Data Standards for Precision Irrigation

Dan Berne, CEO

Next Chapter Marketing, dan@nextchaptermarketing.com, 360.904.0968

Romana Cohen, Initiative Manager

421 SW Sixth Avenue, Suite 600, Portland, OR 97204, 503.688.5400, RCohen@neea.org, Northwest Energy Efficiency Alliance

R. Andres Ferreyra, Ph.D., Manager of Special Projects

Ag Connections, Inc., andres.ferreyra@agconnections.com, 270.435.4369 x230

Charles Hillyer, Assistant Professor (Senior Research)

Oregon State University, Dept. of Biological & Ecological Engineering, 116 Gilmore Hall, Corvallis, R, 97333, 541 737-2041, hillyer@engr.orst.edu

Joe Russo, President

ZedX, Inc., 369 Rolling Ridge Drive, Bellefonte, PA 16823, (814) 357-8490, russo@zedxinc.com

Terry Schiltz, President

AgSense, 259 Dakota Ave S, PO Box 53, Huron SD 57350, (605) 352-8350, tschiltz@agsense.net

Geoff Wickes, Senior Product Manager, Emerging Technology Group

421 SW Sixth Avenue, Suite 600, Portland, OR 97204, 503.688.5400, GWickes@neea.org, Northwest Energy Efficiency Alliance

Abstract. *Manufacturers over the years have provided growers with improved equipment for irrigation and advanced software programs for timing and controlling water applications. However, these software programs are proprietary and are not designed to work together. Improving interoperability among these programs would not only save time and money but would also promote the use of precision irrigation management.*

Over the past two years, a group of companies has been collaborating to develop data standards to enable interoperability of broad range of agricultural technologies and software programs. The goal of this collaboration is an industry-wide, standard format that will enable the exchange of data and allow for their use in precision irrigation management systems. The work on this goal is currently taking place in the context of AgGateway's Water Management Group and PAIL project. We will present the results of this collaborative work and the progress made during 2013 and 2014.

Keywords. Irrigation, Data Standards, Decision Support Systems, Schema, Use Case, System Integration

Introduction

Irrigated agriculture in the US accounts for 80-90% of the consumptive water use and approximately 40% of the value of value of agricultural production(USDA, 2009; Schaible and Aillery, 2012). This value, totaling nearly $118 billion, is produced on 57 million acres. Given the increasing challenges in water availability caused by climate change, and the likelihood of increased water conflicts from competing users, irrigated agriculture must increase its efficiency without sacrificing a reduction in the value it produces (Schaible and Aillery, 2012). Much of this efficiency can be derived through application of precision irrigation technologies, and on-farm management systems that facilitate sound agricultural practices. However, less than 10% of irrigated farms use any type of advanced decision support tools or technologies (USDA, 2009). Improving adoption of these technologies is critical to increasing efficiency.

SIS has been advocated for the past 3 decades as a technique that improves water management practice (Bjornlund et al. 2009; Leib et al. 2002; Montoro et al. 2011; Ortega et al. 2005; Quinones et al. 1999). Early on, it was recognized that growers required accurate and agriculturally appropriate meteorological data support to implement SIS. This need led to the development of agricultural weather networks such as the California Irrigation Management Information System (CIMIS) and the AgriMet system. CIMIS started in 1981 and grew rapidly. By 2001, CIMIS had 4700 users, thus the network served 15000 farms (Eching 2002). The first advantage of agricultural weather networks is the relative low cost (to the grower); the secondary benefit is that the data collection and assimilation can be automated.

Automated data entry into SIS systems remains an active research topic today, and technological progress in soil moisture sensing and data telemetry has made possible the development of spatially distributed networks of soil sensors that automatically upload data to SIS software (Bjornlund et al. 2009; Evans et al. 2012; Zotarelli et al. 2011). However, for all the advancement in data services, growers must still enter their own irrigation water use to the SIS software e.g. (Laboski et al. 2001) or other checkbook methods (Li et al. 2011; Lundstrom; Stegman 1983; Steele et al. 2010).

There is a variety of technologies available for precision management of irrigation (Smith et al, 2010). Remotely actuated center pivots, drip irrigation systems, soil moisture sensing, on-farm weather stations all enable precise application with precise timing. Numerous software tools exist for deciding when and how much water to apply. However, rarely do these tools interoperate effectively. Data must be moved manually from one application to another and the burden is on the grower to do the data management.

An important remaining task required for the full automation of SIS is automated data input of irrigation water use: timing, placement, and depth. Irrigation equipment suppliers have realized the importance of data automation and have introduced technological solutions e.g. Valley (2012); however these technologies may remain challenging for small farms because of their high capital costs relative to the returns they produce.

Data Standards provide a foundation for agricultural irrigation solutions. They define the structure and format of information sent and received between two or more devices. Technology has provided many tools to help growers irrigate their land more efficiently. However, these tools rarely work together well, and; growers using them must invest extra effort to bring the information together. Improving the ability to share data among these tools will reduce users' effort, increase adoption, and lead to greater water use efficiency through improved accuracy and precision of irrigation management.

In 2011, the Northwest Energy Efficiency Alliance (NEEA) convened a group of irrigation expert to discuss issues that will lead to improved energy efficiency of agricultural irrigation. One of the conclusions from that conference was that the irrigation industry needs to support more integration of agricultural technologies. To that end, a group of companies, industry representatives, academics, and interested parties are collaborating to address the integration problem. This project, called **Precision Ag Irrigation Leadership** (PAIL), has the specific goal of producing a set of data exchange standards that will enable development of more efficient and easier to use solutions for irrigation management. The PAIL project is taking place in the context of AgGateway's Precision Ag

Council and 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 of complex data in today's agricultural industry.

Target Market for an Integrated Ag Irrigation Solution

The USDA Economic Research Service (ERS) categorizes farms primarily on the basis of Gross Cash Farm Income (GCFI) [1]. Previous versions only used annual sales income. ERS recently updated the typology to reflect three important trends: commodity price increases, a shift in production to larger farms, and the rapid growth of the use of production contracts among livestock producers.

For PAIL's purposes the relevant categories are derived from (Hoppe and MacDonald, 2013):

1. Small Family Farms, GFCI less than $350,000
2. Mid-size Family Farms, GFCI between $350,00 and $900,00
3. Large Scale Family Farms, GFCI greater than $1,000,000
4. Large Family Farms, GFCI of $1M - $499,999
5. Very Large Farms, GFCI of $5M or More
6. Non-Family Farms (includes Corporate Farms and Cooperatives). GFCI level is not specified. Defined as any farm where the operator and persons related to the operator do not own a majority of the business.

The previous version (2001) of the typology included large farms, with sales between $250,000 and $499,999, and very large family farms, with sales of $500,000 or more. However, farm production is shifting to much larger farms, thus the additional category of Mid-size family farms and the much higher levels of GCFI. Farms that annually generate $250,000 plus in sales represent just 10% of the nation's farms, but account for 82% of U.S. food production (CNN Money, Nov 2012).

Due to the size of investment (both time and money) to deploy an integrated solution, the *ideal* target customer for a level 2 or 3 Integrated Ag Irrigation solution is the Large Scale Family Farm or the Non-Family Farm. Mid-size Family Farms who are early adopters may also be targets, but would likely need large incentives as part of purchase. Small Family Farms are more likely to adopt the Level 1 solution, if they are to make a change.

In addition to the definitions above, the ideal target customers have one or more of the following characteristics:

1. They have a requirement or compelling need (either through natural causes or government regulations) to reduce irrigation water use.
2. They must manage multiple brands of equipment, especially center pivots.
3. They already have a level of data management on their farm and employ one or more employees who are dedicated to data management and integration.
4. Their overall attitude toward farming technology is forward thinking.
5. They are required by their local government, utility or crop insurance provider to report applied irrigation and/or chemigation.
6. They are already ready to purchase new irrigation capital equipment.

For the grower, the opportunity is to increase profitability through lower energy use and reduced costs with the availability of an integrated, easy-to-use decision support solution that uses a flexible

[1] GCFI includes the farm's sales of crops and livestock, receipts of Government payments, and other farm-related income. Gross farm sales, in contrast, exclude other farm-related income and include items than are not revenue to the farm: the value of sales accruing to share-landlords and production contractors and Government payments accruing to landlords.

approach combining optimal irrigation techniques with well-integrated soil, moisture, and weather data.

The irrigation data standards should also be seen as part of a larger set of data standard requirements. Growers are seeing an increasing need to integrate distinct sets of farm data. Merging precision farming technologies offer advantages in identifying, managing and tracking their products. However, given the lack of data standards and interoperability between manufacturers and suppliers, they also create significant challenges as dissimilar products and platforms multiply.

Allan Fetters, Director of Technology at J.R. Simplot Company and a PAIL team member, agreed with McDowell. “Growers are inundated with data. We have diagnostic and performance data coming in from each piece of equipment we use, on each and every field of the farm, let alone what and where all the crop inputs are being applied. This is compounded especially if you are running a mixed fleet of equipment,” he explained. “Each source of data received on the farm is displayed in its own configuration, on its own site, so a lot of extra time is being spent trying to analyze this data and interpret it into useful information that is going to make the farmer more productive. We need a free flow of data to enable us to farm with the best real-time data available. Ideally I would have all of my key farm data and digital decision making accessible through one common, easy to use dashboard, so I can control, manage, troubleshoot, view, and analyze my farm data.”

In short, growers do not need more data, so much as the information and insights that the data provides.

Data Standards Important for Complex Sales

Developing and marketing integrated precision agriculture solutions is not a simple matter. These solutions are not widgets that can be shelved and sold like individual sensors or sprinkler heads. In his book, “Dealing with Darwin,” business consultant and author Geoffrey Moore makes a clear distinction between making and selling “widgets” and making and selling integrated solutions. Moore calls the former “high volume” and the latter ‘complex systems.” Complex solutions require the integration of a lot of moving parts. If those parts are not under the control of a single entity, such as a company or agency, it becomes very challenging to get them to work together (e.g. vertical integration).

