

Center Pivot Irrigation Design

In response to water shortages in Arizona, the University of Arizona is establishing an irrigation demonstration and experimental site with center pivot, flood, gravity drip, and pressurized drip irrigation systems. This bid request is for the center pivot irrigation system. Because it is a demonstration site, the pivot should include the manufacturer's most up to date smart technology, controlling individual sprinkler application rates (pulse) and center pivot velocity and providing imaging and remote sensing capability, if possible.

The center pivot will have a 97.6 m (320 ft) radius and use drop tube sprays or bubblers on 40 inch spacing. The maximum pivot velocity should be three rotations per day. The center pivot will cover 7.4 irrigated acres with a maximum daily application rate of 17 mm/day (0.67 inches/day) with 24 hours operation. Nozzle packages should include bubblers, 2 m diameter, and 4 m diameter spray heads. Three nozzle packages are required for experiments on different crops. The height of drop tubes should easily adjustable.

Structural design:

The listed components shall have the following features:

1. Center Pivot General Features:
 - a. Concrete pad for pivot point.
 - b. Under truss design.
 - c. 480-volt system.
 - d. Span length of 160'.
 - e. Overhang properly supported.

- f. Electrically powered and controlled towers.
 - g. Spans supported by self-propelled towers.
- 2. Pivot Point Structures:
 - a. Heavy-duty pivot point structure.
 - b. Non-towable, mounted to the concrete pad per the manufacturer's specifications.
- 3. Pivot Point Components:
 - a. A 90-degree rotating pivot elbow with a 6-5/8" OD or similar.
 - b. Heavy duty collector ring which limits restrictions to flow.
 - c. The pivot head, riser, and joints shall also be 6-5/8" OD or similar.
 - d. Accurate and reliable position encoder.
 - e. The riser pipe shall have a 1/4" pipe thread fitting or similar for installing a pressure gauge and pressure transducer.
- 4. Pivot Point Plumbing: A customized epoxy coated, watertight fitting by flange gooseneck, model number, with stainless steel bolts and nuts, shall be used to make the connection from the below-ground pipeline to the aboveground pivot riser. A minimum thrust block of 5 square feet by 2 feet thick shall be poured perpendicular to the thrust on the gooseneck, with the 5 square feet against undisturbed soil. AR/VR2 and vents (described in other sections) and a quick-acting pressure relief valve shall be properly positioned upstream of the butterfly valve on the gooseneck. Another one shall be located upstream of the control valve. Flanged connections shall be made between the gooseneck, manually operated butterfly valve, magnetic flow meter, and the control valve. The connection to the riser pipe elbow shall be per the pivot manufacturer's specifications. The pressure loss, brand, and model of on/off valves at each pivot must be specified. An

irrigation water flow meter must be provided at each pivot. They shall be full-bore (with signal converter) magnetic meters, which only require a single pipe diameter of straight length upstream and downstream. The bid must include a typical price difference per pivot if the average pivot inlet pressure can be reduced by 2, 4, 6, 8, and 10 psi – as compared to the “standard typical” pivot.

5. Lateral Pipeline:

- a. The pipeline shall be of suitable material to meet the corrosion requirements detailed in these specifications.
- b. The center pivot lateral pipeline size shall be 6-5/8” or similar.
- c. Wall thickness shall be of 11 gauge or thicker.
- d. All flanges shall be of steel material.
- e. Brackets shall be welded to the pipeline for the truss braces.

6. Pipeline Outlets:

- a. The outlets shall be tapered with 3/4” NPT threads.
- b. The outlets shall be watertight.
- c. There shall be a standard 60” spacing of outlets or very similar.

7. Towers:

- a. Heavy duty construction.
- b. The towers shall be tied to the truss braces.
- c. The towers shall have a ladder for maintenance and service.

8. Truss Rods and Braces:

- a. Truss rods shall be made of 3/4” steel.
- b. Truss braces shall be in pairs, with one pair on each side of the lateral pipeline.

