BEFORE THE PUBLIC UTILITIES COMMISSION

STATE OF COLORADO

Docket No. 09A-324E

IN THE MATTER OF THE APPLICATION OF TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION, INC., (A) FOR A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY FOR THE SAN LUIS VALLEY-CALUMET-COMANCHE TRANSMISSION PROJECT, (B) FOR SPECIFIC FINDINGS WITH RESPECT TO EMF AND NOISE, AND (C) FOR APPROVAL OF OWNERSHIP INTEREST TRANSFER AS NEEDED WHEN PROJECT IS COMPLETED

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IN THE MATTER OF THE APPLICATION OF PUBLIC SERVICE COMPANY OF COLORADO (A) FOR A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY FOR THE SAN LUIS VALLEY-CALUMET-COMANCHE TRANSMISSION PROJECT, (B) FOR SPECIFIC FINDINGS WITH RESPECT TO EMF AND NOISE, AND (C) FOR APPROVAL OF OWNERSHIP INTEREST TRANSFER AS NEEDED WHEN PROJECT IS COMPLETED

CROSS ANSWER TESTIMONY OF INEZ G. DOMINGUEZ
STAFF OF THE COLORADO PUBLIC UTILITIES COMMISSION

December 2, 2009

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I. INTRODUCTION

Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.

A. My name is Inez G. Dominguez. My business address is 1560 Broadway, Suite 250, Denver, Colorado 80202.

Q. BY WHOM ARE YOU EMPLOYED AND IN WHAT CAPACITY?

A. I am employed by the Colorado Public Utilities Commission (Commission) as a Staff Engineer.

Q. DID YOU PREVIOUSLY FILE TESTIMONY IN THIS PROCEEDING?

A. Yes, I filed Answer Testimony on behalf of Staff on October 28, 2009.

II. PURPOSE OF CROSS-ANSWER TESTIMONY

Q. WHAT IS THE PURPOSE OF YOUR CROSS-ANSWER TESTIMONY IN THIS PROCEEDING?

A. The purpose of this testimony is to provide Staff's analysis of Mr. James R. Dauphinais' Answer Testimony submitted on behalf of Blanca Ranch Holdings, LLC and Trinchera Ranch Holdings, LLC in the instant docket relating to the application of Public Service Company of Colorado and Tri-State Generation and Transmission Association, Inc. (the Utilities) for a certificate of public convenience and necessity (CPCN) for the San Luis-

Calumet-Comanche Transmission Project. My Cross-Answer Testimony comments Mr. Dauphinais' proposal:

1. to add 250-525 MW of new generation in the San Luis Valley area without any new transmission line additions;
2. to add another Poncha-San Luis 230kV line and the 475-575 MW of new generation this new line can support in the San Luis Valley; and
3. for generation that is a short term solution for the potential solar generation in the San Luis Valley.

III. COMMENTS REGARDING THE 250-525 MW OF NEW GENERATION IN THE SAN LUIS VALLEY WITHOUT ANY NEW TRANSMISSION LINE ADDITIONS

Q. DO YOU HAVE COMMENTS REGARDING MR. DAUPHINAIS' STUDY ON THE POSSIBILITY OF ADDING 250-525 MW OF NEW GENERATION IN THE SAN LUIS VALLEY WITHOUT ADDITIONAL TRANSMISSION LINES?

A. Yes. Before I directly respond to Mr. Dauphinais' comments, let me lay a foundation for my response. Mr. Dauphinais' study results are summarized on Page iii of his testimony entitled "Summary of Answer Testimony of James R. Dauphinais."

Q. WHAT ARE YOUR PRELIMINARY REMARKS?

A. The San Luis Valley area electric system is a radial system, meaning the local peak load of 139 MW (125 MW of load plus 14 MW of losses) in the study is much greater than the amount of local generation of about 42 MW (34 MW of combustion turbines (CT) generation and 8 MW of solar generation). The remaining 97 MW are then supplied by the Poncha-Sargent-San Luis 115kV line and the Poncha-San Luis 230kV line. A 69kV line from Poncha also feeds a small portion of the load. A 2008 Load Duration Curve for the San Luis Valley area shows about a 133 MW peak in July and a minimum load of about 43 MW in November (reference **Exhibit IGD -10)**. The load during this off-peak condition is 32% of the peak. From the table labeled "Monthly Min" on Exhibit IGD-10, eight months out of the year show the minimum load to be less than 50 MW with the spring months of March, April, and May having an average minimum load of 46 MW and the fall months of September, October, and November having an average minimum load of about 44 MW. These spring and fall averages are within three MW of the minimum peak. So the off-peak load in the San Luis Valley can be significantly lower than the maximum summer peak load. Because of the radial nature of the San Luis Valley electric system and the linear nature of the power flow (MW) into it, my analysis of matching generation to load will be done using simple arithmetic. The arithmetic numbers will then raise flags where these numbers can then be fine tuned if need be with power flow and stability simulations.

An ideal situation for the San Luis Valley would be for the local generation level to be the same as the local load with the transmission lines into the San Luis Valley serving as a regulation source for the frequency and minor load/generation changes. As suggested by Mr. Dauphinais, it is possible that at the time of the 139 MW peak, 150 MW of generation there would resolve the load serving reliability issues with the loss of the Poncha-San Luis 230kV line. However, to totally resolve the reliability issue, the generation has to be online during the time when the valley load is 65 MW and higher. It is possible that solar generation may not be on at night when the sun is not shining and the load may be 65 MW and higher, putting the San Luis Valley area at risk for the Poncha-San Luis Valley 230kV outage.

Following Mr. Dauphinais' approach, my educated guess for the amount of additional generation the San Luis Valley can accommodate would be 65 MW plus the minimum load of the year, roughly another 44 MW (32%*139 MW) for a total of 109 MW, which would also include the 34 MW of CT plus the 8 MW of existing solar generation, leaving a balance of new generation of 67 MW. This total of 109 MW of generation would allow load service in the valley plus a 65 MW export out of the valley during minimum load conditions.

Q. WHAT ABOUT THE 250 MW GENERATION SCENARIO?

A. For the 250 MW new generation scenario during the peak, we can assume the 34 MW of CT would be off line leaving 258 MW of solar generation on line in the San Luis Valley. With a 139 MW load, the remaining 119 MW of excess generation would need to flow out of the valley on the 115kV and 230kV lines to the Poncha Substation. Electrically, this system would work under system intact conditions. With an outage of the San Luis-Poncha 230kV line, the San Luis-Sargent 115kV line would have to carry about 119 MW and the Sargent-Poncha 115kV line would have to carry about 94 MW after dropping off 25 MW of load at the Sargent Substation. For the peak condition, the arithmetic shows that this may work from a power flow standpoint. However, this case would have to be tested for stability since the Poncha Substation 115kV bus is not a very strong bus. This observation is made from the fact that 65 MW flowing on the Poncha-Sargent 115kV line

<u>into</u> the San Luis Valley is the trigger point for voltage problems in the San Luis Valley with a Poncha-San Luis 230kV outage. Similarly with a Poncha-San Luis 230kV outage and 65 MW flowing <u>out of</u> the San Luis Valley on the Sargent-Poncha 115kV line, 65 MW is also a flag for potential voltage problems on the 115kV system connected to the Poncha 115kV bus. Also, note that during daylight hours when generation may be at peak and the load is significantly lower than the summer peak (as may be the case in the winter, spring and fall days), the loading on the Sargent-Poncha 115kV line would be higher than the summer peak conditions. For purposes of this discussion, let's assume the load is 44 MW, or 32% of the 139 MW peak, leaving 214 MW to be exported out of the valley. With an outage of the Poncha-San Luis 230kV line, the San Luis-Sargent 115kV line would carry 214 MW (rated 159 MW) and the Poncha-Sargent 115kV line would carry 206 MW (rated 128 MW). So the total length of the Poncha-San Luis 115kV line is overloaded. Now, the voltage collapse flag for the electric system connected to the Poncha 115kV bus is raised higher. So obviously the generation would have to be reduced at least 78 MW so as to not overload the Poncha-Sargent 115kV line.

In Mr. Dauphinais' study approach, because of this heavily loaded 66 mile Poncha-San Luis 115kV line, a stability study would need to be done to determine if this scenario is transiently stable. Due to peak load voltage concerns and transient stability concerns which can be made worse at the times when the load in the San Luis Valley will be less than 125 MW, the 250 MW scenario is suspect for feasibility.

In addition, Public Service Company of Colorado (Public Service) does not have firm transmission rights on Western Area Power Administration's (Western) Poncha-Midway 230kV line nor the Poncha-Curecanti 230kV line. With 250 MW of generation in the San Luis Valley, Public Service and Western would need to do studies to determine the required amount of firm transmission service, if available. Since this power would likely mainly be Public Service's responsibility, PSCo and Western would have to work out a contractual relationship for Public Service's use of Western's system.

Q. STABILITY IS AN ISSUE YOU KEEP RAISING WITH REGARD TO MR. DAUPHANAIS' PROPOSALS. YOU DISCUSS ON PAGE 5, LINES 1 TO 7, OF YOUR ANSWER TESTIMONY THE USE OF THE SWING EQUATION TO RAISE STABILITY CONCERNS. IS IT POSSIBLE TO USE THE SWING EQUATION TO LOOK AT YOUR STABILITY CONCERNS WITH MR. DAUPHANAIS' PROPOSALS?

A. Yes, but let me discuss the swing equation further in this testimony. Mr. Dauphinais and I discussed in a telephone conversation on November 23, 2009 the swing equation as presented in my Answer Testimony. Mr. Dauphinais clarified that the swing equation requires a 90 degree number for the δ portion of the swing equation as used in technical reference books. That makes Sine 90 equal to 1.0 and therefore Pmax equals 1301 MW for the benchmark study I discussed in my Answer Testimony.

Q. DO YOU AGREE WITH MR. DAUPHINAIS' CLARIFICATION?

A. Yes. However, the Pmax equals 1301 MW number does not make sense to me. It is way too high. In my experience doing stability studies with conditions similar to the instant scenario, the number should be closer to 400 MW. As stated in my Answer Testimony, stability studies should have been run to test the bench mark study. Stability studies definitely have to be run to test the proposed San Luis-Calumet-Comanche project.

Q. DOES MR. DAUPHINAIS' CLARIFICATION REGARDING THE SWING EQUATION PRECLUDE YOU FROM USING IT TO CONSIDER STABILITY?

A. No, I believe it is still a very useful tool. Let me elaborate. For the San Luis Valley area, there are long distances between load serving substations on the 115kV and 230kV system from the San Luis Substation. The longer the distances, the larger the reactance (X in the denominator of the swing equation) becomes while the angle δ increases getting closer to 90 degrees.

Q. WHAT ABOUT THE 525 MW GENERATION SCENARIO WITH A PONCHA 230-115KV TRANSFORMER AND A REMEDIAL ACTION SCHEME?

A. Using the same reasoning as in the 250 MW case discussed above, the 525 MW generation scenario plus 8 MW existing with a 139 MW load would leave 394 MW to be exported out of the area over the 115kV and 230kV lines to the Poncha Substation. The 394 MW would have a significant impact on Western's 230kV lines out of the Poncha Substation. The 394 MW would definitely require a careful look and study on the impact it would have on Western's 230kV and 115kV electric system as well as others that would now be impacted due to the addition of the Poncha 230-115kV transformer. In addition, Western would have to investigate the feasibility and the contractual implications on its system out of the Poncha Substation followed by contract negotiations between Western and Public Service. It is unclear how much time these studies and contract issues would take to do, however it typically takes years rather than a few months to complete.

For an example of transmission costs associated with needing to export 394 MW out of the San Luis Valley, let's assume that 100 MW could be handled by Public Service's 115kV system leaving 294 MW of wheeling from Western, assuming Western has transmission capacity for this amount. Western's present firm transmission charge is $1.48/kW-month or $17.76/kW-year (reference **Exhibit IGD-11**). For 294 MW, the firm transmission cost would be approximately $5.2 million a year ($17.76/kW-year*294 MW*1000kW/MW). This cost would need to be considered with Mr. Dauphinais' proposal. An equivalent Public Service capital investment for transmission would be about $34.7 million.[1]

Q. WHAT COMMENTS DO YOU HAVE REGARDING THE REMEDIAL ACTION SCHEME PROPOSED BY MR. DAUPHINAIS?

A. A remedial action schemes (RAS) is used in the utility industry to take care of special system conditions and the system disturbances that may occur during those special system conditions. The use of a RAS typically means that there is not enough transmission system to take care of the specified system disturbance. A RAS has an inherent risk that it may fail to operate as planned. Many of the blackouts experienced in the Western Electric Coordinating Council were as a result of failed RAS's. Mr. Dauphinais proposes

[1] Utility's typically use a Fixed Charge Rate (FCR) to levelize on an annual basis the revenue requirements of a capital project. The levelized annual cost is obtained by multiplying the total capital dollars by the FCR, which generally is 15% for transmission lines. To get an equivalent capital dollars cost by having an annual cost, the annual cost is divided by the FCR. In this example, the $5.2 million is divided by 0.15 to get $34.7 million.

to trip generation with an outage of the San Luis-Poncha 230kV line, a single transmission facility, typically referred to by the utility industry as an N-1 contingency. For argument sake, let's assume that out of the 533 MW of solar generation, 135 MW are connected to the 115kV system and the remaining 398 MW are connected to the 230kV system. With an outage of the San Luis-Poncha 230kV line during a 139 MW peak and maximum generation, if the RAS failed, about 398 MW of power would need to flow on the 300 MVA 230-115kV San Luis Substation, loading the transformers to 133%. About 409 MW would also need to flow over the San Luis-Sargent 115kV line, rated at 159 MVA, or a 264% loading. The Sargent-Poncha 115kV section is rated at 128 MVA and it would need to carry 394 MW, or a 308% loading. At this loading, the 115kV line would open up (or be severely damaged) isolating the generation, which would then trip off-line on overspeed. The San Luis Valley would then experience a blackout. Obviously, the situation would be worse during lower load periods and full generation.

I am not in favor of a RAS in general, especially with a RAS associated with new generation and the concept of skimping on necessary transmission given that the cost of new generation far exceeds the cost of transmission. Transmission lines stretching 100 to 150 miles are absolutely necessary to deliver the power to the load center under N-1 criteria, which costs roughly 10% of the generation costs of coal fired generation. Certainly, a RAS that results in load shedding should be scrutinized by the Commission to the extent that load serving reliability is compromised. For this reason, I do not recommend the use of a RAS to accommodate 525 MW of new generation in the San Luis Valley.

IV. COMMENTS REGARDING THE ADDITION OF ANOTHER PONCHA-SAN LUIS 230KV LINE AND THE 475-575 MW OF NEW GENERATION THIS NEW LINE CAN SUPPORT IN THE SAN LUIS VALLEY

Q. WHAT ARE YOUR COMMENTS REGARDING THE ADDITION OF ANOTHER PONCHA-SAN LUIS 230KV LINE AND THE 475-575 MW OF NEW GENERATION THIS NEW LINE CAN SUPPORT IN THE SAN LUIS VALLEY?

A. Another or a second Poncha-San Luis 230kV line in the San Luis Valley would certainly take care of the load serving reliability issue with the outages of the existing Poncha-San Luis 230kV line. If the new 230kV line replaced the San Luis-Sargent-Poncha 115kV line, a 230-69kV transformer would be required at the Sargent Substation to serve the load at that location. A new 230-115kV transformer would then be needed at the Poncha Substation to maintain the 115kV interconnection and 115kV point of delivery to the 115kV lines at the Poncha Substation.

My comments here are similar to the previous discussion where these 475-575 MW of generation are mentioned. The issues that arise and must be resolved have to do with the 115kV and 230kV transmission systems from the Poncha Substation and beyond where the Utilities will be interfacing with Western's transmission system, among others. Transmission studies, including stability, need to be done to identify problems and solutions to the problems identified. As mentioned previously, transmission service contractual issues with Western would also need to be identified and resolved.

V. COMMENTS REGARDING HOW MR. DAUPHINAIS' PROPOSAL IS A SHORT TERM SOLUTION TO THE POTENTIAL OF SOLAR GENERATION IN THE SAN LUIS VALLEY

Q. IN REFERENCE TO THE SOLAR GENERATION POTENTIAL IN THE SAN LUIS VALLEY, WHAT ARE YOUR COMMENTS REGARDING MR. DAUPHINAIS' PROPOSAL THAT YOU DISCUSS ABOVE IN CONNECTION WITH SAN LUIS VALLEY GENERATION IN THE 475-575 MW RANGE?

A. Mr. Dauphinais' proposal of a second Poncha-San Luis 230kV line, coupled with Public Service's proposed addition of a Poncha 230-115kV transformer, certainly has merit to solve the load serving reliability issue in the San Luis Valley. While these transmission facility additions will take care of load serving reliability issues, the immediate transmission issues associated with new generation in the San Luis Valley shift over to the Poncha Substation and the 230kV and 115kV electric systems connected to it. As discussed previously, studies in conjunction with Western and other affected utilities in the area need to be done to look at what transmission facilities are needed at the Poncha Substation and beyond. These studies will determine the transmission facilities needed to accommodate different generation levels in the San Luis Valley area. These studies can then be used to stage the transmission system with each generation addition in the San Luis Valley area.

However, as I discussed in my Answer Testimony, the solar generation potential in the San Luis Valley is 240,000 MW. Limiting generation in the San Luis Valley to 400-500 MW therefore seems shortsighted. Public Service considered a 600 MW level in its studies. I looked at an 800 MW level at the San Luis Substation combined with 1000 MW at the Calumet Substation to evaluate transmission loss savings with a San Luis-Calumet double circuit 345kV when compared to a double circuit 230kV line. In some of its earlier studies, the Colorado Long-Range Transmission Planning Group looked at 1000 MW in the San Luis Valley. Although it is difficult to imagine developing its full 240,000 MW potential, a 2000 MW level, which is less than 1% of the total, seems like a realistic number. Based on the concepts presented in my *Long Term Transmission Study for Colorado* (reference **Exhibit IGD-12**) the 2000 MW level looks reasonable for transmission planning purposes. Based on that study (reference Exhibit IGD-12, page 36), in my Answer Testimony I presented a 2041 heavy summer case with 1700 MW of generation in the San Luis Substation and 776 MW at Walsenburg Substation (reference Exhibits IGD-7 and 8 attached to my Answer Testimony). This case represented a need for a San Luis-Walsenburg-Comanche double circuit 345kV line based on the line loadings beyond what a double circuit 230kV line could accommodate. Obviously, a 2000 MW level of generation would need the double circuit 345kV line. Note that Exhibit IGD-8 in my Answer Testimony shows a Poncha-Sargent-San Luis 230kV line and a Poncha 230-115kV transformer that complements the San Luis-Walsenburg-Comanche double circuit 345kV line.

Q. ASSUMING A GENERATION LEVEL IN THE 1700-2000 MW RANGE, COULDN'T A TRANSMISSION SYSTEM GOING NORTH VIA THE EXISTING SAN LUIS-PONCHA TRANSMISSION CORRIDOR BE PLANNED INSTEAD OF A NEW SAN LUIS-CALUMET TRANSMISSION CORRIDOR?

A. The simple answer is yes, it is possible. However, there are two major issues that need to be resolved. The first issue is finding a suitable transmission corridor for the required transmission system. The second issue is the reliability of the generation transmission system with it being in a common corridor. I will discuss these two issues separately.

Q. PLEASE DISCUSS THE TRANSMISSION CORRIDOR ISSUE.

A. I believe that a 1700-2000 MW power plant complex in the San Luis Valley area will still require the two San Luis-Poncha 230kV circuits as previously discussed and a double circuit 345kV line. Conceptually, for purposes of this discussion, the first section of this double circuit 345kV line would likely follow the San Luis Substation to the Poncha Substation route, a distance of about 60 miles. From the Poncha Substation, this double circuit 345kV would probably then proceed to the Midway Substation to interconnect with the Midway-Daniels Park/Waterton 345kV system, a distance of 124 miles. From the Poncha Substation two new 230kV circuits would be needed. One circuit could be done by upgrading the Poncha-Malta single circuit 115kV line to a double circuit 230kV line with one side operated at 115kV and the other side at 230kV, a distance of 52 miles. This construction would maintain the Poncha-Malta 115kV line and create a new Poncha-Malta 230kV line. The second circuit could be done by upgrading the Poncha-Canon City-West Station-Comanche 115kV line to a double circuit 230kV line to maintain the 115kV circuit and to create a new Poncha-Comanche 230kV circuit, a distance of 130 miles. A 345-230kV substation would be created at Poncha with 345-230kV transformers added as required at the Poncha Substation and Midway Substation. With the Poncha-Comanche 230kV circuit, 230-115kV transformers would be added as required. An equivalent system to the San Luis-Calumet-Comanche proposed transmission project would include the San Luis-Poncha-Midway double circuit 345kV line and the Poncha-Comanche 230kV line. A rough estimate of the above 345kV line is about $249 million and for the 230kV line it is about $150 million; two 345-230kv transformers would cost about $26 million.[2] The total cost is about $400 million. Of course, this new transmission would have to be modeled and tested to make sure that it would work.