For precision agricultural solutions, developing and aligning to a set of data standards is a critical component of a larger system that must be configured before an integrated solution actually reaches the market. The data standards help form the underlying technology architecture that not only supports a well-integrated solution, but makes it easier to tie that solution into a grower’s existing farm management system.

Figure 2 below shows an adaptation of Geoffrey Moore’s model for complex systems (Moore, 2005), as applied to an integrated, agricultural irrigation solution. The model is organized around the grower because market success is dependent upon a relatively small set of customers making relatively large purchase commitments. Qualified customers are the scarcest resource in the system. Growers typically have the power in sales negotiations, and solutions must be customized to fit within their existing farm management processes and equipment infrastructure. No two solutions are identical. Lead times are long.

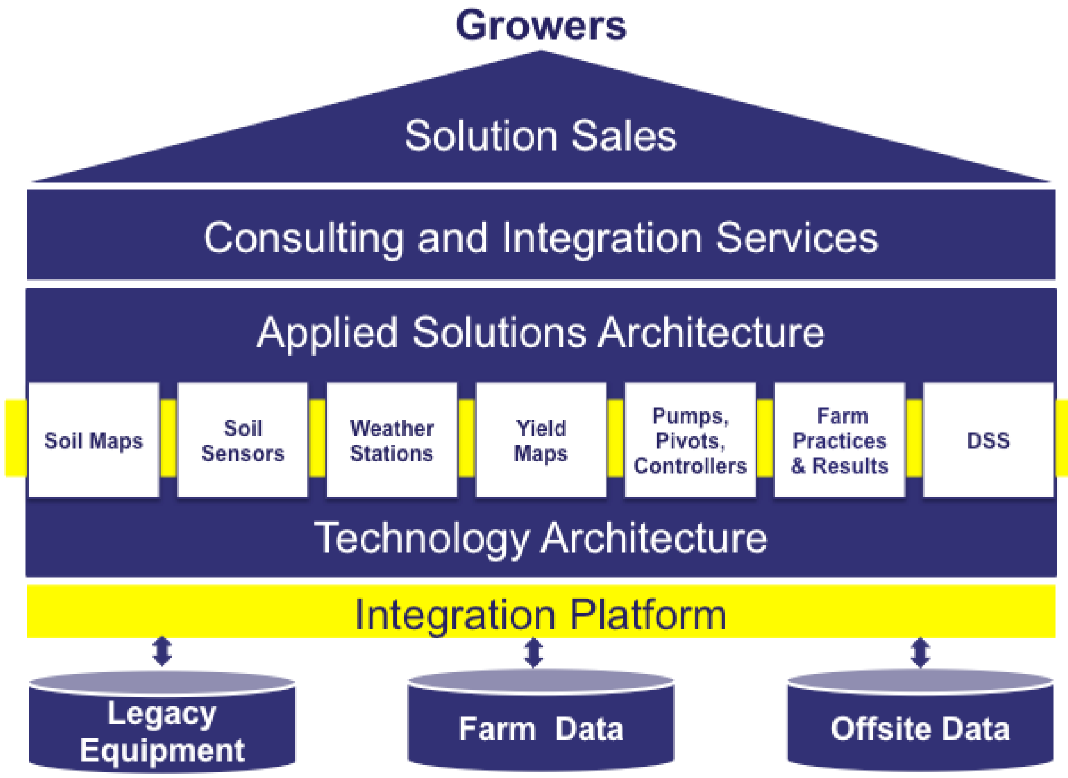

Figure 1 Complex Systems Market Model

Solution Sales can be driven from a local sales source, such as an irrigation equipment retailer, or in conjunction with a consulting service. Irrigation consultants can either work directly with growers or vendors. In some cases, they may be tied directly with a particular pivot or irrigation services provider. Their role is to bridge the specific needs and requirements of the grower and the core capabilities of the Ag Irrigation solution.

Two sub-architectures surround a set of multiple, disparate elements. These elements are modules that can be used to provide the system's ability to generate irrigation prescriptions and to monitor and report the results. Different vendors often supply them. The system is extensible: new modules can be added. And the system can integrate with other FMIS systems if necessary or desired.

The technology architecture unifies the system on the systems-facing side. It includes common facilities and protocols, such as the PAIL data standards and data transfer mechanisms. It would also include the business rules for those data standards. The technology architecture enables disparate elements to be swapped in and out to create different solution sets, without having to reconstruct everything from the ground up.

The solution architecture unifies these elements in a way that is clear and actionable by the grower. It consists of application specific templates that align the generic Ag Irrigation solution with the specific grower's needs. It embodies business and farm processes that are specific to that grower, and communicates the business results of the applied application. It is also understandable and sellable by the consultants and system integrators, as well as the solution sales force. It includes the user interface, as well as instructions and training.

The bottom layer indicates what the grower already has in place: pivots and other equipment, a local database, as well as offsite data, such as SSURGO soil maps or Agrimet weather forecasts. Above that, the Integration Platform provides a buffer that is familiar to the current generation of farm managers, has proven reliability, probable longevity, and is predictable in its interactions with the equipment and systems with which it interfaces.

No one member of the value chain can deliver all the products and services end-to-end. Typically this requires a company that has a reputation in the solution space that gives it permission to lead, bringing in value-added partners who can complete the solution model.

Value Proposition for Growers

While the overall precision irrigation solutions allow growers the potential to save energy and water costs, a common set of data standards provides a different, but compatible, value proposition. As noted above, growers are inundated with many different types of data. In summary:

- Growers spend too much precious time trying to sort through data that comes to them through different portals or websites
- Each piece of 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 make it difficult to convert data to meaningful, actionable information
- Using a mixed fleet (different brands) of equipment compounds the issues above

The need for real time data to effectively manage farms is only going to grow

The output from the PAIL project will allow growers, and their irrigation consultants, use real-time data, from multiple pieces of equipment, from multiple vendors, without having to acquire, digest and translate individual data formats.

Value Proposition for Vendors

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

1. **Financial Benefits**:
   Vendors save time and effort currently required to interact with multiple vendor products. They also increase the likelihood of purchase of their irrigation products and services, removing the barrier of growers 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. A commonly used set of data standards also makes it easier to partner with other businesses, both upstream and downstream.

The following example describes an integration effort that actually occurred between two companies in 2008. Both companies invested a significant amount of time and effort. The collaboration was successful and both companies benefited from the project however, the costs were not trivial. If an API had been available both companies could have achieved the same goal with lest time investment required. This is how the API reduces costs for the grower: by reducing cost of development of new interoperability between existing systems, those savings can be passed on to the customer.

Summary: In 2009, CropMetrics and AgSense worked jointly to develop the industry's first wireless Variable Rate Irrigation solution.

Issue/Problem: CropMetrics developed a VRI speed control prescription program but did not have any way to implement or load the prescription file effectively on the center pivot. At the same time, all center pivots were limited on the number of application adjustments they could make.

Solution: Working collectively with AgSense, they developed a prescription data format to upload wirelessly to AgSense's pivot monitoring and control website via a new API protocol developed by AgSense. AgSense then controls the speed of the pivot to adjust water application based on the CropMetrics variable rate prescription file. This was the first full integration of variable rate speed control irrigation.

Collaboration: Without the close working collaboration of both companies, the success of this technology would have been delayed or halted. Working together to develop a data standard, made wireless data transfer possible with greatly improves the efficiency, effectiveness and overall simplicity of the technology today.

Business Success: The development of this VRI technology introduced new development by pivot manufacturers to improve hardware to accept similar capabilities as well as introduced business opportunity for agronomic service providers. Most importantly, this joint effort delivers a solution to improve water use efficiency and conserve our most valuable natural resource.

The PAIL Project

The fundamental goal of the Precision Agriculture Irrigation Leadership (PAIL) Project is to improve agriculture irrigation by developing a common set of data standards and formats to convert data for use in irrigation data analysis and prescription programs.

"Ultimately, the objective of this project is have a common set of data standards and protocols used across the agriculture industry," says Terry Schlitz, AgSense President and Chair of AgGateway's Water Management Council. "With those in place, industry can deliver much more efficient, easy-to-use solutions for producers, which in turn will help them use available water and energy more effectively."

Producers and manufacturers currently report that it is difficult and time-consuming to make decisions on how much water to apply when and where. That's because weather, soil moisture and other relevant data are stored in a variety of Original Equipment Manufacturer (OEM) formats and data sources.

"Growers have many more options now to irrigate their fields more effectively," said Andres Ferreyra, AgGateway Precision Agriculture Council Chair, and AgConnections research and development coordinator. "For example, they can invest in soil maps, install different types of pumps or flow meters, use soil moisture sensors, and put variable rate irrigation systems on their center pivots. There are a few software applications that tie them together. However, these tools don't actually talk to each other effectively or efficiently."

As noted, the PAIL Project is housed within AgGateway, and collaborates with other AgGateway projects, where leverage can be gained. For example, PAIL has been collaborating with AgGateway's Standardized Precision Ag Data Exchange (SPADE) Project to ensure that common terms and data formats are the same. Specific areas of collaboration include data management for location and boundary, soil testing, and crop identification. Adjacent activities to support the development and adoption of the PAIL data standards include a list of glossary definitions and helping to create the ontology for irrigation terms.

Areas that PAIL addresses include:

- Irrigation system setup, configuration, performance specification
- Irrigation system operation, control, and status
- Pumps
- Data acquisition systems (Observations. Source is on- farm)
- External Data Inputs (Offsite, weather networks, etc.)
- Data Outputs (climate data, yield analysis, water balance results, NRCS IWM reporting, etc.)

