

# LUMEN TERRAIN

# USER'S MANUAL

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# 1 Prefix

## 1.1 Product Registration

Thank you for purchasing Lumen Terrain from Baker Hughes. Please register your product at [www.gemeasurement.com/productregistration](http://www.gemeasurement.com/productregistration) for product support such as the latest software/firmware upgrades, product information, and special promotions.

## 1.2 Services

Baker Hughes provides customers with an experienced staff of customer support personnel ready to respond to technical inquiries, as well as other remote and on-site support needs. To complement our broad portfolio of industry-leading solutions, we offer several types of flexible and scalable support services including: Training, Product Repairs, Service Agreements and more. Please visit [www.gemeasurement.com/services](http://www.gemeasurement.com/services) for more details.

## 1.3 Typographical Conventions

The following typographical information can be found throughout the manual. Here are the meanings of each

**Note:** *These paragraphs provide information that provides a deeper understanding of the situation but are not essential to the proper completion of the instructions.*

**IMPORTANT:** *These paragraphs provide information that emphasizes instructions that are essential to proper setup of the equipment. Failure to follow these instructions carefully may cause unreliable performance.*



**CAUTION!** This symbol indicates a risk of potential minor personal injury and/or severe damage to the equipment, unless these instructions are followed carefully.



**WARNING!** This symbol indicates a risk of potential serious personal injury, unless these instructions are followed carefully.

**NOTICE**

**NOTICE!** This symbol indicates information considered important but not hazard related.

## 1.4 Safety



**WARNING!** It is the responsibility of the user to make sure all local, county, state and national codes, regulations, rules and laws related to safety and safe operating conditions are met for each installation.

### **NOTICE**



**NOTICE!** For EU customers, to meet CE Mark requirements for all units intended for use in the EU, all electrical cables must be installed as described in this manual.

## 1.5 Auxiliary Equipment

### 1.5.1 Local Safety Standards

The user must make sure that he operates all auxiliary equipment in accordance with local codes, standards, regulations, or laws applicable to safety.

### 1.5.2 Working Area

	<b>WARNING!</b> Auxiliary equipment may have both manual and automatic modes of operation. As equipment can move suddenly and without warning, do not enter the work cell of this equipment during automatic operation, and do not enter the work envelope of this equipment during manual operation. If you do, serious injury can result.
	<b>WARNING!</b> Make sure that power to the auxiliary equipment is turned OFF and locked out before you perform maintenance procedures on this equipment.

### 1.5.3 Qualification of Personnel

Make sure that all personnel have manufacturer-approved training applicable to the auxiliary equipment. Please make the factory aware of any customer visits so that any further support to the customer can occur immediately.

### 1.5.4 Personal Safety Equipment

Make sure that operators and maintenance personnel have all safety equipment applicable to the auxiliary equipment. Examples include safety glasses, protective headgear, safety shoes, etc.

### 1.5.5 Unauthorized Operation

Make sure that unauthorized personnel cannot gain access to the operation of the equipment. Security levels need to be set properly at the completion of any customer visit.

## 1.6 Product Security

<b>NOTICE</b>	<b>NOTICE!</b> This instrument is intended to be used in closed network environments. Customers should take standard cyber security precautions when adding this device to their network infrastructure (i.e. network firewalls, anti-virus, etc.) This is only a concern when the instrument is connected via ethernet.
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The customer shall provide adequate physical site security measures to protect the Lumen Terrain Sensor Nodes, Base Station, and supporting hardware (antennas, solar panels, weather station, etc.) from damage due to vandalism, airborne debris, theft, security breaches.

Lumen Terrain provides data encryption to protect customer data from intentional snooping that is transmitted via the RF over the air interfaces (between base station and sensor node and between the base station and cloud).

The system also has built in diagnostics for monitoring of the health of system components in the event of sub system degradation or failure. The equipment requires adequate physical security to protect the equipment from damage or intrusion due to forces beyond the design intent of the system.

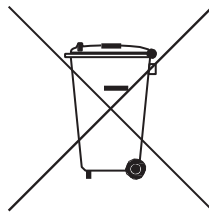
## 1.7 Environmental Compliance

### 1.7.1 RoHS

The Sensor Solutions Lumen-Terrain fully complies with RoHS regulations (Directive 2002/95/EC).

### 1.7.2 Waste Electrical and Electronic Equipment (WEEE) Directive

Baker Huhges is an active participant in Europe's *Waste Electrical and Electronic Equipment* (WEEE) take-back initiative (Directive 2012/19/EU).



The equipment has required the extraction and use of natural resources for its production. It may contain hazardous substances that could impact health and the environment.

To avoid the dissemination of those substances in our environment and to diminish the pressure on the natural resources, we encourage you to use the appropriate take-back systems. Those systems will reuse or recycle most of the materials of your end life equipment in a sound way.

The crossed-out wheeled bin symbol invites you to use those systems.

If you need more information on the collection, reuse and recycling systems, please contact your local or regional waste administration.

Please visit <http://www.gemeasurement.com/environmental-health-safety-ehs> for take-back instructions and more information about this initiative.



## 1.8 FCC Statements

### FCC Interference Statement (Part 15.105 (b))

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

### RF Exposure Guidance

In order to comply with FCC / ISED RF Exposure requirements, this device must be installed to provide at least 20 cm separation from the human body at all times.

“Afin de se conformer aux exigences d'exposition RF FCC / ISED, cet appareil doit être installé pour fournir au moins 20 cm de séparation du corps humain en tout temps.”

### FCC Part 15 Clause 15.21

“Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment”

### FCC Part 15.19(a)

“This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.”

### ISED RSS-Gen Notice (in English and French):

“This device complies with Industry Canada's licence-exempt RSSs. Operation is subject to the following two conditions:

- 1) This device may not cause interference; and
- 2) This device must accept any interference, including interference that may cause undesired operation of the device.”

“Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:

- 1) l'appareil ne doit pas produire de brouillage;
- 2) l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.”

### ISED Canada ICES-003 Compliance Label

“CAN ICES-3 (B)/NMB-3(B)”

Base Station FCC ID: 2AZ9Q-LTBS

Sensor Node FCC ID: 2AZ9Q-LTSN

## 2 Introduction

### 2.1 Overview

The reduction of fugitive methane emissions is one of the most pressing needs in the Oil & Gas industry today. Traditional measurement practices are often inaccurate and inefficient – putting operators at risk of dangerous, damaging and costly leaks. In response to this, Baker Hughes has developed a unique and flexible digital platform that integrates continuous, 24/7 monitoring via ground-based sensors.

The LUMEN TERRAIN is a high accuracy fugitive methane gas leak detection system that will continuously and remotely detect leaks without the need for human intervention. This ground-based monitoring technology provides real-time quantification and notification of methane emissions while enabling prescriptive analytics for preventative maintenance.

### 2.2 Theory of Operation

The LUMEN TERRAIN uses metal oxide semiconductors to detect methane. When semiconductor particles are heated, they absorb methane, which changes the resistance of the semiconductor. This change is a linear and proportional relationship to the methane concentration. Once calibration has been completed at the factory, measuring the semiconductor's resistance will provide the methane concentration.

To accurately pin-point the location of fugitive methane emissions, an array of these methane detectors will be spread around an area of interest. The sensors are mounted onto the Sensor Nodes of the system, which will transmit data back to the Base Station and to the cloud for analysis.

### 2.3 System Components

The system contains a main hub – the Base Station, and several other smaller units – the Sensor Nodes.

#### 2.3.1 Base Station

As the hub of the system, the Base Station is responsible for collecting data transmitted by the Sensor Nodes and sending this data to the cloud where it will be analyzed.

The Base Station consists of the stainless steel enclosure, the 50W solar panel, and the weather station. The stainless steel enclosure contains the electronic boards, wireless router, battery, and a magnetic stylus to reset the Sensor Nodes. Primary

power comes from the solar panels, while the batteries will act as a backup during nighttime or low sunlight. The battery is expected to keep the system running for 7 days without solar power if data is transmitted twice a day.



### **2.3.2 Sensor Node**

The Sensor Nodes contain the metal oxide semi-conductor methane sensors and temperature/humidity sensors. Ideally, multiple Sensor Nodes are to be installed in an array that is spread across an area of interest to best pinpoint the location of fugitive methane emissions.

Each Sensor Node contains the electronic enclosure and the 30W solar panel. Inside the electronic enclosure is a battery that is charged by the solar panel. Primary power comes from the solar panel, while the battery can supply power for the Sensor Node for 7 days at a data transmission rate of twice per day.

## 3 Installation

### 3.1 Installation Guidelines

	<b>WARNING!</b> The LUMEN TERRAIN Sensor Nodes are installed in hazardous areas where flammable methane gas may be present. The importance of proper safety practices cannot be overemphasized.
	<b>WARNING!</b> Be sure to follow all applicable local safety codes and regulations for installing electrical equipment. Consult company safety personnel or local safety authorities to verify the safety of any procedure or practice.

