



IN THE MATTER OF THE
APPLICATION OF PUBLIC SERVICE
COMPANY OF COLORADO FOR A
CERTIFICATE OF PUBLIC
CONVENIENCE AND NECESSITY FOR
THE MIDWAY - WATERTON 345KV
TRANSMISSION PROJECT

DIRECT TESTIMONY
AND EXHIBITS
OF

DANNY PEARSON

**BEFORE THE PUBLIC UTILITIES COMMISSION
OF THE STATE OF COLORADO**

IN THE MATTER OF THE APPLICATION OF	)	
PUBLIC SERVICE COMPANY OF	)	
COLORADO FOR A CERTIFICATE OF	)	
PUBLIC CONVENIENCE AND NECESSITY	)	DOCKET NO.
FOR MIDWAY – WATERTON 345 KV	)	
TRANSMISSION PROJECT	)	

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DANNY PEARSON**

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DANNY PEARSON**

I. INTRODUCTION AND STATEMENT OF PURPOSE

1 **Q. PLEASE STATE YOUR NAME AND BUSINESS ADDRESS.**

2 A. My name is Danny Pearson. My business address is 550 15th Street,
3 Denver, Colorado 80202.

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

5 A. I am employed by Xcel Energy Services Inc., the service company subsidiary
6 of Xcel Energy Inc., the parent of Public Service Company of Colorado. My
7 title is Principal Transmission Design Engineer, Transmission Engineering.

8 **Q. ON WHOSE BEHALF ARE YOU TESTIFYING IN THIS DOCKET?**

9 A. I am testifying on behalf of Public Service Company of Colorado ("Public
10 Service" or the "Company").

11 **Q. HAVE YOU PREPARED A STATEMENT OF YOUR EXPERIENCE AND**
12 **QUALIFICATIONS?**

13 A. Yes. That statement is included as Attachment A.

1 planning objective is to electrically connect the Midway Substation to the
2 Waterton Substation. The testimony of Company witness, Thomas Green,
3 describes the system need for this Project in greater detail. This Project
4 proposes a 345kV capable transmission line and structures spanning the
5 approximately 82 miles from the Midway Substation to Waterton Substation.
6 The Project uses the existing Front Range transmission corridor between
7 Public Service's Midway Substation and the Daniels Park Substation and
8 proposes to rebuild existing transmission facilities in the Daniels Park to
9 Waterton transmission corridor.

10 **Q. PLEASE DESCRIBE THE PROPOSED TRANSMISSION LINE DESIGN**
11 **FOR THE MIDWAY – WATERTON PROJECT.**

12 A. This Project will consist of two segments; 1) Midway – Daniels Park
13 (“Southern Section”)² and 2) Daniels Park – Waterton (“Northern Section” or
14 “Daniels Park – Waterton”). As indicated above, the Commission previously
15 approved the design for the Southern Section in Docket No. 05A-072E.

16 Again, my testimony from this point on will focus on the Northern
17 Section of the Project. The Northern Section of the Project between Daniels
18 Park Substation and Waterton Substation involves rebuilding an existing
19 single circuit 230kV transmission line to a double circuit 345kV capable
20 transmission line with the operation of one circuit at 345kV and the operation
21 of the other at 230kV. The conductor will be placed in a vertical, two

² This 345kV capable transmission circuit will bypass the Daniels Park Substation and connect directly to one of the rebuilt Northern Section's 345kV capable circuits terminating at Waterton Substation.

1 conductor, bundled configuration. The support structure will be self-
2 weathering steel similar in color to wood poles. Support structures will be
3 single pole, about 120-150 feet height, on average as shown in Exhibit No.
4 DJP-1B. Where feasible, the structures will be placed near adjacent
5 structures, to avoid a "picket fence" appearance. The line will use low corona
6 hardware to minimize audible noise. Overall, Public Service engineers
7 attempted to choose a structural style and configuration that balances
8 electrical, structural and aesthetic considerations.

9 **Q. WHAT CONSIDERATIONS GUIDED PUBLIC SERVICE'S DESIGN OF THE**
10 **DANIELS PARK TO WATERTON TRANSMISSION LINE?**

11 A. The determination of the transmission line style, configuration and height is a
12 difficult balancing issue. Design engineers must consider the aesthetics, the
13 structural capacity, the electrical requirements, prudent avoidance of EMF,
14 mitigation of audible noise, and economics. Public Service attempted to
15 strike a reasonable balance among these issues.

16 **Q. WHY DID PUBLIC SERVICE CHOOSE STEEL AS THE MATERIAL FOR**
17 **THE SUPPORT STRUCTURES THAT ARE TO BE REBUILT IN THE**
18 **NORTHERN SECTION?**

19 A. Steel was chosen for its structural capability. Wood is an inadequate material
20 choice for a double-circuit line at 345kV spacing dimensions and with two
21 wires per phase. Wood structures would have to be spaced much closer
22 together in order to carry the weight of the wires. If Public Service were
23 required to use wood poles for the Northern Section, significantly more poles

would be required than if the structures are steel - possibly even twice the number of poles would be needed.

Q. PLEASE DISCUSS THE CONFIGURATION OR STYLE AND HEIGHT OF THE STRUCTURES?

A. Exhibit No. DJP-1A shows the style of the structures as currently configured in the Northern Section of the corridor, and Exhibit No. DJP-1B shows the structures in the Northern Section after the completion of this project.

