DATA EXCHANGE OPTION REPORT

Presented by:

SURROUND NEW ZEALAND
OPENWORK LTD
PANGAEA INNOVATIONS PTY LTD
EVOLVE & AMPLIFY
MCKENZIE & CO

9 MARCH 2022

SURROUNDNZ.COM

1 Data Exchange Options Report 3

2 Encoding Categories 13

3 Overview of Syntax Encoding Technologies 14

3.1 LandInfra / InfraGML 18

3.2 Crosswalks 18

3.2.1 BIM / IFC in Cadastre 18

3.2.2 CityGML 19

3.3 3D Topology 20

3.4 Software Support Issues 21

3.4.1 OGR Conversion of GML to Expand XLinks 21

3.4.2 Ogr2ogr to Resolve xlinks 22

3.4.3 Issues Mapping CityGML to IFC 22

3.5 Mapping Use Case 7 Requirements to Existing and Emerging Standards 23

3.6 Note on JSON encodings 30

3.6 Note on GeoPackage 31

3.7 Suggested Roadmap 32

3.8 Towards an optimal set of encoding options 34

3.9 Related Standards Review Road Map 34

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

1 Data Exchange Options Report

This ICSM 3D Cadastral Survey Data Model (CSDM) was specified to be encoding agnostic so as to be implemented in whole or part with a range of different encoding technologies. So we began the 3D CSDM project with a review of existing standards and encodings for data exchange with a review of 3D Cadastre and related models and from a survey of stakeholders and solution providers. We canvassed for both existing use and potential improved options. This provided a foundation of knowledge of what is possible and what is feasible.

Standard	
BuildingSmart IFC (IFC4) IFC 5 under development	Broadly supported in tools that surveyors currently use. Focused on 3D built objects. Does not support survey points and observations well. Uses a geometry model that differs from the other standards reviewed here (ISO 10303-43:1992). Allows Solid Geometries, Swept Volumes, B-Rep, among others. ifcSpace
ISO LADM (ISO19152:2012)	A conceptual model. Current implementations are largely limited to compliant cadastral databases.
- OGC InfraGML (OGC 15-111r1)	Designed to supersede LandXML InfraGML parts 6 & 7 Survey and Land Division
LandXML (landxml.org)	The lack of any conceptual model behind this standard led the OGC to create LandInfra rather than adopt LandXML.
- ICSM ePlan (ICSM ePlan v10)	A regional effort to improve the ability to capture cadastral features in 3D. Based on LandXML.
ISO GML (ISO19136:2020)	An XML encoding of 19107. Multiple versions with increasing capability.
- OGC CityGML (OGC 20-010)	Version 2 in wide use, version 3 has more capabilities and is more closely aligned with other relevant standards such as IFC and LandInfra. Version 3 supports multiple encodings - currently JSON and XML.

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

IETF geoJSON (Reference RFC 7946)	Focus on providing simple geometry features over the web. Not part of the OGC suite.
- TopoJSON (github - topojson)	Based on GeoJSON, but with 2.5d topology support. Not currently under development. Can support multiple CRS but without identifying them.
OGC GeoPackage (OGC 12-128r18)	An SQLite database with capability to store spatial data. Actively under development. Additional capabilities are added frequently.
ISO Geographic Information Spatial Schema (ISO19107:2019)	Not implemented directly but with standards such as GML, GeoSPARQL, etc.

Each of these were then analysed for suitability to the needs of a 3D CSDM to gain a better understanding of the role and scope of each. (It should be noted that some of the Standards included in these tables are not encodings but conceptual models. Namely LADM and ISO19107. They are included because their influence on encoding standards is significant. They will not be discussed in detail in this document.)

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

Legend

N/A	Feature Not Applicable
?	Feature implementation details are unknown
Yes	Feature is available and fully supported
Yes ?	Feature is available, but needs further investigation
Partial	Feature is partially implemented or supported
No?	Feature is not available, but needs further investigation
No	Feature is not available

Standard Name	**BSi IFC (IFC4 ISO10303)**	**ISO LADM (ISO19152: 2012)**	**- OGC LandInfra (OGC 15-111r1)**	**LandXML (landxml.org)**	**- ICSM ePlan (ICSM ePlan v10)**	**ISO GML (ISO19136: 2020)**	**OGC CityGML (OGC 20-010)**	**GeoJSON (IETF RFC 7946)**	**GeoPackage (OGC 12-128r18)**	**Geographic Information Spatial Schema (ISO19107: 2019)**
Primary Users	BIM & AEC	Land Admins	Asset Mgrs, Engineers, Surveyors	Survey Engineering	Cadastral Surveyors	Geographic information modellers	3D City modellers	Web developers	GIS	Geographic information modellers
Project Gov’	Strong	Strong	Strong	Weak	Medium	Strong	Strong	Strong	Strong	Strong
Cadastre Features	Partial	Yes	Yes	Yes	Yes	Yes?	No	No	Yes?	No

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

Cad. Feat Support	No	?	Yes	Yes	Yes	Yes?	No	?	No	N/A
Cad. Evidence	No	No	Yes	Yes	Yes	Yes?	No	No	Yes	No
Evid. Support	No	?	Yes	Yes	Yes	Yes?	No	No	Yes	N/A
Features (ISO 19109)	No	?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Features Tool Support	N/A	?	Yes (Leica, FME, etc)	?	?	Simple Features only (FME, GDAL)	?	Yes (Various web tools)	Yes (SQLite)	N/A
Simple Geom	Yes (ISO10303)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Complex Geom	Yes (ISO10303)	Yes	Yes	Partial	Partial	Yes	Yes	No	Yes	Yes