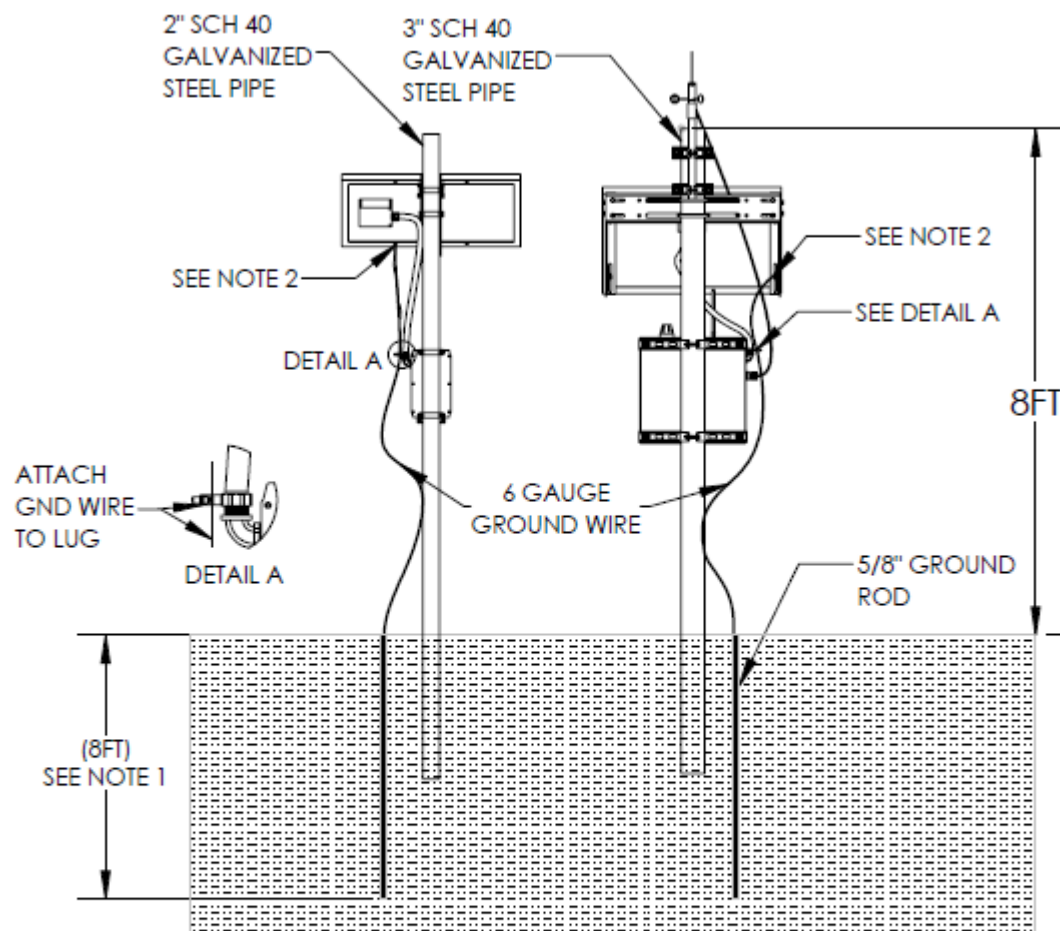
<b>NOTICE</b>	<b>NOTICE!</b> For EU Customers, to meet CE Mark requirements, all cables must be installed as described in Appendix D.
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This section provides general information with respect to the mechanical and electrical installation and should be thoroughly reviewed before the system is installed. To ensure safe and reliable operation of the LUMEN TERRAIN, the system must be installed in accordance with the established guidelines per application engineering drawing. Those guidelines, explained in detail in this chapter, include the following topics:

- Unpacking the LUMEN TERRAIN System
- Installing the Base Station, Sensor Nodes, and Solar Panels
- Site Considerations
- Making Electrical Connections

### 3.2 Customer's Responsibility

Prior to installation of the LUMEN TERRAIN System, the Baker Hughes field engineer must ensure that the proper infrastructure is pre-installed by the customer. It is the customer's responsibility to properly install the poles needed for the Base Station and Sensor Nodes, and the associated grounding rods and 10 feet of 6 gauge, stranded insulated grounding wire. Figure 1 provides a guideline for the infrastructure.



NOTES:

1. UNDERGROUND DEPTH MUST BE BELOW FROST LINE. VARIES BY REGION
2. 6 GAUGE WIRE TO BE CRIMPED TO A RING TERMINAL 1/4" STUD SIZE AND FASTENED TO GROUNDING SLOTS ON SOLAR PANEL USING GROUNDING FASTENERS.

Figure 1: Recommended Grounding Infrastructure

## 3.3 Unpacking the Lumen Terrain System

The LUMEN TERRAIN will typically be packaged in a wooden crate, the size of which will depend on the number of Sensor Nodes ordered for the system.

Please inspect the Base Station, Sensor Nodes, and Solar panels upon receiving the package. Each instrument manufactured by Baker Hughes is warrantied to be free from defects in material and workmanship. Before discarding any of the packing materials, account for all components and documentation listed on the packing slip. If anything is missing or damaged, contact Baker Hughes Customer Care immediately for assistance.

### 3.3.1 Inspection

Prior to installation, inspect all material to be used in the installation, including:

- Nuts & Bolts – check for debris and damaged threads
- Solar Panels – check for cracks or delamination of solar cells
- Weather Station – check for damaged anemometer cups

## 3.4 Site Considerations

Proper installation of Lumen Terrain is important to achieve optimum performance from the system. The following installation recommendations provide general guidelines of how this system should be installed. If the following recommendations cannot be met, please consult an application engineer for a more detailed review of the application to see what performance may be achievable. Following these recommendations may not be the solution for all, since every installation is different.

### 3.4.1 Installation Location – Base Station



**WARNING!** Installation of the Base Station in areas other than General Purpose may create a dangerous environment that may include fires and explosions that may lead to serious injury, or death.

The Base Station is not rated for hazardous locations and must be installed in a general-purpose area. Following local building and electrical codes, the customer is responsible for providing a pre-installed pole for the Base Station to mount on. The standard pole is an 8-ft tall, 3" SCH 40 pole. This is the minimal recommended size due to the weight of the Base Station and solar panel, and external loads from the environment such as snow accumulation and wind gusts.

### 3.4.2 Sensor Nodes

The Sensor Nodes are certified by a third-party certification agency to be used in Class I Division 2 areas, meaning they can be installed in hazardous locations that will occasionally contain ignitable concentrations of gases or vapors and are rated for IP65. It is recommended to spread out the installation of the Sensor Nodes around the area of interest. Following local building and electrical codes, the customer is responsible for providing a pre-installed pole for each Sensor Node to mount on. The standard pole is an 8-ft tall, 2" SCH 40 pole. This is the minimal recommended size due to the weight of the Sensor Node and solar panel, and external loads from the environment such as snow accumulation and wind gusts.



## 3.5 Base Station Installation

This section will guide you through the installation of the Base Station enclosure, solar panel, weather station, and necessary electrical connections.



**CAUTION!** The Base Station weighs 52 lbs. with the battery installed. This requires two people to lift and install.

### 3.5.1 Weather Station Installation

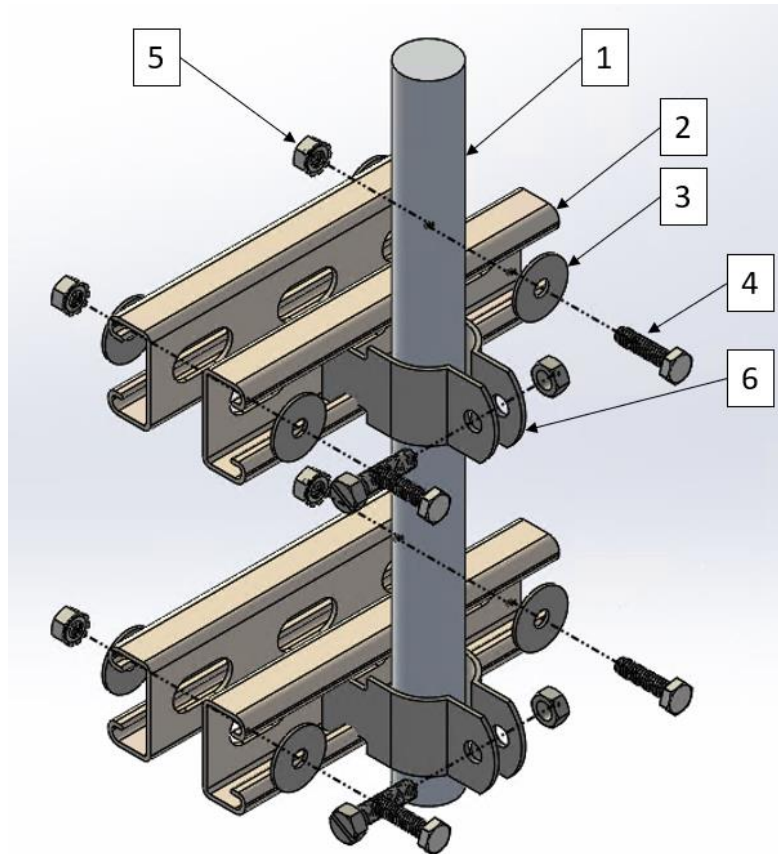
Tools Required:

- 1/2" sockets for 1" pole clamp
- 5/8" sockets for 3" pole clamp
- 7/16" sockets for struts
- Phillips Screwdriver for weather station set screws
- Step ladder
- Tape Measure
- Marker

To assemble the weather station mounting, reference the following figure and table, and follow the proceeding steps:

**Table 1: Weather Station Mounting Assembly Item Table**

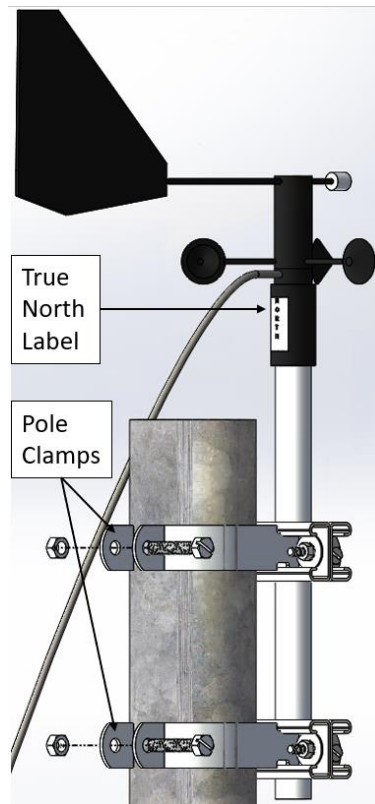
Item No.	Description	Quantity
1	1" Aluminum Rod	1
2	6" Aluminum Unistrut	4
3	1" OD Washer	8
4	1/4-20 Bolt	4
5	1/4 -20 Keps Nut	4
6	15/16" Strut Clamp	2



**Figure 2: Weather Station Mounting Assembly, Exploded**

1. Take two pieces of Item 2 and have them face back to back. Use Items 3, 4, and 5 to fasten the two pieces of Item 2 together as shown in Figure 2.
2. Repeat Step 1 for the other pair of Unistrut (Item 2).
3. Loosen the bolt/nuts on Item 6 and slide the brackets into one of the two pieces of assembled Unistruts from Step 2. Insert Item 1 (Aluminum Rod) in between the brackets.
4. Ensure the end of the rod is levelled with the bottom of the Unistrut before tightening the bolt/nut that was previously loosened in Step 3.
5. Repeat Step 3 for the other set of Unistruts, and space it 4" above the other Unistrut assembly before tightening the bolt/nut for the clamp.

For mounting the fixture to the pole and attaching the weather station, the following steps, refer to following figure:



**Figure 3: Weather Station Assembly Pole Mount**

6. Slide the pole clamps onto the struts of the weather station assembly completed on the previous steps, and mount it onto the pole – an inch or two below the top of the pole as seen in Figure 3 and tighten the bolts.
7. Place the weather station on top of the aluminum rod, and orient it such that the “North” label is facing true north.
8. Tighten the set screws on the weather station.

### 3.5.2 Solar Panel Installation

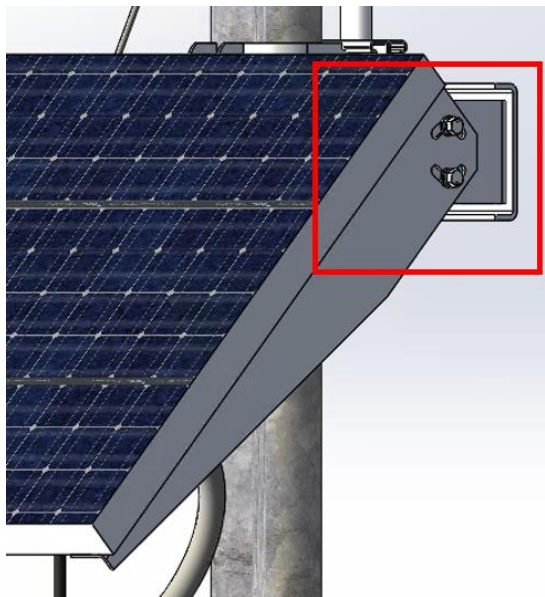
Tools Required:

- 9/16 in. socket wrench for u bolt
- ½ in. socket wrench for solar panel brackets
- 7/16 in. socket wrench for solar panel to brackets
- Angle finding device (protractor, digital level, phone app etc.)
- Step Ladder
- Tape Measure
- Marker
- Tarp



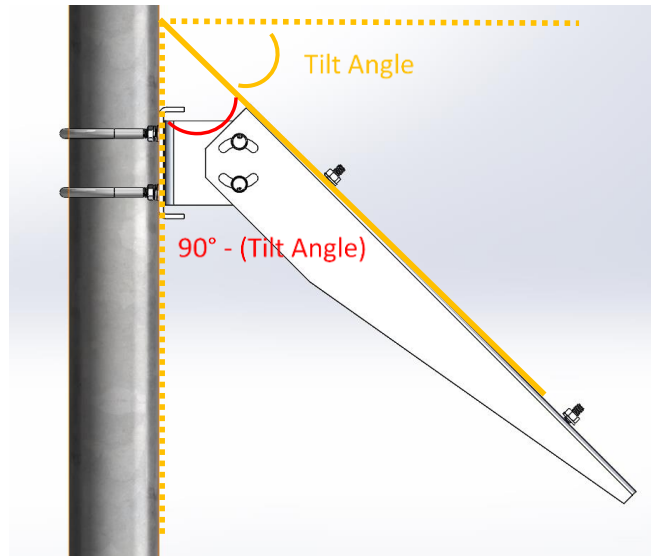
**WARNING!** The solar panel must be covered with an opaque material when connecting solar panel outputs to the system. Failure to do so may lead to injury and/or damaged components.

1. The bracket for the Base Station solar panel comes in a long rectangular box, and it is recommended to assemble the kit before mounting it. The instructions are provided in the kit, and is shown in the Appendix B for reference, but do not tighten the angling bolts. Tighten all other bolts to 6ft-lbs. The angling bolts are shown in figure below:



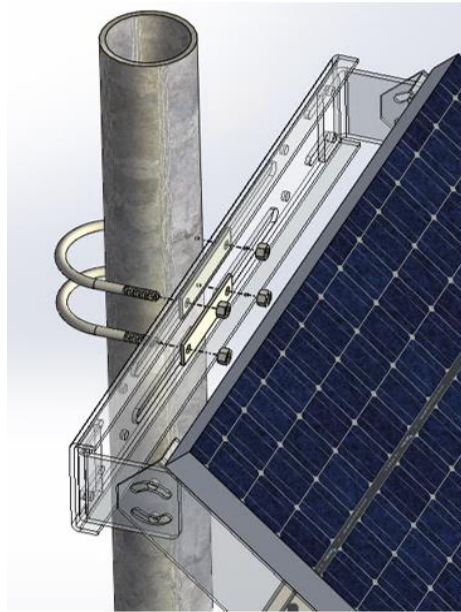
**Figure 4: Solar Bracket Angling Bolts**

2. Using a protractor phone app, and the reference table in the Appendix E set the solar panel to the optimal angle and then tighten the angling bolts to 6ft-lbs. A convenient reference when assembling the mounting bracket is to use the angle to the vertical pole, which is the angle highlighted in red in figure below:



**Figure 5: Solar Bracket Angling**

3. On the 3" pole, mark the pole at approximately 87 inches from the ground, with the marker on the side of the pole that is facing towards the equator. This should be slightly lower than the weather station previously installed.
4. Raise the completed solar panel assembly to the marked point and secure the assembly with the U-bolts.
5. Torque the U-bolts to 6ft-lbs.