Public Service has proposed a structure style and height that strikes a reasonable balance among several factors. For many years the majority of all 345kV transmission lines were constructed on "lattice" towers. Public Service ruled out using lattice towers on this right-of-way because of their larger footprints and large visual appearance. Due to the right-of-way configuration on the Daniels Park – Waterton section of this Project, Public Service will utilize a standard construction style on steel poles, with three sets of phase wires stacked in a vertical configuration on each side of the pole, as depicted in my Exhibit No. DJP-1B. Typical structures for this Project should be 120-150 feet tall.

Q. WHAT FACTORS DETERMINE INDIVIDUAL POLE HEIGHTS?

A. Individual pole heights are determined by the terrain, span length, and sag of the adjacent wire and the minimum clearances prescribed in the National Electric Safety Code. Public Service uses a "buffer" above minimum clearances to ensure continued safe operations. The buffer is usually about 3-5 feet. The support structures will be higher than the average where the

1 line crosses other electric lines or highly traveled roads. Some structures,
2 particularly those crossing over other electrical circuits, may need to be over
3 170 feet tall, but the taller towers are the exception and not the norm for this
4 project.

5 **Q. HOW WILL THE STRUCTURES FOR THE PROJECT BE SPACED?**

6 A. Because the Northern Section of the line from Daniels Park - Waterton
7 replaces an existing line, the choice for structure spacing for this Project is to
8 place the new structures in a similar location to where they were before the
9 rebuild. The new structures will be generally located adjacent to any parallel
10 line structures. If the new structures were placed at different intervals, such
11 as at mid-span to the other line, it could give a "picket fence" appearance.

12 **Q. WHAT CONSIDERATIONS INFLUENCED THE CHOICE OF SELF-WEATHERING STEEL AS THE COLOR FOR THE STRUCTURES?**

14 A. Public Service chose self-weathering steel to minimize the metallic
15 appearance of the poles. This steel has a maintenance-free, earth tone color
16 that is similar to wood poles. It starts as a lighter orange-brown and changes
17 to a dark brown over time. Colors are a personal preference and a highly
18 debatable issue. Public Service finds that the self-weathering brown poles
19 appear to be generally preferred over an industrial gray galvanized finish.
20 Public Service rejected the idea of using a painted finish because paint
21 systems wear through over time and become unsightly until they are
22 repainted, which is an additional expense. The maintenance-free, earth tone
23 color provides the least objectionable color.

1 quality, handling and packaging, construction techniques, conductor tensions
2 and design alternatives considering the spatial arrangement of phasing of
3 conductors.

4 **Q. PLEASE DESCRIBE WHAT PUBLIC SERVICE HAS DONE TO MEET THE**
5 **REQUIREMENTS OF RULE 3102(c)?**

6 A. Since the primary purpose of the Project is to gain additional transmission line
7 capacity from southern Colorado to the Denver metro area, the first decision
8 is the electrical conductor. Public Service has designed the Daniels Park to
9 Waterton rebuild using 2-1272 Kcmil ACSR "Bittern" conductor. This
10 conductor was chosen based on the increased capacity it created between
11 Daniels Park and Waterton which is consistent with long-range studies that
12 show such additional capacity is warranted. Designing the double circuits
13 between Daniels Park and Waterton using the 2-1272 Kcmil ACSR "Bittern"
14 conductor also reduces noise which supports Public Service's objective to
15 balance a number of issues such as audible noise, EMF and economics.
16 Public Service believes choosing 2-1272 Kcmil conductor is a prudent and
17 sound approach for this corridor. Public Service chose to use "non-specular"
18 wire, which reduces reflection, and adds to the aesthetics at a small
19 incremental cost. The Project will employ a standard bundled conductor
20 configuration with corona free hardware that has been used on several other
21 projects. A bundled configuration refers to the use of two wires per phase, in
22 a vertical configuration. The two wires per phase configuration has the
23 benefit of increased capacity while at the same time reducing the audible

1 noise that would occur with only one wire per phase. An alternative choice
2 would be to use only one larger conductor per phase. Public Service rejected
3 the single large conductor because it would provide less capacity and would
4 emit greater audible noise.

5 Industry recognized prudent techniques will be used, which
6 significantly reduce the effects of corona and thus corona-generated audible
7 noise. The phases will be spaced adequately apart so as not to create an
8 excessive voltage gradient, which, if not taken into account, would generate
9 constant and excessive corona. Attachment hardware of a corona-free
10 nature will be specified and procured. Conductor of high quality will be
11 specified and procured.

12 The conductor will be handled and packaged properly so as not to
13 damage it. The construction crews will use great care; they will have well
14 maintained equipment and use proper construction techniques so as not to
15 damage the conductor. Damaged conductor can emit corona and thus emits
16 higher sound levels than undamaged conductor. Proper line tensions will be
17 applied so as not to create loose conductor, as with damaged conductor,
18 loose conductor emits higher sound levels than conductor of proper tension.
19 By using these prudent techniques the transmission line will operate as
20 quietly as possible given the voltage and location. All of these requirements
21 are included in our Construction Specifications, which follows IEEE standard
22 534, IEEE Guide to the Installation of Overhead Transmission Line
23 conductors.

