BEFORE THE PUBLIC UTILITIES COMMISSION

OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF THE APPLICATION BY NORTH BEND WIND PROJECT, LLC FOR A PERMIT TO CONSTRUCT AND OPERATE THE NORTH BEND WIND PROJECT IN HYDE COUNTY AND HUGHES COUNTY, SOUTH DAKOTA

SD PUC DOCKET EL21-018

PRE-FILED TESTIMONY OF DR. CODY CHRISTENSEN

Q. State your name.

A. My name is Dr. Cody Christensen.

Q. State your employer.

A. South Dakota State University.

Q. State your specific job at South Dakota State University.

A. I am the program coordinator for aviation at South Dakota State University. I am the only tenured professor at South Dakota State University in that capacity. My job involves teaching pilots, service, and research related to aviation education. My resume is attached as Exhibit A.

Q. Explain the range of duties you perform.

A. My job includes preparing future commercial pilots to be able to safely handle many types of airplanes, including airline aircraft. Safety, complying with federal aviation regulations, and airplane operating limits is essential to these occupations. There is little room for error in handling airplanes.

Q. On whose behalf was this testimony prepared.

A. This testimony was prepared on behalf of Michael Bollweg, Judi Bollweg, Bollweg Family, LLLP, and Tumbleweed Lodge.

Q. What were you asked to do.

A. I was asked to review and render a professional opinion concerning agricultural flight operations around wind turbines, specifically around T112N, Ro74W section 10 and 11 in Hughes County, South Dakota.

Q. What did you conclude.

A. There are three main considerations when addressing the pilot perspective of operations around obstacles. The three factors include margin of safety, operation of aircraft, and aircraft performance factors associations with the flight.

- The first main consideration when evaluating an operating area, whether that be a field to spray or a ground-based maneuver designated by the Federal Aviation Administration (FAA) for training such as an Eight on Pylon, is the margin of safety. The margin of safety when obstacles are present in a field decreases options in the event of an emergency such as a powerplant failure or stall/spin situation. From personal experience I know that operating directly behind or in between wind turbines creates considerable turbulence that can lead to loss of control events- a leading cause of aircraft accidents in the United States. Additionally, flying with known obstacles increases workload because the operator must evaluate the proper course of action with little to no room for error. The margin of safety decreases as the height and number of obstacles increases.
- It should be noted that the calculations in the pilot's operating handbook assume standard conditions of 29.92 barometric pressure setting, 59° and sea level. Higher temperatures and altitudes diminish performance. Harrold, South Dakota, is just under 2,000 feet above sea level.
- The second consideration when operating around obstacles that are unavoidable is that of pilot training and pilot response. Professional agricultural pilots knowingly take considerable, calculated risks related to obstacles other pilots do not take. They are responsible for flying between 3-12 feet above the ground, making multiple low

passes, multiple takeoff and landings, and operating at the max capacity of the aircraft. Doing this operation on a zero wind, cool day, with no elevation or obstacles take precision and professional skills few possess. Adding additional obstacles that decrease the margin of safety and decrease the reaction time a pilot has to deal with unforeseen situations such as mechanical issues, bird strikes, wire strikes, wind changes, and product issues decreases the safety of the operation.

- The final major concern when operating around obstacles is the aircraft performance, including climb rate, turn radius, and environmental conditions. The climb rate of a standard Air Tractor 502, a common midlevel agricultural application aircraft, is 664 feet per minute and a typical working speed of 135mph. Every second the airplane is traveling approximately 198 feet per second while on target. At the end of a field the pilot would turn off the spray and begin a climb, followed shortly by a climbing turn usually away from the spray pass to complete a course reversal to realign for the next spray pass. In a normal situation with no obstacles, ending the spray and the initial climb out might all occur within five to eight seconds, resulting in a straight-line distance of almost ¼ mile. The turnaround for ag operators, generally considered a 45° downwind turn, followed by a 225-course reversal to come back on target requires a 30-45° turn to do a back-to-back turn. The time of the course reversal is approximately 25 seconds, resulting in close to one mile of total distance traveled per swath. Assuming a 30° bank, the calculated turn radius of an aircraft going 135mph is 2,119 feet and the diameter of the turn is 0.8 miles. It should be noted that for an Air Tractor 502, it is close to one mile to make a turn, but for an Air Tractor 802, currently the largest single engine commercially used ag application airplane, that distance increases to 1.82 miles to complete a turn.

