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Precision Agriculture Irrigation Language: Core Concepts, Processes, and Objects



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ASABE, 2950 Niles Road, St. Joseph, MI 49085-9659, USA, phone 269-429-0300, fax 269-429-3852, hq@asabe.org

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Precision Agriculture Irrigation Language: Core Concepts, Processes, and Objects

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0 Introduction

The need to feed a growing global population with limited resources, in the context of ever-increasing regulatory pressure, supply-chain interest in traceability and sustainability, and market price volatility, requires principled decision-making regarding the usage of crop inputs such as water, fertilizers, and crop protection. Better decision-making requires the capture and sharing of a variety of data across multiple hardware and software platforms; a necessary condition for this greater *interoperability* is the rapid deployment of standard formats for data exchange in agricultural field operations, and irrigation is no exception.

Current irrigation technologies allow growers to use water and fertilizers more efficiently, while maintaining or increasing their yield. It is especially useful in fields where the soil is not uniform. Precision irrigation technology relies upon the capture and analysis of multiple sets of data from various pieces of equipment and databases to support analysis, planning, operations and reporting of results. Exchange of information between these devices is a normal and necessary process for effective use of the devices when employing them for irrigation management. A standardized communication method between inputs for the system and the control devices is needed to maximize the utility, application and desired outcome of advanced, precision irrigation methods and applications. Data exchange 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 harvest yield. Among the benefits they provide there are two that are noteworthy:

- Data exchange standards facilitate broader (i.e., more technologies) and more comprehensive (i.e., greater level of detail and precision) systems integration. This is achieved by reducing development and maintenance costs for data handling systems.
- The standards promote reliable system interoperation: standards-compliant tools are expected to work together; the end user benefits by having confidence that two products from different sources will work together as expected.

1 Purpose and Scope

This Standard enables the exchange 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. The goal is to standardize data formats for irrigation equipment, including, but not limited to, weather stations, soil-moisture sensors and irrigation control systems, soils data, GIS data, and other agricultural irrigation-related information impacting irrigation methods and applications.

1.1 The scope of the Standard is based on two major irrigation data processes:

1. Observations are the field, atmospheric, plant, or other *in situ* measurements that apply to irrigation management. This includes weather stations, soil moisture sensors, or crop-related sensing. This work is an agricultural implementation of the ISO 19156 standard for observations and measurements (ISO, 2011).
2. Operations are all of the activities associated with the application of water with an irrigation system. This includes, but is not restricted to, management-level communications and record keeping. The operations data set is based around a *Recommendation*, which describes a suggested course of action; a *Work Order*, which describes a desired course of action; and a *Work Record*, which describes what actually happened. This work is based on, and extends, the ISO11783-10 standard for communications between agricultural machinery and FMIS (ISO, 2015).

1.2 The Standard consists of three parts:

1.2.1 Part 1 (this document): Core Concepts, Processes, and Objects

- Business processes associated with the irrigation field operation
- The Actors and their role(s) in the process
- Core Documents and their relationships
- Common components
- Identity — Compound identifiers
- Time, space, people, data pedigree, geopolitical-context-dependent data
- Reference data
- Setup and configuration data

1.2.2 Part 2: Observations and Measurements

- Observations: An agriculture-specific implementation of the ISO 19156 standard
- Field observations, including soil water content and local field weather
- Setup and configuration of sensors and loggers
- Derived weather data

1.2.3 Part 3: Irrigation System Operations

- Location and geometry of the irrigation system
- End gun, corner arm specification
- Flows and pressure schedules (how much and when)
- Irrigation Work Orders to drive pivot controllers
- Error reporting
- Work records: Reporting how much, and where, water was applied

1.2.4 Annex A contains an XML schema implementation of the object model described in the preceding sections.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/FDIS 6709 Standard representation of geographic point location by coordinates

ISO 8601 Data objects and interchange formats — Information interchange — Representation of dates and times

ISO/IEC 9834-8 Information technology — Procedures for the operation of object identifier registration authorities — Part 8: Generation of universally unique identifiers (UUIDs) and their use in object identifiers

ISO 11783-10 Tractors and machinery for agriculture and forestry — Serial control and communications data network — Part 10: Task controller and management information system data interchange

ISO/IEC 13249-3:2011 Information technology — Database languages — SQL multimedia and application packages — Part 3: Spatial (WKT)

ISO 19109 Geographic information — Rules for application schema

ISO 19112:2003 Geographic information — Spatial referencing by geographic identifiers

ISO 19156:2011 Geographic information — Observations and measurements

ISO/IEC 19510:2013 Information technology — Object Management Group Business Process Model and Notation

ISO/IEC 19757-3:2006 Information technology — Document Schema Definition Language (DSDL) — Part 3: Rule-based validation — Schematron

ISO 22006:2009 Quality management systems — Guidelines for the Application of ISO 9001:2008 to crop production

Quantities, Units, Dimensions, and Data Type (QUDT) Ontologies

UN Recommendation No. 20 Units of Measure

Unified Code for Units of Measure, version 2.0.1

WMO No. 8. Guide to Meteorological Instruments and Methods of Observation, 7th Edition. 2008. Geneva

3 Definitions

3.1 center pivot irrigation: a form of overhead sprinkler irrigation consisting of a number of self-propelled towers supporting a pipeline rotating around a pivot point, and through which water supplied at the pivot point flows radially outward for distribution by sprayers or sprinklers located along the pipeline. (ISO 16705-3:2015)

3.2 chemigation: an injection of agrochemicals, such as pesticides, herbicides or other growth-enhancement products, to the irrigation system, together with irrigated water (ISO/IWA 20:2017)

3.3 crop plan: a high-level document describing how a crop will be grown on a given piece of land during a crop season. It can range from very abstract to very specific.

3.4 decision support system (DSS): a site (field-specific) irrigation system that includes a set of defined rules, criteria and guidelines to be used by the software structure and simulation models in making basic decisions to be implemented by a microprocessor-based pivot control system. A Decision Support System is a type of, or may be part of, a Farm Management Information System.

3.5 end guns: large impact sprinklers located at the far end of the center pivot.

3.6 evapotranspiration: the total evaporation of an area covered with vegetation. It is comprised of water that is intercepted by the vegetation followed by evaporation, the evaporation from the dry surface of plant leaves (transpiration), and the evaporation from the soil (ISO 6107-8:1993).

3.7 farm management information system (FMIS): a computerized information system that enables a grower to collect, process, analyze, and use data to plan and manage farm operations. The FMIS may reside locally on the farm or may be a cloud-based system.

3.8 fertigation: the application of fertilizers with irrigation water (see chemigation).

3.9 GNSS: acronym for Global Navigation Satellite System, a generic term to denote satellite-based navigation systems with global coverage, such as Beidou, Galileo, GLONASS, and GPS.

3.10 irrigation efficiency: the amount of productivity (yield) in relation to the amount of water applied. Irrigation efficiency units are normally presented as the weight of yield per volume of water applied (ISO/IWA 20:2017).

3.11 irrigation system: the physical components and configuration of pipes, components, and devices installed in the field for the purpose of irrigating a specific area used to apply water by irrigation (ISO 16075-2:2015).

3.12 measurement: a set of operations having the object of determining the value of a quantity.

3.13 observation: the act of measuring or otherwise determining the value of a property.

3.14 pivot controller: the device that controls the pivot's basic functions, including speed, direction of travel, water output, the operation of end guns, as well as additional pumps. It may include the combination of the pivot's control panel and an associated telemetry unit.

3.15 recommendation: a course of action proposed by someone with *expertise* (e.g., an agronomist, crop scout or irrigation consultant). A recommendation is advisory ("This is what I recommend we should do.")

3.16 variable rate irrigation (VRI): a method of managing water application in a spatially explicit manner. VRI regulates the speed of the pivot and equips a center pivot system with the ability to turn on and off valves for groups of sprinklers on the pivot system during operation.

3.17 variable speed irrigation (VSI): a method of managing water application by varying the speed of the center pivot as it moves around the field.

3.18 work item: a specific instance of a Work Order, matched to one field.

3.19 work order: a set of instructions, given by someone with authority for a specific course of action to take. ("This is what we are going to do.") An irrigation Work Order describes the amount of water to apply to a given piece of land over a certain time period.

3.20 work record: a document that describes what actually happened while performing the field operation. ("This is what was actually done.") It may differ from the Work Order because the operator performing the field operation may have had to make adjustments to particular conditions (e.g., suspended the operation because the ground was too wet and returned the next day.)

4 The Management Process

Field operations such as planting, irrigation and harvest are grower business processes. These processes must be supported with data exchange, both for coordination among the different actors directly involved in each process, and for communication with information consumers, such as trade partners and regulatory agencies. These processes vary in detail from grower to grower, but there is value in defining a broadly applicable core set. Modeling the irrigation process enables clarity and quality control for precision irrigation decision-making. The models are inevitably a simplification of everything that happens on a farm associated with irrigation. Nonetheless, this standard uses process models to support a quality management approach to precision irrigation.

5 Business Process Model and Notation (ISO/IEC 19510:2013)

Business Process Modeling Notation (BPMN) diagrams provide a visual representation of a workflow, and the exchanges of data that take place among the actors participating in it. In this standard, BPMN diagrams represent the workflow for acquiring input into an irrigation decision process, communicating that decision as a Recommendation and Work Order, and acquiring a record of what happened as the work was executed. The models provide a clear representation of the irrigation workflow that can be easily understood by all participants, thus supporting a structured method for achieving high quality irrigation decision-making.

Figure 1 below shows a BPMN key diagram. The diagram is divided into horizontal pools, which correspond to different actors and the processes they execute. Interactions among actors are represented as *messages* that can flow between pools. The BPMN defines all of the actors, processes, and messages that are relevant to the irrigation management process.