In describing this new system, please note I have portrayed the system as following existing transmission corridors. However, this does not mean they are easily expandable to build new transmission lines. We only know that they are there. The local permitting jurisdictions would still need to be approached for permits for rights-of-way (ROW) acquisitions. Western would probably enter into the picture as a joint participant in the project with all of its federal mandates/requirements for upgrading existing lines and/or building new lines. In short, the ROW permitting process would be starting over.

Lastly, I acknowledge the construction of the above described facilities will be much more expensive than the proposed San Luis-Calumet-Comanche transmission project.

Q. PLEASE DESCRIBE THE GENERATION/ TRANSMISSION RELIABILITY ISSUES.

[2] Costs were provided by Tri-State for a double circuit 345kV line and a double circuit 230kV line. The average cost for the 345kV line was $1,354,714 per mile and for the 230kV line $961,842 per mile. The $26 million for the 345-230kv transformers was my estimate based on the average cost per transformer for the Comanche 3 transmission system.

A. There are two reliability issues with the system as I described in my response to the previous question. The first issue is that the two 230kV circuits and the two 345kV circuits carrying the 1700-2000MW are all in the same San Luis-Poncha transmission corridor. The obvious problem is the simultaneous loss of all the circuits and the subsequent loss of all the generation. The second issue is a common termination point for all the circuits at the Poncha Substation. Although the substation would be constructed to properly terminate all the lines in a reliable configuration, the Poncha Substation would present a common point of failure for a severe disturbance, such as a fault at the substation and a breaker failure. The whole 1700-2000 MW would be at risk.

The San Luis-Calumet-Comanche transmission project provides two transmission outlets and terminations from the San Luis Substation—one to the proposed Calumet Substation and one to the existing Poncha Substation. This system by design would be a more reliable system than having all the circuits in one corridor with a common termination at the Poncha Substation.

VI. CONCLUSIONS

Q. WHAT ARE YOUR CONCLUSIONS FROM YOUR DISCUSSION?

A. After reviewing Mr. Dauphinais' testimony, my conclusions are as follows:

1. Mr. Dauphinais states that 150 MW of new solar generation in the San Luis Valley will take care of the load serving reliability concern. I disagree. Mr. Dauphinais' opinion would typically be true for a more conventional generation. However, in this case, the new generation is solar with storage that will be on at

full capacity when the sun shines during day time hours. At night the generation will be off line. During the night, the load typically reduces significantly well below the daily peak, particularly during the fall, winter, and spring months. During these off peak periods when the generation is off and when the load in the San Luis Valley exceeds 65 MW, the system will be at risk of a voltage collapse with an outage of the Poncha-San Luis 230kV line. Only when the sun shines during the day will the generation take care of the reliability concern.

2. Mr. Dauphinais states that significant generation up to 525 MW could be added in the San Luis Valley with Public Service's proposed Poncha 230-115kV transformer and a remedial action scheme (RAS) where generation is tripped with the loss of the Poncha-San Luis 230kV line. There are two problems with this idea. The first is RAS sometimes fail to operate when they should. Although the loss of a transmission line with a RAS failure may be rare, it is not a good practice to start when the consequences of RAS failure are high. Should a RAS failure occur in this system design, there is great potential for facility damage and the subsequent loss of load. The Commission should rule against transmission related RAS that result in loss of load. The second problem is that the 230kV transmission system from the Poncha Substation cannot accommodate the proposed additional Public Service generation. Public Service does not have 230kV transmission rights beyond the Poncha Substation. And, it is not known as this time whether Western has firm transmission capacity that will be available to Public Service.

3. Mr. Dauphinais' proposal of a Poncha-Sargent-San Luis 230kV line coupled with Public Service's proposed Poncha 230-115kV transformer is a good long term solution to the load serving reliability issue in the San Luis Valley. However, Mr. Dauphinais' claim that these project additions can accommodate 475-575 MW with other minor transmission additions is premature. As previously discussed, the 115kV and 230kV system from the Poncha Substation and beyond requires further analysis, including the capabilities of Western's system.

4. Mr. Dauphinais' proposal of limiting the San Luis generation to a 475-575 MW range while expanding the generation in the Walsenburg/Calumet area beyond that range is short sighted when considering the San Luis Valley solar generation potential of 240,000 MW. At this level of potential, a 2000 MW solar generation development in the San Luis Valley, or less than 1%, appears reasonable. A 2000 MW generation level would require a transmission system equivalent to the San Luis-Calumet-Comanche transmission project with the San Luis-Calumet line being a 345kV line in addition to a new Poncha-San Luis 230kV line. A 2000 MW generation scenario would also require studying what other transmission lines may be required at the Poncha Substation and beyond.

5. With the great solar generation potential in the San Luis Valley, it makes sense to apply a long term planning concept of a potential 2000 MW generation complex in the San Luis Valley area and plan a transmission system consistent with that generation level, which is also consistent with the legislative intent of Senate Bill 07-100. For reliability and economic reasons, a new transmission corridor that

includes a San Luis-Calumet double circuit 345kV line makes for long term planning sense.

VII. SUMMARY AND RECOMMENDATIONS

Q. PLEASE SUMMARIZE STAFF'S RECOMMENDATIONS.

A. Staff's most significant recommendations are as follows:

1. Staff agrees with Mr. Dauphinais that a generation level of 150 MW that closely matches the load could be installed in the San Luis Valley without major transmission additions. However, it should be understood that solar generation may not be on when the sun does not shine and the load may be above 65 MW during those times requiring to import the power from the Poncha Substation into the San Luis Valley area. This scenario maintains the voltage collapse risk with the outage of the San Luis-Poncha 230kV line.
2. Staff agrees with Mr. Dauphinais that generation tripping remedial action schemes (RAS) may be used to maintain higher generation levels then the transmission system may typically allow with an N-1. However, the generation levels considered by Mr. Dauphinais in the San Luis Valley have an inherit high risk of potential transmission facility damage and loss of load with a RAS failure together with an outage of the Poncha-San Luis 230kV line. For this reason, the Commission should reject this recommendation.
3. Staff disagrees with Mr. Dauphinais that generation levels in the 525 MW range will require minor transmission fixes at Poncha Substation and beyond. Public

Service does not have 230kV transmission service rights at the Poncha Substation on Western's system. Western may not have firm transmission available for Public Service's use. The Commission should not accept Mr. Dauphinais' testimony since, at this time, Western and Public Service have not negotiated a contractual relationship whereby Public Service is assured firm transmission capacity from Western's system.

4. Staff agrees with Mr. Dauphinais that a second Poncha-San Luis 230kV line coupled with a Poncha 230-115kV transformer takes care of the load serving reliability issue in the San Luis Valley. However, Staff disagrees that these two transmission facility additions can accommodate generation in the valley in the 475-575 MW range with minor transmission facility fixes at the Poncha Substation and beyond. Public Service does not have transmission service rights on Western's 230kV system at the Poncha Substation and it is not known whether Western has firm transmission capacity to offer Public Service. A joint study involving the affected utilities with transmission facilities at the Poncha Substation needs to be done to determine the problems and solutions, in addition to negotiating and settling transmission contract issues between Public Service and Western. For these reasons, the Commission should question the generation levels as proposed by Mr. Dauphinais.

5. Staff disagrees with Mr. Dauphinais to limit the generation level in the San Luis Valley to about 525 MW consistent with what a second Poncha-San Luis 230kV line coupled with a Poncha 230-115kV transformer would allow. This generation level is shortsighted. The potential solar generation level in the San Luis Valley is

240,000 MW and therefore a 2000 MW level appears reasonable as it is consistent with long term planning concepts and the legislative intent of Senate Bill 07-100. Staff recommends that the Commission maintain a long term planning concept consistent with a 2000 MW generation approach and reject Mr. Dauphinais' recommendation.

6. Staff recommends the Commission adopt the concept of a new San Luis-Calumet-Comanche double circuit transmission line to allow for a potential 2000 MW generation complex in the San Luis Valley and to improve the load serving reliability in the San Luis Valley. As I stated in my Answer Testimony, with generation in the San Luis Valley greater than 800 MW, the losses savings start to be significant enough to justify the construction of the San Luis-Calumet transmission line for 345kV. As 2000 MW of generation will require the San Luis-Calumet line to be a double circuit 345kV line, it makes sound long term planning and economic sense to initially construct the San Luis-Calumet line for 345kVeven if it is initially operated at 230kV until 345kV operation is required.

Q. DOES THAT CONCLUDE YOUR TESTIMONY AT THIS TIME?

A. Yes, it does.

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IN THE MATTER OF THE APPLICATION OF TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION, INC., AND PUBLIC SERVICE COMPANY OF COLORADO, (A) FOR A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY FOR THE SAN LUIS-CALUMET-COMANCHE TRANSMISSION LINE PROJECT, (B) FOR SPECIFIC FINDINGS WITH RESPECT TO EMF AND NOISE, AND (C) FOR APPROVAL OF OWNERSHIP INTEREST TRANSFER AS NEEDED WHEN PROJECT IS COMPLETED.

I, Inez G. Dominguez, being duly sworn, state that the attached testimony was prepared by me or under my supervision, control, and direction; that the testimony is true and correct to the best of my information, knowledge and belief; and that I would give the same testimony orally if asked under oath.

Inez G. Dominguez
Inez G. Dominguez

Subscribed and sworn to before me in the County of Denver State of Colorado, this 2nd day of ~~3rd~~ December 2009.

Deborah Tagin
NOTARY PUBLIC

My Commission expires:

7/10/13

BEFORE THE PUBLIC UTILITIES COMMISSION

STATE OF COLORADO

Docket No. 09A-324E

IN THE MATTER OF THE APPLICATION OF TRI-STATE GENERATION AND TRANSMISSION ASSOCIATION, INC., (A) FOR A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY FOR THE SAN LUIS VALLEY-CALUMET-COMANCHE TRANSMISSION PROJECT, (B) FOR SPECIFIC FINDINGS WITH RESPECT TO EMF AND NOISE, AND (C) FOR APPROVAL OF OWNERSHIP INTEREST TRANSFER AS NEEDED WHEN PROJECT IS COMPLETED

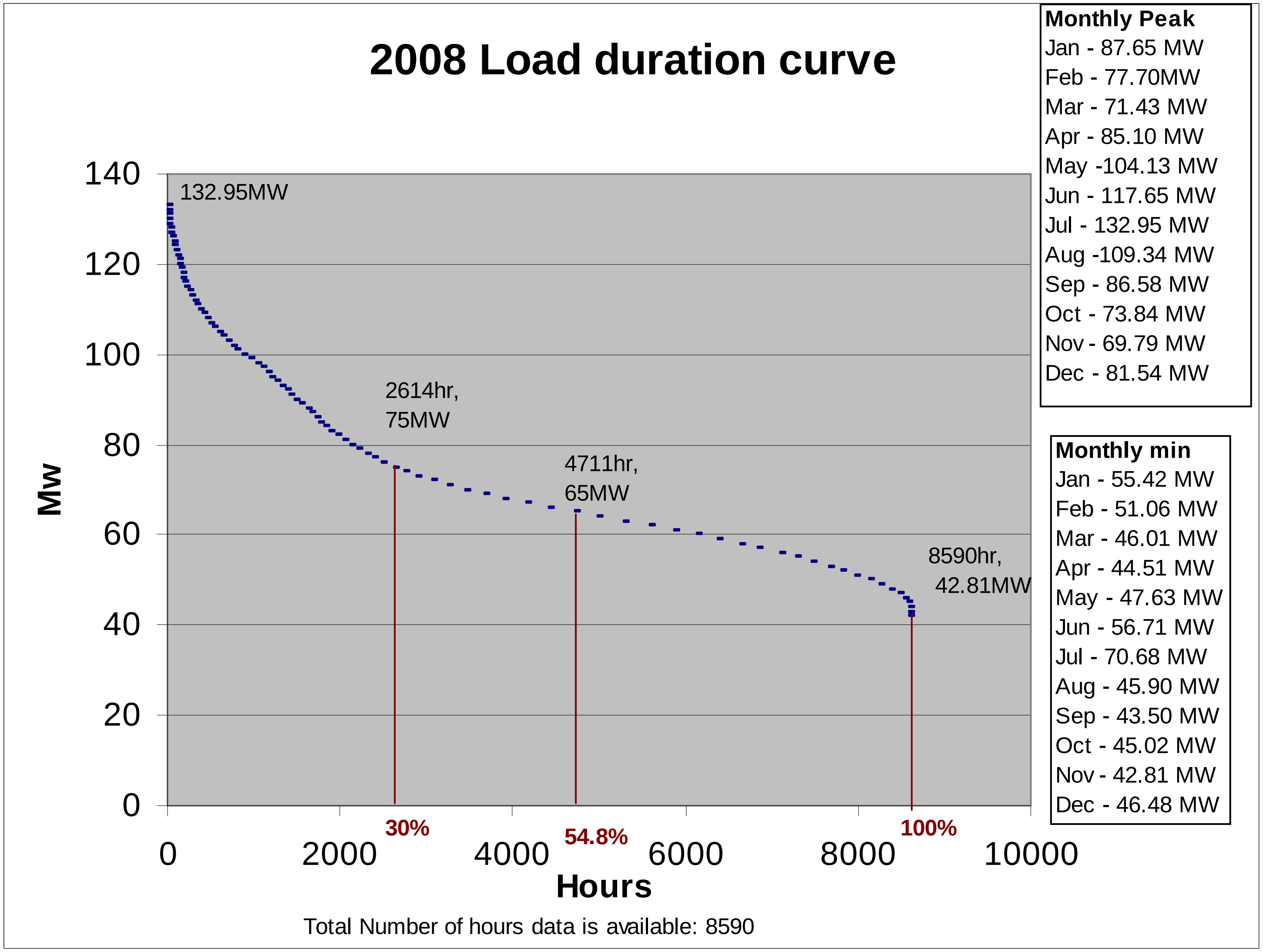
Docket No. 09A-325E

IN THE MATTER OF THE APPLICATION OF PUBLIC SERVICE COMPANY OF COLORADO (A) FOR A CERTIFICATE OF PUBLIC CONVENIENCE AND NECESSITY FOR THE SAN LUIS VALLEY-CALUMET-COMANCHE TRANSMISSION PROJECT, (B) FOR SPECIFIC FINDINGS WITH RESPECT TO EMF AND NOISE, AND (C) FOR APPROVAL OF OWNERSHIP INTEREST TRANSFER AS NEEDED WHEN PROJECT IS COMPLETED

EXHIBITS OF INEZ G. DOMINGUEZ
STAFF OF THE COLORADO PUBLIC UTILITIES COMMISSION

December 2, 2009

Attachment CPUC3-1b.A2



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Attachment CPUC3-1b.A3

Stellern, Gerald M

From: Taylor, Joseph C
Sent: Monday, November 02, 2009 8:54 AM
To: Stellern, Gerald M
Subject: RE: Point to point transmission service form WAPA and black Hills

Provider	Schedule 1 Scheduling/Dispatch	Schedule 2 Reactive $/kW-Month	Schedule 7 Firm Point to Point $/kW-Month
WAPA CRSP	$40.89 Per tag per day	0.18	1.478
WAPA LAP	$40.89 Per tag per day	0.18	3.13
Black Hills CO	$0.065/kW-Month	0.061	0.454

Schedule 1 and 2 are the required ancillaries for a point to point. When we estimate the cost for WAPA, we assume 1 tag per day, which would be 40.89x30 = $1260/month for each MW reserved.

TRANSMISSION LINES STRATEGY FOR THE FUTURE

STARTING WITH COLORADO

Prepared by

Inez G. Dominguez

Staff Engineer

Colorado Public Utilities Commission

Disclaimer: This report represents that opinion of the author who is a member of the staff of the Colorado Public Utilities Commission. It does not necessarily represent the opinion of the Commission, nor does it in any way bind the Commission or its decisions in future proceedings being considered by the Commission.

27 April 2009

TRANSMISSION LINES STRATEGY FOR THE FUTURE STARTING WITH COLORADO

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SUMMARY

A 30+ year planning horizon

In the mid-1950's, Public Service Company of Colorado (PSCo) committed itself to build the 230kV outer belt that starts at the Ft. St. Vrain Switchyard and proceeds in an easterly and westerly direction, interconnects at the Cherokee Switchyard, and continues south to the Daniels Park Substation. Construction of the outer belt 230kV lines started in the early 1960's. In the early 1980's, 230kV lines begin to be built from the outer belt into the inner system's load center. In 2001, the Ft. St. Vrain-Green Valley 230/345kV (operation/construction) transmission line was built. This new 230/345kV line signaled that the northern portion of the 230kV outer belt was full therefore requiring a new line, approximately 40 years later from the initial outer belt 230kV construction. The southern portion of the outer belt still has some room for some transmission lines. A vacant circuit exists on a triple circuit 230kV tower from Waterton Substation to Lookout Substation. Vacant right-of-way (ROW) exists between Daniels Park Substation and Smoky Hill Substation that can accommodate a double circuit 345kV line. It is possible that these potential circuits will be built within the next five years, thus completing the intended use of the outer belt transmission plan. In reality, then the planners of the 1950's implemented a 50 year plan. With that historical perspective, a future 30+ year transmission plan does not seem unreasonable.

Presently, PSCo has a 10 year planning horizon for transmission lines as dictated by the North American Electric Reliability Council (NERC)/Western Electricity Coordinating Council (WECC) rules. PSCo takes the 10 year plan approach and incorporates it into its 5-year capital budget process with focus on the next three years. On the other hand, the Colorado electric resource planning (ERP) process requires a 20 to 40 year planning horizon with a new ERP process required every 4 years. In reality, there is a timing disconnect between the generation planning process and the transmission planning process. Major new transmission lines take 5-10 years to get one built and yet they last 40-50 years or longer once they are built. The implication here is that since generation and transmission go hand-in-hand, then the planning of both should have similar planning horizon years. Therefore the transmission planning should have a 20-40 year planning horizon.

A 30+ year transmission plan

This report presents an analysis and a process by which future transmission plans can be conceptually developed 30 plus years out into the future for the State of Colorado. Work done by PSCo as required by Colorado Senate Bill 07-100 and information provided by the Colorado Senate Bill 07-091 report were used as a basis for the analysis and preparation of this report. Attached Figures 1 and 2, Maps 1, 2A, 2B-4A, 4B and Maps 2A,2B off-peak-4A, 4B off-peak and attached Tables 1-4 capture the narration of the analysis done in coming up with transmission plans for three different generation location scenarios – 1) Balanced scheduled generation, 2) Heavy North scheduled generation, and 3) Heavy South scheduled generation. *These figures, maps and tables are the heart of this report*. Energy resource zones (ERZ's) and the potential for renewable energy sources (RES) generation in each ERZ were used to determine where and how much generation to add in each ERZ. Table A below, a portion of Table 4, shows the transmission lines that could be developed for the year 2041 time frame with an intermediate 2025 time frame for the “Balanced scheduled generation” scenario. The “Balanced generation” scenario allocates the required incremental generation to meet the heavy summer peaks for 2025 and 2041 in proportion to the potential maximum RUS generation in each ERZ as a fraction of the total composite generation. This is one of many possible approaches to planning a long-term transmission system.

Transmission planning is traditionally done using maximum peak conditions, typically occurring in the summer or winter, when generation is at maximum generation. Colorado peaks in the hot summer months. So it makes sense to use the summer peak approach in starting this analysis. In using this approach, and using Table A, we want to start with the system under the column heading “2041 HS balanced.” However, we also need to examine the column entitled “2041 off-peak Balanced.” From Table A, it can be seen from the off-peak case that wind generation now creates the need for more transmission lines, at an additional cost. We then need to determine early in the planning process whether the additional transmission to accommodate the wind generation should be built or should we reduce conventional generation to free transmission capacity for the wind. For the purposes of this analysis it was decided to build the necessary transmission to accommodate the wind. The desired transmission system now becomes the greater of the 2041 HS system or off-peak systems. The columns for the 2025-year then informs the planner as to what voltage level the 2041 transmission system should be initially operated at as transformers

Transmission Lines	2025 HS Balanced	2025 off-peak Balanced	2041 HS Balanced	2041 off-peak Balanced
San Luis to Walsenburg - 86 miles	2-345	-	2-345	-
Walsenburg to Comanche - 50 miles	2-345	2-230/345	3-345	2-345
Gladstone to Lamar - 110 miles	2-345	2-500	2-500	3-500
Lamar to Boone - 100 miles	2-345	2-345	2-345	2-500
Boone to Comanche - 30 miles	2-345	2-345	2-345	2-500
Comanche to Midway - 50 miles	1-345	1-345	2-345	2-345
Midway to Daniels Park - 75 miles	3-345**	3-345**	4-345**	4-345**
Lamar to Big Sandy - 144 miles	1-230/345	1-345	1-345	1-500
Lamar to Burlington - 100 miles	1-230/345	1-345	1-345	1-500
Burlington to Big Sandy - 80 miles	1-230/345	1-345	1-345	1-500
Big Sandy to Midway - 80 miles				
Big Sandy to Missile Site - 44 miles	2-230/345	2-345	2-345	2-500
Pawnee to Ft. Lupton-60 miles				
Pawnee to Missile Site-49 miles	1-345	2-230/345	2-345	2-345
Missile Site to Smoky Hill - 45 miles	2-345	4-345	4-345	4-345*
Comanche to Black Hills - 30 miles	2-230	2-230	2-230/345	2-230
Midway to Colo Spgs U - 50 miles	2-230	2-230	2-230	2-230
Ault to PRPA - 35 miles	2-230	1-230	2-230	2-230
Ault to Denver - 80 miles		2-230/345	1-230	2-345

**Existing
* w/3-1272 kcmil acsr

Table A

add an additional initial cost to the transmission costs. (See attached Map 1 which presents a general semi-geographical picture of the key substations and transmission line corridors connecting the various substations as used in this analysis; see Figure 1 and Figure 2 which present years 2025 and 2041, respectively, transmission systems derived from Table A above.)

