February 10, 2015

REPORT #E15-007

Agricultural Irrigation Initiative: Data Exchange Standards

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Acknowledgments

Several key participants in the agricultural irrigation data standards work have contributed greatly to the content of this report.

- Allan Fetters (Simplot) provided key insights into growers' needs and desires regarding data management.
- Dr. Andres Ferreyra (Ag Connections) has provided guidance on the process for developing data standards.
- Joe Russo (ZedX, Inc.) has been a key player in helping to reconcile agronomic terms used by the Natural Resources Conservation Service (NRCS) and machine language used by the International Organization for Standardization (ISO).
- Terry Schlitz (AgSense) serves as the Chairman of the Water Management Group in AgGateway, under which the PAIL project is funded and managed.
- Steve Melvin (Lindsay Corporation) and Andy Smith (Valmont) played championship roles within their respective pivot manufacturing companies.
- Other key contributors to the PAIL project include:
    - Lance Donny (OnFarm Systems)
    - Mark Elliot (Ranch Systems)
    - Bart Nef (Campbell Scientific)
    - Tom Penning (Irrometer)

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Executive Summary

Lack of integration remains a key barrier to the use of precision agricultural technologies. Precision irrigation relies upon the capture and analysis of multiple sets of data from various sensors and databases. As a foundational element of its Agricultural Irrigation Initiative, the Northwest Energy Efficiency Alliance (NEEA) brought together industry stakeholders to develop an agreed-upon set of data exchange standards[1] for the transmission of data necessary to develop, execute, and record a precision irrigation plan.

Together with NEEA, the industry stakeholders decided to initiate a data standards development project within AgGateway called the Precision Ag Irrigation Leadership (PAIL), a non-profit organization focused on helping growers, ag retailers, and supply chain partners capture, transfer, and manage data. The goal of the PAIL project is to provide an industry-wide format that will enable the exchange and use of data from irrigation management systems, which are currently stored in a variety of proprietary formats. Whenever possible, the PAIL project adopts existing data standards, such as the United Nations Economic Commission for Europe (UNECE) Recommendation No. 20, Codes for Units of Measure.

The project has included vendor and grower participant companies, each of which has paid fees and provided employee time in order to complete the work. NEEA has funded the project manager position to keep the project focused and moving forward.

To date, the PAIL project has completed Phase One of this project: writing data standards for collecting field information, such as soil moisture and weather conditions and forecasts, as well as for center pivot operations and reporting. The PAIL team is in the process of submitting these standards to the AgGateway Standards and Guidelines Committee in January, 2015. Once approved there, the standards will be published for comment and submitted to the American Society of Agricultural and Biological Engineers (ASABE), a standards body that works with international standards organizations such as the International Organization for Standardization (ISO). Working through AgGateway and ASABE increases the likelihood of industry stakeholders adopting the PAIL data standards. Several PAIL participants stated at the 2014 AgGateway annual meeting that they plan to adopt the PAIL data standards as quickly as possible.

Phase Two of the PAIL project will focus on working with industry stakeholders to test and promote the data standards developed to date, and on developing and testing the next set of data standards.

This report is one in a series of twelve reports addressing particular areas of NEEA's Agricultural Irrigation Initiative. All twelve reports are available at http://neea.org/reports.

[1] For simplicity, referenced as "data standards" throughout this report

1. Introduction

Technology has come a long way in helping growers to irrigate their land more efficiently. Growers can invest in technologies such as soil mapping, installation of various types of pumping plants and flow meters, soil sensors, putting Variable Rate Irrigation (VRI) systems on center pivots, and can even tie some of these together through software applications and communication. However, few of these tools actually communicate effectively or efficiently with one another between brands.

Key strategies for improving these inter-brand communications include the development of a common set of data standards for agricultural technologies – work that is currently underway and that forms the basis of this report. These data standards can assist utilities in providing more energy efficient technologies to their key customers so that they can use water and electricity more effectively.

Given the industry-specific and scientific natures of some terms used in this report, please refer to the AgGateway AgGlossary (http://agglossary.org/wiki/index.php/main_page) for definitions.

1.1. Data Standards in Precision Agriculture

Data standards are documented agreements on the representation, format, definition, structuring, tagging, transmission, and use of data. They provide a consistent way in which data are sent and received from one device to another device. As an analogy, all individuals in the United States address mail envelopes in the same way; confusion would reign if some customers transposed the lines for the street address, the recipient's name, or the zip code. Likewise, if a company such as Amazon had to deal with different versions of order forms for each of its customers, its operational efficiency would be challenged.

The irrigation equipment industry currently experiences this type of variation in representing data. Precision agriculture technology has provided many tools to help growers irrigate their land more efficiently. Growers have adopted these new tools over time, and their equipment inventory often consists of different brands or even generations of the same brands.

These tools rarely work together well. Each proprietary tool sends pieces of data such as soil moisture, weather, or water measurements in its own way. This lack of consistency among tool data formats greatly hinders agronomists' and growers' abilities to quickly and cost-effectively synthesize information in order to recommend irrigation schedules and prescriptions. They must expend extra effort to bring the information together, which impacts growers. Improving the capabilities for sharing data among these tools will reduce users' required levels of effort, increase adoption, and lead to greater water and energy efficiency through improved accuracy and precision of irrigation management.[2] The use of data standards in improving precision irrigation tools can ultimately improve yield and crop quality.

[2] NEEA's research in this Initiative to date supports the claims and recommendations in this report; however, readers should consider them advisory/ directional. The demonstration and exploratory natures of much of NEEA's research by design limits the ability to generalize to all users or all members of other stakeholder groups.

The Precision Ag Irrigation Leadership (PAIL) project, a data standards development project within AgGateway,[3] is developing data standards to enable the transmission and receipt of weather, soil moisture, and other relevant data, currently stored in a variety of proprietary original equipment manufacturer (OEM) formats, in an industry-wide format that can be used by irrigation data analysis and prescription programs. Making such standards reality requires the development of working relationships among the various vendors, including irrigation consultants, hardware manufacturers, and software service organizations.

1.2. NEEA's Role

The Northwest Energy Efficiency Alliance (NEEA) is an alliance funded by more than 140 Northwest utilities and energy efficiency organizations in Idaho, Oregon, Montana, and Washington working to accelerate the innovation and adoption of energy-efficient products, services, and practices in the Northwest. NEEA, recognizing the potential energy savings and benefits of data standards to the region's growers and its utilities, undertook the important task of launching the Agricultural Irrigation Initiative with the goal of reducing agricultural irrigation energy use by twenty percent by 2020. Multiple vendors participated in NEEA's initial Agricultural Irrigation Initiative meeting in November, 2011. From that base, NEEA began an active outreach campaign to involve additional equipment manufacturers and software service providers.

The working PAIL project began when NEEA hosted a meeting at the Irrigation Association Conference in November 2012, at which the team presented preliminary work on business use cases. At that meeting, NEEA and the vendors decided to house the data standards work within AgGateway. With support and leadership from NEEA as part of its Agricultural Irrigation Initiative, the group of companies working together as the PAIL project has been collaborating to develop data standards to enable interoperability among the various hardware and software components of a precision irrigation system.

This data standards report describes NEEA's and PAIL's activities and progress toward completing these standards. It is one in a series of twelve reports addressing specific areas of NEEA's Agricultural Irrigation Initiative, all of which are available at http://neea.org/reports.

The data standards work began at the same time as the NEEA Agricultural Irrigation Initiative demonstrations started their second year. In many ways, the concurrent performance of the data standards work and the NEEA demonstrations proved beneficial. The demonstrations provided a real-life "blueprint" that helped the PAIL team to determine which datasets were required and how they would be used; the data standards work helped to develop trust and cooperation among the vendors. If issues arose with equipment during the demonstrations, the NEEA team was able to get rapid responses via the members of the PAIL team.