1 I should emphasize that there is no overhead construction technique
2 that Public Service can employ to prevent the transmission line from
3 becoming wet and, during wet periods, from emitting audible noise at levels
4 substantially higher than fair weather levels. Fortunately, in Colorado, the wet
5 weather periods are relatively short-lived.

6 IV. AUDIBLE NOISE

7 **Q. DID YOU PREPARE AN EXHIBIT TO ILLUSTRATE THE AUDIBLE NOISE**
8 **EXPECTED TO BE GENERATED FROM THE TRANSMISSION LINE?**

9 A. Yes. Exhibit No. DJP-2a and 2b illustrate the expected audible noise
10 generated from the Midway - Waterton Project, specifically the Daniels Park
11 to Waterton section of the Project, by using a sound-modeling program.

12 **A. BPA / EPRI Noise Model**

13 **Q. WHAT METHOD DID YOU USE FOR DEVELOPING EXHIBIT NO. DJP-2?**

14 A. I used a sound-modeling program developed by the Bonneville Power
15 Administration ("BPA") and the Electric Power Research Institute ("EPRI").

16 **Q. PLEASE ADDRESS THE ACCURACY OF THE TRANSMISSION LINE**
17 **MODELING PROGRAM THAT YOU USED.**

18 A. The audible noise modeling program used by Public Service are empirical
19 models that were developed using field-testing as the basis of origin. Sound
20 modeling is an inexact science, but it does provide good insight or predictions
21 on what corona-generated audible noise activity will likely occur. BPA and
22 EPRI did thousands of field measurements of transmission power lines. They

1 then plotted the graphs from those field results and developed equations,
2 algorithms and modeling, which consider the input variables from the field
3 tests. These audible noise modeling programs allow Public Service to predict
4 the audible noise that will be generated from a proposed project by inputting
5 variables such as the conductor and static wire dimensions and spacing, the
6 overall geometry of the project, the elevation of the project, the operating
7 voltage, and the rain rate. The models are statistically based and provide
8 output figures, which are the expected average audible noise levels. Public
9 Service used the same modeling algorithm in the Midway - Daniels Park
10 Rebuild Project, PUC Docket No. 03A-276E and the Comanche – Daniels
11 Park Transmission Project, PUC Docket No. 05A-072E, that I used in
12 developing Exhibit No. DJP-2.

13 **Q. PLEASE PROVIDE A PRACTICAL COMPARISON FOR THE dB(A)**
14 **SCALE.**

15 A. The following is a reference chart provided in the EPRI Transmission Line
16 Reference Book – 345kV and Above. This chart provides a reasonable and
17 useable guide to how people experience sound at various decibel levels:

18 130-140 – Threshold of Pain

19 120-130 – Pneumatic chipper

20 110-120 – Loud audible horn (1 mi. distance)

21 100-110 – (no example)

22 90-100 – inside subway (New York)

23 80-90 – Inside motorbus

- 1 70-80 – Average traffic on street corner
- 2 60-70 – Conversational speech
- 3 50-60 – Typical business office
- 4 40-50 – Living room, suburban area
- 5 30-40 – Library
- 6 20-30 – Bedroom at night
- 7 10-20 – Broadcasting studio
- 8 0-10 – Threshold of hearing

9 **Q. IN YOUR OPINION, IS THE SOUND MODELING CALCULATION THAT**
10 **YOU HAVE PROVIDED ACCURATE?**

11 A. Yes. The sound modeling that I have presented is based upon thousands of
12 field readings in many states and has specific inputs for altitude. The models
13 provide accurate projections of the average level of audible noise expected to
14 emanate from the Project. After developing the model algorithms, BPA and
15 EPRI tested the model results against field readings; the results are reported
16 in what is known to transmission engineers as the “Red Book”, the EPRI
17 Transmission Line Reference Book – 345kV and Above. In reviewing this
18 report, I find that modeling versus field verification is usually plus or minus 2
19 to 3 dB(A).

20 **Q. ARE YOU FAMILIAR WITH THE ELEMENTS OR ASSUMPTIONS THAT**
21 **ARE USED IN THE SOUND MODELING PROGRAM DEPICTED IN YOUR**
22 **GRAPH?**

23 A. I am.

1 **Q. PLEASE DESCRIBE THOSE ELEMENTS OR ASSUMPTIONS.**

2 A. The following elements were considered in the sound modeling of Public
3 Service's proposed Project: a) the ENVIRO program calculating the
4 Bonneville Power algorithm was used, a recognized software program in the
5 utility industry typically used for sound analyses; b) readings were predicted
6 for mid-span locations, at conductor low points, without the influence of the
7 transmission structures; c) assumed elevation was 6500 feet between Daniels
8 Park and Waterton; d) the operating voltages are shown on the exhibits; e)
9 "wet" or "rain" signifies when water droplets were formed on the line, the L50
10 curve is represented (a common statistical indicator); f) audible noise
11 reflection from the ground or other objects is not known (for example,
12 concrete amplifies sound by reflecting sound waves, whereas dirt or grass
13 conditions absorb sound waves or dampen audible noise); g) a "burn in"
14 period exists for a few months after new construction and the model predicts
15 audible noise after the "burn-in" period.