- As early discussed, an Air Tractor 502 climb rate is 664 feet per minute or approximately 11 feet per second (fps) climb rate. Considering at the end of the field, an applicator pulls up into a climb, it would take 18 seconds (200ft/ 11fps) to clear a 200 feet obstacle located at the end of a field. Using a working speed of 135MPH or 198fps the aircraft would travel forward 3,564ft (198fps*18 sec to climb) to clear a 200ft obstacle. If a 600-foot obstacle was considered, it would take 54 seconds to outclimb the obstacle and would travel forward over two miles (198fps *54sec= 10,800ft). Even assuming the pilot slowed to 111mph (best rate of climb at max weight) the distance covered is still 1.6 miles (162fps *54 sec). This assumes the pilot adds max power, performs a perfect climb, the airplane performs perfect, and the field conditions were conducive to a climb (sea level, standard atmosphere, low humidity, calm or head winds prevailing). Anything less than perfect conditions would decrease the climb rate.
- The other option would be instead of pulling up to climb over an obstacle to fly around it, below it, or through the blade arc or guy-wire, all of which are not prudent options, especially considering any abnormal operations. Additionally, the turbulence created by the wind turbines would have a direct and immediate impact on the pilot operating downwind of the turbine.
- In reviewing the plat map of 112N, R 074W, section 10 and 11 in Hughes County, SD I am most concerned about the placement of towers 8, 9, 14, &15 within the

sections and any towers that are adjacent such as #20-22 as they are well within a normal margin of safety for a typical pilot to safety spray that area. Based on the map and field layout, an east/west swath pattern would prevail and the presence of wind turbines or any obstacle at the end of those fields, especially on two sides, would be detrimental to safety. In my opinion, I would advise against a pilot maneuvering in the field presented with obstacles in the placement suggested.

Q. Did the PUC ask you any follow up questions.

A. The staff of the PUC asked me certain follow up questions.

- First, they asked where I obtained my calculations and numbers for aircraft performance. That reply is attached and dated 11/3/21. Those numbers were taken off the specifications for the airplanes that are spraying the Bollweg fields currently. Those are hard numbers from which deviations are illegal and dangerous. My calculations are conservative, and are minimum clearance distances for safe operations. There may be pilots that deviate from these calculations. That does not mean that they are safe operations and the thin margins of safety may eventually catch up with them; mistakes in aviation are unforgiving.
- The PUC asked if I maintain that a pilot cannot safely fly around a turbine that is shut down and not moving as ordered for the Crowned Ridge Wind II Project, and I do not maintain that. If the wind towers were not in operation, it would substantial decrease the turbulence created by the wind turbines. As long as the distance from the field to the obstacle can be maintained, pilots could safety operate around a wind turbine.

- The PUC asked me to explain how flying around a wind turbine that is shut down is different than flying around stationary obstacles, such as a power line, grain bin, house, trees, or cell tower. My response to them was that as a professional pilot and flight instructor, I do not see a major difference between obstacles when height and circumference are adequately considered. I would not try to outmaneuver an obstacle without proper setback clearances for any stationary obstacles such as a wind turbine, powerline, grain bin, house, trees, or cell tower. The height and size of the obstacle must be taken into consideration when operating an aircraft in the vicinity of known obstacles. I would recommend if a 100 ft grain bin was located within the area of operation, it would be considered much like a 100-foot shut down wind turbine would be except that a wind turbine can rotate so the orientation of the blades in relation to the aircraft turn would have to be taken into consideration. An operator could fly closer to a 100 ft grain bin because the climb required to clear a 100ft bin is less than a taller obstacle. A 600-foot-tall grain bin with the same circumference as a 600-foot- tall wind turbine would be treated with equal caution. I have yet to encounter a 600-foot-tall grain bin so the best description would be trying to operate in downtown Manhattan with 60 story buildings on multiple sides. It would be possible to operate around them, but the distance between the building (wind turbine/grain bin/obstacle) would need to be sufficiently away to allow for a proper turn. The margin of error decreases and safety margins virtually disappear. If the PUC request was to evaluate a new tower that was 600ft tall with known guy wires, I would treat it the same as a 600-foot wind turbine using the height and circumference of the obstacle. The tower along with the guywires constitute an obstacle that is not able to be flow through. Yes, it is possible to fly under, over, or through guy wires but the margin of safety decreases with each pass. Flying under or through stopped wind turbine blades is much like guy wires. As a professional pilot I would not fly under shut down wind turbine blades, nor would I teach that maneuver to any student.

