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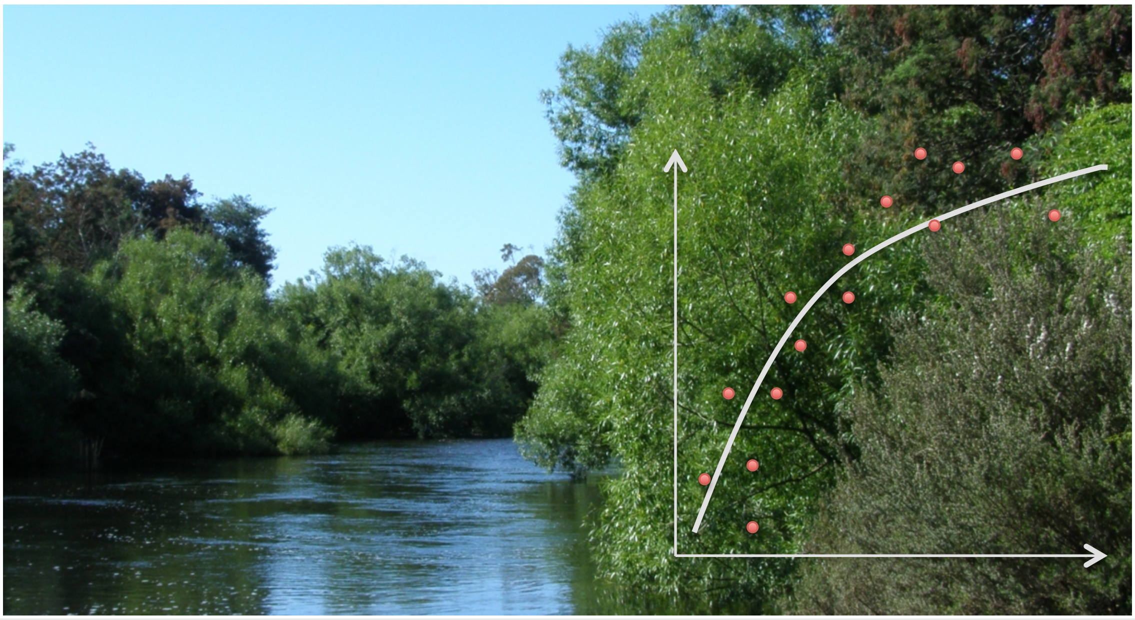

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Rating curve and gauging information

Report on data exchange formats

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The Water for a Healthy Country Flagship aims to provide Australia with solutions for water resource management, creating economic gains of $3 billion per annum by 2030, while protecting or restoring our major water ecosystems. The work contained in this report is collaboration between CSIRO and The Bureau of Meteorology.

For more information about Water for a Healthy Country Flagship or the National Research Flagship Initiative visit www.csiro.au/org/HealthyCountry.html

Cover Photograph:

Description: South Esk River, Tasmania.

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ACKNOWLEDGMENTS

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The authors also wish to acknowledge the previous background work of Laurent Lefort.

INTRODUCTION

This report is a preliminary investigation into exchange formats for rating curves, gaugings and related data (cross-sections etc.). The primary focus is on ratings and gaugings, although related concepts will be considered.

There is increasing interest in the international community to define open standards to cover these concepts, most likely as an extension to the existing work within the Open Geospatial Consortium on WaterML2.0 – time series. The report gives an overview of some of the core concepts and identifies a number of existing exchange formats from various countries and organisations. Some initial analysis of the scope of the existing formats is provided. Future work will progress harmonization of these concepts through defining a common information model.

1. CONCEPT OVERVIEW

1.1. Development of rating curves

Rating curves – which may also represented as tables – are mathematical relationships allowing conversion from a physical phenomena to an estimate of a related phenomena; the captured relationship represents an approximation of a physical relationship. The most commonly employed rating curves are stage-discharge rating curves, which allow for estimates of the volumetric flow rate of water at a point in a river.

Rating curves are developed from multiple observations – often termed gaugings – of stage and flow at a particular measuring location. The relationship is a complex one and many techniques exist for building up rating curves; from equipment used in the observation process to the methods of computation and conversion. The subtleties are out of scope for this report but the approaches used will have a varying degree of influence on the requirements for representation of a curve and/or table.

The most common method for determining an estimated discharge measurement is the velocity-area method, roughly described in the following steps:

- The velocity of water is measured in different segments of the river cross-section.
- The volume for each segment is calculated based on the velocity using a selected method (arithmetical, graphical etc.)
- Summation of the segments given an estimate of total discharge.

Figure 1 shows an example cross-section with example measurement points of the river segments.

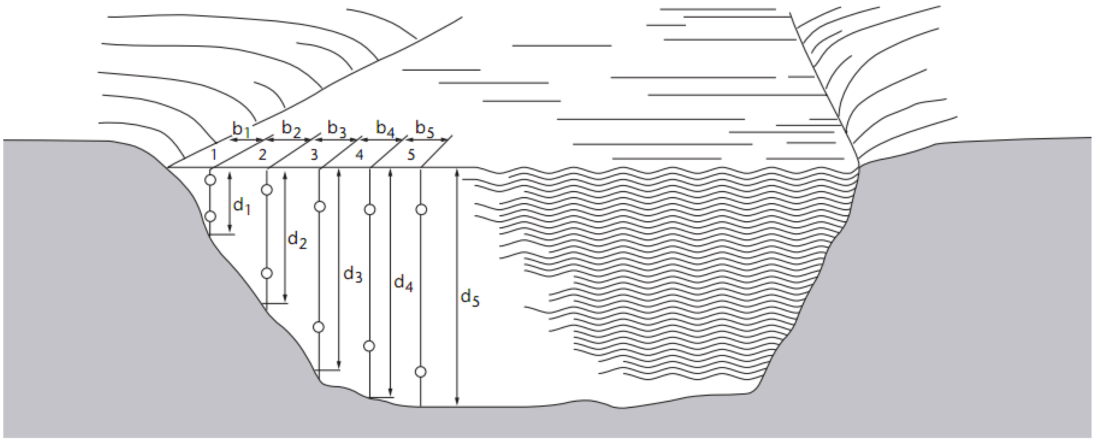

Figure 1 - View of a stream cross-section showing the location of points of observation[1]

The method used to determine the velocity at each point varies – more traditional techniques involve the use of a current meter attached to a propeller that is lowered into the river, sometimes from a boat or directly by an operator standing in the river.