[3] AgGateway is a non-profit organization focused on helping growers, ag retailers, and supply chain partners capture, transfer, and manage data.

Participation and recruitment of pivot manufacturers required ongoing effort from NEEA. NEEA has to date funded a project manager position for the PAIL effort, which allowed a neutral voice for project coordination and management. NEEA has been able to involve providers of the following in this data standards work:

- Center pivots
- Sprinklers, emitters, and sprayers
- Soil moisture monitoring equipment and systems
- Soil mapping
- In-field weather stations
- Precision agriculture decision support system providers
- In-field eddy covariance systems
- Farm Management Information Systems

Vendor representatives at NEEA's Technical Advisory Group (TAG) webinar on October 3, 2014, clearly indicated that without NEEA's leadership, they would be unlikely to sit down at the same table to develop these common standards. However, more work remains to complete the data standards for center pivot irrigation and to support other irrigation technologies whereby the regional utilities can realize gains in energy efficiency in the agricultural sector.

Table 1 lists the companies participating in the PAIL project as of December 2014.

Table 1. PAIL Vendor Participants

Ag Connections	Lindsay Corporation (Zimmatic)
Agrian	MapShots
AgSense	Monsanto
Campbell Scientific	Observant
Crop IMS	OnFarm Systems
CropMetrics	Ranch Systems
Decagon	Simplot
FirstWater Ag	Valmont (Valley)
Irrinet	Wysocki Farms
IRROMETER	ZedX, Inc.
John Deere Water	

Team Makeup

Due to the variety of types of equipment and interest in accelerating progress, the PAIL team divided into sub-team working groups, which included:

- Inbound Field Data
- Remote Data
- Setup and Configuration Data
- Work Order to Pivot Data
- Work Record (aka As-Applied) Data
- Glossary and Ontology

Companies provided participants to the project based on their areas of expertise. The PAIL team expected participants to have technical knowledge of the manner in which their companies currently handle data exchange, as well as sufficient knowledge of their companies' business models to make recommendations that could be supported by their companies.

1.3. Information That Growers Need for Irrigation

In order to make the data standards relevant, the PAIL project team identified the types of information that growers and irrigation consultants will need as they plan, execute, and evaluate their irrigation practices. As Figure 1 illustrates, these include:

- Creating a crop plan and supporting irrigation plan
- Executing the irrigation plan, given the current soil and weather conditions
- Recording and reporting results, with an eye to improving the next year's plan
- Managing the irrigation equipment as a farm asset

Figure 1. Information Requirements Supported by PAIL

1.4. Progress to Date (January 2012 through December 2014)

The PAIL team has completed the following deliverables:

- Business and technical use cases, including description of processes supported by the messages that arise from PAIL
- Datasets and definitions
- Glossary of terms used in this project (lists and definitions)
- Agreed-upon units of measure for reporting the data
- Schema describing messages for retrieving data from the field and for sending prescriptions to the field

- Object models for describing the relationships among datasets as they are moved from one device to another
- PAIL Communication Plan and presentation of PAIL project and data schemas at multiple venues, such as the Irrigation Show, ASABE, and InfoAg conferences
- Alpha testing of data schemas in two controlled environments (see Section 2.2.5 for details)

1.5. Project Approach

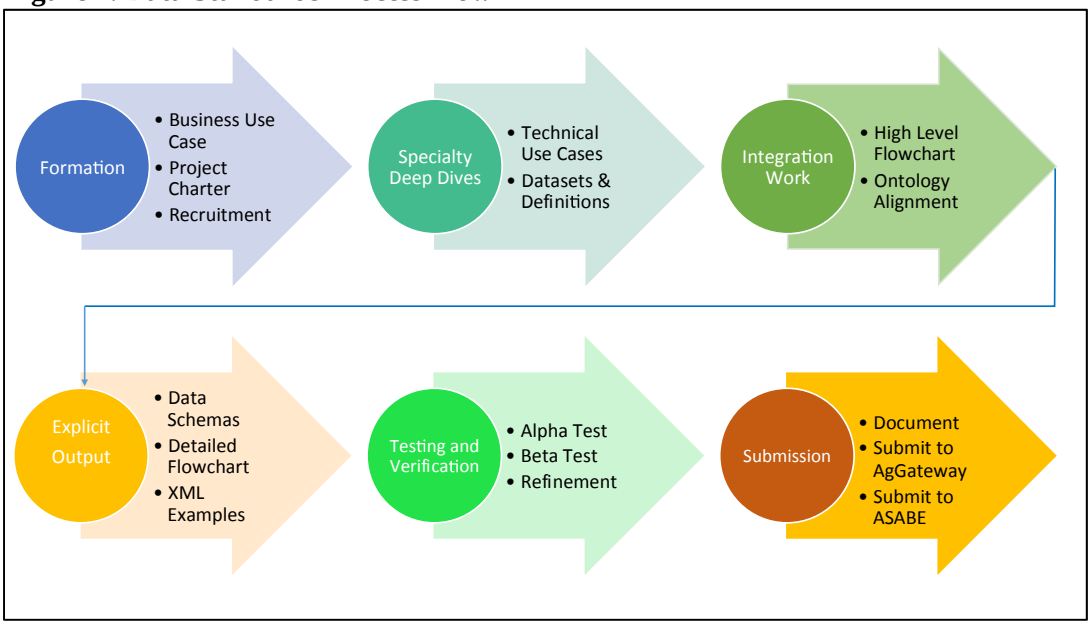
The PAIL project now resides within AgGateway's Water Management Group. AgGateway is a non-profit consortium of over two hundred companies focused on helping growers, retailers, manufacturers, and supply chain partners reduce the cost and frustration of managing complex data in today's agricultural industry. Companies that want to participate in PAIL must join AgGateway and provide additional funding for the project.

The PAIL team has ratified three important guidelines:

1. Adopt existing standards and guidelines wherever possible
2. Protect proprietary data flows where necessary
3. Allow for new extensions to the data standards as new technology solutions evolve

While no common process exists for developing data standards, PAIL has taken the approach shown in Figure 2 below. While the diagram indicates a smooth linear progression, the work frequently required multiple iterations as team members gained new insights.

Figure 2. Data Standards Process Flow



Section 2.2 of this report (Activities and Output by Process Stage) provides more detailed descriptions of the stages and the outputs of the above processes.

2. Overview of Project Findings

2.1. Data Standards Accomplishments and Deliverables

The PAIL project succeeded in developing data schemas and formats for inputs into, and outputs from, irrigation decision support systems. Figure 6 in Section 2.2.3.1 shows the PAIL data flows. Completed data schemas and formats include:

- Irrigation system (not restricted to pivots) setup, configuration, performance specification
  - Location and geometry of the irrigation system
  - End gun, corner arm specification
  - Flows and pressure

- Field and environmental information
  - Location
  - Soil conditions
  - Local and regional weather conditions and forecasts

- Irrigation system operation, control, and status
  - Schedules (how much application and when)
  - Irrigation work orders to drive pivot controllers
  - Error reporting
  - Reporting on how much, and where, water was applied