- Finally, the PUC asked me if I was aware of any governmental entity that has ordered a similar setback for wind turbines from a property line to facilitate aerial spraying. I am not aware of any governmental entity that has ordered a similar setback for wind turbines from property line to facilitate aerial spraying. My job was to evaluate the threats to safety to agricultural spray aircraft posed by the turbines. That analysis had to do with the hard science of physics as it applied to aircraft and pilot performance. No political considerations were evaluated. Governmental agencies sometimes take other factors into consideration.

Dated this ____ of 1/7/2022 | 10:08 PST, 2022.

DocuSigned by:

Cody Christensen

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DR. CODY CHRISTENSEN

CODY CHRISTENSEN

Cody.Christensen@sdstate.edu

143 Wagner Hall Box 2275A Brookings, SD 57007 Ph: 605-688-4983

EDUCATION

- University of South Dakota (USD) Vermillion, SD May 2013
    - *Doctorate of Education; Educational Administration; Adult and Higher Education*

- South Dakota State University (SDSU) Brookings, SD December 2006
    - *Masters of Education; Curriculum and Instruction*

- South Dakota State University (SDSU) Brookings, SD May 2005
    - *Bachelor of Science in Education; Career and Technical Education*

AVIATION LICENSES AND CERTIFICATIONS

- FAA Airline Transport Pilot Certificate (AMEL)
    - Type Rating: Beechcraft 1900D
- FAA Commercial Pilot Certificate (ASEL)
- Medical: Second Class- no restrictions
- FCC Restricted Radiotelephone Operator Permit
- FAA Gold Seal Instructor ratings
    - CFI, CFII, MEI, IGI

AVIATION EXPERIENCE

Associate Professor/Program Coordinator -South Dakota State University Brookings, SD 01/09-Present

- Oversee Aviation Program including five full time staff and 15 part time staff
- Teach multiple aviation related courses in accordance with FAA regulations
- Publish articles and conduct peer reviewed research
- Secure grants and funding to continue supporting aviation program mission
- Oversee Aviation Accreditation Board International specialized accreditation
- Coordinate, secure funding, and organize summer aviation ACE (Aerospace Career and Education) Camp for high school aged students
- Progress check instructor and CFI instructor

Captain- Great Lakes Airlines Cheyenne, WY 01/07- 12/08

- Act as Pilot in Command of a 19 seat Beechcraft 1900 airliner
- Ultimately responsible for the safe and efficient operation of the aircraft and crew
- Utilize Crew Resource Management techniques to create a positive cockpit environment
- Supervise fueling, baggage handling, deicing procedures to ensure compliance with company policies
- Effectively communicate with ground, flight and support staff to ensure a safe, on time flight

Ground Instructor- Great Lakes Airlines Cheyenne, WY 05/08-12/08

- Instruct captains/first officers in aircraft systems, emergency procedures, company policies and procedures
- Qualify former pilots who were rehired to the company
- Conducted emergency drills including evaluation, fire detection and prevention, and hijacking
- Advised pilots on proper procedures during emergency operations

PEER REVIEWED ARTICLES

Leonard, A., **Christensen, C.,** & Hendricks, J. (2020). Needs Based Assessment of Agricultural Pilots in the Upper Midwest. International Journal of Aviation, Aeronautics, and Aerospace, 7(1). https://doi.org/10.15394/ijaaa.2020.1434

Smith, M.; Smith, G., Bjerke, E., **Christensen, C.**, Carney, T., Craig, P., and Niemczyk, M. (2017). Pilot Source Study 2015: A Comparison of Performance at Part 121 Regional Airlines Between Pilots Hired Before the U.S. Congress Passed Public Law 111-216 and Pilots Hired After the Law's Effective Date. *Journal of Aviation Technology and Engineering*: Vol. 6: Iss. 2, Article 4.

