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Semantic Representation of Topographic Data for Cartographic Presentation and Application

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Outline

- Semantics and Ontology for Topographic Features
- Semantic Web RDF
- Semantics Examples
  - Hydrography
  - Mapping
  - Data Integration
- Conclusions

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Semantics for Topographic Data

Hill surrounded by valleys that enclose streambeds, streams, bounded by other hills

Stream includes stream bed, water in stream, source, left bank, right bank, stream bottom, mouth, has tributaries, flows into stream, lake, bay

Canyon has floor, walls, mouth, surrounding mountains and hills

Urban park has trees, open space, playground, buildings, walkways

The semantics provide meaning to the features

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An Ontology for Topographic Data based on Geospatial Semantics

A taxonomy of all features on standard topographic maps

A formal machine readable vocabulary of feature names and definitions

Predicates formed from attributes and relationships of the features

Actual instance data, including geometric coordinates and topological relations, encoded as predicates in a machine interpretable triple format

All built as RDF with URIs and interlinked to become a part of Linked Open Data

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Feature Domains – A Taxonomy for Topographic Map Data

Events

Divisions

Built-up areas

Ecological regime

Surface water

Terrain

Domains derived from ground surveys incorporated in DLG standards

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Events

Security		**Historical site**	
Hazard	Hazard zone	Military history	Archeological site
Earthquake	Incident	Historical marker	Cliff dwelling
Flood	Fire	Tree	Ruins
Area to be submerged	Restricted area		

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Divisions

Civil Units		Boundaries
Cadastral	Nation	Fenceline
Parcel	Territory	Hedge
Public Land Survey System	Tribal reservation	Place
Land grant	State	Region
Homestead entry	County	Locale
Survey line	Census	Boundary line
Principle meridian	State	Boundary point
Baseline	County	Hydrologic unit
Survey point	Census county division	
Point monument	Block group	**Shipping**
Survey corner	Block	Lane
Government unit	Tract	Traffic separation scheme area
Municipality	Special use zone	Pilot water
City	Time zone	Roundabout
Town	Nature reserve	Inshore trafic zone
Villiage		Exclusive Economic Zone

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Built-up

Transportation and warehousing	60
Entertainment and Recreation	26
Utilities	16
Resource Extraction	13
Structure	12
Agriculture and Fishing	11
Military	10
Communication	7
Waste Management	7
Real Estate	6
Place of Worship	6
Manufacturing	4
Institutions	3
Burial Grounds	3
Disturbed Surface	3
Trade	3

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Ecological Regime

Tundra

Desert

Grassland

Scrub

Forest

Pasture

Cultivated Cropland

Transition area

Nature reserve

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Natural/Artificial
Reach
hasPart: Bottom
Channel
Pond
Basin

Natural

Marine/Estuarine

Cove
Foreshore
Flat
Ice field (regional)

Marine
Ocean
Sea
Gulf
Submerged Stream
Shore
hasPart: Shingle
Shoreline
Beach
Ice floe (regional)
Polyna (regional)

Estuarine
Estuary
Bay
Inlet

Freshwater

Watercourse
Stream
hasPart: Mouth
hasPart: Source
hasPart: Streambed
hasPart: Streambanks
hasPart: Crossing
hasPart: Ford

River
Creek
Brook
Arroyo
Rapids
Bend
Falls
Cascade
Waterfall
Innundation area
Spring
Mud pot
Geyser
Slope spring
Ice berg (regional)
hasPart: Iceberg tongue
Glacier (regional)
Crevasse (regional)

Wetland
Marsh
Swamp
Bog

Waterbody
Lake
Ice cap (regional)
Snow field (regional)
Sastrugi (regional)

Artificial

Impounded
Reservoir
Fish ladder

Diked
Levee
Embankment
hasPart: Revetment
Dam
Masonry shore

Channel
Siphon
Aqueduct
Canal
Flume
Turning basin

Flow Control
Weir
Lock
*hasPart:*Lock chamber
hasPart: Stram
Spillway
Jetty
Breakwater
Water intake

Pump

Surface Water

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Terrain includes 56 USGS landform features