The planning process as described above focused on the "Balanced generation scheduled" scenarios. The "Heavy North" and the 'Heavy South" scenarios also outline transmission systems for consideration. These transmission systems present the extreme transmission line loadings from the northern and from the southern parts of the system requiring additional transmission lines when compared to the "Balanced generation" scenario. These extreme northern and southern loadings transmission systems can then be used to provide guidance as to what additional transmission lines may be required further into the future beyond the year 2041.

<u>The next step</u>

The conceptual transmission system, as outlined in Table A above and depicted in attached Figure 2, is a starting point to be followed up with detailed power flow studies simulating the year 2041 system looking at the "Balanced generation scheduled" scenario. The power flow studies will then be used to verify and fine-tune the conceptual bulk power transmission system. In addition, this 2041 power flow would provide the Colorado utilities an opportunity to jointly develop a load-serving network, preferably a 230kV system/network, to feed their respective loads.

<u>A description of the tables and maps</u>

As mentioned previously, the attached maps and tables are the heart of this report. These tables and maps are described below.

Table 1: This table shows the composite demand and energy forecasts of Public Service Company of Colorado (PSCo), Black Hills Energy (BHE), Platte River Power authority (PRPA), Colorado springs Utilities (CSU), and Tri-State Generation and Transmission Association (Tri-State) for the base year 2008 and future years 2025 and 2041. The table shows the incremental generation needed for 2025 as 3962 MW and 10300 MW for 2041. From the energy forecast, the renewable resource energy (RES) generation required per state statute was calculated for each of the utilities – PSCo and BHE 20% and PRPA, CSU, and Tri-State 10% by the year 2020 and thereafter. Assuming an annual 35% capacity factor for RES generation and 12.5% its demand being on-line during the summer peak, the total composite demand RES generation was calculated as being 3927 MW for the year 2025 and 5281 MW for the year 2041.

Table 2: This table shows how the incremental generation, broken up into conventional and RES generation, needed for the 2025 and 2041 heavy summer peaks is allocated amongst the five energy resource zones (ERZ's) for the three different generation location scenarios. The same is done for the 2025 and 2041 off-peak periods when wind is increased from 12.5% capacity during the peak to 100%

during the off-peak and solar is decreased to 0%. The off-peak period load is assumed to be 50% of the peak.

Table 3: This table shows the conceptual bulk power transmission lines required to deliver the incremental power generation from each of the ERZ's for the heavy summer peak periods for each of the generation location scenarios for the years 2025 and 2041. Transmission line costs and transformation costs are also provided for each of the generation location scenarios.

Table 4: This table shows a side by side comparison of the transmission lines required for the three generation location scenarios for the heavy summer peak periods versus the off-peak periods for the years 2025 and 2041.

Map 1: This map presents a general semi-geographical picture of key substations and transmission line corridors connecting the various substations. Substation names with small circles connected to them represent potential generation injection points. The distances in miles of particular transmission corridors between the various substations are also shown. This map was used to illustrate the various generation scenarios and their associated generation injections, required transmission lines, and the costs of the transmission lines and transformation requirements for each of the heavy summer peak scenarios.

Map 2A 2025 balanced: This map shows the heavy summer *2025 balanced* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 2B 2041 balanced: This map shows the heavy summer *2041 balanced* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 3A 2025 Heavy North: This map shows the heavy summer *2025 Heavy North* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 3B 2041 Heavy North: This map shows the heavy summer *2041Heavy North* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 4A 2025 Heavy South: This map shows the heavy summer *2025 Heavy South* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 4B 2041 Heavy South: This map shows the heavy summer *2041 Heavy South* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 2A 2025 balanced Off-peak: This map shows the heavy summer *2025 balanced Off-peak* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 2B 2041 balanced off-peak: This map shows the heavy summer *2041 balanced Off-peak* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 3A 2025 Heavy North Off-peak: This map shows the heavy summer *2025 Heavy North Off-peak* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 3B 2041 Heavy North Off-peak: This map shows the heavy summer *2041Heavy North Off-peak* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 4A 2025 Heavy South Off-peak: This map shows the heavy summer *2025 Heavy South Off-peak* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

Map 4B 2041 Heavy South Off-peak: This map shows the heavy summer *2041 Heavy South Off-peak* scenario. Generation injection locations and magnitudes are shown; the conceptual anticipated power flows are shown between substations; the required transmission lines and transformation needs are shown; and the associated transmission and transformation costs are shown.

INTRODUCTION

Transmission lines are needed to get the power/energy from the power plants or sources to the distribution system where the load is located. Serving the electric load is the critical reason generation and its associated transmission lines are needed. Blackouts are an undesirable consequence of not having the necessary generation and transmission to feed the load. The Colorado Public Utilities Commission is therefore very concerned about keeping the lights on.

Colorado SB 07-091 and SB 07-100 resulted in creating energy resource zones (ERZ) for the state of Colorado – ERZ's 1-5. ERZ-1 is in northeastern Colorado; ERZ-2 is in east central Colroado; ERZ-3 is in southeast Colorado; ERZ-4 is in the San Luis Valley; ERZ-5 is between ERZ-3 and ERZ-4. SB 07-091 indentifies the potential renewable resource development in terms of GW (billion watts), i.e., ERZ-1 has 25 GW, ERZ-2 28 GW, ERZ-3 37 GW, ERZ-4 20 GW, and ERZ-5 8 GW, for a total of 118 GW. Based on these figures, the generation potential of each ERZ as a percentage of the total is ERZ-1 21%, ERZ-2 24%, ERZ-3 31%, ERZ-4 17%, and ERZ-5 7%.

SB 07-100 requires investor owned utilities, namely PSCo and Black Hills Energy (BHE), to determine the necessary transmission lines to access these ERZ's to get the power and energy to the load centers. PSCo has been actively working with interested parties/stakeholders to address potential transmission lines to the ERZ's. In October 31, 2007 PSCo put together a SB 07-100 plan from which a CPCN application for the Pawnee-Smoky Hill 345kV line was submitted to access resources in ERZ-1. PSCo is now working in its second set of studies as required by SB 07-100 due October 31, 2009 to come up with its second set of recommended transmission lines and associated CPCN's.

Recently, the Commission completed hearings on the Colorado electric resource plan (ERP). The emphasis was on renewable resources to meet the resource needs that begin to focus on the ERZ's as the location where the generation could be built. Interestingly, the ERP process with its subsequent generation additions must be coordinated with the SB 07-100 transmission lines planning process. Therefore, a need is created to make the two processes mesh well – generation by default requires transmission lines.

Presently, PSCo has a 10 year planning horizon for transmission lines as dictated by the North American Electric Reliability Council (NERC)/Western Electricity Coordinating Council (WECC) rules. In reality, PSCo is governed by a 5-year capital budget process with a focus on the next three years. On the other hand, the ERP requires a 20 to 40 year planning horizon with a new ERP process required every 4 years. There is a timing disconnect between the transmission planning process and the generation planning process.

Major new transmission lines take 5-10 years to get built and yet they last 40-50 years or longer once they are built. The implication here is that since generation and transmission go hand-in-hand, then the planning of both should have similar planning horizon years. Therefore the transmission planning should have a similar 20 to 40 year planning horizon.

The following analysis conceptually looks at transmission planning 32 years into the future, year 2041, with an interim look at 16 years into the future, year 2025. The intent of this approach is to provide guidance as to what bulk power transmission system to start to build now that will allow a smooth transition in the future. This approach provides guidance as to what voltage level and conductor size to build the next transmission line from the generation sites to the load centers. This will result in taking the right first step that should minimize expensive upgrades in the future.

Generation planning and the associated transmission lines are needed to feed future load growth. So the basic assumption is that load growth will continue into the future. Therefore company forecasts are the start of generation and transmission planning.

LOAD FORECAST AND ASSOCIATED GENERATION FOR THE STATE OF COLORADO

Heavy summer

Using recent summer peak demand (MW) load forecasts from PSCo, BHE, Tri-State Generation and Transmission, Inc, (Tri-State), Platte River Power Authority (PRPA), and the City of Colorado Springs Utilities (CSU) a composite Colorado demand load forecast can be created (see attached Table 1) that reflects the majority of the Colorado load. These utilities then need to provide the required generation to serve their respective loads. In addition, most of the load exists along the I-25 corridor from Wyoming to New Mexico. The load forecast information shows that the 2008 composite load for these utilities was 9902 MW with PSCo having 68% of the load. A 2025 forecast shows a composite load of 14145 MW with PSCo having 66% of the load. The load increase from 2008 to 2025 is 4243 MW. Assuming a 16% reserve margin, the incremental generation needed to cover this load is 4992 MW. Subtracting 700 MW Comanche 3 and 260 MW St. Vrain generation leaves a net generation of 3962 MW. A 2041 forecast shows a composite load of 19609 MW with PSCo having 69% of the load. The load increase from 2008 to 2041 is 9707 MW. Assuming a 16% reserve margin is needed, the incremental generation to cover this new load would be 11,260 MW (9707*1.16). Subtracting 700 MW Comanche 3 and 260 MW St. Vrain generation leaves 10,300 MW of required new generation to cover the incremental load.

In addition, from the energy (GWh) forecasts from PSCo, BHE, and Tri-State, an average load factor was calculated and then used to create energy forecasts for PRPA and CSU. This was done to carve out the amount of energy generated by renewable energy sources (RES) required by state statute after year 2020 (20% for PSCo and Black Hills Energy, 10% for PRPA, CSU, and Tri-State). Assuming an annual capacity factor of 35% for RES generation, the total associated generation demand necessary to generate the total energy was calculated (see Table 1). RES generation considered in this analysis are wind and solar. Wind generation was assumed to be at 12.5% of its total demand capacity during the peak, and solar at 100% of its demand capacity. By statute, solar generation should be at a minimum 4% of the RES total energy requirements (see Table 2).

Traditional transmission planning is done using peak load conditions (typically heavy summer or heavy winter) where the maximum generation on the total system can be expected. These heavy peak periods then define the transmission lines that need to be built to get the power to the load centers. A conceptual plan therefore was created to look at the heavy summer conditions for Colorado since electricity consumption peaks during the summer.

Off-peak

An off-peak case was created to present the magnitude of the challenges RES generation presents to the transmission planning picture. For purposes of this analysis, the off-peak load was assumed as 50% of the peak. A 2001 analysis for PSCo showed PSCo's minimum peak load to be 42% of its maximum summer peak load, so a 50% representation of the summer peaks for the whole state of Colorado appears to be a reasonable representation for off-peak periods. As with the summer peak generation, the off-peak generation was calculated to be 1.16*load to cover reserves.

The off-peak conditions are expected to occur during the night where wind is assumed at 100% of capacity and solar generation to be at 0% of capacity. The total required off-peak generation for 2025 is calculated to be 8204 MW and 11373 MW for 2041 (see Table 2).

TRANSMISSION LINES CHARACTERISTICS AND COST ESTIMATES USED IN THE DIFERENT SCENARIOS OF THIS ANALYSIS

The voltage level of a transmission line (or network) is determined by the distance and the magnitude of power to be transferred from Point A to Point B. The number of lines required depends on the reliability criteria in effect. For this analysis, an N-1 criterion was used, i.e., the loss of the single worst contingency will not result in voltage violations, thermal overloads, or stability problems. The thermal rating of a 3-1272 conductor bundle 500kV line is 3767 MVA; a 2-1431 conductor bundle 345kV line has a rating of 1852 MVA; a 3-1431 conductor bundle 345kV line has a rating of 2819; a single 1272 conductor 230kV line has a rating of 578 MVA; a 2-1272 conductor bundle 230kV line has a rating of 1155 MVA. Lines of 50 miles or less in length can be loaded to their thermal rating with minor concerns for voltage regulation and stability problems. For lines longer than 50 miles, voltage regulation and stability problems begin to show themselves. The power transfer capability of longer lines may be limited by stability considerations which is typically less than their thermal ratings. A steady state stability limit can be calculated by knowing the receiving end voltage, the sending voltage, the reactance between the receiving and sending voltages, and the electrical angle between them. In this analysis, the longest transmission line is the Lamar-Big Sandy line of 144 miles. For a line this long, a 500kV line has a steady transfer limit of 3158 MW; a 345kV line has a limit of 1537 MW; a 2-conductor 230kV line has a limit of 680 MW; a single conductor 230kV line has a limit of 510 MW. By using the thermal rating of lines, the steady state limits, and the magnitude of power to be transferred between substations, a transmission network was conceptually developed for the scenarios of this analysis.

For each of the heavy summer scenarios described below, transmission line costs and transformer costs were estimated. These costs are costs obtained from information provided to the CPUC as part of the Rule 3206 filings and CPCN applications. Transformer 500-230kV and 345-230kV costs and 500kV transmission line costs were obtained form Tri-State's Eastern Plains Transmission Project; 345-230kV transformer and 345kV transmission costs were obtained from PSCo's Pawnee-Smoky Hill 345kV Transmission Project CPCN application. The distances between the various substations depicted in Map 1 were used in the calculations.

For a double circuit 345kV line with a 2-1431 kcmil acsr, $1,189,000 per mile was used; for a double circuit 345kV line with a 3-1272 bundle, $1,284,000 per mile was used. For a single circuit 500kV line, $970,000 per mile was used. For a single circuit 230kV line, $650,000 per mile was used and $866,000 per mile for a double circuit. 500 MVA 345-230kV, 500-345kV, and 500-230kV transformers were assumed with the 500-230kV ones costing $43,000 per MVA, the 345-230kV ones costing $27,000 per MVA, and the 500-345kV ones costing $65,00 per MVA.

Table 2 lists the transmission systems and associated costs for each heavy summer peak scenario. This cost analysis was done to present a relative magnitude as to how much a 30+ year transmission system would cost to build. From Table 2, one can see the similarities and differences of the transmission lines required in each of the transmission corridors for the different scenarios.

GENERATION LOCATIONS AND SCENARIOS

These load and generation scenarios then present two obvious questions:
1) Where is the new load growth taking place? And, 2) Where should new generation be located in order to feed the new load? Load is growth is occurring throughout the state of Colorado, but for the purpose of this evaluation, it is assumed that load growth is primarily occurring along the I-25 corridor with growth/expansion of existing cities and towns. Therefore, the generation and associated transmission lines would be built to feed primarily the loads in these cities and town along the I-25 corridor.

It is assumed that the generation to feed the load growth will be built in the identified ERZ's. However, the five identified ERZ's present multiple generation location combinations and it is difficult to determine which is the right one. But there are several logical location combinations that can be evaluated for transmission planning purposes. The three generation location scenarios that have merit are – 1) a generation balanced approach for heavy summer and off-peak, 2) a heavy north generation schedule approach for heavy summer and off-peak, and 3) a heavy south generation schedule approach for heavy summer and off-peak. These three generation location scenarios were picked since this approach proved to be very useful and helpful for studies completed in the early 1980's. The studies provided insight into transmission systems that would be required in the future. This approach will give three different perspectives as to the transmission networks that may be required to get the estimated 3962 MW of peak new generation in 2025 and 10,300 MW of new peak generation in 2041, to the load centers (see Table 3 and Maps 2A, 2B-4A, 4B). The off-peak case scenarios look at the implications that the RES generation presents to transmission planning when wind generation increases from 12.5%

during the peak to 100% of its capacity during the off-peak (see Maps 2A off-peak, 2B off-peak- Maps 4A off-peak, 4B off-peak).

Under each ERZ generation scenario, a coordinated transmission network can be developed to bring in the power/energy to the load centers. Transmission networks are presented for years 2025 and 2041. For this evaluation, power injection points are identified as follow: ERZ-1 Pawnee and Ault; ERZ-2 Missile Site (Corner Point); ERZ-3 Gladstone/Lamar; ERZ-4 San Luis; and ERZ-5 Walsenburg. Attached Map 1 presents a conceptual transmission corridor layout from the different ERZ's.

Year 2025 Heavy Summer

Scenario 1 – a balanced approach (see Map 2A)
This scenario divides up the 3962 MW of generation to each ERZ in proportion to each ERZ's percentage share of the total potential renewable resources. This approach may be the most reasonable since each ERZ is developed in proportion to its potential generation capability, as shown in Table 2. For example ERZ-1's 21% share of 3962 MW would be 832 MW (730 MW convetional+102MW wind); ERZ-2's 24% share 951 MW (833MW conventional+118MW wind); ERZ-3's 31% share 1228 MW (1077MW conventional+151MW wind); ERZ-4's 17% share 674 MW of solar; and ERZ-5's 7% share 277 MW (241 conventional +36MW wind).

Transmission systems for these magnitudes of power from each of the injection points would conceptually require the following:

ERZ-1
Ault 416 MW – two 230kV lines to the PRPA load area.
Pawnee 416 MW – one 345kV lines to Missile Site.

ERZ-2
Missile Site 1981 MW (951 at Missile Site+614 from Big Sandy+416 from Pawnee)-two 345kV lines to Smoky Hill.

ERZ-3
Gladstone 1228 MW- two 345kV lines to Lamar, 345 kV line Lamar-Burlington, 345kV line Lamar- Big Sandy, 345kV line Burlington-Big Sandy, two 230kV lines Big Sandy-Missile Site, two 230kV lines Lamar-Boone-Comanche, one new 345kV line Comanche –Midway (three total), three existing 345kV lines total Midway-Daniels Park/Waterton.

ERZ-4 and ERZ-5
San Luis 674 MW – two 345kV lines to Walsenburg
Walsenburg 951 MW (674 from San Luis+277 MW injection) - two 345kV lines to Comanche.

Scenario 2 – heavy north (see Map3A)
This scenario divides up the 3962 MW of generation minus solar generation between ERZ-1 and ERZ-2 in proportion to each ERZ's percentage share of the total potential renewable resources. The solar generation is assumed not to be in ERZ-1 and ERZ-2. From Table 1, the total RES

generation is 3927MW of which 12.5%, or 491MW, is on during the peak. Of these 491MW 4%, or 20MW, is for solar leaving 471MW for wind in ERZ-1 and ERZ-2. For example ERZ-1's share of 3942 MW would be 1853 MW (1632 conventional+221MW wind). ERZ-2's share would be 2089 MW (1839 conventional+250MW wind).

ERZ-1
Ault 927 MW – two 230kV lines to the PRPA load, and 2-230/345kV lines to the Denver load.
Pawnee 926 MW – two 345kV lines to Missile Site.

ERZ-2
Missile Site 3015 MW (926 MW from Pawnee+2089 MW injection) – three 345kV lines to Smoky Hill w/2-1272 (or 2-1431 kcmil acsr)or two 345kV lines w/3-1272 kcmil acsr, two 230kV lines Missile Site-Big Sandy, one 230kV line Big Sandy-Midway.

<u>Scenario 3 – heavy south (see Map 4A)</u>
This scenario divides up the 3962 MW of generation between ERZ-3, ERZ-4 and ERZ-5 in proportion to each ERZ's percentage share of the total potential renewable resources. For example ERZ-3's share of 3962 MW would be 2219 MW (1946 conventional+273 wind); ERZ-4's share would be 1228 MW of solar; and ERZ-5's share would be 515 MW (451 conventional+64 wind).

ERZ-3
Gladstone 2219 MW – two 500kV lines Gladstone-Lamar, one 345kV line Lamar-Big Sandy, one 345kV line Lamar-Burlington, one 345kV line Burlington-Big Sandy, two 345kV lines Big Sandy-Missile Site, two 345kV lines Missile Site-Smoky Hill, two 345kV lines Lamar-Boone-Comanche, one new 345kV line Comanche-Midway, three existing 345kv lines Midway-Daniels Park/Waterton, two 230kV lines Comanche-Black Hills load, two 230kV line Midway-CSU load.