Adjekum, D. K., Walala, M., Keller, J., **Christensen, C.,** DeMik, R. J., Young, J. P., & Northam, G. (2016). An Analysis of the Effects of Demographic Variables and Perceptions on the Safety Reporting Behavior in Collegiate Flight Programs. International Journal of Aviation Sciences: Vol. 1. Iss.2. Available at: https://www.ijas.us/images/V1Issue2/AdjekumEtAl2016.pdf

Smith, G., Bjerke, E., Smith, M., **Christensen, C.**, Carney, T., Craig, P., and Niemczyk, M. (2016). Pilot Source Study 2015: An Analysis of FAR Part 121 Pilots Hired after Public Law 111-216—Their Backgrounds and Subsequent Successes in US Regional Airline Training and Operating Experience," Journal of Aviation Technology and Engineering: Vol. 6: Iss. 1, Article 9. Available at: http://dx.doi.org/10.7771/2159-6670.1140

Adjekum, D. K., Keller, J., Walala, M., **Christensen, C.,** DeMik, R. J., Young, J. P., & Northam, G. J. (2016). An Examination of the Relationships between Safety Culture Perceptions and Safety Reporting Behavior among Non-Flight Collegiate Aviation Majors. *International Journal of Aviation, Aeronautics, and Aerospace, 3*(3). http://dx.doi.org/10.15394/ijaaa.2016.1134

Bjerke, Elizabeth; Smith, Guy; Smith, MaryJo; **Christensen, Cody**; Carney, Thomas; Craig, Paul; and Niemczyk, Mary (2016). Pilot Source Study 2015: US Regional Airline Pilot Hiring Background Characteristic Changes Consequent to Public Law 111-216 and the FAA First Officer Qualifications Rule. *Journal of Aviation Technology and Engineering*: Vol. 5: Iss. 2, Article 1. Available at: http://dx.doi.org/10.7771/2159-6670.1133

Adjekum, D. K., Keller, J., Walala, M., Young, J. P., **Christensen, C.,** & DeMik, R. J. (2015). Cross-Sectional Assessment of Safety Culture Perceptions and Safety Behavior in Collegiate Aviation Programs in the United States. International Journal of Aviation, Aeronautics, and Aerospace, 2(4). http://dx.doi.org/10.15394/ijaaa.2015.1074

Christensen, C. & Card, K. A. (2014). *Specialized Aviation Flight Accreditation Under Public Law 111-216 Aviation Program Administrators' Perceptions*. Collegiate Aviation Review.32 (2).

Christensen, C. & Dunn, B. (2011) Fleet characteristics of collegiate aviation flight programs. *Collegiate Aviation Review*, 29 (2), 13-20

MAGAZINE ARTICLE (EDITOR REVIEWED)

Christensen, C. (2011) *The art of professionalism*. CFI to CFI. 2(1).

PRESENTATIONS

Christensen, C. The Status of Aviation Education in South Dakota. (2018). South Dakota Pilots Association in Brookings, SD.

Christensen, C. The status of aviation education in South Dakota. (2018). South Dakota Airports Conference in Deadwood, SD.

Christensen, C., Aviation Education Flight Simulator, (2017). South Dakota Airports Conference in Mitchell, SD.

Christensen, C. & Leonard, A. (2016). Millennials in Aviation. University Aviation Association Conference in Omaha, NE.

Christensen, C., Carney, T., Niemczyk, M. (2016) *Pilot Source Study*. University Aviation Association International Conference in Omaha, NE.

Christensen, C. (2016) *Pilot Source Study Updates and Aviation in South Dakota*. South Dakota Aeronautics Commission Meeting. Deadwood, SD.

Smith, G., Bjerke, E., Smith, M., Christensen, C., Carney, T., Craig, P., & Niemczyk, M. (2016). Pilot Source Study 2015: US Regional Airline Pilot Hiring Background Characteristic Changes Consequent to Public Law 111-216 and the FAA First Officer Qualifications Rule. Aviation Accreditation Board International Conference-Town Hall meeting in Atlanta, GA.

Dow, A., Christensen, C., & Marshall, S. (2015). Reaching New Heights in Recruitment for Smaller Aviation Programs. University Aviation Association Conference in Snowbird, UT.

Christensen, C. & Leonard, A. (2014). Benefits of Early Alerts on Flight Training. University Aviation Association Conference in Daytona Beach, FL.