2.2. Activities and Output by Process Stage

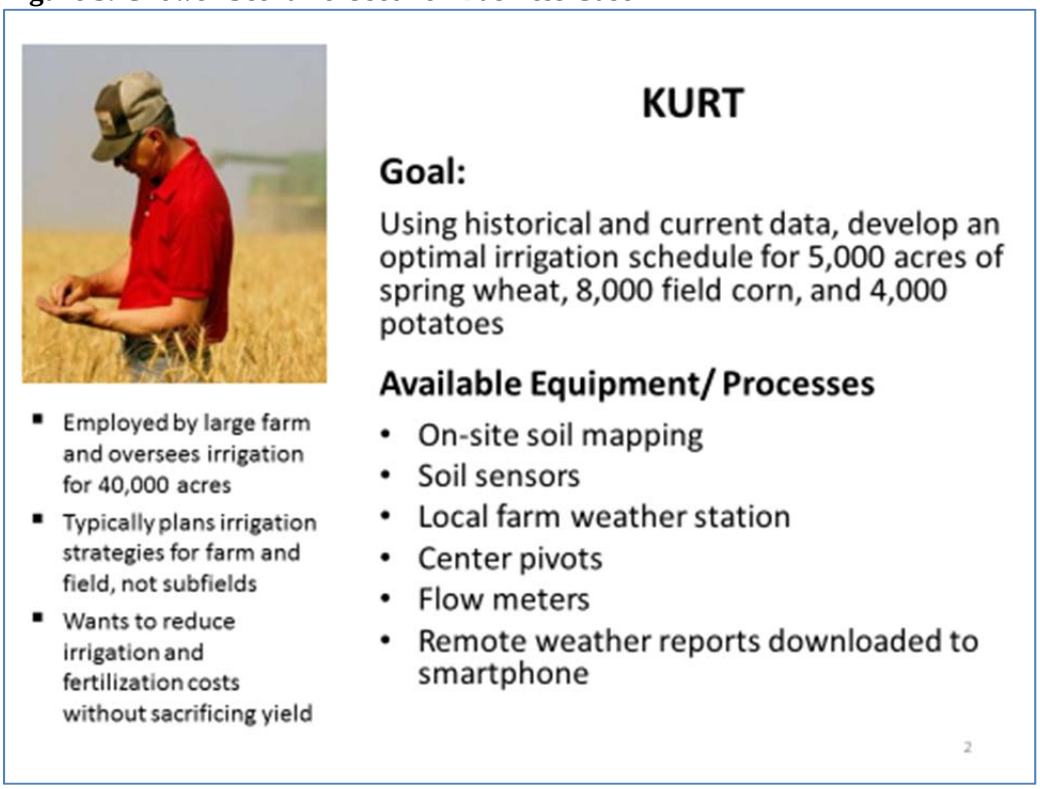
This section details the six process stages and output outlined earlier in Figure 2.

2.2.1. Formation

2.2.1.1. Business Use Case

NEEA developed preliminary business use cases in preparation for a November, 2012 data standards meeting in Orlando, Florida. Figure 3 below provides an example from one of the business use cases. The profiles provided the basis for defining the scope and charter for PAIL, as well as for developing the technical use cases.

Figure 3. Grower Scenario Used for Business Case



2.2.1.2. Project Charter

AgGateway's Board of Directors approved the PAIL Charter in April, 2012. Companies wishing to participate in the PAIL project signed letters of commitment and contributed to the funding of the project.

2.2.1.3. Recruitment

NEEA recruited vendors from major irrigation equipment manufacturers. Many of these vendors, such as AgSense, Valmont, Lindsay, Decagon, and CropMetrics, were already participating in the NEEA demonstrations.

2.2.2. Specialty Deep Dives

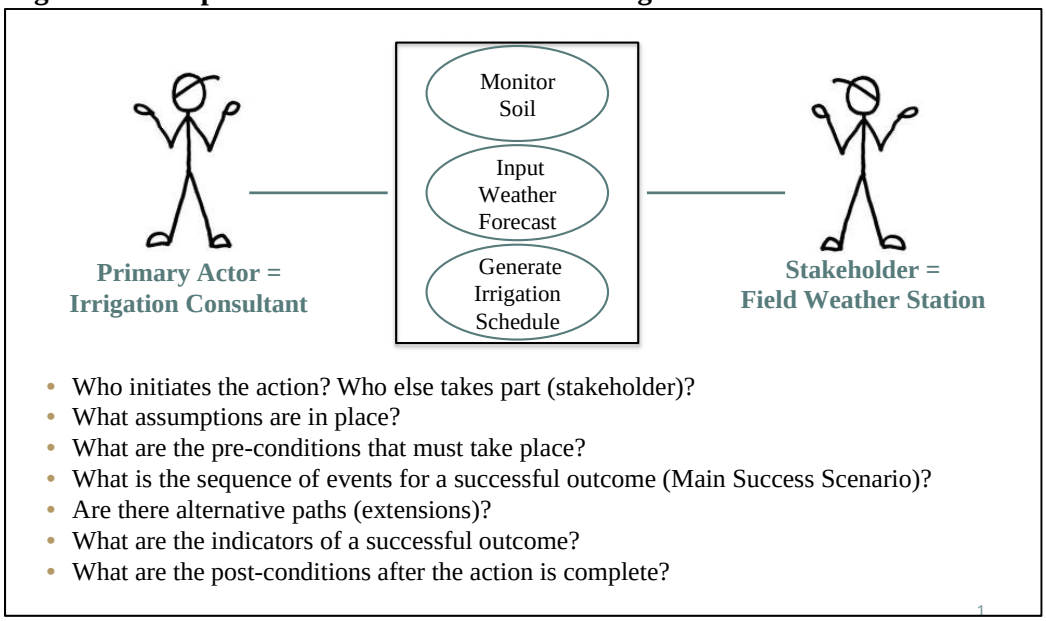
2.2.2.1. Technical Use Cases

In this stage, subject matter experts developed technical use cases to document the data requirements for an integrated irrigation system. The PAIL team started with four specialty sub-teams:

- Setup and Configuration
- Inbound Data from the Field (soil sensors and field weather stations)
- Work Order Data
- As-Applied Data

The sub-teams began developing technical use cases in order to identify the types of data that would be needed. Figure 4 illustrates a typical starting point for developing a technical use case.

Figure 4. Example of a Technical Use Case Starting Point



2.2.2.2. Datasets and Definitions

Each sub-team next defined the datasets for which they would adopt or develop standards, an example of which appears in Figure 5 below.

Figure 5. Example of PAIL Datasets

INbound, setup, or inbound reference data	Element Name	Description	Frequency (Needed with Every Reporting or Metadata?)
INbound	ID	Logger ID	M
Setup	LocationLat	GPS Location of the device	M
Setup	LocationLon	GPS Location of the device	M
INbound reference	Manufacturer	Manufacturer of device	M
inbound reference	Firmware Version	Firmware version of device	M
Setup	Telemetry	type of telemetry being used	M
inbound	Power status	battery power level	NER