Aeolian	Dish	Isthmus	Ridge
Arch	Divide	Karst	Ridge line
Bar	Drainage basin	Lava	Salt pan
Basin	Dunes	Mineral pile	Shaft
Beach	Fault	Moraine	Sink
Bench	Floodplain	Mount	Solution chimneys
Cape	Fracture	Mountain Range	Summit
Catchment	Fumarole	Peak	Talus
Cave	Gap	Peneplain	Terrace
Chimney	Glacial	Peninsula	Valley
Cirque	Ground surface	Pinnacle	Volcano
Cliff	Hill	Plain	
Coast	Incline	Plateau	
Crater	Island	Quicksand	
Delta	Island cluster	Reef	

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Topographic Vocabulary – Machine readable

Examples from:

- Events
- Divisions
- Builtup
- Ecological regime
- Surface water
- Terrain

Available from Ontology Project Webpage:

http://cegis.usgs.gov/ontology.html

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Semantic Web RDF format

An *RDF triple* contains three components:

the *subject*, which is an RDF URI reference or a blank node

the *predicate*, which is an RDF URI reference

the *object*, which is an RDF URI reference, a literal or a blank node

An *RDF graph* is a set of RDF triples

An example URI:

<http://cegis.usgs.gov/TopoVocab/1.0/Terrain#/crater>

Semantic Web RDF is the basis for Linked Open Data

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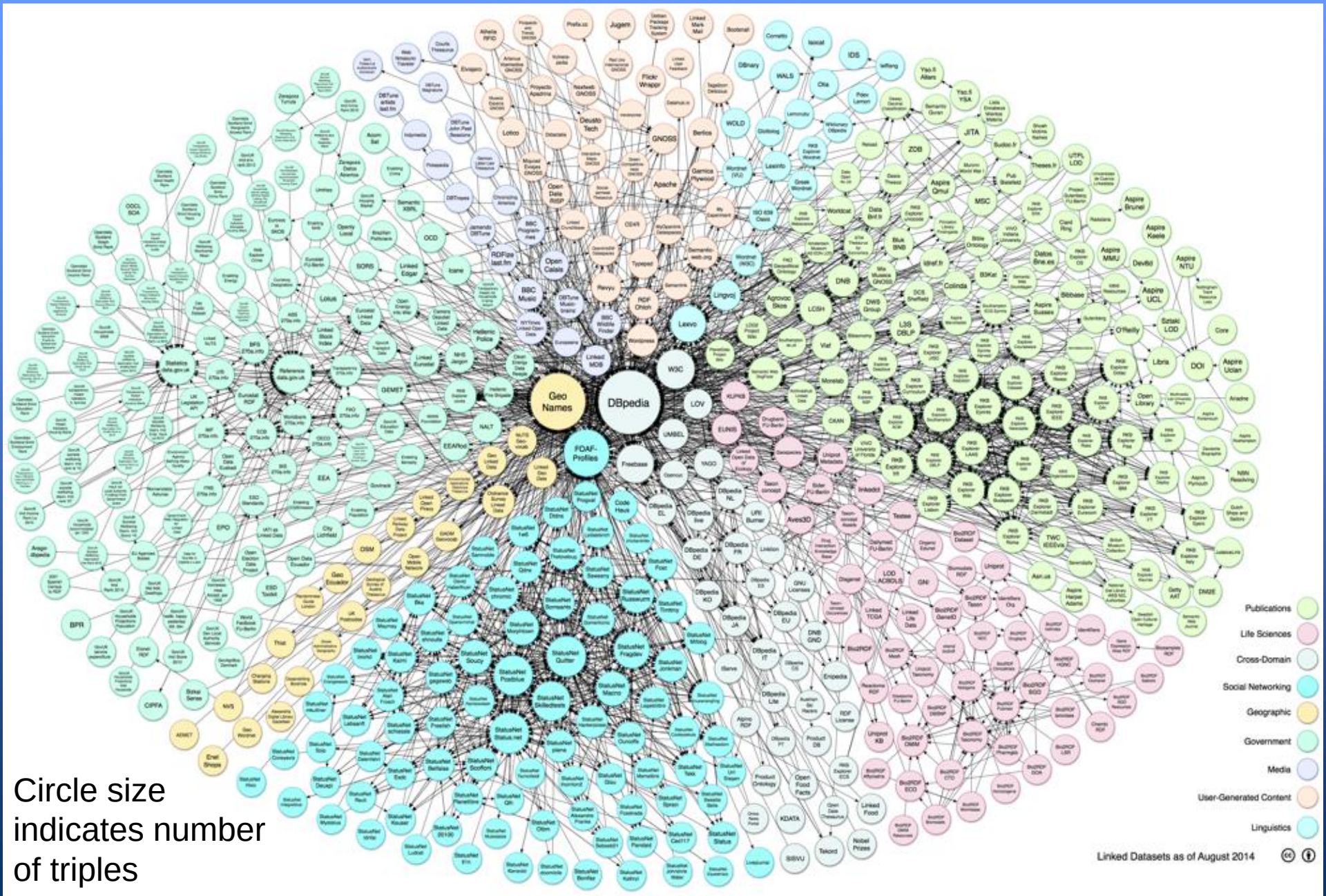
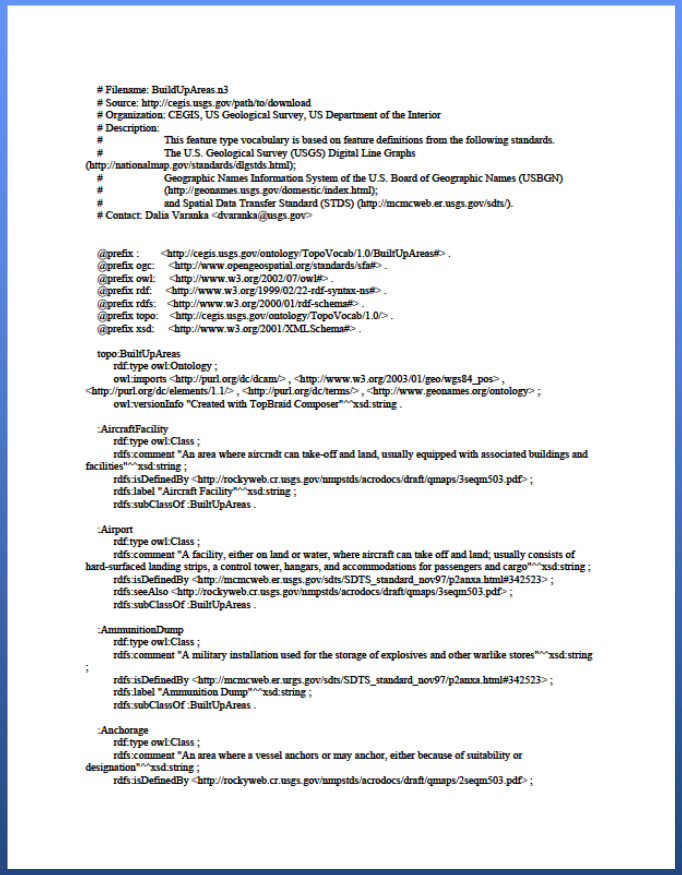
Linking Open Data cloud diagram 2014, by Max Schmachtenberg, Christian Bizer, Anja Jentzsch and Richard Cyganiak. http://lod-cloud.net/