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

Simple Geom Tool Support	Yes	Yes (PostGIS, etc.)	Yes (Leica)	Yes (12d, FME, etc.)	Yes (12d, FME, etc.)	Yes	Yes	Yes	Yes (Most GIS)	N/A
Complex Geom Sup	Yes (ISO10303)	?	Yes (Leica)	?	?	Yes (FME, GDAL)	?	No	?	N/A
2D Topology	Yes (ISO10303)	?	Yes	Yes?	Yes?	Yes	Yes	No	Yes	Yes
3D Topology	Yes (ISO10303)	?	No	No?	No?	Yes	No	No	No	Yes
2D Topo Support	Yes	?	Yes (Leica)	Yes Limited	Yes Limited	Yes (FME)	Yes (FME)	N/A	Yes	N/A
3D Topo Support	Yes	?	?	No	?	?	?	No	No	N/A
Code Lists	Enums	Yes *	Yes *	Yes	Yes	Yes *	Yes *	Yes	Yes *	Yes

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

CRS	Many	Many	Many	Many	Many	Many	Many	1	Many	Many
Metadata	Extensive, inconsistent	ISO 19115	ISO 19115	Basic	Basic	ISO 19115	Basic	STAC, OAPIRec	ISO 19115	N/A
Extensions allowed	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A
Extension Support	Medium	Low	Low	Medium	Low	Medium	Medium	Broad	Low	N/A

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

The current state of the art in our region's digital cadastral data submission utilises LandXML based schema encodings. These include ePlan and the LINZ LandonLine (LoL). The LINZ LoL LandXML encoding is mandated for use throughout New Zealand and fully implemented by at least one software vendor (12D). Therefore, this LandXML profile seemed a natural starting point for testing our model and investigating 3D CSDM encoding options.

However, LandXML has several limiting factors. The lack of 3D support meant that we would need to invent new elements to hold such information. The lack of good governance of this standard had led many stakeholders to dismiss it as a long term solution. LandXML is not based on any particular underlying model or implementation patterns, therefore to extend it requires identification of new schema elements and a process for agreement to change the core. A more modular approach based on well-known patterns is needed to provide a forward looking pathway for more types of observational data for example. For a full discussion see Annex C of the ICSM Conceptual Model for 3D Cadastral Survey Dataset Submissions. LandXML itself was not suitable for demonstrating and testing the model, however there is no barrier to mapping the parts of this model that can be represented to the relevant LandXML elements. Translations to and from LandXML could be used within the scope of existing usage - this could allow leverage of tools based heavily on LandXML encoding such as business rule validation and 2D submissions, and allow the 3D model to be tested and used as a basis for more flexible systems in the future.

The solution was to explore the ISO based patterns (ISO 19107 spatial schema, ISO 19109 General Feature Model and ISO 19156 Observations and Measurements) to manually create example files roughly based on the LINZ LoL profile of LandXML but use GML elements to express the more complicated geometries. This required the creation of several bespoke XML elements. While not suitable for production, (and not backed by a specific schema as this is out of scope) this provides a framework for exploring capabilities of GML encoding for testing and demonstration.

A summary of issues faced by three most significant encodings is covered in the table below:

Standard	Issue	Recommendations	Benefits

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

GML	Not generally used as a data format by itself but rather an encoding for other standards such as IndoorGML,CityGML, etc. This means that few tools read GML natively	GML can be used but should be as an encoding in another standard such as CityGML and InfraGML	Well known standard that is comprehensible to LandXL communities.
	Too many options for building geometry could make a standardised implementation difficult	Implementation standards using gml encodings should include canonical approaches to describing geometries.	
	While GML supports the use of xlinks, the ability to resolve xlinks is not well supported in most software.	Xlinks are valuable to this work by providing compatibility with linked data processes, enforcing some topology rules and reducing filesize. Therefore, when using xml encodings, vendors should be encouraged to include xlink support to take full advantage of this technology. Short term solution is to create temporary files using the widely supported GDAL libraries to create temporary, fully expanded versions of the data.	

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

CityGML	Points are not well supported in CityGML. Building geometry from a set of reference (survey) points is difficult.	Ids on point Properties when they first occur can be referenced by xlinks and preserve single entry of point values. These points may be retrieved from a more complete format such as InfraGML (or a database) and used in CityGML when required.	Well suited to applications where search and visualisation of 3D parcel boundaries in a city context is important.
	CityGML 2 does not support interior geometries needed to describe many unit tiles unless using LOD4	The new version of CityGML (v3) supports interiors at all LODS	
	Alignment of elements with other related standards such as IFC or LandInfra is poor at CityGML 2	Promote the use of CityGML 3 where CityGML is needed as alignment with other standards is much improved	
	Limited tools available to work with CityGML - especially version 3	Promote the development of appropriate tools.	
IFC	IFC, with its root in the world of CAD, is based on a very different conceptual approach to GIS data structures. This makes translation difficult.	Support ongoing effort in multiple communities to bridge the BIM GIS divide.	STEP encoding provides a very compact format that natively supports referenced geometry similar to the xlink approach.

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

	IFC has difficulty portraying point objects such as survey marks.	Consider using other standards to capture observations and measurements. Alternatively work with the BIM community to support the inclusion of non-built, nonphysical objects	
	Capture of any information that is not a designed and built object is difficult. This includes IFCSPACE which is a lead candidate to hold parcel boundaries.		
		Work with the BIM community to encourage simplifying the display of IFCSPACE and other conceptual (non-built, non-physical) objects.	

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

2 Encoding Categories

Encodings tell a computer how to decode the data. These encodings exist at many levels, from computer storage methods and messaging bits of ones and zeros to the display of human-readable information.