16 **Q. WHAT PHENOMENA PRODUCE AUDIBLE NOISE ON HIGH VOLTAGE**
17 **TRANSMISSION LINES?**

18 A. Several factors produce audible noise on high voltage transmission lines.
19 The higher the voltage on the transmission circuit, the greater the corona
20 activity on the line. Corona is what creates the hissing, crackling or random
21 popping sound. Corona is a small electrical discharge, not unlike the static
22 electrical charge that a person may experience when touching a metal object
23 when walking on carpeting. Corona increases substantially in wet weather,

1 when water droplets form on a transmission line. All high voltage
2 transmission lines experience significant corona during wet weather. In
3 normal, fair weather conditions, corona and its corresponding audible noise
4 are usually at low levels.

5 **Q. WHAT OTHER CONDITIONS AFFECT THE AUDIBLE NOISE LEVEL?**

6 A. Corona activity is substantially increased at higher altitudes because of the
7 corresponding decrease in air density. A rough rule of thumb is that corona-
8 generated audible noise increases by about 1 dB(A) for every 1000 feet in
9 elevation gain. A transmission line constructed in the Colorado Front Range
10 area will have corona noise about 6 dB(A) higher than a similarly constructed
11 line at sea level.

12 The second source of audible noise on a transmission line is a 120 Hz
13 synchronous hum created by systems operating at 60 Hz. This 120 Hz hum
14 is generally of little consequence, but it can be a contributor to audible noise.
15 The audible noise generated by corona causes most concerns.

16 **Q. WHAT ARE THE PROJECTED AUDIBLE NOISE LEVELS ASSOCIATED**
17 **WITH THIS PROJECT?**

18 A. Exhibit No. DJP-2a & 2b sets forth Public Service's projections as to the
19 audible noise that will be expected from the Daniels Park – Waterton Project
20 under both fair and wet/rainy weather conditions. When there is moisture on
21 the line, whether due to rain, snow or fog, the audible noise-modeling
22 program predicts that the audible noise levels can be as high as 25 dB(A)
23 higher than under fair weather conditions, until the line dries. Over 100

different options were modeled to come up with the four cases I am submitting here.

Q. PLEASE DESCRIBE THE PROCESS YOU USED TO COME UP WITH THE 100 DIFFERENT OPTIONS YOU MODELED FOR THIS PROJECT?

A. The existing corridor between Daniels Park and Waterton Substations has a double circuit 230kV capable transmission line and a single circuit 230kV transmission line, see Exhibit No. DJP-1A. First, we modeled the existing lines to come up with current EMF and audible noise values to base our new modeling upon (all circuits at 230kV with existing phasing). The proposed configuration for this corridor is to replace the single circuit 230kV transmission line with a double circuit 345kV capable transmission line and leave the existing double circuit 230kV transmission line, see Exhibit No. DJP-1B.

The phasing arrangement for the lines was the basis for a majority of the different options considered. Step 1) With the phasing for the existing lines held constant, every combination of phasing for the new double circuit line was run. Step 2) The phasing on one of the circuits on the existing line was reversed, and the different combinations of phasing for the new line was run again. The runs made in Steps 1 & 2 established all the EMF values for this project. Using Steps 1 & 2 as the basis, we then changed other variables that have an effect on audible noise. Some of the variables that have an effect on audible noise but do not change the EMF values are: A) Vertical bundle spacers with 18" or 12" spacing (18" is our standard). B) Conductor

1 diameter or different types and number of conductors (2 conductor bundle of
2 954 kcmil ACSR "Cardinal", 2 conductor bundle of 1272 kcmil ACSR "Bittern"
3 and a 3 conductor bundle of 636 kcmil ACSR "Grosbeak").

4 **Q. WHAT PROCEDURE DID YOU UTILIZE TO REDUCE THE 100 DIFFERENT**
5 **OPTIONS YOU MODELED FOR THIS PROJECT DOWN TO THE FOUR**
6 **CASES YOUR ARE PRESENTING WITH YOUR TESTIMONY?**

7 A. After all the runs were completed, the audible noise and the EMF data was
8 entered into a spreadsheet and saved as two different files (one was titled
9 "EMF" the other as "AN" (audible noise)). Each data file was then sorted
10 several different ways. For the "EMF" file, the data was sorted, with the
11 primary sort being on EMF values and the secondary sort being for audible
12 noise values. The 100 different cases were then reduced to approximately 15
13 different cases based upon the lowest EMF values.

14 The same process for the "AN" file was followed, with the audible noise
15 values being the primary sort and the EMF values being the secondary sort.
16 The 100 different cases were then reduced to approximately 15 different
17 cases based upon the lowest audible noise values (55 dB(A) or less).

18 These 30 cases were then reviewed to see if any of the 15 EMF cases
19 matched any of the 15 AN cases, there were no common cases. All of our
20 criteria for audible noise was to have 55 dB(A) or less at the edge of the right-
21 of-way. Reconsidering this criteria, we determined that for a reasonable
22 additional cost we could increase the capacity of the transmission facilities
23 between Daniels Park and Waterton Substations consistent with the long-

1 range planning objectives, reduce the audible noise to close to 50 dB(A) or
2 less at each edge of the right-of-way, and achieve reasonable EMF levels, by
3 using one of our standard, larger diameter bundle conductors.

4 The 30 different cases were then reduced to the 4 Cases below. I am
5 presenting 2 Cases with 954 kcmil ACSR "Cardinal" conductor and 2 Cases
6 with the larger diameter 1272 kcmil ACSR "Bittern" conductor.