The use of acoustic methods, such those provided by Doppler instruments, are increasing in use due to their practicality and availability of commercial instruments. For example, an Acoustic Doppler Current Profiler (ADCP) is attached to a boat that makes use of the Doppler effect to measure velocity of suspended particles in the river. It will simultaneously

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[1] WMO Guide to Hydrological Practices, Volume I.

measure the depth and path of the vessel to calculate discharge. Multiple transects are taken by the boat to provide a more accurate measurement.

Once a rating curve has been established it is an estimate of the stage-discharge relationship at a given point. The relationship is based on time discrete observations that represent the flow through the river cross-section in varying conditions. The cross-section of the river is often not static due to factors such as erosion, changes in vegetation among others. Thus rating curves often have an associated period of applicability; they need to be continually evolved as conditions change. Most river operations will regularly perform gaugings to keep rating relationships up to date.

The exchange of rating curves may be done through definition of a table that represents the stage-discharge relationship or by definition of an (often polynomial) equation representing a fitted curve. Figure 2 shows an example plot of a rating curve (on a log scale) with the individual gauging points and rating period of application. WMO recommends a curve should *"…include at least 12 to 15 measurements, all made during the period of analysis"* and these should be "…*well distributed over the range of gauge heights experienced*."

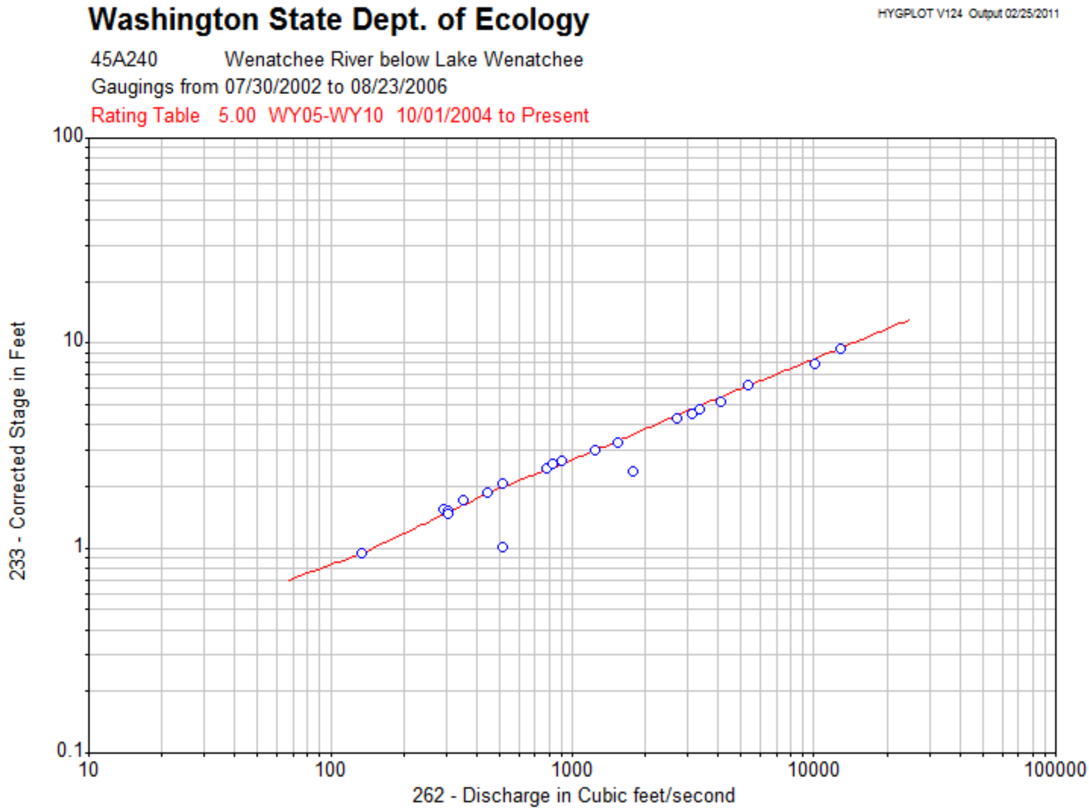

Figure 2 - example rating curve with individual gaugings[2]

1.2. Gauging information

The individual discharge measurements, or gaugings, that make up the definition of a rating curve are also commonly exchanged in information systems. WMO recommends[3] at least the following items to be described in individual gaugings (from the perspective of data management):

[2] https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?sta=45A240#block2
[3] WMO Manual on Stream Gauging – Computation of discharge

(a) Unique identification number;
(b) Date of measurement;
(c) Gauge height of measurement. If there is a difference between inside and outside gauge readings, list both readings;
(d) Total discharge;
(e) Accuracy of measurement;
(f) Rate-of-change in stage during measurement, a plus sign indicating rising stage and a minus sign indicating falling stage.

2. EXISTING EXCHANGE FORMATS

The following sections give a brief overview of some existing standards that represent different aspects of the concepts described in the previous section. UML overviews and XML snippets are provided where available; refer to the Appendices for full examples.

2.1. HydroXC - NOAA

The Hydrology XML Consortium[4] has defined schema to capture the following hydrological information objects:

- Reservoirs;
- River reaches;
- Rating curves;
- Channel cross-sections.

The schema defines a number of base spatial objects such as polygons, lines, bounding boxes etc. as well as fairly generic element (termed a coverage) that defines the location information (site and related spatial data) and an associated array that represents the data. This array has uses an array definition component to define the structure followed by the data array.

An example rating table:

```
<ParameterSet Name="" Count="1">
  <DataElementSet Comment="stage-discharge">
        <DataElementArrayDefinition Name="STGQ" Comment="stage-discharge">
              <Item Name="Count" DataType="Number" Units="" Location="Header" Description="Rating Count"/>
              <Item Name="Begin" DataType="Datetime" Units="" Location="Header" Description="Rating Date and time Begin"/>
              <Item Name="INDEP" DataType="Number" Units="feet" Location="Body" Description="Gage height in feet"/>
              <Item Name="SHIFT " DataType="Number" Units="" Location="Body" Description="Shift"/>
              <Item Name="DEP" DataType="Number" Units="cfs" Location="Body" Description="Discharge in cfs"/>
              <Item Name="STOR" DataType="Boolean" Units="" Location="Body" Description=""/>
        </DataElementArrayDefinition>
        <DataElementArray Count="1570" Begin="20041001000000">
              <DataElement ID="1">
                    <Item Name="INDEP" Value="0.30"/>
                    <Item Name="SHIFT" Value="0"/>
                    <Item Name=" DEP" Value="2500"/>
                    <Item Name="STOR" Value="1"/>
              </DataElement>
```

[4] http://www.weather.gov/oh/hydroxc/

```
<DataElement ID="2">
        <Item Name="INDEP" Value="0.31"/>
        <Item Name="SHIFT" Value="0"/>
        <Item Name=" DEP" Value="2510"/>
        <Item Name="STOR" Value=""/>
</DataElement>
```

It is also possible to encode the rating equation using this schema. See Annex B for an example.