PAIL Project Deliverables include:

- Business and technical use cases, including description of processes supported by the messages that arise from PAIL
- Glossary of terms used in this project (lists and definitions)
- Ontology document for representing and uniquely identifying the different variables referenced in the project (e.g., air temperature at 2 m, pressure at the base of the irrigation system, latitude of the pivot center, etc.)
- Schema describing messages for retrieving data from the field and for sending prescriptions to the field.
- Results of testing the proposed standard
- Proposed standard(s) submitted to ASABE and/or other standards organizations for discussion / implementation use by the industry

Project Plan

The PAIL group officially began work in early 2013. The project will have two phases. The first will focus on specifying the standard. The second phase will focus on testing and implementation, expansion of the standard to include other uses of irrigation technology, and inclusion of emerging issues. Specific deliverables of the first phase are:

- Use Cases - These will describe most (or all) of the likely scenarios where systems will use the data standards. The use cases also help to define the scope of the data standard.
- Glossary - a robust dictionary of terms and definitions as they are used within the context of specifying the data standard.
- Ontology - a technical specification of each of the quantities and variable referenced in the standard. The ontology uniquely identifies each of the variables referenced in the project.
- Schema - a technical document that unambiguously specifies all of the potential information, its structure, and interrelationships. This document is the basis for creating, verifying, and using documents and messages that conform to the data standard.
- Multiple tests of the standards wherein the standard’s function and completeness are verified within the context of an integrated irrigation management system
- A proposed standard submitted to the American Society of Agricultural and Biological Engineering

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 progression, work was often iterative, as team members gain new insights.

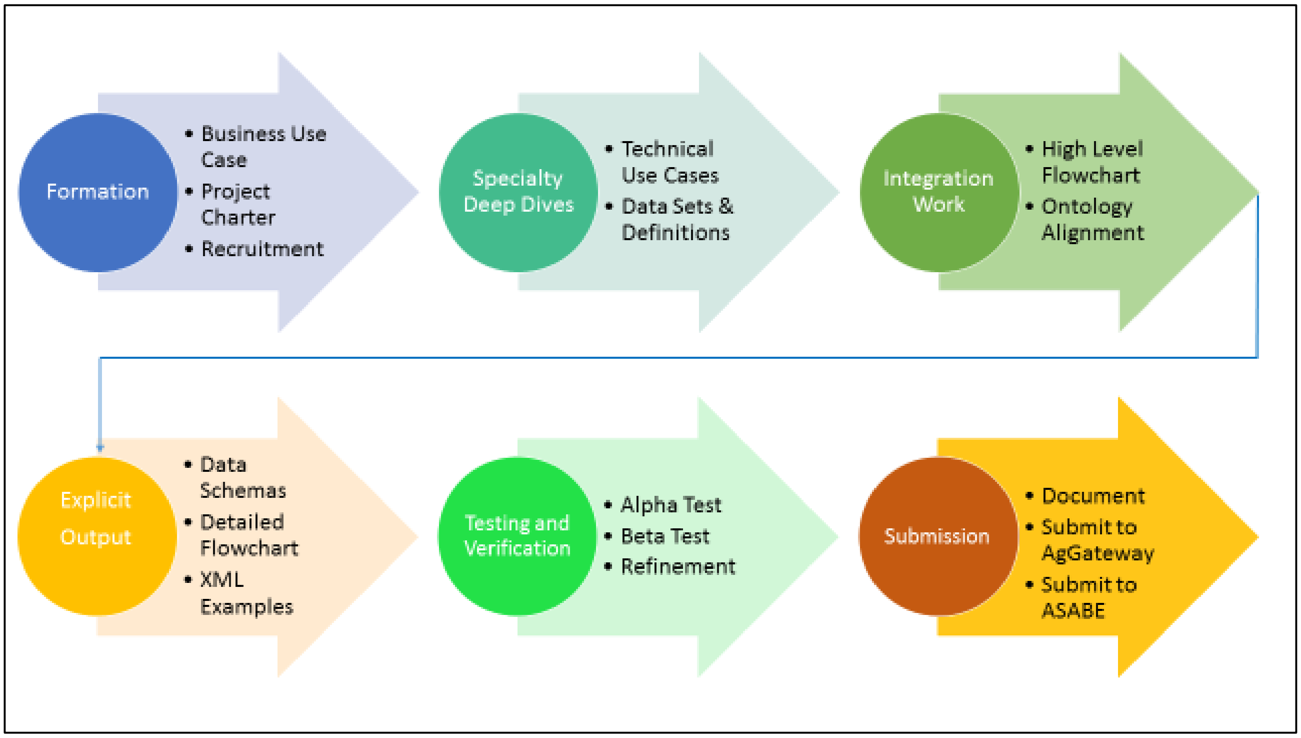

Figure 2: Data Standards Process Flow

Project Scope

A broad definition of the PAIL scope is included in the PAIL project charter. The scope of the PAIL project is shown in the following two inset boxes.

In Scope

1. Irrigation system (not restricted to pivots) setup, configuration, performance specification
    1. Location and geometry of the irrigation system
        1. Opportunity to discuss end gun, corner arm specification
    2. Flows and pressure
2. Irrigation system operation, control, and status
    1. Schedules (how much and when) and Prescriptions (where)
        1. Data representation for establishing a schedule / prescription's scope in space and time
    2. Error reporting, Alerts
    3. As-applied / resource use accounting (non-economic)
3. Pumping Plants
    1. Setup & Configuration
    2. Monitoring & Control
4. Data acquisition systems (Where source is on-farm)
    1. Setup & Configuration
    2. General environmental monitoring
    3. Soil monitoring
    4. Atmospheric monitoring
    5. Plant-based monitoring
5. External Data Inputs (weather networks, etc.)
    1. Weather Forecast, aggregated weather / climate info, weather networks
    2. Soil (SSURGO and other soil maps, EC maps, holding capacity maps)
    3. Energy
    4. DEM
    5. Historical Yield Data (Explore cooperation w SPADE)
    6. Manual Soil Sampling
    7. Crop Performance, Crop coefficients
6. Data Outputs
    1. Historical Weather summary
    2. Yield analysis
    3. Water balance (e.g., NRCS IWM reporting)

Out-of-Scope

1. Data exchange below the OSI (Open Systems Interconnection) Transport Layer, corresponding to the International Standards Organization (ISO) 7498 standard.
2. Crop simulation details
3. Biotic factor scouting details.
4. Considerations / recommendations about sampling rates.
5. Crop performance: Yield modeling
6. Human-mediated data acquisition (e.g. scouting)
    1. Stand density, quality, growth stages
    2. Abiotic stress factors, such as water and flooding
    3. Biotic stress factors, such as insects and diseases
7. Economics (energy use, energy cost, water costs, revenue forecast (estimated yield & price), estimated costs of other production practices (fertilizers, crop protection).

Technologies

The following methods and processes will be used during the development process:

- **Use Cases -** These will describe the most likely scenarios where systems will use the data standards. The use cases also help to define the overall scope of the data standard.
- **User Stories** – These are textual narratives that describe specific hypothetical cases where the data exchange standards might be used. User Stories are different from Use Cases in that they are less structured and less abstract. The stories are essentially a fictional construction where the data exchanges are explicitly described
- **Glossary** - a robust dictionary of terms and definitions as they are used within the context of specifying the data standard.
- **Business Process Model Notation** diagrams (Weidlich and Weske 2010) – This is a graphical tool for describing business processes. These are similar to flow charts or UML activity diagrams and are useful for describing where and when data exchanges occur relative to expected farming activities.
- **XML Schemas** (Fallside and Walmsley 2004) - a technical document that unambiguously specifies all of the potential information, its structure, and interrelationships. This document is the basis for creating, verifying, and using documents and messages that conform to the data standard.

Organization

The preceding scope statement includes a broad variety of information sources and types. Accordingly, the PAIL participants also represent a diverse group of technologies. Companies producing Farm Management Information Systems, Pivot Irrigation Systems, environmental monitoring equipment, soil moisture monitoring equipment, and a few large growers are participating in the PAIL project.

Table 1: PAIL Vendor Participants

AgConnections	Lindsay Corporation
Agrian	Map Shots
AgSense	Monsanto
Campbell Scientific	Observant
CropIMS	OnFarm Systems
Crop Metrics	Ranch Systems
Decagon	Simplot
FirstWater Ag	Valmont
Irrinet	Wysocki Farms
Irrometer	ZedX, Inc.
John Deere Water	

AgGateway

The irrigation data standards work is happening within the Water Management Working Group, part of AgGateway's Precision Ag Council. In November 2012 the companies that had previously been working on data standards development with NEAA agreed to move the standards development effort into the AgGateway environment. This moved allowed the PAIL group to benefit from AgGateway's anti-trust umbrella, AgGateway's existing infrastructure and standards development and maintenance services, and to benefit from the synergies that could arise from exposure to a larger group of businesses committed to data exchange standards. As a result, AgGateway's Precision Ag Council chartered the PAIL (Precision Ag Irrigation leadership) Project in early 2013.

Northwest Energy Efficiency Alliance

The Northwest Energy Efficiency Alliance (NEEA) is a non-profit organization working to increase energy efficiency to meet our future energy needs. NEEA is supported by and works in collaboration with the Bonneville Power Administration, Energy Trust of Oregon and more than 134 Northwest utilities on behalf of more than 12 million energy consumers. NEEA uses the market power of the region to accelerate the innovation and adoption of energy-efficient products, services and practices. Since 1997, NEEA and its partners have saved enough energy to power more than 600,000 homes each year.

Workgroups

Given the breadth of information covered by PAIL's scope, it is impractical to have the entire group address the entire scope simultaneously. Instead three sub groups have been formed: Inbound data sources, Field Operations, Off-site data. The scope of the different groups illustrates the collaborative development process used in PAIL. The work groups were not defined *a priori*. The groups evolved out of several of the PAIL group meetings. The different company representatives whose products interacted or performed similar functions gravitated together to focus on data exchanges that their products were likely to perform. Not only does this partitioning provide a practical decomposition of the scope, it also provides a convenient way for new participants to find the right workgroup for their participation.