ERZ-4 and ERZ-5
San Luis 1228 MW – two 345kV lines San Luis-Walsenburg.
Walsenburg 1745 MW(1228 MW from san Luis+ 515 MW injection) - two 345kV lines Walsenburg-Comanche.

Year 2041 Heavy Summer

<u>Scenario 1 – a balanced approach (see Map 2B)</u>
This scenario divides up the 10,300 MW of generation to each ERZ in proportion to each ERZ's percentage share of the total potential renewable resources. This approach may be the most reasonable since each ERZ is developed in proportion to its potential capability. For example ERZ-1's 21% share of 10,300 MW would be 2165 MW (2054 conventional+111wind); ERZ-2's 24% share 2472 MW (2343 conventional+129 wind); ERZ-3's 31% share 3193 MW (3029 conventional+164 wind); ERZ-4's 17% share 1751 MW of solar; and ERZ-5's 7% share 721 MW (684 conventional+37 wind).

Transmission systems for these magnitudes of power from each of the injection points would conceptually requires the following:

ERZ-1
Ault 1082 MW – three 230kV lines to the PRPA/Denver load area.
Pawnee 1082 MW – two 345kV lines to Missile Site.

ERZ-2
Missile Site 5151 MW (2472 at Missile Site+1597 from Big Sandy+1082 from Pawnee)-four total 345kV line to Smoky Hill w/2-1272 or three 345kV w/3-1272. I think only the 3-1272 lines would work from a noise perspective.

ERZ-3
Gladstone 3193 MW- two 500 kV lines to Lamar, 345 kV line Lamar-Burlington, 345kV line Lamar- Big Sandy, 345kV line Burlington-Big Sandy, two 345kV lines Big Sandy-Missile Site, two 345kV lines Lamar-Boone-Comanche, two new 345kV lines Comanche –Midway (four total), four existing 345kV lines total Midway-Daniels Park/Waterton, two 230kV line Midway-CSU load, two 230kV lines Comanche-Black Hill load.

ERZ-4 and ERZ-5
San Luis 1751 MW – two 345kV lines to Walsenburg
Walsenburg 2472 MW (1751 from san Luis+721 MW injection) - three 345kV lines to Comanche.

<u>Scenario 2 – heavy north (see Map 3B)</u>
This scenario divides up the 10,300 MW of generation minus solar between ERZ-1 and ERZ-2 in proportion to each ERZ's percentage share of the total potential renewable resources. From Table 1, there are 5281MW or RES generation, of which 12.5%, or 660MW, is on during the peak. Solar generation is 4% of the RES, or 26MW, assumed not to be in ERZ-1 and ERZ-2, leaving 10274 MW to be shared by ERZ-1 and ERZ-2. For example ERZ-1's share of 10,274 MW would be 4829 MW (4531 conventional+298 wind). ERZ-2's share would be 5445 MW (5109 conventional+336 wind).

ERZ-1
Ault 2414 MW – two 230kV lines to the PRPA load center and two 345kV lines to the Denver load center.
Pawnee 2415 MW – three 345kV lines to Missile Site.

ERZ-2
Missile Site 7860 MW- (2415 MW from Pawnee+5445MW at Missile site) four 345kV lines to Smoky Hill w/3-1272 kcmil acsr, two 230/345kV lines Missile Site-Big Sandy, two 230/345kV lines Big Sandy-Midway.

Scenario 3– heavy south (see Map 4B)
This scenario divides up the 10,300 MW of generation between ERZ-3, ERZ-4 and ERZ-5 in proportion to each ERZ's percentage share of the total potential renewable resources. For example ERZ-3's share of 10,300 MW would be 5767 MW (5555 conventional+212 wind); ERZ-4's share would be 3193 MW of solar; and ERZ-5's share would be 1339 MW (1290 conventional+49 wind).

ERZ-3
Gladstone 5767 MW – three 500kV lines Gladstone-Lamar, 500kV line Lamar-Burlington, 500kV line Lamar-Big Sandy, 500kV line Burlington-Big Sandy, two 500kV lines Big-Sandy-Missile Site, three 345kV lines Missile Site-Smoky Hill, two 500kV lines Lamar-Boone-Comanche, three new 500kV lines Comanche-Midway, upgrade existing four 345kV lines Midway-Daniels Park/Waterton w/3-1272 kcmil acsr, two 230kv lines Comanche-Black Hills load, two 230kV lines Midway-CSU loads.

ERZ-4 and ERZ-5
San Luis 3193 MW – two 500kV lines to Walsenburg.
Walsenburg 4532 MW – (3193 from San Luis+1339MW Walsenburg injection) three 500kV lines Walsenburg-Comanche.

Year 2025 Off-peak

Scenario 1 – a balanced approach (see Map 2A off-peak)
This scenario divides up the increased generation due to wind, from 12.5% to 100% as it goes from 3962 MW of generation during the peak to 6137 MW during the off-peak, to each ERZ in proportion to each ERZ's percentage share of the total potential renewable resources. This approach may be the most reasonable since each ERZ is developed in proportion to its potential generation capability, assuming ERZ-4's solar generation goes to 0 MW. For example ERZ-1's share of 6137 MW would be 1546 MW (730 conventional + 816 wind); ERZ-2's share 1777 MW (833 conventional + 944 wind); ERZ-3's share 2285 MW (1077 conventional + 1208 wind); and ERZ-5's share 529 MW (241 conventional + 288 wind).

Transmission systems for these magnitudes of power from each of the injection points would conceptually require the following:

ERZ-1
Ault 773 MW – one 230kV line to the PRPA load area, two 230/345kV lines to Denver area.
Pawnee 773 MW – two 23/345kV lines to Missile Site.

ERZ-2
Missile Site 3691 MW (1777 at Corner Point+1141 from Big Sandy+773 from Pawnee)-four 345kV line to Smoky Hill.

ERZ-3

Gladstone 2282 MW- two 500kV lines to Lamar, 345 kV line Lamar-Burlington, 345kV line Lamar- Big Sandy, 345kV line Burlington-Big Sandy, two 345kV lines Big Sandy-Missile Site, two 345kV lines Lamar-Boone-Comanche, one new 345kV line Comanche –Midway (three total), three existing 345kV lines total Midway-Daniels Park/Waterton.

ERZ-4 and ERZ-5

San Luis 0 MW – no lines to Walsenburg.

Walsenburg 529 MW (0 San Luis+529 MW injection) - two 345kV lines to Comanche

<u>Scenario 2 – heavy north (see Map3A off-peak)</u>

This scenario divides up the increased generation of 7239 MW (from 3962 MW of generation due to wind generation increasing from 12.5% to 100%) between ERZ-1 and ERZ-2 in proportion to each ERZ's percentage share of the total potential renewable resources. For example ERZ-1's share of 7239 MW would be 3400 MW (1632 conventional + 1768 wind) and ERZ-2's share would be 3839 MW (1839 conventional + 2000 wind).

ERZ-1

Ault 1705 MW – one 230kV line to the PRPA load, and two 345kV lines to the Denver load.

Pawnee 1705 MW – two 345kV lines to Missile Site.

ERZ-2

Missile Site 5364 MW (1705 MW from Pawnee+3850 MW injection-191Mw to Big Sandy) – four 345kV lines to Smoky Hill w/3-1272 kcmil acsr, two 230kV lines Missile Site-Big Sandy, two 230kV lines Big Sandy-Midway.

<u>Scenario 3 – heavy south (see Map 4A off-peak)</u>

This scenario divides up the 5093 MW of generation (increase from 3962 MW due to the wind generation increasing from 12.5% to 100%) between ERZ-3 and ERZ-5, (ERZ-4 solar generation goes to 0 MW) in proportion to each ERZ's percentage share of the total potential renewable resources. For example ERZ-3's share of 5093 MW would be 4130 MW (1946 conventional + 2184 wind) and ERZ-5's share would be 963 (451 conventional + 512 wind).

ERZ-3

Gladstone 4130 MW – three 500kV lines Gladstone-Lamar, one 500kV line Lamar-Big Sandy, one 500kV line Lamar-Burlington, one 500kV line Burlington-Big Sandy, two 500kV lines Big Sandy-Missile Site, three 345kV lines Missile Site-Smoky Hill, two 500kV lines Lamar-Boone-Comanche, two new 345kV line Comanche-Midway, three existing 345kv lines Midway-Daniels Park/Waterton, two 230kV lines Comanche-Black Hills load, two 230kV line Midway-CSU load.

ERZ-4 and ERZ-5

San Luis 0 MW –no lines to Walsenburg.

Walsenburg 963 MW(0 MW from San Luis+ 963 MW injection) - two 345kV lines Walsenburg-Comanche.

Year 2041 Off-peak

<u>Scenario 1 – a balanced approach (see Map 2B off- peak)</u>
This scenario divides up the increased generation, due to wind (12.5% on peak to 100% off-peak) from 10,300 MW to 11638 MW of generation, to each ERZ in proportion to each ERZ's percentage share of the total potential renewable resources, assuming ERZ-4's solar generation goes to 0 MW. This approach may be the most reasonable since each ERZ is developed in proportion to its potential capability. For example ERZ-1's share of 11,638 MW would be 2942 MW (2054 conventional + 888 wind); ERZ-2's share 3375 MW (2343 conventional + 1032 wind); ERZ-3's share 4341 MW (3029 conventional + 1312 wind); and ERZ-5's share 980 MW (684 conventional + 296 wind).

Transmission systems for these magnitudes of power from each of the injection points would conceptually require the following:

ERZ-1
Ault 1471 MW – two 230kV lines to the PRPA area, two 345kV lines to Denver load area.
Pawnee 1471 MW – two 345kV lines to Missile Site.

ERZ-2
Missile Site 7013 MW (3375 at Missile Site+2171 from Big Sandy+1471 from Pawnee)-four total 345kV line to Smoky Hill w/3-1272.

ERZ-3
Gladstone 4341 MW- three 500 kV lines to Lamar, 500 kV line Lamar-Burlington, 500kV line Lamar- Big Sandy, 500kV line Burlington-Big Sandy, two 500kV lines Big Sandy-Missile Site, two 500kV lines Lamar-Boone-Comanche, two new 345kV lines Comanche –Midway (four total), four existing 345kV lines total Midway-Daniels Park/Waterton, two 230kV line Midway-CSU load, two 230kV lines Comanche-Black Hill load.

ERZ-4 and ERZ-5
San Luis 0 MW – no lines to Walsenburg.
Walsenburg 980 MW (0 from san Luis+980 MW injection) - two 345kV lines to Comanche.

<u>Scenario 2 – heavy north (see Map 3B off-peak)</u>
This scenario divides up the 14,712 MW of generation (increase from 10,274 MW of generation due to increased generation from 12.5% to 100%) between ERZ-1 and ERZ-2 in proportion to each ERZ's percentage share of the total potential renewable resources. For example ERZ-1's share of 14,712 MW would be 6915 MW (4531 conventional + 2384 wind) and ERZ-2's share would be 7797 MW (5109 conventional + 2688 wind). However, the needed generation is 11,373 MW so the available conventional generation has to be decreased by 3339 MW proportionally in ERZ-1 and ERZ-2. ERZ-1's share is reduced to 5378 MW (2994 conventional + 2384 wind) and ERZ-2' share is reduced to 5995 MW (3307 conventional + 2668 wind).

ERZ-1

Ault 2689 MW – two 230kV lines to the PRPA load center and three 345kV lines to the Denver load center.

Pawnee 2689 MW – three 345kV lines to Missile Site.

ERZ-2

Missile Site 8344 MW- (2689 MW from Pawnee+5995MW at Missile site-340MW to Big Sandy)- four 345kV lines to Smoky Hill w/3-1431 kcmil acsr, two 230kV lines Missile Site-Big Sandy, two 230kV lines Big Sandy-Midway.

Scenario 3 – heavy south (see Map 4B off-peak)

This scenario divides up the 8993 MW of generation between ERZ-3 and ERZ-5 in proportion to each ERZ's percentage share of the total potential renewable resources. Although the wind increases from 12.5% to 100%, this is a decrease of 1307 MW from 10,300 MW due to the ERZ-4 solar generation going to 0 MW. ERZ-3's share of 8993 MW would be 7251 MW (5555 conventional + 1696 wind) and ERZ-5's share would be 1682 MW (1290 conventional + 392 wind).

ERZ-3

Gladstone 7251 MW – four 500kV lines Gladstone-Lamar, two 500kV line Lamar-Burlington, two 500kV line Lamar-Big Sandy, two 500kV line Burlington-Big Sandy, two 500kV lines Big-Sandy-Missile Site, three 345kV lines Missile Site-Smoky Hill, three 500kV lines Lamar-Boone-Comanche, three new 345kV lines Comanche-Midway, four 345kV lines Midway-Daniels Park/Waterton w/3-1272 kcmil acsr, two 230kV lines Comanche-Black Hills load, two 230kV lines Midway-CSU loads.

ERZ-4 and ERZ-5

San Luis 0 MW – no lines to Walsenburg.

Walsenburg 1682 MW – (0 from San Luis+1682MW Walsenburg injection) two 345kV lines Walsenburg-Comanche.

WHAT DOES THIS EVALUATION TELL US?

Transmission planning for the heavy summer peak periods

This traditional heavy summer peak evaluation process tells us conceptually how a back bone bulk power transmission system could be developed for the state of Colorado for the different scenarios as depicted in Maps 2A-4B and listed in Table 3. For major transmission lines that are being contemplated to be built soon, this conceptual look could help guide the utilities as to how they should build those transmission lines now to fit into an ultimate development of the system that looks 30 years out into the future. This approach would give insight for engineering judgment on how to take the first steps.

However, RES generation presents a totally different challenge to the transmission planning process, especially wind since its output changes from 12.5% of capacity during the peak to 100% capacity during the peak, an increase of 8 times over the summer peak. Transmission planning is now required to be coordinated with the off-peak periods as discussed below.

<u>Transmission planning for off-peak periods</u>

RES generation presents a transmission planning challenge which needs discussion up front. The problem is coordinating and dealing with the conventional generation needed for the summer peak with the RES generation during the off-peaks when the RES are at maximum generation output. In my heavy summer examples, it is assumed that the RES generation is at 12.5% of its nameplate capability for wind generation and solar at 100%. For the off-peak periods, the wind is assumed at 100% generation and solar is at 0%. This 100% maximum wind generation has a significant effect on all the ERZ's except ERZ-4. Following are several examples first focusing on the 2025 and 2041 Balanced scenarios.

For ERZ-3, a wind rich generation area, Gladstone is shown as the injection point (see Table 2 and Map 2A) which shows 1228 MW (31% of the 3962 MW) of generation for the 2025 heavy summer balanced scenario. Of these 1228 MW, 1077 MW would be conventional generation and 151 MW wind generation (31% of 487 MW) which represents 12.5% of its capability during the peak. Therefore the wind generation capability is 1208 MW (8*151 MW) making the Gladstone total generation capability 2285 MW (1077 + 1208). For 2025, the off-peak generation capability at Gladstone increased by 1057 MW over the heavy summer generation. Using the same approach for 2041, Gladstone has 3193 MW of generation (31% of 10300 MW). Of these 3193 MW, 3029 MW would be conventional generation and 164 MW is from wind generation (31% of 529 MW) which represents 12.50% of its capability. Therefore the wind generation capability is 1312 MW (8*164 MW) making the Gladstone total generation capability 4341 MW (3029 + 1312 MW). For 2041, the Gladstone generation increases by 1148 MW over the heavy summer generation. This additional off-peak generation at Gladstone creates the need for additional transmission all along the paths to the load centers, especially the need for 500kV lines.

For the Heavy North off-peak and Heavy South off-peak scenarios, wind increasing to 100% of capacity creates the need for additional transmission. For the Heavy North off-peak scenarios, the additional wind generation creates the need for four 345kV lines Missile Site-Smoky Hill and a need for a 3-1431 kcmil acsr bundle for the 2041 off-peak case. An interesting note, to meet a 50% reduction in generation for the 2041 Heavy North off-peak case, 3339 MW of conventional generation had to be reduced to accommodate 100% of the wind generation at the injection points, otherwise the Missile Site-Smoky Hill corridor would require six 345kV circuits with a 3-1431 kcmil bundle. For the Heavy South off-peak cases, the need for additional 500kV lines arises from the Gladstone area to Lamar and on two the load centers.

The off-peak conditions result in more generation being available due to an increase in wind generation by eight times over the summer peak generation. This increase in generation results in the need for additional transmission lines when compared to the peak case. The obvious question then arises, "Should the transmission system be built to accommodate the sum of the total wind generation plus the conventional generation at the injection points? Or, should the conventional generation be reduced at the point of injection so that it matches the injection number of the peak conditions?" It is recommended to build the transmission system that can accommodate the sum of the total conventional generation plus 100% of the wind generation to meet the load plus reserves, 50% of peak in this analysis.

What transmission system should be built?

The balanced, heavy north, and heavy south generation scenarios present various options that lead to future transmission systems to pursue. However, as a start, I would recommend the transmission systems that result from the "Balanced generation scheduled" scenarios since generation for the cases is allocated in each ERZ in proportion to its share of the total composite potential generation of the five ERZ's. In addition, the 2041 year transmission system would depict the maximum transmission lines required for each corridor, picking the greater need from the heavy summer peak case or the off-peak case. The 2025 case transmission lines would then be built in preparation for the eventual development of the 2041 case, with the intent being to postpone the addition of transformers until needed as transformers add an additional significant cost to the transmission system. Attached Figure 2 shows the proposed 2041 year transmission system and Figure 1 shows the 2025 system that would grow into the 2041 system. Using the Figure 1 2025 system and the Figure 2 2041system for the "Balanced scheduled generation" scenarios, guidance can be provided to the SB 07-100 transmission planning process.

Looking at ERZ's 2, 3, 4 and 5:

In ERZ-3, for the Gladstone-Lamar corridor, the Figure 2 2041 system shows 3-500kV lines. In developing this corridor, ROW could be initially purchased to eventually accommodate three single circuit 500kV lines. The Lamar-Boone-Comanche corridor shows 2-500kV lines. In developing this corridor, ROW could be initially purchased to eventually accommodate two single circuit 500kV lines. The Lamar-Burlington-Big Sandy and Lamar-Big Sandy corridors show 1-500kV line. In developing these two corridors, ROW should be initially purchased to eventually accommodate single circuit 500kV lines. The Big Sandy-Missile Site corridor shows 2-500kV lines. In developing this corridor, ROW should be initially purchased to eventually accommodate two single circuit 500kV lines. The Comanche-Midway corridor shows 2-345kV lines. In developing this corridor, additional ROW could be initially purchased to eventually accommodate a double circuit 345kV line. In looking at the Figure 1 2025 system, the Gladstone –Lamar corridor shows 2-500kV lines. Construction could then begin to build two single circuit 500kV lines, with the third line built when needed between 2025 and 2041. The Lamar-Boone-Comanche, the Lamar-Burlington-Big-Sandy, the Lamar-Big Sandy, and the Big Sandy-Missile Site corridors show their respective 500kV lines operating at 345kV. This 345kV option presents the opportunity for phasing in the 500kV system from initial 345kV operation, or perhaps initial 230kV operation for this whole system depending on how the system generation additions progressively develop. Transformers can be timely installed/moved as the overall system develops. Please note that the 2041 500kV system is consistent with the proposed 500kV High Plains Express. Initial 230kV operation is mentioned because the 230-115kV Gladstone Substation is in need of a second 230kv source to eliminate the load shedding during the peaks and the outage of the Walsenburg-Gladstone 230kV line.

In ERZ's-4 and 5, the Figure 2 2041 system shows the San Luis-Walsenburg corridor with two 345kV lines so ROW should be purchased to accommodate two 345kV lines. The Walsenburg-Comanche corridor shows three 345kV lines so ROW should be purchased to accommodate three 345kV lines. The Figure 1 2025 system shows two San Luis-Walsenburg-Comanche 345kV circuits so initial construction should start with these two circuits. The third Walsenburg-Comanche 345kV circuit would then be built as needed between 2025 and 2041. For the San Luis-Walsenburg-Comanche corridor, PSCo and Tri-State are planning to build joint transmission projects. This analysis provides guidance as to what projects to pursue. Depending on how the system generation additions develop, the two initial San Luis-Walsenburg-Comanche 345kV circuits could be initially operated at 230kV. Transformers can be timely installed/moved as the overall system develops. The San Luis Substation is in need of a second source to eliminate load shedding during the peak much like the Gladstone substation area.

The last example is in ERZ-2 and it involves the proposed Pawnee-Smoky Hill 345kV line before the CPUC. Figure 2 shows the Missile Site-Smoky Hill corridor with 4-345kV circuits needing a 3-1272 kcmil acsr bundle. Potential heavy imports from Pawnee, generation injections at Missile Site, and power flows from Big Sandy create the need for the four 345kV lines to have a 3-1272 conductor bundle. Figure 1 shows initially two 345kV circuits on this corridor. This analysis shows that PSCo would be on solid ground to build the Missile Site-Smoky Hill section of this initially proposed 345kV line with a 3-1272 bundle.