2.2. Standard Hydrometeorological Exchange Format (SHEF) – NOAA

SHEF is an ASCII exchange format defined by the National Weather Service in NOAA. It is an interagency format, specifically designed for real-time application. Accordingly the format uses internal identifiers and an optimized encoding for efficiency.

HydroXC also provides tools and data mappings to convert from the SHEF format.

2.3. Rating curve exchange – KISTERS

This is an internal system format that is used for exchange rating curves within the KISTERS suite of products. Generally the format covers the following aspects:

- Rating table points
- Rating versions and periods of validity
- Gaugings
- Associated metadata concerning interpolation types, methods of measurement etc.

2.4. HydroML – USGS, National Water Information System (NWIS)

HydroML is a detailed set of schema that includes the following concepts (a non-exhaustive list):

- Cross-sections
- Gaugings and related observations
- Rating shifts
- Rating periods
- Rating tables
- Rating equations
- Calibrations
- Site information:
    - Specialized types, e.g. aquifers, water use, power plants, water quality to carry specific metadata;
    - Site visits;
    - Equipment changes;
- Sensor and equipment information (e.g. Acoustic dopplers, velocity sensors etc.)
- Method, or process information.
    - Computation methods (velocity-discharge, peak flow etc.)
    - Observation methods (e.g. Wire gaugings etc.)

- Maintenance inspections/observations (bubble gauge checks, stream flow control checks/cleaning, zero flows etc.)

HydroML provides a high level of detail of the methods involved in measurements relating to development of rating curves – for example, the data and metadata associated with ADCP transects. See Annex B for example encodings.

2.5. Flood Early Warning System (FEWS) Published Interface (PI) -- Deltares

This XML format specifically deals with encoding of rating tables. Figure 3 gives an overview the core information objects.

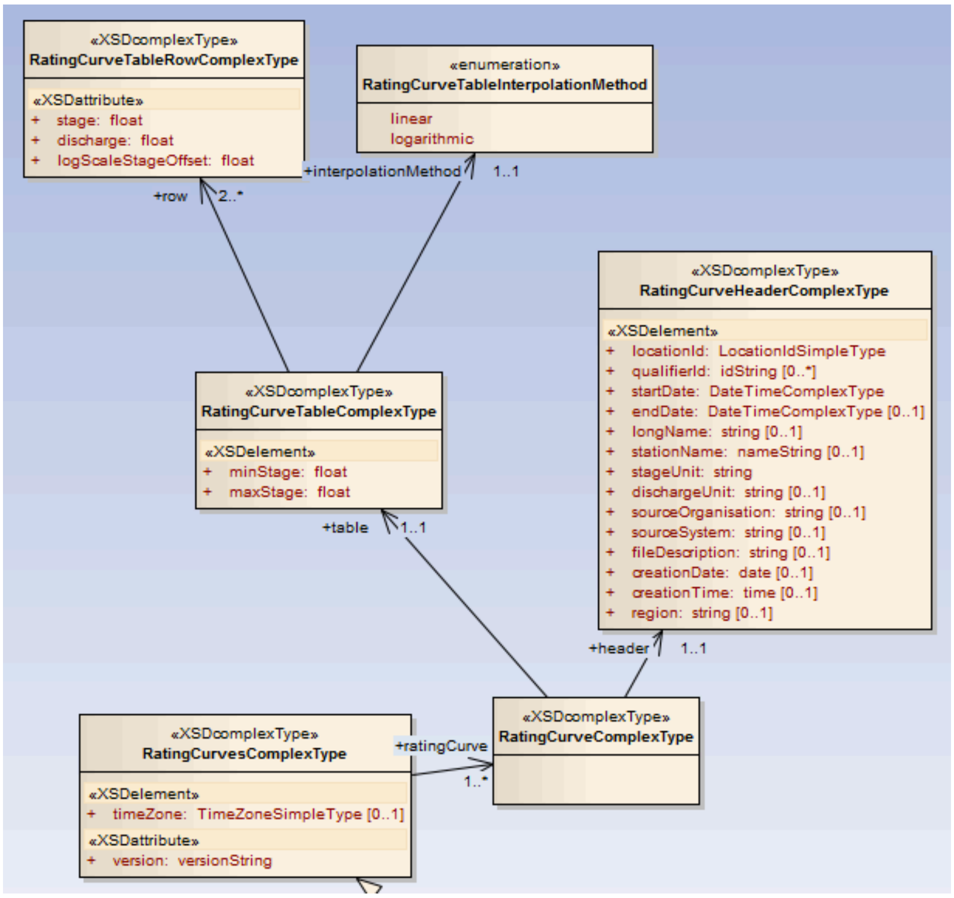

Figure 3 - FEWS PI - rating curves

2.6. The Water Data Transfer Format (WDTF) – Australian Bureau of Meteorology

The Australian Water Regulations 2008[5] require the transmission of rating table information, specifically for the purpose of calculation of volumetric flow and surface area and storage volume of major storages.

10a	Tables that enable the derivation of volumetric flow from water level or stage height — the complete historical sequence of rating tables, indicating the time span across which the rating should apply

[5] http://www.comlaw.gov.au/Details/F2010C00349/Html/Text#param138

10b	Rating tables for the surface area and storage volume derivation of major storages — the complete historical sequence of rating tables relating major storage water level to reservoir surface area and storage volume, indicating the dead storage level and volume, and indicating the time span across which the rating should apply

WDTF abstracts the concept of rating tables into three core aspects: Conversions, Conversion Tables and Duration Groups. Figure 4 provides an overview of the WDTF conversion model in UML.