- c. The braces shall connect to the brackets on the lateral pipeline.
- d. The lateral pipeline shall be supported by truss braces at a minimum of every 20 feet.
- e. An angle truss plate shall be bolted between two truss brace pair on each side of the pipe.
- f. The truss braces shall be supported by the truss rods.

9. Ground Clearance:

- a. A ground clearance at the lowest point in the span, which is the truss supports, shall be a minimum of 9 feet.

10. Fasteners:

- a. All bolts shall be grade 5 or better.
- b. Locknuts shall be used with all structural assemblies. All bolts shall be zinc plated or stainless steel.

11. Structural Safety Factors:

- a. There shall be a minimum safety factor of 1.5, applied to yield strength.
- b. The pivot structure and all structural members shall be designed to applicable AISC specifications.

12. Welding:

- a. All welding shall be done in accordance with the American Welding Society (AWS).
- b. Welding shall be done by qualified welders.

Span couplers and joints:

1. Couplers and Boots:

- a. The coupler shall be flexible.
 - b. A one-piece boot shall provide a watertight seal.
 - c. The rubber boot shall be easily replaced.
- 2. Joints:
 - a. The joint shall be constructed to allow movement in each of the spans.
- 3. Drains:
 - a. Each joint shall be equipped with an automatic drain in the lowest point of the span.
 - b. These drains shall close when under pressure and open when the pressure is relieved.

Wheel Gear Boxes:

- 1. Wheel Gear Box:
 - a. A heavy-duty gear box shall be used.
 - b. A gear box shall be located at each wheel.
 - c. The gear box shall have an output ratio of 50:1.
- 2. Seals and Lubrication:
 - a. The wheel gearbox shall have seals adequate to prevent leaking.
 - b. Oil shall be filled to normal operating level, to submerge all bearings.

Center Drive Gear Boxes and Electrical Motors:

- 1. Center Drive:
 - a. Each tower shall be propelled by a center drive gearbox and a 1 HP electric motor located at the center of each drive tube.

- b. Each center driver shall be rated as “high speed” with an output of 50 RPM minimum.

2. Electric Motors:

- a. The electric motor designs shall comply with applicable provisions of NEMA and IEEE standards.
- b. The motors shall be required to keep moisture out.
- c. The electric motors shall be rated for a continuous duty cycle.
- d. Each motor shall have overload protection.
- e. Each motor shall be rated at 1 horsepower.

Wheel Specifications

1. Tires:

- a. Each self-propelled tower shall be provided with a minimum of two rims and rubber tires.
- b. All tires provided shall be of the same manufacturer and model.
- c. A tire size of 11.2 x 38 or similar shall be used for flotation purposes.
- d. The extra cost to substitute non-inflatable tires (to avoid flats) rather than the standard tires shall be provided.

Field Stops and Auto Reverse:

At the end of each part of the circle a large, heavy-duty barrier shall be constructed to prevent the pivot from leaving the field boundary. Each pivot shall be equipped with an auto reverse feature.

Wheel Tracks

The contractor shall be responsible for providing a compacted, raised wheel track for each set of tires, for the complete circumference of the tower (minus areas outside the part circle, such as in a wetlands area which the pivot will not cross). The raised wheel track shall not be constructed using adjacent soil (which would cause a depression to be formed on each side of the wheel track). Wheel tracks shall be twice the width of the tires and shall be raised 4 inches above the normal ground surface. Wheel tracks shall be constructed well enough that they will shed water satisfactorily for a minimum of 2 years.

Electrical Specifications:

1. ASAE Standards: Electrical service to the center pivots shall meet the American Society of Agricultural and Biosystems Engineers (ASABE) Standard S397.2 “Electrical Services and Equipment for Irrigation” and Standard S362.2 “Wiring and Equipment for Electrically Driven or Controlled Irrigation Machines.”
2. NEC Standards: The following sections of the National Electric Code (NEC) apply to electric drive center pivot irrigation systems, and shall be adhered to accordingly:
 - a. Article 250-51 Effective grounding.
 - b. Article 250-114 Effective grounding.
 - c. Article 310 Minimum size of conductors.
 - d. Article 210-5 Color code for branch circuits.
 - e. Article 430 Motors, motor circuits or controlled.
 - f. Article 675 Irrigation machines.
3. Control Panel Housing:
 - a. The control panel shall be readily accessible to the maintenance personnel.
 - b. The control panel shall be weatherproof.