Schema

The primary technical product of the PAIL group is an XML Schema that defines the structure of the information that is exchanged during the process of irrigation management. A process preceded development of the schema where the PAIL group examined tasks and problems typical of precision irrigation. Documentation of these tasks is embodied as a set of Use Cases that effectively defined the scope of the PAIL schema. Development of the Use Cases was followed by an examination of the data flows that occurred in each of the tasks.

Dataflow overview

Using Figure 2 as an overall guideline, the PAIL team developed specific flow charts to simulate the data flow in support of the grower use case, including the following steps:

1. A grower communicates a crop plan to an irrigation consultants
2. The consultant gathers and analyzes relevant data
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 Field Management Information System (FMIS)

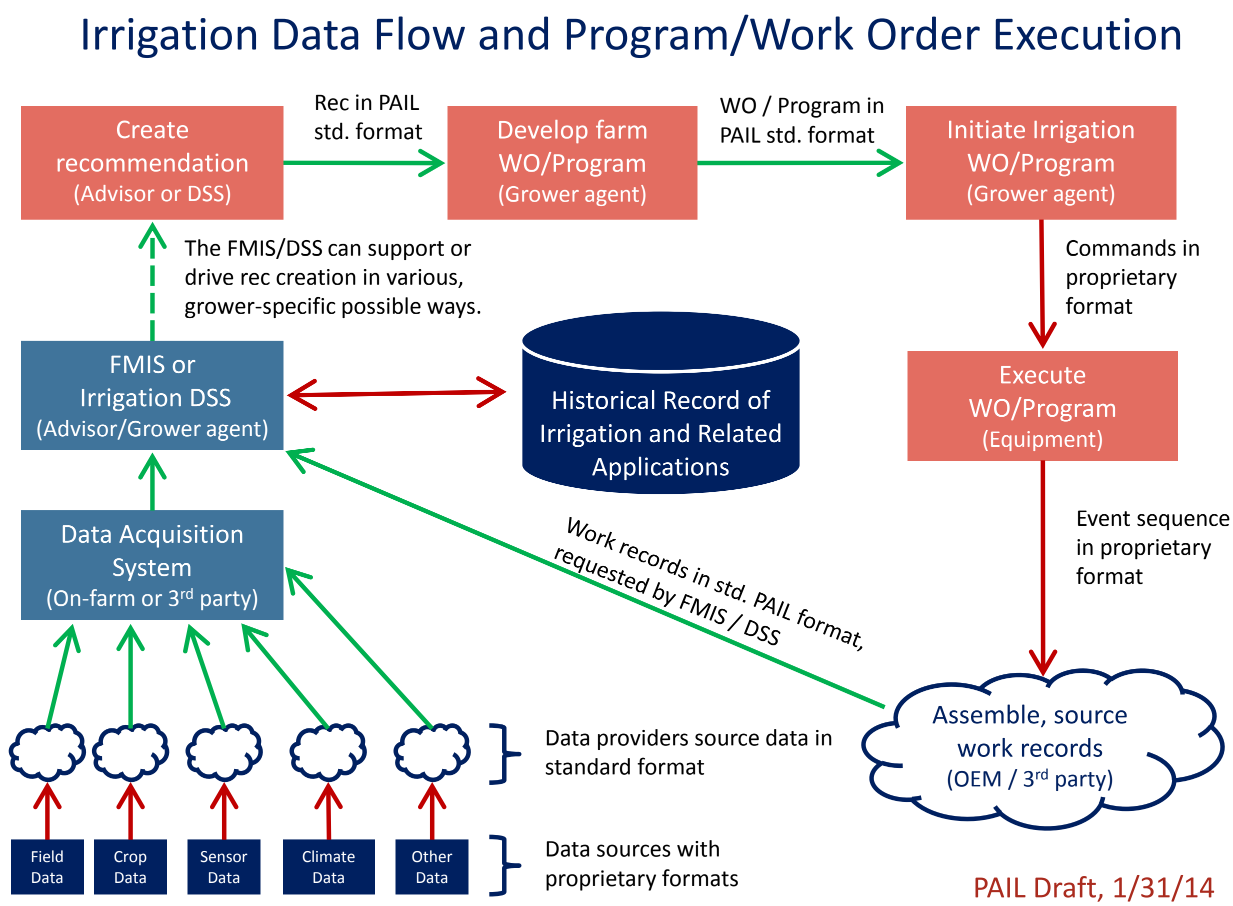

Figure 3 Overview of expected data flows occurring in precision irrigation management

BPMN Diagrams

Figure 3 and Figure 4 show the BPMN diagram that corresponds to the simulation described in the previous section (the original diagram is too large to be readable in a single figure so it has been split into two parts). These are the interactions that are expected during a typical irrigation management cycle.

Readers familiar with current irrigation management practices may find the interactions overly specified. In many operating farms the interactions are not formal in any sense and do not involve any exchange of information other than simple verbal communication. The level of specificity in the BPMN diagram is by design. The management practices being modeled here are those needed to execute precision irrigation management. This management practice is necessarily more complex, and thus more information intensive than conventional management styles. It should also be noted that the process described by the BPMN is not the only possible form that irrigation management may take. This specification is intended to represent what is considered the most likely form of the process. Extensions and modifications are still possible and the data standards will be designed to accommodate those differences.

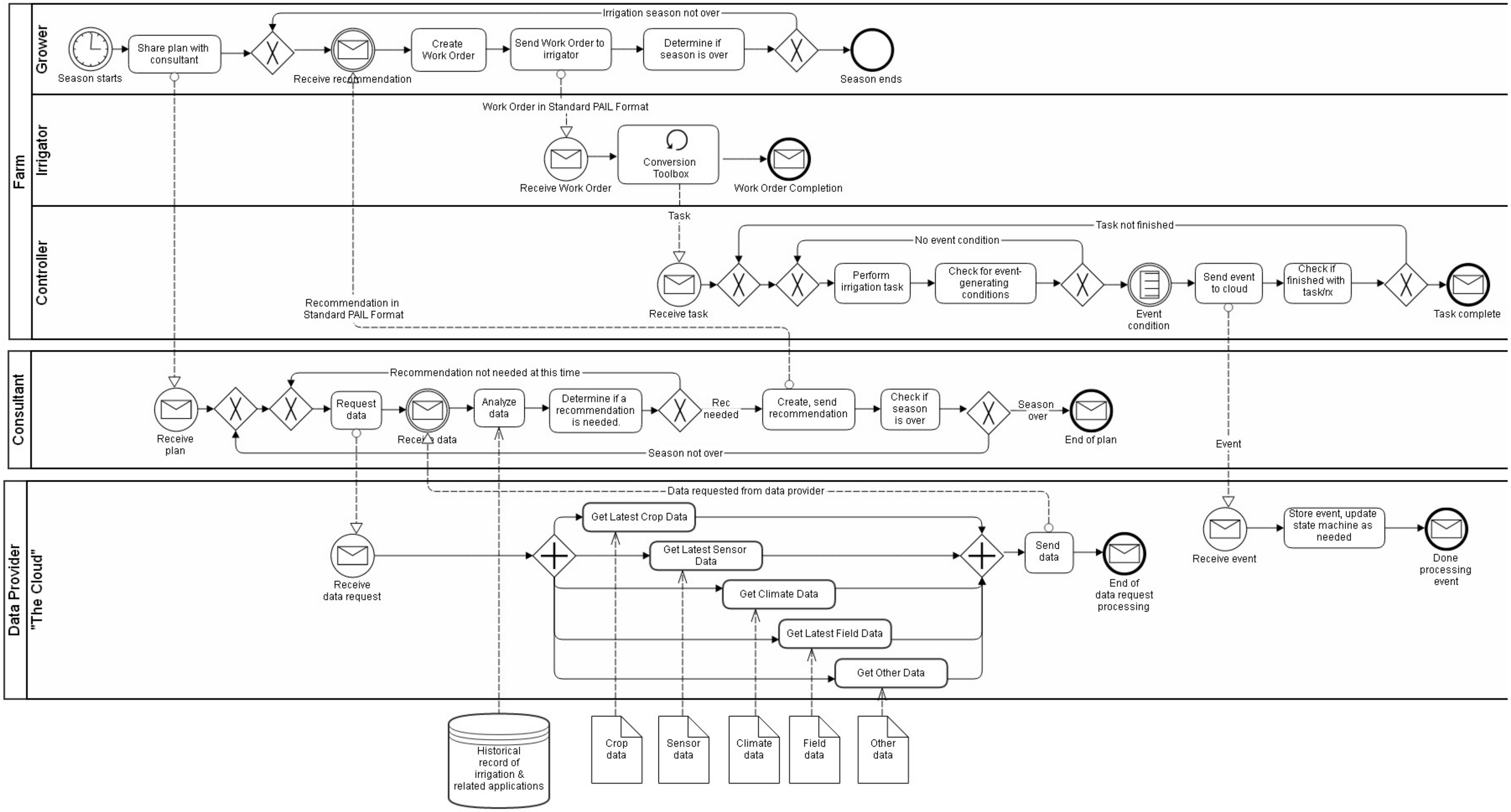

Figure 4 BPMN Diagram (part 1)

