

Grounded Fuel Mapping Standard (GFMS-1.0)

Specification for the Representation, Spatial Propagation, Uncertainty Reporting, and Cryptographic Provenance of Physical Fuel Data — **Public Cut**

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License	CC-BY-ND 4.0 (specification text); see §4.2

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Part 1: Scope & Terminology

1.1 Scope

This standard specifies the technical requirements for creating, publishing, and verifying spatial fuel layers used in wildfire hazard modeling, asset protection, defensible space evaluation, and underwriting. It defines the formal boundary between direct physical observation, algorithmic inference, and grounded synthesis, establishing strict rules for:

- Mandatory basis tagging at the cell/feature level.
- Spatial support bounds and decay enforcement for field measurements.
- Statistical uncertainty propagation and adequacy thresholds.
- Cryptographic provenance, offline verification, and canonical payload hashing.

1.1.1 Limitations / Out of Scope

This standard does **not** prescribe specific fire behavior spread algorithms (e.g., Rothermel equations) or loss-function curves. It governs the data integrity and spatial representation of the underlying fuel inputs. This public specification does **not** disclose proprietary field-collection protocols, internal threshold engines, or registry implementation details. Conformant payloads may be produced by any protocol that meets the interface requirements herein.

1.2 References

1.2.1 Normative References

- ISO 19115-1: Geographic Information — Metadata
- RFC 8785: JSON Canonicalization Scheme (JCS)
- CEDE v2.0: Common Risk model Exposure Data Exchange Standard

1.2.2 Informative References

Proprietary field-collection protocols may produce GFMS-1.0-conformant payloads; they are not required for external conformance and are outside the scope of this public specification.

1.3 Terminology & Definitions

1.3.1 Basis Classes

- **Measured** (basis: measured): A value derived strictly from physical, direct empirical observation (e.g., quadrat clipped fuel dry-mass, point-count rod curing) traced to an unalterable field collection event.
- **Modelled** (basis: modelled): A value derived from spectral proxies, satellite classifications, spatial interpolations, or machine learning inferences where zero biomass was physically weighed on site.
- **Grounded** (basis: grounded): A spatial fuel surface initiated as a model and mathematically constrained by local, temporally co-located measured anchors, validated against held-out ground clips.

1.3.2 Spatial & Evidence Definitions

- **Asset Monument (Anchor Origin):** A permanent physical feature of the asset (e.g., substation fence corner, turbine pad) used as the spatial origin for all offset geometry.
- **Support Radius (R_s):** The maximum horizontal distance over which a physical measurement anchor is permitted to influence or calibrate adjacent spatial cells.
- **Stratum Boundary:** A discrete ecological, vegetation, or management zone transition beyond which a measurement anchor's spatial influence is forcibly terminated.
- **Canonical Payload:** A standardized, deterministic serialization of measurement data (sorted keys, fixed float precision, ISO-8601 UTC dates) used to compute cryptographic digests.

1.3.3 Notation

Symbol	Meaning
R_s	Support radius (meters); normative maximum = 10.0 m
n	Sample count of measured plots in a zone
$\bar{x}$	Sample mean fuel load
σ	Sample standard deviation
UCB_{95}	95% upper confidence bound
$CI_{95}\text{-half}$	Half-width of the 95% confidence interval

Figure 1 — Basis tag decision (same stratum)
Illustration (non-normative). Stratum boundary crossed → MODELLED immediately.

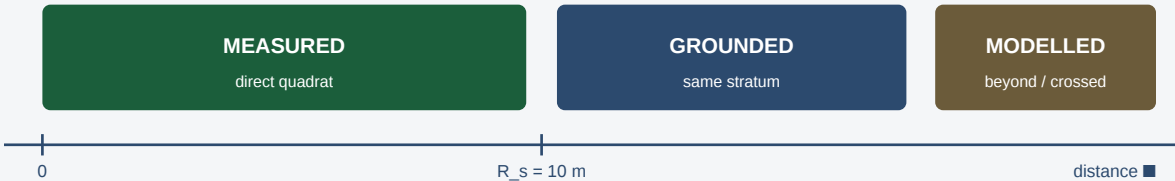


Figure 1 — Basis tag decision schematic. Illustration (non-normative).