The transmission lines recommended from the planning process as described above focused on the "Balanced generation scheduled" scenarios. The "Heavy North" and the 'Heavy South" scenarios also outline transmission systems for consideration. These transmission systems present the extreme transmission line loadings from the northern and from the southern parts of the system requiring additional transmission lines when compared to the "Balanced generation" scenario. These extreme northern and southern loadings transmission systems can then be used provide guidance as to what additional transmission lines may be required further into the future beyond the year 2041.

<u>Renewable Energy Sources</u>

The intent of this analysis is to look at the transmission line needs for the future needed generation as identified in the different ERZ's in the different scenarios. However, one of the jobs of a transmission planner is to insure that the transmission system and the generation mesh well together so as to not create instability problems as a result of a disturbance. Another issue that is arising involves the 60 HZ frequency versus load/generation regulation required of the balancing authorities, formerly called area control regulation. RES generation present a transmission reliability challenge as well as a balancing authority regulation challenge. The following discussion is presented to raise the issues so that they may be studied and solutions found to the problems before they arise.

The total energy forecast yields the expected energy generation from renewable energy sources (RES) and the associated demand generation to generate the energy, assuming a 35% annual capacity factor as shown on Table 1. Table 1 also assumes that the amount of power (demand) at the time of the peak is also 12.5% of the total nameplate capacity of the available RES on line. For example, in the year 2025, the incremental new generation from 2008 is 3962 MW which would include 491 MW of RES during the peak while the nameplate capacity of the RES is 3927 MW. In the year 2041, the incremental new generation from 2008 is 10,300 MW which would include 660 MW of RES. However, the nameplate capacity of the RES is 5281 MW. The installed RES in 2025 as a percentage of the load is 25% (3927/16408*100) and 27% (5281/19609*100) in 2041. The total state load factor in the year 2025 is 59% ((73444 GWh/14145MW* 8760 h)*100) and 57% ((98164GWh/19609MW*8760)*100) in 2041.

The wind penetration levels as a function of peak load of 25% and 27% for the years 2025 and 2041, respectively, certainly raise an immediate flag to this writer. The decreasing load factor from 59% in 2025 to 57% in 2041 raises the flag a little higher. In a 2001 prudency review, the minimum PSCo peak as a percentage of the summer peak was 42%. If this minimum peak ratio is applied to the 2025 year, it gives a 5941 MW load. Of the 3927 of RES generation , assume 4% for solar (or 157 MW) leaving 3770 MW of wind generation. Then it is possible that the wind RES generation could be close to supplying 63% of the load for at least one hour. What happens to the stability of the system and its associated load if at the end of the hour 50-100% of the wind suddenly stops blowing for the next 10-15 minutes? This is an obvious question that must be addressed. However, it also leads to another question that must be answered sooner rather than later, “What is the reliable wind penetration level for Colorado when taking the off-peak periods into consideration?”

WHAT ABOUT THE LOAD SERVING TRANSMISSION NETWORK?

This analysis did not address the transmission elements required to distribute the power from receiving points on the load serving network to the distribution system. That would require additional analysis to be performed in the near future. But the following are some specific recommendations to keep in mind when developing a load serving transmission network:

All future new transmission lines that are built to be a part of load serving networks should be built as 230kV lines, even if they are initially energized at a lower voltage. As one looks at the load serving networks along I-25, one sees many 230kV lines. These 230kV lines can be connected to the various distribution voltages with little difficulty. A typical 230kV with a 1272 kcmil acsr can have a thermal rating of 500-600 MW, depending on the line design, and deliver that amount to the distribution substations; a 2-1272 bundle operated at 230kV would have a thermal rating of 1000-1200MW. As a rule of thumb, the planner can look at a receiving substation and determine that it needs one 230kV line from there to the load centers for every 500-600 MW of power injection. For the year 2025, the 3962 MW of incremental generation would then need 8 new typical 230kV lines from the point of receipt to the load centers. For the year 2041, the 10300 MW of incremental generation would require a total of 21 new 230kV lines.

Future load serving transmission will have capacity requirements, EMF mitigation needs, and corona noise mitigation needs. To fulfill all these requirements, 230kV lines should be built as double circuit lines using a 2-conductor bundle. This construction would reduce the number of typical 230kV circuits by one half.

CONCLUSIONS

1. Exhibits 2A, 2B – 4A, 4B and Table 4 depict potential bulk power transmission lines that can accommodate the 3962 MW of incremental generation by 2025 and 10300 MW by 2041 for the heavy summer peak conditions.
2. Exhibits 2A, 2B off-peak – 4A, 4B off-peak and Table 4 depict potential bulk power transmission lines that can accommodate the additional generation caused by wind as it goes from 12.5% capacity during the peak to 100% of the capacity during the off-peak periods in the years 2025 and 2041.
3. As summarized in Table 4, off-peak periods create the need for additional transmission lines from the points of injection to the load centers. This raises the question as to whether or not to build these additional lines.
4. As summarized in Table 4, off-peak periods create the need to reduce conventional generation to allow wind generation to be at full output. This creates the need to determine which generation should be reduced.
5. It makes sense to pursue the future bulk power systems as depicted in the Balanced Generation scenarios for years 2025 and 2041 for the heavy summer peak and off-peak periods. In picking this future transmission system, the greater of the transmission lines for the summer peak or the off-peak should be picked for each corridor as depicted in Figure 1 for year 2025 and Figure 2 for year 2041.
6. A 2041 heavy summer power flow case depicting the “Balanced generation schedule” scenario needs to be developed to fine tune the conceptual transmission system. In addition, a 230kV load serving transmission serving network needs to be developed for this 2041 case so all the Colorado utilities can have the needed guidance as to how to begin developing their load serving network in their next budget cycle.
7. **Note:** It is acknowledged that generation built within the load serving network may tend to decrease the need for the transmission lines as outlined in this report. However, internal generation may only postpone the same lines that will eventually be required in the future.

TABLES 1, 2, 3, and 4

FOLLOW THIS PAGE

Colorado Load Forecast - demand (MW) and energy (GWh)

Year	**2008** Demand	**∆1*Demand**	**2025** Demand	**∆2Demand**	**2041** Demand	**∆3**Demand**
Public Service Company of Colorado	6700	2568	9268	4273	13541	6841
Black Hills	76	457	533	169	702	626
Platte River Power Authority	656	335	991	323	1314	658
Colorado Springs Utilities	893	303	1196	349	1545	652
Tri-State G&T	1577	580	2157	350	2507	930
Load - Total	9902	4243	14145	5464	19609	9707
∆1* is (2025 load - 2008 load)						
∆3** is (2041 load - 2008 load)						
Load+16% reserves=Generation	11486	4922	16408	6338	22746	11260
Minus-700MW Comanche & 260 Ft St vrain		960				960
Net new generation		3962				10300

Year	**2008** **Energy** GWh	**RES-E** GWh	**RES-D** Gen-MW	**2025** **Energy** GWh	**RES-E** GWh	**RES-D***** Gen -MW	**2041** **Energy** GWh	**RES-E** GWh	**RES-D***** Gen -MW
Public Service Company of Colorado	34027	1927	1100	43790	8758	2859	59214	11843	3867
Black Hills	388			3029	606	198	4378	876	286
Platte River Power Authority	3649			5929	593	194	8380	838	274
Colorado Springs Utilities	4967			7156	716	234	9853	985	322
Tri-State G&T	9501			13540	1354	442	16339	1634	533
Total energy	52532			73444			98164		
RES demand generation - Total			1100			3927			5281

Note-PSCo and Black Hills - 20% energy and
PRPA, CSU, & Tri-State - 10% energy,
after year 2020

***Includes wind+solar at 35% capacity factor

Table 1

Generation Capability - peak and off-peak (MW)

2025 Heavy Summer Peak
Incremental generation

2025 Off-peak
Incremental generation

Generation Needs - off-peak at 50% of peak

ERZ's	Conventional	RES	Total	ERZ's	Conventional	RES	Total	Total GEN need	ΔGen	ΔNeed
Balanced				Balanced						
ERZ-1	730	102	832	ERZ-1	730	816	1546			
ERZ-2	833	118	951	ERZ-2	833	944	1777			
ERZ-3	1077	151	1228	ERZ-3	1077	1208	2285			
ERZ-4*	0	674	674	ERZ-4	0	0	0			
ERZ-5	241	36	277	ERZ-5	241	288	529			
Total	2881	1081	3962	Total	2881	3256	6137	8204	6137	2067
Heavy North				Heavy North						
ERZ-1	1632	221	1853	ERZ-1	1632	1768	3400			
ERZ-2	1839	250	2089	ERZ-2	1839	2000	3839			
Total	3471	471	3942	Total	3471	3768	7239	8204	7239	965
Heavy South				Heavy South						
ERZ-3	1946	273	2219	ERZ-3	1946	2184	4130			
ERZ-4*	0	1228	1228	ERZ-4	0	0	0			
ERZ-5	451	64	515	ERZ-5	451	512	963			
Total	2397	1565	3962	Total	2397	2696	5093	8204	5093	3111

2041 Heavy Summer
Incremental generation

2041 Off-peak
Incremental generation

Balanced				Balanced						
ERZ-1	2054	111	2165	ERZ-1	2054	888	2942			
ERZ-2	2343	129	2472	ERZ-2	2343	1032	3375			
ERZ-3	3029	164	3193	ERZ-3	3029	1312	4341			
ERZ-4*	0	1751	1751	ERZ-4	0	0	0			
ERZ-5	684	37	721	ERZ-5	684	296	980			
Total	8110	2192	10302	Total	8110	3528	11638	11373	11638	-265
Heavy North				Heavy North						
ERZ-1	4531	298	4829	ERZ-1	4531	2384	6915			
ERZ-2	5109	336	5445	ERZ-2	5109	2688	7797			
Total	9640	634	10274	Total	9640	5072	14712	11373	14712	-3339
Heavy South				Heavy South						
ERZ-3	5555	212	5767	ERZ-3	5555	1696	7251			
ERZ-4*	0	3193	3193	ERZ-4	0	0	0			
ERZ-5	1290	49	1339	ERZ-5	1290	392	1682			
Total	6845	3454	10299	Total	6845	2088	8933	11373	8933	2440

*Solar

Table 2

Transmission Plans for Years 2025 and 2041 peaks

Lines	2025 Balanced	Cost $M	2041 Balanced	Cost $M	2025 Heavy North	cost $M	2041 Heavy North	cost $M	2025 Heavy south	Cost $M	2041 Heavy South	Cost $M
San Luis to Walsenburg - 86 miles	2-345	102	2-345	102					2-345	102	2-500	167
Walsenburg to Comanche - 50 miles	2-345	60	3-345	89					2-345	60	3-500	145
Gladstone to Lamar - 110 miles	2-345	131	2-500	213					2-500	213	3-500	320
Lamar to Boone - 100 miles	2-345	119	2-345	119					2-345	119	2-500	194
Boone to Comanche - 30 miles	2-345	36	2-345	36					2-345	36	2-500	58
Comanche to Midway - 50 miles	1-345	30	2-345	60					1-345	30	3-500	146
Midway to Daniels Park - 75 miles	3-345**	0	4-345**	0					3-345**	0	4-345*	193
Lamar to Big Sandy - 144 miles	1-230/345	86	1-345	86					1-345	86	1-500	140
Lamar to Burlington - 100 miles	1-230/345	60	1-345	60					1-345	60	1-500	97
Burlington to Big Sandy - 80 miles	1-230/345	48	1-345	48					1-345	48	1-500	78
Big Sandy to Midway - 80 miles		0		0	1-230	52	2-230/345	95		0		0
Big Sandy to Missile Site - 44 miles	2-230/345	52	2-345	52	2-230	38	2-230/345	52	2-345	52	2-500	85
Pawnee to Ft. Lupton-60 miles		0		0		0		0		0	1-230	39
Pawnee to Missile Site-49 miles	1-345	29	2-345	58	2-345	58	3-345	87		0		0
Missile Site to Smoky Hill - 45 miles	2-345	54	4-345	107	2*or3-345	80	4*-345	116	2-345	54	3-345	80
Comanche to Black Hills - 30 miles	2-230	26	2-230/345	36	2-230	26	2-230/345	36	2-230	26	2-230/345	36
Midway to Colo Spgs U - 50 miles	2-230	35	2-230	35	2-230	35	2-230	35	2-230	35	2-230	35
Ault to PRPA - 35 miles	2-230	30	2-230	30	2-230	30	2-230	30	2-230	30	2-230	30
Ault to Denver 80 miles		0	1-230	33	2-230/345	60	2-345	60		0		0
Transmission Cost - total		895		1162		379		511		949		1841

**existing
*with 3-1272 kcmil acsr

Transformers	2025 Balanced Cost $M	2041 Balanced Cost $M	2025 Heavy North cost $M	2041 Heavy North cost $M	2025 Heavy south Cost $M	2041 Heavy South Cost $M
Ault	0	0	0	27	0	0
Big Sandy	0	0	0	0	14	0
Boone	0	0	0	0	0	0
Burlington	14	22	0	0	0	22
Comanche	0	27	0	0	0	43
Daniels Park	0	41	0	0	27	135
Denver Area	0	0	0	54	0	0
Gladstone	14	22	0	0	22	22
Lamar	41	249	0	0	176	22
Midway	14	27	0	0	14	498
Missile site	0	0	14	27	14	195
Pawnee	14	14	14	14	14	0
San Luis	14	14	0	0	41	22
Smoky Hill	54	149	81	203	14	81
Walsenburg	14	14	0	0		22
Transformers Cost - total	176	576	108	324	333	1060
Xmission + Xformers - total cost	1071	1738	487	835	1281	2901

Table 3

Transmission Plans for
Years 2025 and 2041 peaks
Years 2025 and 2041 off-peaks

Transmission Lines	2025 HS Balanced	2025 off-peak Balanced	2041 HS Balanced	2041 off-peak Balanced	2025 HS Heavy North	2025 off-peak Heavy North	2041 HS Heavy North	2041 off-peak Heavy North	2025 Heavy south	2025 off-peak Heavy South	2041 Heavy South	2041 off-peak Heavy South
San Luis to Walsenburg - 86 miles	2-345	-	2-345	-					2-345	-	2-500	-
Walsenburg to Comanche - 50 miles	2-345	2-230/345	3-345	2-345					2-345	2-345	3-500	2-345
Gladstone to Lamar - 110 miles	2-345	2-500	2-500	3-500					2-500	3-500	3-500	4-500
Lamar to Boone - 100 miles	2-345	2-345	2-345	2-500					2-345	2-500	2-500	3-500
Boone to Comanche - 30 miles	2-345	2-345	2-345	2-500					2-345	2-500	2-500	3-500
Comanche to Midway - 50 miles	1-345	1-345	2-345	2-345					1-345	2-345	3-500	3-345
Midway to Daniels Park - 75 miles	3-345**	3-345**	4-345**	4-345**					3-345**	4-345**	4-345*	4-345*
Lamar to Big Sandy - 144 miles	1-230/345	1-345	1-345	1-500					1-345	1-500	1-500	2-500
Lamar to Burlington - 100 miles	1-230/345	1-345	1-345	1-500					1-345	1-500	1-500	2-500
Burlington to Big Sandy - 80 miles	1-230/345	1-345	1-345	1-500					1-345	1-500	1-500	2-500
Big Sandy to Midway - 80 miles					1-230	2-230	2-230/345	2-230				
Big Sandy to Missile Site - 44 miles	2-230/345	2-345	2-345	2-500	2-230	2-230	2-230/345	2-230	2-345	2-500	2-500	2-500
Pawnee to Ft. Lupton-60 miles											1-230	
Pawnee to Missile Site-49 miles	1-345	2-230/345	2-345	2-345	2-345	2-345	3-345	3-345				
Missile Site to Smoky Hill - 45 miles	2-345	4-345	4-345	4-345*	2*or3-345	4-345*	4-345*	4-345***	2-345	3-345	3-345	4-345
Comanche to Black Hills - 30 miles	2-230	2-230	2-230/345	2-230	2-230	2-230	2-230/345	2-230	2-230	2-230	2-230/345	2-230
Midway to Colo Spgs U - 50 miles	2-230	2-230	2-230	2-230	2-230	2-230	2-230	2-230	2-230	2-230	2-230	2-230
Ault to PRPA - 35 miles	2-230	1-230	2-230	2-230	2-230	1-230	2-230	2-230	2-230	1-230	2-230	2-230
Ault to Denver 80 miles		2-230/345	1-230	2-345	2-230/345	2-345	2-345	3-345				

**Existing
* w/3-1272 kcmil acsr
***w/3-1431 kcmil acsr

Table 4

Map 1,

Figure 1 and Figure 2

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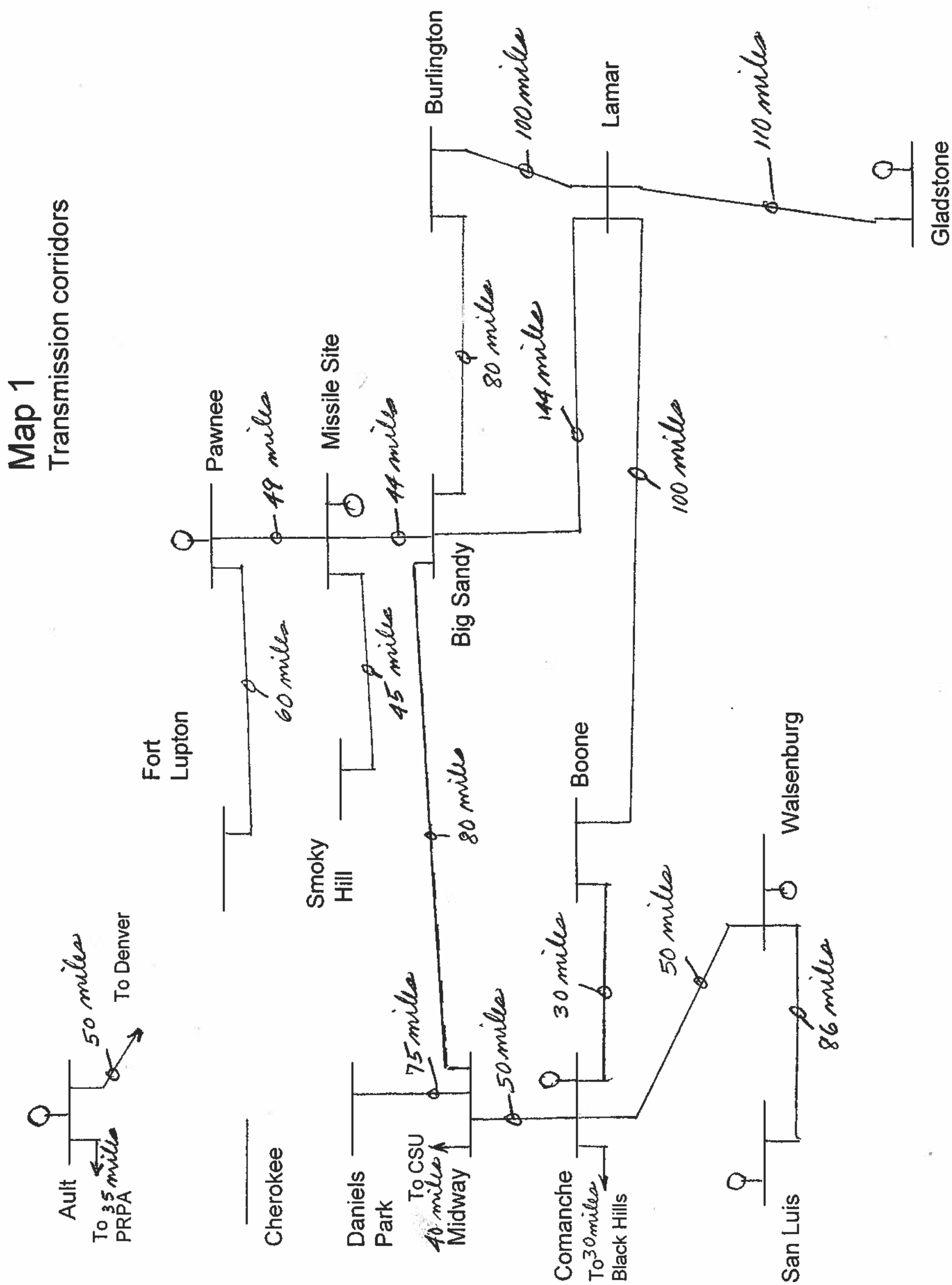

Map 1
Transmission corridors
Ault
To PRPA
35 miles
50 miles
To Denver
Cherokee
Fort Lupton
Pawnee
49 miles
60 miles
Missile Site
44 miles
Smoky Hill
45 miles
Big Sandy
80 miles
Burlington
100 miles
Lamar
110 miles
Gladstone
144 miles
100 miles
Boone
80 miles
Daniels Park
75 miles
To CSU
40 miles
Midway
50 miles
Comanche
To Black Hills
30 miles
30 miles
50 miles
Walsenburg
86 miles
San Luis