2.2.3. Integration Work

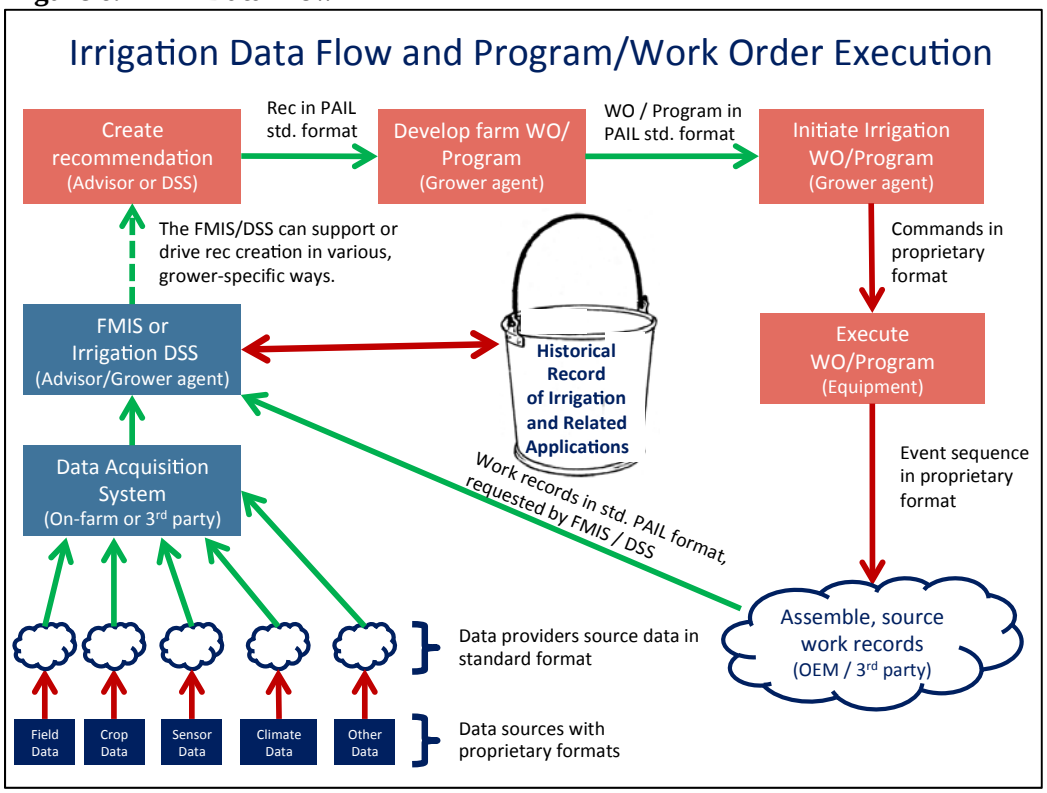
Once the PAIL team completed the use cases and defined the key datasets, the team members diagrammed a high-level view of data flow that identified which datasets would be in an open, PAIL format and which would remain proprietary. This was a breakthrough activity; all of the participating vendors aligned on which data they would allow to be open and which they would keep private for competitive reasons.

2.2.3.1. High-Level Flowchart – How Information Moves through the System

In Figure 6 below, the green arrows represent data that is sent in the PAIL format. Red arrows indicate data that is kept proprietary. Starting from the lower left:

- An irrigation advisor can request data from a number of sources and have it sent either through a third-party data acquisition system or directly to a Farm Management Information System (FMIS).
- The advisor can either use that data within his/her own device or send it to a decision support system that may be used to collect and analyze the data and to provide a recommendation for an irrigation schedule or prescription.
- Once the recommendation is approved by the grower, the advisor can create a work order in PAIL format and send it to a pivot or pivot controller.
- A data schema conversion tool converts the PAIL work order to a machine task in proprietary format.
- Once the irrigation program is executed, the advisor or a third party can obtain a work record of how much water was applied, as well as where and when it was applied. The historical record is kept in proprietary format.

Figure 6. PAIL Data Flow



Notes: Green arrows indicate open standards. Red arrows indicate flow of proprietary data. AgGateway is launching a new project to enable software plug-ins that vendors can use for conversion between the PAIL open standard and their proprietary systems.

2.2.3.2. Irrigation Terminology, Definitions, and Their Ontological Alignment

The PAIL team submitted terms for inclusion in the AgGateway AgGlossary (AgGateway 2014), aligning these with existing terms whenever possible and leveraging a great body of work already created. All twelve reports in the NEEA Agricultural Irrigation Initiative series refer readers to the AgGateway AgGlossary for definitions of terms.

In collaborating with other teams at AgGateway, PAIL team members learned about differences in approach between the Natural Resources Conservation Service (NRCS) and the International Organization for Standardization (ISO) when using agricultural terms. NRCS typically uses agronomic terms, such as “seeding,” which are more suited to agricultural practices such as irrigation. ISO almost always uses machine-based terms, such as “pivot,” in its standards documentation. Members of the PAIL team then worked with representatives from ISO and NRCS to align irrigation terms that are primarily agronomic with ISO terms that are primarily equipment-oriented, using an ontological process to develop hierarchies for the terms. Bridging this gap is important for facilitating alignment of irrigation schedules and prescriptions with execution on equipment. Figure 7 and Figure 8 below show examples of this work.

Figure 7. Context and Structure for Agricultural Irrigation Terminology

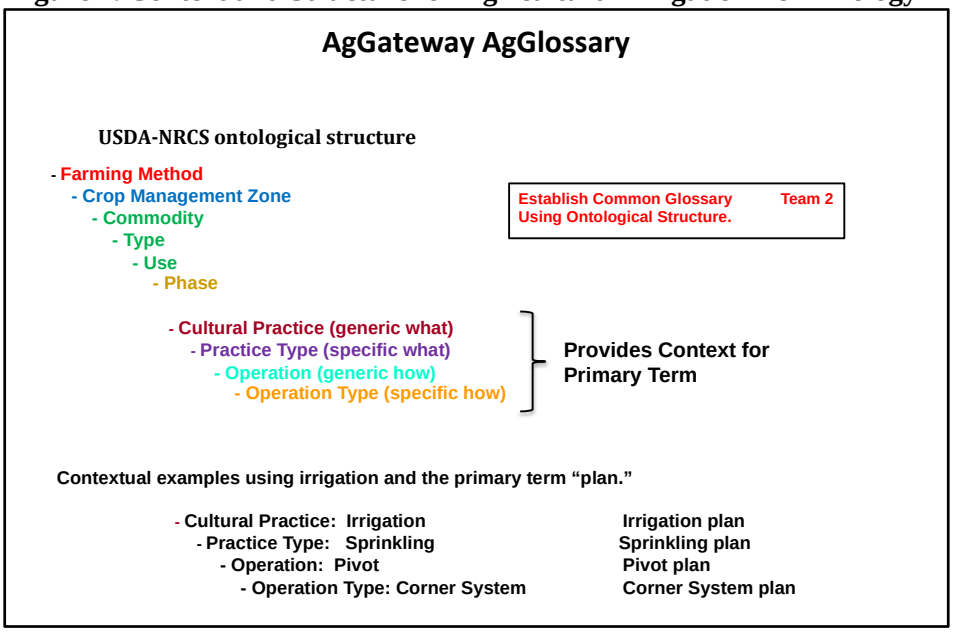
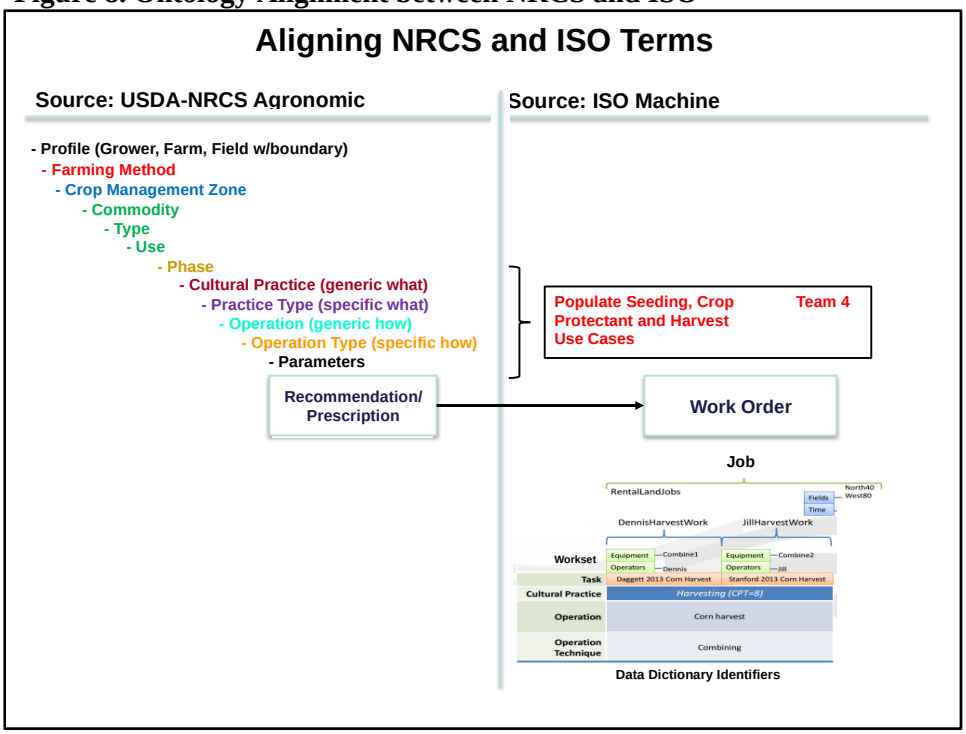