Christensen, C. (2014). Specialized Aviation Flight Accreditation Under Public Law 111-216 Aviation Program Administrators' Perceptions. University Aviation Association Conference in Daytona Beach, FL.

Christensen, C. (2014). FAA Airspace Review. Presented at the East River Aviation Symposium. Brookings, SD.

Christensen, C. & Leonard, A. (2013). *Integrating a Mobile Training Lab into an Aviation Curriculum.* Presentation at the International University Aviation Association Conference, San Juan, PR.

Christensen, C. (2013). *Influence of military service on student success in an aviation program.* Abstract presentation at the International University Aviation Association Conference, San Juan, PR.

Christensen, C. & Leonard, A. (2012). *Integrating Aviation Concepts into Curriculum.* Presentation at the SD STEM Initiative, Sioux Falls, SD.

Christensen, C. (2011). *Implications of Public Law 111-216 and outcomes based accreditation on specialized aviation accreditation.* Presentation at the International University Aviation Association Conference, Indianapolis, IN.

Christensen, C. (2011). *South Dakota Aviation Safety Initiative*. South Dakota Aeronautics Commission. Pierre, SD.

Christensen, C. and Dunn, B. (2011). *Fleet characteristics of collegiate aviation flight programs.* Presentation at the International University Aviation Association Conference. Indianapolis, IN.

Christensen, C. (2011). *Perfecting the preflight.* FAA national safety-stand down event. Brookings, SD.

Christensen, C., Hovland, W., Kelm, W., Hoogerhyde, S., Leonard, A., & Kwasniewski, G. (2011) *Setting Personal Minimums*. Federal Aviation Administration Safety Seminar. Brookings, SD.

Christensen, C. (2011). *Energizing PowerPoint's using Prezi's in the classroom and conference environments*. Faculty Showcase presented by the Teaching Learning Center. Brookings, SD

CONFERENCE PUBLISHED ABSTRACT (COMMITTEE CHAIR REVIEWED):

Christensen, C. & Leonard, A. (2015). Needs Based Assessment of Agricultural Pilots in the Upper Midwest. University Aviation Association Conference in Snowbird, UT.

Christensen, C. & Leonard, A. (2013). *Integrating a Mobile Training Lab into an Aviation Curriculum.* Conference proceedings at the International University Aviation Association Conference, San Juan, PR.

Christensen, C. (2013) *Influence of military service on student success in an aviation program.* Abstract conference proceedings at the International University Aviation Association Conference. San Juan, PR.

Christensen, C. (2011). *Implications of Public Law 111-216 and outcomes based accreditation on specialized aviation accreditation.* University Aviation Association Conference, Indianapolis, IN.

DISSERTATION

Christensen, C. (2013). *Aviation program administrators' perceptions of specialized aviation accreditation under public law 111-216*. (Doctoral dissertation), University of South Dakota, Vermillion, SD.

GRANTS:

Increasing the Aviation Workforce in South Dakota. $159,083. Federal Aviation Administration (not funded)

SDSU Mobile Simulator. $11,000. South Dakota Space Grant Consortium. 2016-2018

Aerospace Career and Education Camp. $5,000. South Dakota Aeronautics Commission. 2016. (PI: Christensen, C.)

South Dakota Aviation Symposium. $2,500. South Dakota Space Grant Consortium. 2016 (Co-PI: Christensen, C. & Funk, C.)

SDSU Mobile Aviation Simulator. $75,000. South Dakota Aeronautics Commission. 2016. (PI: Christensen, C)

SDSU Mobile Aviation Simulator. $42,000. Brookings School District. 2016. (PI: Christensen, C)

Aerospace Career and Education Camp. $5,000. South Dakota Aeronautics Commission. 2015. (PI: Christensen, C)

Scholarly Travel Grant. $1,000. SDSU Office of Academic Affairs and Department of Consumer Sciences. 2013. (PI: Christensen, C)

Aerospace Career and Education Camp. $5,000. South Dakota Aeronautics Commission. 2014. (PI: Dalsted, K. & Co-PI: Christensen, C)

Accreditation Self-Study Funding. $6,400. SDSU Office of Academic Affairs, 2012. (Co-PI: Christensen, C, Co-PI: Leonard, A., Co-PI: Boulware, J.).

