7. ENGINEERING AND OPERATIONAL DESIGN OF THE PROPOSED HVTL AND SUBSTATIONS

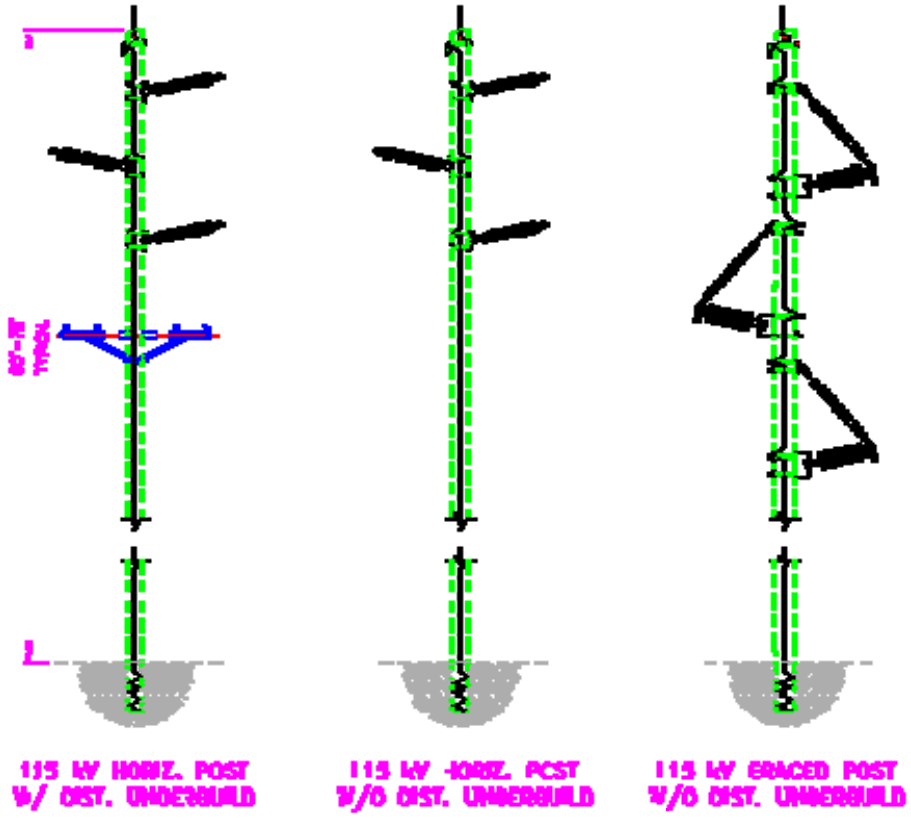
7.1 Transmission Structures

Design voltage of the proposed transmission line is 115 kV. The project would have a total length of approximately 12 miles, with slight variations depending on the exact route chosen. The entire line and associated facilities would be within Crow Wing County, Minnesota.

The transmission line would be constructed with 795 aluminum conductor steel supported (ACSS) conductors. These provide greater load capacity with less sag than other traditional conductors, including 795 aluminum conductor steel reinforced (ACSR). ACSS provides more current carrying capability than ACSR with comparable structures, poles and appearance. The line would use three single conductors (not bundled).

Structure types to be used for this project are shown in Figure 7-1.

Figure 7-1 Schematic Diagrams of Typical GRE Structures



Single pole wood structures with horizontal post insulators will be used for the project. Horizontal post insulators will be used unless design requires longer spans beyond the capability of the insulators, in which case a braced post design will be utilized to accommodate the increased loadings. Angles in the line will require guying (the use of anchors and support cables) or specialty structures. Where guying is not practicable, direct embedded laminated wood poles or steel poles on drilled pier foundations will be utilized.

GRE single circuit structures will have three single conductor phase wires and one shield wire. The phase wires will be 795 thousand circular mil ACSS with seven steel core strands and 26 outer aluminum strands. The shield wire will be 0.465 optical ground wire. The average span will be 250-300 feet and heights will range from 60 to 75 feet. Structures, pole heights and spans will vary depending upon topography and environmental constraints (such as highway crossings, stream crossings, and required angle structures).

7.1.1 Construction Considerations

Clearances

The transmission line will be designed to meet the National Electrical Safety Code (NESC) (Institute of Electrical and Electronics Engineers, 2002) standards. The NESC recommends minimum safety standards for clearances over roadways, buildings, signs, light standards, and other facilities.

GRE has company standards that meet or exceed the NESC requirements, and also follows the Rural Utilities Service (RUS) Design Manual for High Voltage Transmission Lines (US Department of Agriculture, 2005), which recommends clearances above the minimum NESC values to account for construction tolerances, such as a pole that is set deeper than originally specified.

Clearances over highways and roadways will exceed the 23 feet recommended by the NESC and RUS standards and may be limited by the DOT or local county highway permitting. Although the existing standards give recommended clearances over buildings, GRE generally does not locate transmission lines directly over a building unless it cannot be avoided. Horizontal clearances to buildings, signs, light standards, and other installations will be determined by calculating the blowout of the wire, structure deflection, and safe electrical clearance from the line.

7.1.2 Material Requirements

The construction of the transmission line will require the use of both renewable and non-renewable resources. The renewable resources consist of the wooden poles and the non-renewable resources consist of insulators, conductors, shield wires, and related hardware.

7.2 Substations

The proposed project involves modifications at the Mud Lake Substation and addition of a 115/69 kV substation at the Wilson Lake Substation as discussed in Section 5.2.

7.2.1 Mud Lake Substation

The Mud Lake Substation is owned by MP. The new 115 kV transmission line will enter the Mud Lake Substation from the east, and a new 115 kV termination will be built there to accommodate the new line. There is no additional grading, fence expansion, or expansion of the control house planned at this site.