Circle size indicates number of triples

Vocabulary – Built-up Areas



```
# Filename: BuildUpAreas.n3
# Source: http://cegis.usgs.gov/path/to/download
# Organization: CEGIS, US Geological Survey, US Department of the Interior
# Description:
#                This feature type vocabulary is based on feature definitions from the following standards.
#                The U.S. Geological Survey (USGS) Digital Line Graphs
(http://nationalmap.gov/standards/dlgstds.html);
#                Geographic Names Information System of the U.S. Board of Geographic Names (USBGN)
#                (http://geonames.usgs.gov/domestic/index.html);
#                and Spatial Data Transfer Standard (STDS) (http://mcmcweb.er.usgs.gov/sdts/).
# Contact: Dalia Varanka <dvaranka@usgs.gov>


@prefix :      <http://cegis.usgs.gov/ontology/TopoVocab/1.0/BuiltUpAreas#> .
@prefix ogc:    <http://www.opengeospatial.org/standards/sfa#> .
@prefix owl:    <http://www.w3.org/2002/07/owl#> .
@prefix rdf:    <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs:   <http://www.w3.org/2000/01/rdf-schema#> .
@prefix topo:   <http://cegis.usgs.gov/ontology/TopoVocab/1.0/> .
@prefix xsd:    <http://www.w3.org/2001/XMLSchema#> .

topo:BuiltUpAreas
    rdf:type owl:Ontology ;
    owl:imports <http://purl.org/dc/dcam/> , <http://www.w3.org/2003/01/geo/wgs84_pos> ,
<http://purl.org/dc/elements/1.1/> , <http://purl.org/dc/terms/> , <http://www.geonames.org/ontology> ;
    owl:versionInfo "Created with TopBraid Composer"^^xsd:string .

:AircraftFacility
    rdf:type owl:Class ;
    rdfs:comment "An area where aircradt can take-off and land, usually equipped with associated buildings and
facilities"^^xsd:string ;
    rdfs:isDefinedBy <http://rockyweb.cr.usgs.gov/nmpstds/acrodocs/draft/qmaps/3seqm503.pdf> ;
    rdfs:label "Aircraft Facility"^^xsd:string ;
    rdfs:subClassOf :BuiltUpAreas .

:Airport
    rdf:type owl:Class ;
    rdfs:comment "A facility, either on land or water, where aircraft can take off and land; usually consists of
hard-surfaced landing strips, a control tower, hangars, and accommodations for passengers and cargo"^^xsd:string ;
    rdfs:isDefinedBy <http://mcmcweb.er.usgs.gov/sdts/SDTS_standard_nov97/p2anxa.html#342523> ;
    rdfs:seeAlso <http://rockyweb.cr.usgs.gov/nmpstds/acrodocs/draft/qmaps/3seqm503.pdf> ;
    rdfs:subClassOf :BuiltUpAreas .

:AmmunitionDump
    rdf:type owl:Class ;
    rdfs:comment "A military installation used for the storage of explosives and other warlike stores"^^xsd:string
;
    rdfs:isDefinedBy <http://mcmcweb.er.usgs.gov/sdts/SDTS_standard_nov97/p2anxa.html#342523> ;
    rdfs:label "Ammunition Dump"^^xsd:string ;
    rdfs:subClassOf :BuiltUpAreas .

:Anchorage
    rdf:type owl:Class ;
    rdfs:comment "An area where a vessel anchors or may anchor, either because of suitability or
designation"^^xsd:string ;
    rdfs:isDefinedBy <http://rockyweb.cr.usgs.gov/nmpstds/acrodocs/draft/qmaps/2seqm503.pdf> ;
```

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Semantic Web Example Implementations

Hydrography

Mapping

Data integration – USGS and EPA

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Hydrography Example

Query – Find the tributaries of West Hunter Creek

Default Graph URI
http://cegis.usgs.gov/rdf/ontologytest/

```
PREFIX ogc: <http://www.opengis.net/rdf#>
PREFIX fid: <http://cegis.usgs.gov/rdf/nhd/featureID#>

SELECT ?feature ?type
WHERE {
fid:_102217454 ogc:hasGeometry ?geo1.
?geo1 ogc:touches ?geo2.
?feature ogc:hasGeometry ?geo2.
?feature a ?type }
```