7 **Q. PLEASE EXPLAIN THE INFORMATION THAT IS SET FORTH ON YOUR**
8 **EXHIBIT No. DJP-2.**

9 A. Exhibits No. DJP-2a & 2b, show the audible noise modeling associated with
10 the segment between Daniels Park and Waterton. Exhibit No. DJP-2a
11 predicts the L5 average audible noise levels in fair weather and Exhibit No.
12 DJP-2b predicts the average L50 audible noise levels when the lines are wet.
13 The wet/rainy weather models assume that the line is saturated with moisture,
14 and therefore predict the average worst-case scenario. As lines begin to dry,
15 from the heat of the current, from the sun and wind, audible noise levels will
16 decrease from the model predictions.

17 We have included four Cases (1, 2, 3, and 4) in Exhibit No. DJP-2.
18 The Company believes these four Cases give the most reasonable balance
19 between audible noise, EMF (magnetic fields) and costs. Public Service is
20 recommending we construct the Daniels Park – Waterton double circuit
21 transmission line utilizing Case 4.

22 **Q. PLEASE EXPLAIN THE VERTICAL DOTTED LINES ON EXHIBIT NO. DJP-**
23 **2.**

1 A. The vertical dotted lines are the edge of Public Service's right-of-way,
2 applying the conservative assumption that all of the right-of-way in the
3 Daniels Park to Waterton corridor is 210 feet. I show the edge of the right-of-
4 way because this is the location that the Commission rules specify is to be
5 used to measure audible noise limits for transmission lines.

6 **Q. WHAT IS THE LEGAL STANDARD THAT APPLIES TO THIS PROJECT?**

7 A. The Colorado State law, C.R.S. § 25-12-103 (12), provides that the
8 Commission can determine whether the projected audible noise levels for
9 electric transmission lines are reasonable when reviewing applications for
10 certificates of public convenience and necessity, without regard to the audible
11 noise levels otherwise set forth in the state statute.

12 **Q. HOW CAN THE COMMISSION DETERMINE WHETHER THE PROJECTED**
13 **AUDIBLE NOISE LEVELS OF THE PROJECT ARE REASONABLE?**

14 A. Colorado Revised Statutes §25-12-103 sets forth audible noise levels for
15 various "zones" that the General Assembly found acceptable for uses other
16 than electric transmission lines. They are as follows (measured from 25 feet
17 or more from the property line of the audible noise generator):

Zone	7:00 a.m. to next 7:00 p.m.	7:00 p.m. to next 7:00 a.m.
Residential	55 dB(A)	50 dB(A)
Commercial	60 dB(A)	55 dB(A)
Light Industrial	70 dB(A)	65 dB(A)

Industrial	80 dB(A)	75 dB(A)
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1
2 However, in passing this new law, the General Assembly stated that it was a
3 matter of statewide interest and concern that the State of Colorado have an
4 adequate, reliable, and cost-effective electricity infrastructure to serve the
5 needs of the people of Colorado for their homes, businesses and industries.
6 The general assembly found that electric transmission facilities are linear and
7 may pass through several local jurisdictions and zoning districts. So, the
8 General Assembly left it up to the Commission to determine whether the
9 predicted audible noise levels from proposed transmission facilities were
10 reasonable.

11 As I mentioned earlier, Public Service is proposing Case 4. As can be
12 seen in Exhibit No. DJP-2a, when the line is not wet, the predicted audible
13 noise levels are well below the most stringent limits set for residential zone
14 use. When the lines are saturated with moisture, as seen in Exhibit No. DJP-
15 2b, the lines will temporarily be noisier than the most stringent limits set for
16 residential zone use, but the audible noise will diminish as the line dries. The
17 saturated line case shows that the noise level of the Northern Section will be
18 on average 49.8 dB(A) on the south edge of the existing right-of-way corridor
19 and will be on average 50.1 dB(A) on the north edge of the existing right-of-
20 way corridor. The predicted audible noise levels on the north side of the
21 corridor are only slightly above the most restrictive zone (50 dB(A)) and will
22 only be temporary until the line dries. It should be noted, in the area where

1 we expect noise levels to be as high as 50.1 dB(A) on average when the line
2 is saturated and wet, the right-of-way width is 210 feet. Just west of US
3 Highway 85, there is an additional fifty feet of right-of-way along the north
4 edge and the noise level will drop below 50 dB(A).

5 **Q. IS IT POSSIBLE TO CONSTRUCT THE NORTHERN PORTION OF THE**
6 **PROJECT TO DECREASE THE AUDIBLE NOISE AT ALL LOCATIONS SO**
7 **THAT IT IS PREDICTED TO BE 50 dB(A) OR LESS EVEN WHEN WET?**

8 A. Yes. Audible noise can be slightly reduced by arranging the phasing to meet
9 the 50 dB(A), however such a configuration results in significantly higher EMF
10 (magnetic fields levels). Public Service believes taking measures to mitigate
11 0.1 dB(A) is not in the public interest and thus the Company recommends
12 Case 4.

13 **V. ELECTROMAGNETIC FIELD MITIGATION**

14 **Q. CAN YOU DESCRIBE THE REQUIREMENTS OF SECTION 4 CCR 723-**
15 **3102 (d) OF THE CODE OF COLORADO REGULATIONS?**

16 A. Yes. When applying for a CPCN, Rule 3102(d) of the Commission's Rules
17 Governing Electric Utilities requires a utility to describe the actions and
18 techniques applied when they were planning, siting, constructing and
19 operating the line, relating to prudent avoidance of EMF.