**Figure 6: Solar Bracket U-Bolt Mounting**

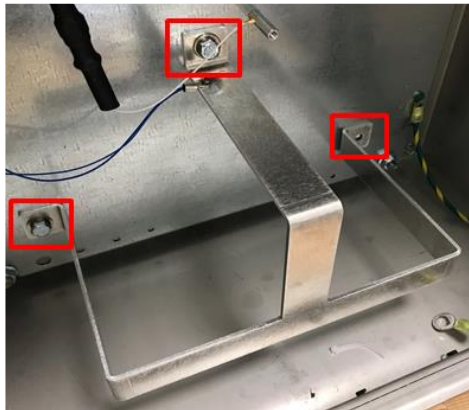
### 3.5.3 Enclosure Installation

Tools Required:

- 1/2" sockets for brackets
- 7/16" socket for battery removal
- Slotted Screwdriver for quarter latch on enclosure
- Tape measure

The enclosure is to be installed at the recommended height of 65 inches measured from the base of the pole to the top of the enclosure. Removing the battery prior to installation is recommended, as this will decrease the weight of the enclosure and make it easier to handle. This can be done by first removing the three 7/16 in. bolts shown in red boxes of Figure 7.

Once the battery mounting bracket has been removed, the battery can be pulled out.



**Figure 7: Battery Mounting Bracket**

When the enclosure is raised to the specified height, insert the routing clamps into the struts mounted on the back of the enclosure and torque the bolts to 9 ft-lbs.

### 3.5.4 Antenna Installation

Tools Required:

- 5 in.-lb torque wrench, 5/16"

Due to the length of the Sub-1G antenna, the antenna does not come installed on the Base Station. Remove the protective cap on top of the Base Station enclosure and torque the supplied Sub-1G antenna on the exposed bulkhead to 5 in-lbs as shown in Figure 8.



**Figure 8: Antenna Installation**

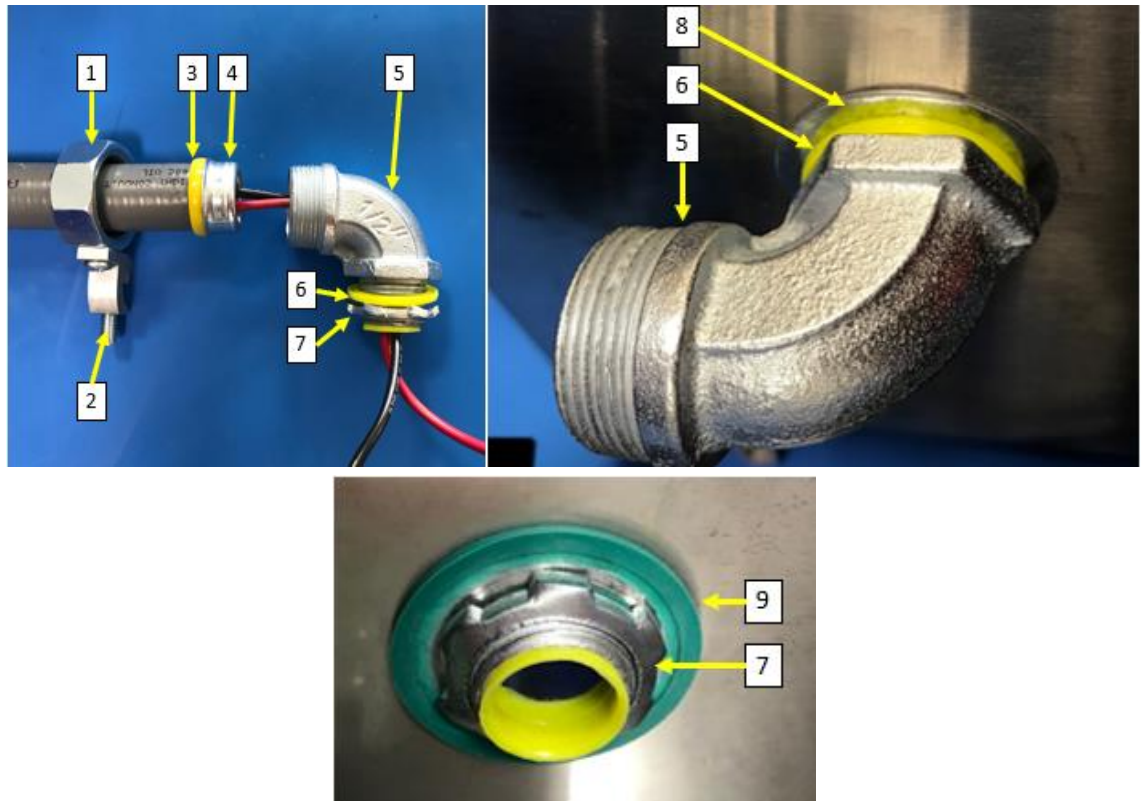


### 3.5.5 Conduit Connection (Base Station Enclosure End)

Tools Required:

- Adjustable wrench for conduit (capable of at least 1.3 in.)
- Phillips Screwdriver for ground lug
- Hammer + slotted screwdriver for tightening

For the Base Station Conduit installation, all instructions will refer to **Figure 9** to **Figure 11**:



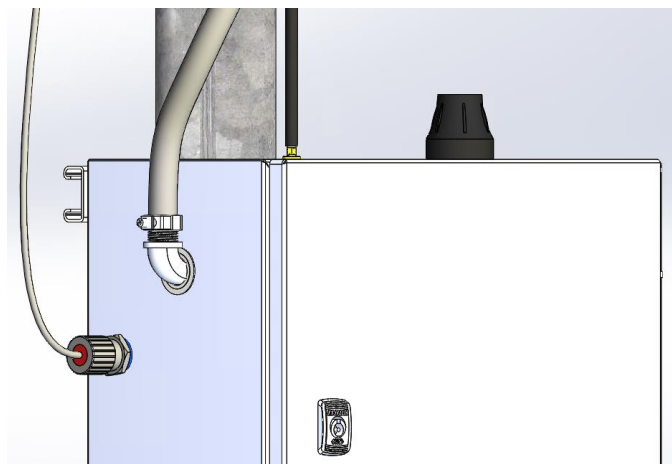
**Figure 9 (Left): Right Angle Conduit Detail**

**Figure 10 (Right): Right Angle Exterior Connection**

**Figure 11 (Bottom): Interior Right-Angle Adapter Connection**

1. To attach the right-angle conduit adapter to the base station enclosure, loosen Item 1 from Item 5 so they are disconnected as shown in **Figure 9**. Note that Items 3 and 4 should already be attached to the conduit as shown.
2. Ensure Item 4 is fully inserted by turning it clockwise until there is no more movement.
3. Remove the cables from Item 5 and remove the lock nut (Item 7). There is a supplied washer kit – one metallic ring (Item 8, **Figure 10**) and one rubber ring (Item 9, **Figure 11**) – to adapt Item 5 to the hole in the enclosure.
4. Insert Item 8 onto Item 5 with Item 6 separating the two pieces, as seen in **Figure 10**. Then, insert the right-angle adapter into the enclosure hole.
5. Insert the rubber ring (Item 9) in such a way that the raised groove is fitted into the enclosure hole. Note that the groove will not sit perfectly flush with the enclosure wall.
6. Hand tighten Item 7 first to get the lock nut to grip onto Item 9. Then, turn Item 5 until the free end points up towards the antennas (refer to Figure 12). Note that Items 7 and 5 may need to be adjusted to achieve this orientation.
7. Once Item 5 has been hand-tightened, use a wrench and give Item 5 one complete turn. Visually inspect that Item 6 is compressed to ensure a watertight connection.
8. Remove Item 2 from Item 1 and ensure the cables from the conduit reach the interior of the enclosure via Item 5.
9. Re-attach Item 1 onto Item 5 until it is hand-tight, then use a wrench to tighten Item 1 by giving it 1.25 to 1.5 turns. Reinstall Item 2 onto Item 1. If Item 1 is oriented in such a way that Item 2 cannot be attached, continue tightening Item 1 until there's enough clearance for Item 2.

The finished assembly should look similar to Figure 12. Note that the orientation of Item 2 may be different. Install the customer provided grounding wire into the ground lug (Item 2) and ensure the other end of the ground wire is attached to the customer installed grounding rod.