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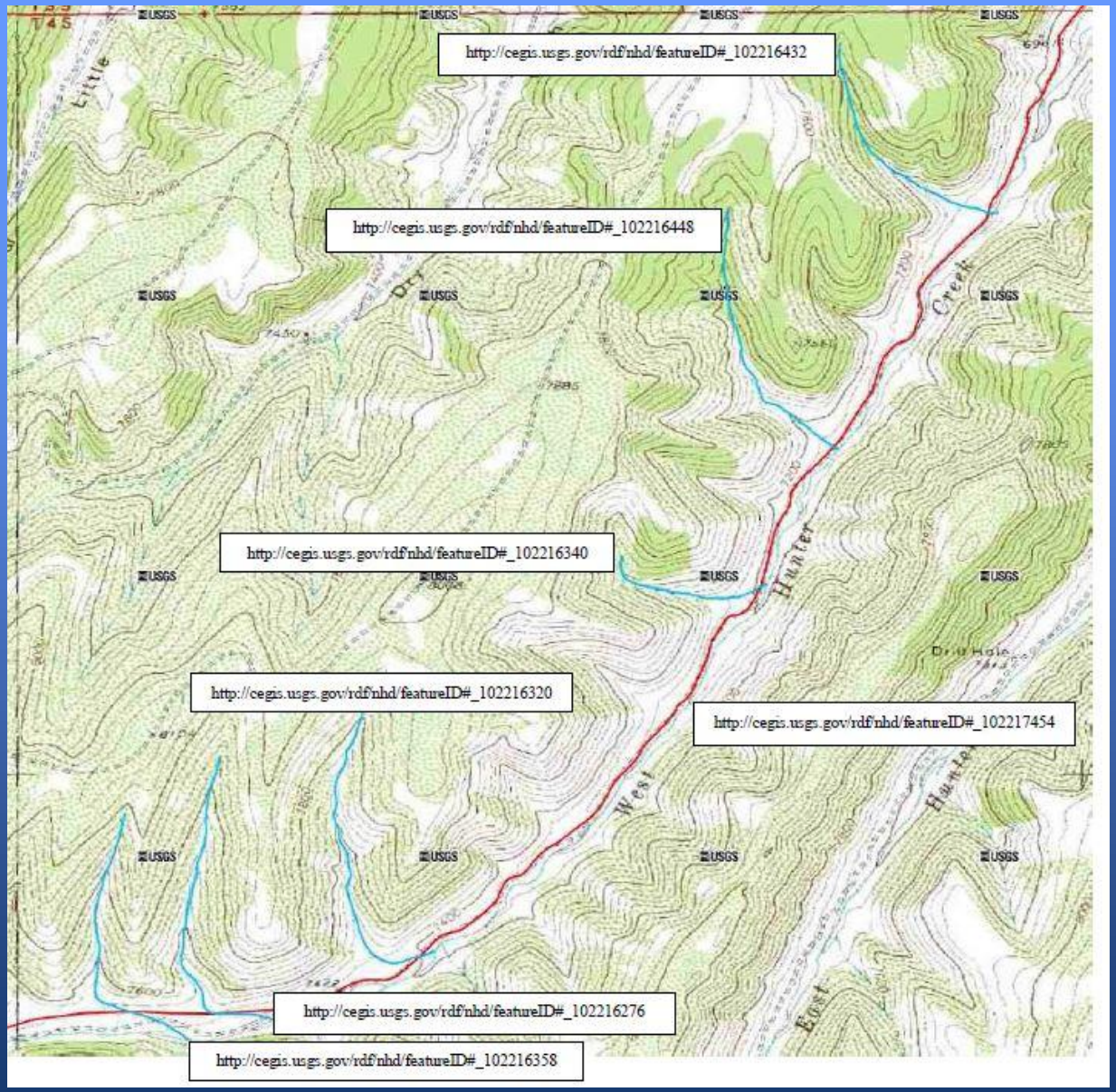
An Example of Geographic Features with URI tags for the Semantic Web – Hydrography



Blue streams are the result of a SPARQL query on the Semantic Web: “Find all tributaries of West Hunter creek” shown in red.

We are creating the same access (URIs) for terrain features, however, unlike hydrography with streams and other features predefined by geometry, terrain features have to be defined in the source geographic data including images, maps, DEMs, lidar.

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Converting Data to RDF from *The National Map*

Relational databases can be converted automatically

- Rows become subjects, columns predicates, and cell values objects

USGS has developed an online, publically accessible tool to convert data from the relational databases of *The National Map* to RDF triple form

The user simply specifies the area to be converted by either a named reference, Polk County, MO for example, or from a polygon boundary in shapefile or Well Known Text (WKT) format

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Mapping Example from RDF

Geometry is handled as strings of coordinates represented as WKT or as Geography Markup Language (GML).