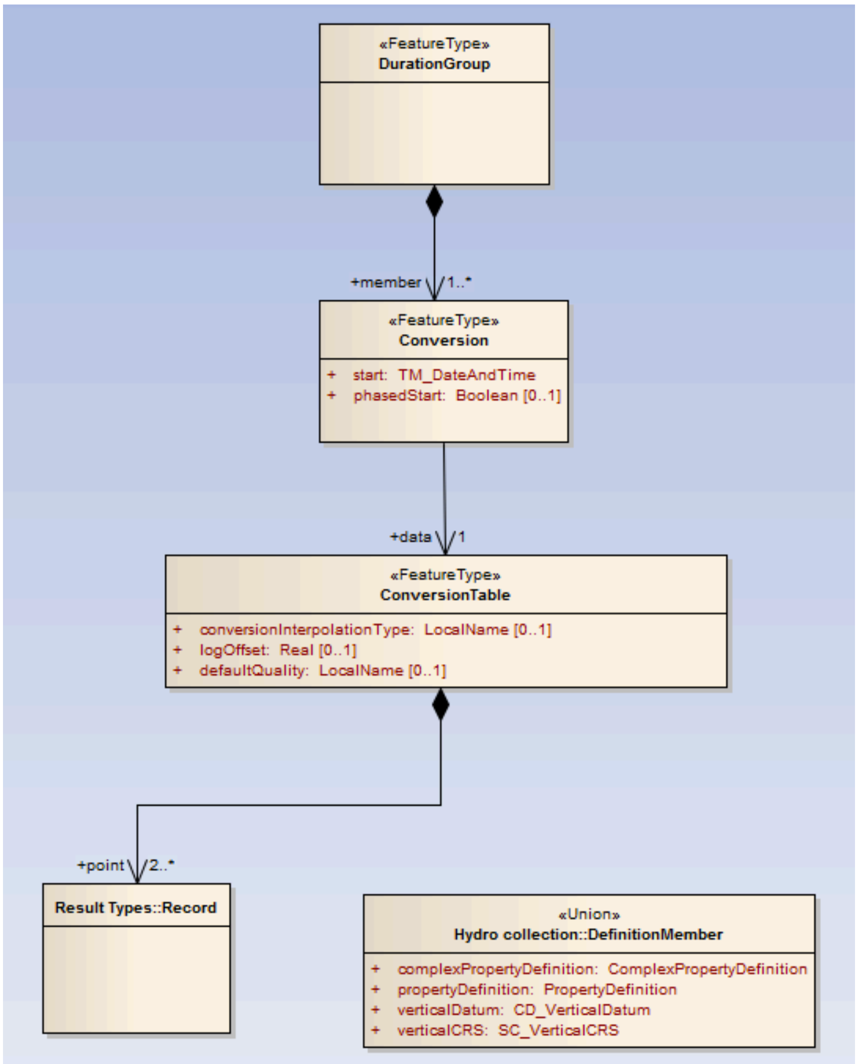

Figure 4 - Overview UML of WDTF conversion model

DurationGroups are a grouping of Conversions; for example, all the conversions for a particular site. Each Conversion has a period of applicability that represents the time from which this conversion should be used.

It is also possible to encode the gauging measurements within WDTF through the use of the ComplexObservation type. At an abstract level, this is implemented as an observation where the result is a record structure. A specific example would be an observation where the result is a tuple including the river level measurement and corresponding flow (discharge) measurement.

WDTF also provides, through the GeometryObservation class, the ability to encode cross-section observations. It makes use of the GML spatial types to do this.

3. SUMMARY AND FUTURE WORK

Table 1 provides an overview of the scope of the identified standards. This provides a basic categorisation; the level of support for each of the listed concepts varies among the standards as well as across versions – it should only be used as a guide.

Table 1 - Basic comparison of functionality

	HydroXC	**KISTERS**	**HydroML**	**FEWS-PI**	**WDTF**
Rating table	Yes	Yes	Yes	Yes	Yes
Rating equation	Yes	No	Yes	No	No
Rating periods	Yes	Yes	Yes	Yes	Yes
Gauging information	Yes	Yes	Yes	No	Yes
Cross-section	Yes	No	Yes	No	Yes

Whilst the scope of the formats varies considerably, the representation of rating tables, equations and gaugings have sufficient overlap to suggest a common information model would be viable. The main issue will be with handling the variations in metadata that relate to methods of measurement, curve fitting and methods of calculation (velocity-discharge etc.). Clarifying the scope of requirements for data exchange will assist in setting the granularity of such a common model.

4. APPENDIXES

4.1. Appendix A – Example data and sources

A Hydstra site summary containing rating period descriptions:
http://www.derm.qld.gov.au/watershed/precomp/124001a/sdr.htm

Example rating table output:
https://fortress.wa.gov/ecy/wrx/wrx/flows/stafiles/18A050/18A050_2003_DSG_RT.txt
As a curve with gaugings plotted:
https://fortress.wa.gov/ecy/wrx/wrx/flows/stafiles/viewpng.asp?imageref=18A050/18A050_2003_DSG_RC.png

Example site using irrigation ditch control:
https://fortress.wa.gov/ecy/wrx/wrx/flows/stafiles/viewpng.asp?imageref=18K250/18K250_2001_DSG_RC.png

Common conversions from example set of measuring locations (http://waterinfo.nsw.gov.au/pinneena/pinneena-cm9.pdf)

VarFrom (Stored Data) VarTo (Computed Data)

10 Rainfall (mm) 9 Rainfall (Points)
10 Rainfall (mm) 20 Rainfall Intensity (mm/hr)
100 Stream Water Level (M) 101 Stream Water Level (Feet)
100 Stream Water Level (M) 141 Instantaneous Discharge (Ml/d)
100 Stream Water Level (M) 151 Stream Discharge Volume (Ml)
100 Stream Water Level (M) 2006 Salt Transport (tonnes/day)
100 Stream Water Level (M) 2007 Total Salt Load (Tonnes)
130 Storage Water Level (M) 136 Reservoir Volume (Ml)
130 Storage Water Level (M) 137 Reservoir Surface Area (Ha)
130 Storage Water Level (M) 433 Spillway Discharge (Ml/d)
141 Instantaneous Discharge (Ml/d) 140 Inst discharge (Cumecs)
141 Inst Discharge (Ml/d) 143 Inst Discharge (Litres/sec)
141 Ins Discharge (Ml/d) 144 Instantaneous Discharge (Cusecs)
141 Inst Discharge (Ml/d) 151 Stream Discharge volume (M)
151 Stream Discharge Volume (Ml) 160 Catchment Runoff Depth (mm)

4.2. Appendix B – XML examples

HydroXC

Schema overview available at:
http://www.weather.gov/oh/hydroxc/Documents/ContinuingWork/HydroXCschema2_0_07.pdf