7.2.2 Wilson Lake Substation

The existing Wilson Lake Substation is owned by MLEC. The new Wilson Lake 115 kV transmission substation will be built using a “low-profile” or “lattice box structure” design, similar to that of the existing Wilson Lake distribution substation. It will be a conventional outdoor open-type air-insulated bus-and-switch arrangement.

The primary components of the new substation will initially include:

- Three 69 kV breakers used to accommodate two 69 kV transmission line terminations and one as the low side transformer breaker, with associated relaying.
- One GRE 115 kV/69 kV/84 megavolt-ampere (MVA) transformer with load tap changing equipment and associated switching and protection equipment.
- One 115 kV switch with associated bus work for the termination of this line.
- One MLEC 69 kV/12.47 kV/37 MVA transformer with load tap changing equipment, associated switchgear, and four 12.47 kV distribution line feeders.
- Grading, fencing, installation of a control building, and steel structure installation will be included in the construction.

GRE will own the new Wilson Lake Substation and MLEC will have a permanent easement for their facilities on the western ¼ portion of the proposed substation. GRE will own and operate all the high voltage (115 kV and 69 kV) facilities, the control house, and all common facilities (land, fence, etc.). GRE and MLEC will own and operate their respective low voltage distribution facilities.

The Wilson Lake Substation will be laid out to accommodate additional equipment should significant load growth occur in the area. Ultimately, the substation may contain two or three additional rows of breakers and equipment to accommodate additional transmission line terminations, capacitor banks, transformers, and related feeders.

7.3 Electric and Magnetic Fields

The term EMF refers to electric and magnetic fields that are coupled together such as in high frequency radiating fields. For lower frequencies such as for power lines, EMF should be separated into electric fields and magnetic fields. Transmission lines operate at a frequency of 60 hertz (cycles per second), which is in the non-ionizing portion of the electromagnetic frequency spectrum. Fields are considered ionizing when they cause electrons to eject from their orbits around a normal atom. This will typically occur with frequencies in the range of 10^{16} to 10^{22} hertz.

Magnetic fields result from the flow of electricity (current) in the transmission line. The intensity of the magnetic field is related to the current flow through the conductors. The magnetic field associated with the transmission line surrounds the conductor and rapidly decreases with the distance from the conductor. The value of the magnetic field density is expressed in the unit of gauss (G) or milligauss (mG). Recent studies of the health effects from power frequency fields conclude that the evidence of health risk is weak (Minnesota Department of Health, 2002; National Institute of Environmental Health, 2002; National Research Council, 1997; http://www.health.state.mn.us/divs/eh/radiation/emf).

A sample of magnetic field calculations for years 2008 and 2020 is provided in Figures 7-2 to 7-9. These figures describe magnetic field exposure along the line with and without underbuild distribution during normal peak and potential maximum conditions with the system intact.

On these figures, the transmission conductors are identified as the highest “A”, “B”, “C”, and “GO”, and the distribution conductors are identified as the lowest “A”, “B” , “G1” and “C”, and are shown on a two-dimensional graph as if they were attached to a pole. The dimension up the right side of the graph is distance in feet above grade and only relates to the height of the conductors. The distance left (negative distance) and right (positive distance) of the center (0’) of the pole is shown at the bottom of the graph.

The figures also show the magnetic field strength (bell shaped curve) measured in mG (the left side of the graph or “B field”). The magnetic field graph shows that the strength of the field increases the closer you are to the center of the transmission line. In this case, the left and right bounds were selected at 100 feet because the field strength from the line is essentially equivalent to other magnetic field background sources at that distance.