The geometry (coordinates) are represented in the triple as subjects or more commonly objects.

GeoSPARQL was developed as an Open Geospatial Consortium (OGC) standard to handle geometry (as coordinates) and the common topological relations used with geospatial data

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GeoSPARQL

GeoSPARQL is an extension of SPARQL

Associates a Geometry with a feature using geo:hasGeometry

<http://cegis.usgs.gov/rdf/nhd/Features/102204610> rdf:type nhd:flowline .

<http://cegis.usgs.gov/rdf/nhd/Features/102204610> geo:hasGeometry
<http://cegis.usgs.gov/rdf/nhd/Geometries/102204610> .

<http://cegis.usgs.gov/rdf/nhd/Geometries/102204610> rdf:type geo:Geometry .
<http://cegis.usgs.gov/rdf/nhd/Geometries/102204610> geo:asWKT
"LINESTRING (-93.387722032150236 38.166983407423857 0,-93.387682298816969
38.167539207422976 0,-93.388619432148857 38.168476474088209 0,-93.391319032144679
38.169734874086259 0,-93.396768432136241 38.171924274082869 0,-93.398635898799967
38.172490274081952 0,-93.398990298799447 38.17260060741512 0,-93.399145698799202
38.172711207414977 0,-93.399287298798981 38.172574207415153 0,-93.399409832132108
38.172571607415193 0)"^^<http://www.opengis.net/def/sf/wktLiteral> .

GeoSPARQL example – Find counties in Missouri that cover the Pomme de Terre watershed

- http://144.47.160.23:8000/viz - An RDF triplestore for the Pomme de Terre watershed in Missouri
- Enter the query:

```
SELECT
?label ?wkt
WHERE {
    ?feature rdf:type gu:countyOrEquivalent .
    ?feature rdfs:label ?label .
    ?feature geo:hasGeometry ?g .
    ?g       geo:asWKT       ?wkt .
}
```

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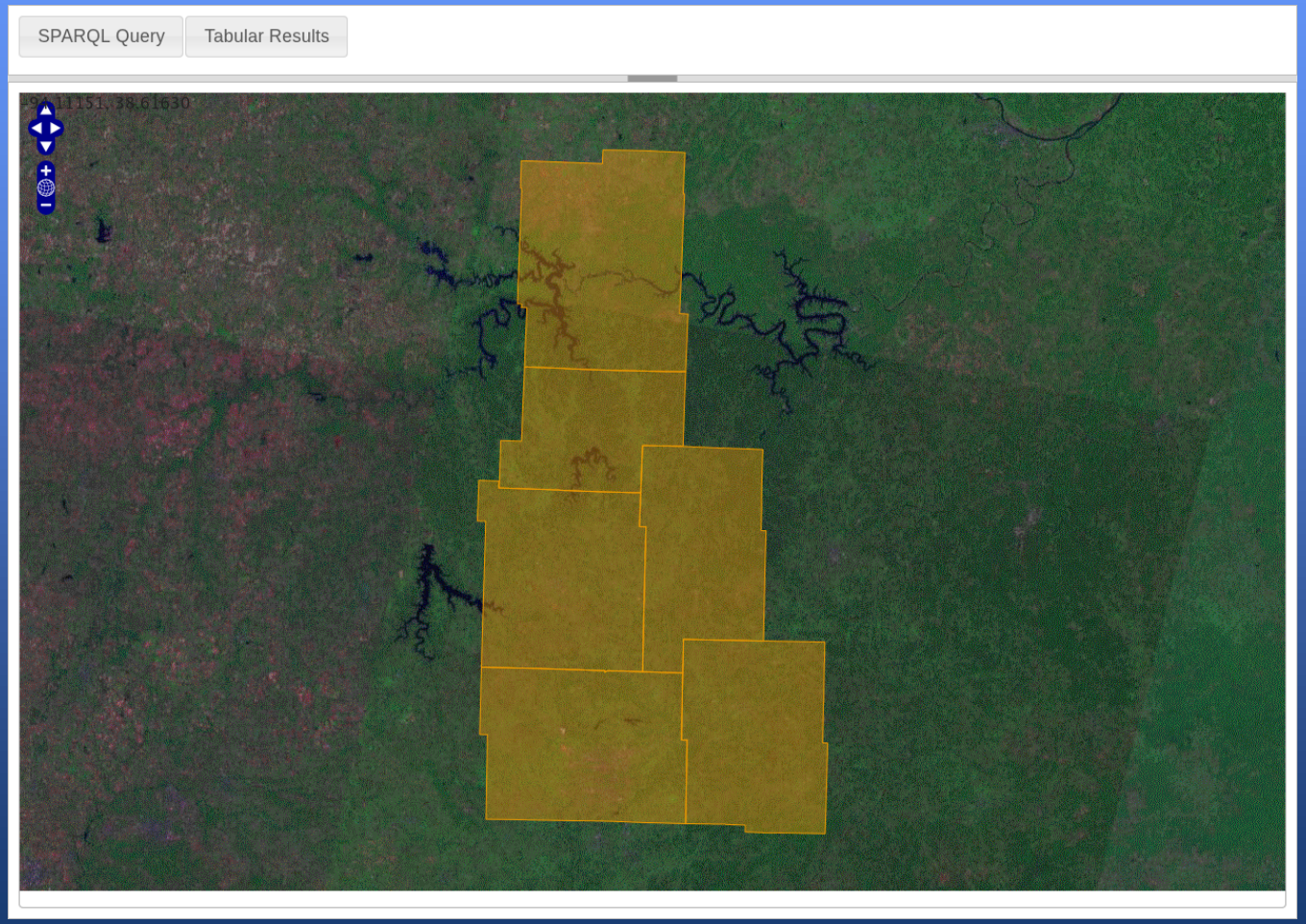
GeoSPARQL Result