As an analogy, the Latin alphabet could be considered an encoding standard for writing any number of languages. The syntax and grammar of these languages are unaffected by the selection of the Latin alphabet encoding. A computer may use several character encoding options to encode the Latin alphabet. Encoding the syntax of a language happens at another level. The following diagram illustrates the relationship between these different levels of encoding options.

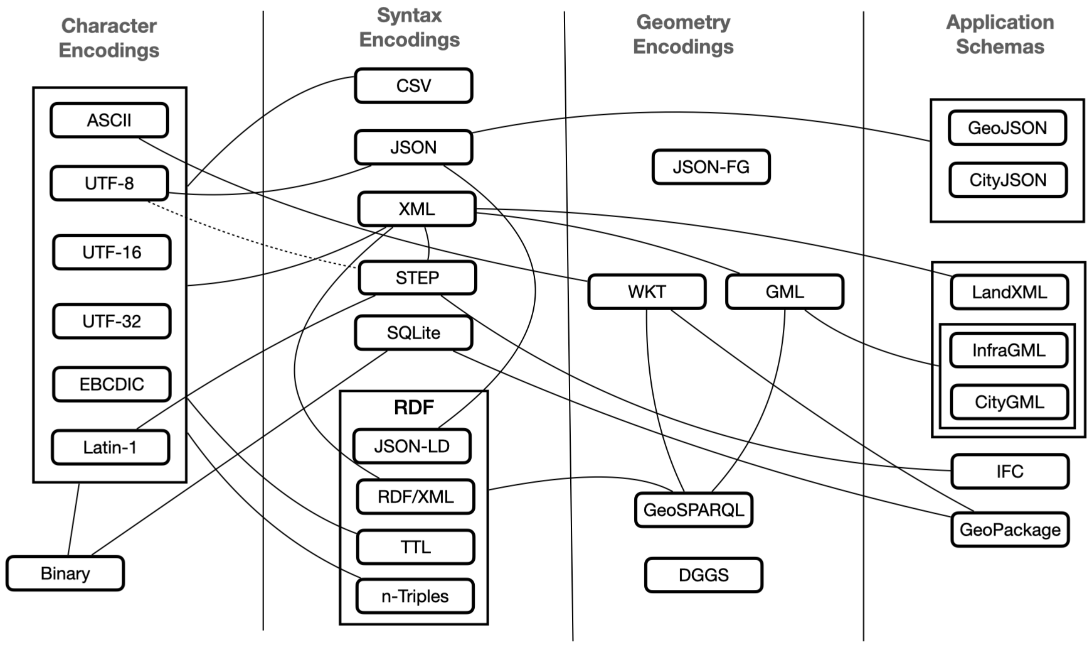

Figure 1. Encoding standards - Categories and their relations

This diagram serves to aid understanding of the type of encodings discussed. However, because capabilities and design decisions differ between encodings, the categorisations of encodings may be rough and open to interpretations.

- Character Encodings - How symbols (letter, numbers, etc.) encoded in binary bits

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

- Syntax Encodings - How to extract structure from a sequence of bytes
- Geometry Encodings - Special encodings for spatial data types,
- Application Schemas - File encodings suitable for consumption by software applications
- Profiles - Specialisations of Application Schemas for more particular applications.

Our focus will be on Syntax encodings and associated Application schemas. In addition, Geometry encodings will be discussed where pertinent.

3 Overview of Syntax Encoding Technologies

This table provides an overview of Syntax Encoding options listed in the diagram above and evaluates this against several important partners the 3DCSDM seeks to implement.

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

Encodings	Governance	Modular components	Feature / Geometry Distinction	3D Solid Geometry	Topology of 3D Solids	Domain Compatibility	Linked Data Support
Syntax							
CSV	None - stable	No	No	Possible	No	High	No
JSON	ISO/IEC - Strong	Partial	Possible	Possible	Possible	Medium	No
XML	IETF - Strong	Partial	Yes	Possible	Possible	High	Possible
STEP	ISO - Strong	Partial	No	Yes	Yes	Very High	Possible
SQLite	Strong - Closed	Possible	Yes	Possible	Possible	Medium	Possible
RDF (JSON-LD, RDF/XMl, TTL, n-Triples)	W3C - Strong	Yes	Yes	Possible	Possible	Medium	Very High

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

Geometry							
JSON-FG	OGC - Strong - New	Partial	Yes	Developing	Possible	Low	Developing
GML	OGC - Strong	Partial	Yes	Yes	Possible	High	XLinks
WKT	ISO/IEC/OGC - Strong	Yes	Yes	Yes	Possible	Medium	via GeoSPARQL
GeoSPARQL	OGC - Strong	Yes	Yes	Yes	Yes	Medium	Yes
DGGS	OGC/ISO - Strong	Yes	Yes	Yes	Yes	Medium	Yes
App Schemas							
GeoJSON	IETF - Strong	Partial	Yes	Minimal	No	Medium	No
CityJSON	OGC - Strong - New	Partial	Yes	Yes	Possible	High	Low
LandXML	LandXML.org - Weak - Inactive	No	Yes	Possible	Possible	High	No

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

InfraGML	OGC - Strong	Partial	Yes	Yes	Possible	High	XLinks
CityGML	OGC - Strong	Partial	Yes	Yes	Yes	Medium	XLinks
IFC	bSI/ISO - Strong	Partial	No	Yes	Partial	Very High	Developing
GeoPackage	OGC - Strong	Possible	Yes	Developing	Developing	High	Possible

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

3.1 LandInfra / InfraGML

A top contender for encoding 3D CSDM was InfraGML which is based on the OGC LandInfra conceptual model. Work on this standard began when the OGC determined, due to lack of a well governed underpinning model and large installed community users, that they could not adopt LandXML directly. Work on a new standard, LandInfra, properly modelled and governed was initiated.