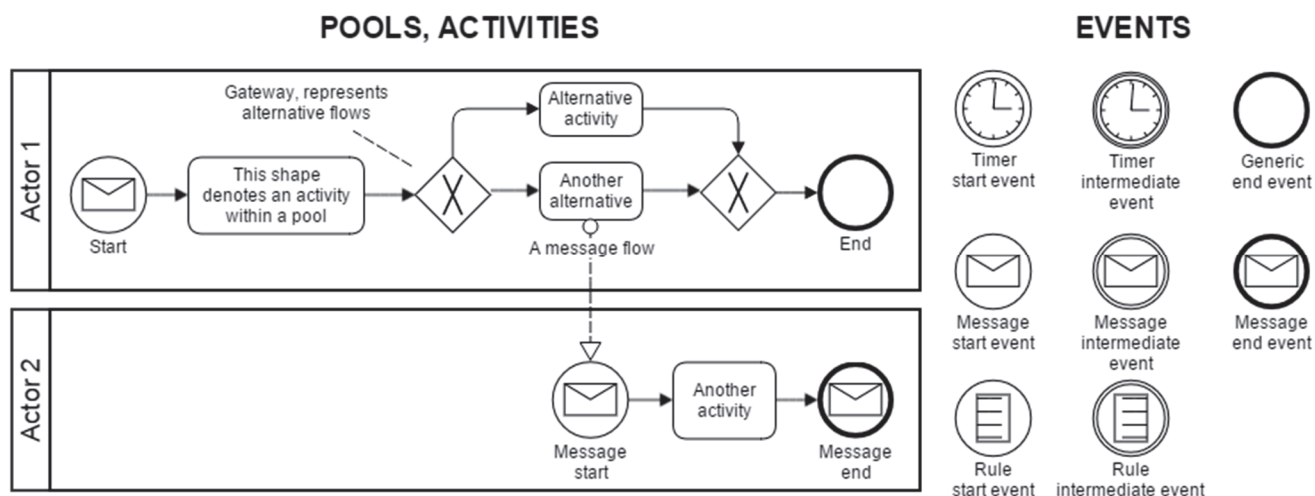


Figure 1 – BPMN key diagram

Different processes are initiated in different ways. Those processes shown starting with a clock face icon have a scheduled start time. Those that are shown starting with an envelope icon start when the corresponding message is received. The diagram in Figure 2 shows the multiple concurrent processes that take place in an irrigation operation.

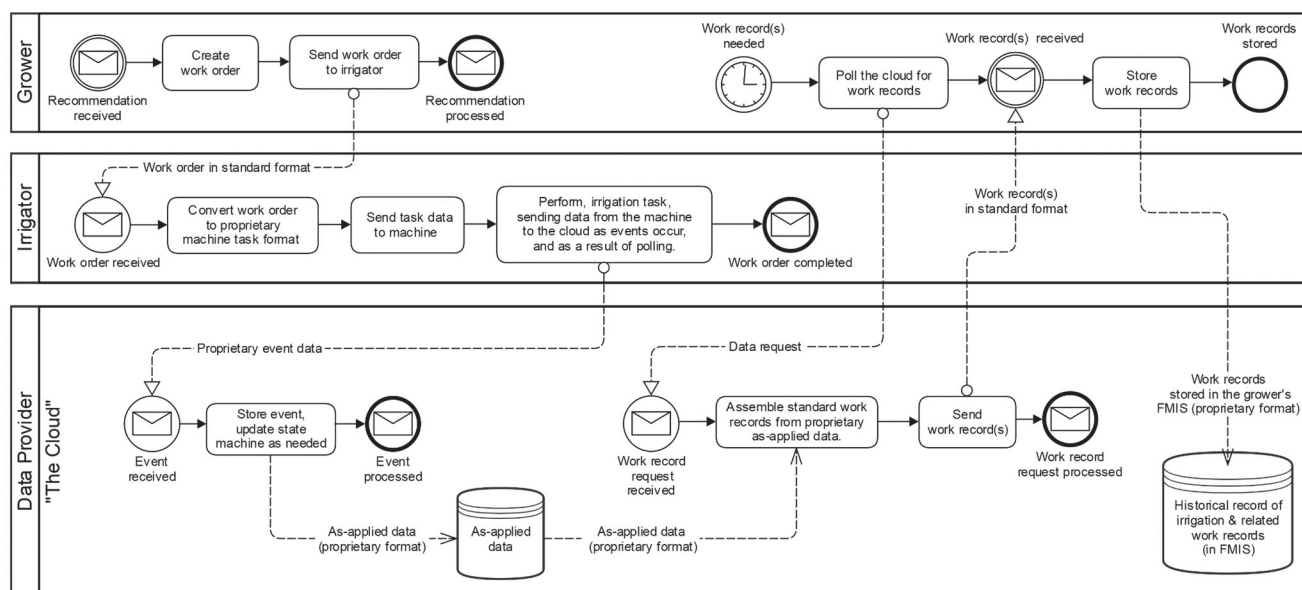


Figure 2 – Sample BPMN diagram for precision irrigation data

Part 2 of this Standard describes the specific BPMN for irrigation observations and measurements, while Part 3 describes a BPMN for irrigation operations.

5.1 The Actors

The Standard is built on the needs of the various *actors* in irrigation: growers, their farm staff, consultants, and service providers. The BPMN diagrams specify actors in the irrigation process. This helps to ensure that the Standard supports principled irrigation decision-making. These actors are defined in Table 1. Each of these actors must share data, in the form of Core Documents.

Table 1 – The Actors

Actor	Description
Grower	Has authority. Uses that authority to create Work Orders out of Recommendations received from the Consultant.
Irrigator	Uses Work Order received from the Grower to initiate a Field Operation.
Consultant	Has expertise. Uses that expertise to translate data into a document called a Recommendation. The data is received from the Grower (Crop Plan) and procured from a Data Provider (observations & measurements).
Data Provider	- Collects and stores various forms of observations and measurements (O&M) data. - Makes the O&M data available to the Consultant. - Collects and stores proprietary irrigation operations event data. - Derives Work Records from the irrigation operations event data - Makes the Work Records available to the Grower. NOTE: more than one Data Provider could perform these tasks. For example, the irrigation operations could be handled by one provider, the weather data by another, and the soil moisture by yet another.

5.2 Core Document Model

In the BPMN diagrams shown in Figure 2, actors share documents. Growers and their partners use multiple documents to exchange field operations information as part of their business processes. There has been work done on standardizing farm processes (ISO 22006), but the documents and many of the terms used within them have yet to be unambiguously defined. The Core Documents shown in Table 2 define the data exchanged during irrigation, but can also be used for other field operations (with the intent of making it easier for growers to adopt and use). The definitions are quite flexible, in view of the myriad ways in which different growers implement their record-keeping in response to region-specific regulatory requirements, particular characteristics of their markets or farming operations, and personal preference.

Table 2 – The Core Documents

Document	Type	What It Conveys	Actor Involved
Crop Plan	Strategic	A high-level document describing how a crop will be grown on a given piece of land during a crop season. "This is how we're going to grow this crop this season."	Grower, or other actor involved in the strategic planning for the field operations.
Observations and Measurements	Tactical/ Predictive	A document containing data measured/ observed in the field. "This is what's happening (or what we think might happen) in the field."	Crop scout, remote observation or a person tasked with monitoring or forecasting conditions in the field.
Recommendation	Tactical	"This is what I recommend we should do." This document is not always acted upon; it is acted upon via a Work Order, upon approval.	An individual, such as a consultant or agronomist, with the expertise/ licensing necessary to recommend a course of action.
Work Order	Tactical	"This is what we are going to do."	An individual with authority to order the work done.
Work Record	Tactical/ Historical	"This is what we actually did in the field."	May be automatically generated; otherwise, an operator that performed the task.
Reference, Setup, and Configuration Data			
Reference, setup, and configuration data	All	"This is the common information we need in order to set up and support accurate and efficient data exchange."	Grower, or other actor involved in managing the grower's production data.

5.2.1 Document Contents

Documents contain information focused on completing a work item, that is, the specific instance of a Work Order. A work item may, for example, be the specific order to place a specified amount of water over a specific area of a field. Specific contents of a document may include some, or all, of the detailed items shown in Table 3.

Table 3 – Core Document contents

Content	Description
What	This is specified using IrrItems in the specific classes that use them (Plan, Recommendation, Work Order, and Work Record); e.g., water or chemicals applied.
Where	GrowerRef, FieldRef, CropZoneRef, etc. These are references to the corresponding object instances of a grower, a field, a crop zone, etc. where the irrigation operation takes place.
Who	PersonRoleRefs, references to objects encapsulating the actors involved, and the role they play.
When	TimeScopes represent various times and time intervals associated with the field operation, ranging from crop season, to requested start time, to actual start time.
How	This is specified using IrrItems in the corresponding classes; e.g., application rates.
With What	This is specified using IrrItems in the corresponding classes; e.g., references to the machine (or sections thereof) that are applying water and other products.

5.2.2 Relationship among the Core Documents

The Core Documents rarely stand on their own: they exist as part of a complex network of decision-making processes within a grower's operation. Core Documents are linked through various relationships: causal (e.g., a Recommendation *informs* a Work Order), contextual (e.g., a product label helps identity a fertilizer used in a Work Order), and compositional (e.g., observations and measurements can form part of a Work Record, documenting weather conditions during the field operation). Figure 3 shows the Core Documents, the causal relationships among them, and the contextual relationships afforded by Reference, Setup and Configuration data.