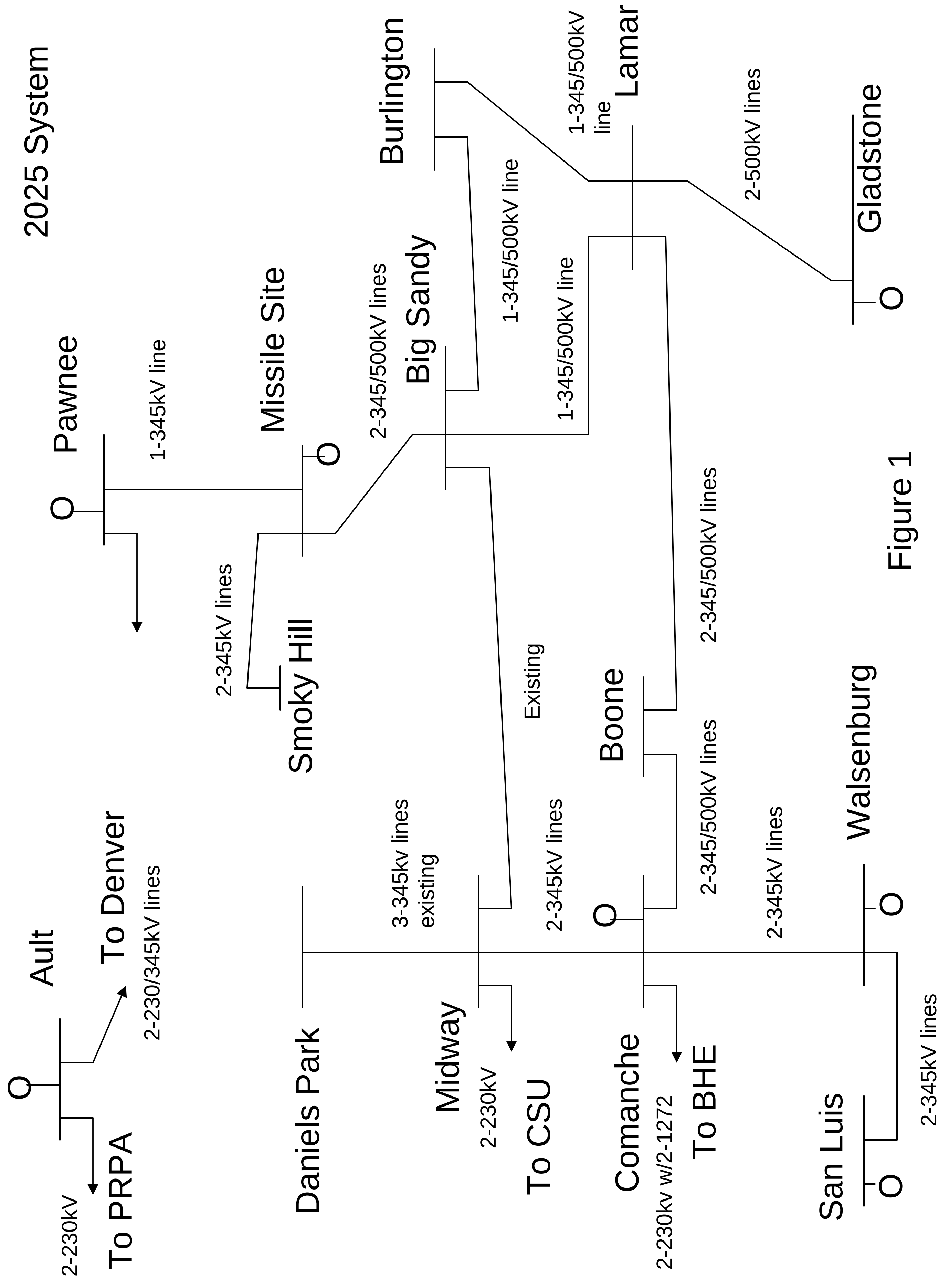

2025 System
Ault
To Denver
2-230/345kV lines
2-230kV
To PRPA
Pawnee
1-345kV line
Missile Site
2-345kV lines
Smoky Hill
2-345/500kV lines
Big Sandy
Burlington
1-345/500kV line
1-345/500kV line
1-345/500kV line
Lamar
2-500kV lines
Gladstone
Existing
2-345/500kV lines
Boone
2-345/500kV lines
Daniels Park
3-345kv lines existing
Midway
2-230kV
To CSU
2-345kV lines
Comanche
2-230kv w/2-1272
To BHE
2-345kV lines
Walsenburg
San Luis
2-345kV lines

Figure 1

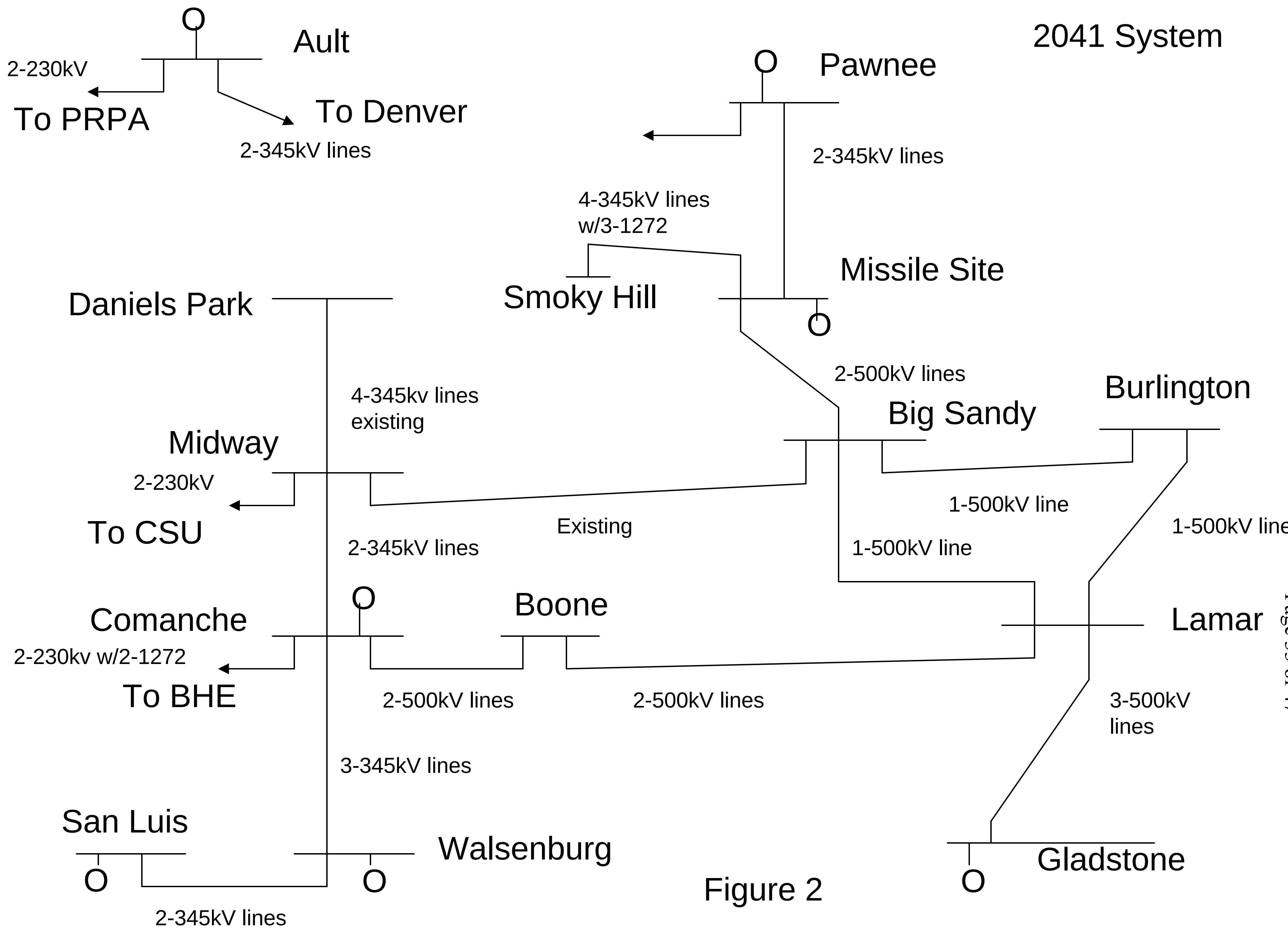

2041 System
Ault
2-230kV
To PRPA
To Denver
2-345kV lines
Pawnee
2-345kV lines
4-345kV lines
w/3-1272
Missile Site
Smoky Hill
Daniels Park
2-500kV lines
Big Sandy
Burlington
4-345kv lines
existing
Midway
2-230kV
To CSU
1-500kV line
1-500kV line
Existing
1-500kV line
2-345kV lines
Comanche
Boone
Lamar
2-230kv w/2-1272
To BHE
2-500kV lines
2-500kV lines
3-500kV
lines
3-345kV lines
San Luis
Walsenburg
Gladstone
2-345kV lines