Rating curve example (table encoding)

```
<Dataset DatasetID="Sample" Schema="http://noaa.gov/uhd_v2.xml">
  <Header>
    <DatasetType Code="FLD" Name="Rating Curve"/>
    <MeasurementSystem Code="E" Name="ENGLISH"/>
    <Language Code="E" Name="ENGLISH"/>
```

```
<TimeFormat Code="YYYYMMDD24HHMMSS" Description="Standard Time Format"/>
<TimeZone Code="CST" Name="Central Standard Time (USA Canada)"/>
<Comment>This is the Sample Dataset to illustrate mapping data in Hydro XML format</Comment>
</Header>
<Report>
<CoverageSet Count="1">
<Coverage Number="1 " ID="ZZ5506" Name="Sample Data">
<LocationSet ID="Z2234" Name="Discharge">
<LocationDataElement Comment="Geographic Information for the Location">
<LocationArrayDefinition Name="" Comment="Station Location">
<Item Name="Agency" DataType="Character" Units="" Location="Body" Description=""/>
<Item Name="StationID" DataType="Character" Units="" Location="Body" Description=""/>
<Item Name="StationName" DataType="Character" Units="" Location="Body" Description=""/>
</LocationArrayDefinition>
<LocationDataArray Name="Station Location" Count="1">
<Item Name="Town" Value="USGS"/>
<Item Name="StationID" Value="05369500"/>
<Item Name="StationName" Value="CHIPPEWA RIVER AT DURAND, WI"/>
</LocationDataArray>
</LocationDataElement>
</LocationSet>
<ParameterSet Name="" Count="1">
<DataElementSet Comment="stage-discharge">
<DataElementArrayDefinition Name="STGQ" Comment="stage-discharge">
<Item Name="Count" DataType="Number" Units="" Location="Header" Description="Rating Count"/>
<Item Name="Begin" DataType="Datetime" Units="" Location="Header" Description="Rating Date and
time Begin"/>
<Item Name="INDEP" DataType="Number" Units="feet" Location="Body" Description="Gage height in
feet"/>
<Item Name="SHIFT " DataType="Number" Units="" Location="Body" Description="Shift"/>
<Item Name="DEP" DataType="Number" Units="cfs" Location="Body" Description="Discharge in cfs"/>
<Item Name="STOR" DataType="Boolean" Units="" Location="Body" Description=""/>
</DataElementArrayDefinition>
<DataElementArray Count="1570" Begin="20041001000000">
<DataElement ID="1">
<Item Name="INDEP" Value="0.30"/>
<Item Name="SHIFT" Value="0"/>
<Item Name=" DEP" Value="2500"/>
<Item Name="STOR" Value="1"/>
</DataElement>
<DataElement ID="2">
<Item Name="INDEP" Value="0.31"/>
<Item Name="SHIFT" Value="0"/>
<Item Name=" DEP" Value="2510"/>
<Item Name="STOR" Value=""/>
</DataElement>
<DataElement ID="3">
<Item Name="INDEP" Value="0.32"/>
<Item Name="SHIFT" Value="0"/>
<Item Name=" DEP" Value="2530"/>
<Item Name="STOR" Value=""/>
</DataElement>
<DataElement ID="4">
<Item Name="INDEP" Value="0.33"/>
<Item Name="SHIFT" Value="0"/>
<Item Name=" DEP" Value="2540"/>
<Item Name="STOR" Value=""/>
</DataElement>
<DataElement ID="5">
<Item Name="INDEP" Value="0.34"/>
```

```xml
            <Item Name="SHIFT" Value="0"/>
            <Item Name=" DEP" Value="2550"/>
            <Item Name="STOR" Value=""/>
          </DataElement>
          .........


          <DataElement ID="1570">
            <Item Name="INDEP" Value="15.99"/>
            <Item Name="SHIFT" Value="0"/>
            <Item Name=" DEP" Value="91900"/>
            <Item Name="STOR" Value=""/>
          </DataElement>
        </DataElementArray>
      </DataElementSet>
    </ParameterSet>
   </Coverage>
  </CoverageSet>
 </Report>
</Dataset>
```

Rating curve example (equation encoding)

```xml
<Dataset xsi:noNamespaceSchemaLocation="HydroXC.xsd" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
 <Header>
  <DatasetType Code="RC" Name="Rating curve"/>
  <MeasurementSystem Code="E" Name="ENGLISH"/>
  <Language Code="E" Name="ENGLISH"/>
  <Comment>Rating Curve representation in HydroXC</Comment>
 </Header>
 <Report Name="Rating Curves" ID="0128071057" Count="1">
  <CoverageSet Count="2">
   <Coverage Count="1" ID="788012" Name="Edgerton, MO">
    <LocationSet Count="1">
     <LocationDataElement>
      <Coordinates SRS="WGS84" coordinateUnits="Meters">
       <Point>
        <Northing>4373719</Northing>
        <Easting>359806</Easting>
       </Point>
      </Coordinates>
     </LocationDataElement>
    </LocationSet>
    <ParameterSet Code="RC" ID="1" Name="Standard Rating Equation">
     <DataElementSet Count="2">
      <DataElement>
       <DataElementArrayDefinition ID="1" Name="Standard Equation Terms">
        <Item Name="FirstAdditiveValue" DataType="float" Description="Term b in the equation y = a(x+b)^c + d"/>
        <Item Name="SecondAdditiveValue" DataType="float" Description="Term d in the equation y = a(x+b)^c + d"/>
        <Item Name="MultiplierValue" DataType="float" Description="Term a in the equation y = a(x+b)^c + d"/>
        <Item Name="PowerValue" DataType="float" Description="Term c in the equation y = a(x+b)^c + d"/>
       </DataElementArrayDefinition>
       <DataElementArray Count="1">
        <DataElement ID="1" StartingDateTime="2006-01-11T14:00:00Z" EndingDateTime="2006-07-11T14:00:00Z">
         <Item Name="FirstAdditiveValue" Value="1"/>
```

```xml
                <Item Name="SecondAdditiveValue" Value="5"/>
                <Item Name="MultiplierValue" Value="1.5"/>
                <Item Name="PowerValue" Value="2"/>
              </DataElement>
            </DataElementArray>
          </DataElement>
        </DataElementSet>
      </ParameterSet>
    </Coverage>
    <Coverage Count="1" ID="7800012" Name="Chesapeake estuary">
      <LocationSet Count="1">
        <LocationDataElement>
          <Coordinates SRS="WGS84" coordinateUnits="Decimal Degrees">
            <Point>
              <Latitude>38.47</Latitude>
              <Longitude>-76.39</Longitude>
            </Point>
          </Coordinates>
        </LocationDataElement>
      </LocationSet>
      <ParameterSet Code="RC" ID="2" Name="Polynomial Equation">
        <DataElementSet Count="2">
          <DataElement>
            <DataElementArrayDefinition ID="3" Name="Polynomial Equation Terms">
              <Item Name="InterceptValue" DataType="float" Description="Term a in the equation y = a1 +
b1(x^c1)+a2 + b2(x^c2)+..."/>
              <Item Name="MultiplierValue" DataType="float" Description="Term b in the equation y = a1 +
b1(x^c1)+a2 + b2(x^c2)+..."/>
              <Item Name="PowerValue" DataType="float" Description="Term c in the equation y = a1 +
b1(x^c1)+a2 + b2(x^c2)+..."/>
            </DataElementArrayDefinition>
            <DataElementArray Count="2">
              <DataElement ID="3" StartingDateTime="2006-01-11T14:00:00" EndingDateTime="2006-07-
11T14:00:00">
                <Item Name="InterceptValue" Value="3.1"/>
                <Item Name="MultiplierValue" Value="2"/>
                <Item Name="PowerValue" Value="2"/>
              </DataElement>
              <DataElement ID="4" StartingDateTime="2006-01-11T14:00:00" EndingDateTime="2006-07-
11T14:00:00">
                <Item Name="InterceptValue" Value="0"/>
                <Item Name="MultiplierValue" Value="3"/>
                <Item Name="PowerValue" Value="3"/>
              </DataElement>
            </DataElementArray>
          </DataElement>
        </DataElementSet>
      </ParameterSet>
    </Coverage>
  </CoverageSet>
 </Report>
</Dataset>
```