We frequently referenced InfraGML when building and testing the 3D CSDM. But due to some structural limitations discussed more fully in ICSM Conceptual Model for 3D Cadastral Survey Dataset Submissions, we could not use this encoding for demonstration and testing. We could however, map most of the required elements of the 3D CSDM to this encoding as illustrated in implementation examples included in the model document.

Consortium members participate in the work of the OGC LandInfra domain working group. Building Smart International and a number of large software providers were involved in the development of LandInfra and InfraGML. InfraGML has been implemented by at least one international vendor but struggles to gain more brand adoption. Our aim is to incorporate the findings of the 3D CSDM into future LandInfra work. This would also influence the development of LADM as LandInfra is closely tied to LADM,

3.2 Crosswalks

Through this analysis, two standards stood out as important to support semantic interoperability at some level - IFC and CityGML. Beyond cadastral purposes, these two standards are central to many Digital Twin and Smart City initiatives. Sharing 3D cadastral information in these domains is highly valuable. Both these however have defined scopes that do not match the 3D CSDM requirements and are not designed for modular reuse of components. IFC in particular is both regularly expanded and published as a "monolithic version" - which leads to long term challenges for any effective reuse.

3.2.1 BIM / IFC in Cadastre

The frame of reference for BIM / IFC is the CAD world of manufactured things focused on architecture, engineering and construction (AEC) and facilities management (FM). The fundamental purpose is to create plans for production of physical objects. BIM is the verb, Building Information Modelling. The aim of BIM is to extend these plans to a live state that reflects the

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

current state of Buildings so as to support the whole of life management and in doing so gain great efficiencies.

Because of the focus on real world designed objects, IFC provides few class objects that can conceivably be used to represent abstract objects like a cadastral parcel. ifcSpace is the one available class that is most generally recommended to represent parcels and their boundaries. IfcGeographicElement can act as an appropriate candidate entity to support the storage of cadastral survey data such as survey marks and traverse lines in the BIM environment. Forcing a common approach to adding metadata to these elements means switching to a different modelling environment to specify attributes, and the semantics of feature relationships does not naturally fit.

The fundamental limitation was that no BIM software could visualise survey points and these points are typically presented as attributes in BIM models. This limitation can be addressed in the future enhancements of the IFC schema to support various types of survey marks such as control points, traverse points, and boundary points.

IFC is a widely used encoding to support the sharing of BIM data. Most current software vendors support IFC and much of the 3D data needed to support cadastral purposes (buildings, tunnels, etc.) has already been captured in design software which can export to IFC. Support for bidirectional sharing of data has obvious advantages.

While most surveyors rely on software that lives in the BIM / CAD world, the conceptual underpinnings of IFC do not well support their requirements. Because the focus of this domain is the design of real world objects, IFC has poor support for anything with less than three dimensions. In our IFC demonstration software, we can show 0 and 1 dimensional survey observations, but only as mock ups - the observations portrayed are extracted from source and converted to 3D in order to display in the viewer.

So whilst an IFC encoding is regarded as possible it is not natural and should only be attempted when more effective encodings have been used to test the model. Software needed to enforce the additional metadata structures imposed on general IFC mechanisms would be an expensive and difficult undertaking whilst initial testing phases are underway.

3.2.2 CityGML

The OGC CityGML standard defines a conceptual model based on levels of detail and utilises GML encoding as an exchange format for the representation, storage and exchange of virtual 3D city models. It facilitates the integration of urban geodata for a variety of applications for Smart Cities

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

and Urban Digital Twins, including urban and landscape planning; Building Information Modelling (BIM); mobile telecommunication; disaster management; 3D cadastre; tourism; vehicle & pedestrian navigation; autonomous driving and driving assistance; facility management, and; energy, traffic and environmental simulations.

However, similar to IFC, this standard does not well support cadastral observations. But 3d parcels can be mapped to _bldg:BuildingPart. With geometry encoded in GML, export to this standard from our prototype XML test encoding is somewhat simplified. Export of 3D CSDM data to CityGML is most likely something that will be done from the corporate cadastral database and not as frequent at the time of survey dataset submission.

CityGML uses an ad-hoc approach to profiling ISO19107, specifying in text what GML data types are allowed.

3.3 3D Topology

The necessity of and challenges to support 3D topology became evident early in the encoding testing process. The integrity of space and the shareability of observations are central to the requirements of cadastral surveying. These become all the more challenging and necessary in 3D where visual inspection is more difficult.

Central to the concept of cadastral surveying is the unambiguous descriptions of observations, spatial definitions of the surveyed objects and the ability to reproduce these. Basic topological relationships must be retained. This is even more challenging in 3D. Topological issues include:

1. Integrity of the spatial unit geometric descriptions
    - They are properly closed solids - no leaks
    - No geometric abnormalities
2. From - to details of observations and Inside - outside of spatial units definitions are clear No gaps or overlaps between spatial units (of the same type)
3. Common boundary elements are recorded once as shared geometric objects - nodes (corners, edges, faces). This is closely related to the database design pattern First Normal form - record objects once - and provides numerous other advantages including reduced file size.

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

  - ○ In a 3D cadastre the readjustment of one node (corner) could easily affect 8 different spatial units.

Topology was determined early on to be important to the model and the one thing that was least supported by any existing encoding. Neither GIS or BIM formats proved sufficient to capture the provenance and topological details required. Unlike design and representation work, a cadastral survey must convey the details behind a survey feature, e.g. Start and end points, what is to the left and right, which direction the traverse runs.