- c. A minimum of a NEMA 3R enclosure shall be used.
- d. The enclosure shall be large enough for all required components.
- e. The enclosure shall be made of corrosion-resistant materials.

4. Master Control Panel:

- a. The master panel for the pivot shall be mounted at the pivot point structure.
- b. The center pivot shall be equipped with a networkable panel capable of communicating with central computer for control.
- c. The panel shall have a large display that is highly visible in sunlight.
- d. The panel shall be GPS capable.
- e. The panel shall be end-gun capable.
- f. The panel shall be highly customizable.
- g. The panel shall be able to control the flow (on/off) of the individual sprinklers on both spans such that water application can be varied to experimental plots by turning on or off for selected passes.
- h. A weatherproof outlet with 15 amp, 110V, shall be provided.

5. Main Disconnect Switch for the Pivot:

- a. A main disconnect switch shall be provided with overcurrent protection and it shall be capable of being locked in the OFF position.
- b. It shall be located at the point of connection to the electric power to the machine.
- c. The switch shall be rated at 20 amps and 600 volts minimum.
- d. A lightning arrestor shall be provided.

6. Tower Alignment Control:

- a. Tower alignment control shall use micro switches and motor contactors actuated through a mechanical linkage or equivalent.
 - b. The tower alignment mechanism shall be electrically and/or mechanically operated.
 - c. The alignment mechanism shall not be affected by changes in the terrain.
- 7. Machine Safety:
 - a. Safety switches shall shut the system off if normal alignment is not maintained.
 - b. The water supply shall be shut off automatically at the pivot point during the time the system is down.
- 8. Grounding: All systems shall have proper grounding according to local, state, and federal codes.
- 9. Safety Signs: Safety signs describing the automatic starting of the machine, grounding requirements, high voltage, caution and other pertinent safety signs shall be provided and prominently displayed.
- 10. Buried Electrical Wire to the Pivot Point:
 - a. A plan view drawing is needed for all electrical supply wires, and the wire sizing must be approved by a registered electrical engineer.
 - b. The information for the pivot must include the following information: Amps, 3-phase, voltage and Hz, length, voltage drop, metal type (e.g., copper or aluminum), number and size and model/brand of the bundle (e.g., “#4-4C CU THHN”), diameter and material of conduit pipe.
 - c. The wire and its installation must conform to all applicable ASTM specifications:
 - o UL Standard 83, 1581, and 1063(MTW)
 - o CSA
 - o NOM-ANCE 90° C
 - o Federal

Specification A-A-59544 o The National Electrical Code o VW-1 - Sizes 14 through 1 AWG o CT - UL 1685, Sizes 1/0 AWG and larger for CT use o FT1 - Sizes through 500 kcmil o T90 Nylon - Sizes through 500 kcmil o TWN 75 - Sizes through 500 kcmil o RoHS Compliant o Sunlight Resistant - Marked and listed in all colors 2 AWG and larger o NEMA WC 70 Construction Requirements.

Corrosion

The pivot package shall be guaranteed against any functional corrosion damage for a period of 10 years after installation, assuming operation of 2,000 hours/year. Damaged components or structural members, as well as all other identical components/members, shall be completely replaced by the vendor, at the full cost to the vendor, including labor and tax.