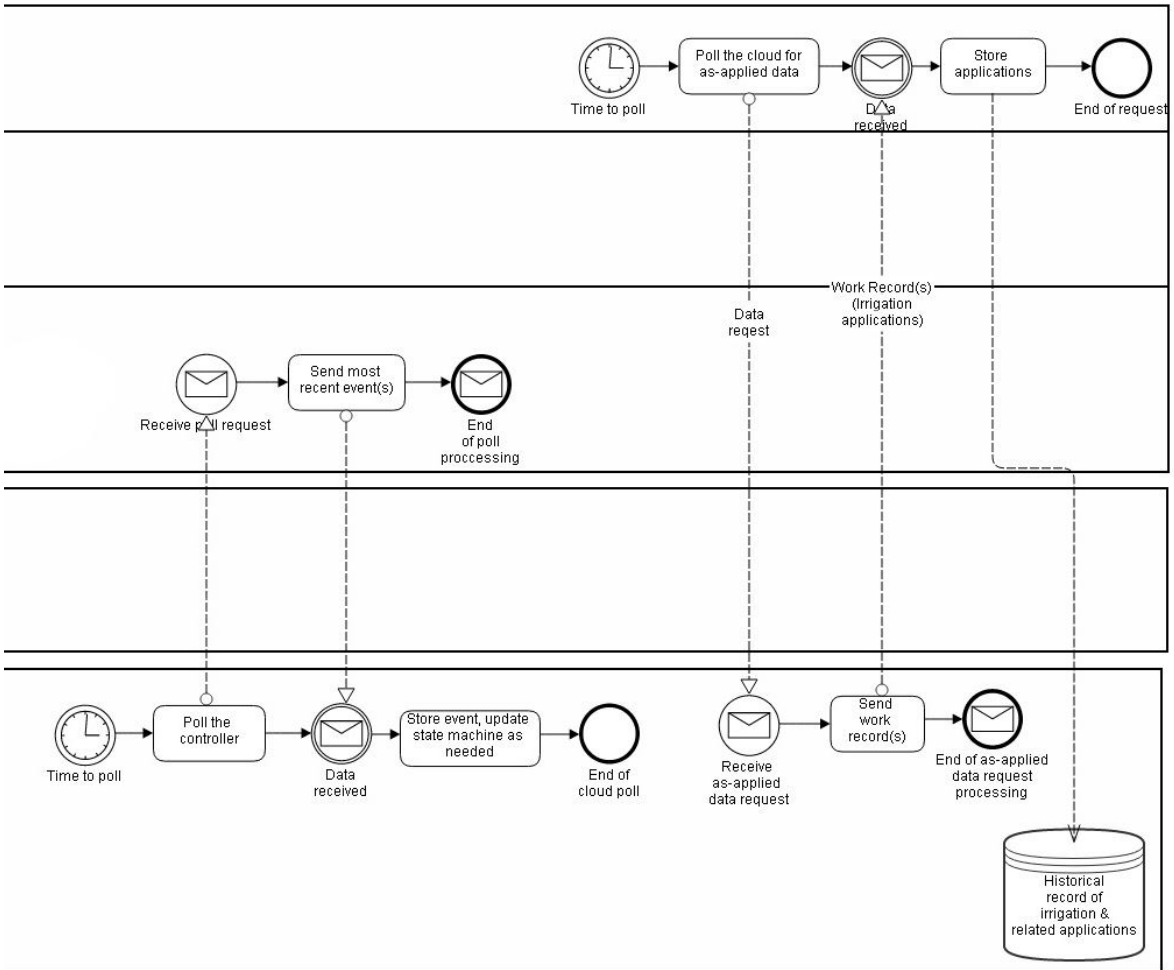

Figure 5 BPMN Diagram (part 2)

Schema Elements

PAIL XML files can contain several different types of 'document' as shown in Figure 6[2]. The documents effectively contain the information that is moving with each of the interactions shown in the BPMN diagram. The PAIL schema can be roughly divided into three parts: InBound, AsApplied, and OffSite. The three parts correspond to the three main working groups within the PAIL project. Each of these parts is described in the following sections.

[2] These diagrams were generated with Altova's Xml Spy schema development software.

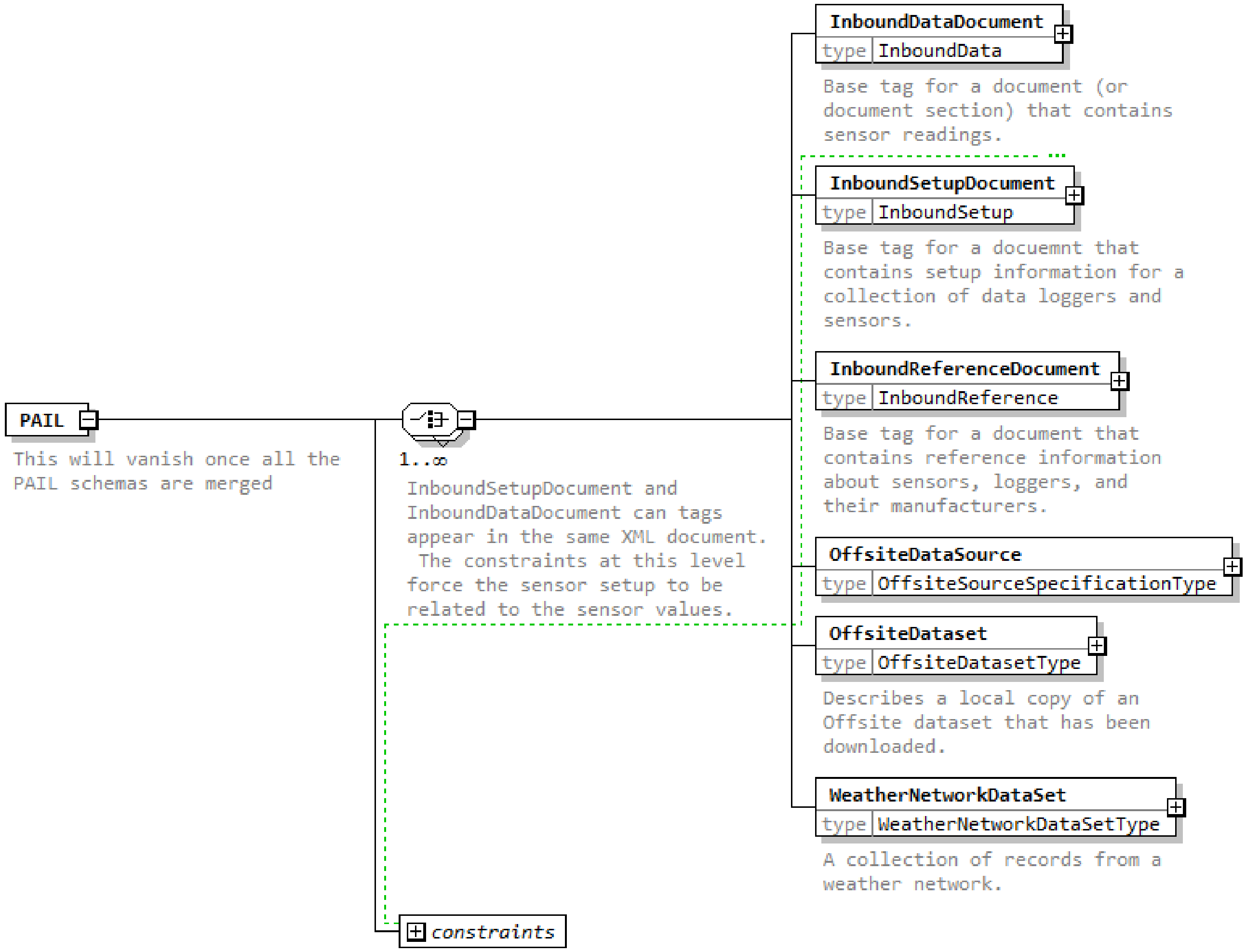

Figure 6 Schema top level elements

As Applied

This schema includes specification of irrigation work orders and elements for describing water applications that have been completed (i.e. the 'as applied' water use records). Figure 8 shows the **WorkRecordItemType** which is used to describe irrigation that has occurred or will occur. This element can also contain elements used to specify variable rate irrigation prescriptions. The AsApplied section also contains the elements that describe the physical characteristics of an irrigation system. The element that describes pivots is shown in Figure 7. The current schema development has focused on pivot systems however later development will also include drip, micro sprinkler, and other system types.