**Figure 12: Finished Right Angle Conduit Connection**

### 3.5.6 Weather Station Wiring

Tools Required:

- Small slotted screwdriver

An assortment of colored wires housed in a gray cable should extend from the weather station. Figure 13 displays a cutaway view of the electrical panel in the enclosure. Refer to the below figures and tables when following the instructions in this section:

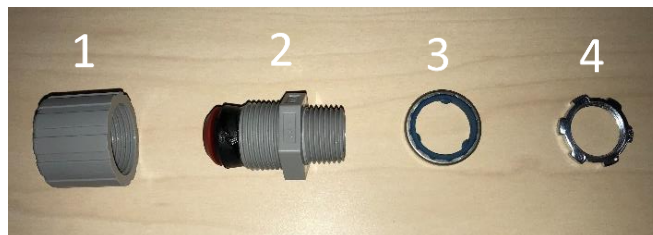
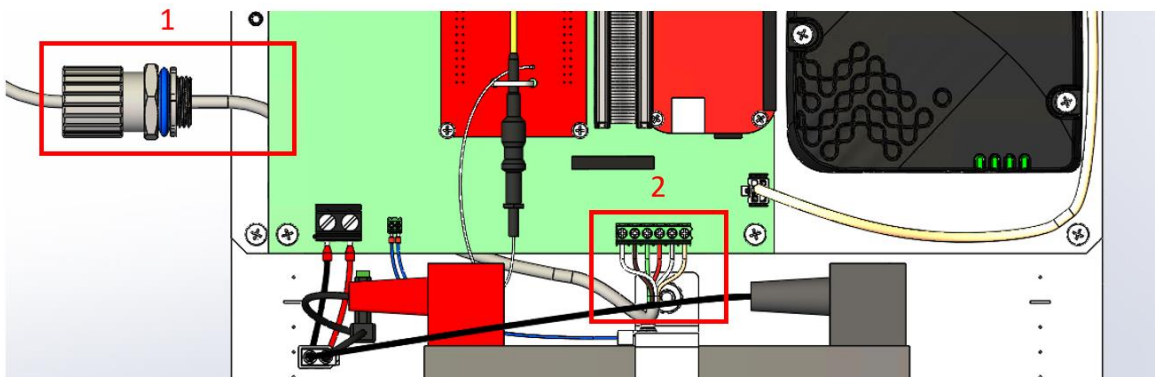


Figure 13 (Top): Weather Station Connection

Figure 14 (Middle): Cord Grip Components

Figure 15 (Bottom): Weather Station Wiring

Table 2: Weather Station Wiring Scheme

Abbreviation	WHT	BRN	GRN	RED	BLK	SHLD
Color	White	Brown	Green	Red	Black	Shield
Order (L to R)	1	2	3	4	5	6

1. Assemble the cord grip highlighted in box 1 of Figure 11 by inserting the gray cable through Items 1 and 2 in Figure 12. Ensure that the colored wires in the gray cable can reach the terminal in Box 2 in Figure 11.
2. Screw Item 1 onto Item 2, then proceed to attach Item 3 onto the the other end of Item 2 snug against the hexagonal portion. Item 3 will be on the outside of the enclosure.
3. Insert this assembly into the lower left hole on the base station enclosure, then secure by attaching Item 4 on the inside of the enclosure and tightening with a wrench. The red portion should grip the gray cord firmly to ensure a water-tight connection. The colored wires should reach the screw terminal that is highlighted by box 2 in Figure 11.
4. Use a small slotted screwdriver to secure each colored wire to its terminal, as displayed in **Error! Reference s**  
**ource not found.** Table 2 indicates the correct order in which to arrange the wires in the screw terminal.

### 3.5.7 Power Connection



**WARNING!** If none of the LEDs illuminate, power must be disconnected immediately. In general, if the system is not operating correctly, all power sources must be disconnected and exposed wire leads must be wrapped in electrical tape.

Tools Required:

- Small slotted screwdriver

1. Connect the leads of red and black wire from the conduit that are threaded through the right angle adapter completed from Section 3.5.5 to the terminal board as shown in box 1 of Figure 16.
2. Plug the connection shown in box 2. The green lights on the wireless modem and blue lights on the right PCBA will illuminate, as shown in boxes 3 and 4 of Figure 16 respectively.
3. If no lights turn on after a few seconds, unplug the battery connection and remove the solar panel power from Step 1. Check the fuses on the solar panel connection (to the right of the solar panel power connection), and the battery cable (in-line) by removing them and performing a continuity test on the leads. Refer to Appendix A for spare components.

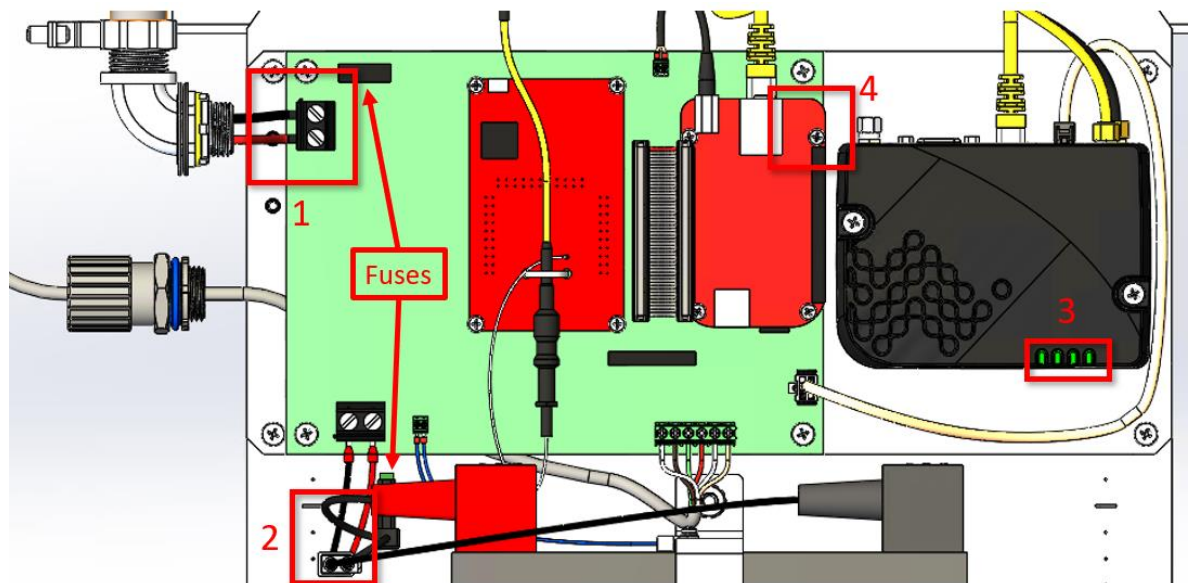


Figure 16: Base Station Power Connections

## 3.6 Sensor Node Installation

This section will guide you through the installation of the Sensor Node enclosure, solar panel, weather station, and necessary electrical connections.

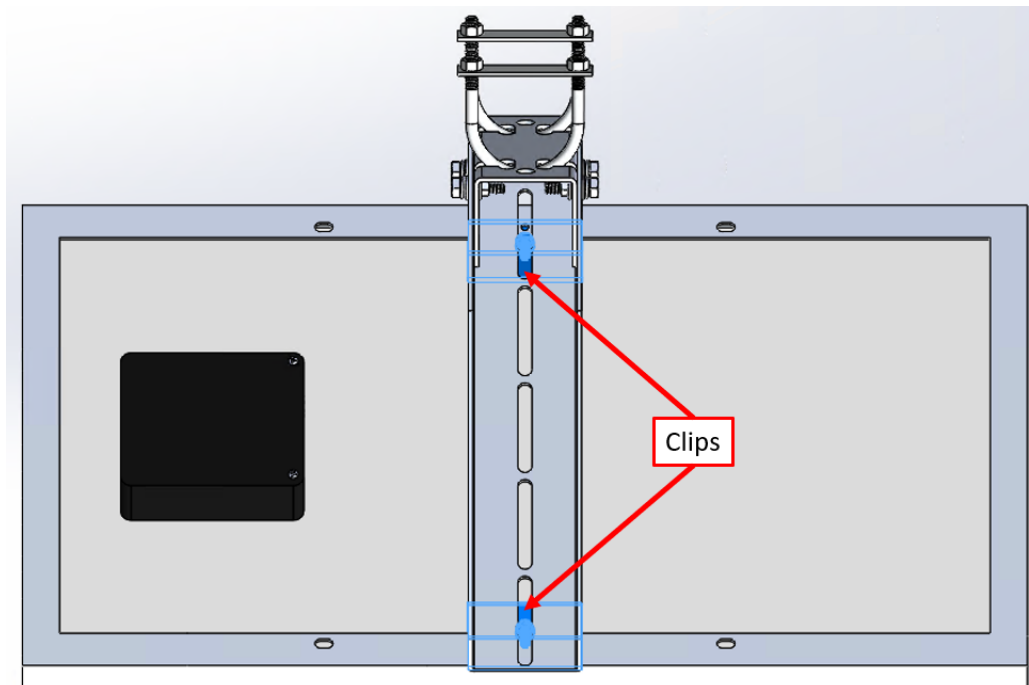
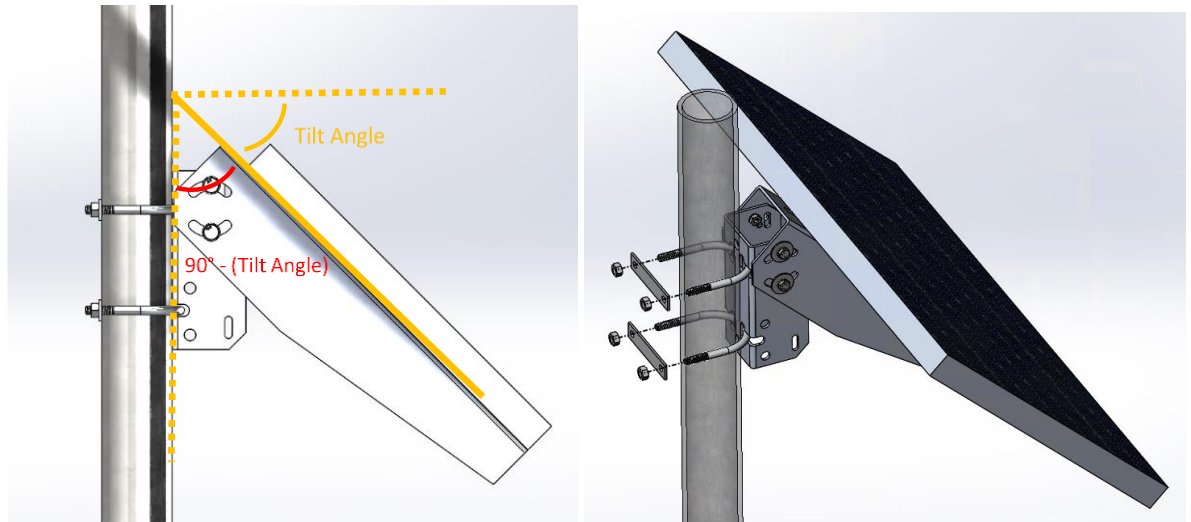
### 3.6.1 Sensor Node Solar Panel