Part 2: Comparative Analysis with Existing Standards (Informative)

Existing spatial and fuel standards address file structures or remote-sensing classifications, but none enforce physical ground-truth grounding, spatial support limits, or cryptographic proof.

Table 1 — Fuel & Spatial Data Standard Comparison (Informative)

Capability	LANDFIRE	GeoJSON	CEDE	LAS	GFMS-1.0
Primary domain	30 m landscape class.	Vector geometry	Financial exposure	Canopy point cloud	Fuel mass & provenance
Basis tagged	No	No	No	No	Mandatory
Spatial support bound	No	N/A	N/A	N/A	Mandatory
Under-canopy fuel	Blind	N/A	N/A	Partial	Native
Uncertainty attached	No	Optional	No	No	Mandatory
Crypto verification	None	None	None	None	Dual SHA seals

Part 3: Grounded Fuel Mapping Specification (Normative Clauses)

Clause 1: Basis Tagging & Schema Integrity

1. Every attribute payload or spatial feature delivered under this standard **SHALL** explicitly declare its data basis using the `basis` field.
2. Acceptable values **SHALL** be restricted to: `measured`, `modelled`, or `grounded`.
3. A spatial cell or attribute **SHALL NOT** inherit the value `measured` unless it represents a direct physical sample verified via the 5-point chain of custody (**Place, Date, Method, Recorder, Evidence**).

Illustration (non-normative) — example payload:

```
{
  "plot_identfier": "PLOT-TX-0921",
  "basis": "measured",
  "load_tons_per_acre": 4.12,
  "uncertainty_upper": 4.85,
  "support_radius_m": 10.0,
```

```
"vault_seal_sha256": "e3b0c44298fc1c149afb4c8996fb92427ae41e4649b934ca495991b7852b855"
}
```

Clause 2: Spatial Support Boundaries & Reversion Rules

1. A physical measurement anchor **SHALL NOT** exert spatial influence or perform surface calibration beyond a maximum Support Radius (R_s) of **10.0 meters**.
2. Spatial propagation **SHALL** terminate immediately upon intersecting a Stratum Boundary (e.g., transition from shrub-steppe to bare gravel or managed turf), regardless of remaining distance.
3. Any spatial cell lying outside the Support Radius (R_s) or across a Stratum Boundary **SHALL** automatically revert to basis: modelled.

Requirement — Cell basis assignment:

Condition	Required basis
Distance = 0 (direct quadrat location)	measured
$0 < \text{Distance} \leq R_s$ and same stratum	grounded
Distance $> R_s$ or stratum boundary crossed	modelled

Clause 3: Statistical Uncertainty & Zone Adequacy

1. A single fuel loading value **SHALL NOT** be reported as a naked scalar. Every zone or surface output **SHALL** carry its associated dispersion metrics:
 - Sample Count (n)
 - Mean ($\bar{x}$) and Standard Deviation (σ)
 - 95% Upper Confidence Bound (UCB_{95})
2. **Adequacy Rule:** A zone surface **SHALL** be flagged as adequacy: provisional if:
 - $n < 3$ measured plots, **OR**
 - The half-width of the 95% confidence interval exceeds **40%** of the calculated mean ($CI_{95}\text{-half} / \bar{x} > 0.40$).
3. Conformance evaluation against wildfire hazard thresholds **SHALL** be evaluated against the 95% Upper Confidence Bound (UCB_{95}), forcing statistical uncertainty to count against asset risk.

Clause 4: Cryptographic Provenance & Offline Verification

1. The measurement payload **SHALL** be canonicalized prior to hashing using RFC 8785 rules:
 - Keys sorted lexicographically.
 - All finite numeric values rounded to exactly six decimal places.
 - Timestamps formatted as ISO-8601 UTC strings (YYYY-MM-DDTHH:MM:SSZ).
2. The payload **SHALL** generate two concurrent digests: **SHA-256** and **SHA3-256**.
3. Derived legal/regulatory lookups **SHALL** ride alongside the canonical payload in the record envelope and **SHALL NOT** be sealed inside the physical measurement digest.
4. Verification **SHALL** run completely offline without requiring API access, proprietary server authentication, or vendor intervention.