Figure 8. Ontology Alignment between NRCS and ISO

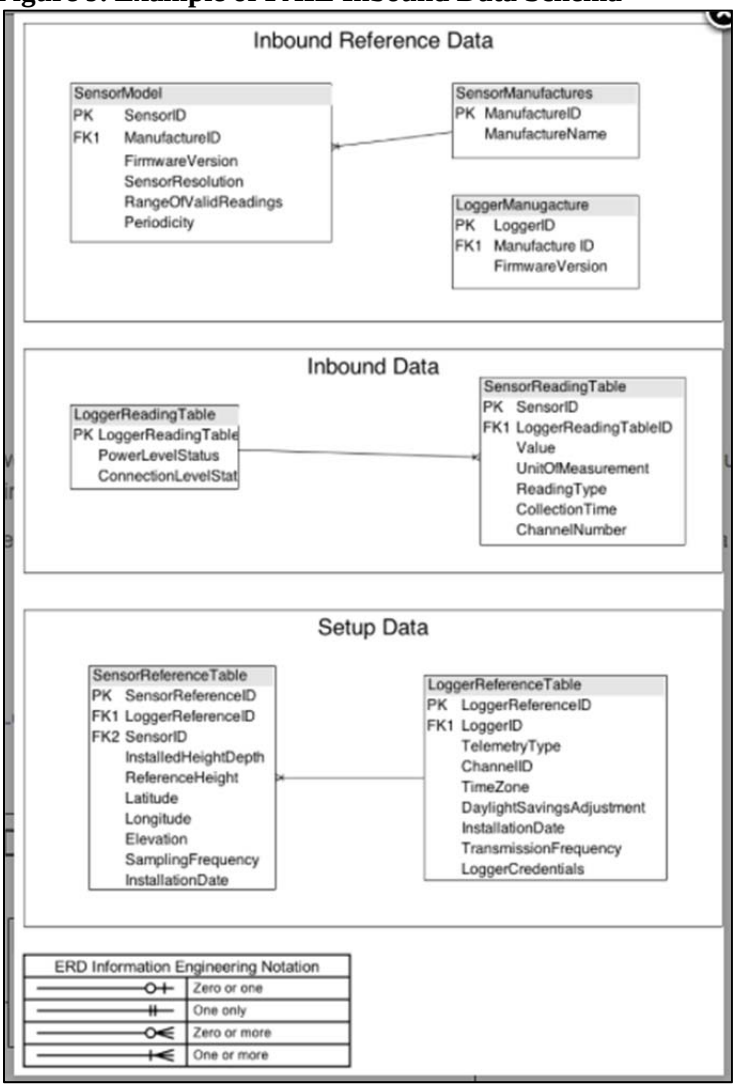


2.2.4. Explicit Output

2.2.4.1. Data Schemas

Each PAIL team developed a data schema to support the requested data flow. Figure 9 illustrates an example for inbound reference data.

Figure 9. Example of PAIL Inbound Data Schema

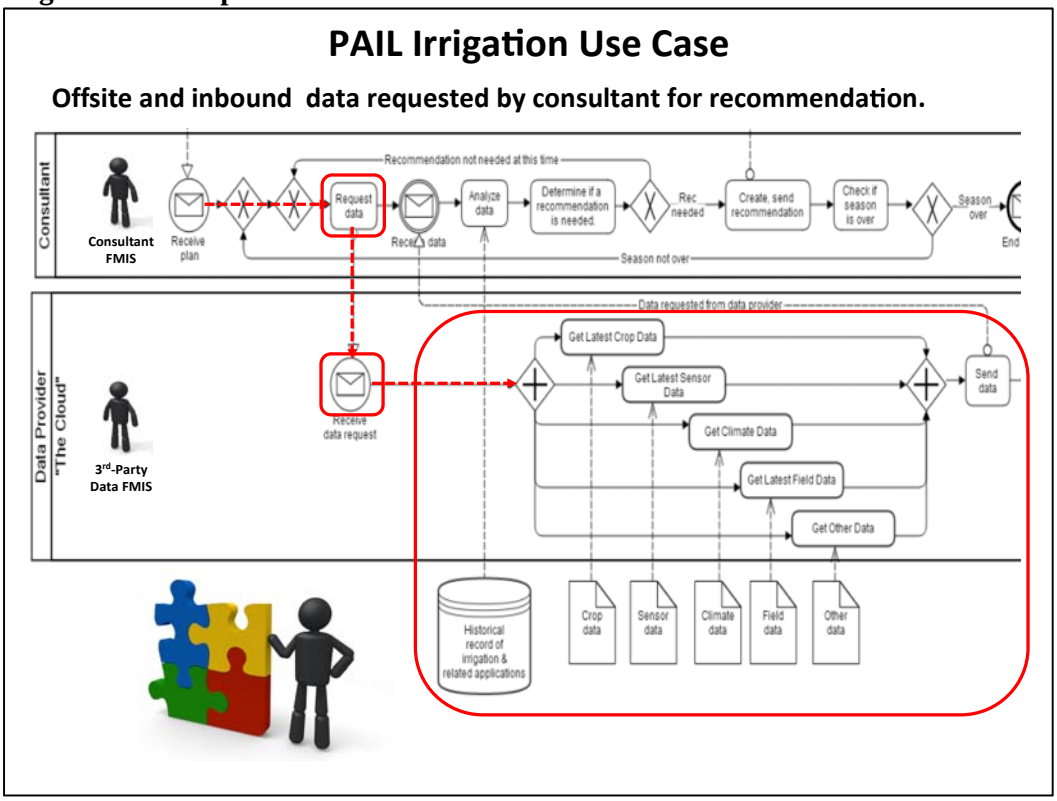


2.2.4.2. Detailed Flowchart

Using the high-level flowchart in Figure 6 (Section 2.2.3.1) as an overall guide, the PAIL team next developed specific detailed flowcharts (such as the example in Figure 10) to simulate the data flow in support of each grower use case, an example of which is described in the following steps:

1. A grower communicates a crop plan to an irrigation consultant
2. The consultant gathers and analyzes relevant data (such as weather, soil, evapotranspiration)
3. The consultant communicates a recommendation
4. The grower and irrigation consultant create a work order (with an irrigation schedule and/or prescription)
5. The work order is converted to machine task (ISO 11783) language
6. A work record captures the results, which can be stored at the grower's or consultant's Farm Management Information System (FMIS)

