Design for the National Flood Inundation Mapping Services

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List of Acronyms

AHPS - Advanced Hydrologic Prediction Service
APIs - Application Programming Interfaces
CMS - Coordinated Management System
CWMS - Corps Water Management System
DOD - Department of Defense
EAP - Emergency Action Plan
EPA - Environmental Protection Agency
FGDC - Federal Geographic Data Committee
FIM - Flood Inundation Map or Mapping
FK - Foreign Key
FOUO - For Official Use Only
FSP - Federal Standard Policy
FY - Fiscal Year
GIWT -Geospatial Integrated Working Team
GUID - Global Unique Identifier
HEC - Hydrologic Engineering Center
HQ - Headquarter
HPM - Hydro Program Managers
IDP - Integrated Dissemination Program
IDSS - Impact Decision Support Services
ISF - Information Services Framework
IWRSS - Integrated Water Resources Science and Services
LDM - Logical Data Model
MMC - Modeling, Mapping and Consequences
MOU - Memorandum of Understanding
NAD - North American Datum
NAVD - North American Vertical Datum
NCEP - National Center for Environmental Prediction
NDS - NOAA Deployment Services
NFHL - National Flood Hazard Layer
NHD - National Hydrography Dataset
NIST - National Institute of Standards and Technology
NLD - National Levee Database
NOAA -National Oceanic Atmospheric Administration
NWIS - National Water Information Service
NWS - National Weather Service
O&M - Operation and Maintenance
OGC - Open Geospatial Consortium
OMB - Office of Management and Budget
OSW - Office of Surface Water
PK - Primary Key

POCs - Point of Contacts
RAS - River Analysis Software
RGB - Red Green Blue
ROM - Rough Order of Magnitude
SDS - Spatial Data Standards
SDSFIE - Spatial Data Standards for Facilities, Infrastructure, and Environment
SOP - Standard Operating Procedure
USACE - U.S. Army Corps of Engineers
USGS - U.S. Geological Survey
USNG - U.S. National Grid
UTC - Universal Time Coordinated
VTEC - Valid Time Event Code
WFS - Web Feature Service
WGS - World Geodetic System
WMS - Web Mapping Service
WPS - Web Processing Service
WSC - Water Science Center
WTS - Web Tile Service

Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

Executive Summary

This design for the Integrated Water Resource Science and Services (IWRSS) national flood inundation mapping services focused on a subset of the September 2013 *Requirements for the National Flood Inundation Mapping Services*. The requirements document addresses comprehensive requirements for sustaining a coordinated long-term flood inundation map (FIM) approach. The design charter had a narrower focus, primarily to identify strategies for exchanging FIM, their source data and their descriptive metadata and secondarily to identify starting points and recommend a path forward for future development of IWRSS FIM tools.

Exchanging flood inundation maps and their source data is the logical first step toward accomplishing the broader IWRSS FIM goals and objectives, and that is the focus of this design. There are three core elements to the design: 1) the IWRSS FIM data standard and its logical data model, 2) the IWRSS FIM cartography standard and 3) standards and specifications for Open Geospatial-Consortium (OGC)-compliant web map and data services. The web services are the mechanism through which FIM data and information are to be exchanged. Adherence to the data standard and cartography standard ensures that services deployed by all agencies are mutually consistent. In combination they provide the ability for the agency-level FIM databases to function as a single federated FIM database.

Readers seeking general understanding of the design should review Sections 1, 2, 5 and 6. Sections 3 and 4 are necessarily lengthy, with considerable technical detail. The draft implementation plans presented in Section 5 provide details on a path forward. The critical actions are for each agency to begin the process to review and adopt the IWRSS FIM standards, to modify existing FIM databases to be standards compliant, and to deploy data services that are accessible by all member agencies.

A critical decision must be made by IWRSS leadership as the IWRSS member agencies begin to review this design document and consider options for the subsequent implementation phases:

- *Is it IWRSS' intent to provide a single public point of access for FIM information?*
  The design team recommends consolidated IWRSS FIM services as the ultimate solution.
  - *If so, what is a reasonable timeline?*
    Time is needed to deploy agency-level data exchange services and then to deploy the consolidated IWRSS services.
- *Should each IWRSS member agency deploy public-accessible FIM services?*
  This would be the long term solution if consolidated services are not desired, or it could be an interim solution prior to deploying consolidated IWRSS services. The decision must weigh tradeoffs between the merits of providing a single authoritative federal FIM source, the effort required to achieve consolidated services and the potential for confusion and data conflicts that would result from each agency providing public-accessible services.

The IWRSS FIM design is intentionally flexible and can guide implementation regardless of the above decisions.

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Section 1: Introduction to the IWRSS FIM Design

This Interagency Water Resources Science and Services (IWRSS) Flood Inundation Mapping (FIM) design document was completed by a team representing the National Weather Service (NWS), U.S. Army Corps of Engineers (USACE) and U.S. Geological Survey (USGS). The team was tasked through the *Charter for the National Flood Inundation Mapping Design Team*. This effort built upon an IWRSS FIM requirements phase that produced *Requirements for the National Flood Inundation Mapping Services* (Appendix A). The design team charter established the scope of this effort, tasking the design team to identify strategies for exchanging FIM, their source data and their descriptive metadata. Since the requirements document had a broader scope, only a subset of the requirements was used as the basis for the design.

1.1. Organization of the Design Document

Readers seeking general understanding of the design should review Sections 1, 2, 5 and 6. Section 1 summarizes goals and objectives and provides a broad overview of the IWRSS FIM data exchange design and its sub-components. Section 2 summarizes the process used to review, update and prioritize requirements per the tasking of the design charter as well as the resulting design specifications. Section 5 addresses tools and provides drafts of implementation plans that would accomplish FIM data service deployments and would update existing agency tools to be compliant with IWRSS FIM data standards. Some of the proposed implementation tasks also meet immediately-addressable tool requirements. Section 6 documents the project assumptions and constraints identified by the design team.

Sections 3 and 4 of this design document are necessarily technical in nature, written to guide an implementation team. Section 3 provides the framework of the design, the IWRSS FIM data standard, the IWRSS FIM logical data model, the IWRSS FIM cartography standard, existing community standards adopted by the design, further design specifications and use cases that were used to test the design and that must be supported by the implementation. Section 4 provides business rules and examples of data flow and data content necessary to satisfy requirements through the logical data model.

Throughout the document and appendices, individual requirements are noted with the format (R001) referencing the first requirement from the *Requirements for the National Flood Inundation Mapping Services* (Appendix A). These are a convenient reference for the reader only and are not a ranking of importance.

1.2. Vision

The IWRSS FIM vision is to undertake a highly collaborative and integrative approach to sharing, exchanging and consuming flood inundation maps, associated metadata and related documentation. FIM developed and/or hosted by one member agency should be shareable, exchangeable and consumed seamlessly by the other member agencies.

1.3. Goals

FIM Design goals as identified in the design team charter:

- Use community-adopted standards where possible;
- Embrace existing governance structures (e.g. Open Geospatial Consortium);
- Utilize available commercial or government off the shelf solutions;
- Identify strategies for efficient IWRSS FIM development; and
- Promote broad participation by non-IWRSS stakeholders and partners.

1.4. Objectives

The charter requested that the design address the following objectives:

- Strategies for exchanging and utilizing FIM between IWRSS partners, non-IWRSS partners and stakeholders and ensuring FIM can be consumed by IWRSS partners and non-IWRSS partners via latest technologies and techniques;
- Metadata and georeferencing standards;
- Metadata and/or information that conveys understanding of underlying mapping methodologies, inherent assumptions and known flood risks; and
- Options for maintaining and sustaining FIM capabilities amongst member agencies.

1.5. Process

The team followed a standard design process and schedule of deliverables requested in the charter. The process is summarized in Table 1.1.

Table 1.1. FIM Design Process

Pre-Design Phase ● Signed Charter ● IWRSS POCs assign team members ● Kickoff Meeting **(JAN 2015)** **Phase 1 (initial design)** ● Review requirements and develop rank-ordered list ● Draft initial design specifications ● Develop design recommendation (include options for consideration) ● Submit Phase 1 report for POC review **(APR 2015)** **Phase 2 (revised design)** ● Complete specifications ● Validate map standard ● Develop data standard ● Revise specifications ● Submit Phase 2 report for POC review **(JUN 2015)**	**Phase 3 (final design)** ● Finalize map standard ● Finalize data standard ● Develop recommendations for collaborative tool development ● Develop recommendations for post-design activities ● Develop recommendations for implementation charter ● Submit Phase 3 report for POC review **(SEPT 2015)** ● Brief final deliverable to IWRSS POCs **(OCT 2015)** **DESIGN PHASE COMPLETE** **Future Actions** ● Future pre-implementation activities ● Future implementation charter ● Future implementation phases

1.6. Strategic Options

During the initial design phase the design team identified that centralized and decentralized standard-based, service-based and tool-based strategies were possible to achieve the IWRSS FIM vision, goals and objectives. The design team realized that uncertainties about long-term vision, funding limits and IWRSS governance were likely to constrain design options. Strategic options were presented to the IWRSS points of contact (POCs) as part of the Phase 1 report. The following strategic design recommendation resulted from subsequent discussions and feedback from IWRSS POCs.

1.7. Strategic Design Recommendation

Based on IWRSS POC feedback, the design team recommends an IWRSS FIM evolution strategy that begins with a decentralized implementation phase where all member agencies endorse common IWRSS standards, each member agency deploys independent FIM services and member agencies collaborate to develop and deploy first-generation FIM tools through existing agency information technology (IT) infrastructure. This phase focuses on agency-level efforts that provide the foundation of the IWRSS FIM system.

Figure 1.1 depicts how IWRSS FIM would function during the decentralized phase. Adherence to IWRSS-adopted standards drives consistency. Each member agency deploys IWRSS-

compliant services to expose their information, and consumes information from the services deployed by the other member agencies. Each member agency can choose to develop and deploy tools that utilize the IWRSS-compliant services. The “public”, here meaning users from the general public and from non-IWRSS federal agencies, could be enabled to access tools from any or all member agencies based on agency security policies and user rights and use restrictions inherent within all FIM data.

As IWRSS FIM agency-level services are deployed and begin to mature it will be timely to initiate the next phase of system evolution, where FIM services and some tools are consolidated, possibly to a central IWRSS architecture, as depicted in Figure 1.2. The consolidation layer would function to consume data from the agency-level services, consolidate the data, and publish services that would provide a single point of access to authoritative federal FIM data. This would allow for more robust data conflict identification and resolution processes. The IWRSS governing body can make rational decisions to migrate agency-level tools to a centralized platform over time as data coordination, performance or duplicative tool development inefficiencies are identified.