HydroML

One example is provided here, with other relevant examples available:

- Cross section survey: http://water.usgs.gov/XML/NWIS/4.11/Samples/CrossSectionSurvey.xml
-

ADCP transects:


```xml
<UsgsHydroML xsi:schemaLocation="http://water.usgs.gov/XML/NWIS/4.11 http://water.usgs.gov/XML/NWIS/4.11/schema/UsgsHydroML.xsd" xmlns:nwis="http://water.usgs.gov/XML/NWIS/4.11" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xmlns="http://water.usgs.gov/XML/NWIS/4.11">
    <Version>NWIS4.11</Version>
    <Source>
        <SoftwareName>HydromlWriter</SoftwareName>
        <SoftwareVersionText>Version 4.11 Build 20090305</SoftwareVersionText>
        <AgencyCode>USGS</AgencyCode>
        <DataBaseName>nwisvadev1.er.usgs.gov::nwishq</DataBaseName>
        <EmailAddress>jdchrist@usgs.gov</EmailAddress>
    </Source>
    <UnitsFamily>English</UnitsFamily>
    <Site>
        <SiteIdentifier organizationCode="USGS">88888803</SiteIdentifier>
        <Name>NWIS Java Unit Test Station 88888803</Name>
        <SiteData>
            <SiteVisit>
                <StartDateTime timeDatumCode="MDT">1999-10-02T11:00:00</StartDateTime>
                <EndDateTime timeDatumCode="MDT">1999-10-02T17:00:00</EndDateTime>
                <PartyText>JDC</PartyText>
                <CollectionAgencyCode>USGS</CollectionAgencyCode>
                <WeatherDescription>Weather test comment</WeatherDescription>

    <RecorderRecordRemovedIndicator>true</RecorderRecordRemovedIndicator>
                <InstrumentBatteryVoltageMeasure inputPrecision="4" roundedPrecision="3">12.3</InstrumentBatteryVoltageMeasure>

    <WaterQualitySampleIndicator>true</WaterQualitySampleIndicator>
                <SedimentSampleIndicator>true</SedimentSampleIndicator>
                <BiologicalSampleIndicator>true</BiologicalSampleIndicator>
                <OtherSampleIndicator>true</OtherSampleIndicator>
                <LevelsRunIndicator>true</LevelsRunIndicator>
                <GwWaterLevelsIndicator>true</GwWaterLevelsIndicator>

    <SafetyInspectionPerformedIndicator>true</SafetyInspectionPerformedIndicator>
                <Comment>Site visit test comment</Comment>
                <DataAgingCode>W</DataAgingCode>
                <CreatorUserName>nwistest</CreatorUserName>
                <CreateDateTime timeDatumCode="UTC">1999-10-02T16:50:31</CreateDateTime>
                <ModifierUserName>nwistest</ModifierUserName>
                <ModifyDateTime timeDatumCode="UTC">1999-10-02T16:50:31</ModifyDateTime>
                <DischargeMeasurement>
                    <MeasurementNumber>2</MeasurementNumber>
                    <DischargeDateTime timeDatumCode="MDT" timeDatumEnteredCode="EST">1999-10-02T14:45:00</DischargeDateTime>
                    <StartDateTime timeDatumCode="MDT" timeDatumEnteredCode="EST">1999-10-02T14:30:00</StartDateTime>
                    <EndDateTime timeDatumCode="MDT" timeDatumEnteredCode="EST">1999-10-02T15:00:00</EndDateTime>

    <MeasurementQualityCode>EXCL</MeasurementQualityCode>
                    <DischargeCode>MEAS</DischargeCode>
```

```
<DischargeMeasure inputPrecision="5"
roundedPrecision="3">2013.600</DischargeMeasure>
<StageMeasure inputPrecision="3"
roundedPrecision="3">2.66</StageMeasure>
<StageDifferenceMeasure inputPrecision="3"
roundedPrecision="3">1.44</StageDifferenceMeasure>
<StageDifferenceDurationMeasure inputPrecision="2"
roundedPrecision="2">1.5</StageDifferenceDurationMeasure>
<MeanIndexVelocityMeasure inputPrecision="2"
roundedPrecision="2">0.66</MeanIndexVelocityMeasure>
<StandardSectionAreaMeasure inputPrecision="3"
roundedPrecision="3">4.55</StandardSectionAreaMeasure>
<SectionVelocityMeasure inputPrecision="3"
roundedPrecision="3">5.66</SectionVelocityMeasure>
<BaseFlowCode>UNSP</BaseFlowCode>
<ReviewerName>nwistest</ReviewerName>
<Comment>Disharge measurement, test
comment</Comment>
<Channel>
<ChannelNumber>1</ChannelNumber>
<ChannelName>Left Channel</ChannelName>
<DischargeMeasure inputPrecision="5"
roundedPrecision="3">1250.000</DischargeMeasure>

<DeploymentMethodCode>WADE</DeploymentMethodCode>

<MeasurementMethodCode>QADCP</MeasurementMethodCode>

<VelocityMethodCode>VADCP</VelocityMethodCode>

<ChannelMaterialCode>SAND</ChannelMaterialCode>

<ChannelStabilityCode>FIRM</ChannelStabilityCode>

<ChannelEvennessCode>EVEN</ChannelEvennessCode>

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<VelocityDistributionCode>STDY</VelocityDistributionCode>

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<MethodCode>VADCP</MethodCode>
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<ModelNumber>unspecified VADCP</ModelNumber>
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<ModifierUserName>sbarthol</ModifierUserName>
<ModifyDateTime timeDatumCode="UTC">2009-12-22T22:50:35</ModifyDateTime>
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<LeftEdgeCoefficient inputPrecision="2" roundedPrecision="2">0.08</LeftEdgeCoefficient>
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inputPrecision="5" roundedPrecision="5">268.88</AttributeMeasure>

                        <RemarkCode>></RemarkCode>

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                        <ShiftRatingNumber>112</ShiftRatingNumber>
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roundedPrecision="2">0.55</IndicatedShiftMeasure>
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roundedPrecision="2">0.50</AppliedShiftMeasure>
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inputPrecision="2" roundedPrecision="3">0.100</UnshiftedPercentDifference>
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roundedPrecision="3">0.070</ShiftedPercentDifference>

                        <AssociatedRating1Number>110</AssociatedRating1Number>

                        <AssociatedRating2Number>109</AssociatedRating2Number>

                        <WriteProtectIndicator>false</WriteProtectIndicator>
                                        </ShiftAnalysis>
                                   </DischargeMeasurement>
                              </SiteVisit>
                         </SiteData>
                    </Site>
</UsgsHydroML>
```