Part 4: Conformance & Adoption Roadmap

GFMS-1.0 adoption is structured across three phases applicable to any enterprise, regulatory body, or data intermediary implementing spatial fuel layers for wildfire hazard assessment, asset protection underwriting, or mitigation plan submission.

Phase 1 — Baseline Registry. Every spatial feature carries an explicit basis field. Untagged layers default to basis: modelled until validated.

Phase 2 — Cryptographic Ingestion. Ingest records into Clause 4 canonical format; compute dual digests at entry; legal codes ride outside the seal.

Phase 3 — Auditable Docket Submission. Submit conformant layers to WMP dockets, underwriting, and regulatory filings. Third parties verify offline via §4.1.

4.1 Reference Verification Algorithm

Conformance verification **SHALL** be executable offline without proprietary tooling. Normative POSIX procedure:

```
# Step 1 – Canonicalize payload per RFC 8785
python3 -c \
"import json,sys; c=lambda o:(round(o,6) if isinstance(o,float) else
{k:c(v) for k,v in sorted(o.items())} if isinstance(o,dict) else
[c(i) for i in o] if isinstance(o,list) else o);
print(json.dumps(c(json.load(sys.stdin)),separators=(',',':')))" \
```

```
< payload.json > canonical.json
```

```
# Step 2 – Compute dual digests
```

```
SHA256=$(openssl dgst -sha256 -hex canonical.json | awk '{print $2}')
```

```
SHA3=$( openssl dgst -sha3-256 -hex canonical.json | awk '{print $2}')
```

```
# Step 3 – Compare against stored vault_seal_sha256 / vault_seal_sha3
```

Reference implementation: <https://github.com/highplainsshield/gfms-spec>

4.2 Licensing

The GFMS-1.0 specification document text is licensed under CC-BY-ND 4.0. Adopters may freely cite, quote, and implement this specification. Modification of the specification text for redistribution requires prior written consent from High Plains Shield, LLC. This license does not extend to proprietary internal implementations, algorithms, or software engines.

4.3 Conformance Classes Summary

Class	Meaning
Basis-tagged	Every feature carries basis $\in$ {measured, modelled, grounded} (Clause 1)
Spatially bounded	$R_s \leq 10.0$ m; stratum termination; out-of-bound $\rightarrow$ modelled (Clause 2)
Uncertainty-complete	n , $\bar{x}$, σ , UCB_{95} present; provisional if $n < 3$ or $Cl_{95}\text{-half}/\bar{x} > 0.40$ (Clause 3)
Cryptographically sealed	Dual SHA-256/SHA3-256 over RFC 8785 payload; legal codes outside seal; offline verify (Clause 4)

A payload claiming full GFMS-1.0 conformance **SHALL** satisfy all four classes.

Document Control

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Revision History

Version	Effective	Summary / Gates
GFMS-1.0 Revised Final Cut	prior	Normative interface spine (Final Cut master — retained).
GFMS-1.0 Public v1.1	2026-09-24	Public cut: High Plains Shield, LLC authorship + metadata; face block; proprietary collection-protocol product codes scrubbed to generic interface language; DOCX artifacts eliminated; math restored (R_s , n , $\bar{x}$, σ , UCB_{95} , adequacy); Part 2 Informative; JSON Illustration; Conformance classes + Limitations; Figure 1 visual proof; clean Markdown $\rightarrow$ PDF. Technical Review + Publication Review completed under High Plains Shield, LLC process.

Pre-Publish Checklist (Hard Gate) — Recorded Pass

- Format F2; normative spine complete
- Author = High Plains Shield, LLC everywhere (incl. metadata)
- Face block complete
- Naming locks; restricted-IP product codes absent from public body
- Claims vs illustrations labeled; limitations present
- IP gate cleared
- Visual proof: Figure 1 basis-tag decision
- Production clean from Markdown; math restored
- Technical Review + Publication Review recorded
- Interface-only / teach tone verified

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