Increasing Aviation Activity in South Dakota. $2,500. South Dakota Space Grant Consortium. 2011-2012. (PI: Christensen, C)

Assessment and development plan for aviation program accreditation. $5,400. SDSU Office of Academic Affairs, 2011 (PI: Christensen, C & Co-PI: Leonard. A.).

Online course redevelopment for Advanced Flight Principles. $1,500. College of EHS Academic Excellence funds, 2011. (PI: Christensen, C)

Capital utilization among aviation flight programs. $1,000. College of EHS Academic Excellence funds. 2011 (PI: C. Christensen, C. & Co-PI: Dunn, B).

Female mentor in the SDSU Aviation program. $2,400 SDSU Foundation-Women in Giving, 2009-2011. (PI: Christensen, C)

MEMBERSHIPS & AFFILIATIONS

- FAASTeam safety counselor (2010-current)
    - 2016 SD FAASTeam Rep of the Year
- SDSU Flying Jacks-Advisor (2012-current)
- University Aviation Association (2009-current)
- Alpha Eta Rho Aviation Fraternity-Advisor (2009-2012)
- Aircraft Owners and Pilots Association (2001-current
- Brookings County Youth Mentor (2012-2016)
- South Dakota Pilots Association (2009-current)
- Women in Aviation member (2011-current)

09/02/2021

James Malters
727 Oxford St.
Worthington, MN 56187

Mr. Malters,

My name is Dr. Cody Christensen, I serve in a professional capacity as the only tenured aviation faculty member in South Dakota wherein my role at South Dakota State University, I am tasked with teaching, service, and research related to aviation education. My primary role within the university is teaching new pilots, commercial pilots, and advanced systems in aviation operations. I have been a licensed pilot for over twenty years, a FAA Goal Seal flight instructor for 15 years, and hold certificates in both single and multiengine aircraft including an Air Transport Pilot (ATP) certificate. I am answering your questions as a former airline captain for a small regional airline operating into and out of the Midwest, including South Dakota and the area depicted in Hughes County.

This letter is in request to addressing agricultural flight operations around wind turbines, specifically around T112N, R074W section 10, and 11 in Hughes County, SD. Three main considerations must be factored when addressing the pilot perspective of operations around obstacles. Those three factors include margin of safety, operation of aircraft, and aircraft performance factors associated with the flight.

The first main consideration when evaluating an operating area, whether that be a field to spray or a ground-based maneuver designated by the Federal Aviation Administration (FAA) for training such as an Eight on Pylon, is the margin of safety. The margin of safety when obstacles are present in a field decreases options in the event of an emergency such as a powerplant failure or stall/spin situation. From personal experience I know that operating directly behind or in between wind turbines creates considerable turbulence that can lead to loss of control events- a leading cause of aircraft accidents in the United States. Additionally, flying with known obstacles increases workload because the pilot must evaluate the proper course of action with little to no room for error. The margin of safety decreases as the height and number of obstacles increases.

The second consideration when operating around obstacles that are unavoidable is that of operation of aircraft including pilot training and pilot response. Professional agricultural pilots knowingly take considerable, calculated risks related to obstacles other pilots do not take. They are responsible for flying between 3-12 feet above the ground, making multiple low passes, multiple takeoff and landings, and operating to the max capacity of the aircraft. Doing this operation on a zero wind, cool day, with no elevation or obstacles take precision and professional skills few possess. Adding additional obstacles that decrease the margin of safety and decrease the reaction time a pilot has to react to unforeseen situations such as mechanical issues, bird strikes, wire strikes, wind changes, and product issues decreases the safety of the operation.

The final major concern when operating around obstacles is the aircraft performance, including climb rate, turn radius, and environmental conditions. The climb rate of a standard Air Tractor 502, a common midlevel agricultural application aircraft, is 664 feet per minute and a typical working speed of 135mph. Every second the airplane is traveling approximately 198 feet per second while on target. At the end of a field the pilot would turn off the spray and begin a climb, followed shortly by a climbing turn usually away from the spray pass to complete a course reversal to realign for the next spray pass. In a normal situation with no obstacles, ending the spray and the initial climb out might all occur within five to eight seconds, resulting in a straight-line distance of almost ¼ mile. The turnaround for ag operators, generally considered a 45° downwind turn, followed by a 225-course reversal to come back on target requires a 30-45° turn to do a back-to-back turn. The time of the course reversal is approximately 25 seconds, resulting in close to one mile of total distance traveled per swath. Assuming a 30° bank, the calculated turn radius of an aircraft going 135mph is 2,119 feet and the diameter of the turn is 0.8 miles. It should be noted that for an Air Tractor 502, it is close to one mile to make a turn, but for an Air Tractor 802, currently the largest single engine commercially used ag application airplane, that distance increases to 1.82 miles to complete a turn.