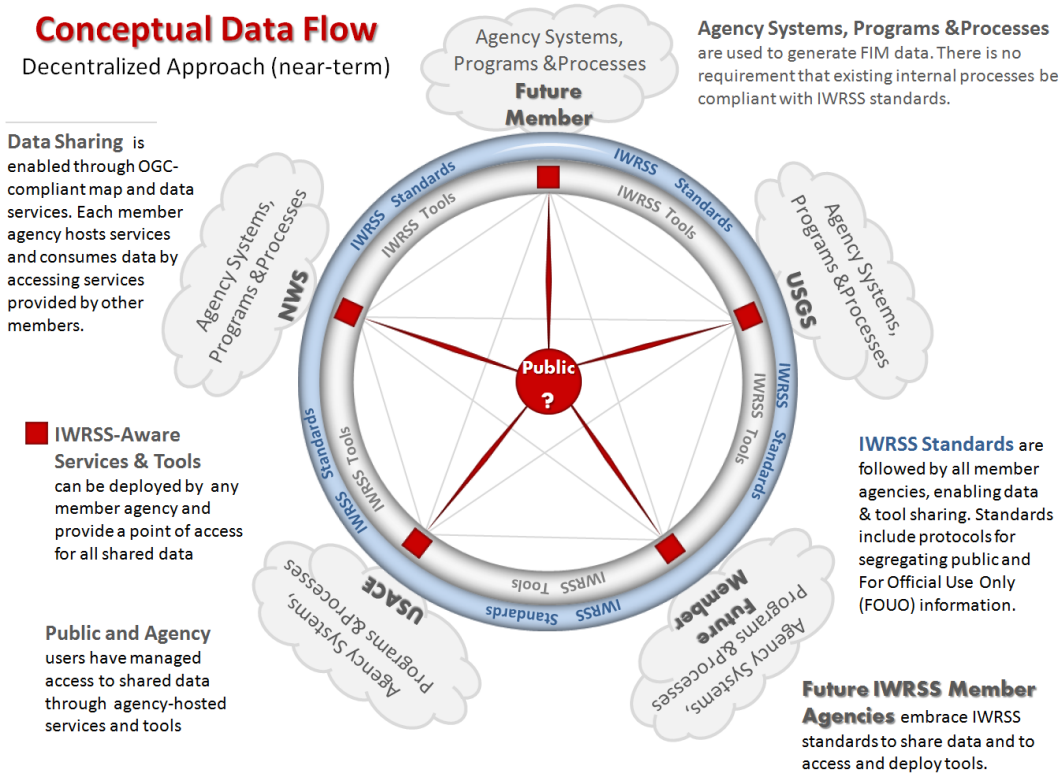

Figure 1.1. Recommended initial decentralized IWRSS FIM data sharing approach

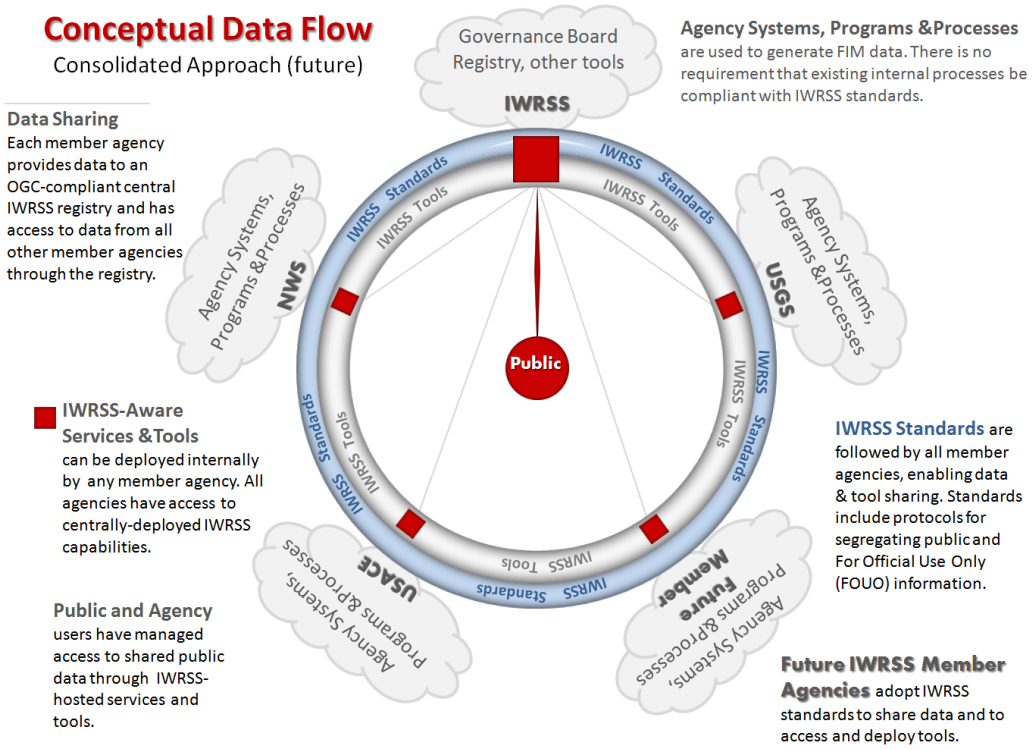

Figure 1.2. Recommended future consolidated IWRSS FIM data sharing approach

The system evolution strategy leaves open the following decisions that must be made by IWRSS leadership:

- *Is it IWRSS' intent to provide a single public point of access for FIM information?* If so, the centralized development and deployment phase is necessary following the initial agency-level service deployment phase.
    - *What is a reasonable timeline to deploy consolidated IWRSS FIM services?* Consolidated IWRSS services would always consume from agency-level services.
- *Should each IWRSS member agency deploy public-accessible FIM services?* Although this is a potentially viable long term strategy, a single public point of access for authoritative federal flood inundation maps would be preferable. Additionally, there would be limited ability to identify and resolve cross-agency data conflicts and inconsistencies that would be especially concerning for event maps. Section 4 provides additional rationale with a detailed use case example for a centralized end state achieved through a collaborative development process.

1.8. Key Components of the IWRSS FIM Design

The design is composed of the following principal components. These design components fully or partially address 79 of the original 173 requirements deemed to be within the scope of the design team charter. In addition, the team addressed requirements for information unique to emergency action plan maps. The core of the design consists of the IWRSS map (cartography)

standard, the IWRSS data standard and the resulting data services that can be consistently deployed to those standards by any IWRSS member agency.

1.8.1. Specifications. Precise requirements for performance, accessibility and content of FIM design elements. Specifications for the design components are provided in Sections 2, 3, 4 & 5.

1.8.2. Community standards. Following the goals and objectives of the charter, the following community standards have been adopted within the FIM design. Further details are included in Section 3.

- Horizontal datum - North American Datum 1983;
- Vertical datum - North American Vertical Datum 1988;
- Projection for models - Albers equal area conic USGS (recommended);
- Projection for map display - World Geodetic System (WGS) 1984 Web Mercator (Auxiliary Sphere);
- Geospatial data - Spatial Data Standard for Facilities, Infrastructure and Environment (SDSFIE) 3.1; and
- Geospatial metadata - Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM), with possible future migration to ISO 19115.

1.8.3. IWRSS standards. As the design effort progressed, the team concluded that the first step to realizing the IWRSS FIM goal of broad participation is to develop robust, platform independent standards for sharing FIM data and for visualizing flood inundation maps. The standards that form the core of the FIM design started from existing community standards, but were adapted to more fully address IWRSS FIM requirements. These standards are defined in Section 3.

- Map (cartography) standard - Published in the *Requirements for the National Flood Inundation Mapping Services* in Appendix A (adaptation of USACE flood map standard); ensures common presentation of geospatial information in data services and map products; necessary to obtain consistent presentation of map layers within IWRSS data services, tools and end products.
- Data standard - Appendix D (adaptation of SDSFIE 3.1); ensures common definition of FIM geospatial feature, attribute and metadata data structures; necessary to deploy consistent IWRSS data services. The IWRSS FIM logical data model is the core of the data standard. Through use of globally unique identifiers the data model supports deployment as either a single physical database or a federated database.
- Geospatial metadata standard - Appendix E (USGS FIM adaptation of XML-based CSDGM).

1.8.4. IWRSS Business Rules. Business rules enhance the interagency consistency and interoperability that can be achieved with a data model and were identified during the requirements and design processes are documented in Section 4.

1.8.5. IWRSS Data Services. Open Geospatial Consortium (OGC) compliant services that provide IWRSS standards compliant metadata, attribute information and geospatial information

are the first and highest priority IWRSS capability to support sharing of FIM information. These services are defined in Section 5.

1.8.6. IWRSS Tools. Once standards-based services are deployed, IWRSS tools to support FIM production, visualization, dissemination and decision support can be designed in greater detail and deployed to a broad user base. A conceptual design and recommended approach for developing IWRSS tools is provided in Section 5.

1.9. Recommended Next Steps

These steps are recommended by the FIM design team to IWRSS leadership for consideration for future activities. A schedule sequence is provided in Figure 1.3.

1.9.1. Pre-Implementation. Activities to be undertaken prior to an implementation charter are items that the agencies must complete and approach in a highly coordinated and collaborative fashion to ensure that formal implementation phase(s) are successful.

- Formal adoption of IWRSS FIM map and data standards:
    - Each agency to adopt the IWRSS FIM standard and issue guidance.
    - Each agency to develop plan and schedule for internal coordination of IWRSS FIM cartography and data standards, obtaining buy-in and feedback from technical groups involved with producing FIM or FIM-related activities.
- IWRSS POCs routinely discuss ongoing activities to determine level of coordination and collaboration required to ensure alignment with IWRSS FIM objectives. Examples:
    - Minimum Collaborative Activities (member agencies must collaborate)
        - Reviewing IWRSS data and map standards based on appropriately broad internal review of all member agencies prior to adoption, further refinement of IWRSS FIM data services standards, joint testing of deployed services.
        - Recurring (annual?) IWRSS standards updates to evaluate recommended revisions, make revision decisions & document revisions.
    - Optional Collaborative Activities (member agencies should collaborate)
        - Any pre-implementation charter activities undertaken by member agencies such as service maintenance, service modifications, or development of applications envisioned in FIM requirements (e.g., registry, common operating picture, map generator services, report generator services).
    - Agency Specific Activities: (member agencies could benefit from collaborating)
        - USACE integrating Corps Water Management System outputs into IWRSS-FIM services, USGS supporting FIM maps within NWISweb/Streamgage program, NWS to integrate IWRSS member agencies FIM into Forecast and Warning Processes so that public can better understand the flood forecasts, future plans for tools that are beyond the scope of FIM requirements but leverage the FIM services.

1.9.2. Implement Agency Services. IWRSS leadership needs to determine if a charter is necessary for the initial independent, decentralized agency service deployments.

- Each agency to develop plan and schedule for deploying IWRSS FIM services adhering to this design.
- Each agency to develop, test and deploy IWRSS FIM services.
- IWRSS to execute communication plan to promote broad national awareness of available IWRSS services.

1.9.3. Full Implementation. Guidelines to consider for incorporation into implementation charter(s).

- Tools Implementation
  - Recurring coordination meetings to discuss status and progress and to ensure consistent data integration approaches as each agency undertakes internal tool development initiatives. Helps to ensure consistency, sharing of lessons learned, and any proposed modifications to IWRSS FIM standards identified during implementation.
- Interaction between design team and implementation team(s)
  - Design team made available to address implementation team questions during development of implementation and testing plans.
  - Design team involved with implementation review and testing to verify deployed components meet original design intent.