20 **A. Prudent Avoidance**

21 **Q. WHAT IS PRUDENT AVOIDANCE?**

1 A. Prudent Avoidance: “means the striking of a reasonable balance between the
2 potential health effects of exposure to magnetic fields and the cost and
3 impacts of mitigation of such exposure, by taking steps to reduce the
4 exposure at reasonable of modest cost. “ Rule 3102(d).

5 **Q. PLEASE DESCRIBE WHAT PUBLIC SERVICE HAS DONE TO MEET THE**
6 **REQUIREMENTS OF SECTION 3102(d) OF THE CODE OF COLORADO**
7 **REGULATIONS?**

8 A. Public Service has been using “prudent avoidance” concepts for many years.
9 Of course, not all of the prudent avoidance concepts listed in Section 3102(d)
10 can be implemented on every project because it is not cost effective to do so.
11 On many transmission projects only one or two of the techniques can be
12 reasonably applied.

13 In this case Public Service proposes to use two basic avoidance
14 techniques. First, Public Service has studied and will use the technique of
15 reverse phasing (referenced in the Commission rule as “design alternatives
16 considering the arrangement of phasing of conductors”). The reverse
17 phasing application will reduce the EMF created by the Project.

18 The second minimization avoidance technique Public Service can
19 reasonably employ for the Project is the use of higher structures. The
20 structures that we will use are about five feet higher than the minimums
21 required for ground clearance by the National Electric Safety Code. This
22 small height increase will provide an additional EMF reduction along with
23 increased safety clearances.

1 For the Northern Section of the Project between Daniels Park and
2 Waterton Substations, Public Service plans to use its existing right-of-way to
3 upgrade the existing 230kV single circuit transmission line to a double circuit
4 345kV capable transmission line. As such, the prudent avoidance measures
5 that would be used in acquiring new right-of-way are not applicable. On this
6 section of the Project, the populated areas grew up around the existing
7 transmission corridor. The Daniels Park - Waterton corridor is 210 feet in
8 width from Daniels Park to a point just west of US Highway 85 and then it is
9 260 feet in width from that point to the Waterton Substation. This width is
10 more than sufficient to support the lines and to keep EMF and audible noise
11 within reasonable levels. Additional widening of the right-of-way could require
12 the condemnation of property, which would be very expensive and unpopular,
13 and is not recommended by Public Service.

14 Burial of the line, which is listed as an avoidance technique in Section
15 3102(d) is also not available at reasonable or modest cost.

16 Constructing transmission lines underground is often perceived as a
17 way to accomplish the electrical objectives of a transmission project while
18 minimizing environmental impacts. However, undergrounding entails
19 significant costs as well as significant environmental and technological
20 impacts associated with burying the transmission line. It should also be noted
21 that underground transmission lines do not eliminate EMF; the lines simply
22 have a different EMF profile that is more concentrated. When looking at an
23 EMF cross-section profile of an overhead transmission line, it is generally a

1 bell-shaped curve with low value tails that dissipate with distance. The EMF
2 cross-section profile for an underground line is shaped like a sharp spike and
3 the tails dissipate much quicker on the sides. This means the EMF field
4 associated with underground transmission is elevated and concentrated in a
5 much tighter band.

6 **B. Underground Versus Overhead Transmission Lines**

7 **Q. WHAT CHALLENGES ARE PRESENTED BY UNDERGROUNDING A** 8 **TRANSMISSION LINE?**

9 A. Placing a high voltage transmission line underground requires electrically
10 insulating each of the three phases (wires) and dissipating the heat generated
11 by the wires. Public Service generally uses underground construction only
12 with low voltage distribution lines that operate at 25kV or less. At these
13 relatively low voltages, the problems of electrically insulating each wire and
14 dissipating the heat generated by the wires is not a concern. With lines of
15 greater voltage, such as those associated with the Northern Section of the
16 Project, material costs, construction costs and the heating of the wire all
17 become a greater concern.

18 Public Service has buried short lengths of 230kV and 115kV
19 transmission lines in other parts of its service territory when required by
20 technical constraints or paid for by those requesting burial. Public Service
21 has not constructed underground transmission lines in rural areas, nor has

1 the Company constructed any transmission line underground for the distance
2 required by this Project.

3 **Q. HOW DO THE COST AND RELIABILITY OF UNDERGROUND**
4 **TRANSMISSION LINES COMPARE TO OVERHEAD LINES?**

5 A. Historically, the cost of constructing a high voltage line underground can be
6 up to ten times as expensive as overhead construction. When planning to
7 construct high voltage, underground transmission lines in rolling hills and
8 rugged terrain, such as exists along the transmission path for the Northern
9 Section of this Project, the engineering and technical challenges may
10 increase the cost to more than ten times that of overhead construction.
11 Public Service only considers underground construction if the difference in
12 cost between overhead construction and underground construction is paid for
13 by those requesting it or if technical constraints make it impossible to
14 construct the line overhead. Out of a total of over 3,000 miles of transmission
15 lines, Public Service has only about 40 miles of transmission lines
16 constructed underground, most of which are in high load and density areas
17 and in and around airports.