**WARNING!** The solar panel must be covered with an opaque material when performing any electrical connections and troubleshooting. Failure to do so may damage components or injure personnel

Tools Required:

- 1/2" sockets for U-bolts
  - 5/16" sockets for bracket to solar panel
  - Step Ladder
  - Tape Measure
  - Angle finding device (protractor, digital level, phone app etc.)
  - Marker
  - Tarp
1. Mark the 2" Sch 40 pole at 90 inches measured from the base, facing towards the equator.
  2. Attach the solar panel to the mounting bracket assembly.
  3. Remove the backing plate of the U-bolts and position Install the Sensor Node solar panel on the pole at a height close to 90 inches measured from the top of the mounting bracket to the base of the pole.
  4. The orientation of the bracket will depend on location of the site. As a rule of thumb, always orient the bracket so the solar panel will face towards the equator, using true north and true south when orienting the panel. Mark the height and orientation of the solar panel to ensure accurate installation.
  5. At a fixed installation angle, the optimal tilt angle is approximately the value of the latitude of the location. Figure 17 illustrates the tilt angle. During the mounting bracket assembly, it may be more convenient to utilize the angle measured from the vertical, which is highlighted in red. Check the references section for more detail on optimal angles.
  6. Loosen the clips of the bracket and slide them into the panel and center it, as seen in Figure 19
  7. Install the entire assembly onto the pole at the specified height, as shown in Figure 18, and torque the U-bolts to 90 in-lbs.



**Figure 17 (Left): Solar Panel Tilt Angle (Node Assembly)**

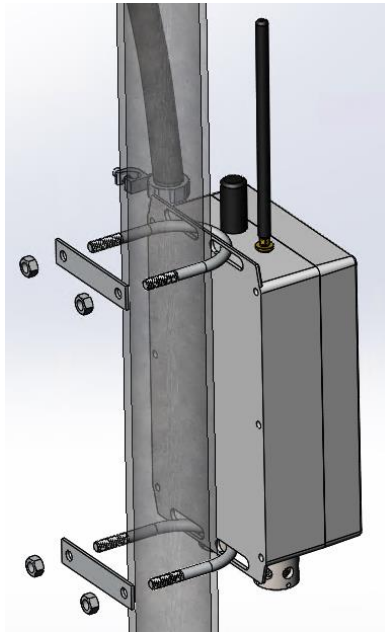
**Figure 18 (Right): Solar Panel Assembly Pole Mount**

**Figure 19 (Bottom): Solar Panel Bracket Clips**

### 3.6.2 Sensor Node Enclosure Installation

Tools Required:

- 1/2" Sockets for U-bolts
  - Tape Measure
  - Marker
1. Mark the pole with the requirements mentioned in Section 3.4.2 at a height of 64 inches measured from the pole base.
  2. Position the Node enclosure to the marked height and orient it directly under solar panel.
  3. Insert the U-bolts into the elongated holes as shown in Figure 20 and torque the U-bolts to 90 in-lbs, or until the U-bolt brackets start to bend. Ensure that the backplate rests on the pole itself and not on the flange of the enclosure.



**Figure 20: Node Enclosure Installation**



### 3.6.3 Antenna Installation

Tools Required:

- 5 in.-lb torque wrench, 5/16"

Due to the length of the Sub-1G antenna, the antenna does not come installed on the Base Station. Simply remove the protective cap on top of the Base Station enclosure and torque the supplied Sub-1G antenna on the exposed bulkhead to 5 in.-lbs as shown in Figure 21.

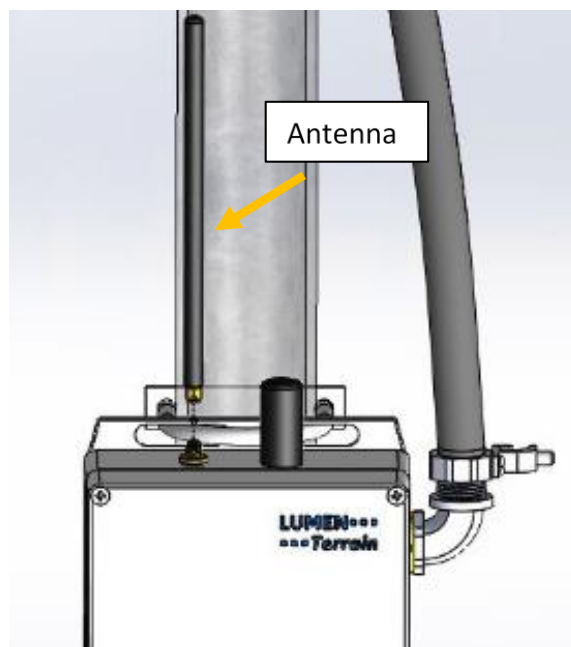


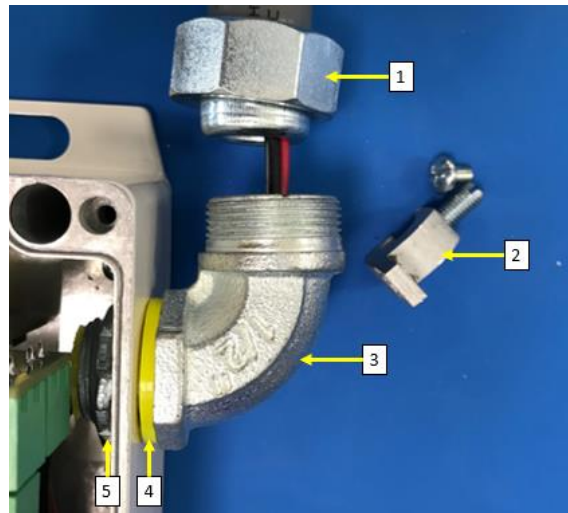
Figure 21: Sensor Node Antenna Installation

### 3.6.4 Sensor Node Conduit Connection (Enclosure)

Tools Required:

- Long-tip needle nose pliers
- Adjustable wrench for conduit (capable of at least 1.3 in.)
- Phillips Screwdriver for ground lug and enclosure cover screws

Refer to the following Figure for Item callouts in the upcoming steps:



**Figure 22: Sensor Node Right Angle Adapter Item Callouts**

1. Unscrew the 6 screws on the front of the enclosure.
2. Remove Item 1 from Item 3 along with the red and black cables. Then, remove Item 5 from Item 3 and insert this end into the open hole of the Sensor Node enclosure, keeping Item 4 on the outside of the enclosure as shown adjacent.
3. In the same manner as the Base Station installation, Items 5 and 3 should be adjusted such that the open end of Item 3 points in the opposite direction as the antennas.
4. Proceed to use a wrench to turn Item 3 one-half turn and visually inspect that Item 4 is compressed to ensure a water-tight connection. Item 3 should point in the same direction as the antennas.
5. Pull the red and black cables from the conduit through Item 3. Needle-nosed pliers may be needed.
6. Remove Item 2 from Item 1 and hand-tighten Item 1 onto Item 3. Using a wrench, tighten Item 1 by turning it 1.5 turns to ensure a water-tight connection is made.

7. Reattach Item 2 onto Item 1. If Item 1 is oriented such that Item 2 cannot be attached, continue tightening Item 1 until there is enough clearance for Item 2.