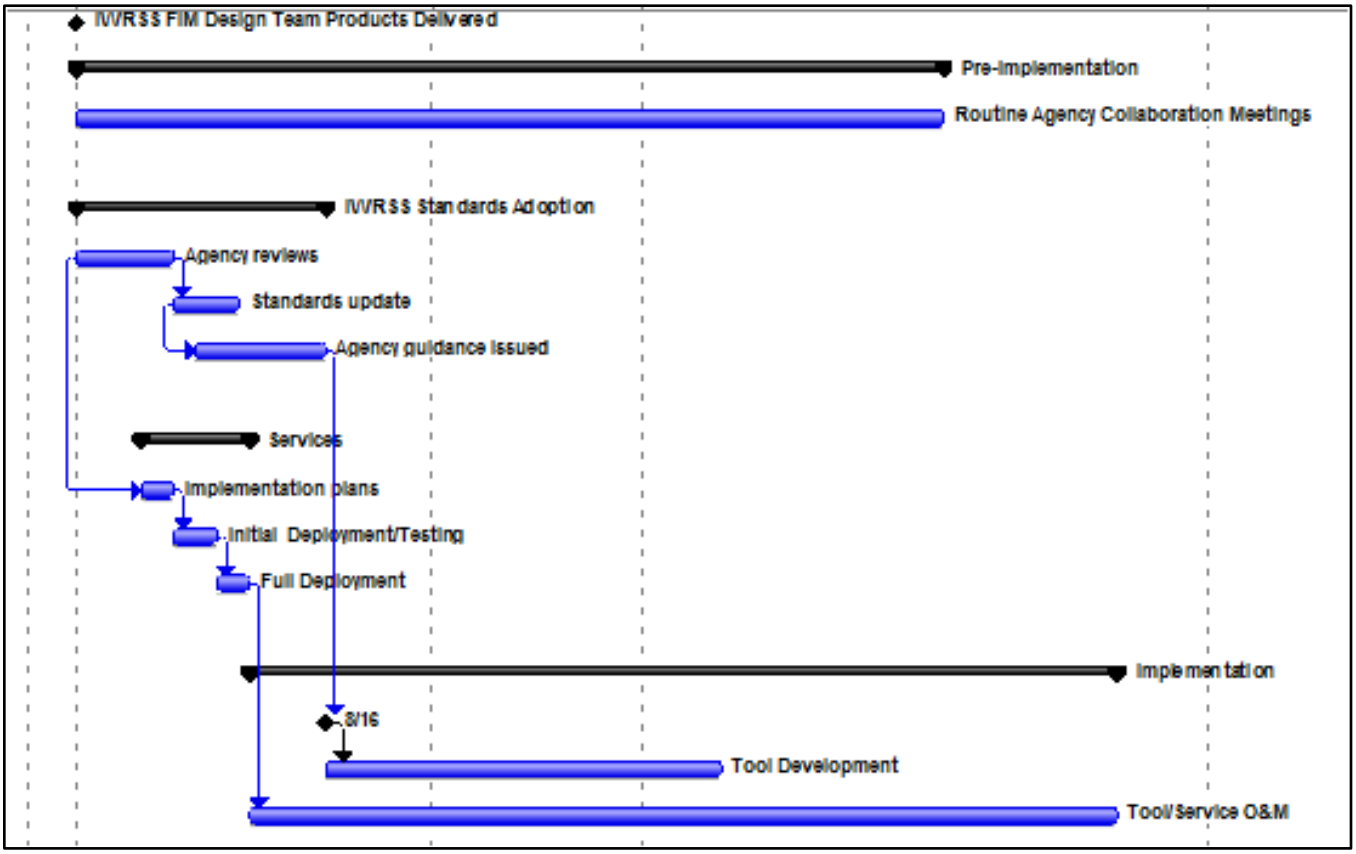

Figure 1.3. Recommended sequence of next steps with schedule sequence

Section 2: Requirements Validation

The IWRSS Memorandum of Understanding (MOU) and FIM Design Charter states, "*a goal of the MOU is to develop an information system that will serve as a reliable and authoritative basis for adaptive water- related planning, preparedness, and response activities from national to local levels*. *The USACE, USGS and NOAA NWS envision building a highly collaborative and integrative modeling and information services framework to establish a common operating picture, improve modeling and synthesis and to support the production of a new, comprehensive, seamless and consistent suite of high- resolution water resources information, including flood inundation maps*." With the end goal of developing flood inundation maps that share a common data and cartographic standard, specific flood inundation map types were identified as the target output for a National Flood Inundation Mapping Service. Each of the four map types are described below.

2.1. Map Library

A map library is a collection of electronic maps developed based on the same source data, modeling parameters, and common methods for an intended purpose. The flood inundation map types defined below should all be deployed as map libraries within the National Flood Inundation Mapping Services.

2.2. Stream Reach Map

A stream reach map contains a set of predetermined inundation boundary maps for a particular stream reach. The extent and depth of flood inundation is based on known, generally stable, channel geometry and land features. The maps are typically created at one-foot to two-foot stage intervals in the vicinity of a streamgage. These types of maps are sometimes labeled as "static maps." The stream reach map limits the user to evaluate of a set of predetermined conditions at specific river locations, with an assumption that the duration of the flood event is significantly long, such that a steady-flow condition may be assumed. Non-steady flow conditions are generally not captured in a stream reach map. Geographically extending the inundation maps from a stream reach map upstream or downstream of the modeled reach is not recommended due to the nonlinear response of river stage to flow.

2.3. Event-Based Map

An event-based map is a map connected to a specified set of real or anticipated hydraulic and/or land feature boundary conditions. A map library of event-based maps must inform the user of the expected inundation based on current and/or forecasted hydrologic conditions for a selected location over a determined length of time covering the onset of flooding, flood crest and flood cessation. These maps are generally not applicable after the end of the modeled time period and at the cessation of the modeled hydrologic conditions. These types of maps are sometimes labeled as "dynamic maps." For most flood events, it may be necessary to evaluate existing stream reach flood map libraries to identify the available map that most closely depicts the pending flood event and present that information as the "pending event map." During critical flood fight situations, it is in the interest of all IWRSS member agencies, and all Flood Inundation Mapping (FIM) stakeholders, that a single authoritative event-based map be provided.

Event-based maps are most useful when hydrologic events occur in a specific location with conditions that are not adequately represented by existing stream reach maps and render them

less useful for those specific instances. In these cases, event-based flood inundation maps can more accurately depict the extent, timing and depth of flooding and provide additional benefits for the unique flood event. When there is a need to estimate the flood inundation and its timing during more complicated flooding events to account for phenomena such as extensive backwater flooding, flood routing, drawdown hydraulics, control structure degradation, hysteresis, tidal impacts and sediment transport, an event-based map would be generated to represent more current, forecast and operational hydrology, using a robust hydraulic model and a relevant digital elevation model.

2.4. Emergency Action Plan Map

An emergency action plan (EAP) map is a map subset of the event-based maps, it is defined by a specified set of emergency planning scenarios (e.g., dam breach emergency action plan or levee breach/overtop emergency preparedness plan). A map library of EAP maps inform the user of the expected inundation based on the planning scenario including covering the onset of flooding (specific times and depths), flood crest and flood cessation. The maps are only applicable for the modeled emergency scenario, such as breach of a particular dam. (Previously considered a subtype of an event-based map, the emergency action plan map has been identified as a new requirement due to further evaluation of specific data requirements and cartographic standards for EAP maps.)

2.5. Historical Flood Documentation Map

A historical flood documentation map shows the extent, and generally not depth, of peak flooding as a record of flood inundation at a specific location and based on flood observations for a given flood event. This map type could also be modeled or derived from high water marks, satellite imagery or other in situ or remotely sensed data. It is a depiction of the actual extent of flooding, acts as a record for historical and planning purposes and can be used for inundation map calibration purposes.

In the absence of a stream reach map or an event-based map, a historical flood documentation map may be the best available map for emergency support purposes.

2.6. Specifications

Requirements to support a National Flood Inundation Mapping Service (previously developed by the FIM Requirements Team) were evaluated against the FIM Design Charter to define the necessary specifications for a supporting data standard for each map type. These specifications were evaluated against the initial requirements to support the priority design functions requested in the FIM Design Charter and to identify which requirements that were in scope for the design. A total of 79 of the original 173 requirements were considered in-scope for the priority design functions:

- Exchanging and utilizing FIM between IWRSS partners and stakeholders;
- Specifying metadata and georeferencing standards;
- Capturing and conveying the understanding of the underlying mapping methodologies, inherent assumptions of the maps and the known flood risks; and
- Maintaining and sustaining FIM capabilities amongst member agencies.

Gap analysis of the in-scope requirements (provided in Appendix B) was performed by developing typical scenarios in which a National Flood Inundation Mapping Service would be employed. These perspective use cases were selected to evaluate the data design standards by identifying the role of an *actor*, wanting to *perform an action*, for a specific *reason*. Using this

construct, several use cases were identified as possible uses of the IWRSS data standards by defining the steps a user would take when performing a FIM effort. The use cases were used to test the data design to verify that it would meet the needs of future user actions and data requests. Each individual use case has identified specific actions; however, a general use case is provided below and can be extended for a more specific user action. The compiled list of various uses cases is provided in Appendix C.

2.7. Example Use Case

Use Case: Perform study and upload a FIM project library for display via IWRSS data services
Actors: Data creator
Description: A FIM Library Creator would perform a study, create a FIM library and display the FIM library on an IWRSS data service. Openly sharing data with others in the approved format supports consistency and standardization between different organizations.

1. Identify and collect model data (IWRSS or other sources)
    a. Terrain
    b. Gage information
    c. National Levee Data information
    d. Other observed and historic information
    e. additional various other data needs
2. Perform study
    a. Various steps
3. Prepare data for IWRSS submittal
    a. Assign a 23-character unique Library ID (required)
    b. Provide study, purpose and external data connection (e.g. USGS Gage ID) information.
    c. Additional various reports and metadata
4. Upload Geospatial Data [FIMGeoData/Inundation] to IWRSS
    a. FloodExtent (required)
    b. StudyExtent (required)
    c. FloodDepth
    d. FloodInfo
    e. MappedCrossSections
    f. LeveedAreaFloodExtent
    g. PotentialInundationArea
    h. MappedStreamCenterline
    i. ModelLimits
    j. RiverStation
    k. WaterSurfaceElevationContour
    l. ReferencePoint
5. Upload Model Data [Model] to IWRSS
    a. Hydraulic model including geometry, configuration files and forcing data.
    b. ModelGeoData (spatial features and their attributes):
        i. BoundingPolygon
        ii. ModeledCrossSections
        iii. StorageAreas

        iv. ModeledStreamCenterline
    c. Terrain data - uploaded to the ModelGeoData folder with model files, or provide the link to an external public database (e.g. U.S. Interagency Elevation Inventory) within media table (mediaID = FK reference to mModelGeodata PK, FilePath stores hyperlink, Comments describes the information stored at the hyperlink)
6. Upload supporting documentation to IWRSS
    a. FGDC metadata files (template provided)
        i. Library (some are required)
        ii. FIMGeoData
        iii. Inundation
        iv. ModelGeoData
        v. Model
    b. Attributes in addition to current metadata standard
        i. Library
        ii. FIMGeoData
        iii. Inundation
        iv. ModelGeoData
        v. Model
        vi. Citations for reports on methods
7. IWRSS FIM reports the upload is complete and makes the available data visible to appropriate users as determined by the Use Restriction Type and Status Type.