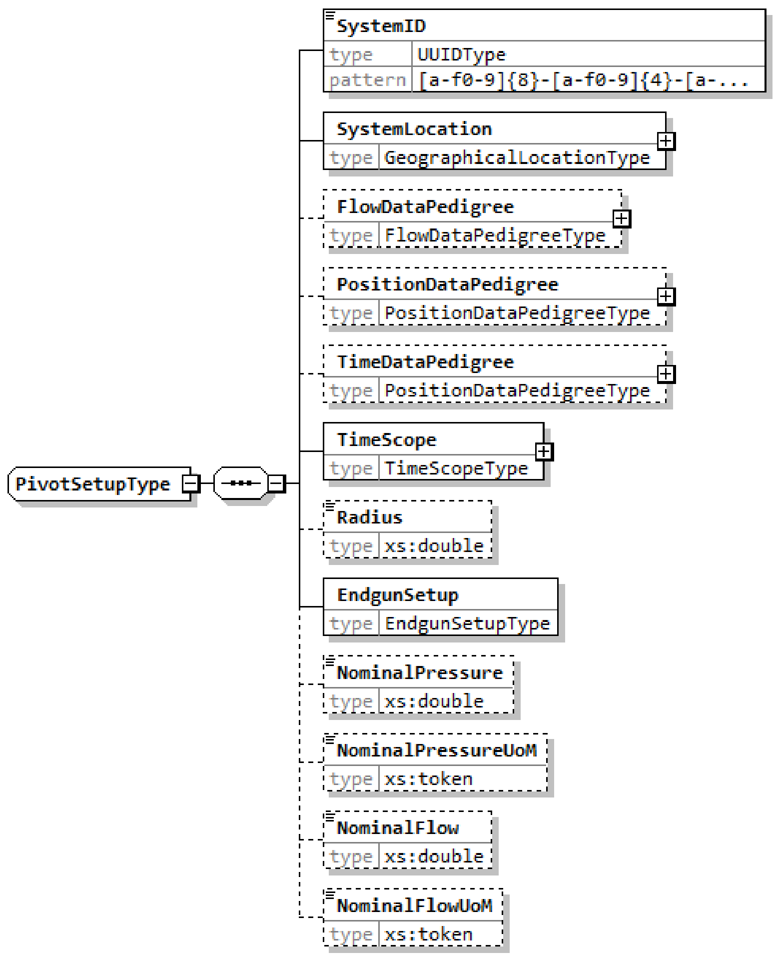

Figure 7 PivotSetupType schema element

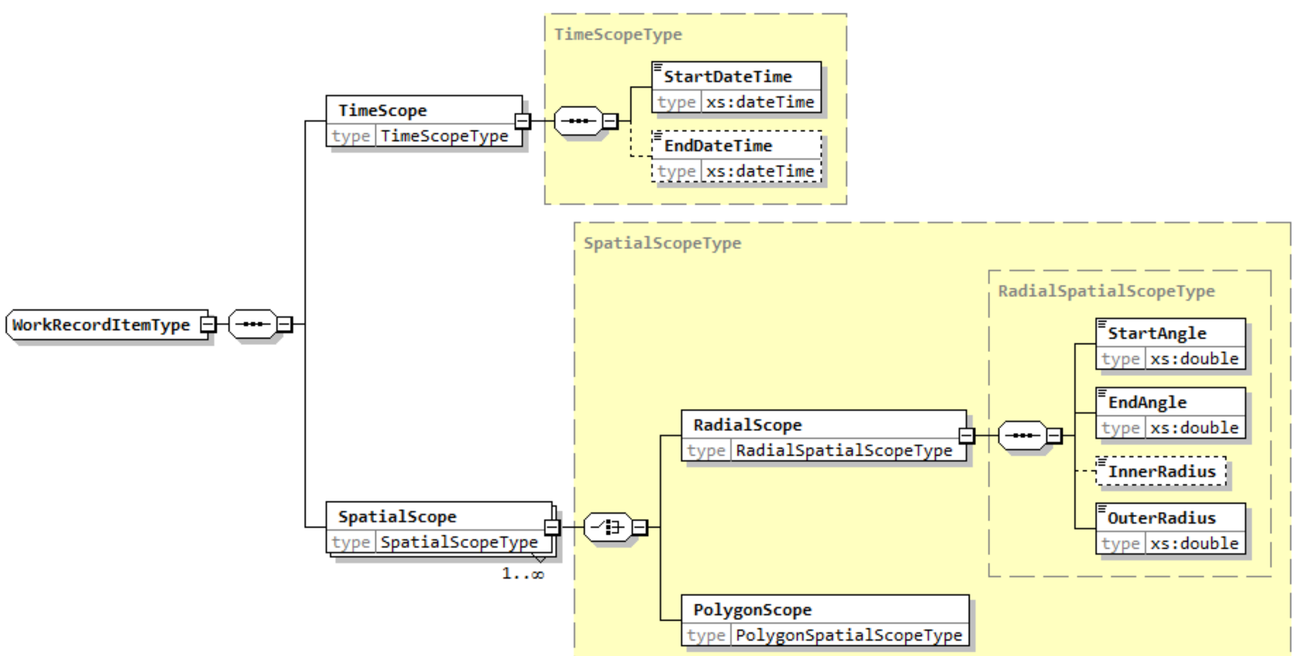

Figure 8 **WorkRecordItem** Type schema element

Inbound

This schema section describes any data collected on farm using sensing devices (e.g. a weather station). The three main document types in this section are

1. **InboundData** (Figure 9) which contains data collected by on-farm sensing devices,
2. **InboundSetup** (Figure 10) which describes the deployment of the sensors and dataloggers as well as their technical capabilities,
3. **InboundReference** (not shown) which is used to identify reference properties (e.g. unique identifiers) that are manufacturer specific.