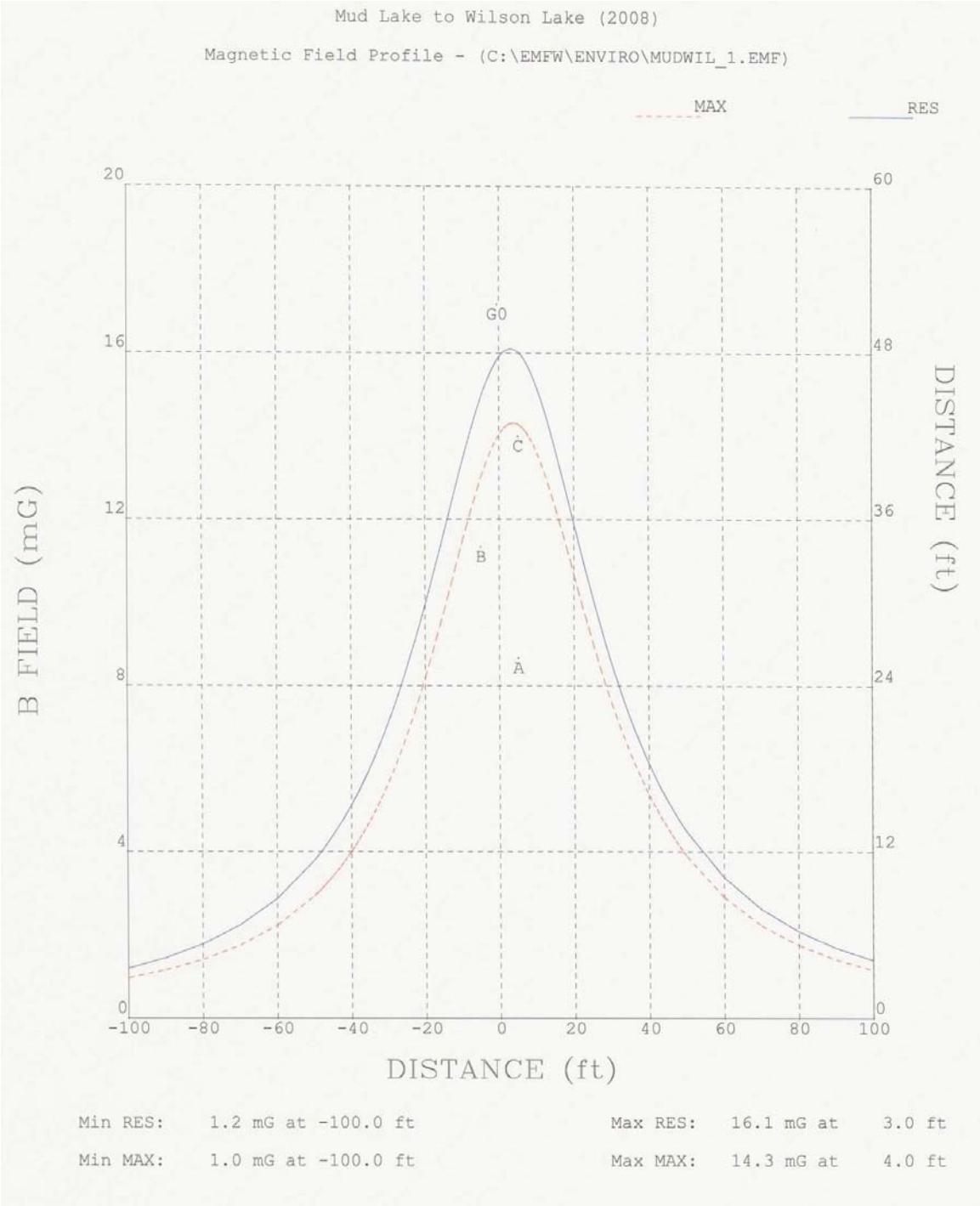


Figure 7-2 Magnetic Field Profile – 2008

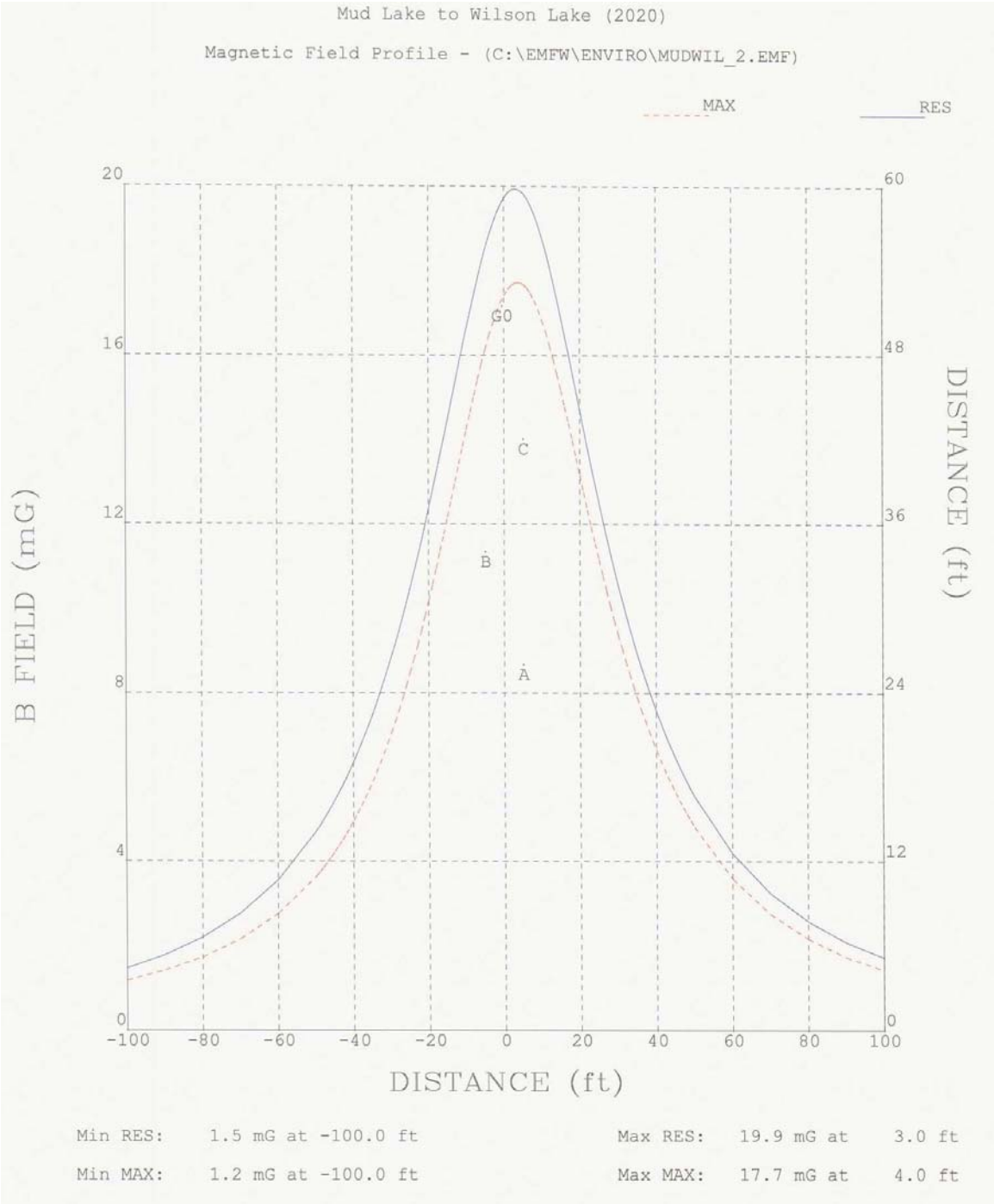


Figure 7-3 Magnetic Field Profile – 2020