As early discussed, an Air Tractor 502 climb rate is 664 feet per minute or approximately 11 feet per second (fps) climb rate. Considering at the end of the field, an applicator pulls up into a climb, it would take 18 seconds (200ft/ 11fps) to clear a 200 feet obstacle located at the end of a field. Using a working speed of 135MPH or 198fps the aircraft would travel forward 3,564ft (198fps*18 sec to climb) to clear a 200ft obstacle. If a 600-foot obstacle was considered, it would take 54 seconds to outclimb the obstacle and would travel forward over two miles (198fps *54sec= 10,800ft). Even assuming the pilot slowed to 111mph (best rate of climb at max weight) the distance covered is still 1.6 miles (162fps *54 sec). This assumes the pilot adds max power, performs a perfect climb, the airplane performs perfect, and the field conditions were conducive to a climb (sea level, standard atmosphere, low humidity, calm or head winds prevailing). Anything less than perfect conditions would decrease the climb rate and make the field in question non flyable.

The other option would be instead of pulling up to climb over an obstacle to fly around it, below it, or through the blade arc or guy-wire, all of which are not prudent options, especially considering any abnormal operations. Additionally, the turbulence created by the wind turbines would have a direct and immediate impact on the pilot operating downwind of the turbine.

In reviewing the plat map of 112N, R 074W, section 10 and 11 in Hughes County, SD I am most concerned about the placement of towers 8, 9, 14, &15 within the sections and any towers that are adjacent such as #20-22 as they are well within a normal margin of safety for a typical pilot to safety spray that area. Based on the map and field layout, an east/west swath pattern would prevail and the presence of wind turbines or any obstacle at the end of those fields, especially on two sides, would be detrimental to safety. In my opinion, I would advise against a pilot maneuvering in the field presented with obstacles in the placement suggested.

Respectfully,

Cody Christensen, Ed.D
Airline Transport Pilot
FAA Gold seal flight instructor

11/03/2021

James Malters
727 Oxford St.
Worthington, MN 56187

Mr. Malters,

In regards to the follow up question asked by the SD Public Utilities commission:

> *"In order to accommodate a safe turn radius at the end of a field for an agricultural application aircraft, what is Mr. Christensen recommending as an appropriate setback for a wind turbine from the property line to safely spray that field. Please explain and provide supporting calculations."*

I recommend a setback for a wind turbine no less than 0.8 miles from the end of field.

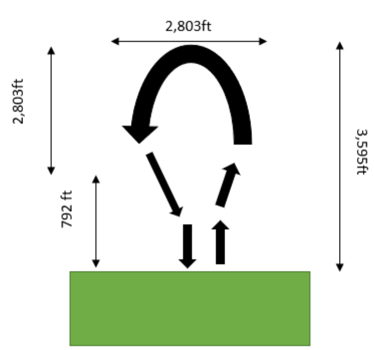
The calculations used to support the 0.8-mile setback include:

A straight out or teardrop/lightbulb pattern leaving the field including a climb, a 180° turn back on target = 3,595ft lateral distance from end of field.

Four seconds to climb and space for lateral distance = 792ft

Then 180° turn = 2,803ft radius

Lateral distance (792ft) +turn (2,803ft) = 3,595ft lateral distance from end of field = 0.68 miles
*15% margin of error = 0.782 mile, rounded up to 0.8-mile minimum setback from obstacles, such as wind turbines.



Calculation:

-Assuming no obstacles, at the end of field, approximately four seconds to climb (135MPH= 198fps*4 sec) = 792ft

-A radius turn is equal to the velocity squared (V^2) divided by 11.26 times the tangent of the bank angle as described in the *Pilot Handbook of Aeronautical Knowledge* (2016):

$$R = \frac{V^2}{11.26 \times \text{tangent of bank angle}}$$

V= 135mph

Air Tractor 502 working speed *Air Tractor AT-502 FAA Approved Flight Manual*. (1987).