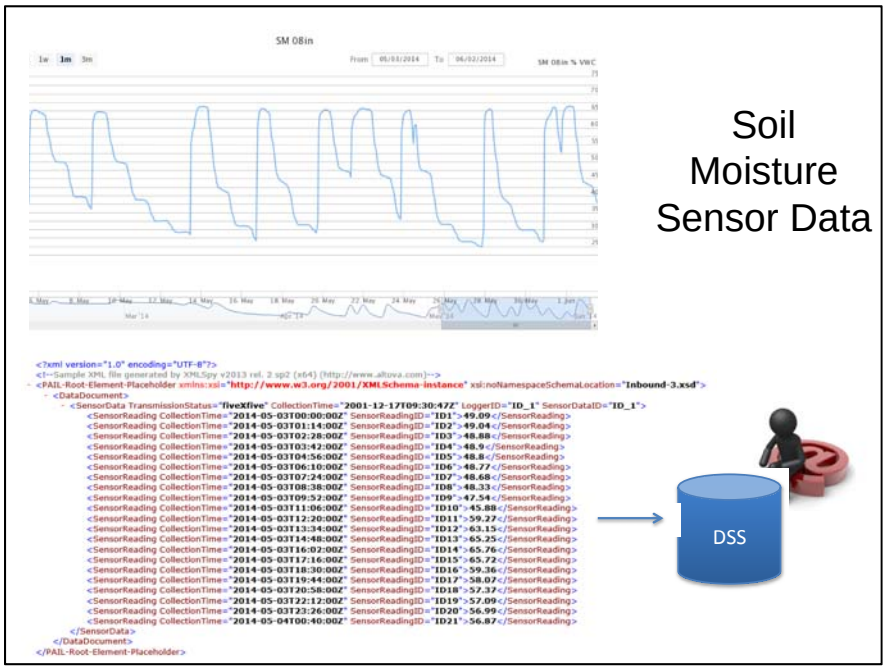
Figure 10. Example of a Detailed PAIL Flowchart



2.2.4.3. XML Examples

Finally, PAIL members were able to write example code that converted the data schemas to actual commands in the PAIL XML format.[4] Figure 11 (using soil moisture content) and Figure 12 (using remote weather climate data) show specific XML examples; the PAIL data standards will include examples of these types.

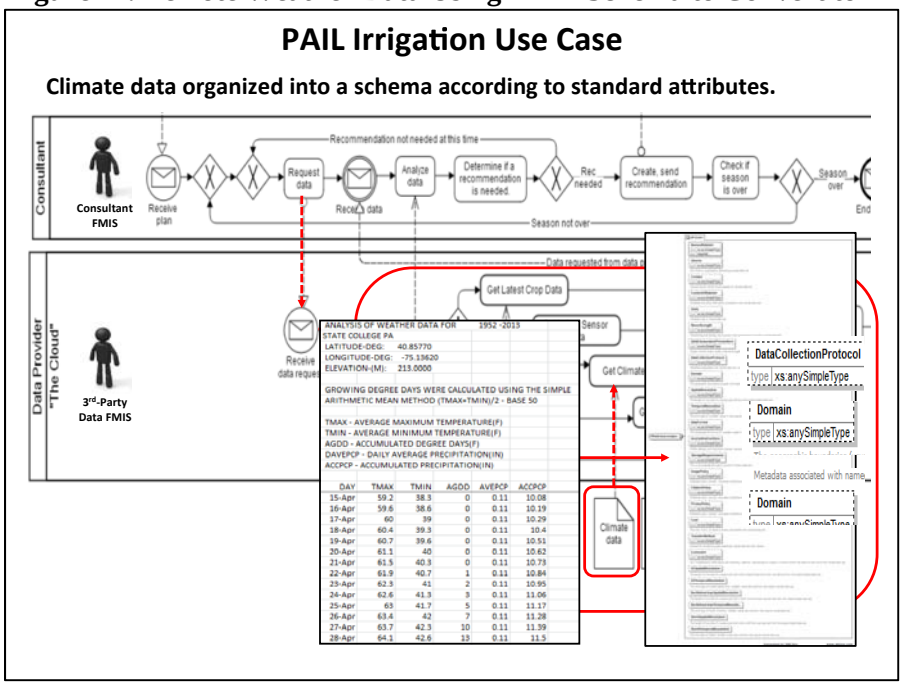
Figure 11. Example of Vendor's Soil Moisture Data Converted to PAIL XML Format



Note: This image is illustrative only to show the manner in which conversion to XML format can simplify presentation of large amounts of algorithmic information.

[4] XML is a computer language commonly used for machinery and instrumentation data. A "cousin" of XML is JSON, which provides much of this type of data in an abbreviated form. PAIL will support both XML and JSON.

Figure 12. Remote Weather Data Using PAIL Schema to Convert to XML



Note: This image is illustrative only to show the manner in which conversion to XML format can simplify presentation of large amounts of algorithmic information.

2.2.5. Testing and Verification

2.2.5.1. Alpha Test

The PAIL team conducted the Alpha tests to validate the structure and format of the completed PAIL data standards. The team designed the tests to determine whether the data are "readable" to and from an FMIS system and equipment using the PAIL data standards. Note that the team did not conduct the Alpha tests to validate the usefulness of the data in creating an irrigation work order or in generating an optimal irrigation prescription, only to validate that the data was readable from one source to another. The PAIL team conducted the tests in external, but controlled, environments at two sites (leveraging existing test facilities):

- An Ag Connections testing farm in Murray, Kentucky
- A site in Huron, South Dakota, used by AgSense

Because the standards are meant to be brand-agnostic, the tests included at least two manufacturers for each type of sensor and center pivot.

The tests focused on the following:

1. Sending data from sensors and weather databases that can be read by an FMIS
2. Sending an irrigation work order (for example, an irrigation schedule and prescription) to a pivot controller
3. Receiving a work record of a completed irrigation task

The results from the Alpha tests showed that soil sensors and local weather stations successfully sent data in PAIL format to an FMIS. The team reported the results at the AgGateway annual meeting in November, 2014 and to the Bonneville Power Administration (BPA). Because the various regional weather networks such as AgriMet and Mesonet use their own formats, the Alpha test team simulated output in PAIL format. Phase Two of PAIL will attempt to address this issue by working with the various weather networks or with third-party vendors who consolidate and report the regional weather data to growers.

2.2.5.2. Beta Test

The PAIL team will begin Beta (field) testing for this project in the spring of 2015. Some of these tests may be implemented in the Northwest.

2.2.5.3. Refinement

While the Alpha tests were underway, the test team was able to identify issues in the XML code. These issues have been addressed and the data schemas updated on the PAIL wiki on the AgGateway site. Additionally, the tests have required the development of application programming interfaces (APIs) in order for the data to be sent to and received by the FMIS. The test team will recommend these APIs as first drafts that can be made available as part of the PAIL standards.