GeoSPARQL Query to Generate Data for US Topo

```
SELECT DISTINCT
?wkt
WHERE {
  GRAPH <http://cegis.usgs.gov/rdf/> {
 ?s rdfs:label "Sentinel" .
 ?s geo:hasGeometry ?g .
 ?g geo:asWKT ?quadwkt .

 ?feature geo:hasGeometry ?g2 .
 ?g2 geo:asWKT ?wkt .

  FILTER(geof:sfContains(?quadwkt, ?wkt))
}
}
```

This query selects all of the features that overlap the Sentinel quad, including itself.

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GeoSparql Query visualization - Mozilla Firefox

File Edit View History Bookmarks Tools Help

GeoSparql Query visualization

usgs-ybother.srv.mst.edu/viz/

Google

SPARQL Query | Tabular Results

-93.21312, 37.89082

SPARQLer Query Results

Count: 2528

wkt
"POLYGON ((-93.25 37.75, -93.375 37.75, -93.375 37.875, -93.25 37.875, -93.25 37.75, -93.25 37.75))" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.270336 37.8732229995, -93.270702 37.8732289995, -93.271533 37.8732599995, -93.271962 37.8732919995)" ^^<http://www.opengis.net/sf#w
"LINESTRING(-93.267546 37.8616539996, -93.267178 37.8616509996, -93.266951 37.8617019996, -93.266683 37.8618279996, -93.26652 37.8619619996, -93.266 37.8621009996, -93.266003 37.8622769996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.3515209999 37.8520249996, -93.3515099999 37.8521829996, -93.3514499999 37.8524969996, -93.3514279999 37.8526159996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.3377209999 37.8434729996, -93.3371619999 37.8429829996, -93.3370049999 37.8427659996, -93.3368489999 37.8425009996, -93.336793999 37.8422259996, -93.3367429999 37.8418309996, -93.3367539999 37.8417399996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.3388519999 37.8350829996, -93.3388649999 37.8347199996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.3524489999 37.8125899996, -93.3520759999 37.8127499996, -93.3519489999 37.8127759996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.3371569999 37.8486239996, -93.3366689999 37.8492359996, -93.3365269999 37.8495479996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.3530679999 37.8593859996, -93.3531039999 37.8594659996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.317633 37.8665699996, -93.317701 37.8656159996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.297594 37.8375369996, -93.297689 37.8373349996, -93.297721 37.8372689996, -93.298094 37.8365359996)" ^^<http://www.opengis.net/sf#w
"LINESTRING(-93.312055 37.8637539996, -93.311964 37.8638669996, -93.311839 37.8641559996, -93.311751 37.8645539996, -93.311646 37.8648799996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.313546 37.8653059996, -93.313322 37.8652889996, -93.313131 37.8653649996)" ^^<http://www.opengis.net/sf#wktLiteral>
"LINESTRING(-93.2533730001 37.8582689996, -93.2534530001 37.8578299996, -93.2533200001 37.8574299996, -93.2532300001 37.8570669996, -93.253220000