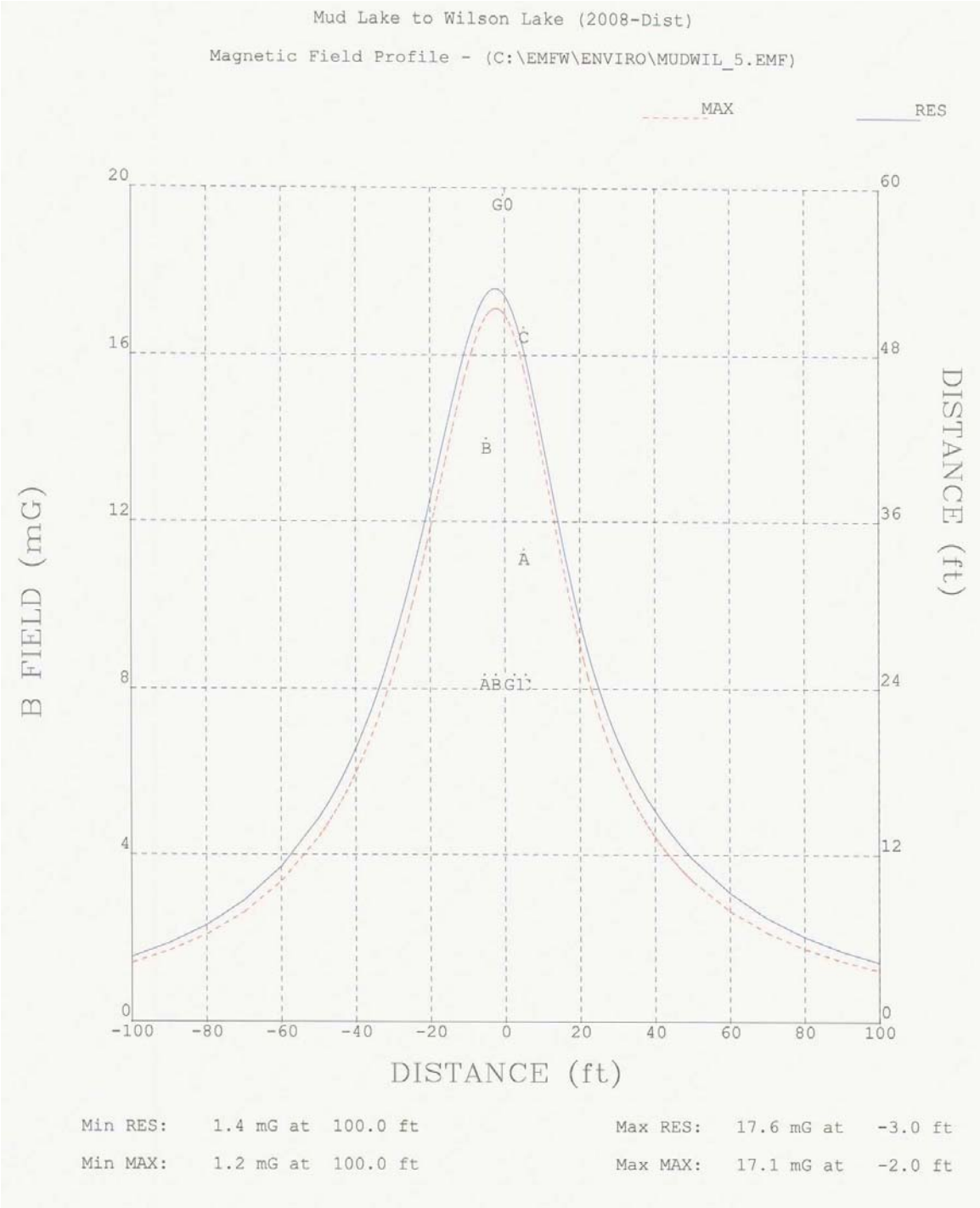


Figure 7-4 Magnetic Field Profile – 2008 with Distribution Underbuild

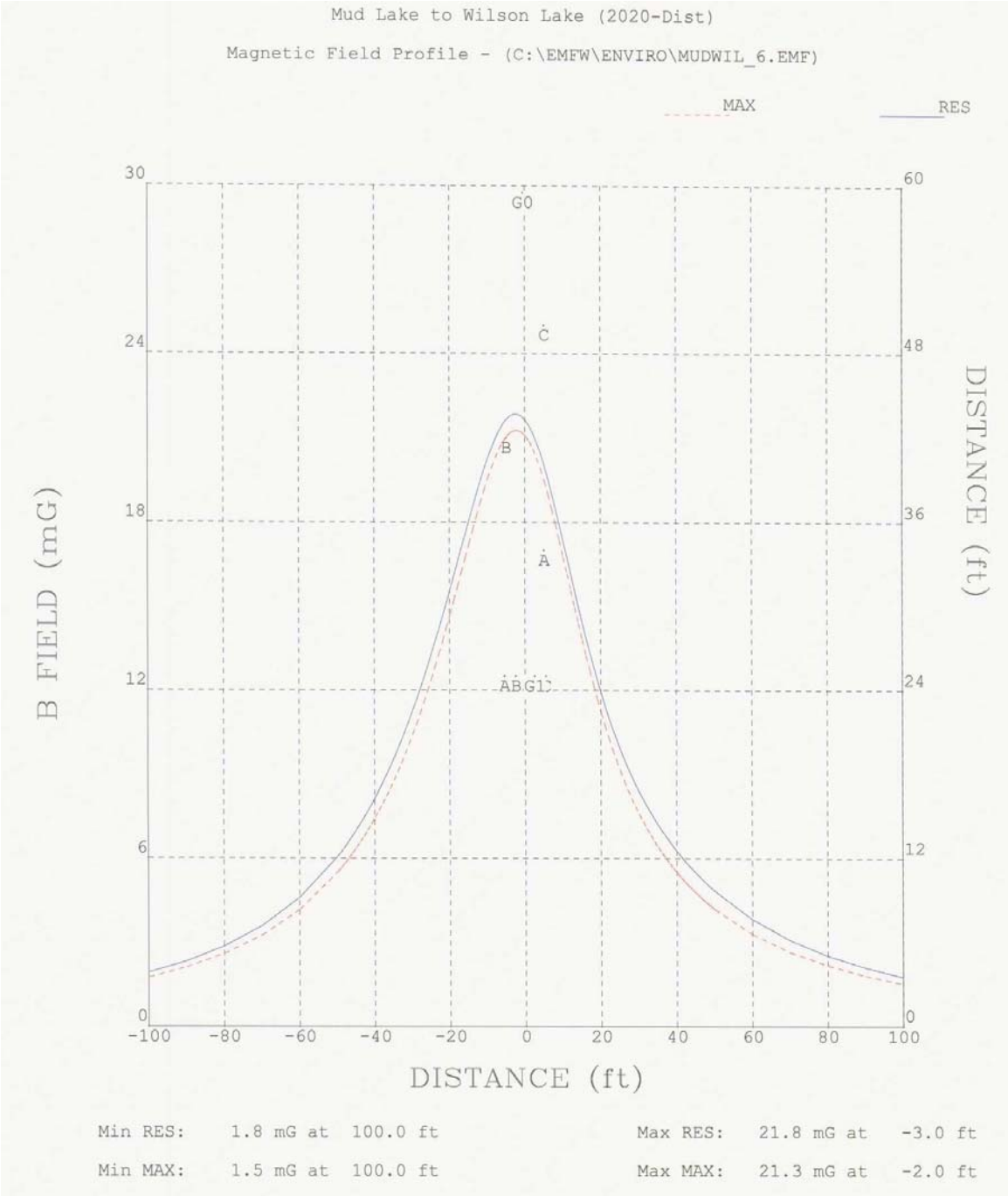


Figure 7-5 Magnetic Field Profile – 2020 with Distribution Underbuild

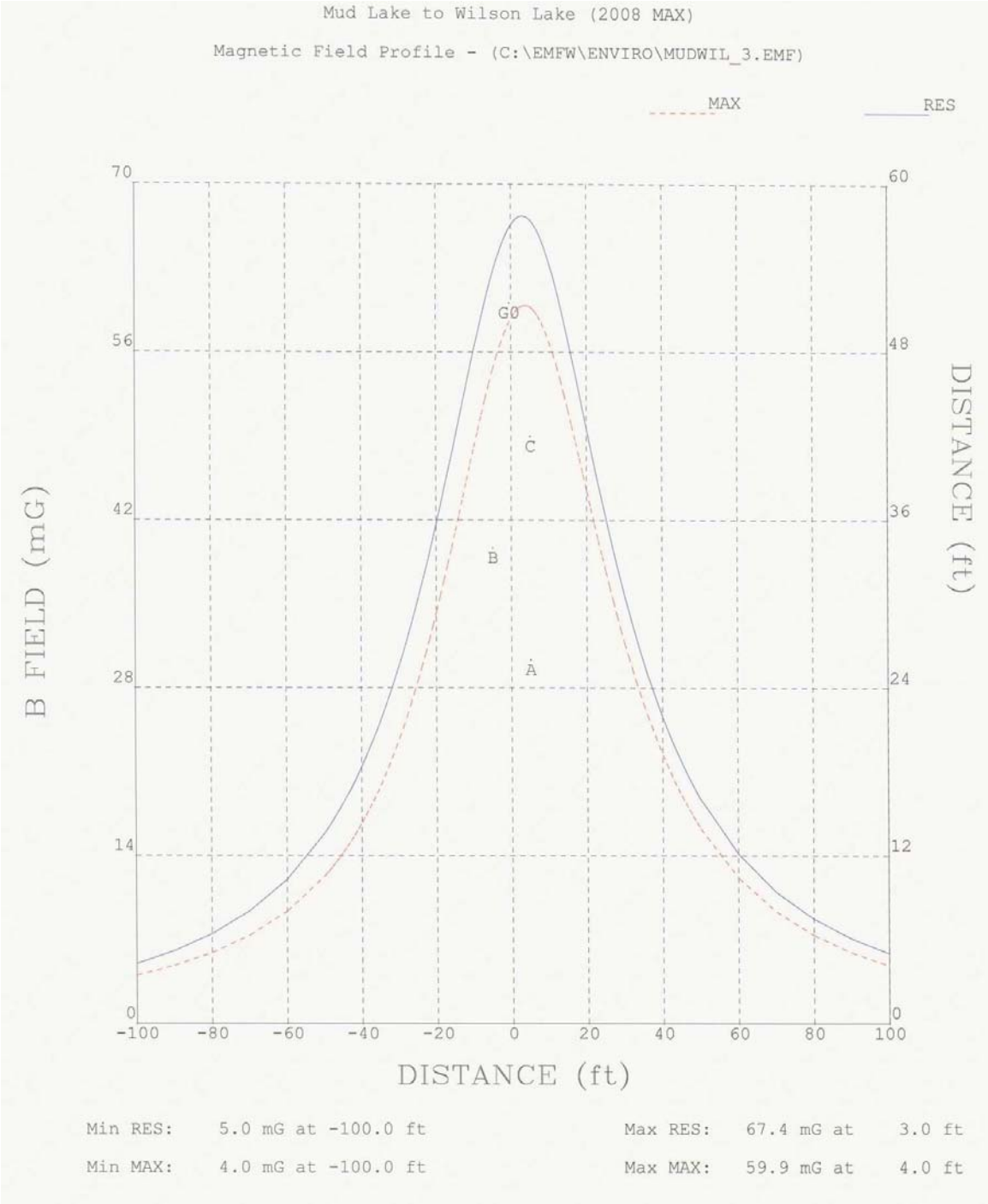


Figure 7-6 Magnetic Field Profile – 2008 Potential Maximum Loading

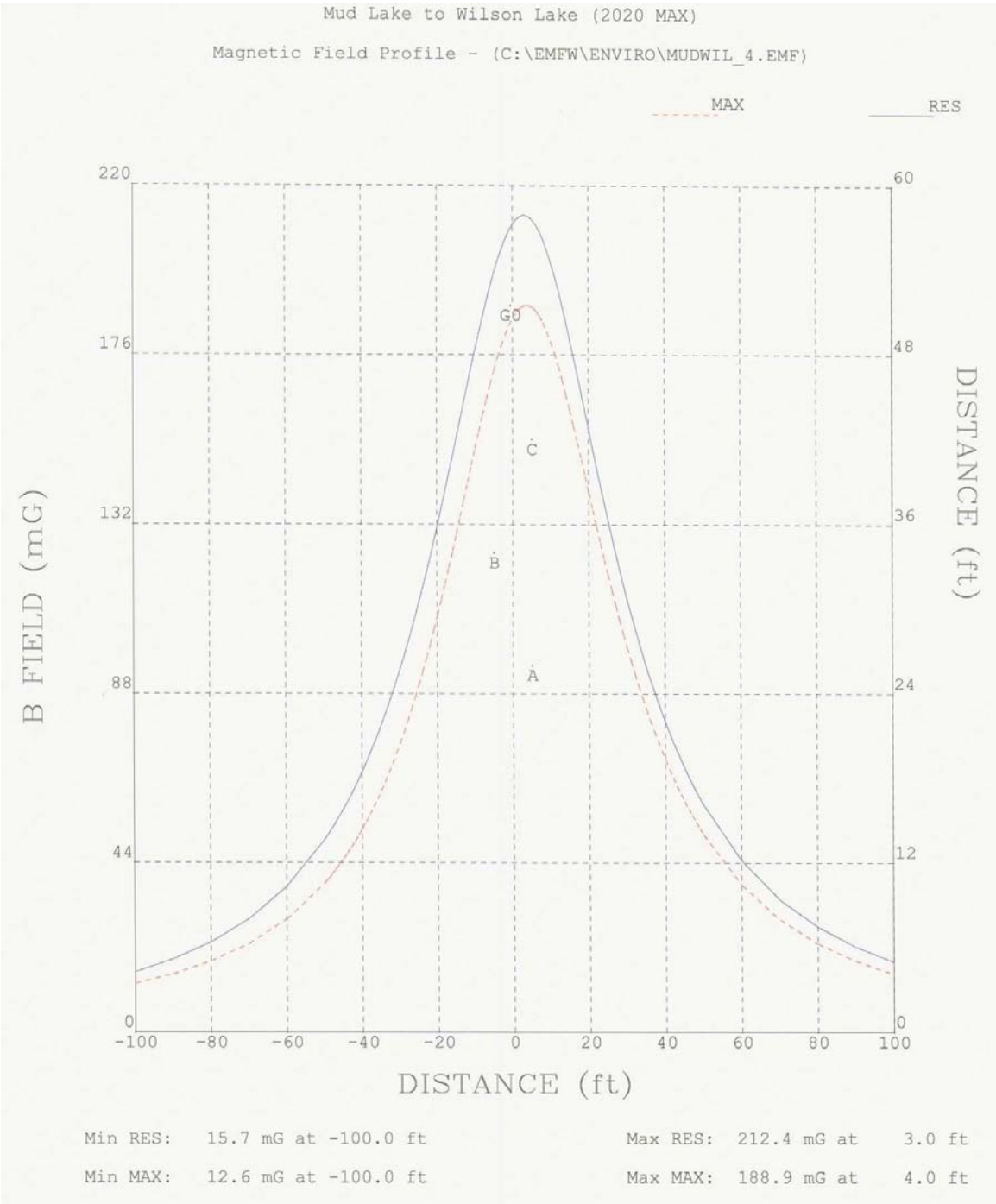