Section 3: Standards and Specifications

This section describes in detail the platform independent standards for sharing FIM data, and for visualizing flood inundation maps. Following the goals and objectives of the IWRSS FIM Design Charter, community standards are those recognized standards that were adopted by the FIM design team without modification. IWRSS standards developed by the FIM design team are based on recognized community standard but were adapted to more fully meet IWRSS FIM requirements.

IWRSS Standards developed by the IWRSS FIM Design team include:

- Data standard
    - Department of Defense Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE) 3.1 ensures common definition of FIM geospatial feature, attribute and metadata data structures necessary to deploy consistent IWRSS data services.
    - Metadata standard
        - USGS FIM adaptation of XML-based CSDGM
        - Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998
- Cartographic standard
    - Adaptation of USACE flood map standard; ensures common presentation of geospatial information in data services and map products; necessary to obtain consistent presentation of map layers within IWRSS data services, tools and end products.

Community standards that were adopted without adjustments include:

- Report and Documentation standard
    - OSW Policy Memo SW2015.03 references the Report Standards below.
    - USGS Flood Inundation Map Library Minimum Report Standards describes the detailed narrative sections required for documenting a FIM study.
- Services standard
    - Open Geospatial Consortium Standards
        - Web Map Service (WMS) standard
        - Web Feature Service (WFS) standard
        - Catalog standard
- Geographic and Measurement standard
    - Standard datums and projections
- IT standards
    - National Institute of Standards and Technology Special Publication 800-60 in the Federal Information Security Management Act of 2002 describes the IT support needed for a Disaster Monitoring and Prediction Information level service.
- External Data Service Dependencies

- Thirteen external services are listed and the detailed interoperability points enumerated.

3.1. Data Standard

This section describes the specifications, object structure, file structures, logical data model, XML metadata delivery options and required data and attributes for the IWRSS FIM data standard. The standard ensures common definition of FIM geospatial feature, attribute and metadata data structures and is necessary to deploy consistent IWRSS data services.

3.1.1. Specifications

The IWRSS FIM Design includes a conceptual and logical data model. The physical data model will be defined during implementation. The IWRSS FIM design team began by distilling the requirements into a conceptual model. The conceptual model then guided a more detailed logical structuring of the data, defining the various detailed data elements.

The core of the IWRSS FIM data standard is a platform independent logical data model that will be implemented by the IWRSS agencies in order to support consistent format and content (R032). This logical data model may be implemented as a physical data model within a variety of relational database management systems or flat file structures on current or future systems in use by the IWRSS agencies. This logical data model is also scalable and may be implemented with a desktop level spreadsheet/shapefile solution or scaled to an enterprise database level. An implemented physical data model or models will host the collection of IWRSS electronic map libraries, including stream reach maps, event-based maps, emergency action plan maps, and historical flood documentation maps (R030). The platform independent logical data model is defined within the full IWRSS data standard, including the object tables with detailed attribute information, which is published in Appendix D in both table form and a database diagram. The full data standard will guide the development of the core data framework for organizing and maintaining consistent flood mapping data and data services between the IWRSS agencies (R032).

The IWRSS data standard was developed by leveraging relevant components of the established Department of Defense Spatial Data Standards for Facilities, Infrastructure, and Environment (SDSFIE) 3.1, and cross-walking the existing relevant FIM data elements with the in-scope design requirements extracted from the IWRSS FIM Requirements Report (Appendix A). The in-scope design requirements were refined in the Milestone 1, and are published in Appendix B as initial design specifications. References to the design requirement numbers appear in the full data standard in Appendix D. The SDSFIE 3.1 is currently in use by DOD/USACE, and the standard was selected because it was determined to be the most robust and fully developed geospatial data standard currently in use by the IWRSS agencies.

3.1.2. Object Structure

In the IWRSS FIM Data Model, a library is an object that stores all the information about a related set of flood inundation models and maps. All FIM data is organized in a series of libraries, at the top level, that may encapsulate multiple models and geospatial data sets

developed for a stream reach or multiple reaches of multiple streams. The spatial organizational concept of the flood mapping library is structured around stream reaches with defined upstream and downstream boundaries. Multiple flood inundation maps may be stored within a library for a stream reach. This includes the full spectrum of map types, including stream reach maps, event maps, emergency action plan maps and historical flood documentation maps developed for varying dates or for varying sub-reaches within the library defined stream reaches. The hierarchical structure of the FIM data objects is illustrated in the object model Figure 3.1. Libraries are named appropriately, and assigned a globally unique identifier (GUID) according to rules established in Section 4.

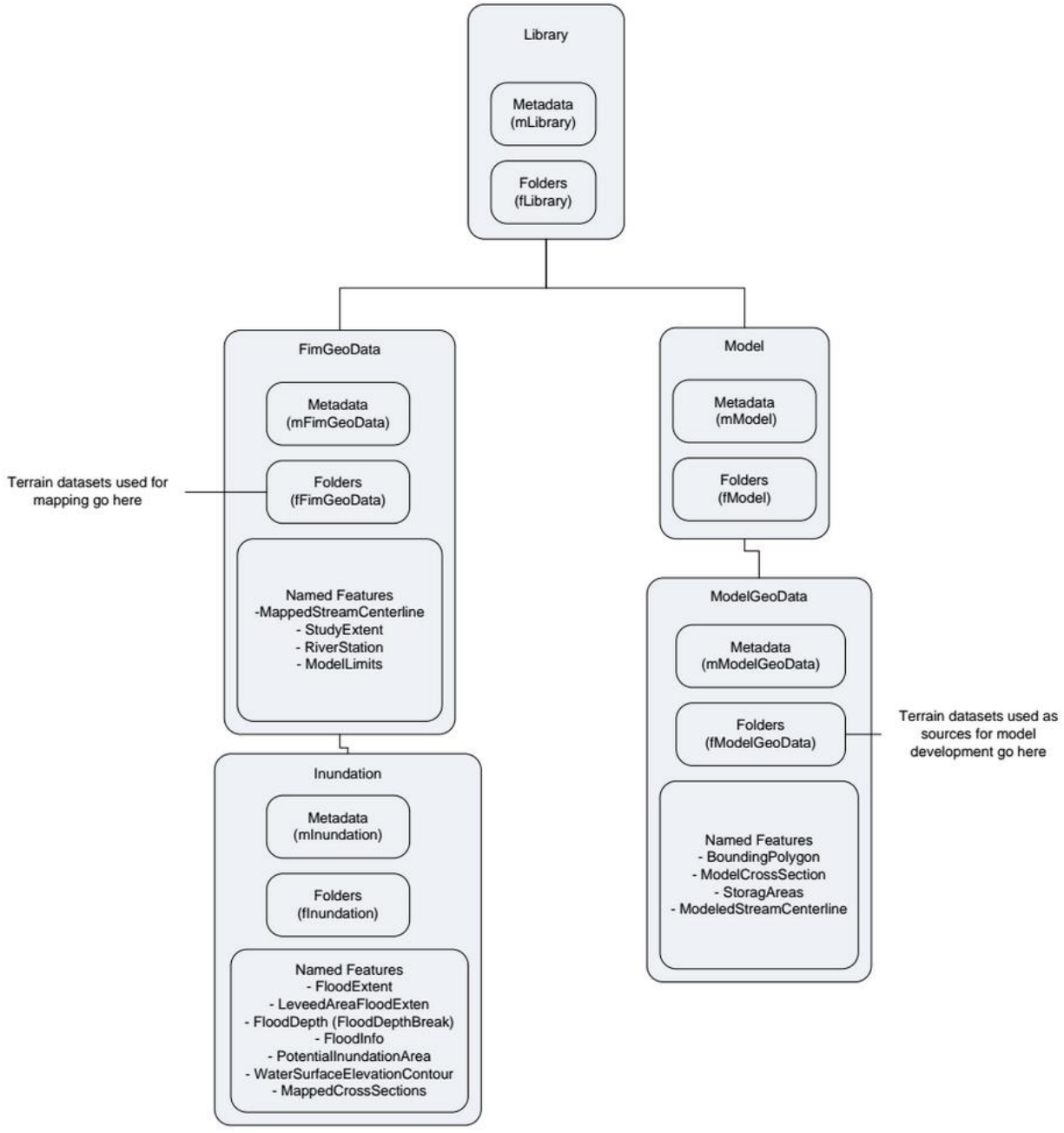

Figure 3.1. IWRSS FIM Conceptual Data Model

3.1.3. File Structure

The purpose of folder objects within the object model is to ensure the data standard can be implemented within flat file systems. For example, templates should be developed to document and populate IWRSS FIM data standard-compliant map libraries using shape files or file geodatabases, spreadsheets and properly named and organized file folders. Such flat file implementations of the logical data model will help to foster broad industry adoption, to include utilization by consultants hired by communities to develop flood inundation maps.

Figure 3.2 depicts how the IWRSS data standard can be implemented within a flat file folder structure while retaining all necessary FIM library object-relational principles; an individual table in the figure could be stored as a spreadsheet for example. Named features (geospatial file, e.g. shapefile) would be stored in its appropriate folder within the hierarchy that encodes the object-relational model. Terrain datasets may be either stored in the FimGeoData folder, if used to construct the inundation map, or ModelGeoData folder, if used to construct the hydraulic model.