Sprinkler Package

Each sprinkler shall be equipped with:

- a. a 20-psi regulator.
- b. A sprinkler weight shall be used to minimize sprinkler movement and shall be attached in a manner that keeps the sprinkler vertical.
- c. Stainless steel hose clamps shall be used for the clamping mechanism.
- d. The sprinkler heights shall be adjustable between 0.5 m (18 inches) and 2.5 m (80 inches)
- e. The sprinkler package on the second span shall be designed for 14.3 gpm per acre.
- f. The sprinklers on the first (inside) span shall have individual flow rates capable of delivering 57.2 gpm per acre.

- g. Flexible hose is to be provided, with necessary auxiliary equipment, that will enable staff to change the vertical position of the sprinklers as the height of the crop changes.
- h. The sprinklers will need to be raised as high as possible when the crop is mature.
- i. The documentation of a DU_{lq} of better than 0.80 must be provided, with a sprinkler height of 0.5 m above a bare ground surface.
- j. Provide two sets of nozzles, with a double nozzle carrier on each sprinkler. One nozzle will be for 100% application rate; the second will be for 50% application rate.
- k. The appropriate sprinkler plate should be selected so that small droplets are created. It is understood that there is a compromise between wind drift and impact energy of the droplets on the soil. Several sprinkler options (pressure, plate design, etc.) should be presented in the bid.
- l. Boombucks, to place sprinklers, so that the pivot tires do not move over soil that is being wetted during that irrigation event, are to be supplied as spare, unattached parts.

Flush Out Line: A 3" high pressure hose with a brass ball valve shall be provided at the end of the machine to flush any material from the lateral pipeline or equivalent. A sand trap shall also be provided.

Warranty Specifications

The contractor (or similar entity) shall specify the warranty for the following, in writing, along with the bid proposal:

1. Component Warranty: For each item that is covered, specify:
 - a. Any cost that shall be borne by the customer (labor, material, tax).
 - b. The life of the warranty (in hours of operation and/or years life after installation)
 - c. Any pro-rating formula used in computing cost sharing or reimbursement.
 - d. Maximum days (from the call by the system user) to complete replacement/repair of this item once a trained technician has arrived.
 - e. How a decision is made as to whether an item is covered by warranty, or if there were some conditions which would negate the warranty.
 - f. Any lemon provisions.
2. Service: Maximum time that is required for a trained technician to respond to a call for a field visit. What parts are kept in stock locally (the definition of “locally” must also be specified)
3. Corrosion (see previous section).
4. Surveying The ultimate responsibility for proper locations of pivot points shall belong to the contractor. The contractor shall also determine the locations of any buried utilities, pipelines, etc. prior to installation of the pivots.

Locations of the pivot point and water and electrical sources are shown in the following diagram (Figure 1).