### 3.6.5 Sensor Node Wiring



**WARNING!** The solar panel must be covered with an opaque material when performing any electrical connections and troubleshooting. Failure to do so may damage components or injure personnel

Tools Required:

- Slotted Screwdriver
1. Fully insert the red wire from the conduit into the Solar Panel Fuse Assembly (highlighted in blue) as shown in Figure 23.
  2. Next, remove the Solar Panel Terminal, insert the black wire into the remaining open port, and secure the wire by tightening the screw terminal.
  3. Plug the Solar Panel Terminal back into the PCB in the position shown in Figure 23.
  4. The battery end of the Battery Fuse Cable should already be connected to the battery connections under the Battery Terminal Shield. Attach the Battery Terminal to the PCB as shown in Figure 23.
  5. Once both green connectors are blocked in, use the supplied 8" cable tie to secure the connections as shown in the figure, and cut off excess length.

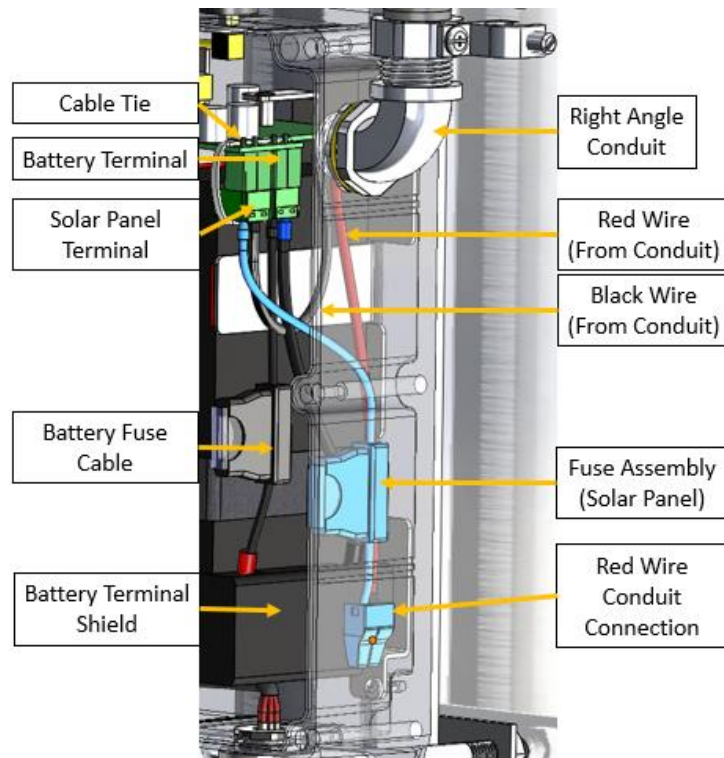


Figure 23: Node Power Connection

### 3.6.6 Enclosure Cover

Tools Required:

- Torque Screwdriver, Phillips Bit

1. Re-install the sensor node cover by torqueing the screws to 12 in-lbs in the order shown in the figure below:

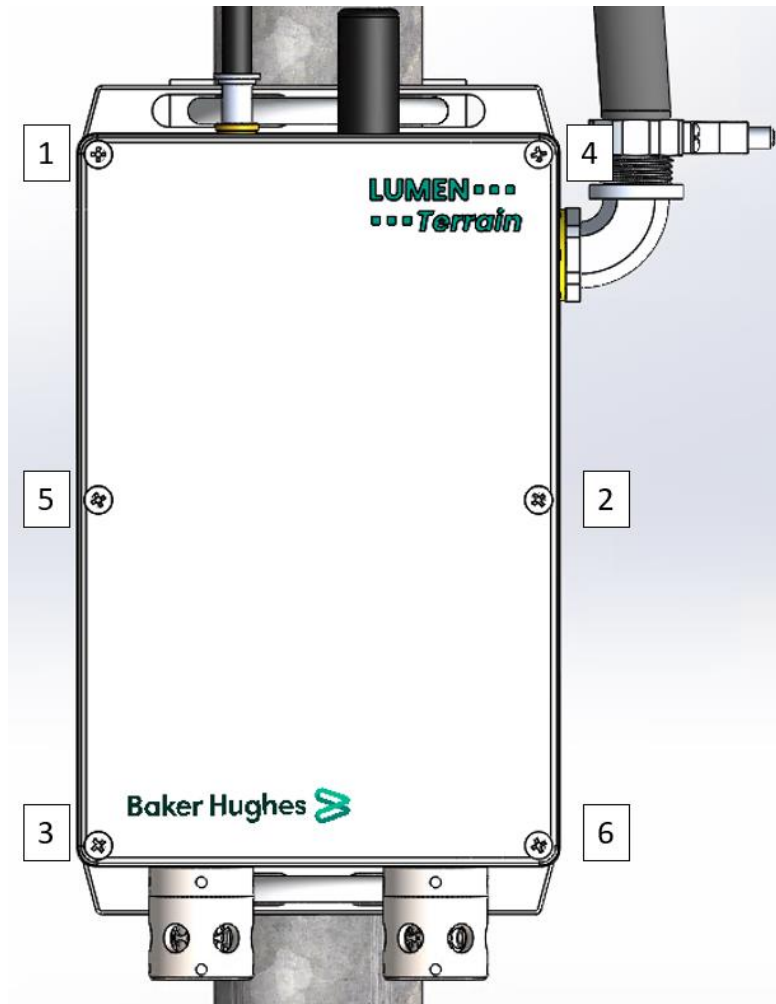


Figure 24: Enclosure Bolting Pattern

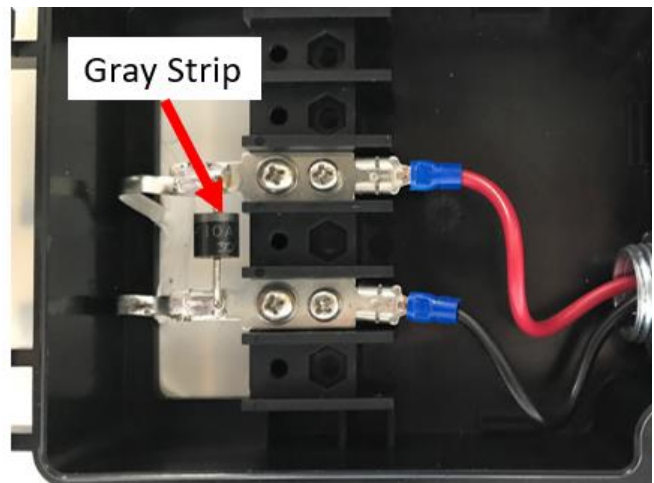
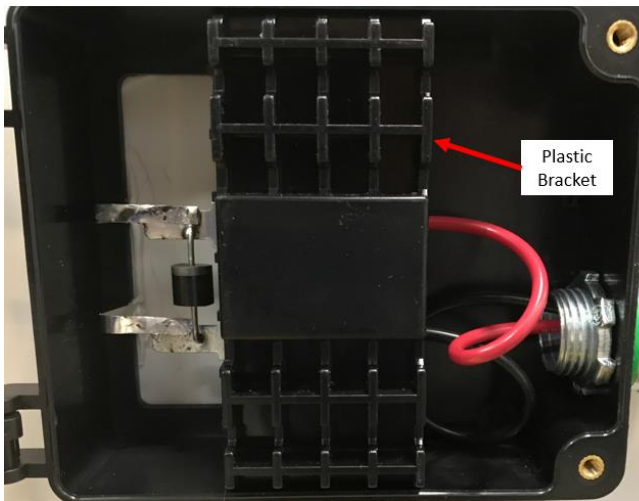
## 4 Troubleshooting

### 4.1 Wiring Connection, Solar Panel

*Tools Required:*

1. Philips screwdriver to unscrew box

In the solar panel, remove the plastic bracket shown in Figure 26. Then, connect the wire lugs of the conduit at the solar panel end to the terminals inside the junction box of the solar panel as seen in Figure 25, ensuring that the red wire (positive) plugs into the terminal connected to the side of the diode with the gray strip. Re-attach the plastic bracket over the terminals such that the finished configuration matches Figure 24.



## Appendix A Spare Parts

This section lists all the spare parts for the Lumen Terrain system if troubleshooting procedures has indicated a hardware failure.