However, it is challenging for any of the existing encodings to support 3D topology. The underlying principles are not well known or consistently applied in the GIS world. The Spatial Schema standard ISO19107, on which the geometry objects of most of these standards is based has complex theoretical support but other than topology-geometry duality it is silent regarding the requirements for encodings to support topology within geometric representations and requirements for these to be consistent with feature topology details. Improving this situation is key to creating a truly useful and sustainable 3D CSDM. In the meantime we address as many topological elements as possible. (NB - The Poincaré Duality theory is reflected in support for Boundary Features of dimensionality less than topologically connected objects - e.g. solids are connected at surfaces, edges or nodes.)

Point 3 from the list above is addressed by some encodings. This is native to IFC. GML based encodings accomplish this through xLinks. However, we found that the use of xlinks by existing software to be poorly supported.

3.4 Software Support Issues

Through the testing process, several issues arose concerning vendor support for the software encodings. First we will discuss the lack of xLink support and ways we found to work around this..

3.4.1 OGR Conversion of GML to Expand XLinks

Issue: XML Linking Language, or XLink, is an XML markup language specification that provides methods for creating internal and external links within XML documents. The use of xlinks is valuable tool for this project that provides the following benefits: Support of Topology rules, e.g. to embed in the file that one face, edge or node is the same as that used by another feature Reduced file size, no need to capture the same spatial element each time it may be used. Linked Data support, xlink refs provide a way to implement RDF functionality

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

While the GML standard supports the use of xlink's in many of its elements, most available software has difficulty resolving and accessing these xlink'd data. This limits the ability to use this valuable technology in GML based encoding standards such as CityGML and InfraGML.

3.4.2 Ogr2ogr to Resolve xlinks

A potential way to resolve links references in xml based encodings is through the use of the GDAL/OGR command "ogr2ogr". GDAL/ORG is a heavily used opensource translator library for raster and vector geospatial data formats. It has implemented a large number of spatial software platforms both open source and proprietary. It has become the de facto standard software for the conversion of spatial data formats, both raster and vector, across the spatial industry. It should be possible for most of these software to use this proposed solution to resolve links without the importation of additional libraries.

The use of the "ogr2ogr" command provides a way to resolve xlink'ed data in any GML based files. The approach could be to use this command on a GML based CSD containing xlinks to create an expanded temporary file suitable for viewing in any software that supports the viewing of GML data.

The command used is:

```
ogr2ogr --config GML_SKIP_RESOLVE_ELEMS None -f GML <temp-file-1>
<input-file>
```

The resulting usable temp file will be named `<input-file>-resolved.gml`. Deletion of both the `` <temp-file-1>`and `<input-file>-resolved.gml `` is recommended after viewing is complete

3.4.3 Issues Mapping CityGML to IFC

Methods of creating IFC files from the GML based canonical test encodings proved to be more challenging than expected. Some of this was due to the xLink issues mentioned above. But much is due to other ongoing challenges created from the different world views of the two encodings.

Since no schemas yet exist by which computers could map our canonical test encoding to other standards this was done manually. Like the canonical test encoding, CityGML geometry is based on GML. This made it simpler than IFC to create manually. The hope was that, using known processes and tools, we could easily produce IFC files from this.

This assumption proved to be false. We did eventually find a free (but not open source) tool, FKZViewer (which appears to be a poorly supported university project) that accomplished the task.

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

This was not deemed to be a good reduction ready solution. Other scripts freely available, were too bespoke for broad use.

The natural tool to use is FME from Safe Software. FME is the Industry standard for this type of processing. We found very limited success with this approach:

- Difficult process with few examples or instructions to follow
  - Somewhat better for the reverse process (IFC to CityGML) but not much
- Due to BIM limitations, only solids could be exported
  - Walls, ceilings and floors objects which are described with planes in CityGML do not convert
  - Terrains do not transfer
- XLinks are not supported well

Research found that this is known to be a difficult process - forums contain many posts from professionals who struggle with it. We have requested help from Dean Hintz from Safe Software. Dean has acknowledged the problems exist and is keen to help resolve them in future 3D CSDM efforts. FME is a valuable tool for at least the near to middle term of implementation. (Beyond that we hope that ETL (Extract, Transform, Load) middleware tools like FME would no longer be necessary.

3.5 Mapping Use Case 7 Requirements to Existing and Emerging Standards

The preceding encoding options analysis focuses on the requirements of submitting cadastral boundary and observation information. In contrast, Use Case 7 consists of the 3D CSDM metadata (header) requirements - these tell the story behind the data and include who, what, when, why and how details necessary to understand the meaning and context of a 3D CSDM fully. Such information may not be included in the measurement data themselves or may need to be accessed separately. UC7 does not cover all header requirements. Some, such as units and measurements, are more appropriately included in other use cases.

The general finding is that various existing candidate encoding standards may support none, some or nearly all the identified requirements. This section of the document details these findings. Of the standards reviewed, only LandInfra came close to supporting all the requirements captured in

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

UC 7. All options would require a companion standardised metadata record to hold some information. To support the cataloguing and discovery of data, we recommend a companion metadata record as best practice regardless of the encoding.