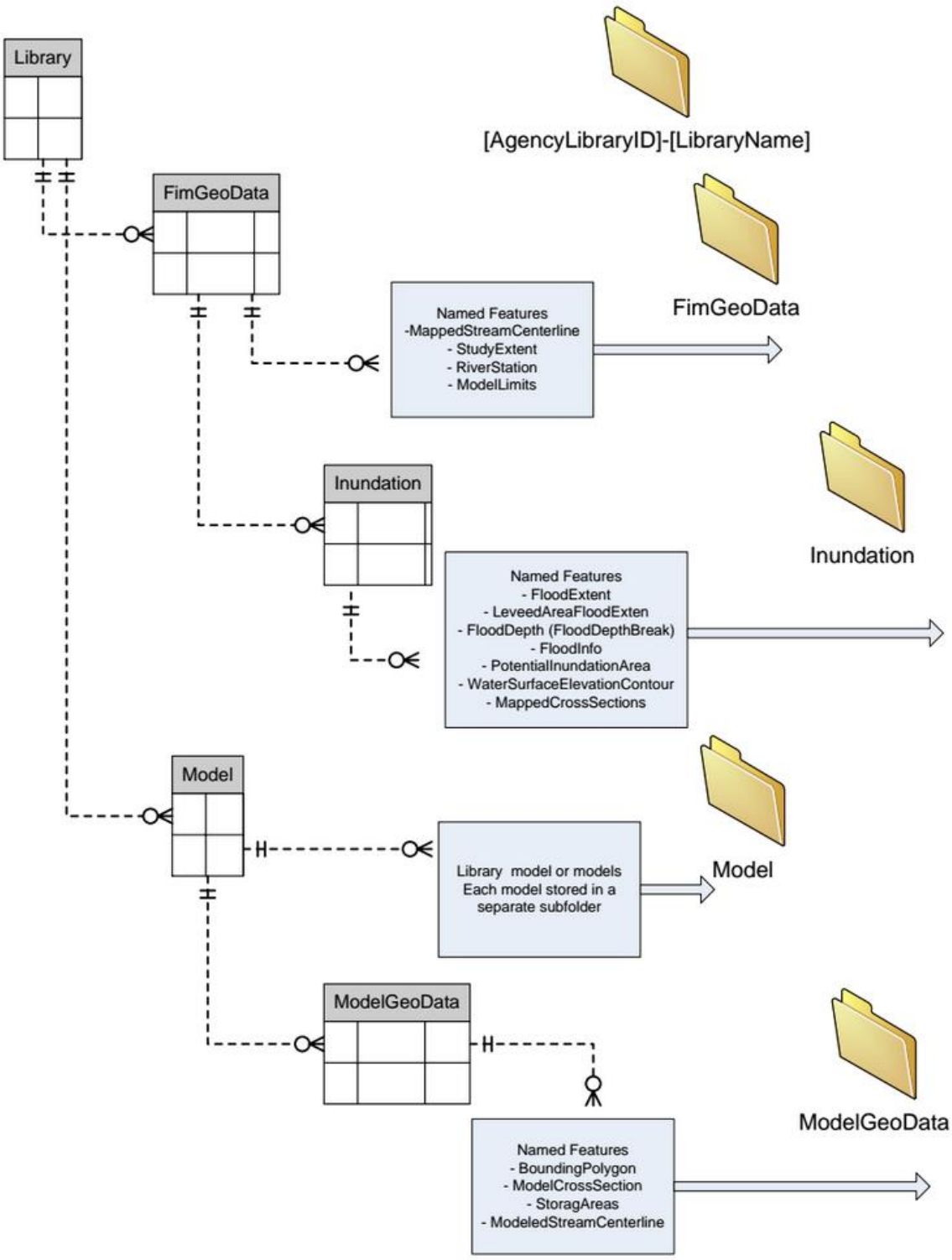

Figure 3.2. Flat file implementation example

3.1.4. Metadata

The IWRSS FIM design intent is to incorporate robust metadata directly within the geospatial data model, and deliver the metadata to the end user in a standardized format. The design team achieved this by: (1) adopting the existing USGS Metadata template as is (Appendix E.2 and E.3); (2) precisely defining the most critical geospatial attributes and metadata attributes necessary to meet IWRSS FIM requirements within the data model; and (3) defining the relationships between geospatial objects (named features) and metadata objects.

3.1.4.1. System Managed Metadata

The proposed logical data model includes a metadata table to store XML-format metadata records, and their corresponding schema definitions. Storing schema definitions future proofs the design by providing flexibility to implement multiple metadata standards or revisions to the USGS metadata standard without translation of legacy metadata. The data standard also includes definition of attributes for entities that do not store spatial features (e.g. Library, Model, FimGeoData, Inundation). In concept, these non-spatial attributes are metadata or very similar to the traditional concept of metadata, in that they describe the content of the spatial features that are related to them. However, many of these attributes require precise control of data types, domains and valid value ranges in order for the envisioned future systems to meet user needs.

A full crosswalk between the USGS metadata template and the IWRSS FIM data model attributes defined by the design team was beyond the scope of this design effort. Therefore, possible redundancy between defined attributes in the logical data model and what could be stored in existing metadata template tags may exist. Consequently, this comparison cannot be fully assessed until a detailed specification is developed for the USGS metadata template. Developing this detailed metadata template specification is recommended as an initial task during the implementation phase.

This is seen as an appropriate implementation-phase task, because as long as the expressed design intent is met, there is flexibility to determine which metadata attributes should be stored as traditional XML-format metadata and which attributes should be stored as fields in tables. These decisions should be based on implementation cost, cost of implementing future modifications and system performance. However, the implemented solution must be capable of providing services that expose all information as structured attributes usable for querying and reporting regardless of whether the information is natively stored as XML tags or as database attributes.

The design team requested review of the metadata approach by a staff developer to verify that the above design intent can be met if a blended solution of XML-format metadata and table attribute metadata is implemented. Recommendation from the developer review is provided in Appendix E.1. Feedback from this review resulted in the design team incorporating the metadata entity and its related schema entity into the logical data model. The team concluded that the design is sufficiently detailed to proceed to the implementation phase with an acceptable level of design risk. The concept presented in Appendix E.1 is one of many methods that may be used to implement the design to provide cross-agency indexing of available data with minimal future data model revision, data translation or application revision.

3.1.4.2. End-User Metadata Standard

The standard for the metadata that is extracted from the system and delivered to the end user was not developed as a part of the IWRSS FIM design process. The implementation team will need to undertake the task to develop the guidelines for providing the metadata to the end-user. The XML-based USGS standard for shapefile and grid metadata (Appendix E.2 and E.3) is suggested as the model for initial deployment and further development of a user metadata documentation standard. The metadata standard must deliver the data in a format that is compliant with the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998) per R101.

3.1.5. Required Data and Attributes

The data standard is flexible in terms of the requirements for users to submit data to a FIM library; however, R102 specifies that required minimum metadata elements must be specified for the data submission process.

Design specifications related to the required attributes and features include:

- Each library should have a proponent agency identified (R011), and the proponent agency is responsible for defining the purpose and use restrictions (R012).
- Each map should have recorded date of production and the most recent review and revision date in the metadata (R024).
- Each map library should have a globally unique reference (GUID) (R026). The business rules for managing this unique reference GUID are described in Section 4.
- The study date should be tagged within the metadata (R147).
- The forecast date should be tagged within the metadata (R148).
- Metadata must be sufficient to identify the event map (R164).

The design specifications above have been translated by the design team into the minimum requirements for the attribute and features include the components listed in Table 3.1 below.

Table 3.1. Required Attributes and Features

Feature Table	Model Name	Definition
Library	Status	Publication status
Library	PurposeAndScope	Purpose and scope narrative for the library. Includes a description of the type of study completed: map library, event map, historical map or dam break EAP map. A general description of the scope of the study.
Library	Disclaimer	Project specific disclaimer information. If FOUO-limited distribution, include the dissemination constraints. (e.g., accuracy of results are limited by the quantified accuracy of the terrain dataset and the uncertainties inherent in the hydraulic model and river forecast)
Library	StudyAreaDescription	A description of the geographic location of the library study area, a description of the study river reach, the streamgage(s) that are tied to the study, the elevations mapped by the study, a list of communities included within the study reach, the flood history and significant flood impacts within the study reach.
Library	DateCreated	UTC date the library record was created.
Library	DateRevised	UTC date the library was last updated.
Library	LibraryName_PK	Name of the library (e.g., Mississippi River at St. Louis, Big 'Ol Dam)
Library	ProponentAgency	Name of the agency responsible for submitting the library to IWRSS
Library	UseRestriction	Classification for use purposes (unrestricted, FOUO-IWRSS, FOUO-Federal, FOUO)
FimGeoData; ModelGeoData; Inundation;	FgdcMetadata	IWRSS FIM-compliant metadata template xml content like: http://water.usgs.gov/osw/flood_inundation/toolbox/preparereport.html
FloodExtent	MapPurpose	Purpose for the map creation (StreamReachMap, ForcastCrestMap, ForecastTimeMap, HistoricalFloodDocumentationMap, EmergencyPlanMap)
N/A	Metadata	Each library will have a corresponding metadata record. Features within a library can have individual metadata records, if needed, but all features within a library inherit the library's metadata.

The minimum required geospatial data, as identified in R049, R051 and R052, includes:

- Flood extent
- Study extents

3.2. Cartographic Standard

The cartographic standard is presented in the *Requirements for the National Flood Inundation Mapping Services*. The *Requirements for the National Flood Inundation Mapping Services* is incorporated in its entirety as Appendix A. The cartographic standard was drafted during the IWRSS FIM requirements phase, and is adopted by the design with the additions below. The cartographic standard forces consistency in presentation of FIM web map services. This

ensures consistency of presentation across the range of web based and desktop map viewing platforms. It also guides map presentations for IWRSS FIM end products (R037). The cartographic standard must be deployed in manner that ensures that end-users may not modify the IWRSS standardized presentation of the mapping products.

An additional standard for the FloodInfo point and ReferencePoint point supplements the Flood Inundation Map Graphics and Specifications standards, and are presented in Figure 3.3 and 3.4 below. Leveed areas will be presented as specified in Figure 3.5.

Label Expression:	[XS_LETTER]	Text Background:	Marker Text Back-ground
Font:	Arial Narrow	Font:	ESRI Default Marker
Size:	14	Unicode:	37
Style:	Bold	Size:	26
Color (RGB) :	0, 0, 0; Black	Color:	255, 255, 255; Arctic White
X, Y Offset:	0, 0	Leader Line:	n/a
Angle:	0	Mask:	1pt; 0, 0, 0; Black
V. Alignment:	Bottom	Placement:	Horizontal
H. Alignment:	Center		

Figure 3.3. FloodInfo Point Cartographic Standard

● **ReferencePoint 6082392702**

Label Expression:
Font: Arial Narrow
Size: 12
Style: Bold

Color (RGB): 0,0,0; Black
X, Y Offset: 0, 0
Angle: 0
V. Alignment: Center
H. Alignment: Center

Text Background: Marker Text Background
Font: ESRI Default Marker
Unicode: 37
Size:26
Color: 255,255,255