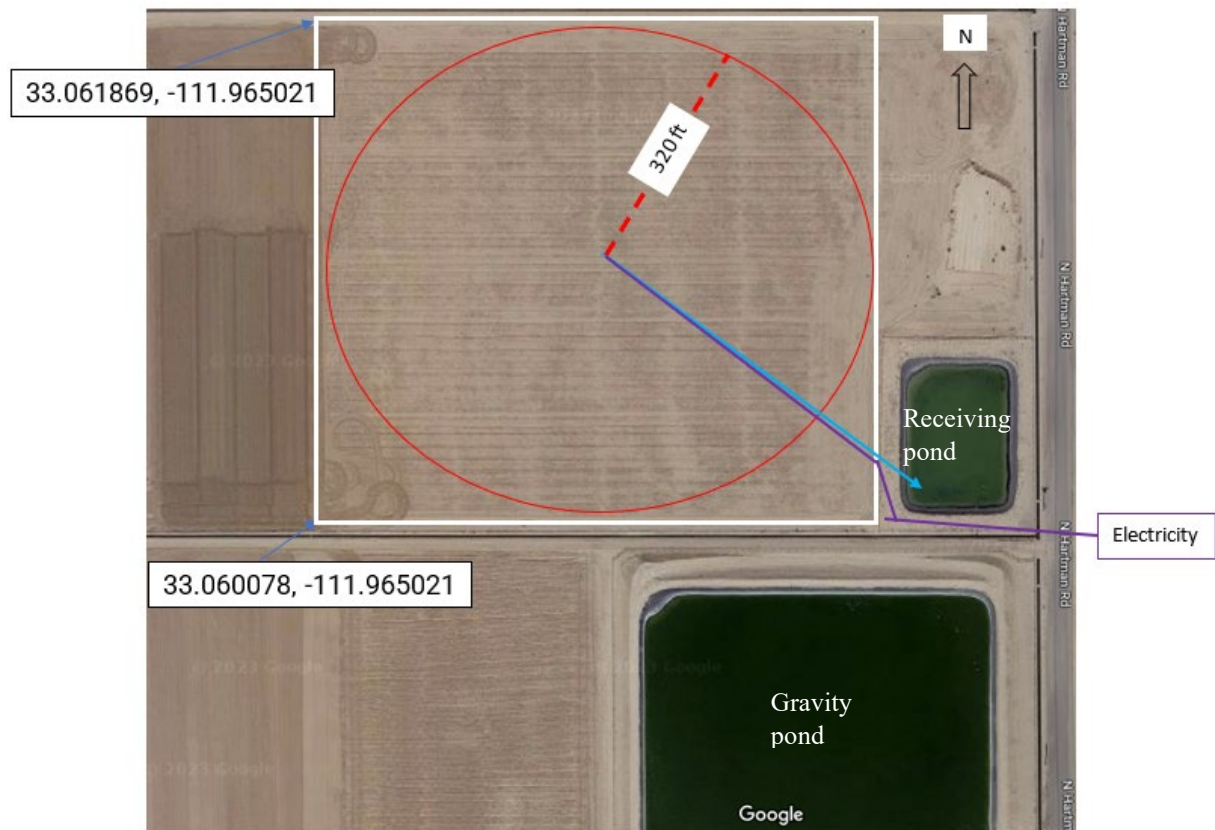


Figure 1. Center pivot location, and water and electrical sources.

Central Control and Monitoring

Equipment shall be installed which can provide the following:

1. Turning the individual pivot movement on/off (this is in addition to the control panel at the individual pivot) as well as the direction and speed of travel.
2. Ability to turn off sprinklers on the first tower, or automatically switch to every second or fourth pass.
3. Reading and recording the flow rates into the pivot.
4. Turning on, and shutting off, an automatic valve at the pivot, which will turn the water on or off.

5. Monitoring and control that is easy to understand and execute.
6. Monitoring and control that shall have warnings, alarms, and shutdown features.
7. Equipment that shall be expandable up to a minimum of 20 pivots.
8. Central control that shall be accessible via an internet connection to a computer and cell phone and provide the following:
 - a. Remote monitoring.
 - b. Remote on/off c.
 - c. Remote control including, but limited to, direction and speed.
 - d. External inputs for soil moisture monitoring equipment or similar.

Plumbing and Connections

Air Vents and Valves and Flow Measurement at the Pivot Point:

- a. A 6-inch Control Valve shall be provided at the pivot point to automatically shut off the flow if the pivot rotation stops due to mechanical or electrical problems.

The valve shall also be able to turn on or turn off the flow if a command from the central control system is received.
- b. All automatic hydraulic valves (e.g., slow opening and closing, pressure regulation) must be equipped with large external filters on the lines/hoses that supply water through the various orifices and pilot valves. These filters must be simple to clean without needing to use tools. All hoses/connections (such as between pressure sensing ports and pilot valves) must be covered with flexible stainless-steel sheathing, to minimize damage by animal chewing.

- c. The control valve shall be fully winterizable and provide protection against animals. The valve shall have drain plug(s) to prevent damage from freezing.
- d. Each pivot shall have a manual butterfly (with gear operator) isolation valve, located upstream of the riser.
- e. A 4-inch valve shall be placed upstream of the manual butterfly valve. This valve will provide quick acting pressure relief to prevent damage to the pipelines and filters.
- f. A flanged end high quality magnetic flow meter shall be supplied and installed approximately 3' upstream of the pivot riser. The display shall be capable of visually displaying (readable any hour of the day) both flow rate (GPM) and totalized volume (AF). It shall also have an electrical 4-20 mA output, which shall be wired to the master panel and transmitted back to the central location for remote manual reading and data collection, as well as a splitter signal to provide information to the fertigation controller.
- g. The wiring shall follow the manufacturer's specifications.