18 The reliability of overhead and underground transmission lines is
19 generally comparable. While underground lines are immune to the effects of
20 weather, this type of facility is susceptible to damage from geologic or subsoil
21 instabilities, as well as inadvertent damage resulting from excavations.
22 Underground lines also present challenges during outages. Faults occurring
23 in underground installations are typically more difficult to locate and repair

1 than on overhead lines. The increased difficulty and duration for repairs
2 cause significantly longer power outages than with overhead power lines.
3 Repair of solid dielectric cables or high-pressure fluid-filled conduits would
4 require pulling in a new section of cable and splicing it into the existing cable
5 at two vaults. Such a repair would take weeks or months. In contrast,
6 overhead line outages can often be repaired within hours, because any
7 damage is readily visible and accessible.

8 **Q. WHAT OTHER CONSIDERATIONS LED PUBLIC SERVICE TO REJECT**
9 **UNDERGROUNDING THIS PROJECT?**

10 A. The impacts of underground transmission lines on soils, surface water,
11 vegetation and wildlife resources are usually greater than those of a similarly
12 located overhead line. This is because any underground technology used
13 would require a continuous trench 4 feet wide by 5 or more feet deep with
14 intermediate vaults 7 feet wide by 20 feet long every 2,000 to 3,000 feet.
15 Additional tree and vegetation cutting within the right-of-way would be
16 required to facilitate construction and overland travel of equipment.
17 Additionally, all rivers, streams and wetland areas must be crossed with
18 equipment and a trench excavated through them to required specifications.

19 In summary, the risks to reliability, environmental impacts, and
20 associated costs outweigh the advantages of burying lines. Burial of
21 transmission lines is considered an acceptable alternative only in areas where
22 overhead right-of-way is not available or where a landowner or developer

1 pays for burial, a second reliable source of transmission exists, and it is
2 technically feasible.

3 **C. Projected EMF Levels**

4 **Q. WHAT ARE THE EMF LEVELS ASSOCIATED WITH THE PROJECT?**

5 A. The EMF curves shown in Exhibit No. DJP-3 provide an accurate
6 representation, using the preliminary design of what can be expected during
7 daily peaks in the near future. The load used to calculate the transmission
8 line magnetic fields is developed from projected system normal peak
9 conditions. Higher currents could occur under certain system operating
10 conditions, however the vast majority of time that the Midway – Waterton
11 project operations will be at steady state.

12 **Q. PLEASE DESCRIBE WHAT YOU HAVE DEPICTED ON EXHIBIT No. DJP-**
13 **3.**

14 A. Exhibit No. DJP-3 shows the EMF model results for the same four Cases as
15 were presented for audible noise. The EMF from the existing facilities is
16 shown by the thick solid blue lines on each graph. The vertical dotted lines
17 show the edge of Public Service's right-of-way. As I stated previously, over
18 100 different options were modeled to come up with the four Cases I am
19 presenting here.

20 The Project proposed by Public Service is shown in EMF Case 4.
21 EMF levels will be slightly higher than the levels that exist today on this
22 corridor, as shown on Exhibit No. DJP-3.

1 **Q. WHY DID YOU MODEL DIFFERENT CONFIGURATIONS FOR EMF?**

2 A. Public Service examined various configurations for the Daniels Park -
3 Waterton section of the project to determine the configuration that has a
4 reasonable balance for lowering both EMF and audible noise. As explained
5 by other Public Service witnesses, after this Project is constructed, the
6 Daniels Park - Waterton corridor will contain one double circuit 345kV capable
7 facility and one double circuit 230kV capable facility. However, at this time,
8 Public Service needs to operate only one of the two rebuilt circuits at 345kV;
9 the other circuit will be operated, for the time being, at 230kV. In all my
10 cases, I looked at the effects of operating both of the 345kV capable circuits
11 at 345kV. The Project proposed by Public Service's Application is
12 represented as EMF Curve 1 in Case 4.

13 **VI. ALTERNATIVE CHOICES FOR EMF AND NOISE**

14 **Q. PLEASE EXPLAIN THE DIFFERENCES IN CASES 1, 2, 3, AND 4?**

15 A. Yes. Case 1, this is a typical 2 conductor bundle with 954 Kcmil ACSR
16 "Cardinal". This configuration provides an EMF value lower than the existing
17 line. However, this configuration has wet/rainy L50 audible noise levels of
18 54.6 dB(A), on the south edge of right-of-way and 52.8 dB(A) on the north
19 edge of right-of-way.

20 Case 2 is also a typical 2 conductor bundle with 954 Kcmil ACSR
21 "Cardinal". This configuration provides an EMF value slightly more than the
22 values of the existing line. This configuration has wet/rainy L50 audible noise

1 levels of 51.1 dB(A), on the south edge of right-of-way and 50.8 dB(A) on the
2 north edge of right-of-way.

3 Case 3 reflects a typical 2 conductor bundle with 1272 Kcmil ACSR
4 "Bittern". This configuration provides an EMF value more than twice the
5 values of the existing line. This configuration has wet/rainy L50 audible noise
6 levels of 48.9 dB(A), on the south edge of right-of-way and 49.0 dB(A) on the
7 north edge of right-of-way.