Leader Line: n/a
Mask: 1pt; 0, 0, 0; Black
Placement: Horizontal

Figure 3.4. ReferencePoint Point Cartographic Standard

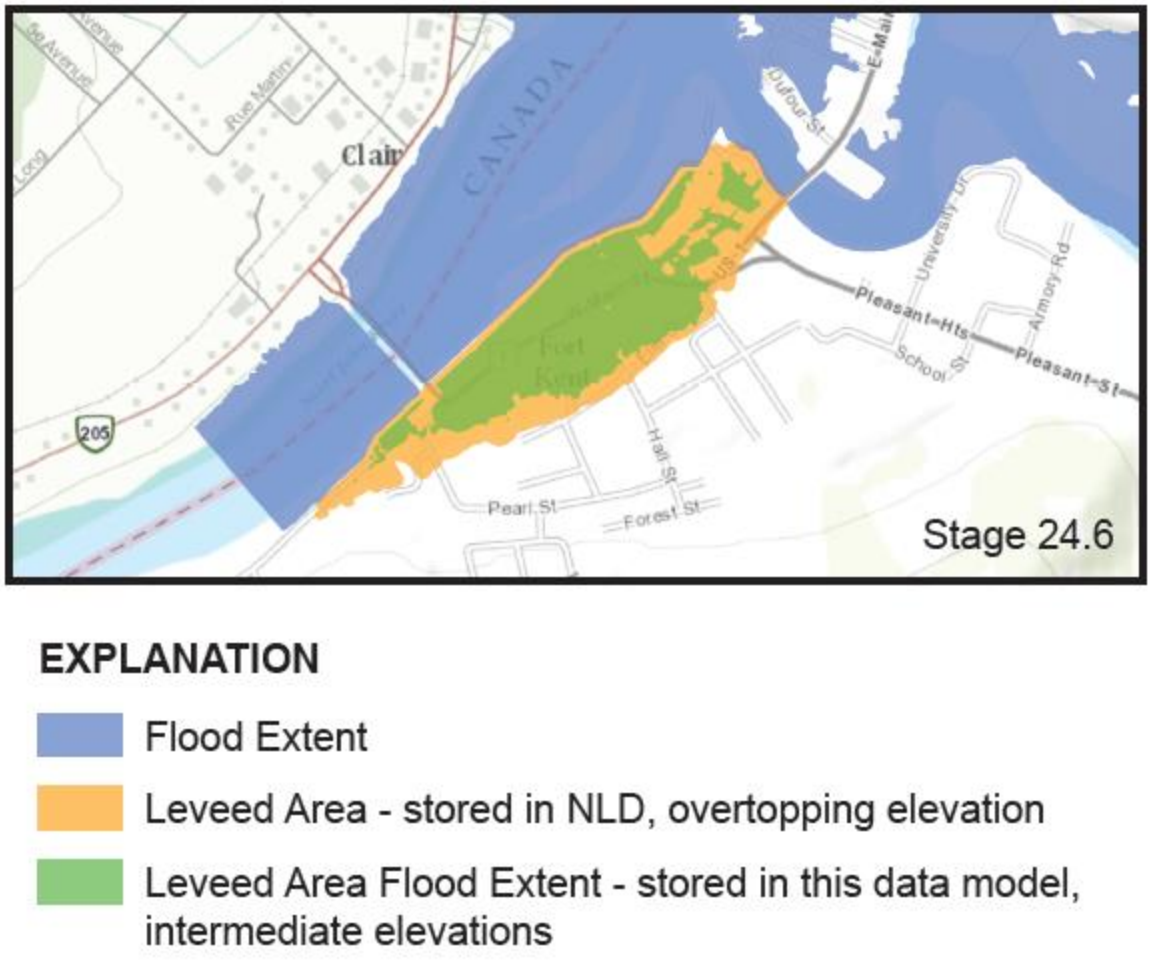

Figure 3.5. Leveed area cartographic example

Depths to be mapped should be defined by the study provider, because appropriate depth ranges must be based on considerations of map purpose and usability as well as underlying elevation data and model accuracy considerations (R118). The data model provides a default category-based method which is documented in the cartography standard. Depth classes or color ramps are both allowable. If a ramp is implemented, the user defines the start and end depth of the color ramp. If categories are used, the user defines number of bins and their ranges. The maximum number of bins that may be established for a category-based map is four. These depth ranges should be consistently represented in all products within a map library, both exported versions and those presented in applications (R119). The rule for how this is implemented is in Section 4.

Uncertainty can be displayed on maps, via the potential inundation area feature, as defined in Flood Inundation Map Graphics and Specifications standards published in the IWRSS Requirements Document and in Appendix A of the design document (R120). The potential inundation layer should be available as an option, and not as part of the standard presentation of an inundation map (R121).

3.3. Report Documentation Standard

The report documentation standard is cited in R100, which defines the minimum requirements for IWRSS agencies submitting FIM data into their agencies respective IWRSS system. The initial documentation standard, published in the IWRSS FIM Requirement Document, has been modified by the USGS. IWRSS will adopt the documentation standards cited by the USGS in the OSW Policy Memo SW2015.03, and documented in the USGS Flood Inundation Map Library Minimum Report Standards.

Reports are to be citable and traceable via a unique identifier (R060); this report number should be derived from the Library ID. Tools that generate reports must include a date stamp (date generated by the system), and a statement that the report is a dynamic product generated based on the info in the library on the date generated. Examples of tools that meet this requirement are discussed in Section 5.

The suggested citation for the report is as follows (R060): IWRSS Flood Inundation Map Library, *Author*, *DateRevised*, *SourceAgency*, *LibraryID*; Report digitally generated on *DatePrinted*.

Documentation must be captured regarding the sources of uncertainty used to define the area (terrain, model, forecast and other considerations) as specified in R122. The intent is to convey an area of uncertainty bounding the “best guess” extent of inundation.

3.4. Services Standards

Services are required to meet the objectives of R031 and R049, so that flood extent, depth map layers and the supporting depth grid model outputs to be provided either For Official Use Only (FOUO), or to the public. Furthermore, the services developed are the point of access to the data that should be advertised through the Federal Geoplatform on data.gov to provide the IWRSS consortium and new stakeholders the ability to discover FIM services and products (R029).

The IWRSS web and data services will be standardized based upon the Open Geospatial Consortium (OGC) standards as specified in R034, and documented on the OGC website. The OGC standards will drive the delivery of the data through a standardized services format. These services must ensure that supporting data are made available for download, including the hydraulic models used to produce flood inundation maps and data layers per R055. The services should conform to a common cartographic standard described in Section 3.2 (R037).

Core requirements driving the OGC services include:

- The complete project data, including geospatial layers, metadata and project report, must be made available for download via the services and applications (R055, R056).
- The spatial web services should provide access to all flood inundation map data, segregating official use only data from public accessible data (R035).
- Web map and web feature services to be made discoverable through the federal geoplatform on data.gov (R036).

The minimum relevant OGC standards of the IWRSS FIM Design include:

- Web Map Service (WMS) - required for implementation of the FIMGeoData service.
- Web Feature Service (WFS) - required for implementation to expose vector info of the FIMGeoData. WFS can also optionally be deployed for ModelGeoData.
- Catalogue Service - highest priority future option for a data registry to expose the non-spatial attribute metadata.
- Web Map Tile Service (WMTS) - future option for serving basemaps and/or supplemental information, or for serving flood inundation maps as map tiles.
- Web Processing Service (WPS) - future option for server side geoprocessing or data request driven tools.

The service-provided geospatial layers, according to R052 will include: flood extent [required], study extents [required], flood depth [desired], flood extent in leveed areas [optional], potential inundation area [optional], reference points [optional], stream centerline [optional], limits of model [desired], model cross-sections [optional], river station/river mile [optional], water surface elevation contours [optional], U.S. National Grid (USNG) zones [provided], USNG 100,000 meter grid ID [provided].

3.5. Geographic and Measurement Standards

Geographic and measurement standards were adopted to unify the data and data attributes that IWRSS partner agencies host within the IWRSS data model.

- The best available topographic data referenced to the North American Vertical Datum of 1988 (NAVD 88) should be used for the development of geometric data for hydraulic model inputs and the generation of flood inundation map products from hydraulic model results (R092).
- The standard unit for measurement of flood mapping products, models and reports shall be specified and the recommended measurement shall be in English units (R095).
- All mapping products should use a common vertical datum, the North American Vertical Datum of 1988 (NAVD 88) (R096).
- All mapping products should use a common horizontal datum, the North American Datum of 1983 (NAD 83) (R097).
- All mapping projects should be submitted with a defined projection that is appropriate for the study. Albers Equal Area Conic USGS is recommended as a suitable model projection projects within the Continental U.S. (R098).

3.6. IT Standards

Agency IT systems shall meet the minimum requirements for system interoperability between agencies and enable technology necessary to share, consume, and exchange FIM amongst IWRSS Member Agencies (R007). These minimum requirements maintain and sustain FIM (R008). Individual IWRSS Agency IT system constraints and security constraints are specified in Section 6 (R009).

A National Institute of Standards and Technology (NIST) IT standard that drives the data access and hosting requirements for the services was identified in R033. This standard states that the FIM end products should be categorized as D 4.1 Disaster Monitoring and Prediction Information Type from the National Institute of Standards and Technology Special Publication 800-60 for the purposes of infrastructure and security (U.S. Department of Commerce NIST, 2008). Security categories must be determined to satisfy the Federal Information Security Management Act of 2002.

3.7. External Data and Service Dependencies

The IWRSS FIM service model is dependent on existing external data and services provided by individual IWRSS agency members and/or other external parties. The dependencies and significance of those dependencies, of IWRSS FIM on the external data services, are outlined below. These external data service dependencies are identified in R052 and R053. The following external services are listed in the order of importance to the design team.

3.7.1. EPA (USGS) NHDPlus Hydrography

Description: A data service that provides a stream centerline, stream address information. This is a core component of the stream addressing system and can be used to create queries within the flood extent boundaries.

The fundamental relationship between NHD and IWRSS Library is the NHD reach definition and its spatial union with the maximum extent of inundation stored in a library. Since the NHD addresses are dynamic/changing and IWRSS libraries may change as frequent as daily or even hourly, managing address versions between these two databases is challenging. Implementing this capability will be important, because many users of IWRSS libraries will initiate inundation map discovery based on knowledge of a stream reach of interest.
Source: EPA Office of Water (http://watersgeo.epa.gov/arcgis/services/OW/WBD_WMERC/MapServer/WMSServer?)
Importance: High - Used for Addressing within the data model

3.7.2. US National Grid Zones and 100,000 meter Grid ID

Description: A static data set that provides spatial boundaries and location information for the USNG coordinate system. The USNG provides the basis for defining extents of IWRSS flood inundation maps and is also necessary for response coordination during emergencies.
Source: Existing static data set maintained by the National Geospatial Intelligence Agency (http://usngcenter.org/portfolio-item/usng-gis-data/).
Importance: High - A core component of the cartographic presentation

3.7.3. National Levee Database (NLD) Levee Centerlines

Description: A data service that documents an alignment of the levee systems across the Continental United States (CONUS). The NLD data service supports the following requirements:

- Levee centerlines to be available for display in online and map sheet products (R081).
- The entire spectrum of levee systems, which may range from a federally constructed/maintained levee system to an agricultural levee system, accredited or non-accredited, certified or not certified to be treated equally as hydraulic features (R082).
- Levee system alignment lines should be acquired and displayed from the National Levee Database (NLD). The NLD levee alignment line to be displayed is an aggregate of the horizontal alignment of all levee centerlines, floodwalls and closure structures (R083).
- If a levee within the FIM project scope does not exist in the NLD, it is the responsibility of the project to submit the necessary data to the NLD for proper display in FIM end products (R084).

Source: Existing USACE National Levee Database WMS Service (http://geo.usace.army.mil/cgi-bin/wms/nldwms?)
Importance: High - A core component of the cartographic presentation and modeling

3.7.4. National Levee Database (NLD) Leveed Areas

Description: A data service that documents the location of the levee system protected areas across the CONUS.