Data Integration – USGS and Environmental Protection Agency (EPA) Data

We will search for EPA listed pollution sites within 5 km of Pittsburg Firehouse near Sentinel, Missouri.

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GeoSPARQL Query to Connect EPA Data to a USGS Quadrangle

First define the needed **prefixes**

```
PREFIX geo: <http://www.opengis.net/geosparql#>
PREFIX geof: <http://www.opengis.net/geosparql/function/>
PREFIX gml: <http://www.opengis.net/gml#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX gnis: <http://cegis.usgs.gov/rdf/gnis/>
PREFIX gnisf: <http://cegis.usgs.gov/rdf/gnis/Features/>
PREFIX nhd: <http://cegis.usgs.gov/rdf/nhd/>
PREFIX nhdf: <http://cegis.usgs.gov/rdf/nhd/Features/>
PREFIX gu: <http://cegis.usgs.gov/rdf/gu/>
PREFIX guf: <http://cegis.usgs.gov/rdf/gu/Features/>
PREFIX category: <http://dbpedia.org/class/yago/>
PREFIX foaf: <http://xmlns.com/foaf/0.1/>
PREFIX units: <http://www.opengis.net/def/uom/OGC/1.0/>
PREFIX xsd: <http://www.w3.org/2001/XMLSchema#>
PREFIX dgtwc:   <http://www.data.gov/semantic/data/alpha/1050/dataset-1050.rdf
```

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GeoSPARQL Query to Connect EPA Data to a USGS Quadrangle

Then enter the query and execute

```
SELECT DISTINCT
?name ?wkt1
WHERE {
GRAPH <http://cegis.usgs.gov/rdf/> {

  # Match features with type EPA DataEntry
  ?feature rdf:type   <http://data-gov.tw.rpi.edu/2009/data-gov-twc.rdf#DataEntry> .
  ?feature geo:asWKT ?wkt1 .
  ?feature dgtwc:primary_name ?name .

  # Get geometry of the firehouse
  <http://cegis.usgs.gov/rdf/struct/Features/10474482> geo:hasGeometry ?geo .
  ?geo geo:asWKT ?fire_wkt .

 # Create a 5km buffer around the firehouse
 BIND (geof:buffer(?fire_wkt, 5000, units:metre) AS ?fire_buff)

 # Restrict matches to the buffer
 FILTER(geof:sfContains(?fire_buff, ?wkt1))
}
}
```

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Text result of query

name	wkt1
ASH GROVE AGGREGATES, INC	POINT(-93.304139 37.823306))
DALE & SHELLY WHITESIDE	POINT(-93.295654 37.858091))
MDNR, DIV OF STATE PARKS	POINT(-93.300556 37.833889))
ROYAL SCHOOL	POINT(-93.38 37.83611))

USGS

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GeoSparql Query visualization

usgs-ybother.srv.mst.edu/viz/

Google

SPARQL Query | Tabular Results

Conclusions

- Geospatial semantics offer potential to build semantic spatial relations to capture geographic feature characteristics and relations not available in current geospatial datasets and models, such as GIS.
- The strength of the approach is in linking datasets for solutions requiring data from various sources and of disparate types.
- Geometry is implemented in the RDF model and can be used for mapping and spatial analysis
- GeoSPARQL provides an ontology that supports geometric and topological operations
- Creation of standard mapping products is possible with linked data
- The RDF linked data process allows integrating data from multiple sources and organizations to create environmental and thematic maps and analyses to support decision-making requiring spatial data

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