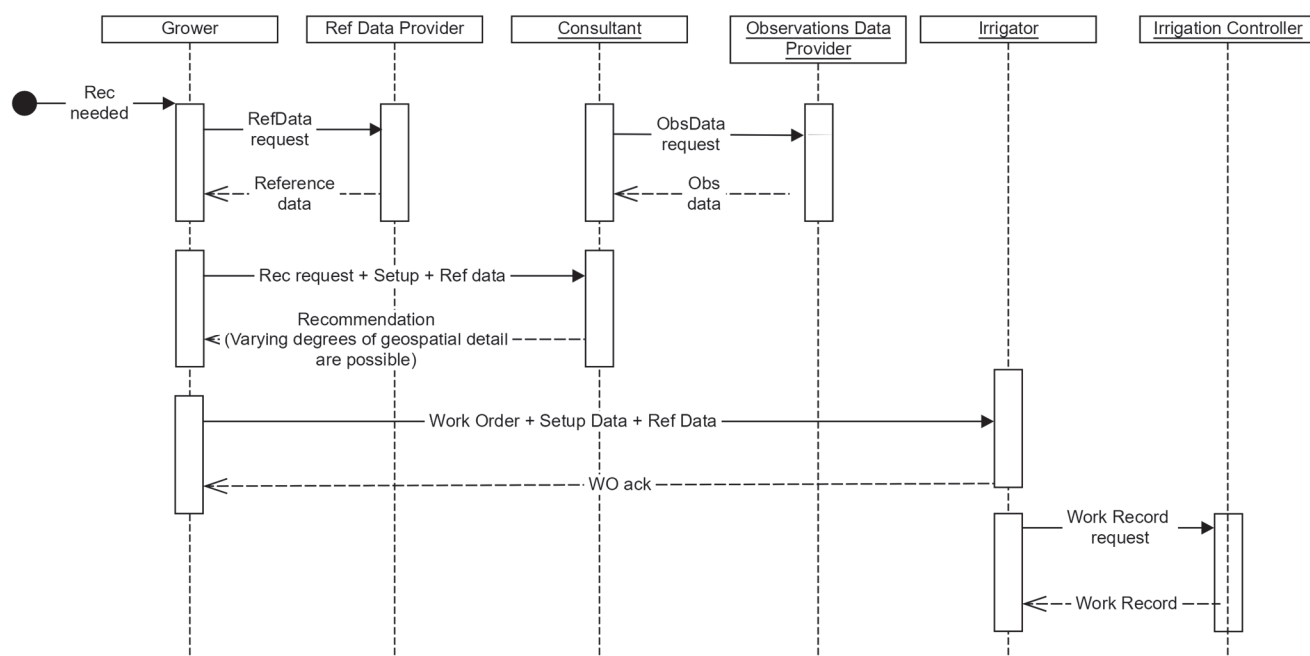


Figure 3 – Core Document relationships

5.2.3 Formalizing the concept of Document

This standard defines a class called Document, shown in UML class diagram form in Figure 4, along with its descendant classes, the Core Documents. The Document class contains data common to all the Core Documents; each of the specific Core Documents additionally contain specific properties not shared by the others.

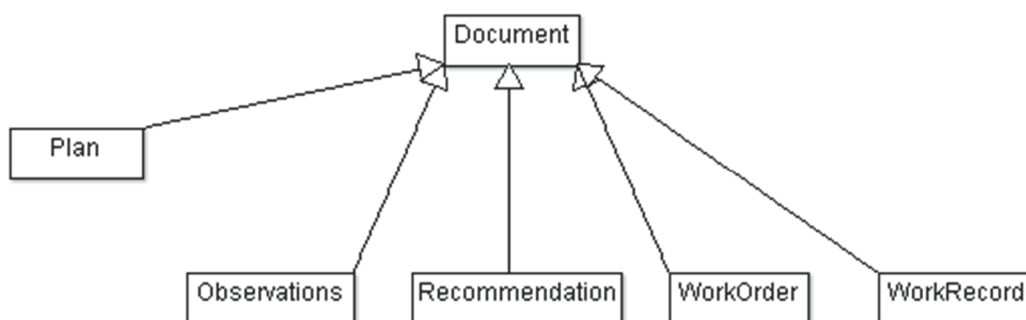


Figure 4 – The Document class, along with its descendant classes

6 Central Concepts

This section describes fundamental concepts that are used throughout the standard, introducing each object as a concept. The concepts presented in this section manifest in the standard as class definitions. This section introduces each object as a concept and describes its purpose.

6.1 Identity

Many objects specified by the Standard are used by reference in other objects (for example, a grower, farm and field may be referenced in a Work Order) and thus need identifiers that can be used by the referencing object. Figure 5 shows a Unified Modeling Language (UML) class diagram (International Organization for Standardization, 2005) of the mechanism used by the Standard to do this. It centers on an object class called CompoundIdentifier, which provides objects with a simple integer identifier (the Referenceld) for use in the local scope of any particular instance of a data model, and allows associating an arbitrary number of (optional) unique identifiers (the list of Uniquelds) to that Referenceld. Compound Identifiers work as a sort of “basket of identifiers” that associate an object with one or more identifier-source pairs, analogous to what is enabled in ISO11783 Annex E-mediated Linklist files.

Every class that needs to “stand alone” and be referenced by other objects contains a CompoundIdentifier.

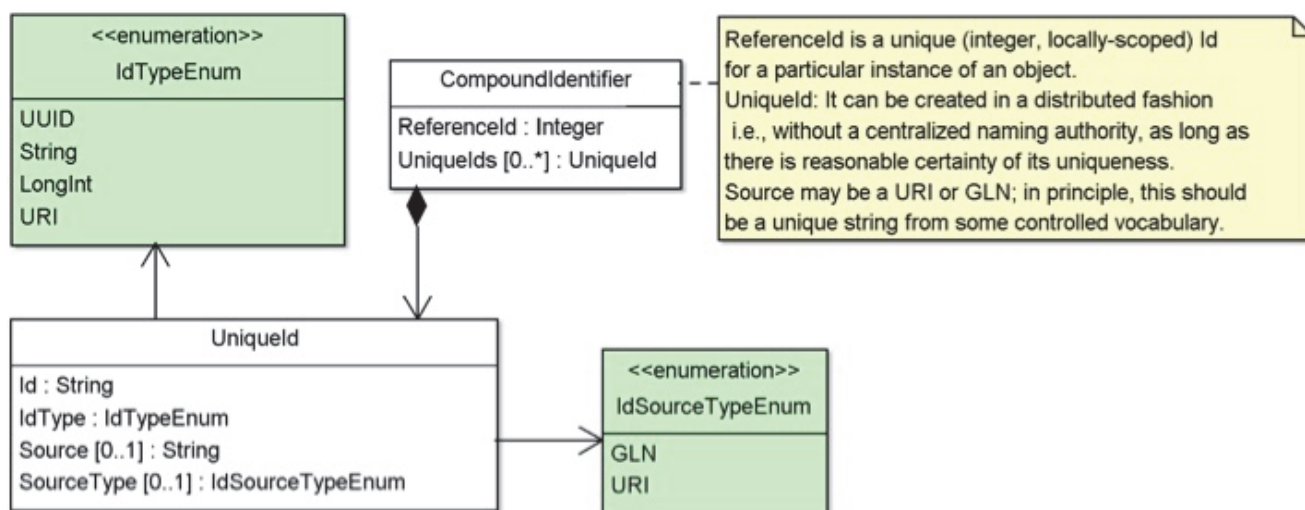


Figure 5 – The CompoundIdentifier and Uniqueld classes and supporting enumerated vocabularies

6.1.1 CompoundIdentifierClass

The CompoundIdentifier class accommodates the need for unique IDs in the context of keeping datasets as compact as possible. Table 4 shows the properties of CompoundIdentifier.

Table 4 – Compound Identifier types

Attribute	Class	Multiplicity	Description
ReferenceId	Integer	1	A unique (integer, locally-scoped) ID for a particular instance of an object.
Uniquelds	Uniqueld	0 . . . n	Can be created in a distributed fashion (i.e. without a centralizing naming authority, as long as there is a reasonable certainty of its uniqueness. Note that a given object can be associated with multiple unique IDs.

6.1.2 Uniqueld

CompoundIdentifiers are meant to be used in a distributed context, where a Document may circulate among two or more FMIS. Since each FMIS may have its own set of unique identifiers (for fertilization or chemigation products, for example), Uniquelds can specify their originating organization by populating the SourceId attribute with either a Global Location Number/GLN (GS1, 2014) or a URI. The SourceIdType attribute specifies the type of source identifier being used. Each Uniqueld, in turn, can be of four different types shown in Table 5:

- A Universally Unique Identifier, or UUID (Leach et al., 2005)
- An arbitrary string (meant to accommodate proprietary alphanumeric identifiers)
- A long integer (meant to accommodate proprietary integer identifiers)
- A uniform resource identifier, or URI (W3C/IETF, 2001).

The Uniqueld itself is stored as a string, but the type of Uniqueld is specified with the CType attribute.

The UniqueldType defines a unique identifier that will be associated with a locally-scoped integer as part of a CompoundIdentifier. It can reference a source, i.e., the organization that “minted” (created) that identifier. Table 5 shows the attributes of Uniqueld.

Table 5 – Uniqueld attributes

Attribute	Class	Multiplicity	Description
CType	CompoundIdentifier	1	An enumeration. Its possible values are: • UUID • GLN • URI • String • Long
ID	String	1	Can be created in a distributed fashion (i.e. without a centralizing naming authority, as long as there is a reasonable certainty of its uniqueness.
SourceType	IdSourceTypeEnum	0 . . . 1	An enumeration. Its possible values are: • GLN • URI This attribute is required if Source is present.
Source	String	0 . . . 1	Source may be a GLN or URI. Should be a unique string from a controlled vocabulary.