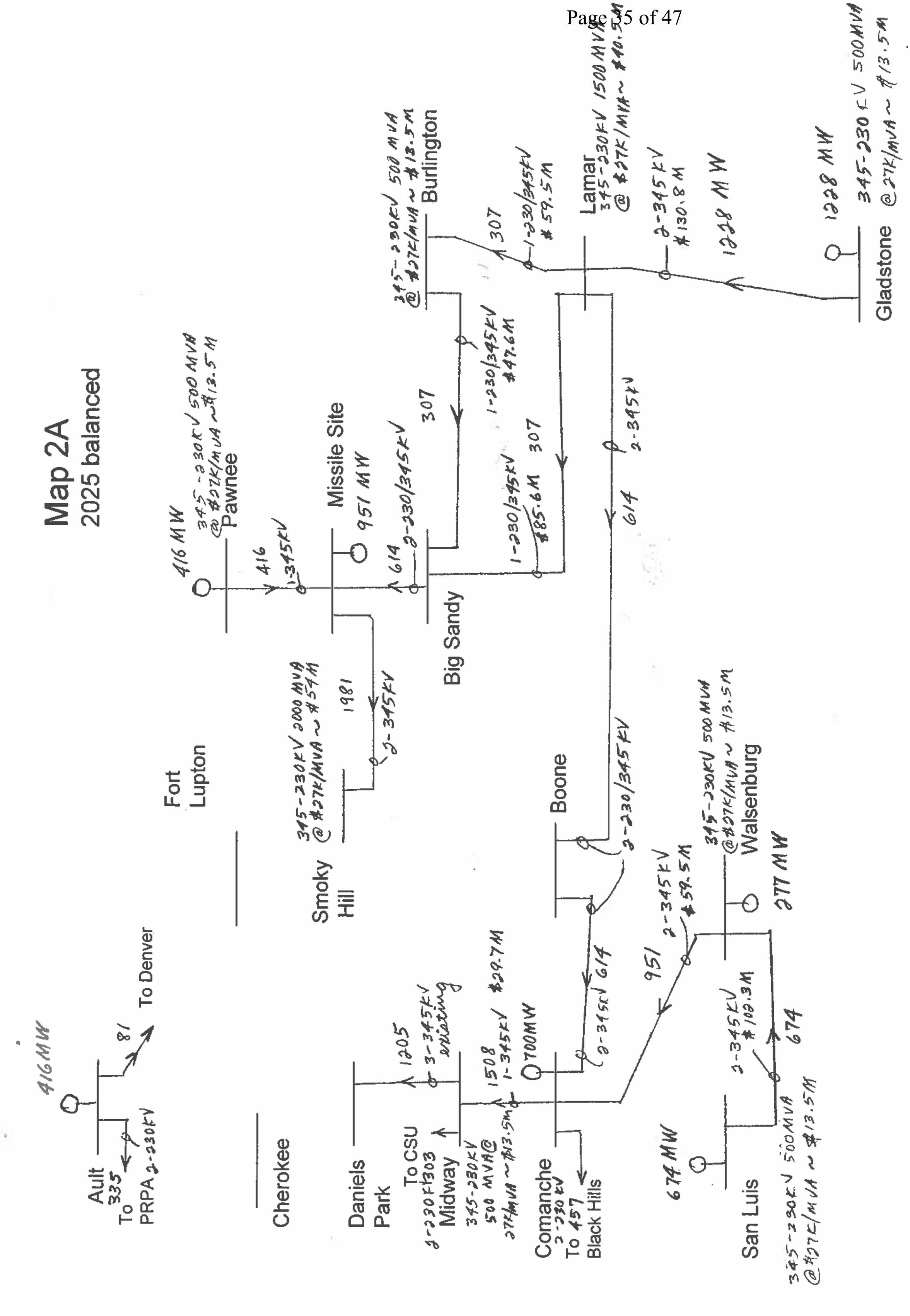
Figure 2

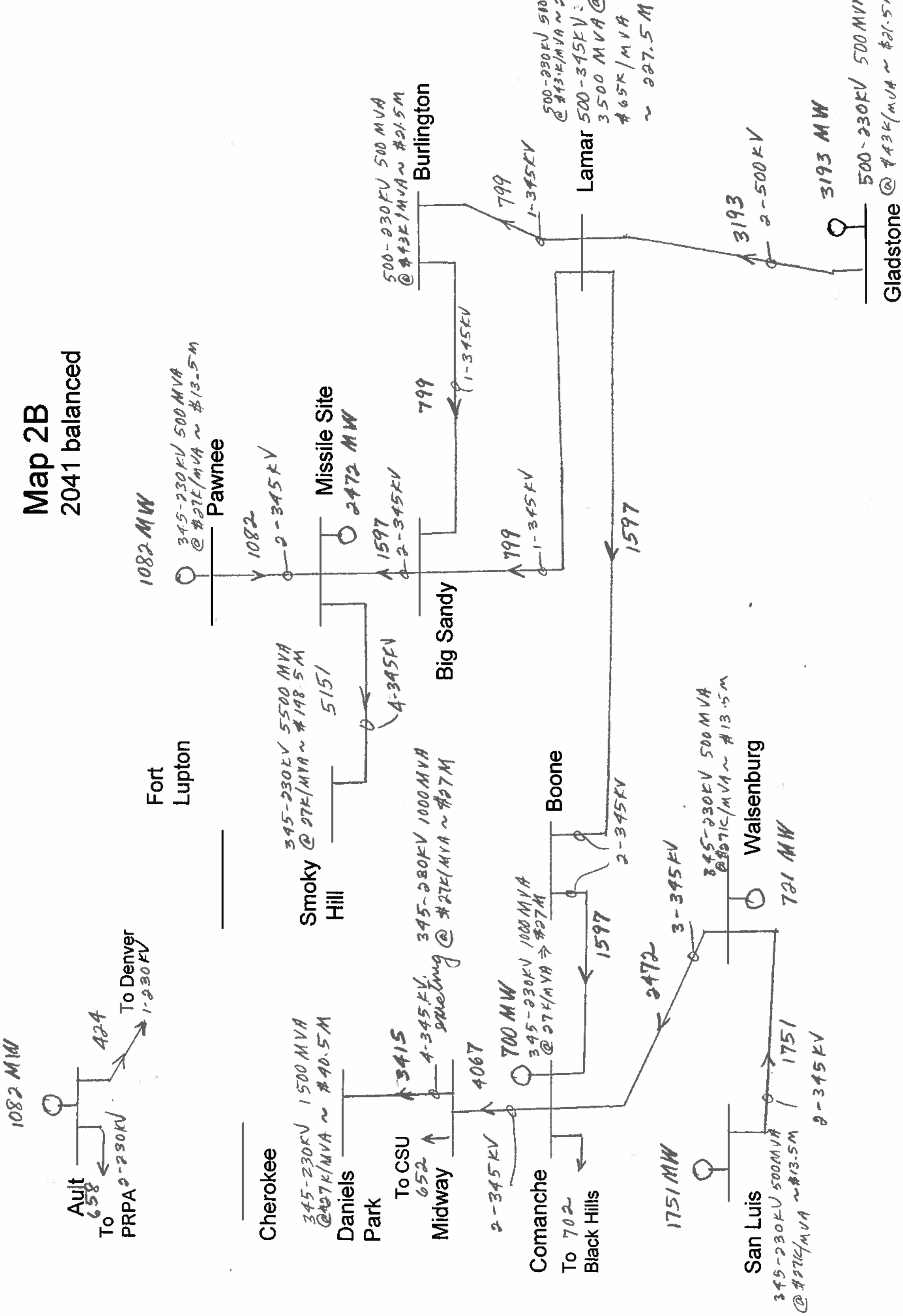
Map 2A, Map 2B

Map 3A, Map 3B

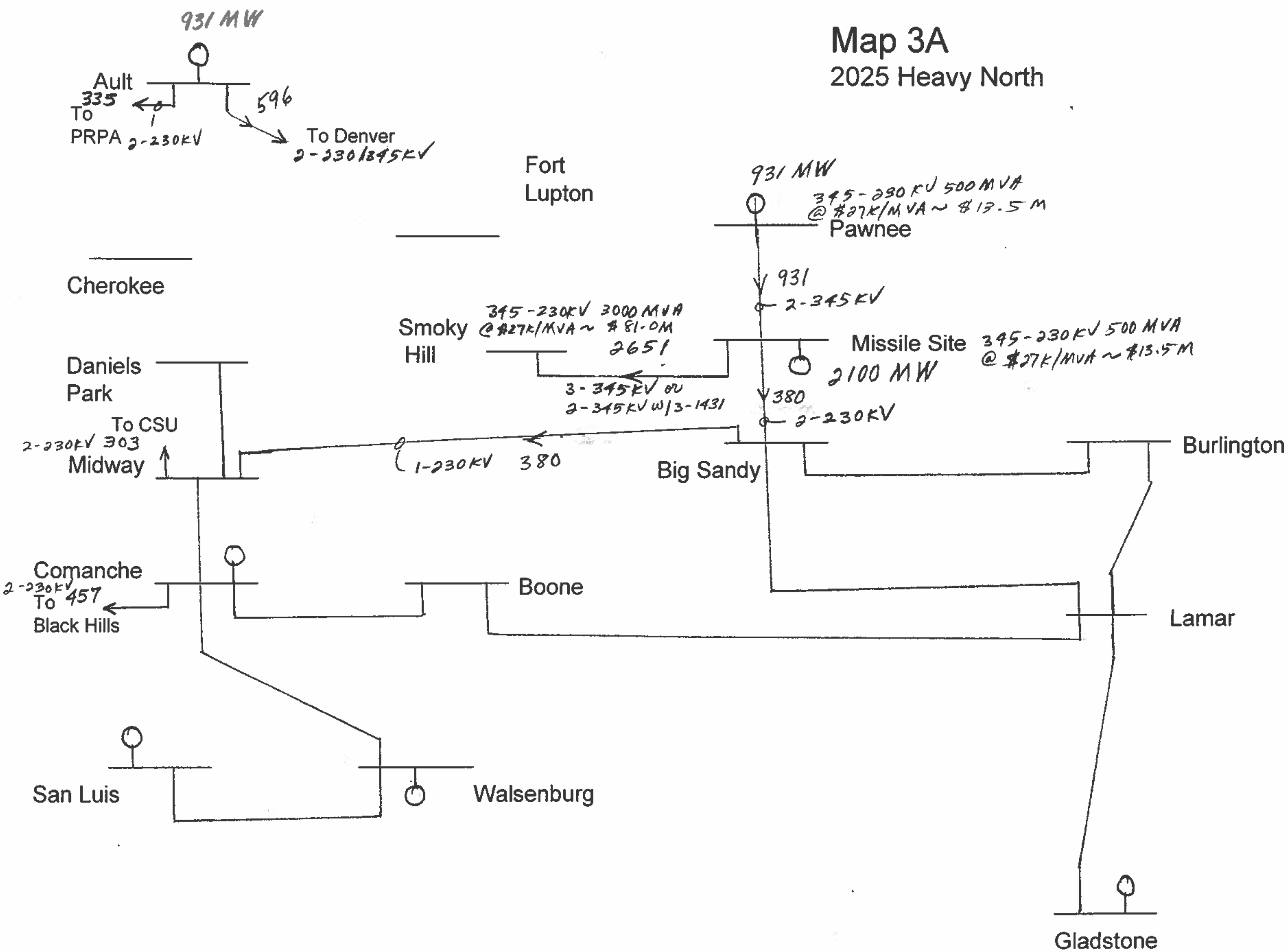
Map 4A, Map 4B

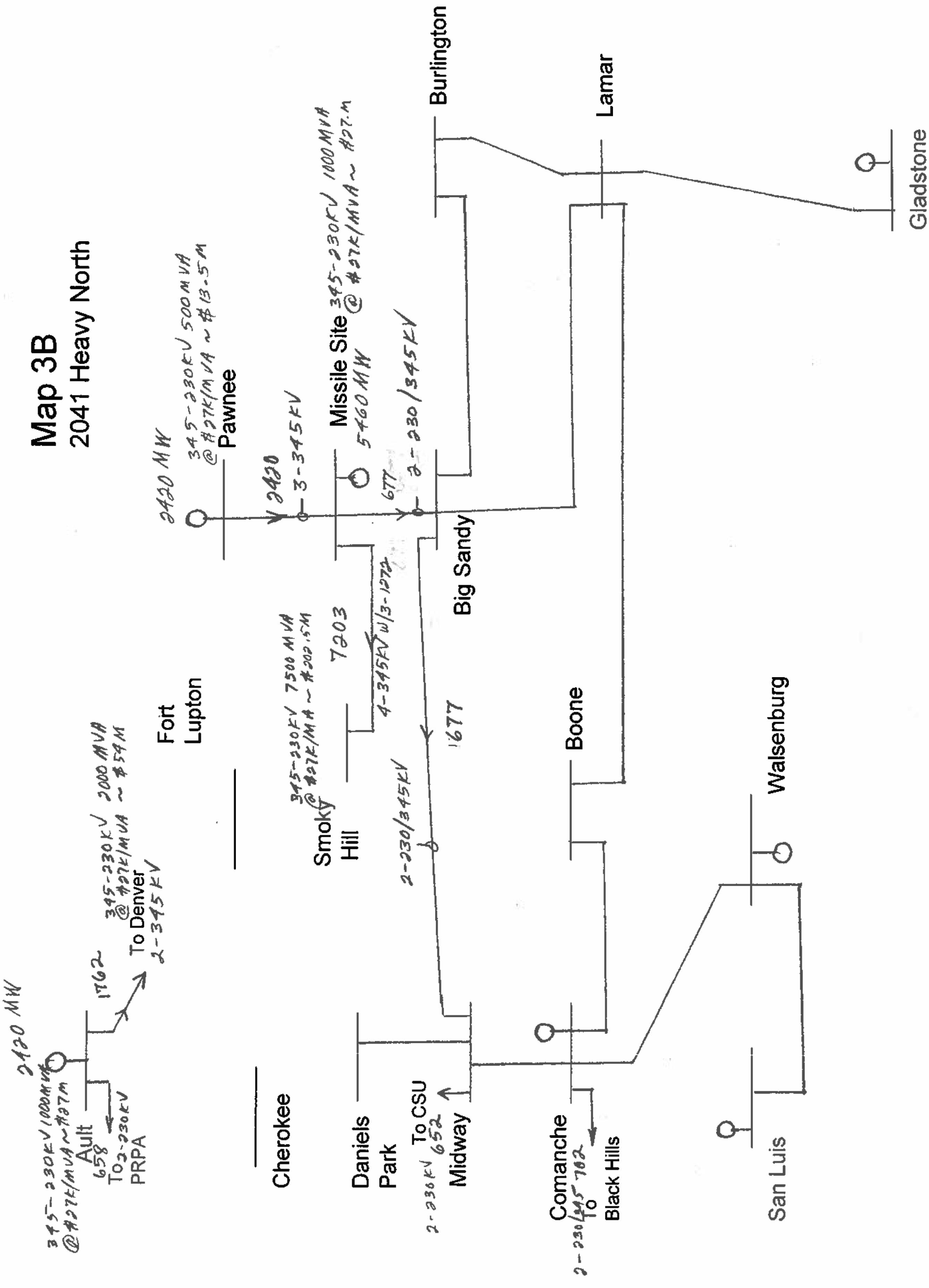
FOLLOW THIS PAGE

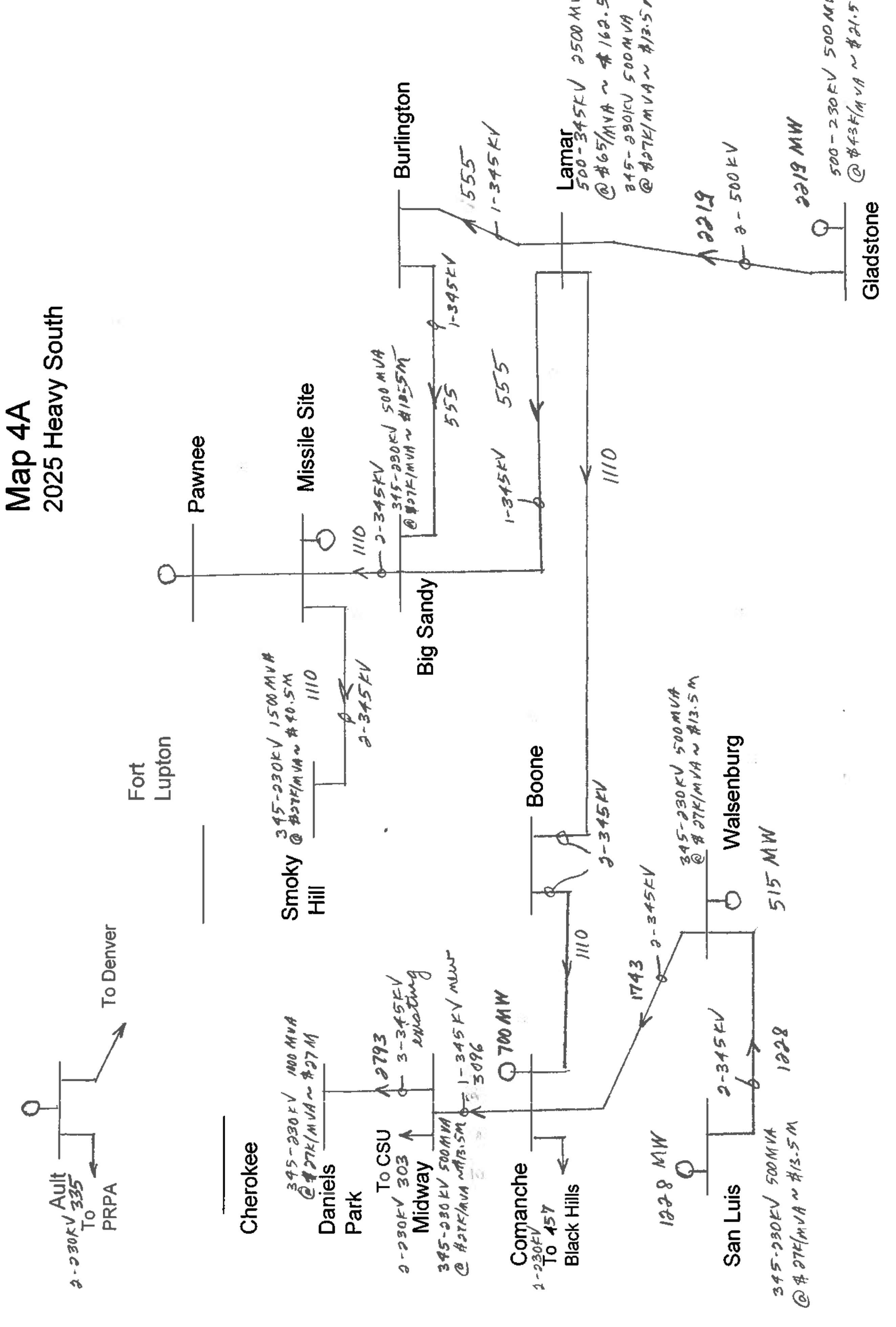

Map 2A
2025 balanced
Ault
To PRPA
335
2-230kV
416MW
81
To Denver
Cherokee
Fort Lupton
Daniels Park
1205
3-345kV existing
To CSU 2-230kV 1303
Midway
345-230kV 500 MVA@ 27k/MVA ~ $13.5M
1508
1-345kV $29.7M
700MW
Comanche
To Black Hills 2-230kV 457
2-345kV 614
951
2-345kV $59.5M
674 MW
San Luis
345-230kV 500MVA @ $27k/MVA ~ $13.5M
2-345kV $100.3M
674
Walsenburg
277 MW
345-230kV 500 MVA @ $27k/MVA ~ $13.5M
Boone
2-230/345kV
Smoky Hill
345-230kV 2000 MVA @ $27k/MVA ~ $54M
1981
2-345kV
Pawnee
416 MW
345-230kV 500 MVA @ $27k/MVA ~ $13.5M
416
1-345kV
Missile Site
951 MW
614
2-230/345kV
Big Sandy
307
1-230/345kV $85.6M
1-230/345kV $47.6M
614
2-345kV
Burlington
345-230kV 500 MVA @ $27k/MVA ~ $13.5M
307
1-230/345kV $59.5M
Lamar
345-230kV 1500 MVA @ $27k/MVA ~ $40.5M
2-345kV $130.8M
1228 MW
Gladstone
1228 MW
345-230kV 500MVA @ 27k/MVA ~ $13.5M

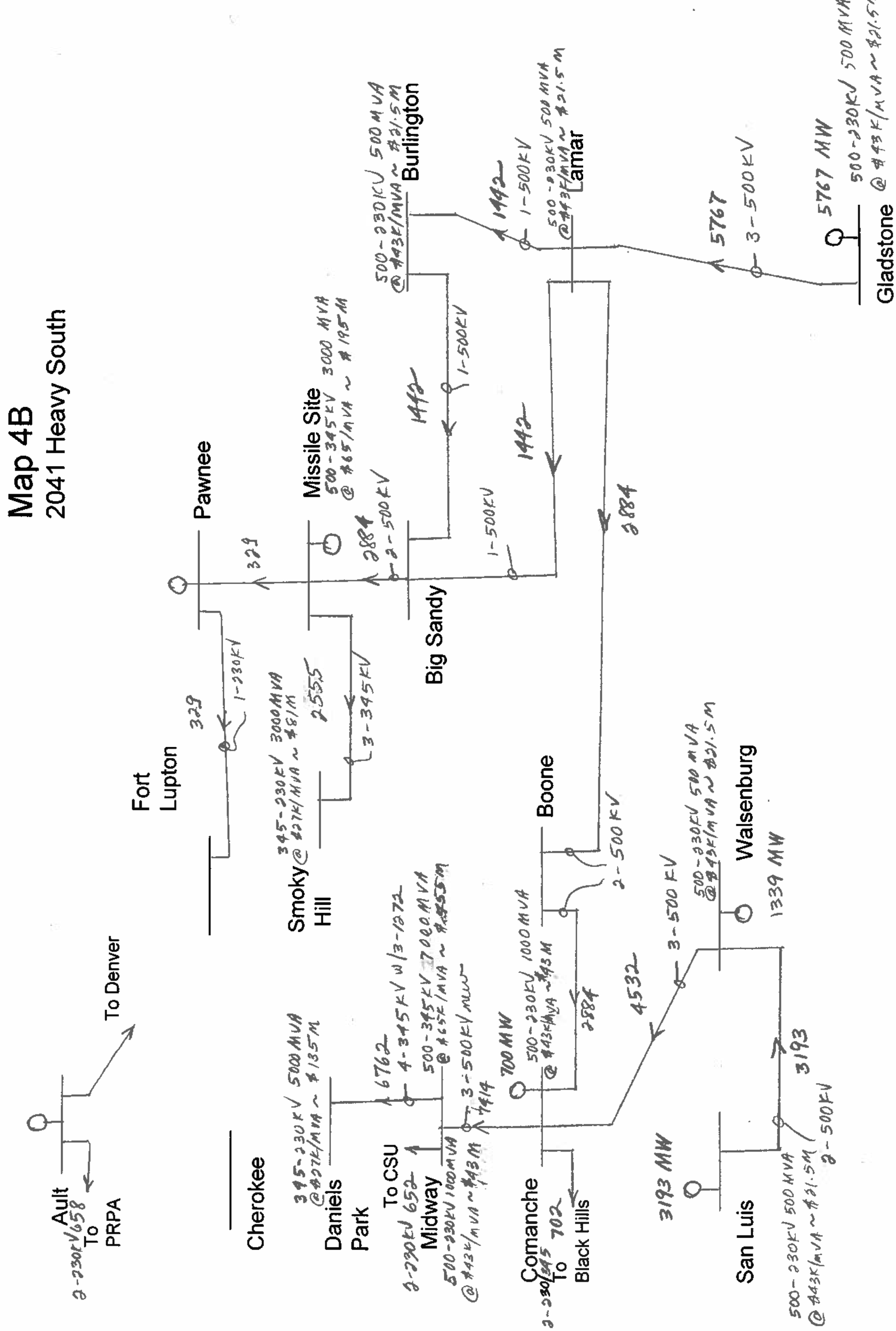

Map 2B
2041 balanced
Pawnee
1082 MW
345-230KV 500 MVA @ $27K/MVA ~ $13.5M
1082
2-345KV
Missile Site
2472 MW
1597
2-345KV
Big Sandy
799
1-345KV
Burlington
500-230KV 500 MVA @ $43K/MVA ~ $21.5M
Lamar
500-345KV 3500 MVA @ $65K/MVA ~ 227.5M
Gladstone
3193
2-500KV
3193 MW
500-230KV 500 MVA @ $43K/MVA ~ $21.5M
Fort Lupton
Smoky Hill
345-230KV 5500 MVA @ 27K/MVA ~ $148.5M
5151
4-345KV
Boone
2-345KV
1597
Walsenburg
345-230KV 500 MVA @ $27K/MVA ~ $13.5M
721 MW
3-345KV
2472
San Luis
1751 MW
1751
2-345KV
345-230KV 500MVA @ $27K/MVA ~ $13.5M
Comanche
700 MW
345-230KV 1000 MVA @ 27K/MVA ⇒ $27M
To 702 Black Hills
Midway
4067
2-345KV
To CSU 652
345-230KV 1000 MVA @ $27K/MVA ~ $27M
4-345KV existing
3415
Daniels Park
345-230KV 1500 MVA @ $27K/MVA ~ $40.5M
Cherokee
Ault
1082 MW
To PRPA 658 2-230KV
424
To Denver 1-230KV

Map 3A
2025 Heavy North




Map 3B
2041 Heavy North
Burlington
Lamar
Gladstone
2420 MW
345-230kV 500MVA
@ #27k/MVA ~ #13.5M
Pawnee
Missile Site
345-230kV 1000MVA
@ #27k/MVA ~ #27M
5460 MW
3-345kV
2420
677
2-230/345kV
Big Sandy
7203
4-345kV w/3-1272
345-230kV 7500 MVA
@ #27k/MA ~ #202.5M
Fort Lupton
Smoky Hill
1677
2-230/345kV
Boone
Walsenburg
345-230kV 2000 MVA
@ #27k/MVA ~ #54M
To Denver
2-345kV
1762
2420 MW
345-230kV 1000MVA
@ #27k/MVA ~ #27M
Ault
658
To 2-230kV
PRPA
Cherokee
Daniels Park
To CSU
2-230kV 652
Midway
Comanche
2-230/345 782
To
Black Hills
San Luis


Map 4A
2025 Heavy South
Pawnee
Missile Site
Big Sandy
Burlington
Lamar
Gladstone
2219 MW
Fort Lupton
Smoky Hill
Boone
Walsenburg
515 MW
To Denver
Ault
To PRPA
Cherokee
Daniels Park
To CSU
Midway
Comanche
700 MW
To Black Hills
San Luis
1228 MW


Map 4B
2041 Heavy South
Pawnee
Missile Site
Big Sandy
Burlington
Lamar
Gladstone
5767 MW
Fort Lupton
Smoky Hill
Boone
Walsenburg
1339 MW
To Denver
Ault
To PRPA
Cherokee
Daniels Park
To CSU
Midway
Comanche
To Black Hills
700 MW
San Luis
3193 MW
329
2884
1442
5767
2555
6762
4532
3193
1-500KV
2-500KV
3-500KV
3-345KV
1-230KV
500-230KV 500MVA
500-345KV 3000MVA