Pressure Transducer: A ½ inch female pipe thread port shall be provided on the riser pipe in a horizontal position. The port will allow for the connection of a pressure gauge and a pressure transducer for remote monitoring and automatic shutdown.

Connections: A water-tight compression fitting shall be made between the gooseneck and the PVC pipeline. All other connections shall be flanged with the exception of the connection to the center pivot riser pipe. That connection is dependent on the pivot manufacturer.

Winterizing It can be expected that there will be occasional freezing conditions during the irrigation season. Any valve tubes, components, etc. which are susceptible to damage from freezing must be provided with protection. In addition, a manual shall be provided which details all steps necessary to properly winterize the equipment.

Component Description: The customer shall be provided with a complete listing of various items that may need serviced (gear boxes, valves, sprinklers, pressure regulators, etc.), including maintenance manuals. The customer shall also be provided with a checklist for periodic maintenance.

Filtration:

- a. Filtration is required with 1/16-inch perforations in an appropriately sized stainless steel screen filter.
- b. Modification:
 - i. install a flush gate valve on the filter, centered on the end cap.
 - ii. Install pressure gauges upstream and downstream to identify when to manually flush the filter, inlet and outlet flanges and butterfly valves on the inlet and outlet.
 - iii. Install a continuous acting air vent. Specify a NPT threaded galvanized coupling on the top of the downstream end of the filter

Fertilizer Injection Pumps at the Pivot

Each pivot must be supplied with four (4) fertilizer injectors that can provide variable chemical injection rates. Required characteristics include:

1. Individual injectors must accurately pump within a 1:10 range, with a maximum required injection rate of 10 liters per hour (lph).
2. The accuracy of the controlled injector flow rate must be insensitive to the viscosity and density of the fluid being injected. In other words, the calibration of the injection rate must not be dependent upon the liquid being injected.
3. The fertigation pumps must be guaranteed to stay within 1% of their calibrated rate.
4. The fertigation pumps shall be equipped with materials that are capable of injecting acids and fertilizers, a list of which will be provided by the owner.
5. Each pump shall be equipped with an easily serviceable filter.
6. Each pump shall be capable of being manually controlled and calibrated, without the use of any programmable logic controller, in addition to being set up for automation.
7. Pumps and associated hardware shall be capable of functioning properly with chemical line inlet pressures as high as 60 psi.
8. Pumps shall be capable of injecting into irrigation lines with pressures of up to 75 psi.
9. The injection rate shall remain constant even if the irrigation line pressure varies with time.
10. Each injector shall have a magnetic flow meter that provides excellent accuracy over the range of injection.
11. The flow rates for individual magnetic flow meters must be displayed in a manner so that they are readable in the sunlight.
12. The fertilizer injectors must have inverter-duty motors that operate with variable frequencies.

13. Each injection discharge hose shall have a downstream end device that inserts the chemical into the middle of the flow stream of the irrigation pipe. These discharge devices must be spaced at least 0.5 m apart. They must each be equipped with a spring-loaded check valve, suitable for all injected chemicals, which will prevent backflow of the irrigation water into the chemical discharge hose/pipe.
14. Electrical injector pumps must have an automatic disconnect that completely stops injection and flow of fertilizer if:
 - a. There is no irrigation water flow, and
 - b. If the pivot stops rotation. (It should be noted that the chemicals arrive at each pivot under pressure.).
15. The injectors must be equipped with a controller that:
 - a. Provides automatic operation.
 - b. Has target flow rates that can be set in the field, or remotely from the office.
 - c. Can be attached to, and integrated into, the farm telemetry system.
 - d. Is capable of automatically providing proportional injection, if the flow rate changes (due to sprinklers being turned off).