6.2 Time

Accurately capturing the time at which various events happen is an important part of agricultural record keeping. This is particularly true in irrigation, where water volumes are frequently calculated as a flow rate (e.g., in gallons

per minute) multiplied by duration. Figure 6 shows (in UML form) the mechanism used by the Standard to represent time. It is a simplification of the TimeScope used in AgGateway's ADAPT toolkit (AgGateway, 2016), and consists of two timestamps, a required Context attribute that specifies the meaning of the TimeScope through an enumerated vocabulary (not shown), and an optional human-readable Description.

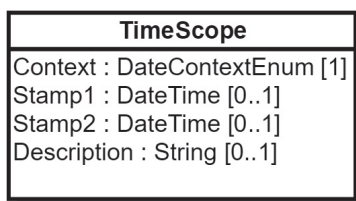


Figure 6 – UML Class diagram of the TimeScope class

6.2.1 TimeScope

TimeScope is a flexible tool for specifying time, end/start time, etc. It is used primarily to specify time intervals.

Context: Enumerated value, defined by the DateContextEnum enumeration, which describes the meaning of the TimeScope. The enumerated values are shown in Table 6.

Stamp1: This time stamp is optional to accommodate the case where there is a time interval or timing event that does not have a precise date, but does have a time-related meaning; e.g., a crop season.

Stamp2: Optional second time stamp, used to denote a time interval.

Description: Optional name for the TimeScope. A typical use would be "2018 Crop Season."

Table 6 – DateContextEnum enumerated values

Value	Annotation
GNSSOnEvent	The system tags the event with a GNSS-mediated timestamp corresponding to the moment when the event happened. This is the most accurate approach.
DeviceClockOnEvent	The system tags the event with an internal device clock-mediated timestamp corresponding to the moment when the event happened. Unless the device clock is synchronized via GNSS or a timeserver, there may be drift, and timestamps may have systematic error. Durations will be accurate, however.
ServerClockOnTransmission	The event is tagged with a timestamp corresponding to when the event was successfully communicated to a server, which is not necessarily the same as when the event occurred. These time sources are susceptible to error in the presence of communication errors in the field.
DeviceClockOnTransmission	The event is tagged with an internal device clock-mediated timestamp corresponding to when the event was successfully communicated to a server, which is not necessarily the same as when the event occurred. These time sources are susceptible to error in the presence of communication errors in the field, as well as susceptible to clock drift.
ManualInput	The Stamp1 and/or Stamp2 values were input manually by a user.
Unknown	The origin of the timestamp data used to tag events in the system is unknown.

6.2.2 TimeDataSourceEnum

Different telemetry systems use different strategies for assigning timestamps to events. Table 7 lists the values defined by TimeDataSource and descriptions of how they enable the user to interpret the timing of received data.

Table 7 – TimeDataSourceEnum enumerated values

Value	Annotation
CropSeason	A time interval that represents a crop season. This is very useful in farm management information systems, because records tagged with a crop season can be easily allocated to the corresponding season for the purposes of calculating costs, etc. The crop season may or may not have actual timestamp information.
TimingEvent	A time interval (which may or may not contain actual timestamp information) representing an operational phase or process during a crop season. For example, pre-planting, harvest, etc.
Validity	A time interval, used to specify the time interval during which a Document such as a Recommendation is valid.
Proposed	A time stamp, used to specify the date/time for a field operation (or part thereof) as proposed in a Recommendation.
Requested	A time stamp, used to specify the date/time for a field operation (or part thereof) as requested in a Work Order.
Actual	A time stamp, used to specify the date/time in which a field operation (or part thereof) actually happened, as represented in a Work Record.
ProposedStart	A time stamp, used to specify the date/time for the start of a field operation (or part thereof) as proposed in a Recommendation.
ProposedEnd	A time stamp, used to specify the date/time for the end of a field operation (or part thereof) as proposed in a Recommendation.
Expiration	A time stamp, used to specify the date/time after which a Work Order for a field operation will no longer be valid (i.e., will expire).
RequestedStart	A time stamp, used to specify the date/time for the start of a field operation (or part thereof) as requested in a Recommendation.
RequestedEnd	A time stamp, used to specify the date/time for the end of a field operation (or part thereof) as requested in a Work Order.
Approval	A time stamp, used to specify the date/time in which a Work Order is approved.
ActualStart	A time stamp, used to specify the starting date/time in which a field operation (or part thereof) actually happened, as represented in a Work Record
ActualEnd	A time stamp, used to specify the ending date/time in which a field operation (or part thereof) actually happened, as represented in a Work Record
Installation	A time stamp, used to specify the date/time in which a piece of equipment was installed.
Maintenance	A time stamp, used to specify the date/time in which maintenance was performed on a piece of equipment.
Unspecified	A time stamp with an unspecified meaning.
Creation	A time stamp, used to specify the date/time in which a Document (or part thereof) was created.
Modification	A time stamp, used to specify the date/time in which a Document (or part thereof) was modified.

6.3 Space

The classes defined in the following section support specification of the spatial aspects of irrigation records. Figure 7 shows a UML class diagram detailing classes relevant to spatial data.

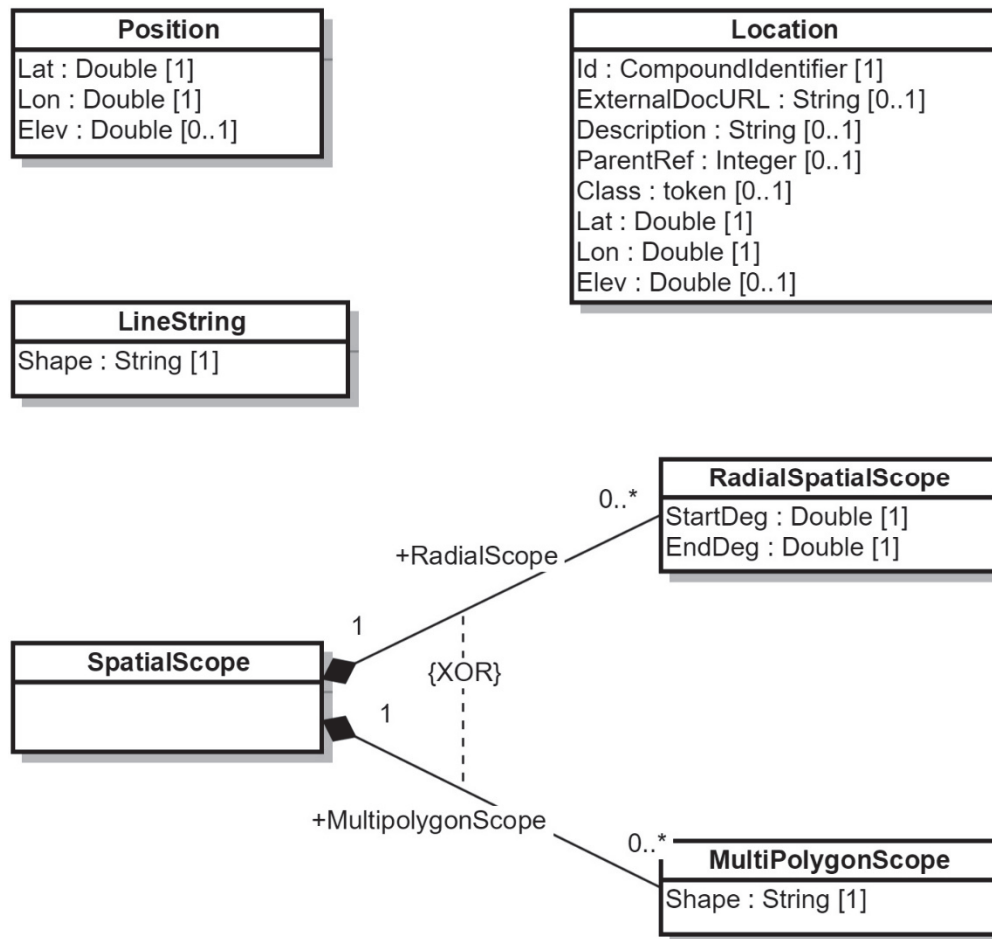


Figure 7 – UML class diagram of the space and position types

6.3.1 Position

Position specifies the geographic coordinates for an object or action, in terms of latitude, longitude and elevation. The geographical coordinates are compliant with WGS-84.

Lat: Degrees of latitude in WGS84. Positive north of the equator, negative to the south.

Lon: Degrees of longitude in WGS84. Positive east of Greenwich meridian, negative to the west.

Elev: Assumed to be meters above the WGS84 geoid.

6.3.2 Location

Location can be understood as a Position with an identifier and additional metadata. It should also be compliant with the World Geodetic System 1984 (WGS-84). Location types include the following properties:

Id: A CompoundIdentifier. Used primarily in observation datasets to provide an efficient way for multiple observations to identify their (common) location. (Required)

ExternalDocURL: A URL for providing (presumed human-readable) external documentation, metadata, etc.

Description: An optional string name.

ParentRef: An optional reference to a parent location. This enables describing a hierarchical system of stations, sites/shelters and sampling features.

Class: An optional description of the location's meaning (Station, Site, Shelter, SamplingFeature, Unknown).

Lat: Degrees of latitude in WGS84. Positive north of the equator, negative to the south.

Lon: Degrees of longitude in WGS84. Positive east of Greenwich meridian, negative to the west.

Elev: Assumed to be meters above the WGS84 geoid.