Figure 7-7 Magnetic Field Profile – 2020 Potential Maximum Loading

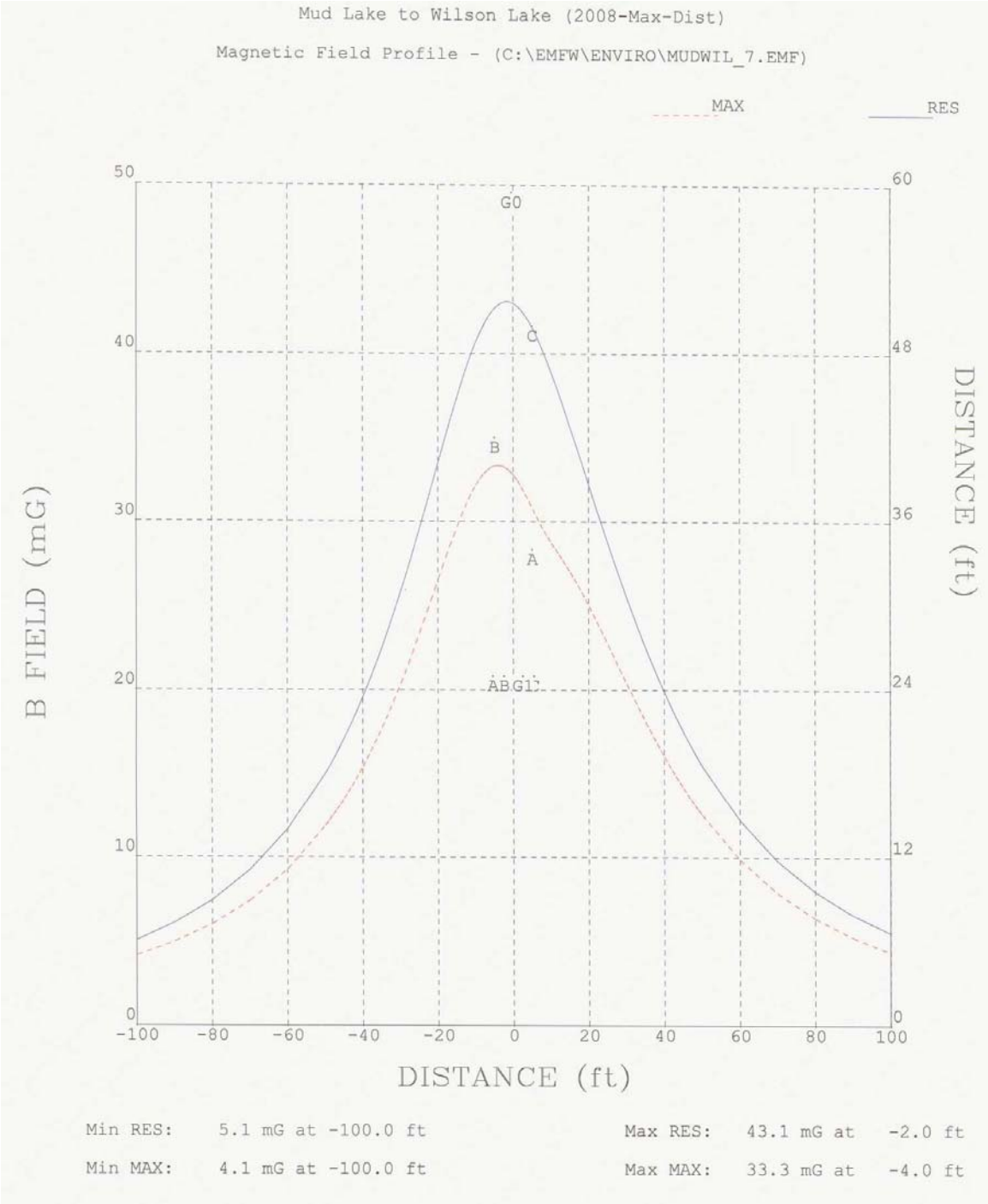


Figure 7-8 Magnetic Field Profile – 2008 Potential Maximum