Water Data Transfer Format (WDTF)

Shows encoded rating table (ConversionTable), rating period and example gauging observations.

```
<!-- defining a complex property for use in the complex observations -->
        <!-- properties that are used later have local ids defined here -->
        <wdtf:definitionMember>
                <wdtf:PropertyDefinition
                        gml:id="level">
                        <wdtf:uom>m</wdtf:uom>
                        <wdtf:definition

        xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/property//bom/WaterCourseLevel_m"/>
                </wdtf:PropertyDefinition>
        </wdtf:definitionMember>
        <wdtf:definitionMember>
                <wdtf:PropertyDefinition
                        gml:id="flow">
                        <wdtf:uom>ML/d</wdtf:uom>
                        <wdtf:definition

        xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/property//bom/WaterCourseDischarge_MLd"/>
                </wdtf:PropertyDefinition>
```

```xml
		</wdtf:definitionMember>
		<!-- A complex property definition combines mulitple properties in a simple list.  A mapping in allowed
			where there are two properties to define a default direction of mapping of values in the properties. -->
		<wdtf:definitionMember>
			<wdtf:ComplexPropertyDefinition
				gml:id="level_flow">
				<!-- define the default direction of mapping.  Reverse mapping may be possible -->
				<wdtf:mapping
					from="#level" to="#flow"/>
				<wdtf:property
					xlink:href="#level"/>
				<wdtf:property
					xlink:href="#flow"/>
			</wdtf:ComplexPropertyDefinition>
		</wdtf:definitionMember>

		<!-- transaction Members indicate the transaction associated with the document -->
		<wdtf:transactionMember>
			<!-- A synchronizationTransaction is used to replace a block in the time period -->
			<wdtf:SynchronizationTransaction
				gml:id="synch1">
				 <!-- a nil period would indicate that the new data replaces the entire existing data set -->
				<wdtf:period>
					<om:TimePeriod>
						<om:begin>2006-06-17T09:00:00+10:00</om:begin>
						<om:end>2006-06-18T09:00:00+10:00</om:end>
					</om:TimePeriod>
				</wdtf:period>
			</wdtf:SynchronizationTransaction>
		</wdtf:transactionMember>

		<!-- observations for conversions -->
		<wdtf:observationMember>
			<wdtf:ComplexObservation
				gml:id="c1">
				<gml:description>water level/flow observation for calibration of ratings curves</gml:description>
				<!-- the name below represent the set of observations for the ratings, so members must use the same name -
->
				<gml:name

		codeSpace="http://www.bom.gov.au/std/water/xml/wio0.2/feature/ComplexObservation/w00001/">410729/1/WaterCourseLevel
Flow/1</gml:name>
				<om:samplingTime>2006-06-17T09:00:00+10:00</om:samplingTime>
				<!-- the example procedure here shows a reference to the calibration technique used at 410729.
					ideally this would resolve to a detail description of the procedure -->
				<om:procedure

		xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/procedure//w00001/410729/calibration"/>
				<om:observedProperty
					xlink:href="#level_flow"/>
				<om:featureOfInterest

		xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/feature/SamplingPoint/w00001/410729/1"/>
				<wdtf:relatedSamplingFeature

		xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/feature/SamplingGroup/w00001/410729"/>
				<wdtf:metadata>
					<wdtf:ObservationMetadata>
						<wdtf:relatedTransaction
							xlink:href="#synch1"/>
```

```xml
						</wdtf:ObservationMetadata>
					</wdtf:metadata>
					<wdtf:result>
						<wdtf:Record>
							<wdtf:item definition="#level">10</wdtf:item>
							<wdtf:item definition="#flow">300</wdtf:item>
						</wdtf:Record>
					</wdtf:result>
				</wdtf:ComplexObservation>
			</wdtf:observationMember>
			<wdtf:observationMember>
				<wdtf:ComplexObservation
					gml:id="c2">
					<gml:description>water level/flow observation for calibration of ratings curves</gml:description>
					<!-- the name below represent the set of observations for the ratings, so members must use the same name -
->
					<gml:name

		codeSpace="http://www.bom.gov.au/std/water/xml/wio0.2/feature/ComplexObservation/w00001/">410729/1/WaterCourseLevel
Flow/1</gml:name>
					<om:samplingTime>2006-06-18T09:00:00+10:00</om:samplingTime>
					<!-- the example procedure here shows a reference to the calibration technique used at 410729.
						ideally this would resolve to a detail description of the procedure -->
					<om:procedure

		xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/procedure//w00001/410729/calibration"/>
					<om:observedProperty
						xlink:href="#level_flow"/>
					<om:featureOfInterest

		xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/feature/SamplingPoint/w000001//410729/1"/>
					<wdtf:relatedSamplingFeature

		xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/feature/SamplingGroup/w00001/410729"/>
					<wdtf:metadata>
						<wdtf:ObservationMetadata>
							<wdtf:relatedTransaction
								xlink:href="#synch1"/>
						</wdtf:ObservationMetadata>
					</wdtf:metadata>
					<wdtf:result>
						<wdtf:Record>
							<wdtf:item definition="#level">15</wdtf:item>
							<wdtf:item definition="#flow">450</wdtf:item>
						</wdtf:Record>
					</wdtf:result>
				</wdtf:ComplexObservation>
			</wdtf:observationMember>

			<!-- Conversion tables -->
			<wdtf:conversionMember>
				<wdtf:ConversionTable
					gml:id="table1">
					<gml:description>Table mapping level to volume</gml:description>
					<!-- the name represent the permanent identity of the table.  The tables are globally unique
						and the use of a conjugated name, in this case: SamplingGroup/SamplingPoint/FromTo/ID,
						is simply to aid readability and cannot be relied on in interpretation -->
					<gml:name
codeSpace="http://www.bom.gov.au/std/water/xml/wio0.2/feature/ConversionTable/w00001/">410729/1/WaterCourseLevelFlow/1</gml:na