8 Case 4 reflects a typical 2 conductor bundle with 1272 Kcmil ACSR
9 "Bittern". This configuration provides an EMF value slightly more than the
10 values of the existing line. This configuration has wet/rainy L50 audible noise
11 levels of 49.8 dB(A), on the south edge of right-of-way and 50.1 dB(A) on the
12 north edge of right-of-way. Public Service is recommending we construct the
13 line utilizing Case 4.

14 By utilizing a bundle of 1272 Kcmil ACSR "Bittern", one of our standard
15 conductors, we expect the differential cost to be between \$600,000 and
16 \$700,00 more than the cost for constructing the line with a bundle of 954
17 Kcmil ACSR "Cardinal" (Note: this is for only the segment between Daniels
18 Park and Waterton). This differential cost would be considerably less than
19 acquiring additional right-of-way in the residential areas along this route. The
20 larger conductor will have no effect on the power flow from Midway and
21 Waterton (due to the Southern section being built with a bundle of 954 Kcmil
22 ACSR "Cardinal"), but will allow for more power flow on the new circuit
23 between Daniels Park and Waterton.

1 **Q. HOW DO THE AUDIBLE NOISE VALUES THAT YOU PRESENT ON YOUR**
2 **EXHIBIT NO. DJP-2 FOR THIS PROJECT COMPARE WITH THE AUDIBLE**
3 **NOISE LEVELS ASSOCIATED WITH OTHER HIGH VOLTAGE LINES ON**
4 **PUBLIC SERVICE SYSTEM?**

5 A. Public Service uses similar techniques as those described here to mitigate
6 audible noise when it constructs all of its high voltage transmission lines.
7 However, as I indicated earlier, audible noise levels from a particular facility
8 are dependent upon numerous factors, such as voltage level, altitude,
9 surrounding structures and ground cover. Therefore, it would not be
10 appropriate to use the measures in my Exhibit No. DJP-2 as the expected
11 audible noise levels from any other line. However, in constructing this
12 Daniels Park to Waterton Project, Public Service is using good utility practice
13 to employ all of the reasonable prudent techniques of which I am aware in an
14 attempt to minimize audible noise impacts.

15 **Q. ARE THERE RISKS ASSOCIATED WITH REBUILDING A LINE IN AN**
16 **EXISTING CORRIDOR, SUCH AS PUBLIC SERVICE IS PLANNING FOR**
17 **THE SEGMENT BETWEEN DANIELS PARK AND WATERTON?**

18 A. Yes. The primary risk involves a construction accident, which would trip out
19 the parallel energized line and could potentially cause a personal injury.
20 However, the construction crews who perform this work are very skilled in
21 working around energized equipment. Due to the limited capacity of existing
22 transmission systems, it is becoming a common practice for contractors to
23 construct a new line next to an existing energized line. Good safety

1 measures are applied and outages are arranged when needed. Other safety
2 precautions, such as grounding the un-energized new line that is being
3 constructed to protect the construction crews from induced current, will be
4 strictly followed

5 **V. RECOMMENDATIONS**

6 **Q. GIVEN ALL YOUR STUDIES, WHY DOES PUBLIC SERVICE BELIEVE**
7 **THAT CASE 4 IS THE MOST REASONABLE DESIGN TO PURSUE?**

8 A. Case 4 has a reasonable balance between EMF, audible noise impacts and
9 costs. The lines are generally very quiet, emitting audible noise far below the
10 most restrictive zone standard unless wet. Without burying the lines, Public
11 Service cannot prevent the lines from becoming wet from time to time. When
12 the lines are wet, the audible noise levels will be temporarily as high or
13 slightly higher than the most restrictive zone.

14 The bundle of 1272 Kcmil ACSR "Bittern" will be slightly higher in cost
15 than building the line with a bundle of 954 Kcmil ACSR "Cardinal", but the
16 larger conductor will allow for an increased power flow on the new circuit
17 between Daniels Park and Waterton and allow for a reduction in audible noise
18 to a level that is close to 50db(A) even when the line is wet.

19 **Q. DOES THIS CONCLUDE YOUR TESTIMONY?**

20 A. Yes.

Attachment A

Statement of Qualifications DANNY PEARSON

I graduated from the University of Nebraska with a BS degree in Electrical Engineering in 1976. Subsequently, I began my employment with Public Service Company of Colorado as a Staff Engineer. I am licensed as a Professional Engineer and Professional Land Surveyor in the State of Colorado. I have held positions of increasing responsibility in the Transmission Engineering Department throughout my career. In 1984-1985, I was acting Supervisor, Transmission Engineering. From 1990 to 1992 I was Supervisor of Transmission Engineering. I currently am a Principal Transmission Design Engineer in Transmission Engineering Department, providing the engineering services needed to construct new PSCo transmission lines as well as the engineering expertise required to maintain existing transmission facilities.

In the past ten years, I have been responsible for the design, construction and Project Management of over 400 miles of energized 345kV transmission lines (Texas – Colorado 345kV transmission line) and 76 miles of 345kV designed (operated at 230kV) double circuit transmission line (Daniels Park – Midway). I have been responsible for the design of over 100 miles of 345kV designed transmission lines (presently energized at 230kV) in the Colorado Front Range (Ft St Vrain – Green Valley and Green Valley – Spruce). I am presently designing a 115kV line

and a 345kV line in Minnesota and South Dakota for Northern State's Power's Wind Project.