Map 2A Off-peak, Map 2B Off-peak

Map 3A Off-peak, Map 3B Off-peak

Map 4A Off-peak, Map 4B Off-peak

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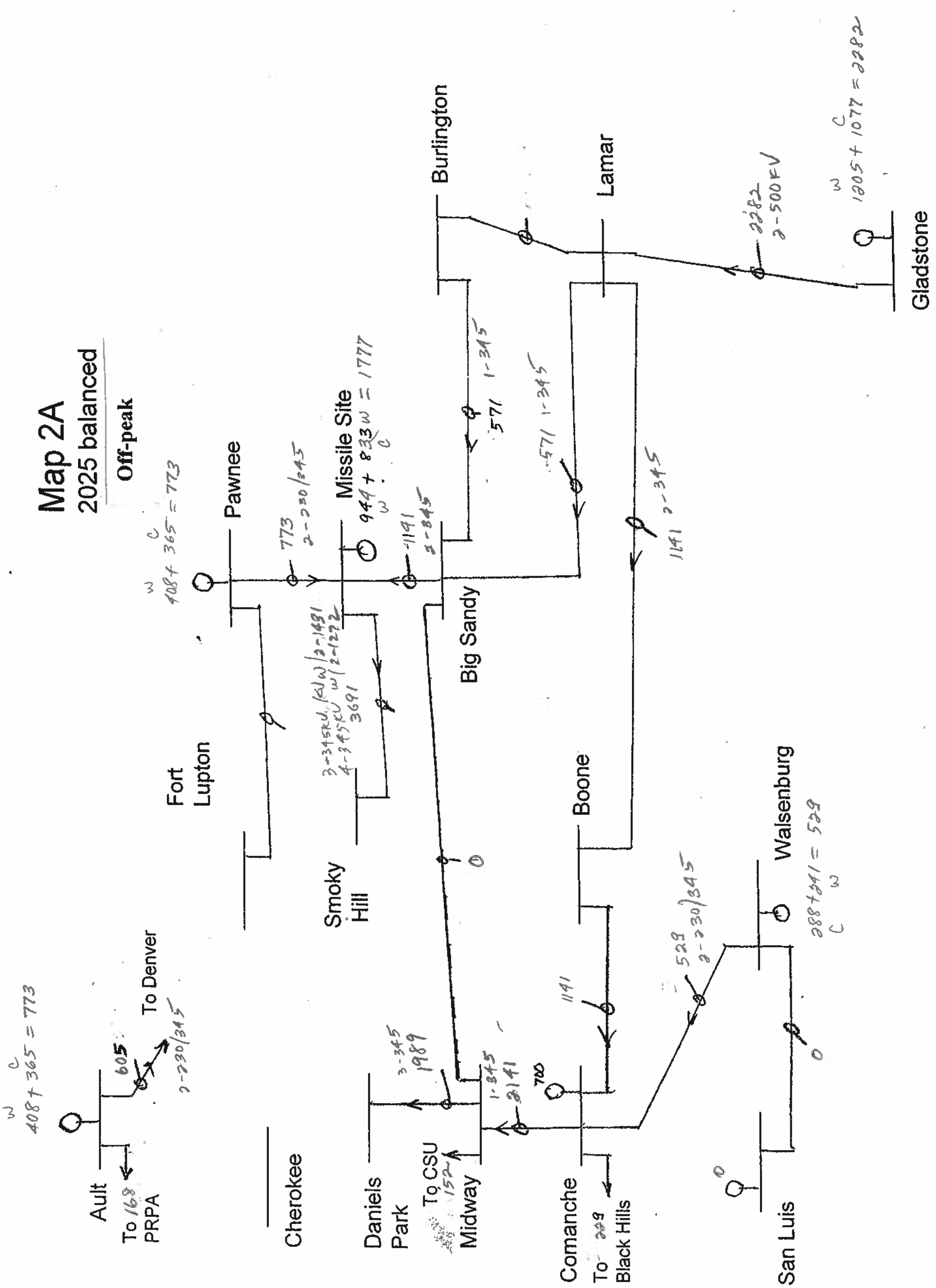
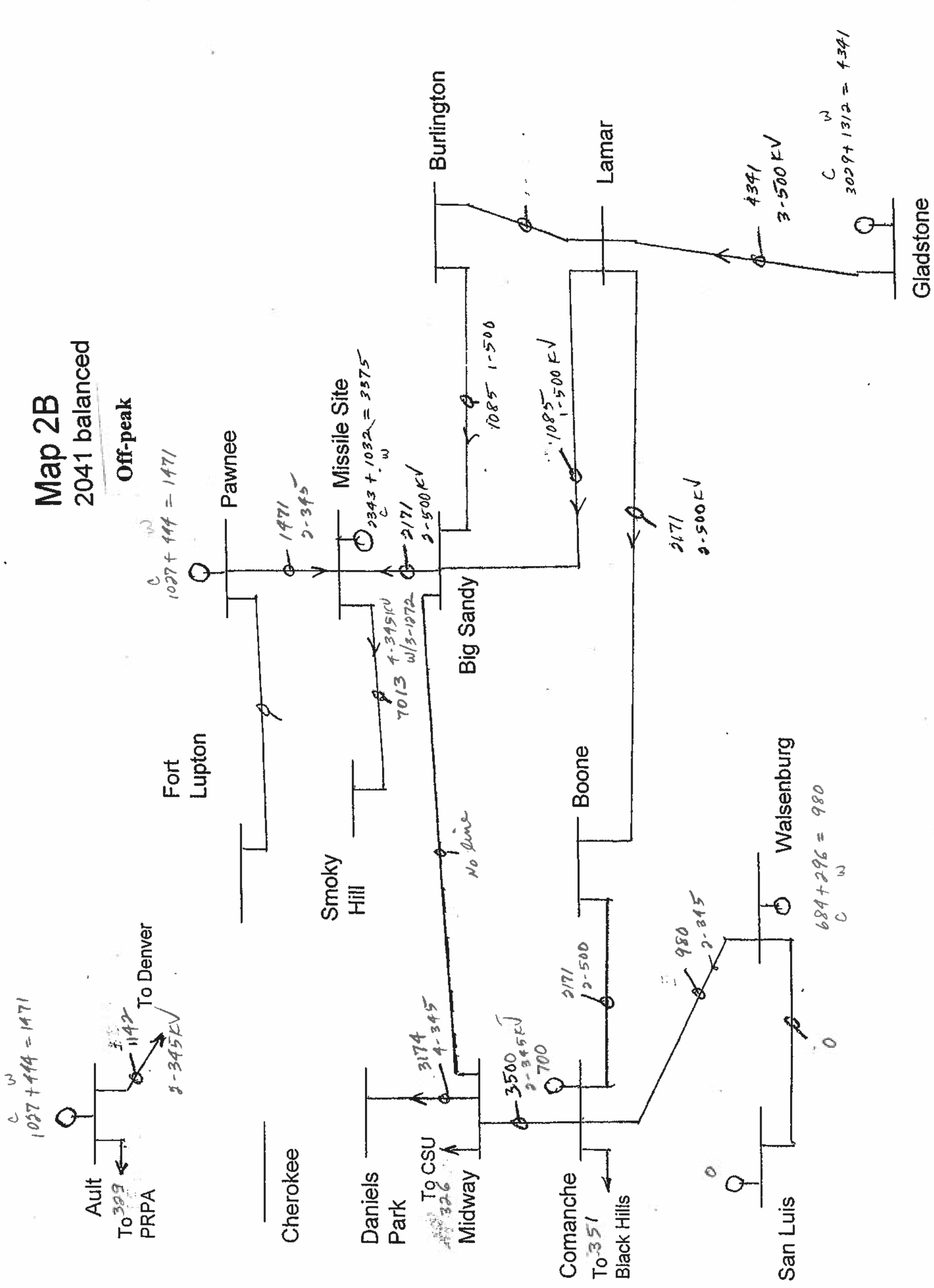
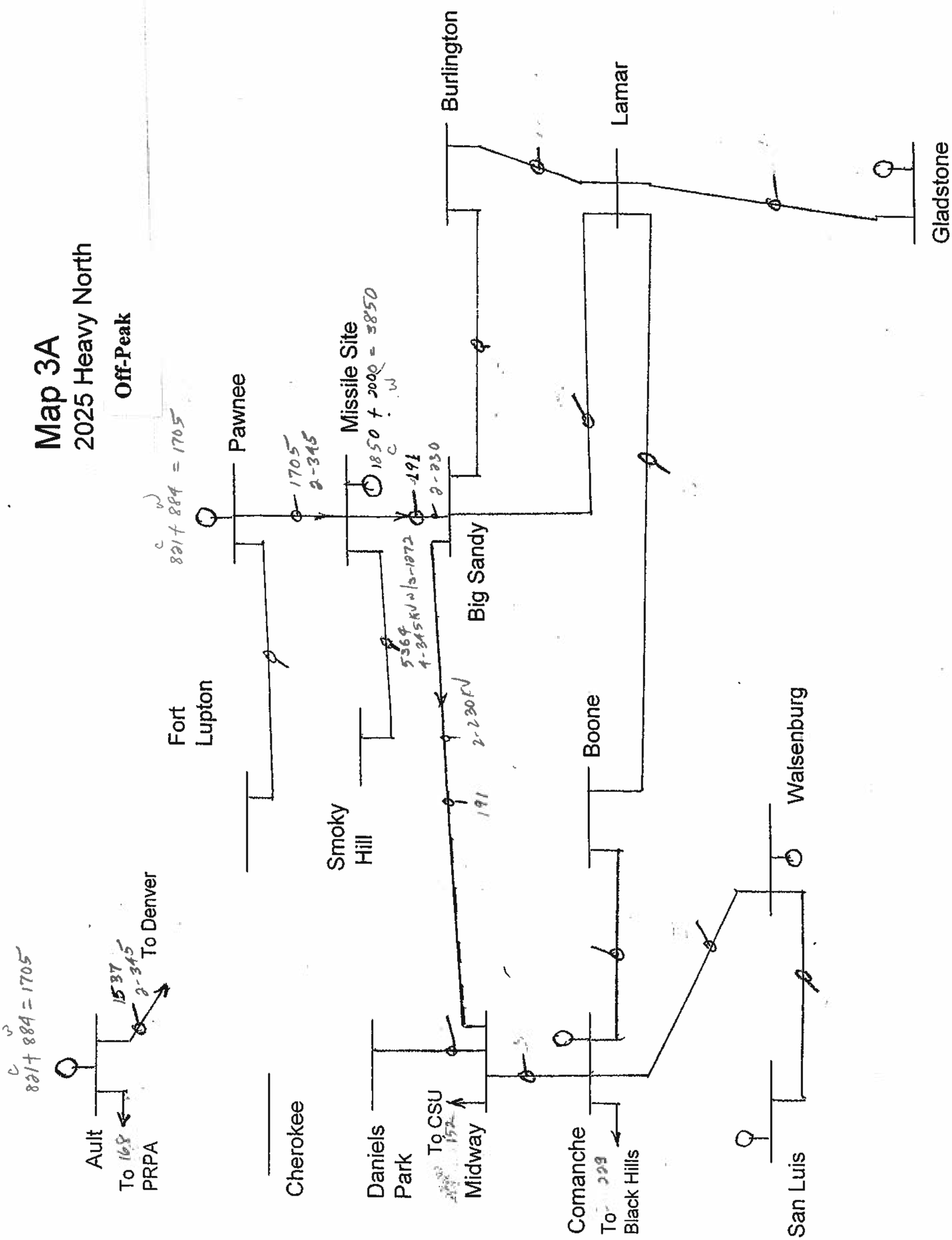
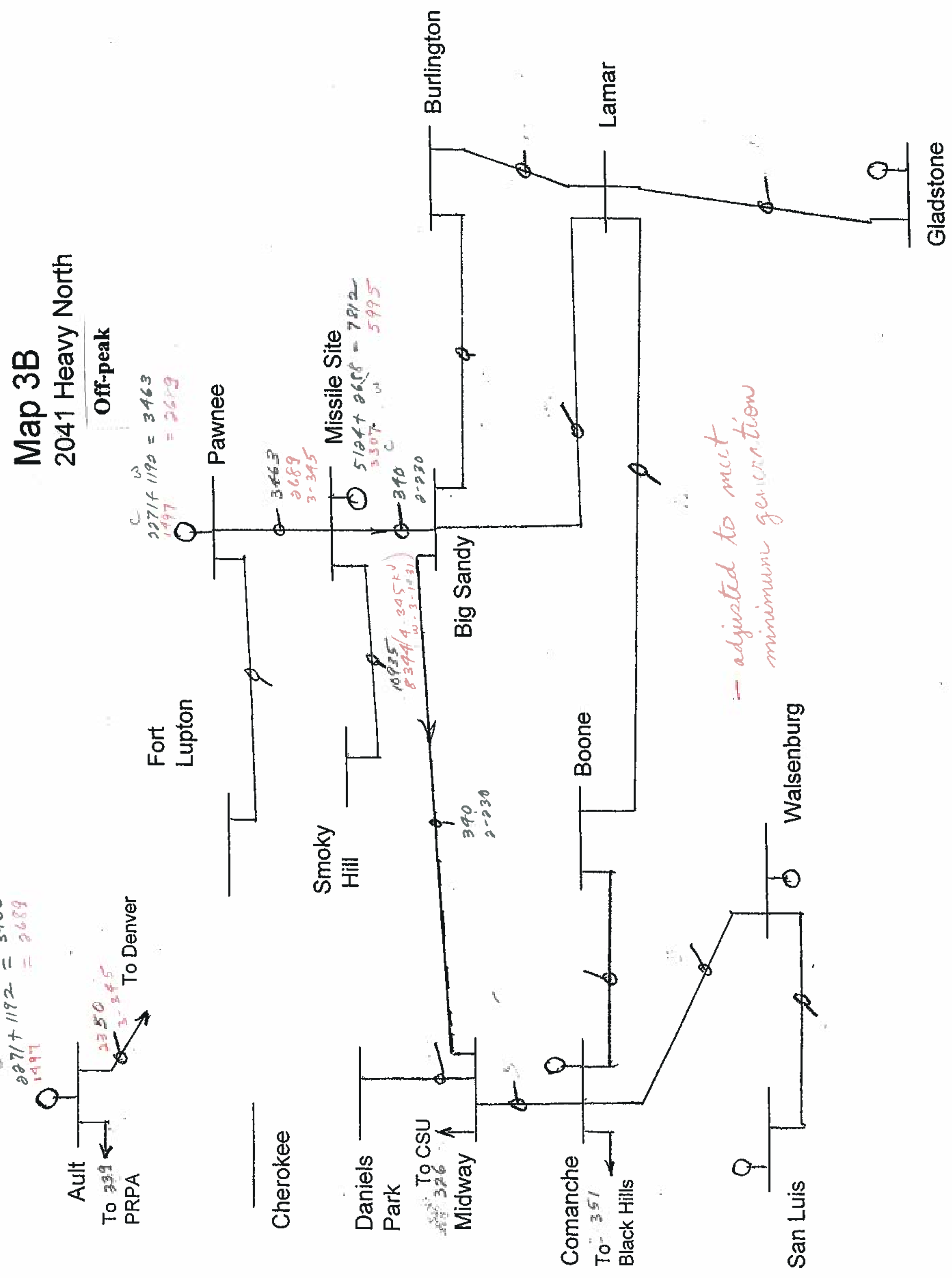
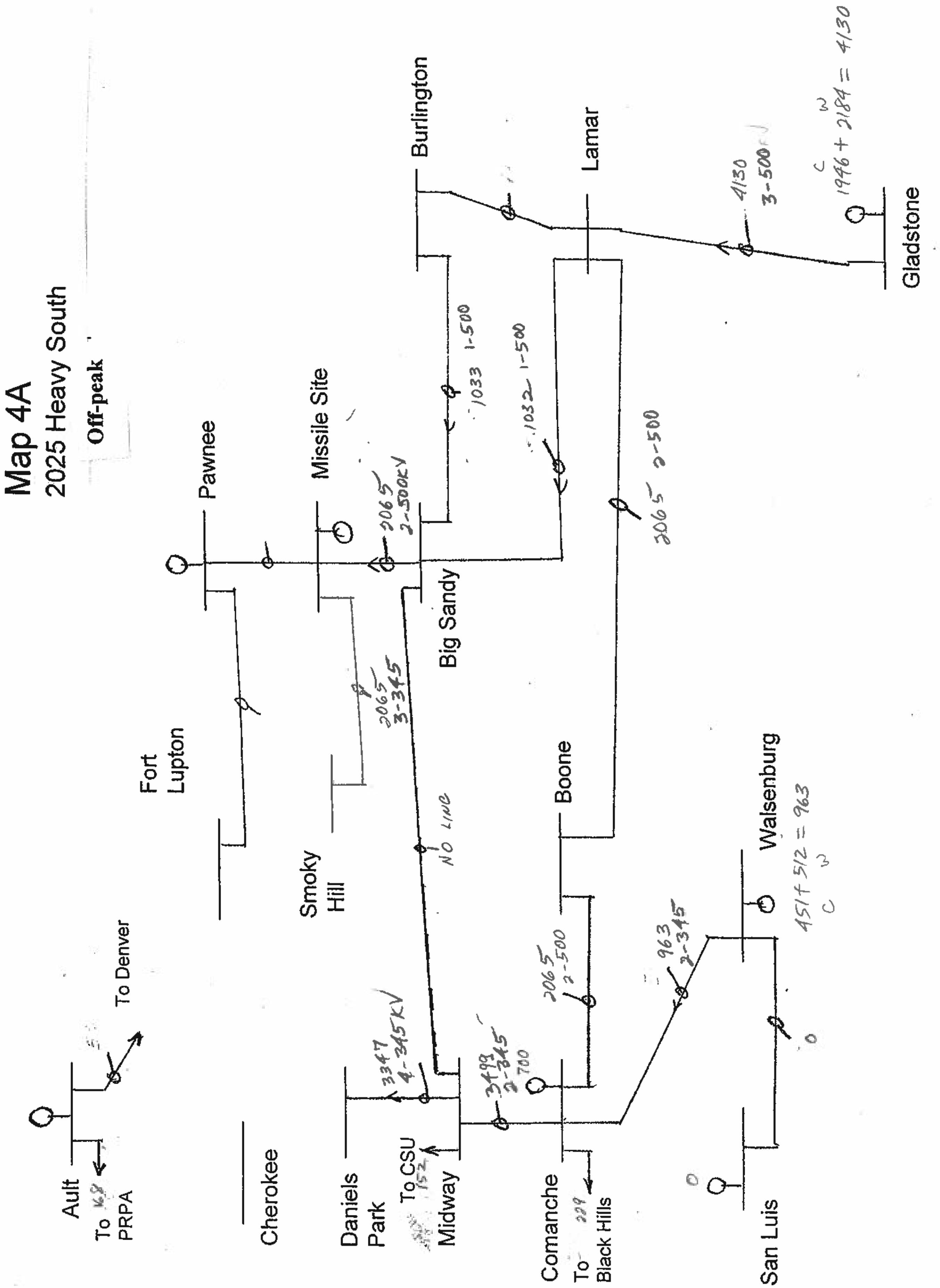
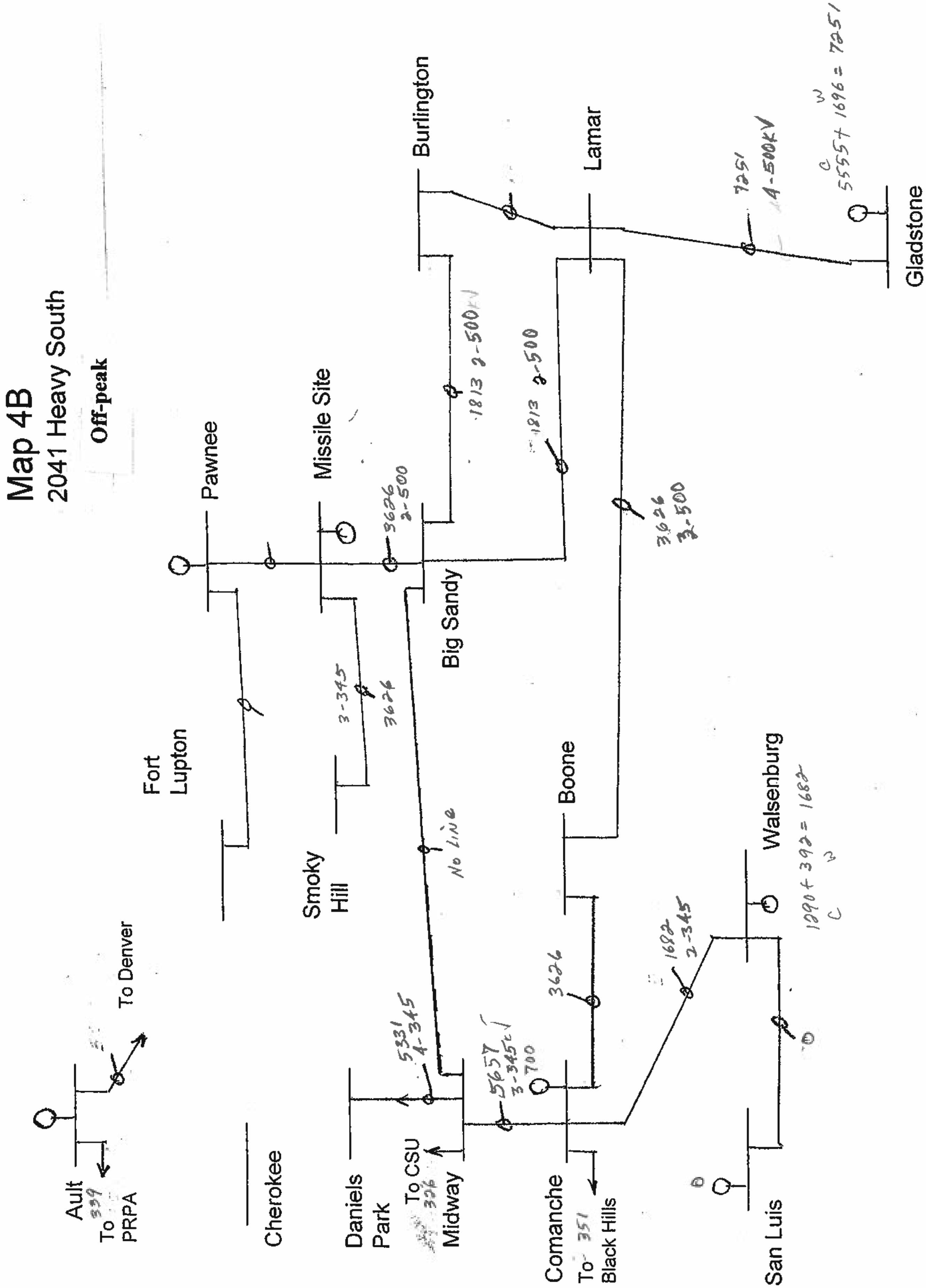

Map 2A
2025 balanced
Off-peak
Ault
To PRPA
To Denver
Cherokee
Fort Lupton
Pawnee
Smoky Hill
Missile Site
Big Sandy
Burlington
Lamar
Gladstone
Daniels Park
To CSU
Midway
Boone
Comanche
To Black Hills
Walsenburg
San Luis
408 + 365 = 773
605
2-230/345
773
944 + 833 = 1777
1191
3691
571
1-345
2-345
1141
2282
2-500kV
1205 + 1077 = 2282
1989
3-345
2141
1-345
529
2-230/345
288 + 241 = 529


Map 2B
2041 balanced
Off-peak
Burlington
Lamar
Gladstone
Pawnee
Missile Site
Big Sandy
Fort Lupton
Smoky Hill
Boone
Walsenburg
Ault
To PRPA
To Denver
Cherokee
Daniels Park
To CSU
Midway
Comanche
To Black Hills
San Luis
1085 1-500
1085 1-500 KV
2171 3-500 KV
4341 3-500 KV
3029 + 1312 = 4341
1037 + 444 = 1471
1471 2-345
2343 + 1032 = 3375
2171 3-500 KV
4-345 KV w/3-1272
7013
No line
2171 2-500
980 2-345
684 + 296 = 980
3174 4-345
3500 3-345 KV 700
1142 3-345 KV


Map 3A
2025 Heavy North
Off-Peak
Burlington
Lamar
Gladstone
Pawnee
Missile Site
Big Sandy
Fort Lupton
Smoky Hill
Boone
Walsenburg
Ault
To PRPA
To Denver
Cherokee
Daniels Park
Midway
To CSU
Comanche
To Black Hills
San Luis
821 + 884 = 1705
1705
2-345
1850 + 2000 = 3850
191
2-230
5364
2-230 kV
1537
2-345


Map 3B
2041 Heavy North
Off-peak
Pawnee
Missile Site
Burlington
Lamar
Gladstone
Fort Lupton
Big Sandy
Smoky Hill
Boone
Walsenburg
Ault
To PRPA
To Denver
Cherokee
Daniels Park
To CSU
Midway
Comanche
To Black Hills
San Luis
3463
2689
= 3463
= 2689
- adjusted to meet minimum generation


Map 4A
2025 Heavy South
Off-peak
Ault
To PRPA
To Denver
Cherokee
Daniels Park
To CSU
Midway
Comanche
To Black Hills
San Luis
Fort Lupton
Smoky Hill
Pawnee
Missile Site
Big Sandy
Boone
Walsenburg
Burlington
Lamar
Gladstone
3347
4-345KV
3499
2-345
700
2065
2-500
963
2-345
451 + 512 = 963
NO LINE
2065
3-345
2065
2-500KV
1033
1-500
1032
1-500
2065
2-500
4130
3-500
1946 + 2184 = 4130


Map 4B
2041 Heavy South
Off-peak
Ault
To PRPA
To Denver
Cherokee
Fort Lupton
Pawnee
Daniels Park
To CSU
Midway
Smoky Hill
Missile Site
Big Sandy
No Line
Comanche
To Black Hills
Boone
Burlington
Lamar
Gladstone
Walsenburg
San Luis