Loading with Distribution Underbuild

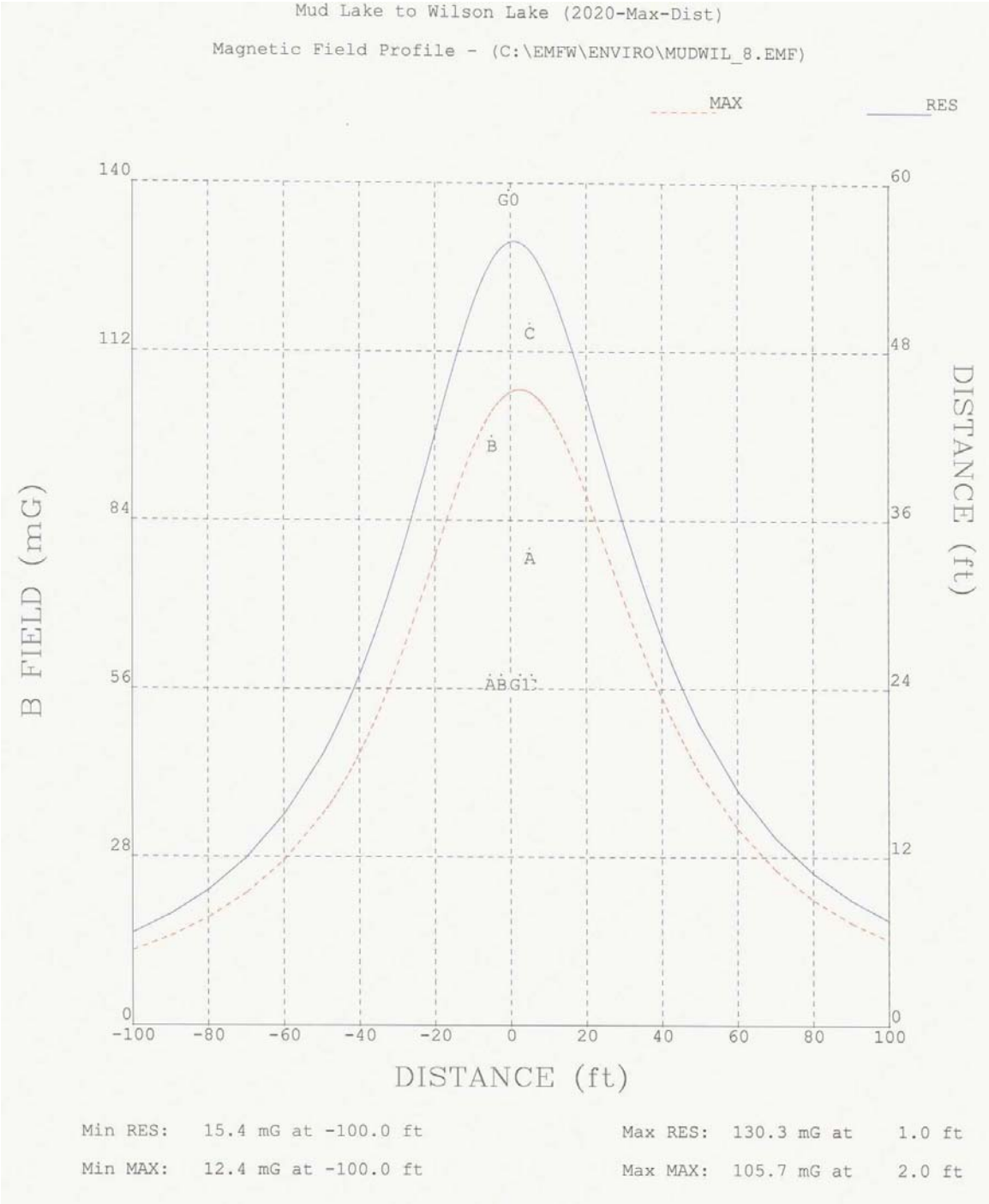


Figure 7-9 Magnetic Field Profile – 2020 Potential Maximum Loading with Distribution Underbuild