6.3.3 SpatialScope

This is a mechanism for specifying the coverage of an irrigation operation. When dealing with a radial section, such as a section of a pivot span, it is most convenient to use the RadialScope; use MultiPolygonScope otherwise. The SpatialScope class is simply a container for zero or more instances of either RadialScope or MultiPolygonScope. An instance of SpatialScope may not contain both RadialScope and MultiPolygonScope instances, except in special cases (e.g., an irrigation system's IrrSetup, described in Part 3 of this standard).

6.3.4 RadialSpatialScope

Specifies a start angle and end angle to describe the movement of a pivot or sections therefrom. The angle is specified with increasing degrees in the clockwise direction.

StartDeg: Start angle, in degrees.

EndDeg: End angle, in degrees.

6.3.5 MultiPolygonSpatialScope

This is a multi polygon expressed in OGC's WKT format.

Shape: A string encoding a multi-polygon in OGC's WKT format.

6.3.6 LineString

This is a multi-segment line expressed in OGC's WKT format.

Shape: A string encoding a linestring in OGC's WKT format.

6.3.7 PositionDataSourceEnum

The PositionDataSourceEnum provides information about the origin and accuracy of geographical location and angular position information. Values of PositionDataSourceEnum are shown in Table 8.

Table 8 – PositionDataSourceEnum examples

Value	Annotation
SingleGNSSWAAS	Single-GNSS (GPS, GLONASS, etc.), with WAAS (Wide-Area Augmentation System) corrections.
SingleGNSSBasicFix	Single GNSS unit, with no differential or WAAS corrections.
DifferentialGNSS	Geographic position data is being derived from a set of two GNSS units: one mobile, and one fixed.
Mechanical	Position data emerges from a mechanical sensor of some form; for example, an optical encoder in the case of a center-pivot irrigation system. These systems are susceptible to biases emerging from an incorrect reference (i.e. zero, or north) position; users are encouraged to calibrate accordingly.
DesktopGeneratedData	Geographic position coordinates were explicitly entered, typically following data processing.
ManualInput	Geographic position data was explicitly entered by a user in the form of numeric coordinates.
Drawn	Geographic position data was drawn on a geographical information system - enabled platform, such as a farm management information system, or other mapping software.
Other	The source of geographic position data is known, but does not conform to one of the options specified above. Users are encouraged to contact the system manufacturer or installer for details.
Unknown	The source of geographic position data is unclear, unknown, or unspecified.

6.3.8 Gazetteer

The Gazetteer class is a container of locations (i.e., named positions). The class, and its associated component Location, are a partial implementation of ISO19112. The purpose of Gazetteer is to contain a list of Location objects that represent named places relevant to setup and configuration of various Observations and Measurements installations. Other objects that are defined in the object model then reference these places.

The **Gazetteer** specifies a list of locations, including geographical position, an identifier, and a description. The Gazetteer shown in Figure 8 is composed only of an optional list of Location instances.

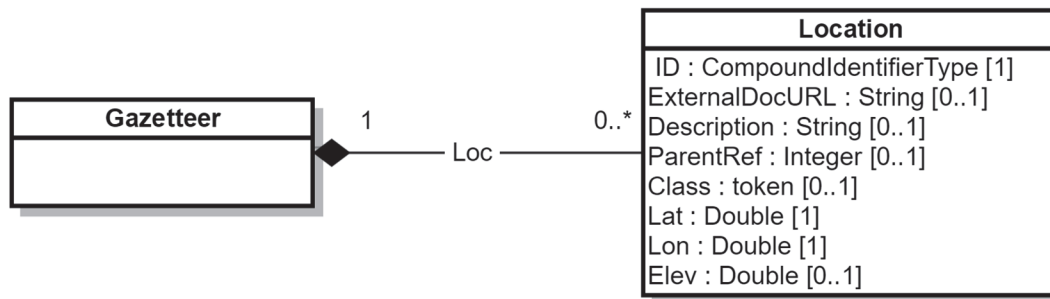


Figure 8 – Gazetteer

The expected use case for Gazetteer is with weather stations, where the instruments are distributed over a (usually small) geographic area. For example, a site containing a rain gauge with Alter wind shield, evaporation pan, and anemometer might have these instruments a few meters apart. Depending on the context, a setup document might refer to the instruments individually or refer to them jointly as a single location. A data provider could, for example, specify the boundary of a collection of instruments (i.e. the fence around the site). The setup data delivered by the data provider could then associate data with the name of that site rather than specifying latitude and longitude for each instrument. While the weather station use case is the exemplar, Gazetteers are not limited to use with weather monitoring sites.

The purpose of referencing the ISO 19112 standard is to enable associating an installation or collection of instruments with a named location in addition to the explicit spatial or geographic specification. By mirroring the SI_LocationInstance class in ISO 19112, the LocationType can be compatible with external Gazetteer services that conform to the ISO 19112 standard.

The Standard does not contain a complete implementation of ISO19112:2003. According to ISO 19112, “A gazetteer is a directory of instances of location types in a spatial reference system.” The Standard does not contain implementation of a spatial reference system. The class LocationType in the Standard is an implementation of the ISO 19112 class SI_LocationInstance. The Standard’s Gazetteer class is a container of location instances but, despite its name, the Standard’s Gazetteer is not an ISO 19112 Gazetteer. This omission is intentional, as the ISO 19112 standard is an abstract specification. The Standard includes a realization of an object model and would thus require a realization of the ISO 19112 model or make reference to an existing implementation. At the time of this writing, there is not widely accepted implementation of ISO 19112 that is also relevant to agricultural observations and measurements. The Standard does not claim conformance as a spatial reference system nor as a Gazetteer, as specified in ISO 19112:2003. Instead, the Standard assumes that a gazetteer exists and the LocationType instances were supplied by the external Gazetteer instance. The Standard’s Gazetteer class is simply a container of the SI_LocationInstance objects supplied by the external Gazetteer.

6.4 Units of Measure

This standard involves representing numerical data, which is frequently associated with units of measure. In many standards (e.g., ISO 11783) the unit of measure is implicit in the variable of interest; for example, distances might always be assumed to be expressed in meters. While this approach is convenient in terms of minimizing the size of a data file, or convenient for implementers, it carries with it the problem that subsequent use of the datasets beyond the original stakeholders involved may be hampered by a lack of shared understanding of the meaning of the data, and interoperability may suffer as a result. For that reason, this standard explicitly associates units of measure to numeric variables.

However, there are numerous controlled vocabularies in the industry for representing units of measure, without the clear emergence yet of a single standard. Thus, it was decided to support several relevant unit of measure code authorities, but that each data file would explicitly declare the system to use. The supported systems are:

- UN Recommendation No. 20: Lists the codes for units of measurement in international trade. This recommendation establishes a single list of code elements to represent units of measure for length, mass (weight), volume and other quantities (including units of count) and covering administration, commerce, transport, science, technology, industry etc.
- QUDT (Quantities, Units, Dimensions and Types): A collection of ontologies that define the base classes properties, and restrictions used for modeling physical quantities, units of measure, and their dimensions in various measurement systems.
- UCUM (Unified Codes for Units of Measure): Includes all units of measures being contemporarily used in international science, engineering, and business. The primary focus is on electronic communication, as opposed to communication between humans. Electronic data interchange (EDI) protocols would be a typical application for UCUM.
- ADAPT: A system of codes used by AgGateway's open-source ADAPT project, based on the representation system used by John Deere machinery. The focus is on numeric values.

6.4.1 Implementation

The S632 standard defines two basic Document types: Observations and Operations. S632-2 and S632-3 describe the content, structure, and purpose of these two Document types. A S632-compliant Document will contain a single instance of the UoMAuthority element, specified at the top level of the document. The UoMAuthority element is an enumeration and Table 9 shows the possible values corresponding to the four authorities described in 6.4.

Table 9 – UoMAuthority enumerated values

Value	Meaning
UNRec20	UN/CEFACT Recommendation 20 codes are used to specify units
QUDT	QUDT codes are used to specify units
UCUM	UCUM codes are used to specify units
ADAPT	ADAPT system codes are used to specify units

The value of the UoMAuthority element applies to the entire Document. The UoMAuthority element is defined in S632-1 because it is used in all subsequent S632 parts.

6.5 Geopolitical-Context-Dependent Data: ContextItems

6.5.1 Handling Static and Dynamic Requirements within a Data Model

Current trends in sustainability, traceability, and compliance reporting often include significant amounts of frequently changing, geopolitical-context-dependent information, such as identification numbers specific to the government agencies that interact with the growers in their jurisdiction. Fulfilling all of these requirements in the data model of farm management information system (FMIS) software is a moving target, with both infrequently- and frequently-changing data. The Standard reconciles these contradictions by using an object class: the ContextItem. The ContextItem can be attached to various objects in a common object model. The ContextItem system can be used jointly with ISOXML's feature of associating unique identifiers to its own locally scoped identifiers defined in ISO11783-10 Annex E (ISO, 2015). This enables adding geopolitical-context-dependent data to ISOXML's otherwise generic and highly machine-specific scope, with no modifications.

The ContextItem system provides a way to preserve the simplicity of data models that utilize it by allowing these models to first focus on expressing "universal" ideas with their core objects and then enhancing those objects with geopolitical-context-dependent specifics through ContextItem(s). Existing data models (like ISO11783) can be extended in a dynamic, data-driven way, and new data models can be created without the burden of including every nuanced instance. And the data models can then grow organically over time.