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

Use Case Prerequisite	LandInfra	IFC 4	CityGML	LADM	iso19115 (-1 and -2)
7.0-1 Administrative area	::Feature::Land Division::Administrative Division	n/a?	n/a?	::LA_AdministrativeParty (::LA_AdministrativePartyRoleType=state Administrator)	:: MD_DataIdentification:: MD_Keywords:keyword with :keywordClass
7.0-2 CSD Status Dates	::Feature::Project::projectStatus and LandInfra::Feature::Project::projectStatus	n/a	n/a	::LA_StatusType Also see ::ExtArchive (for registration recording)	::MD_DataIdentification and ::LI_Lineage::LI_ProcessStep
7.0-3 CSD Description	::Survey::description and/or LandInfra::Survey::purposeOfSurvey	IfcContext:Description	n/a?	::LA_SurveyPurpose??	:: MD_DataIdentification: abstract
7.0-4 Surveyor Certification	::Survey::landSurveyor	ifcActor	n/a	::LA_SurveyParty	::MI_AcquisitionInformation::MI_Requirement

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

7.0-5 CSD Generation Method	::LandInfraDataset:application	n/a?	n/a	::LA_SurveySource::platform::LA_PlatformType	::MI_AcquisitionInformation::MI_Platform
7.0-6 Survey Network Connection (CRS) (See 7.3)	::LandInfraDataset:defaultCRS		gml:srsName?	::SC_CRS (from ISO19111)	::MD_ReferenceSystem
7.0-7 Survey Equipment Details (See 7.2)	::Survey::Equipment	n/a	n/a	n/a	::MI_AcquisitionInformation::MI_Instrument
7.0-8 Survey Point Quality	::SurveyResults:: PointQuality	??	n/a?	::LA_Point (OM_Observation:resultQuality)	:;DQ_DataQuality
7.0-9 Survey Report	(see 7.1-3)	ifcDocumentation	n/a	??	::MD_DataIdentification ::MD_AssociatedResource

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

7.0-10 Survey Type	::Survey::type	n/a	n/a	::LA_SpatialSourceType	::MD_DataIdentification ::MD_Keyword:keyword with :keywordClass
7.1-1 Field Record	::Feature::document as ::Survey::fieldNote See link	IfcContext:Ifc:RelAssociatesDocument:IfcDocumentation	n/a	??	::MD_DataIdentification ::MD_AssociatedResource
7.1-2 Survey Adjustment Report	::Feature::document consist of::Survey::Equipment::ObservationCalibrations	n/a	n/a	::LA_Transformation?	::MI_AcquisitionInformation::MI_Operation
7.1-3 Survey Report	::Feature::document	ifcDocumentation	n/a	??	::MD_DataIdentification ::MD_AssociatedResource
7.1-4 Correspondence	::Feature::document	ifcDocumentation	n/a	??	::MD_DataIdentification ::MD_AssociatedResource

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

7.2-1 Equipment Used	::Survey::Equipment::description	n/a	n/a	n/a?	::MI_AcquisitionInformation::MI_Instrument
7.2-2 Instrument Manufacturer	::Survey::Equipment;dataCollector	n/a	n/a	n/a	::MI_AcquisitionInformation::MI_Instrument
7.2-3 Instrument Model	::Survey::Equipment;dataCollector	n/a	n/a	n/a	::MI_AcquisitionInformation::MI_Instrument
7.2-4 Instrument Serial Number	::Survey::Equipment::serialID	n/a	n/a	n/a	::MI_AcquisitionInformation::MI_Instrument
7.2-5 Firmware Version	::Survey::Equipment::controlSoftware and ::Survey::Equipment::softwareVersion (or under SurveySensor?)	n/a	n/a	n/a	::MI_AcquisitionInformation::MI_Instrument
7.2-6 Instrument Calibration	::Survey::Equipment::SurveySensor::Calibration	n/a	n/a	n/a	::MI_AcquisitionInformation::MI_Instrument

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

7.2-7 Instrument Constants	Multiple under -::Survey::Equipment::SurveySensor???	n/a	n/a	n/a	::MI_AcquisitionInformation::MI_Instrument
7.2-8 Instrument Specifications	Multiple under -::Survey::Equipment::SurveySensor???Depends on type?	n/a	n/a	n/a	::MI_AcquisitionInformation::MI_Instrument
7.3-1 Survey Orientation (CRS)	::LandInfraDataset:defaultCRS	IfcCoordinateSystem	gml:srsName?	::SC_CRS (from ISO19111)	::MD_ReferenceSystem: referencesystemIdentifier with :referenceSystemType
7.3-2 Vertical Datum	(Missing? or part of CRS?)	IfcCoordinateSystem:VerticalDatum	gml:srsName?	::SC_CRS (from ISO19111)	::MD_ReferenceSystem: referencesystemIdentifier with :referenceSystemType

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

3.6 Note on JSON encodings

The options for encoding are more fully articulated in the relevant section of the specification document (http://cad.surroundaustralia.com/spec.html#_encoding_options) as this is regarded as key information for stakeholders considering implementations.

Of particular note is the rationale for considering JSON-LD as the prime candidate for future-ready encoding option:

- It is not exclusive - other encodings such as LandXML can still coexist within the limited scopes they offer.
- There is a industry-wide trend from XML to JSON
  - "Today, JSON is the most widely used format, having overtaken XML within the last 5 years" (https://www.toptal.com/web/json-vs-xml-part-1)
  - And the new OGC service API standards : "`200`-responses of the server SHALL support the following media type: `application/json" (OGC API https://docs.ogc.org/is/18-062r2/18-062r2.html#toc40`)
- JSON is parseable without heavyweight plug-in code or knowledge of schemas to create in-memory objects - and easier to read - developers have voted with their feet..
- JSON-LD is an extension that allows JSON to be directly tied to the underlying data model
  - Allowing validation of data against the data model

Even though this is an clear future trend, the details are still emerging - in particular the relationship between formal data models and JSON schemas, the approach to modularity using particular JSON patterns (e.g. GeoJSON for Simple Features Geometries)

The relative effort to develop a stable JSON-LD encoding would be lower than attempting to retrofit solutions to these same issues to ad-hoc XML or Model-driven XML encodings and persuading industry to adopt.

