2015).

I calculated the Efficiency Gap of each of the 9,452 computer-simulated plans described in the previous section. I then identified only those plans with an Efficiency Gap between -0.5% and +0.5%. Among these plans, I then identified the most compact plan, as measured by average Reock score. This process led to the identification of Simulated Map 43995.

4. Characteristics of Simulated Map 43995

Table 3 provides the following information regarding each district in the enacted Act 43 Map: (1) its population; (2) its Black Voting Age Population share; (3) its Hispanic Voting Age Population share; (4) its Reock compactness score; (5) its Polsby-Popper compactness score; and (6) its Republican vote share as measured by the Chen Composite Measure. Table 4 provides the same information regarding each district in Simulated Map 43995. Figure 2 includes a statewide map of the Act 43 Map's districts (Figure 2a), as well as zoomed-in maps detailing the districts in Milwaukee, Brown, Dane, Racine, and Kenosha Counties (Figure 2b). Figure 3 includes a statewide map of Simulated Map 43995's districts (Figure 3a), as well as zoomed-in maps detailing the districts in Milwaukee, Brown, Dane, Racine, and Kenosha Counties (Figure 3b). In all of these maps in Figures 2 and 3, all districts are shaded by partisanship using the Chen Composite Measure, with Democratic-leaning districts shaded from dark blue (most heavily Democratic) to light blue (least Democratic) and Republican-leaning districts shaded from dark red (most heavily Republican to light red (least Republican).

The maps in Figures 4 and 5 are all shaded at the ward level (using 2011 ward boundaries) by partisanship using the Chen Composite Measure, with Democratic-leaning wards shaded from dark blue (most heavily Democratic) to light blue (least Democratic) and Republican-leaning wards shaded from dark red (most heavily Republican to light red (least Republican). In addition to shading each ward by its partisanship, Figure 4a contains black lines depicting the boundaries of the Act 43 Map's districts for all of Wisconsin, while Figure 4b contains zoomed-in maps detailing the Act 43 Map's districts in Milwaukee, Brown, Dane, Racine, and Kenosha Counties. Similarly, Figure 5a contains black lines depicting the boundaries of Simulated Map 43995's districts for all of Wisconsin, while Figure 5b contains zoomed-in maps detailing Simulated Map 43995's districts in Milwaukee, Brown, Dane, Racine, and Kenosha Counties.

Table 2 compares the plan-wide characteristics of the Act 43 Map and Simulated Map 43995. Simulated Map 43995 pairs 18 incumbents (compared to 22 in the Act 43 Map), splits 43 counties (compared to 58 in the Act 43 Map), splits 53 municipalities (compared to 67 in the Act 43

Map), and contains districts within 248.3 of the ideal district population (identical to the maximum population deviation of the Act 43 Map). Table 7 lists the 53 municipalities split by Simulated Map 43995, while Table 8 lists the 43 counties split by Simulated Map 43995. Furthermore, Simulated Map 43995 has an average Reock compactness score of 0.402 (compared to 0.375 in the Act 43 Map) and an average Polsby-Popper compactness score of 0.271 (compared to 0.250 in the Act 43 Map). Table 9 lists the 96 Assembly incumbents, as of 2012, and identifies the Act 43 district and the Simulated Plan 43995 district within which each incumbent resides, thus identifying whether each incumbent is non-paired ("Protected") or paired ("Not Protected") within each of these two plans.

To calculate the compactness scores of the enacted Act 43 map, I first downloaded a shapefile of the Act 43 Assembly district boundaries from the Wisconsin LTSB website.[5] I found that this shapefile uses the World Geodetic System 1984 (WGS84) coordinate system.[6] I thus calculated the Reock and Polsby-Popper compactness scores for the Act 43 plan using this shapefile and its WGS84 coordinate system. This WGS84 coordinate system is different from the coordinate system used in the Wisconsin LTSB's ward shapefile described earlier in this report. However, I found that regardless of whether the Act 43 Map's compactness is calculated using the WGS84 coordinate system or the Wisconsin Transverse Mercator projected coordinate system used in the Wisconsin LTSB's ward shapefile, the Act 43 Map remains less geographically compact than Simulated Map 43995.

Finally, Figure 6 displays the Efficiency Gap of Simulated Map 43995 under different uniform swing conditions. Specifically, to create this Figure, I applied various alternative uniform swings to the Chen Composite Measure, ranging from -5% to +5% (at intervals of 0.1%). I then re-calculated the Efficiency Gap of Simulated Map 43995 under each of these uniform swing conditions, applying the same uniform swing to all districts in Simulated Map 43995. These Efficiency Gaps for each uniform swing condition are shown in Figure 6.

5. Plaintiffs' Districts in the Act 43 Map and Simulated Plan 43995

Plaintiffs' counsel provided me with a list of 31 plaintiffs, listed in Table 10, and their respective residential addresses. Plaintiffs asked me to identify the districts in the enacted Act 43 Map and in Simulated Plan 43995 in which each of these 31 plaintiffs resides.

[5] https://data-ltsb.opendata.arcgis.com/datasets/wisconsin-assembly-districts-2012
[6] https://epsg.io/4326

I geocoded each plaintiff's residential address and identified each plaintiff's district in the two plans. Table 10 specifies the following information about each of these 31 plaintiffs: (1) In which district in the Act 43 Map the plaintiff is located; (2) what this district's Republican vote share is using the Chen Composite Measure; (3) in which district in Simulated Plan 43995 the plaintiff resides; and (4) what this district's Republican vote share is using the Chen Composite Measure.

The end of this report contains a series of two maps for each of the 31 plaintiffs: One map depicting the plaintiff's residence within the plaintiff's Act 43 Assembly district, and a second map depicting the plaintiff's residence within the plaintiff's district in Simulated Plan 43995. In both maps, the plaintiff's district is shaded using the same blue-red color scale, based on the partisanship of the district (as measured by the Chen Composite Measure), as in Figures 2 and 3. In each map, the Republican vote share (as measured by the Chen Composite Measure) of the plaintiff's district is also reported in the third line in the third row of the header of the map.

I declare under penalty of perjury under the laws of the United States that the foregoing is true and correct to the best of my knowledge.

This 15th day of October, 2018.

Jowei Chen