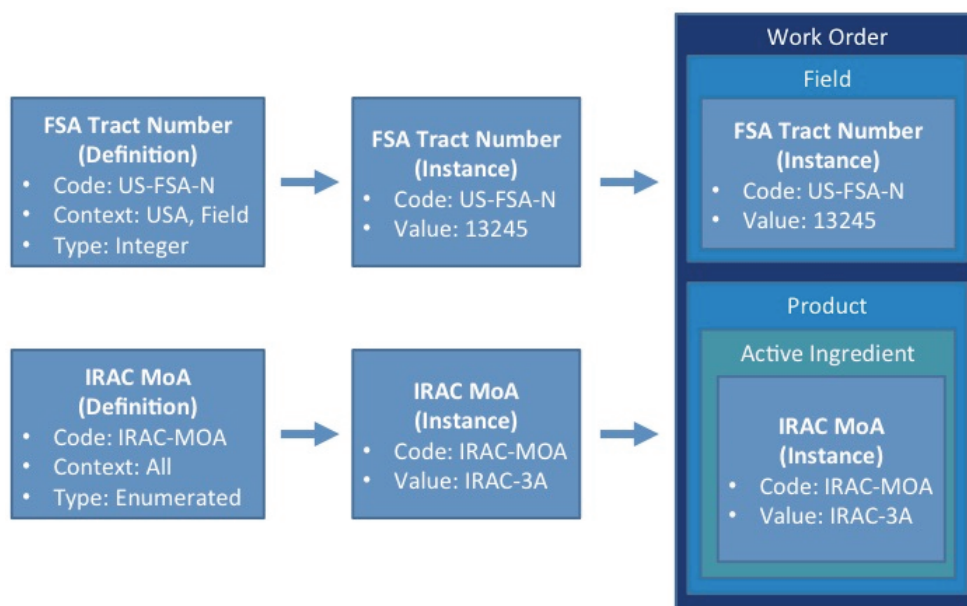


Figure 9 – How a ContextItem is used to provide data of a specific instance of a general concept

In Figure 9, the concept of FSA Tract Number has an identifying code: US-FSA-N. It also has an attribute that indicates what data type to expect, in this case an integer. The ContextItemDefinition provides some additional attributes, a set of Context(s) that states WHERE (the USA) and on WHAT (a Field) that this definition is relevant. As defined earlier, the documentation of a planned field operation is known as a Work Order. It often contains WHERE to conduct the operation (a Field) and WHAT to do (apply a Product). In this example, the Field contains an Instance (or use of) the ContextItem for FSA Tract Number. Again, think of this as a key-value pair where the key is ContextItem code “US-FSA-N” and the value is “13245.” This data type registry, the ContextItem System, contains variable definitions that are used in very specific places or times.

6.5.2 The ContextItem System Data Model

The ContextItem is a key/value structure where the “key” code references a ContextItemDefinition that defines what each ContextItem means. The “value” is composed of a string value along with data needed to interpret it (such as a unit of measure) or a nested list of other CIs (e.g. PLSS cadastral information.) Figure 10 shows a simplified (in that the classes’ attributes are not shown) data model of the ContextItem system, emphasizing the relationships among the classes.

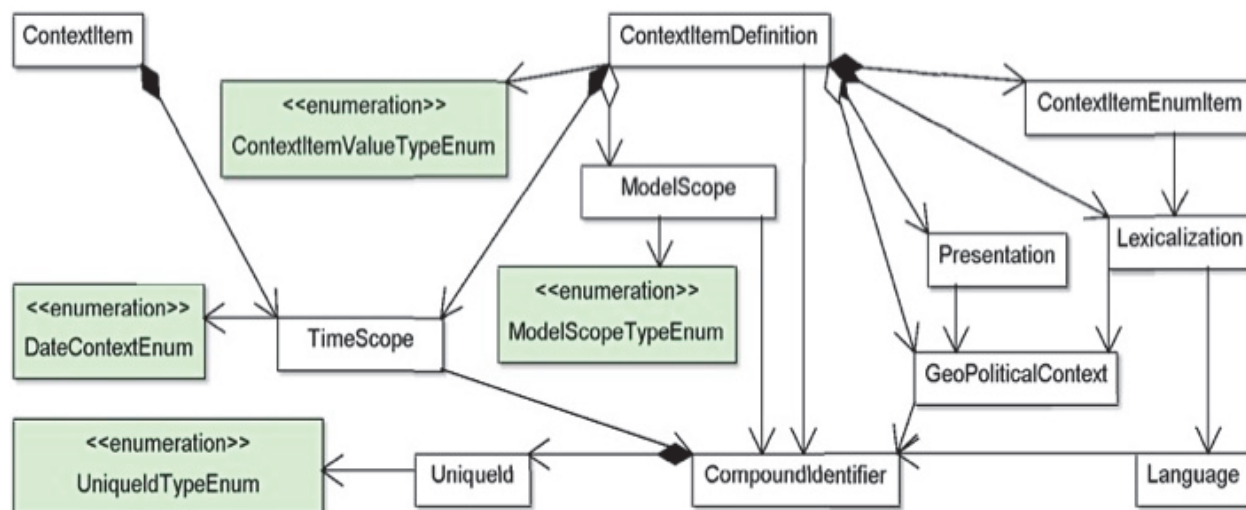


Figure 10 – Simplified ContextItem System Data Model

Table 10 provides a brief description of the purpose of each class, including whether it is a simple enumeration, whether it is used by value or reference, and how it relates to others.

Table 10 – ContextItem classes

Class	Type	Description
ContextItem	Object	A key/value pair used to attach geopolitical-context-dependent information to other objects in AgGateway's ADAPT, ISO11783 files, etc. .
ContextItemDefinition	Object	A definition of a specific kind of ContextItem, including the type of data it can contain, what classes in an object model it can be attached to, and how to display/enter instances of it.
ContextItemValueTypeEnum	Enumeration	An enumerated type that describes the type of value carried by the ContextItem (Integer, Boolean, Double-precision floating point, string, enumeration, datetime, nested...)
ContextItemEnumItem	Object	Description of specific enumeration items for ContextItemDefinitions with an enumerated ContextItemValueType
GeoPoliticalContext	Object	Describes a particular jurisdiction or geopolitical context that a ContextItemDefinition,
Language		Describes a language (e.g., "en-us" for US English, or "pt-br" for Brazilian Portuguese) used to express terms in Lexicalizations.
Lexicalization	Object	Represents a way to express something in a given combination of GeoPoliticalContext and Language.
ModelScope	Object	Used by ContextItemDefinition to denote a data model class to which a corresponding ContextItem instance can be attached.
ModelScopeTypeEnum	Enumeration	Describes what data model a particular class belongs to. This version of the Standard supports ISO11783 and AgGateway's ADAPT.
Presentation	Object	Describes how to enter and display a ContextItem instance that corresponds to a given ContextItemDefinition.
CompoundIdentifier	Object	Provides a mechanism to reference an object from other objects, as well as a mechanism for associating one or more external unique identifiers to an object.
Uniqueld	Object	Captures a unique identifier as part of a CompoundIdentifier.
UniqueldTypeEnum	Enumeration	An enumerated type that describes what kind of unique identifier is contained in a Uniqueld (Integer, String, URI, UUID).
TimeScope	Object	Associates a date/time or range to an object. Also encapsulates the meaning of the timestamp/time interval.
DateContextEnum	Enumeration	Specifies the meaning of a TimeScope.

6.5.3 Properties of ContextItem and ContextItemDefinition

A ContextItem is a single, specific, use of a ContextItemDefinition. Put a simpler way, a ContextItem is a key/value pair. Figure 11 shows the full data ContextItem system model.

The ContextItem's Code is the "key" (corresponding to the unique Code property of a single ContextItemDefinition), while the rest of its properties describe the "value."

- The Value property is ALWAYS expressed as a string even though that may not be how it was collected or how it is expected to be used elsewhere. The ValueType property of the associated ContextItemDefinition supplies the user with this data type information. In some cases, like the presence of NestedItems, there is no real Value to record so this property is optional.
- The ValueUOM property contains the optional unit of measure, further defining the value. A DefaultUOM property is included with the associated ContextItemDefinition and may be used instead of including it locally with the ContextItem.
- If the ContextItemDefinition has a ValueType of "Nested," the NestedItems collection allows a resulting ContextItem to support a hierarchical structure of other instances of ContextItem.
- An optional collection of TimeScope objects is used to record the various relationships a given Value may have with time. For example, there could be a TimeScope that captures when the Value was recorded and another TimeScope that expresses the duration for which the Value is considered valid.

6.5.4 ContextItem Type

Provides a mechanism for representing geopolitical-context-dependent information as a name-value pair along with an optional unit of measure. The unit of measure is assumed to come from the UN Rec 20 list.

Code: The code that explains the meaning of the ContextItem. Expected to emerge from a controlled vocabulary (e.g., as managed by AgGateway's Controlled Vocabularies Working Group).

Value: The value; e.g., 7.

UoM: The unit of measure, to be taken from the UN Rec. 20 list of common codes; e.g., "LTR" (liter), "GLL" (US Gallon) (Optional).

UoMAuthority: The organization that minted / maintains the set of codes used to convey a unit of measure. This is an enumerated set of values, provided by UoMAuthorityEnum: QUDT, UCUM, ADAPT, and UNRec20 (Optional).

TimeScope: Optional list of TimeScopes. Allows setting a validity range and capturing who (and perhaps where) something was tagged with the ContextItem.

ContextItem: Optional nested ContextItems. A good example is the Public Land Survey System (PLSS) data used for cadastral identification in the US.