The values of the magnetic field for the GRE 115 kV transmission line are:

- In 2008, under normal maximum load conditions, the 115 kV transmission line would have a peak value of 17.6 mG directly underneath the transmission line and a value of approximately 7 mG at the edge of the right of way (Figure 7-4).

- In 2008, under contingency conditions, the 115 kV transmission line would have a peak value of 43.1 mG directly underneath the transmission line and a value of approximately 22 mG at the edge of the right of way (Figure 7-8).

The voltage in a transmission line generates an electric field, but the magnitude of the electric field rapidly decreases with distance from the conductor. The electric field is expressed in a unit of volts per meter. Although there is no state or federal standard for transmission line electric field exposures, the Minnesota Environmental Quality Board (EQB) developed a standard of a maximum electric field limit of 8 kV per meter at one meter above ground. That standard, which is used by the Commission in routing assessments, was implemented to mitigate serious hazard from shocks when touching large objects parked under transmission lines with voltage of 500 kV or greater. The proposed 115 kV line will have a maximum magnitude of electric field density of approximately 0.5 kV per meter underneath the conductors one meter above ground level. Research on the biological effects from electric fields on animals and humans has shown no significant association with disease in humans.

7.4 Ozone and Nitrogen Oxide Emissions

Corona, which may produce ozone and oxides of nitrogen, consists of an ionic or electrical discharge from the surface of a transmission line conductor. It occurs when the electric field intensity or surface gradient on the conductor exceeds the breakdown strength of air. For a 115 kV transmission line, the conductor surface gradient is usually below the air breakdown level. Some imperfection, such as loose conductor support hardware or water droplets, is necessary to cause corona. When corona occurs, it will be within a few centimeters or less immediately surrounding a conductor. Ozone also forms naturally in the lower atmosphere from lightning discharges and from reactions between solar ultraviolet radiation and air pollutants such as hydrocarbons from auto emissions.

The natural production rate of ozone is directly proportional to temperature and sunlight and inversely proportional to humidity. Therefore, humidity (or moisture), the same factor that increases corona discharges from transmission lines, inhibits the production of ozone. Ozone is a very reactive form of oxygen and combines readily with other elements and compounds in the atmosphere. Because of its reactivity, ozone is relatively short-lived.

On July 18, 1997 the Environmental Protection Agency (EPA) promulgated a regulation (62 Federal Register 38856) replacing the 1-hour ozone 0.12 parts per million (ppm) standard with an 8-hour standard at a level of 0.08 ppm. The form of the 8-hour standard is based on the 3-year average of the annual fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area. Calculations using the Bonneville Power Administration *Corona and Field Effects Program Ver. 3* (USDOE, BPA, Undated) for a standard single circuit 115 kV project predicted the maximum concentration of 0.008 ppm near the conductor and 0.003 ppm at one meter above ground during foul weather or worst case conditions with rain at 4 inches per hour. During a mist (rain at 0.01 inch per hour) the maximum concentrations decreased to 0.0003 ppm near the conductor and 0.0001 ppm at one meter above ground level. For both cases, the ozone levels are below EPA standards.

Most calculations for the production and concentration of ozone assume high humidity or rain with no reduction in the amount of ozone due to oxidation or air movement. These calculations would therefore overestimate the amount of ozone that is produced and concentrated at ground level. Studies designed to monitor the production of ozone under transmission lines have generally been unable to detect any increase due to the transmission line facility.

7.5 Radio/TV Interference

The most significant factor with respect to radio and television interference is not the level of the transmission line induced noise, but how it compares with the strength of the broadcast signal. Very few problems have arisen with existing 115 kV transmission line radio noise, as radio stations have adequate signal to noise ratios such that interference is usually not a problem.

If radio interference from transmission line corona does occur with AM radio stations presently providing good reception, satisfactory reception can be obtained by appropriate modification of (or addition to) the receiving antenna system.

Interference with FM broadcast station reception is generally not a problem because:

- corona generated radio frequency noise currents decrease in magnitude with increasing frequency and are quite small in the FM broadcast band (88-108 megahertz), and
- the excellent interference rejection properties inherent in FM radio systems make them virtually immune to amplitude type disturbances.

A two-way mobile radio located immediately adjacent to and behind a large metallic structure (such as a steel tower) may experience interference because of signal blocking effects. Movement of either mobile unit so that the metallic structure is not immediately between the two units should restore communications. This would generally require a movement of less than 50 feet by the mobile unit adjacent to a metallic tower. Because no lattice steel towers are anticipated for the proposed 115 kV line, this will not be a problem.

Corona generated radio frequency noise is quite small in the very high frequency range used for television transmission. As a result, television interference from corona generated by the proposed 115 kV line will generally be negligible. Noise in the frequency range of cellular type phones is almost non-existent and the technologies used by these devices is superior to that used in two way mobile radio.

Loose and/or damaged hardware may also cause television interference. If television or radio interference is caused by or from the operation of the proposed 115 kV line in those areas where good reception is presently obtained, GRE will inspect and repair any loose or damaged hardware in the transmission line, or take other necessary action to restore reception to the present level, including the appropriate modification of receiving antenna systems if deemed necessary.