In particular, the need for generic 3D implementation patterns provides an opportunity to test the potential of JSON-LD and feed requirements into this emerging space. The worst-case scenario is a better encoding based on some interim schema patterns that can be replaced by industry standard schemas as they become available as part of a future versioning strategy.

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

3.6 Note on GeoPackage

The OGC GeoPackage data encoding provides an SQLLite database implementation of the OGC Simple Features SQL specification. GeoPackage is an open, standards-based, platform-independent, portable, self-describing, compact format for transferring geospatial information. We did not test GeoPackage in our work because of its current limitations but note it as a potentially useful transfer format.

GeoPackage, in essence, is an SQLite container with OGC encoding standards for storing the Simple Features profile of vector features, tile matrix (raster data), non-spatial attributes data and extensions. GeoPackage advantages include:

- Open source, based on SQLite database
- Very lightweight but highly compatible across environments (esp. in mobile devices where connectivity & bandwidth is limited)
- Geopackages are almost 2x lighter than GeoJSON files because data can be normalised (and thus provide basic topology).
- Since the vector layers in GeoPackage are inherently rtree spatially indexed, loading and queries are fast. There is no limit on the file size.
- A single GeoPackage file can contain multiple layers, with each layer having a different geometry type.
- Can hold non-spatial attribute tables (pandas tables) alongside vector layers.
- GeoPackages can be managed using a wide variety of GIS tools as well as Python, R, SQLite and Postgres (with few limitations on each mode)
- Adding and loading to a Postgres database is much faster than GeoJSON since it is already a database format and spatially indexed.
- Interestingly, GeoPackages can also handle rasters as a tile matrix (of course, there are some limitations to this)

Currently, 3D support is weak in GeoPackage. 3D extensions may emerge but are not yet visible at https://www.geopackage.org/extensions.html. "Smuggling" 3D geometries into textual attributes as a microformat is probably achievable. As such a non-standardised solution is not advised. Furthermore, any such approach would require formalisation to avoid the proliferation of incompatible solutions. Until such formalisation occurs, such forms are probably more relevant for

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

"direct use" than data exchange as they are difficult to self-document and perform localised validation steps against specific aspects.

However, GeoPackage is an active project that seems open to such work. Recent annual OGC Testbeds commonly contain a component of work that leads to extensions added to GeoPackage.

We recommend the exploration of GeoPackage as a 3D CSDM encoding stand in the medium term. Compatibility with mobile devices is a particular area of concern expressed by software vendors. GeoPackage, being SQLite based, works well in these environments. The ability to hold multiple files of different types in one GeoPackage is an advantage to 3D CSDM implementations worth exploring.

3.7 Suggested Roadmap

NB This roadmap is further developed in the project final report as recommendations.

In order to minimise long-term risks it is proposed to develop an implementation strategy predicated on alignment with:

- Encoding preferences of existing software providers and their appetite for change
- Wider community trends towards JSON (developers) and IFC (Digital Twins)
- Emergence of FG_JSON, and possible JSON-LD extensions
- Evidence for and ongoing exploration of potential RDF based encodings
- The OGC API roadmap
- Development of GeoSPARQL 1.2 as a joint ISO/OGC standard
- OGC activities towards improving practices around conceptual model publication
- Consolidation of the proliferation of informal profiles of ISO 19107

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com

The current suite of encoding options may be visualised as shown in Figure 2.

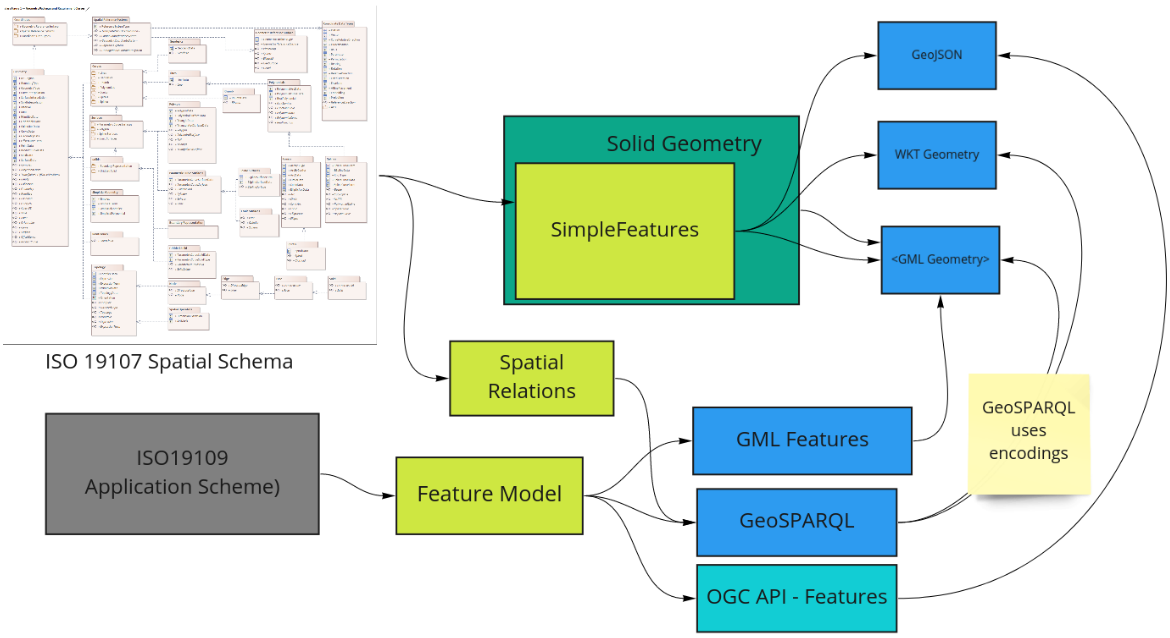

Figure 2. Current implementation of ISO19107 - profiles and encodings

Noting:

- GeoJSON uses an informal subset of GML Simple Features (Multi-) Points, Lines and Polygons..
- CityGML uses an informal subset of GML for 3D geometry
- Industry Foundation Classes (IFC) support is facilitated through the use of the STEP data exchange file encoding standard ISO 10303-21:2016. The specific IFC objects used for an IFC file encoding are defined by ISO 16739-1:2018.