6.5.5 ContextItemDefinition: Basic Properties

The ContextItemDefinition defines the ContextItem: what it means, how to enter it, display it, where it can be used, and so forth. It should communicate everything needed to enable that ContextItem to be captured and displayed appropriately. Properties of the ContextItemDefinition object include:

- The **Code** property
 - is expected to be universally unique within the ContextItemDefinition domain,
 - is used as part of the URI that forms the identity of a ContextItemDefinition,
 - is the same "key" used by ContextItem in its Code property,
 - is issued by a central authority to ensure its uniqueness.
- **Version:** Enables change detection. Whenever a member property of ContextItemDefinition is changed, the Version number is incremented. This allows users who have a cached version of a ContextItemDefinition to realize that a change has taken place. It does NOT communicate what change was made, by whom, or why it occurred; only that it has happened. All ContextItemDefinition(s) start with a Version value of 0.
- **Status:** Selected from an enumeration of two values: "Active" or "Inactive." There will be situations where a ContextItemDefinition or one of its ContextItemEnumItems will need to be "retired" from use. However, those ContextItemDefinition(s) may still be needed in order to interpret historical data. These will be marked as "Inactive." It will be the responsibility of the user to avoid the use of "Inactive" objects in the generation of new data.
- **ValueType:** Describes the expected data type for the "value" of a ContextItem. It is expressed as an enumeration with the values of Bool, String, Double, Integer, DateTime, Enum, and Nested.
 - The first five data types (Bool, String, Double, Integer, DateTime) can be represented as a string and then parsed back to their original form.
 - The "Enum" data type indicates that this ContextItemDefinition is an encoded enumerated list. The items in the list are ContextItemEnumItem objects and are included by value in the EnumItems collection property. When creating a ContextItem using an "Enum" type ContextItemDefinition, the ContextItem Value property corresponds to the Value property of the selected ContextItemEnumItem.
 - The "Nested" data type indicates that this ContextItemDefinition is a container that encapsulates a group of other ContextItemDefinition(s). When creating a ContextItem using a "Nested" type ContextItemDefinition, the ContextItem Value property is left empty, but its NestedItems property contains a collection of ContextItem(s).
 - Description: A human-readable name that makes it simple to correctly choose the ContextItemDefinition of interest from a pick list, etc.

6.5.6 ContextItemDefinition: Advanced Properties

The basic properties described above allow data capture. The advanced properties described below enable a fuller, semantically rich description of the target concept and where it can be used.

- **Keywords:** A collection of strings intended to be an aid for querying. They are expected to be single words.
- **Lexicalizations:** A collection of Lexicalization objects. The concept that a ContextItemDefinition represents may be expressed verbally in a number of different ways; not just in different languages, but also using different terms in the same language. For example, it may express the regional differences in the common name of a pest. A Lexicalization object contains the text, a reference to the language the text is in, and a list of GeoPoliticalContext objects that describe "where" that terminology is used. The Internet Assigned Numbers Authority (IANA) Language Subtag Registry (IANA, d.) will be the controlled vocabulary for languages.
- **Properties:** A collection of ContextItem objects. This is used to supply additional information needed to use the definition. For example, if a ContextItemDefinition involves capturing values for latitude and longitude, it might include in the Properties a ContextItem that indicates the geodetic datum is expected to be WGS84.
- **NestedDefIds:** A collection of references to other ContextItemDefinition(s). This is only populated if ValueType is set to "Nested". It is used when there are groups of data points that need to be collected together rather than individually. For example, the Public Land Survey System used in the United States uses several attributes (such as the Principal Meridian, Township, Range, and Section) to specify the location of a piece of land for cadastral purposes. Each attribute is defined through its own ContextItemDefinition, and is represented as ContextItem(s) that are included by value in the NestedItems property of the PLSS ContextItem.
- **Presentations:** a collection of Presentation objects. The Presentation object contains a "friendly" name description, regular expressions that define how the value is supposed to look when entered or displayed, and a list of GeoPoliticalContext objects that describe "where" this presentation is used. A regular expression is a sequence of one or more characters, alone or in groups, which can be used to describe an expected pattern. It is used to test a given string to see if it follows the pattern.
- **EnumItems:** a collection of ContextItemEnumItem objects. It is used to encode the enumerated values for a ContextItemDefinition of ValueType "Enum". The ContextItemEnumItem contains some of the same properties that ContextItemDefinition does. Instead of having a Code property, it has a Value. This Value is expected to be unique within the domain of the ContextItemDefinition to which it is attached. When creating a ContextItem using an "Enum" type ContextItemDefinition, the ContextItem Value property corresponds to the Value property of the selected ContextItemEnumItem.
- **DefaultUOM:** An optional string describing the expected unit of measure.
- **AllowConversion:** an optional Boolean value that is used in conjunction with the DefaultUOM. This serves as a flag to determine if the user can allow the value to be entered in a unit compatible with DefaultUOM, or are they required to use the default unit.
- **TimeScopes:** an optional collection of TimeScope objects. This collection enables attaching a variety of time-related attributes to the ContextItemDefinition. For example, a TimeScope could describe when its ContextItemDefinition was created, another when it was updated, and a third for which the date range is valid.
- **ModelScopelds:** A collection of references to ModelScope objects. The ModelScope object represents a business object in either the ADAPT model or ISO11783 (potentially other models as well). For example, there is a ModelScope object for the ADAPT Farm class as well as a separate one for the ISO11783 Farm element (FRM). This coded list of business objects forms the controlled vocabulary we use to specify which objects a given ContextItemDefinition can be used to describe.
- **GeoPoliticalContextIds:** A collection of references to GeoPoliticalContext objects. The GeoPoliticalContext object represents an entry in an external controlled vocabulary that describes a particular geographic/political domain or organization. This is a powerful feature that enables tagging ContextItemDefinition(s) with a marker that conveys "where" the data it represents is relevant.

6.5.7 Implementation Examples

Three examples are provided below which illustrate the various uses of ContextItem.

6.5.7.1 Simple integer and string data entry ContextItemDefinitions

Table 11 below shows the relevant properties / attributes of an example ContextItemDefinition representing a USDA Farm Service Agency (FSA) Farm Number, an identifier frequently used by growers in the United States. Note the following:

- It has an arbitrary ID (Referenceld) that is simply meant to be unique within the set of ContextItemDefinitions.
- It also has a Code, shown as 101, which represents the FSA Farm Number value.
- The contents of an embedded (i.e., used by value) Presentation object are shown. Note the regular expression (Kleene, 1956) used to convey information about how to enter/display the FSA Farm Number.
- There is a list of keywords, shown in curly braces.
- ModelScopelds is a list of integer identifiers; Table 11 shows them dereferenced into an object model class names, in brackets.

Similarly, the GPCIds list shows a dereferenced identifier for the United States. An FMIS in Belgium, for example, would know that the FSA Farm Number is not relevant to their geopolitical context.

Table 11 – ContextItemDefinition representing a USDA Farm Service Agency (FSA) farm number

Attribute	Value/Comment
Id	Referenceld = 5
Code	101
Version	0
Status	Active
Value Type	Integer
Description	FSA Farm Number
Keywords	{USDA, FSA, farm}
Presentations	Description
AllowConversion	
ModelScopelds	{[Farm], [Field], [Cropzone]}
GPCIds	{[USA]}

6.5.7.2 Numeric ContextItemDefinitions for auxiliary purposes (e.g. Properties of ContextItemEnumItems)

Table 12 shows the relevant attributes of an example ContextItemDefinition representing Latitude and Longitude values. The purpose of this kind of ContextItemDefinition is to provide the infrastructure for ContextItemEnumItems to express properties. A subsequent example will show how the ContextItemDefinition for Public Land Survey System Principal Meridians can express the latitude and longitude of each enumerated item's reference point. This is done through the use of the Latitude and Longitude ContextItems shown. Comments:

- They have (arbitrary, simply meant to be unique within the set of ContextItemDefinitions) Referencelds.
- They have unique Codes, shown as 107 and 108, which represents the Latitude and Longitude
- Presentation objects are not included, because these ContextItem definitions are not meant to be user-entered.

Table 12 – ContextItemDefinition representing latitude and longitude values

Attribute	Value/Comment	Value/Comment
Id	ReferenceId = 13 (Could be any value)	ReferenceId = 14 (Could be any value)
Code	107 (Represents "latitude")	108 (Represents "longitude")
Version	0	0
Status	Active	Active
Value Type	Double	Double
Description	Latitude	Longitude
Keywords	{Geographical coordinates, geodesy	{Geographical coordinates, geodesy
Default UoM	{degrees	{degrees
AllowConversion	TRUE	TRUE
ModelScopesIds	{[Farm], [Field], [Cropzone]}	{[Farm], [Field], [Cropzone]}

6.5.7.3 Enumerated ContextItemDefinition

Figure 12 shows the relevant properties / attributes of an example ContextItemDefinition representing a World Meteorological Organization (WMO) code for cloud type. Comments:

- It has an arbitrary ReferenceId (simply meant to be unique within the set of ContextItemDefinitions).
- It also has a Code, shown as 130, which represents the Cloud type / genus
- The ValueType is shown as "enum". That implies that there must be a list of ContextItemEnumItems. There is no need for a Presentation object, since the user would be shown the ContextItemEnumItems' Lexicalization strings corresponding to the user's Language and GeoPoliticalContext (or, in their absence, the Description). What would "travel" with the ContextItem, however, would be the ContextItemEnumItems.