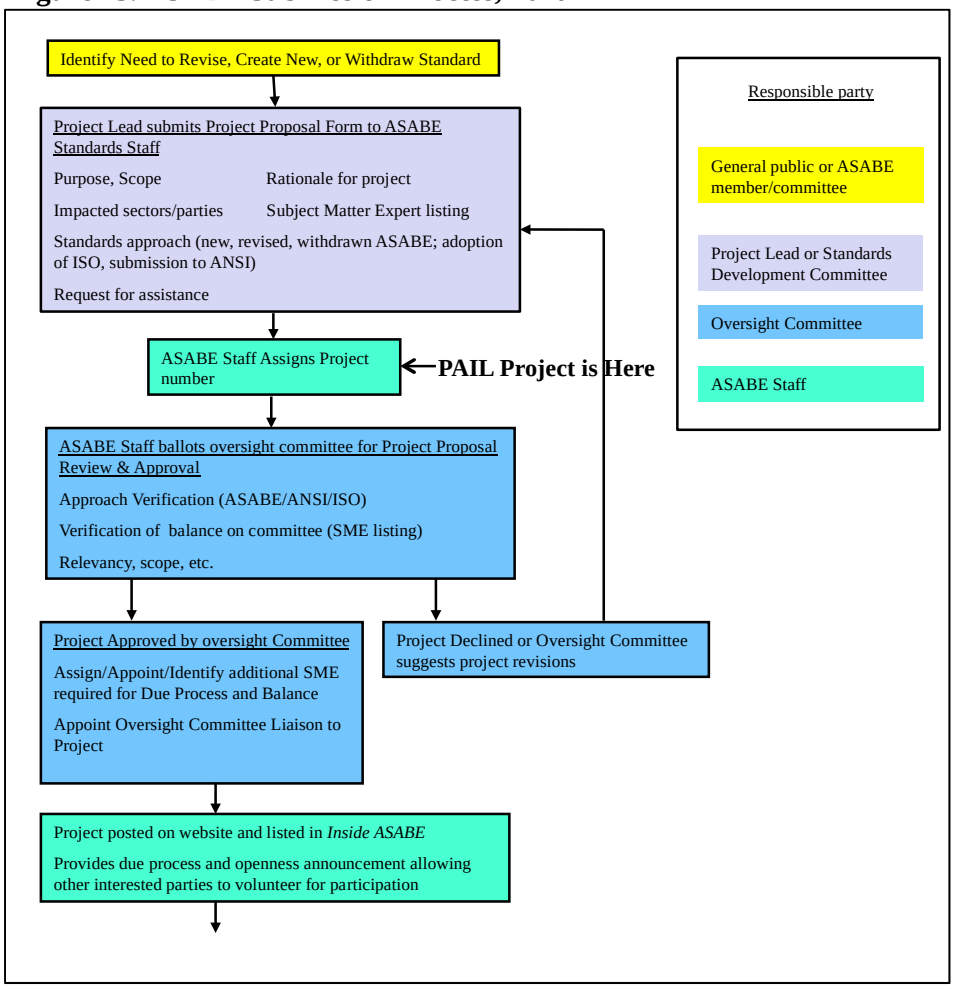
2.2.6. Submission

The PAIL team is in the process of submitting Phase One of the data standards to the AgGateway Standards and Guidelines Committee. That committee will work with the PAIL team to document the standards in a way that enables them to be approved by AgGateway and then sent to the American Society of Agricultural and Biological Engineers (ASABE) for approval. Note that in practice the AgGateway process is faster than the ASABE process.

2.2.6.1. Document and Submit to AgGateway

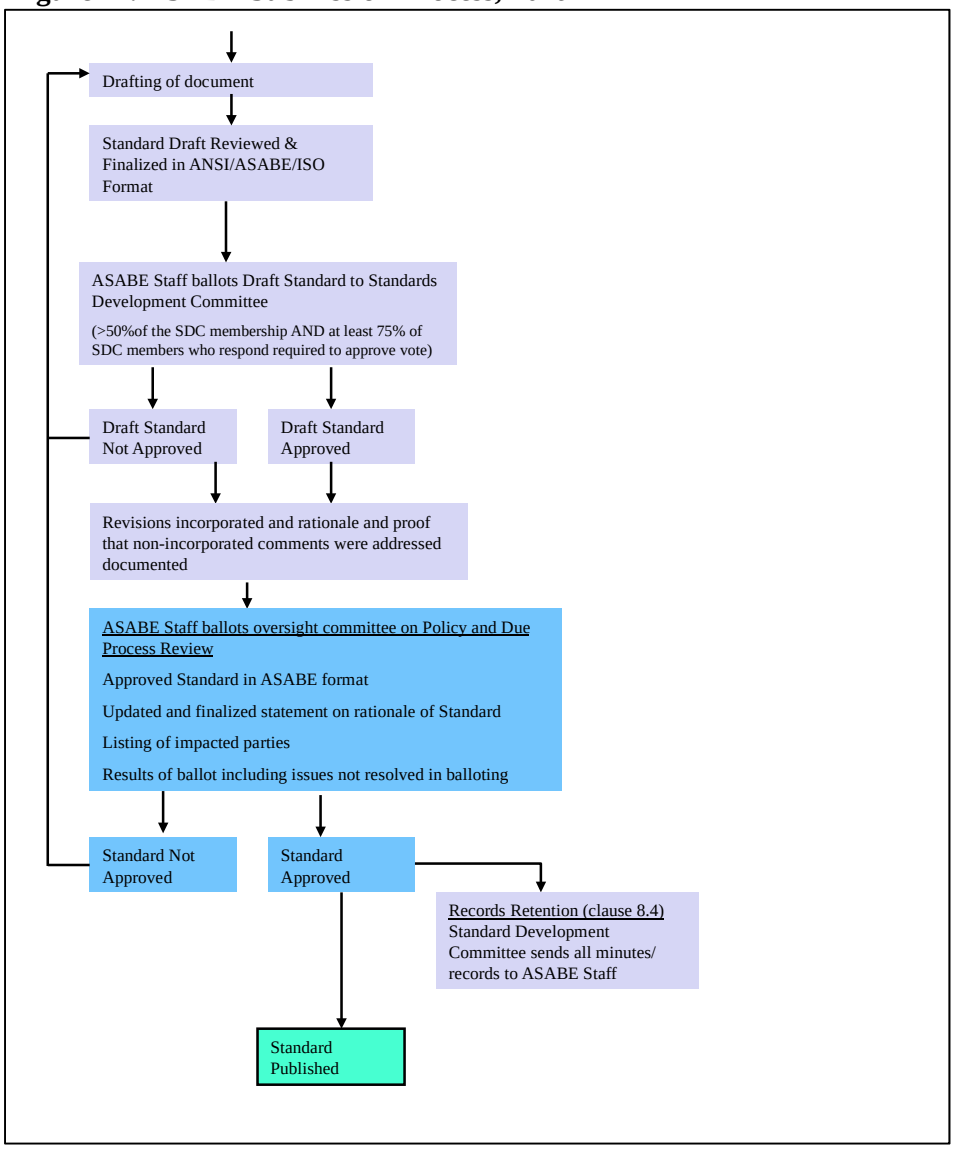
The PAIL Team will document the standards and schemas, including glossary terms and business rules, and send them to the AgGateway Standards and Guidelines Committee. The standard is posted on the AgGateway wiki for review and comments. Once it is confident that comments have been addressed, the Standards and Guidelines Committee will submit the PAIL standards to the Open Applications Group, Inc. (OAGi) for processing and publishing. At that point, AgGateway will also submit the standards to ASABE, following the flowcharts in Figure 13 and Figure 14.

Figure 13. ASABE Submission Process, Part 1



Note: Figure from (ASABE 2011)

Figure 14. ASABE Submission Process, Part 2



Note: Figure from (ASABE 2011)

3. Risks and Challenges

3.1. Risks

The main risk in this project is that the precision irrigation industry may not adopt and use the data standards. To mitigate this risk, NEEA should support Phase Two of the PAIL project and assist with socializing PAIL to other industry partners and to growers. Doing so would allow the communication protocols to become commonplace in all of the hardware and software associated with precision agriculture, and would promote the efficient use of water and electricity while improving profitability for growers and the market supply chain.

3.2. Challenges

This project has experienced several challenges during its life to-date.

Volunteer Time

The reality of working on data standards is that it is essentially a "volunteer" task performed by managers and specialists in companies and universities. Participating companies must continue to see the value of their participation in data standards development if they are going to continue to commit time and resources to the work. Having a consistent, neutral project leader has helped to keep the project on track and has provided the necessary perspective of value to all the industry stakeholders.