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

3.8 Towards an optimal set of encoding options

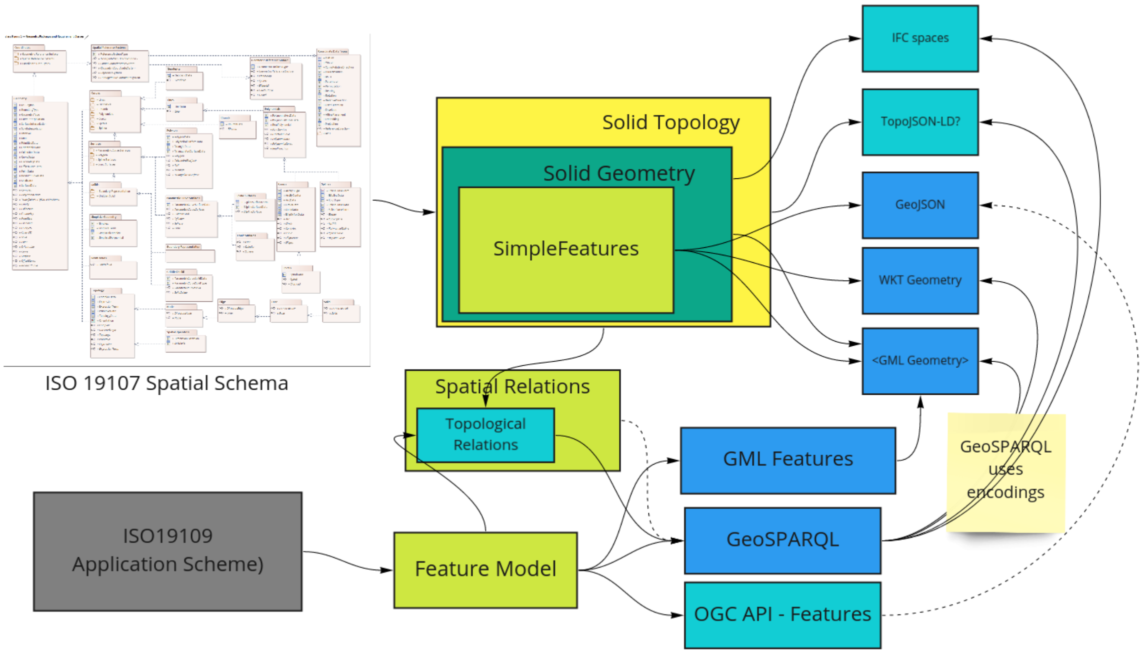

Figure 3. Suggested roadmap to implementation of ISO19107 - to support 3D topology

3.9 Related Standards Review Road Map

For a data model to be sustainable and implementable, it must be aligned to existing well-known standards whenever possible. However, when existing standards do not support the requirements, the existing standards may need to be altered or discarded in favour of other standards. Since many consortia members are involved in standards bodies relevant to this work, we can understand the suitability and reliability and influence the development of standards on which the model relies and must interact.

Standard choices exist in many aspects of this project, from the language of the data model to the encoding standards used by applications supporting the standard. Beyond fitness to requirements, our review included how well-governed the standards are and how open they are to participation. At the implementation level, we sought out standards that existing software vendors are familiar

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand
T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333
surroundnz.com

with and willing to implement. Where the choice exists, we preferred simple, unambiguous standards to decrease implementation differences.

Our standards review includes a continuing watch of the status of significant standards and future trends. We can nominate a consortia member currently involved or peripherally involved for most of these activities to champion 3D CSDM needs.

- ISO19107 - Improve 3D support - Rob Atkinson
- ISO19152 - LADM - Merge findings with Part 2 continuing development - Andrew Hunter
- OGC LandInfra (InfraGML) - Incorporate findings, improve alignment with O&M - Byron Cochrane, Rob Atkinson
- GeoSPARQL - 3D Geometry and Topology support to suit requirements - Nicholas Car, Rob Atkinson
- CityGML 3.0 - Additional Encodings - Rob Atkinson
- CityGML/IFC translation - - Rob Atkinson
- IFC 5 - Andrew Hunter
- FG-JSON - Rob Atkinson
- Observations and Measurements - Rob Atkinson, Nicholas Car
- OGC API - Nicholas Car, Rob Atkinson, Matt Purss

		2022	2023	2024	2025
ISO19107				Review?	
ISO19152 Part 2		TC211 Activity			
IFC 5	bSI Workplan				
CityGML 3.0	Conceptual model	Encodings			
GeoSPARQL 1.1		Version 1.1	Version 1.2		
FG-JSON			OGC TestBed		
GeoPackage			OGC TestBed		

Figure 4. Standards Road Map

RSM House
62 Highbrook Drive
East Tāmak, Auckland, 2014
New Zealand

T +61 2 6243 4828
E info@surroundaustralia.com
NZBN 942 904 776 3333

surroundnz.com