Air vents

Air vents shall be placed before valves.

PVC Pipe and Fitting Pressure Rating:

1. The minimum pressure rating of PVC pipe is Class 7.5 (rated at 7.5 bars working pressure). It is understood that this is greater than what is required for internal pressures; the requirement is based on external loading.

2. All fittings for PVC pipe of 315 mm and greater must have a pressure rating of at least 7.5 bars.
3. Any bolts and nuts must be 316 stainless steel rather than galvanized. Any coating must be guaranteed to have no cracks or nicks and must cover the complete steel fittings, if used.
4. Bolting/fastening mechanisms must be designed to not damage the epoxy coating over any steel fittings.
5. The contractor must define how any unprotected threads on outlets will be protected from corrosion.
6. Thrust blocks must be provided per standard engineering specifications at all elbows, tees, and other such locations that might have problems with separation of the fittings from the pipe, including all gasketed fittings.
7. The minimum cover of the PVC pipe, and the type of bedding that is required (e.g., simple filling in of the trenches versus water tamping), must be determined using the procedures defined in Chapter 7 of the Handbook of PVC (published 2013 by the Uni-Bell PVC Pipe Association), or using the software found at <http://www.uni-bell.org/resources.php?c=45> . Those computations must account for the loading by harvesting and planting equipment. The minimum cover above the top of the pipe must be 1 meter or the result of the computations, whichever is greater.

Pumps:

A VFD pump will be placed at the pond. (120 GPM max flow) 75% efficiency between 60 and 120 GPM.

There are two water reservoirs on site, one of which is called the gravity pond and will be used to supply water to the smaller reservoir, called the receiving pond (Figure 1). The receiving pond is located on the southwestern corner of the actual test field and will be used to supply all experimental irrigation designs with a mixture of reclaimed, well, and canal water.

A high-quality submersible pump of appropriate HP, pressure, and flow rate for the pivot should sit within the receiving pond. The receiving pond should be drained to install a 4ftx4ftx1ft foundation of underwater concrete. This allows for the pump to remain stabilized while operating submerged in the reservoir.

A camlock fitting is used to connect discharge piping to the outlet, bringing the water up out of the reservoir and to the trenched piping that runs to the mainline inlet at the center pivot point.

The power source is located just southwest of the receiving pond and will supply power to the pumping station via outlet tower. The pumping station will in turn have a wire that runs to an outlet tower at the center pivot point to supply the pivot with power.

Each span will also contain 23 LEPA drop tubes and Nelson Sprayhead D3030 Sprinklers with multi-function 3NV nozzles while the overhang will have two of each. Sprinkler head specs include a pressure range between 6-40psi and variable wetted diameters of 1.8-16.5m

The control panel should be comparable to the ICON10 Smart Control Panel for full flex VRI and VRI iS software capability. This gives the research team the ability to irrigate variably for any number of plots underneath the center pivot. Distributing water to the test crop on a single pipe but at different rates of application without this type of software package would

require different types and/or sizes of sprinkler heads on the drop tubes that are coming down from the center pivot pipe to irrigate the crop. This along with new flow rate, application rates, and pipe friction loss calculations would be necessitated so that we could properly calculate the variable rates of application within each plot of the center pivot zone in the test field.

Variable rate application software should provide the ability to apply water variably throughout different zones in the field. Speeding up or slowing down the pivot, changing pipe flow rates, closing sprinklers heads, or adjusting sprinkler output and/or wetted diameters with machine learning algorithms and artificial intelligence detection sensors in real time application is just the beginning of what automation can do for the irrigation industry. Their software allows the user to run prescription checks on the soil moisture content of different areas of the field through NDVI and Thermal/Infrared imaging capabilities. These prescriptions are then imported into the VRI software on the control panel, allowing the software to calculate the necessary rates of application for each zone of the field while adjusting along the pivot as needed.