Limited Participation from Pump Manufacturers

The team has also experienced difficulties in getting active participation from pump manufacturers. Although the Hydraulics Institute publishes data standards, companies must pay to use them – contrary to the philosophy of having the PAIL standards free and open to all. One of the major pump companies has stated its intention to join the PAIL project for the next phase. In addition, a pumps expert from Valmont joined the team in August 2014 and should help to accelerate progress.

Different Formats Used by Regional Weather Systems

Multiple weather reporting systems, such as AgriMet and the California Irrigation Management Information System (CIMIS), each has its own formats and measurements for reporting long-term and historical weather data. PAIL should undertake a next step of reaching out to these organizations and convincing them to align on a common set of reporting formats and definitions.

Need for Value to PAIL Members

The PAIL effort must always provide value to the precision irrigation industry as a whole, as well as to the individual organizations participating. This value can come in the forms of reduced costs, reduced complexity, business expansion, and/or new markets. Should the value cease to exist, the entire group has the potential to disband.

4. Lessons Learned, Next Steps, and Value of Findings

4.1. Lessons Learned

Value Proposition for Growers
Growers are inundated with many types of data. NEEA interviewed six growers in Washington, Oregon, and Idaho by phone and in person between April and August, 2014. Their responses informed the following emergent themes:

- Growers spend too much time trying to sort through data that comes to them through different portals or websites
- Each piece of farm equipment not only sends its own data, but does so in a different format, through its own data portal
- User interfaces vary, and many are difficult to understand
- The issues above hamper the conversion of data to meaningful, actionable information
- Using a mixed fleet (different brands) of equipment compounds the issues above

Data Standards Provide an Opportunity for Industry Collaboration
During PAIL team meetings, companies that normally competed with each other in the marketplace began discuss areas in which they had similar approaches and those in which they differed. These conversations enabled them to identify areas in which taking a common approach to data standards would be beneficial and would help to increase market adoption, while not compromising proprietary approaches where necessary.

The Need to Manage Real-Time Data Is Only Going to Increase
From soil mapping to irrigation management to inventory and supply chain management, precision agriculture is ever more dependent on the automated capturing, transfer, and management of data. Soil mapping, crop, and weather data are especially relevant for precision irrigation. Farms are under increasing pressure to be able to track food products from field to grocery shelf, including tracking their application of water and chemigation on a specific crop in a particular field (as part of their reporting in traceability and chain of custody). Data standards that enable the free flow of data are fundamental in allowing growers and vendors alike to manage data and to make better decisions that use less water and energy resources while protecting yield.

Precision Soil Sampling is Gaining Importance
Although the field of soil sampling and testing has existed for many years, its importance is currently on the rise. The success of precision irrigation (variable water application) and other farming technologies largely depends upon the accuracy of soil-test-based water and fertilizer recommendations. Given the emergence of a number of new techniques for real-time sampling, finding a common way to report these data will help provide integrated solutions that derive from these data.

4.2. Next Steps

Beta Testing
PAIL will begin Beta (field) testing in the Northwest in the spring of 2015, at sites yet to be named. The PAIL team will conduct one or more tests with growers and irrigation consultants taking part, and will provide documentation and/or training to the participants. The purpose of the Beta test is to evaluate the usefulness and usability of the data standards. Feedback from this second round of testing will allow the PAIL team to:

- Make user-led modifications to existing functionality
- Capture any ideas for additional functionality that can be implemented at a later date
- Resolve any other bugs or performance issues that would prevent a fully signed-off official release of the data standards to ASABE

PAIL Phase Two
NEEA and the PAIL leadership team met August 11, 2014 to review the results of the first phase of the PAIL project and to define the second phase. Phase Two of the data standards project will focus on socializing the data standards developed to date, and on developing and testing the next set of data standards for:

- Pump systems
- Flow monitoring
- Ag Weather Networks (Alignment with AgriMet, National Oceanic and Atmospheric Administration (NOAA), and CIMIS)
- Field scouting
- Work orders (coordination with AgGateway's Standardized Precision Ag Data Exchange Project (SPADE))
- Exploring other irrigation delivery methods to make sure that standards can be deployed for multiple delivery systems (fixed, drip, and smaller-scale agriculture)

API
When the PAIL project started, participating companies did not want to develop a common application programming interface (API) for sending data into and out of an irrigation decision support system. Now that the PAIL project has defined some of the data standards, several of the vendor participants are seeing the value of such a common API.

PAIL is working closely with a new AgGateway committee called ADAPT (Ag Data Application Programming Toolkit[5]) by providing input into defining data object models. Whereas data schemas show how datasets move, object models describe the relationship among datasets as they move. The end result will be a collection of tools comprised of an open-source agricultural data model, a common API utilizing that data model, and data conversion tools. Participating FMIS companies would be responsible for completing their own implementations of mapping the common objects to their FMIS data models.

[5] Formerly known as SPADE 2

PAIL is now an official ASABE project (Standard X632). As PAIL Phase One reaches completion, the PAIL team will submit the data schemas to the AgGateway Standards Committee for review and approval. That committee will in turn submit the data standards to ASABE for approval.

4.3. Success and Exit Strategy

As noted above, several of the PAIL participants have stated that they are ready to start incorporating Phase One of the PAIL data standards. The exact timing will vary based upon each individual company's product road map. Although companies have not yet revealed those exact dates, the standards will likely be available in the marketplace by the end of 2015.

The PAIL team estimates completing Phase Two of the data standards development by end of November 2015. The team should be able to leverage many of the data formats and schemas developed in Phase One in Phase Two as well. After completion of Phase Two, the PAIL team will submit those standards to the AgGateway Standards and Guidelines Committee, which will, in turn, submit them to ASABE. That step in the process may trigger the end of NEEA's direct involvement and sponsorship of the data standards development for precision irrigation.

4.4. Value of Findings

As weather-related droughts intensify in the western states, so does the need for increasingly careful irrigation that uses data such as plant available water (PAW). In addition, governmental and regulatory agencies are demanding a more accurate accounting of agricultural water usage. Less available water will result in greater strains on agricultural irrigation and will likely increase energy demand in situations requiring the pumping of irrigation water.

Enabling a free flow of real-time information to growers will allow them to efficiently capture, use, and report data from a mixed fleet of irrigation equipment in order to facilitate more efficient use of water and energy.

PAIL data standards enable growers and irrigation consultants to more effectively plan, manage, and report irrigation applications.

For vendor participants, the data standards work provides three main advantages:

1. Financial Benefits: By reducing the time and effort currently required of growers to interact with multiple vendor products, vendors increase the likelihood of purchase of their irrigation products and services by removing the barrier to growers of having to learn multiple data systems.
2. Technological Benefits: Vendors can enable their equipment or software to interact with an irrigation application without having to rewrite specific code every time a partner's software program or application is changed.
3. New Market Opportunities: Working in partnership or in short-term alliances, vendors can create new market opportunities with data-driven products and services.

While Phase One of the PAIL project has focused on center pivot irrigation, growers and vendors can leverage these data standards to other forms of irrigation such as linear, fixed lines, rolling wheel, and drip.

In a PAIL leadership meeting on October 24, 2014, Andy Smith of Valmont said, “Because of the PAIL project, in precision irrigation today, moving data successfully is now a priority instead of a nuisance.”

5. References

AgGateway. 2014. *AgGateway AgGlossary* [Database]. Washington, DC: AgGateway Corporation. Accessed October 2014 from http://agglossary.org.

American Society of Agricultural and Biological Engineers (ASABE). 2011. *ASABE Standardization Procedures*. St. Joseph, MI: American Society of Agricultural and Biological Engineers. Accessed December 2014 from http://www.asabe.org/media/41352/2011-03-04_ansi-approved_asabe_standardization_procedures.pdf.