### A.1 Base Station Spare Parts

**Table 3: Base Station Spare Parts**

Baker Hughes PN	Description	Picture
126M6391	50W Solar Panel	
126M6398	12V Battery	
130M9040	Sub 1G Antenna	
134M9103	Comm Station Board Stack	

130M8606	Sierra Wireless Modem	
132M5508	5A Fuse	



## A.2 Sensor Node Spare Parts

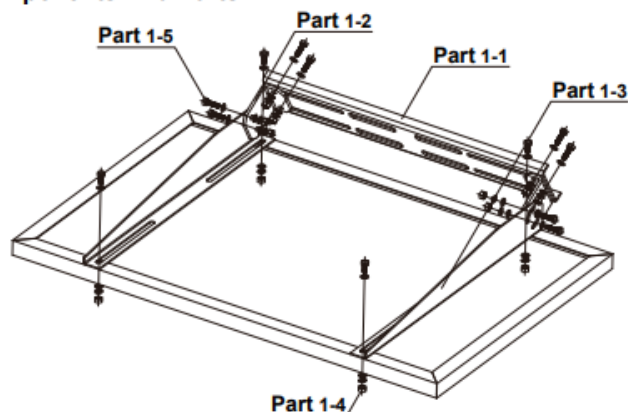
**Table 4: Sensor Node Spare Parts**

Baker Hughes PN	Description	Picture
129M4502	Sensor Node Assembly	 A beige rectangular sensor node assembly with a black antenna on top. It has "LUMEN" and "Terrain" printed on the top right and the Baker Hughes logo on the bottom left.
130M1103	30W Solar Panel	 A rectangular solar panel with a grid of blue cells and a white border.
128M5166	9V Battery	 A black rectangular 9V battery with a red and black terminal on the right side.
130M9040	Sub 1G Antenna	 A thin, black, cylindrical antenna with a gold-colored base.



## Appendix B : Base Station Solar Panel Bracket Assembly

### Components And Parts



#### Part



#### Part 1-1

Component	Fixed Bracket
Material	5052Al
Quantity	1



#### Part 1-2

Component	Strutting Piece
Material	5052Al
Quantity	2



#### Part 1-3

Component	Tilt Arm
Material	5052Al
Quantity	2



#### Part 1-4-1

Component	Mounting Bolt(M8×20)
Material	AISI304
Quantity	4



#### Part 1-4-2

Component	Mounting Bolt(M6×20)
Material	AISI304
Quantity	4



#### Part 1-5

Component	Mounting Bolt(M8×30)
Material	AISI304
Quantity	8

**Step1.** Attach the PV module to the mounting bracket using the nuts, bolts, washers, and lock washers provided. See **figure 1**. Caution: If additional holes on the frame of the PV module are needed, great care must be used when drilling. Damage to the module can easily occur rendering it useless. You may find it helpful to lubricate the nut and bolt to facilitate easy removal at a later date.



figure 1

**Step2.** To adjust the tilt angle of the PV panel, change the location of M8 bolts in the arc hole of the tilt arms. Remember to use lock washers to prevent vibration from working them loose.

**Step3.** Place PV module and mount assembly on mounting surface in the exact place to be installed. See **figure 2**. Use at least 4 fastening points. Use four M8 bolts, washers, lock washers and nuts if possible. Otherwise use wood screws, sheet metal screws, anchors, or molly bolts ( not included ).

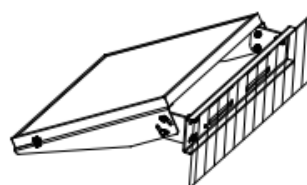


figure 2

**Step4.** Be sure to seal all roof or wall penetrations with a compatible weatherproof sealant.

#### Note

Pole Mounting can be accomplished using two U-bolts (not included). See **figure 3**.

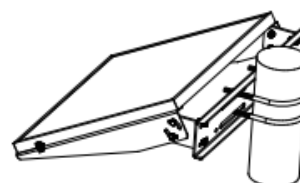


figure 3

## Appendix C Torque Specifications

### C.1 Base Station

Table 5: Base Station Torque Specifications

Component	Torque
Exterior	
Sub-1G Antenna	5–5.25 in-lbs (56–59 N-cm)
Sierra Wireless Antenna	54–57 in-lbs (610–644 N-cm)
Solar Panel Adapter (locknut)	1 turn pass hand-tight
Solar Panel Adapter (conduit)	1.5 turns pass hand-tight
Right Angle Adapter (locknut)	1 turn pass hand-tight
Right Angle Adapter (conduit)	1.5 turns pass hand-tight
Weather Station Enclosure Adapter	½ turn pass hand-tight
Solar Panel Brackets	6–6.3 ft-lbs (8.13–8.54 Nm)
Solar Panel Bracket U-bolts	6–6.3 ft-lbs (8.13–8.54 Nm)
Weather Station Struts and Poles	6–6.3 ft-lbs (8.13–8.54 Nm)
Enclosure Routing Clamps	9–9.5 ft-lbs (12.2–12.88 Nm)
Interior	
Battery Cables	5–5.25 ft-lbs (6.75–7.12 Nm)
Solar Terminals	7–7.35 in-lbs (79–83 N-cm)
Weather Station/Thermistor Terminals	3.5 in-lbs (40 N-cm)
All SMA Connections	5–5.25 in-lbs (56–59 cNm)
Main PCB Board Stack	7–7.35 in-lbs (79–83 N-cm)

### C.2 Sensor Node

Table 6: Node Torque Specifications

Component	Torque
Sub-1G Antenna	5–5.25 in-lbs (6.75–7.12 Nm)
Enclosure Cover	12–12.6 in-lbs (136–142 N-cm)
Solar Panel Brackets	6–6.3 ft-lbs (8.13–8.54 Nm)
Solar Panel U-bolts	90–94.5 in-lbs (1017– 1068 N-cm)
Enclosure U-bolts	90–94.5 in-lbs (1017– 1068 N-cm)
Right Angle Adapter (locknut)	1 turn pass hand tight
Right Angle Adapter (conduit)	1.5 turns pass hand tight
Solar Panel Adapter (locknut)	1 turn pass hand-tight
Solar Panel Adapter (conduit)	1.5 turns pass hand-tight

## Appendix D : Complete List of Tools

### 3.5 Base Station Installation

#### 3.5.1 Weather Station Installation

- 1/2" sockets for 1" pole clamp
- 5/8" sockets for 3" pole clamp
- 7/16" sockets for struts
- Phillips Screwdriver for weather station set screws
- Step ladder
- Tape Measure
- Marker

#### 3.5.2 Solar Panel Installation

- 9/16 in. socket wrench for u bolt
- ½ in. socket wrench for solar panel brackets
- 7/16 in. socket wrench for solar panel to brackets
- Angle finding device (protractor, digital level, phone app etc.)
- Step Ladder
- Tape Measure
- Marker
- Tarp

#### 3.5.3 Enclosure Installation

- 1/2" sockets for brackets
- 7/16" socket for battery removal
- Slotted Screwdriver for quarter latch on enclosure
- Tape measure

#### 3.5.4 Antenna Installation

- 5 in-lb torque wrench, 5/16"

#### 3.5.5 Conduit Connection (Base Station Enclosure End)

- Adjustable wrench for conduit (capable of expanding to at least 1.3 in.)
- Hammer + slotted screwdriver for tightening
- Phillips screwdriver for ground lug

#### 3.5.6 Weather Station Wiring

- Small slotted screwdriver

#### 3.5.7 Power Connection

- Slotted screwdriver for power wires

### **3.6 Sensor Node Installation**

#### **3.6.1 Sensor Node Solar Panel**

- 1/2" sockets for U-bolts
- 5/16" sockets for bracket to solar panel
- Step Ladder
- Tape Measure
- Angle finding device (protractor, digital level, phone app etc.)
- Marker
- Tarp

#### **3.6.2 Sensor Node Enclosure Installation**

- 1/2" Sockets for U-bolts
- Tape Measure
- Marker

#### **3.6.3 Antenna Installation**

- 5 in.-lb torque wrench, 5/16"

#### **3.6.4 Sensor Node Conduit Connection (Enclosure)**

- Long tip needle nose pliers to put wires in
- Adjustable wrench for conduit (capable of at least 1.3 in.)
- Phillips Screwdriver

#### **3.6.5 Sensor Node Wiring**

- Slotted screwdriver for wiring

## Appendix E : Solar Panel Tilt Angles by Region

Table 7: Optimal Tilt Angle by City Reference

Country	Nearest City	Latitude (deg.)	Longitude (deg.)	Optimal Tilt (deg.)
Canada	Calgary	51.12	-114.02	45
Canada	Vancouver	49.18	-123.17	34
Canada	Montreal	45.5	-73.62	37
Canada	Yellowknife	62.45	-114.4	40
Canada	Whitehorse	60.72	135.1	39
USA	Raleigh, NC	35.86	-78.78	32
USA	Bakersfield, CA	35.43	-119.05	29
USA	Raleigh, NC	35.86	-78.78	32
USA	Bakersfield, CA	35.43	-119.05	29
USA	Austin, TX	30.29	-97.74	28
USA	Miami, FL	25.76	-80.19	24
USA	Denver, CO	39.74	-105.0	35