ContextItemDefinition		EnumItems			
Attribute	Value / Comment	Value	Version	Status	Description
Id	ReferenceId = 20 (Could be any value)	/	0	Active	cloud not visible
Code	130 (Represents "Cloud type/genus")	0	0	Active	cirrus (CI)
Version	0	1	0	Active	cirricumulus (CC)
Status	Active	2	0	Active	cirrostratus (CS)
ValueType	Enum	3	0	Active	altocumulus (AC)
Description	WMO Cloud type / genus	4	0	Active	altostratus (AS)
Keywords	Weather, clouds	5	0	Active	nimbostratus (NS)
EnumItems	(See table at right)	6	0	Active	stratocumulus (SC)
AllowConversion	FALSE	7	0	Active	stratus (ST)
		8	0	Active	cumulus (CU)
		9	0	Active	cumulonimbus (CB)

Figure 12 – WMO cloud type/genus, an example of an enumerated ContextItemDefinition

7 Reference, Setup and Configuration Data

7.1 Reference Data

Reference data refers to information that a manufacturer makes available for the purchase, setup and/or use of their products. It pertains to *all instances* of a manufacturer's equipment and/or product and product components; i.e., reference data is not grower-specific or specific to an individual sale or single instance of a thing. For

example, the product name, EPA number and active ingredients are reference data for a crop protection product, but a lot number is not. In another example, the model and series number are reference data for a center pivot irrigation machine, but the serial number is not. The intent is to share reference data sets across the whole industry so that different stakeholders can interpret shared documents the same way. This includes names and identifiers of seed varieties, crop protection products, active ingredients, etc.

7.2 Setup data

Setup data is grower-specific. It provides information needed to set up data exchange between the grower and machinery or other actors (e.g., crop advisors.) It refers to two categories of information. Unlike reference data, setup data is grower-specific. The categories of setup data include:

- **Grower data** represents basic information about the grower, farm, fields, and actors. This may include farm names, field boundaries, the specific products the grower has a permit to use, etc.
- **Configuration data** that specifies the particular state of specific instances of things such as farm equipment and instruments (e.g. soil sensors, irrigation pivots, combines, etc.) This may include their location, what they are connected to, who installed them, etc.

Figure 13 shows the relationship among reference, setup and configuration data and Table 13 illustrates the relationships with some examples of each type of data.

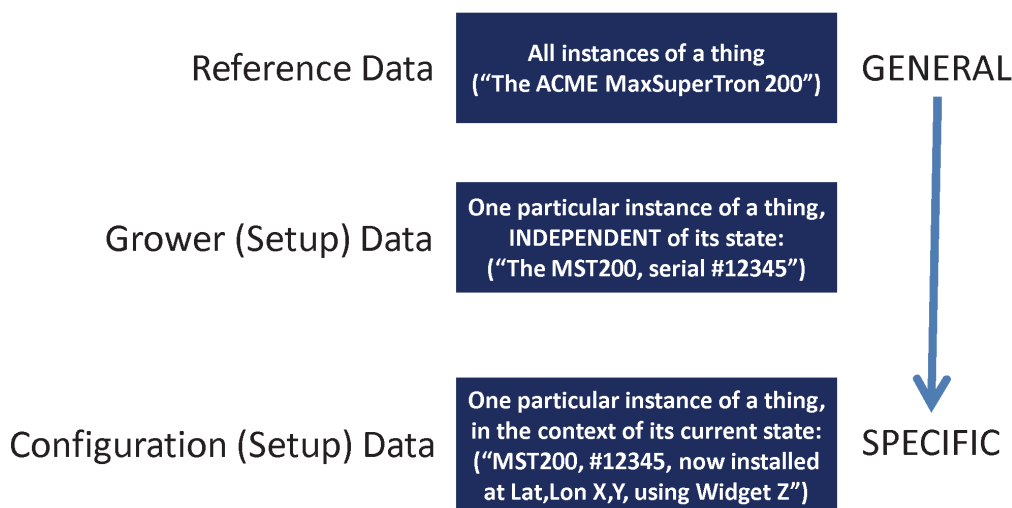


Figure 13 – Reference vs. setup vs. configuration data

Table 13 – Example setup and configuration data

Grower Data (Grower-farm field tree, people) • Grower • Farm • Field • Crop Zone • Field Boundary • Person • Person Roles
Equipment (state-independent description of a particular instance) • Data logger (Logger) — detailed in Part 2 of the Standard • Sensor (Sensor) — detailed in Part 2 of the Standard • Irrigation System (IrrSystem) — detailed in Part 3 of the Standard
Configuration (state-dependent description of a particular instance) • Irrigation System Configuration (IrrConfig) • Data Source Configuration (Source)

7.2.1 Self-contained data vs. URLs

The Standard defines two ways of establishing a relationship a dataset (of observations or operations data) and the corresponding setup and configuration data records:

- Self-contained: Reference data and Setup data are embedded within the dataset, and referred to using locally-scoped identifiers
- URL-referenced: Reference data and Setup data exist separately from the dataset, and are available in the standard format by dereferencing a uniform resource locator (URL) contained in the dataset.

7.2.2 Grower Setup Data

A central concept in the model is that of Grower. The Grower should not be interpreted as a specific individual *person* (the PersonRole class takes care of that, by assigning a role of "Grower" to an instance of Person); instead, an instance of the Grower class should be interpreted as the underlying business entity.

Figure 14 shows the relationships among different objects corresponding to setup data. And, as the figure shows, the Grower class anchors many important concepts in the data model.

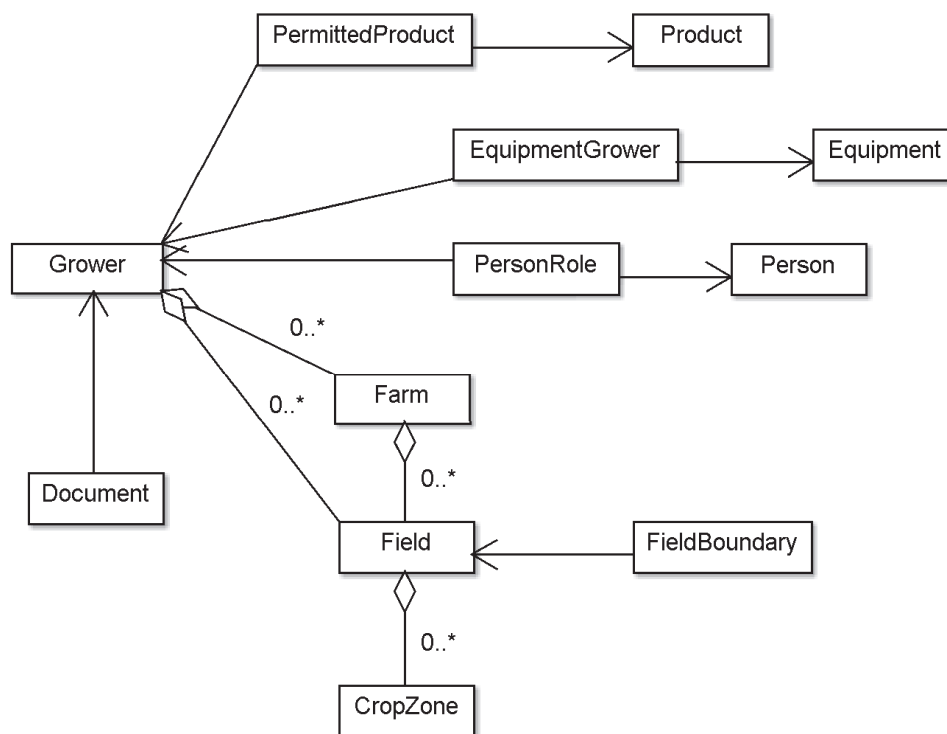


Figure 14 – The Grower class and relationships

7.2.3 Grower

This type represents the grower or business entity that the irrigation system, resource, or Document is associated with.

Id: that establishes a "shorthand" integer used to refer to this grower in the scope of a Document, along with a collection of unique ids that represent the grower in FMIS and other systems.

Description: Human-readable name of the grower or business entity.

ContextItem: List of context items. These allow associating geopolitical-context-specific information to otherwise universal data types.

7.2.4 Person

This type represents the grower or business entity that the irrigation system or Document is associated with.

Id: Compound identifier that establishes a "shorthand" integer used to refer to this person in the scope of a Document, along with a collection of unique ids that represent the grower in FMIS and other systems.

FirstName: First name of the person; e.g., "James" in "James T Kirk."

MiddleName: Middle name or initial of the person; e.g., "T" in "James T Kirk."

LastName: Last name of the person; e.g., "Kirk" in "James T Kirk."

CombinedName: Human-readable name of the grower or business entity.

ContextItem: List of context items. These allow associating geopolitical-context-specific information to otherwise universal data types.

7.2.5 PersonRole

This type represents a role carried out by a person.

Id: Compound identifier that establishes a "shorthand" integer used to refer to this PersonRole in the scope of the XML file, along with an optional collection of unique ids that represent the PersonRole in FMIS and other systems.

PersonRef: Reference identifier of the person in question.

Role: Role being carried out by the person referenced above.

GrowerRef: Optional reference to the grower/business entity to which the PersonRole pertains. It accommodates the use case in which a person is a crop advisor for one grower and an operator for another.

7.2.6 PersonRoleEnum

This describes possible roles a person may have, as shown in Table 14.

7.2.7 Farm

For the purposes of field operations, a farm is a collection of one or more fields that are grouped together functionally or administratively under a business entity (i.e., Grower). That relationship with Grower is optional, however, to maintain compatibility with the ISO11783-10 standard, where a Farm (FRM) can stand-alone without linking to a Customer (CMR, equivalent to Grower). A grower can have multiple farms.

The Farm type represents a farm that the irrigation system or Document is associated with. Note that, in turn, the farm may be associated with a grower.

Id: Compound identifier that establishes a "shorthand" integer used to refer to this farm in the scope of a Document, along with a collection of unique ids that represent the farm in FMIS and other systems.

Description: Human-readable name of the farm.

GrowerRef: Optional shorthand integer id corresponding to the reference identifier of the grower's CompoundIdentifier Id.

TimeScope: Optional set of timestamps (along with their meanings); can be used to qualify the farm.

ContextItem: List of context items; allow associating geopolitical-context-specific information to a farm.