Tangent bank angle = 30°

$$\frac{18{,}225}{11.26 \times 0.57735} = 2{,}803\text{ft radius}$$

Based on the standard Air Tractor 502 (smaller size compared to Air Tractor 802), a setback of 0.8 miles is required with minimal margin of error. This would not take into consideration a faster working speed, non-standard atmospheric days, tailwinds, or pilot error outside of a marginal 15% addition to the calculation. Additionally, this calculation does not add any safety distance margin for the turbulence (which can be considerable) coming off the blades of the turbines.

Based on the provided calculation, I recommend a setback for a wind turbine no less than 0.8 miles from the end of field.

Respectfully,

Cody Christensen, Ed.D.
Airline Transport Pilot
FAA Gold seal flight instructor

Works Cited

Pilots Handbook of Aeronautical Knowledge. (2016). (FAA-H-8083-25B) https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/

Air Tractor AT-502 FAA Approved Flight Manual. (1987). Air Tractor, INC. Olney, Texas.

January 4, 2022

James Malters
727 Oxford St.
Worthington, MN 56187

Mr. Malters,

In regards to the STAFF'S FOURTH SET OF DATA REQUESTS TO MR. MICHAEL BOLLWEG EL21-018:

(a) Does Dr. Christenson maintain that a pilot cannot safely fly around a turbine that is shut down and not moving as ordered for the Crowned Ridge Wind II Project?

No.

If the wind towers were not in operation, it would substantial decrease the turbulence created by the wind turbines. As long as the distance from the field to the obstacle can be maintained, pilots could safety operate around a wind turbine.

(b) Please explain how flying around a wind turbine that is shut down is different than flying around other stationary obstacles, such as a power line, grain bin, house, trees, or cell tower.

As a professional pilot and flight instructor, I do not see a major difference between obstacles when height and circumference are adequately considered. I would not try to outmaneuver an obstacle without proper setback clearances for any stationary obstacles such as a wind turbine, powerline, grain bin, house, trees, or cell tower. The height and size of the obstacle must be taken into consideration when operating an aircraft in the vicinity of known obstacles.

I would recommend if a 100 ft grain bin was located within the area of operation, it would be considered much like a 100-foot shut down wind turbine would be except that a wind turbine can rotate so the orientation of the blades in relation to the aircraft turn would have to be taken into consideration. An operator could fly closer to a 100 ft grain bin because the climb required to clear a 100ft bin is less than a taller obstacle.

A 600-foot-tall grain bin with the same circumference as a 600-foot- tall wind turbine would be treated with equal caution. I have yet to encounter a 600-foot-tall grain bin so the best description would be trying to operate in downtown Manhattan with 60 story buildings on multiple sides. It would be possible to operate around them, but the distance between the building (wind turbine/grain bin/obstacle) would need to be sufficiently away to allow for a proper turn. The margin of error decreases and safety margins virtually disappear.

If the PUC request was to evaluate a new tower that was 600ft tall with known guy wires, I would treat it the same as a 600-foot wind turbine using the height and circumference of the obstacle. The tower along with the guywires constitute an obstacle that is not able to be flow through. Yes, it is possible to fly under, over, or through guy wires but the margin of safety decreases with each pass. Flying under or through stopped wind turbine blades is much like guy wires.

As a professional pilot I would not fly under shut down wind turbine blades, nor would I teach that maneuver to any student.

4-3) Refer to the response to staff data request 2-4. Mr. Christensen recommend a setback for a wind turbine no less than 0.8 miles from the end of the field. Is Mr. Christensen aware of any governmental entity that has ordered a similar setback for wind turbines from a property line to facilitate aerial spraying? If so, please provide supporting documentation.

I am not aware of any governmental entity that has ordered a similar setback for wind turbines from property line to facilitate aerial spraying. My job was to evaluate the threats to safety to agricultural spray aircraft posed by the turbines. That analysis had to do with the hard science of physics as it applied to aircraft and pilot performance. No political considerations were evaluated. Governmental agencies sometimes take other factors into consideration.

Respectfully,

Cody Christensen, Ed.D.
Airline Transport Pilot
FAA Gold seal flight instructor