The NLD leveed area is identified in orange as previously shown in figure 3.5, while the leveed area flood extent is identified in green. The leveed area flood extent is stored in the IWRSS system and not within the NLD.
Source: Existing USACE National Levee Database WMS Service (http://geo.usace.army.mil/cgi-bin/wms/nldwms?)
Importance: High - A core component of the cartographic presentation

3.7.5. Base Map Layers

Description: A geospatial service of satellite imagery, elevation contours or other background mapping that provides a base mapping and provides important spatial context for users to visual flood impacts**.** This is a provided layer in the IWRSS system (R053).
For example, IWRSS implementations must include utilizing some base map services that do allow for PDF rendering within their usage agreements and within the platforms selected to implement IWRSS PDF rendering capabilities.
Source: USGS National Map; ESRI; Google; Bing; other 3rd party vendors
Importance: Medium – Provides context to the mapping products

3.7.6. AHPS Flood Forecast Locations and Forecast Data

Description: A data service that provides the spatial locations of the AHPS forecast points, and the RSS data feed that exposes the forecast time series.

Source: NWS AHPS and NWS Ridge 2--transitioning to NOAA IDP http://water.weather.gov/ahps/shapefiles/national_shapefile_fcst.tgz (AHPS data) and http://gis.srh.noaa.gov/arcgis/rest/services/ahps_gauges/MapServer (Ridge 2 services)
Importance: Medium - Information required for IWRSS tool development for querying forecast information.

3.7.7. USGS National Water Information System (NWIS) Real-Time Data

Description: A data service that provides real-time USGS stream gage locations, discharge and stages.
Source: http://waterservices.usgs.gov/ USGS NWIS Mapper
Importance: Medium - Information required for IWRSS tool development for querying flow and stage information

3.7.8. Georeferenced Flood Impact Statement Points

Description: The requirements report mentions the development of a set of geospatially enabled flood impact reports.
Source: Does not exist. This service should be created by NOAA NWS.
Importance: Low - Supplemental Information

3.7.9. Flood Warning Polygons

Description: A data service of the flood warning polygons that illustrate the location of NWS flood warnings during an event. These polygons that contain the watches, warnings or advisories for counties/county equivalents and/or Public Forecast Zones defined by the NWS Valid Time Event Code (VTEC).
Source: Does not exist, but should be requested as a new service requirement for NWS IDP. The proposed data service is similar to the NOAA NWS Rest service (http://gis.srh.noaa.gov/arcgis/rest/services/watchwarn/MapServer); however, the existing Watch Warning Polygon service would need to be filtered to display only flood-related warnings.
Importance: Low - Supplemental Information

3.7.10. FEMA National Flood Hazard Layer (NFHL)

Description: A data service that provides the location of the 0.2%, 1% and floodway.
Source: Existing FEMA WMS Service (http://hazards.fema.gov/gis/nfhl/services/public/NFHLWMS/MapServer/WMSServer)
Importance: Low - Supplemental Information

3.7.11. National Inventory of Dams

Description: Location and hazard assessment of dams across the CONUS.
Source: USACE (http://nid.usace.army.mil/cm_apex/f?p=838:12)
Importance: Low - Supplemental Information

3.7.12. NEXRAD Radar Mosaic

Description: This service presents a mosaic of NWS Doppler Radar mosaic of the CONUS. This is a base reflectivity image and is updated every five minutes.
Source: NWS Ridge 2--transitioning to NOAA IDP (http://gis.srh.noaa.gov/arcgis/rest/services/RIDGERadar/MapServer)
Importance: Low - Supplemental Information

3.8.13. Flash Flood Guidance

Description: Gridded flash flood guidance products for a 1, 3 and 6-hour time scale that indicates the depth of rainfall required to generate runoff.
Source: NWS Ridge 2--transitioning to NOAA IDP (http://ridgewms.srh.noaa.gov/cgi-bin/mapserv?map=/usr/local/mapserver_config/rfc.map&SERVICE=WMS&VERSION=1.1.1&)
Importance: Low - Supplemental Information

Section 4: Business Rules

This section provides detailed description of specific rules and concepts that need to be followed during implementation in order to make the FIM data model function as designed. The business rules function as the internal assumptions and constraints for the data model. In contrast, Section 6 describes the assumptions and constraints for the IWRSS program that affected the broader design effort.

The event mapping use case from Section 2 was tested and documented because it is the most complex and serves as a robust test case for a distributed implementation of the data model. The test identified the limitations of a distributed implementation if all three agencies make their FIM services publically available. The potential exists for each agency to declare an event map, which could be confusing during a flood fight situation. Within a more centralized implementation, processes could be developed to resolve multiple event map submissions prior to public release from a single federal public-accessible service.

4.1. Logical Data Model Naming Rules

The following conventions were attempted during development of the data standard and logical data model. They are not intended as rules for implementation and some may not be possible within certain relational database management systems.

- CamelCaseConvention was used for objects and field names.
- Alias names followed naming convention of the external standard. Example: Alias name should match the SDSFIE name if the field was derived from SDSFIE.
- Fields already in SDSFIE 3.0 and incorporated into the IWRSS FIM data model without modification may retain the SDSFIE naming convention.
- Enumeration lists use standard or mixed case.
- If a feature or attribute is required within a library, note it as “(Required)” in the definition and is also noted in the IsRequired column.
- If a field is a primary key, “(PK)” is included in the model name field
- If a field is a foreign key, “(FK)” is included in the model name field
- Enumeration names created by the IWRSS FIM Design Team have the word "Type" added after the field name having the enumeration (ex: field BridgeClip has enumeration BridgeClipType). This rule is not followed if multiple fields use the same enumeration. If the enumeration already exists in the SDSFIE, the name was left as is.

4.2. Logical Data Model Unique Identifiers (IDs)

All IWRSS member agency FIM services will include globally unique record identifiers (GUID) for all FIM data elements. The FIM GUID is an intelligent numeric key of fixed 23-character length composed as follows:

- Agency Code (5 characters, agency code is OMB agency code)
- FIM Library ID (9 characters, established by each agency)
- Object Code (3 characters, defined in FIM data standard)

- Object Record ID (6 characters, can be established by each agency)

A GUID is required so that all data elements within the independent member-agency databases and services are uniquely identified. Library record IDs are composed of the agency code and library ID. All other FIM data objects are composed of all four data elements. For Object Code, values 001-099 are reserved for objects within the IWRSS FIM data standard. Values 100 through 999 can be used by IWRSS member agencies to uniquely code data objects added within agency-specific FIM adaptations. Each block is reserved for a specific agency as listed in the ID tab of Appendix D.1.

For example, the purpose statement for a mapped flood extent a USGS library is located in a record with GUID 01012033415000016000014. That key leads to the MapPurpose field in a record (Object Record ID 000014) in the Flood Extent Table (Object Code 016) at a streamgage (FIM Library ID 033415000) within the USGS Agency (Agency Code 01012).

4.3. Use of the Established Binned Color Palette for Displaying Depth Grids

To fulfill requirements 26, 49, 52, 152-156 and most importantly 117-119, the table FloodDepthBreaks stores information that describes how to categorize the FloodDepth and LeveedAreaFloodDepth rasters for cartographic display following the IWRSS FIM cartographic standard. FloodDepthBreaks stores the Min and Max values for a depth map color ramp, and if specified, the breakpoints for a categorical map. Up to five breaks are allowed to define the four classes in a categorical depth map. If there is no record provided in FloodDepth Breaks, then the four default classes from the FIM cartography standard, based on consequence drivers, will be used (Figure 4.1).

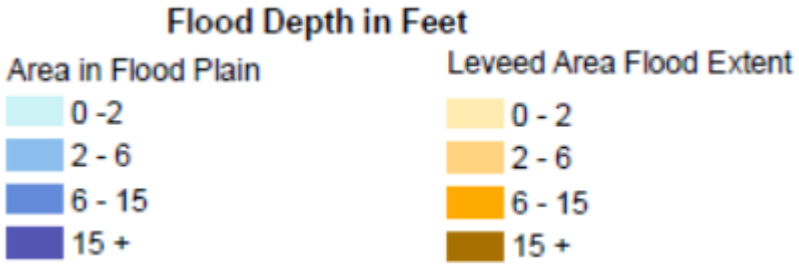

Figure 4.1. Default flood depth classes.

Figure 4.1 was derived from the *Requirements for the National Flood Inundation Mapping Services* (Appendix F in A), which provides the IWRSS FIM cartographic standard. This shows the chosen color swatches and the default depth category breaks to apply if no other bins are defined. Precise color rendering information is included within the standard. If a color ramp is to be applied, the lightest and darkest shades within this pallet define the range of the ramp.

The field Inundation.DepthMapDisplay has several options that discriminate the type of depth map to display. Enumeration options for the color ramp (listed below) have a minimum of 2 and maximum of 5 classes:

- Ramp - Sets default depth map type to color ramp. Min and Max value definitions must be provided in mFloodDepthBreaks. A light (smaller values, edges in floodplain) to dark (higher values near channel) ramp will be used in the cartography.
- 2Class - Sets default map type to categorical with two depth classes. Min, Max and one break value definition must be provided in FloodDepthBreaks.
- 3Class - Sets default map type to categorical with three depth classes. Min, Max and two break value definitions must be provided in FloodDepthBreaks.
- 4Class - Sets default map type to categorical with four depth classes. Min, Max and three break value definitions must be provided in FloodDepthBreaks.
- 5Class - Sets default map type to categorical with five depth classes. Min, Max and four break value definitions must be provided in FloodDepthBreaks.

The table FloodDepthBreaks has three fields that need to be filled out. Inundation has a one-to-many relationship with FloodDepthBreaks (as described above). This data structure operates to control the FloodDepth and LeveedAreaFloodDepth tables:

- BreakLevel - Type of break value (min, max, Break 1, Break 2, Break 3 or Break 4).
- BreakValue - The value for the break ("min", "max" or a number in the same units of measure as the flood depth raster). Specifying "min" or "max" indicates the system should query and use minimum and maximum values from the flood depth raster.
- BreakLabel - The category label to use in legends.

For example, if the map library provider chooses for the system to display a 3-category depth map, the fields would be populated like:
In FloodDepth, DepthMapDisplay would be “3Class”
Four FloodDepthBreaks records will be coded:

BreakLevel “min”
BreakValue “min”
BreakLabel “0”

BreakLevel “Break1”
BreakValue “5”
BreakLabel “5”

BreakLevel “Break2”
BreakValue “10”
BreakLabel “10”

BreakLevel “max”
BreakValue “max”
BreakLabel “15”

This would yield a legend that would read:

- 0-5 feet;
- 5-10 feet;

- 10-15 feet;

and use three of the colors specified in the IWRSS FIM cartography standard.

4.4. Best Practice To Retain Link to NHD Codes During Model Development

MappedStreamCenterline and ModeledStreamCenterline are stream indexing features derived from the hydraulic model. There is a need for universal addressing for modeled streams. The likely IWRSS FIM candidate is to follow the National Hydrography Dataset (NHD) standard for this universal address; however, at this time the data fields and services are not readily available to accomplish data linking and queries. Proponents of the NHD should considered supporting NHD addresses for both hydrologic and hydraulic modeling. Better universal addressing would help support model best practices and the community registry of FIM projects.