me>
```

```
<wdtf:conversionInterpolationType>logarithmic</wdtf:conversionInterpolationType>
<wdtf:logOffset>10</wdtf:logOffset>
<wdtf:property xlink:href="#level_flow"/>
<wdtf:defaultQuality>quality-B</wdtf:defaultQuality>
<wdtf:point>
	<wdtf:Record>
		<wdtf:item definition="#level">10</wdtf:item>
		<wdtf:item definition="#flow">200</wdtf:item>
	</wdtf:Record>
</wdtf:point>
<wdtf:point>
	<wdtf:Record>
		<wdtf:item definition="#level">15</wdtf:item>
		<wdtf:item definition="#flow">300</wdtf:item>
	</wdtf:Record>
</wdtf:point>
			</wdtf:ConversionTable>
		</wdtf:conversionMember>
		<wdtf:conversionMember>
			<wdtf:ConversionTable
				gml:id="table2">
				<gml:description>Table mapping level to volume</gml:description>
				<!-- the name represent the permanent identity of the table.  The tables are globally unique
					and the use of a conjugated name, in this case: SamplingGroup/SamplingPoint/FromTo/ID,
					is simply to aid readability and cannot be relied on in interpretation -->
				<gml:name
codeSpace="http://www.bom.gov.au/std/water/xml/wio0.2/feature/ConversionTable/w00001/">410729/1/WaterCourseLevelFlow/2</gml:na
me>
				<wdtf:conversionInterpolationType>logarithmic</wdtf:conversionInterpolationType>
				<wdtf:logOffset>10</wdtf:logOffset>
				<wdtf:property xlink:href="#level_flow"/>
				<wdtf:defaultQuality>quality-A</wdtf:defaultQuality>
				<wdtf:point>
					<wdtf:Record>
						<wdtf:item definition="#level" quality="quality-B">11</wdtf:item>
						<wdtf:item definition="#flow">200</wdtf:item>
					</wdtf:Record>
				</wdtf:point>
				<wdtf:point>
					<wdtf:Record>
						<wdtf:item definition="#level">16</wdtf:item>
						<wdtf:item definition="#flow">300</wdtf:item>
					</wdtf:Record>
				</wdtf:point>
			</wdtf:ConversionTable>
		</wdtf:conversionMember>

		<!-- conversion Sequence -->
		<wdtf:conversionMember>
			<wdtf:DurationGroup
				gml:id="d1">
				<gml:description>All the conversions for the molonglo river</gml:description>
				<!-- the name represent the permanent identity of the duration group.  The groups are globally unique
					and the use of a conjugated name, in this case: SamplingGroup/SamplingPoint/FromTo,
					is simply to aid readability and cannot be relied on in interpretation -->
				<gml:name
codeSpace="http://www.bom.gov.au/std/water/xml/wio0.2/feature/DurationGroup/w00001/">410729/1/WaterCourseLevelFlow</gml:name
>
				<!-- refer to the location this conversion applies to -->
				<wdtf:relatedSamplingFeature
```

```
        xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/feature/SamplingPoint/w00001/410729/1"/>
                    <wdtf:relatedSamplingFeature

        xlink:href="http://www.bom.gov.au/std/water/xml/wio0.2/feature/SamplingGroup/w00001/410729"/>

                    <!-- Conversion phases -->
                    <wdtf:member>
                        <wdtf:Conversion
                            gml:id="cd2005">
                            <gml:description>Conversions for 2005</gml:description>
                            <wdtf:start>2005-07-31T20:12:01+10:00</wdtf:start>
                            <wdtf:data
                                xlink:href="#table1"/>
                        </wdtf:Conversion>
                    </wdtf:member>
                    <!-- 2006 -->
                    <wdtf:member>
                        <wdtf:Conversion
                            gml:id="cd2006_phase_period">
                            <gml:description>Phase from table 1 to 2 to accommodate ratings during a flood
    event</gml:description>
                            <wdtf:start>2006-07-24T20:12:01+10:00</wdtf:start>
                            <wdtf:phasedStart>true</wdtf:phasedStart>
                            <wdtf:data
                                xlink:href="#table1"/>
                        </wdtf:Conversion>
                    </wdtf:member>
                    <wdtf:member>
                        <wdtf:Conversion
                            gml:id="cd2006">
                            <gml:description>Conversions for 2006</gml:description>
                            <wdtf:start>2006-07-31T20:12:01+10:00</wdtf:start>
                            <wdtf:data
                                xlink:href="#table2"/>
                        </wdtf:Conversion>
                    </wdtf:member>
                    <!-- 2007 -->
                    <wdtf:member>
                        <wdtf:Conversion
                            gml:id="cd2007">
                            <gml:description>Conversions for 2007</gml:description>
                            <wdtf:start>2007-07-31T20:12:01+10:00</wdtf:start>
                            <wdtf:data
                                xlink:href="#table1"/>
                        </wdtf:Conversion>
                    </wdtf:member>
                    <!-- No conversions from 2008 -->
                    <wdtf:member>
                        <wdtf:Conversion
                            gml:id="cd2008">
                            <gml:description>No conversions in 2008</gml:description>
                            <wdtf:start>2008-07-31T20:12:01+10:00</wdtf:start>
                            <wdtf:data
                                xsi:nil="true"/>
                        </wdtf:Conversion>
                    </wdtf:member>
                </wdtf:DurationGroup>
        </wdtf:conversionMember>
```

REFERENCES

WMO Manual on Stream Gauging, Volume II – Computation of Discharge, WMO-No. 1044. 2010

WMO Guide to Hydrological Practices, Volume I.

USGS - DISCHARGE RATINGS AT GAGING STATIONS http://pubs.usgs.gov/twri/twri3-a10/pdf/twri_3-A10_a.pdf

NOAA- SHEF format: http://www.weather.gov/directives/sym/pd01009044curr.pdf

USGS HydroML: http://water.usgs.gov/XML/NWIS/4.11/index.html

HydroXC: http://www.weather.gov/oh/hydroxc/schema3.html

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