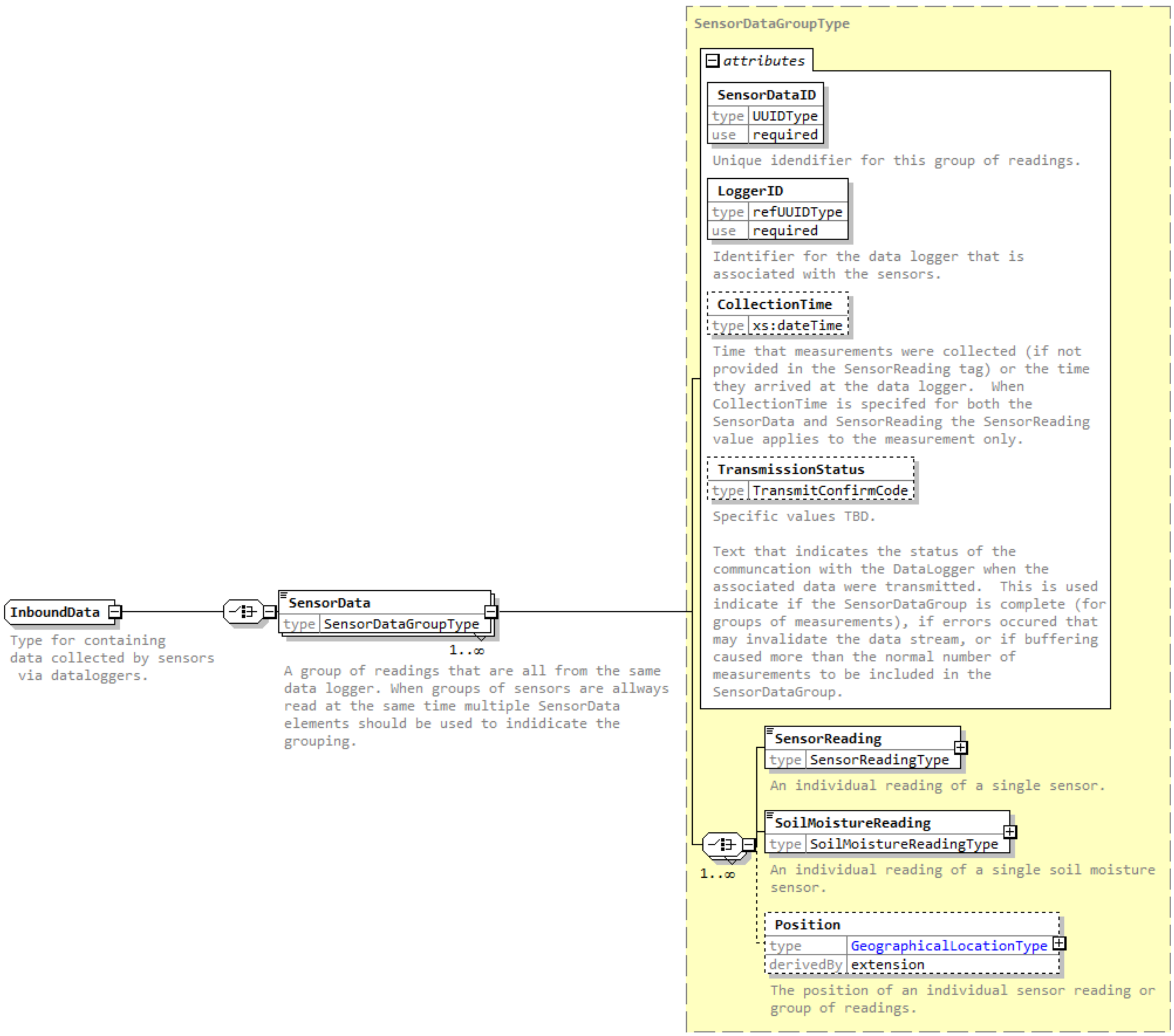

Figure 9 **InboundData** schema element

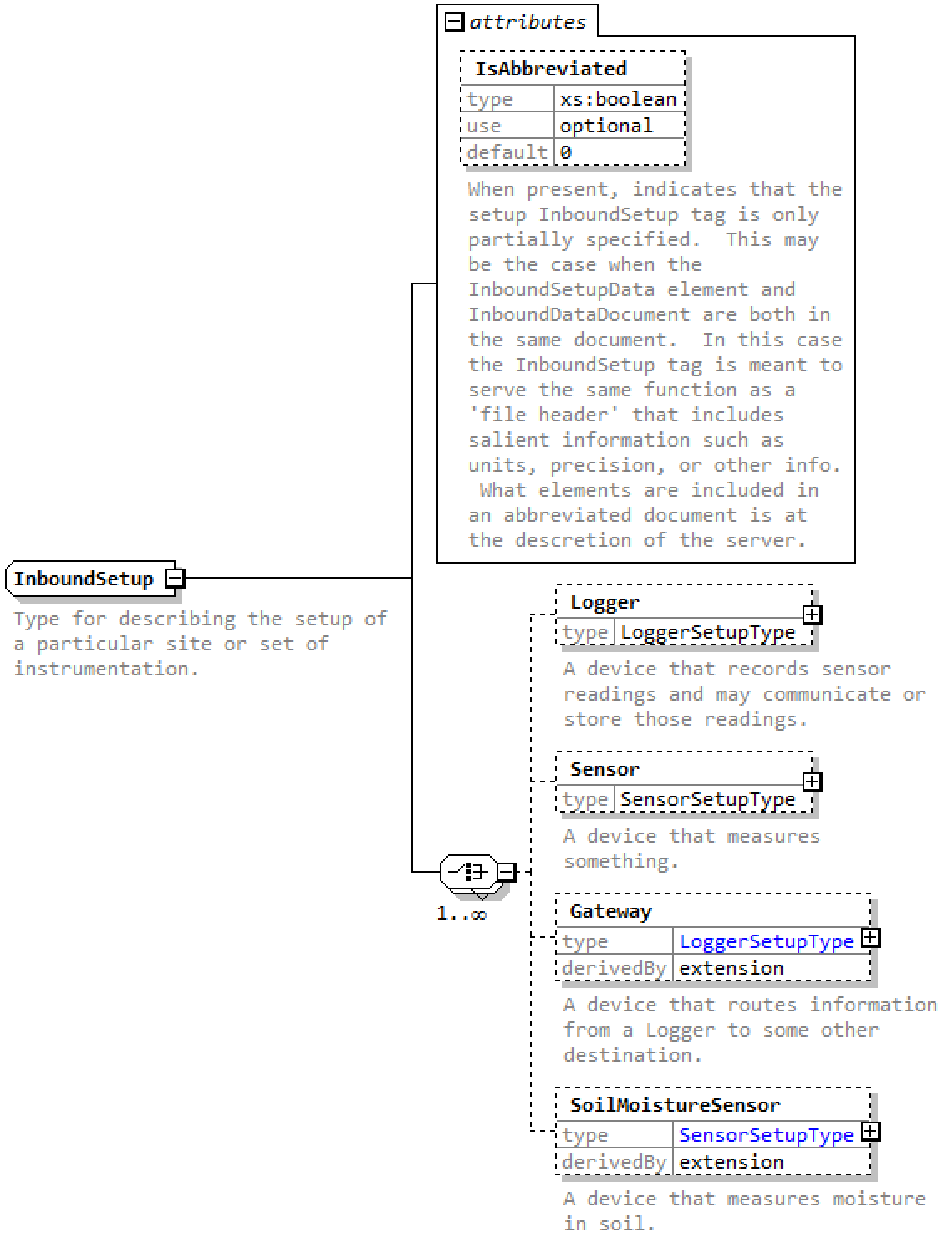

Figure 10 **InboundSetup** schema element

OffSite

This section describes information sources that are external to the farm enterprise. Typical examples are NOAA web services or similar weather data provider's data outputs. This section has documents that describe how/where to obtain data and how/where the data is stored. These two documents, called **OffsiteDataSource** and **OffsiteDataSet** respectively, do not specify the content of the information, only its attributes and means for obtaining the data. A third document type is intended specifically for containing weather data collected by agricultural weather networks. The basic structure of this element is shown in Figure 11.

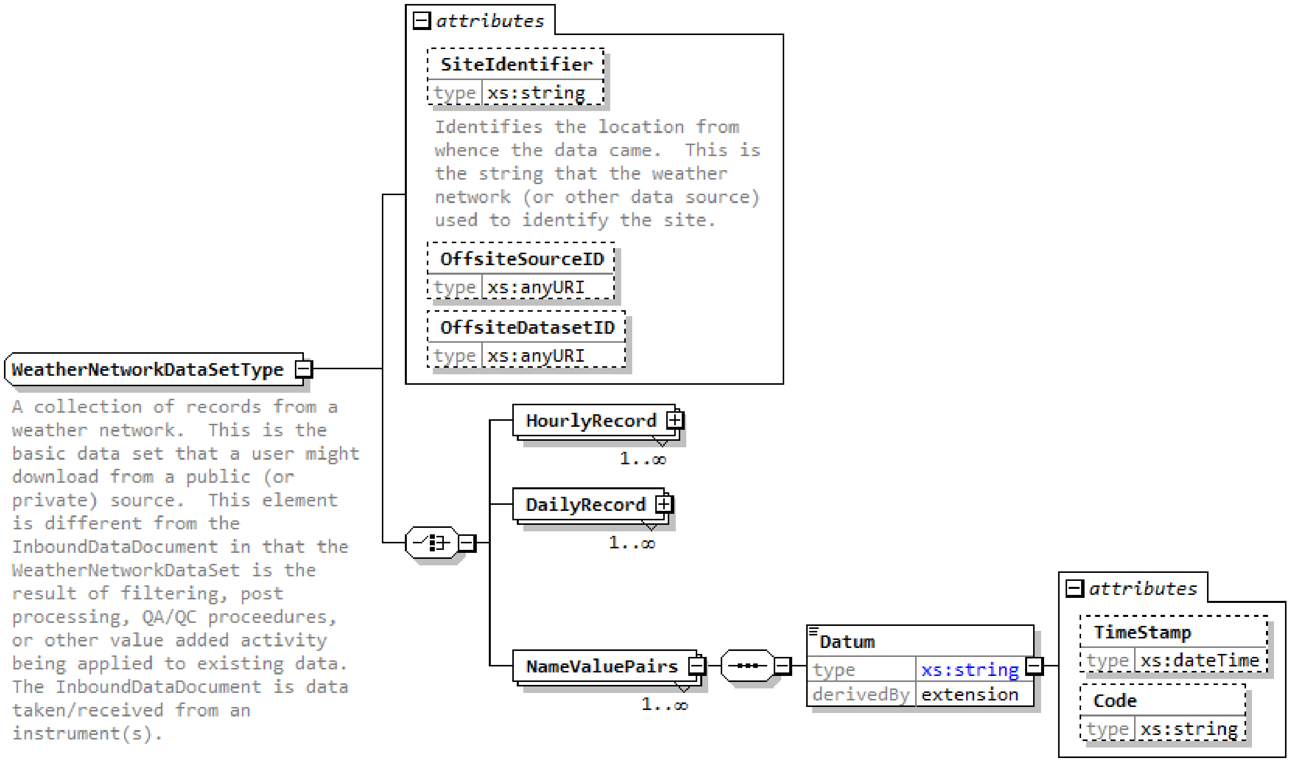

Figure 11 **WeatherNetworkDataSetType** schema element

Development Progress

The PAIL group has been actively working since 2013 and this work will continue into 2015. Preliminary results of the group's efforts are presented in the following sections.

Schema Development

Since beginning work in 2012, the PAIL team has develop a robust set of Use Cases that cover several common irrigation management operations. Schema development has been ongoing since the formation of the first use cases. Each workgroup is developing a separate schema that roughly corresponds to the technical domain of that group. The schemas will, wherever possible, uses schema elements defined by existing AgGateway schemas. Common information elements like units of measure or geographical locations will use existing well recognized schemas already in the public domain. As PAIL schema development progresses these schemas will be merged into a single cohesive document.

Simulation Testing

In order to demonstrate that the proposed schema will support irrigation decision making, a combined simulation and field test is being constructed. This test will act as a proof of concept demonstration and will exercise as much of the schema as is practical. The full details of the simulation test are beyond the scope of this paper; only an overview of the interactions will be described here.

The field trail currently consists of two sites that are generating data. OEM providers and data providers are working to transfer data produced at the test sites using documents that comply with the PAIL schema. Two samples of data produced during the field trial are shown in Figure 12 and Figure 13. Figure 12 shows an example of the work record element described in Figure 8. This document also includes the **PivotSetupType** element described in Figure 7.

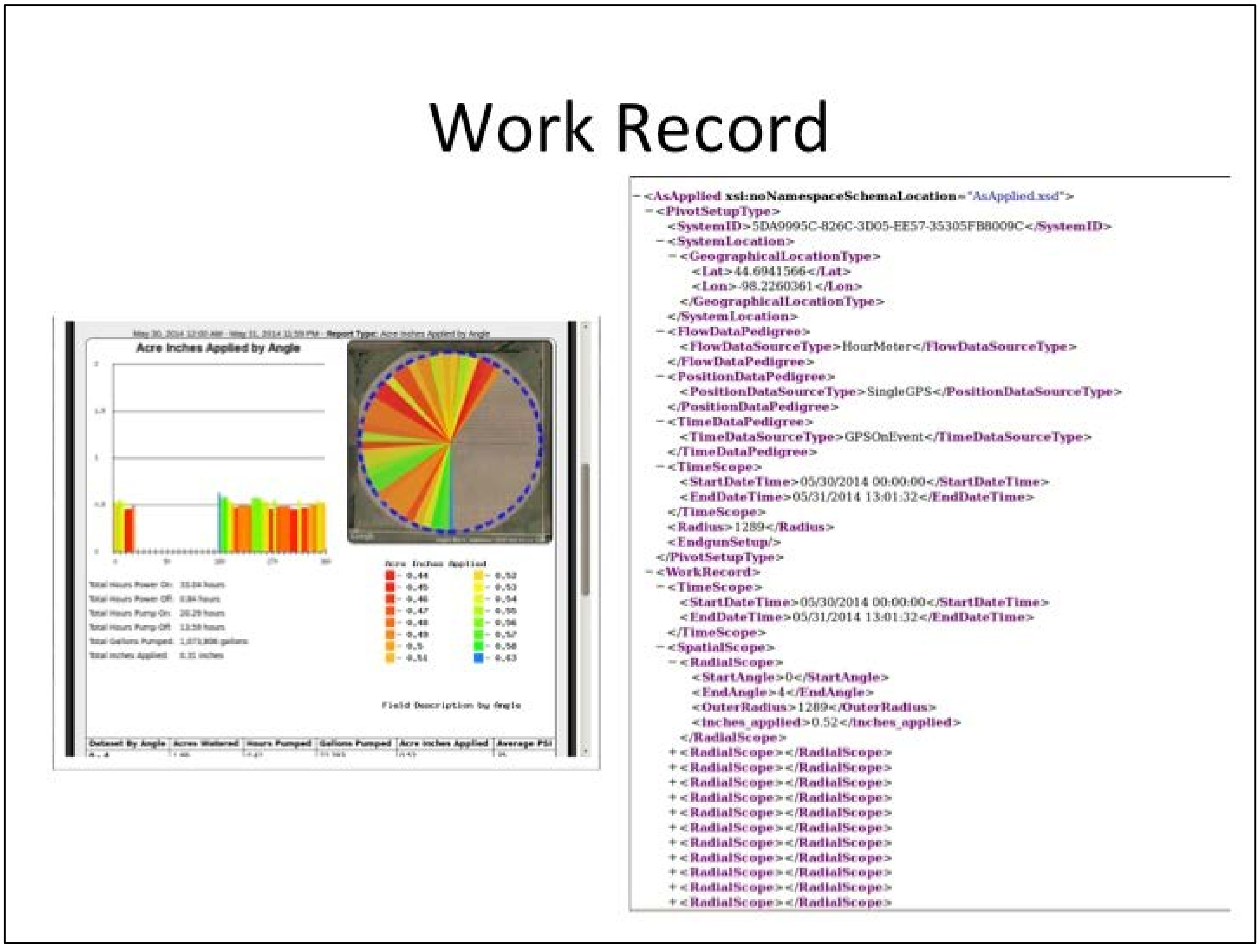

Figure 12 Example of a work record document

Figure 13 shows and example of the InBound data elements produced during the field trial. In this example soil moisture data has been converted into an **InboundData** element as specified in the PAIL schema. In this example, the **DataDocument** element contains an array of sensor readings that are intended for us in a decision support system.

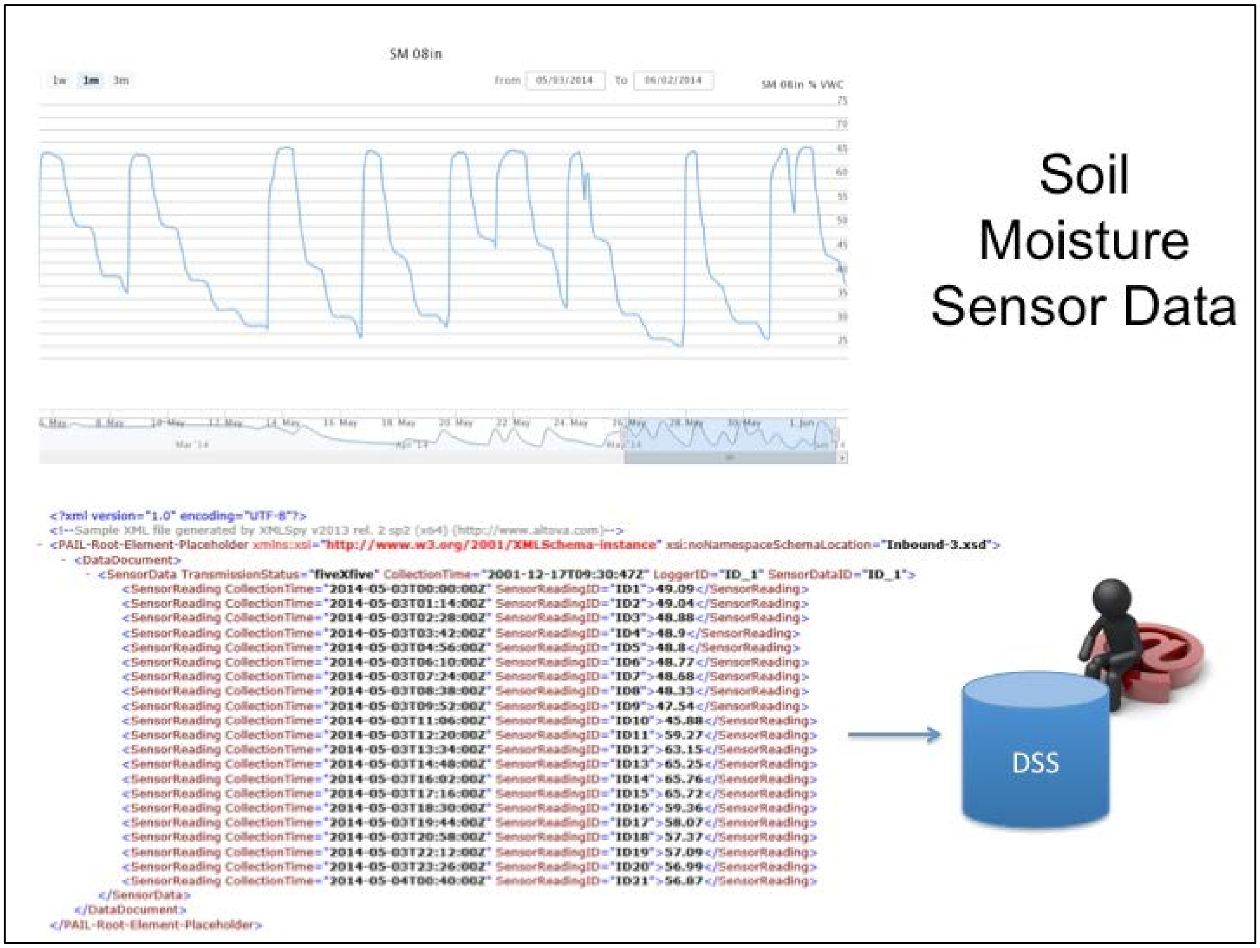

Figure 13 Example of Vendor's Soil Moisture Data Converted to PAIL XML Format

Glossary

AgGateway's SPADE group has already created a substantial glossary of precision agriculture terminology. The PAIL group is building on that glossary and adding terms as they are used in the data schema development. The glossary is being aligned with ASABE S526.3 Soil and Water Terminology standard and ISO/TC 23/SC 18/WG1 Agreed Irrigation Definitions standard.

PAIL worked with ISO and the NRCS to align irrigation terms that are primarily *agronomic* with ISO terms that are primarily *equipment-oriented*. Bridging this gap is important to align irrigation schedule and prescriptions with execution on equipment. Figure 6 below shows an example of this work. Joe Russo from ZedX, Inc. has been the lead on this part of the project.

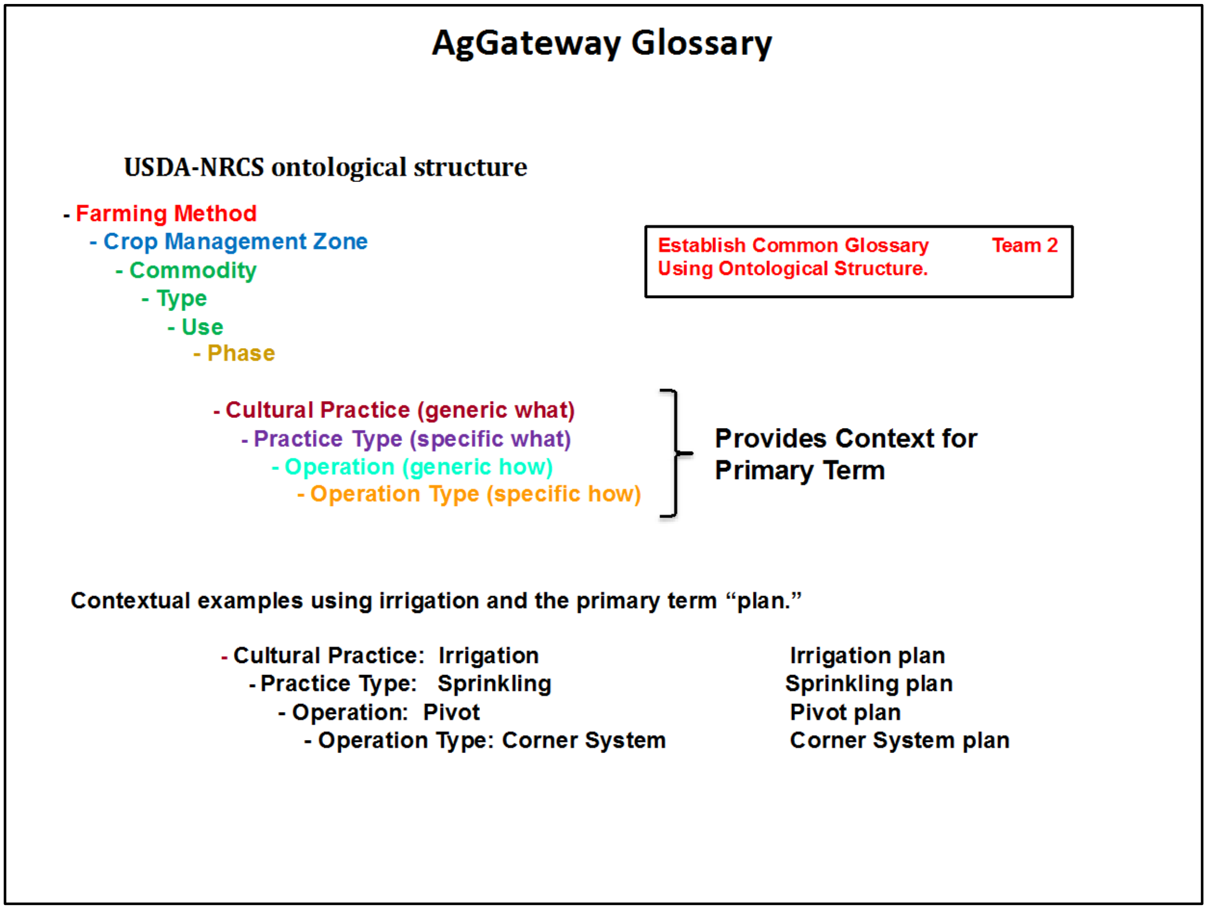

Figure 14: Providing Context and Structure for Agricultural Irrigation Terminology

Proposed ASABE Standard

A standards development project has been initiated within ASABE. This project, titled Agricultural Irrigation Data Exchange Standard (project number X632), will formalize the standards developed within the AgGateway. This project is housed under the SW-244 Irrigation Management committee. Ultimately, this standard will also become an ISO standard.

Conclusion

Precision irrigation management is an information intensive process. A variety of tools and technologies exist that enable or support irrigation. These tools rarely interoperate readily without significant effort by the irrigator. System integration is a significant factor in ease of use of advanced technologies. Adoption of new irrigation technology is limited by the effort required to use the technology. Thus, system integration is a significant factor in ease of use of advanced irrigation technologies. The Precision Ag Irrigation Leadership project is expected to have a lasting beneficial impact on the agricultural irrigation industry. PAIL will improve interoperability of irrigation technologies and, consequently, increase adoption of more efficient irrigation practices. The PAIL project is ongoing and the workgroups expect to complete their goals in 2015. Plans for the second phase, PAIL 2, are already underway. Companies, individuals, institutions, and organizations interested in participating should contact the authors for instructions on how to join AgGateway and how they can contribute to this effort. As of November 2014, membership in the PAIL project is still open to new participants; it requires membership in AgGateway, and membership in the PAIL project. Interested parties should contact AgGateway Member Services (member.services@aggateway.org) for more information.

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