4.5. Library Peer Review and Periodic Certification Rules

The fields DateCreated, DateRevised and DateCertified work together in the Event Map Library functionality (detailed below) and in documenting peer-review and certification (detailed here). During entry of a library into the database, DateCreated populates with current date and does not change for the life of the library. DateRevised defaults to DateCreated but is revised at all subsequent substantial revisions to the map library. DateCertified is used to mark the peer-review completion or “approval” date and is updated as noted below with periodic reviews. By definition, DateCertified should be within the last 5 years for all libraries with Library.Status=”Complete” and UseRestrictionType=”Unrestricted”.

Within Appendix A of this document, E.2.6 outlines an IWRSS FIM review process. Several fields in the IWRSS FIM logical data model were designed to trigger and document this process. In the Library table, Library.Status, DateCertified and Certifier manage the majority of this process. The enumeration table and dependencies for Library.Status are shown in Table 4.1.

Table 4.1. Library.Status working definitions

Library.Status Enumeration	Definition	UseRestrictionType Option Allowed	Certifier Option Allowed
Draft	Submitted for peer review	FOUO; FOUO-IWRSS; FOUO-Federal	ProponentAgency
Complete	Peer review complete and approved for dissemination per use restrictions	FOUO; FOUO-IWRSS; FOUO-Federal; Unrestricted	IWRSS; ProponentAgency
ReReview	Library has been flagged that additional review is required. See list below for conditions.	FOUO; FOUO-IWRSS; FOUO-Federal; Unrestricted	IWRSS; ProponentAgency
Archive	Library is no longer active	FOUO; FOUO-IWRSS; FOUO-Federal	IWRSS; ProponentAgency
RapidDeployment	Typically not reviewed but may be released (Provisional). Special case	FOUO; FOUO-IWRSS; FOUO-Federal	ProponentAgency

	when an undocumented model without sufficient prior review is used to release a map for emergency operations. Minimal to no documentation required. If later converted to an Unrestricted map, all documentation standards apply.		

When a library is loaded into the database, Library.Status defaults to “Draft”. Full documentation is not required at that time but minimum required fields shall be entered. The peer-review process for the ProponentAgency will then be followed; i.e. USGS Fundamental Science Practices.

Once the library has been peer-reviewed and all documentation provided, the library may be updated to Complete and UseRestriction updated as needed. If the library meets the full IWRSS requirements listed in Section 3, the Certifier can be changed to IWRSS indicating that all IWRSS requirements are met. This field allows users to filter data to use only IWRSS level data or any particular agency or any combination of IWRSS and agencies.

At any point in its lifecycle a library may be flagged ReReview. Conditions where a ReReview may be required are when any of the following occur in a substantial part of the mapped reach:

- Flood documentation study is completed by the USGS,
- Collection of high water marks for a major event by any IWRSS partner,
- Infrastructure or land-use changes that would affect the reach hydrology,
- River channel changes as a result of anthropogenic or natural events,
- A non-seasonal, significant, permanent shift to the rating curve at the streamflow gaging station used to calibrate the hydraulic model,
- Collection of the high water record by other means that may include flood documentation by aerial photography or other remote sensing methods,
- Any other condition nominated or determined by an IWRSS FIM stakeholder, or
- After 5 years from last review; Ex. if DateCertified < Now()-5 years, any IWRSS FIM Compliant database shall automatically set the status to ReReview.

Upon identification of a degraded mapping product, the library will be flagged ReReview and the ProponentAgency will be responsible for determining the validity of the map library. If areas of higher uncertainty are found but the library still has value to the stakeholders, use of the PotentialInundationArea feature class is highly recommended. Specific areas or whole map sets within the library can be marked as having a higher uncertainty. All stakeholders should be involved in determining review status and communicating new map updates, changes or uncertainty and use limitations. Libraries with a ReReview status are still allowed to be “Unrestricted” UseRestrictionType but need to have a notice to the end user (via web service and mapping applications) that the library is potentially of higher uncertainty (i.e., requires re-review).

When a library is no longer accurate or for whatever reason not depicting the likely flooded area, Library.Status should be set to “Archive” and UseRestrictionType should be set to “FOUO”. Libraries should never be removed from the system because they could be useful for hindcast verification and other historical documentation.

4.6. Periodic Review of IWRSS Standards

Annually, the IWRSS member agencies should meet and review the IWRSS FIM data standard and IWRSS FIM cartographic standard to identify if revisions are necessary. The design team understands that functional implementation is guaranteed to identify necessary revisions to this design. Once the standards stabilize, reviews can become less frequent. Collaboration and coordination should be common during tool and map development implementation and review of the standards should be part of those communications.

The IWRSS FIM data standard retains the SDSFIE concept of adaptations. This means that agencies are free to make local adjustments as long as they can provide data services that meet the IWRSS-level FIM data standards. Routine reviews of agency adaptations ensure they are compliant with the IWRSS-level standard and also provide a means of continual improvement of the IWRSS-level standard.

4.7. Event Map Coordination Procedures

The IWRSS agencies must carefully consider the implementation of these business rules in order to coordinate event maps, especially important under a distributed implementation where each member agency hosts an independent database and related services. It is recommended that event map workflows be thoroughly tested in collaboration with all IWRSS members prior to an operational implementation by any of the agencies, addressing:

- Close coordination of the “IWRSS” declared event map for a reach of river, in the case where multiple IWRSS member agencies propose an event map.
- Close coordination of the declared event map with the official federal river forecast issued by NOAA.
- Identification and resolution of spatial conflicts between event maps that overlap, where overlapping event maps cannot be otherwise avoided through close coordination.
- Rapid declaration of an event map, 24 hours a day, seven days a week.

It is recommended that the agencies work towards ultimately public users with a single source for consolidated IWRSS FIM services. A consolidated map dissemination function would eliminate the complexities and the issues related to coordinating an event map from multiple libraries maintained by three separate entities in distributed locations. Member agencies involved with event map creation and the agency responsible for event map dissemination would need to reach a coordinated decision to select the event map prior to unrestricted dissemination. The advantages of a centralized unrestricted dissemination function include:

- A structured event map coordination process, which minimizes the risk of unrestricted dissemination of multiple event maps for the same reach, or of disseminating no event map because multiple options exist.

- A single authoritative source of flood inundation maps to minimize public confusion that would result from multiple federal, public accessible FIM services.
- A capability that during significant flood events disseminates event maps through mechanisms distinct from the comprehensive FIM services that also provide the full collection of stream reach maps, historical flood documentation maps and EAP maps. This would eliminate confusion during flood events, especially useful for local emergency management authorities.

4.8. Database Rules for Declaring the Event Map

During a significant flood event, it is important to ensure that the best available map representing the forecast conditions, should it exist, be clearly identified to assist users in a flood-warning situation (R161). The business rules and system level procedures described below outline the processes for loading, declaring, removing and archiving the event map. This process results in the selection and dissemination of one federal event-based map, for a reach of river, during a flood event.

A mechanism to quickly display the event-based map for active flood events and provide a level of visibility that gives the event map primary focus is needed. It should be different from the standard workflow for selecting layers from map libraries, as it would keep users from having to manually select the most appropriate map layer(s) representing an ongoing flood event from all those that exist in available map libraries. An event-based map could be identified from either an event-based map library created based on a recent forecast or an existing stream reach map library inundation layer most near to the current stage or forecasted flood stage. The most current and best-available map scenario should be presented to the user (R164).

4.8.1. Event Map Sources

Event maps may be sourced from maps that exist within a library or from a new map that has been developed from an operational forecast model for rapid deployment as a library. The following types of maps may serve as an event map (R164), including maps created from a:

- Crest based forecast map
- Time Based forecast map
- Stream-reach map
- Leveed Area map
- Historical event map
- Dam break EAP maps

4.8.2. Event Map Typing

There are two types of event maps that may be provided by the system, either a crest map or a time-based map. A crest map will illustrate the spatial extent of a flood wave crest as it routes downstream throughout the entire event. An event crest map has a single publication date and a single beginning/end time stamp to identify the event. An event time-based map provides one or more inundation extents, aligned with water surface profiles derived from forecast hydrograph stages over the duration of an event. The time-based map depicts the extent of flooding (actual or forecast) at a specified point in time. Each flood extent within an incremental event map

library is assigned a single publication date and a variable beginning/end time which aligns with a forecast hydrograph stage. The list below ties the event map source data to the type of event mapping information that could be supported by the source data.

- Crest based forecast map [Crest]
- Time Based forecast map [Time-based]
- Stream-reach map [Crest or Time-based]
- Leveed Area map [Crest or Time-based]
- Historical event map [Crest]
- Dambreak EAP maps [Crest]

4.8.3. Loading the Event Map Source Data into the System

Agencies loading data that is intended for event map display will need to ensure that the data loaded meets the following minimum attribute population requirements and the requirements specified in Section 3. A description of how the data model supports the display of an event map is outlined in Table 4.2; the fields required for loading each event map source type are identified in Table 4.3.

Table 4.2. Data Model Fields Used to Identify the Event Map

Feature Table	Model Name	Field Contents	Event Map Description
Library	UseRestrictionType	Unrestricted; FOUO-IWRSS; FOUO-Federal; FOUO	Must be populated to ensure appropriate data distribution, and that event map is visible to the appropriate audience. Public event maps must be populated as “unrestricted”
Library	Status	Re-review; archive; complete; draft; critical rapid deployment	Publication status must be set as either “complete” or “critical rapid deployment” for all event maps.
Inundation	InundationID	Agency Code|Library ID|Object ID{020}|Object Record ID{unique per each date/time stamped layer}	Identifies the Inundation ID that is related to FloodExtent OR LeveedAreaFloodExtent Layer OR FloodDepth OR LeveedAreaFloodDepth
Inundation	EventStartDate	The UTC date and time of the start of an actual flood event or date of a flood extent (actual or modeled). Null if extent does not represent an actual or forecast event.	Must be populated with a UTC date and time. Used as a toggle to assign a stream-reach map, historical map or EAP as an event map. The field can be set back to “null” at the end of the event.
Inundation	EventEndDate	The UTC date and time of the end of an actual flood event or date of a flood extent (actual or modeled). Null if extent does not represent an actual or forecast event.	Must be populated with a UTC date and time. Used as a toggle to assign a stream-reach map, historical map or EAP as an event map. The field can be set back to “null” at the end of the event.
Inundation	ForecastPublishDate	The UTC date and time of the published forecast used to generate the flood extent.	The system selects the most current map from this field.

Inundation	MapPurposeType	None, ForecastCrestMap, ForecastTimeMap, HistoricalFloodDocumentation Map, EmergencyPlanMap.	The purpose for map creation. The system interprets the map purpose, which triggers the display of key features.
ReferencePoint	ReferencePointStage	Stage value at the gage or interior levee reference point.	Used by the system to trigger the display of stream reach or leveed area layers.
ReferencePoint	ReferencePointElevation	Elevation value at the gage or interior levee reference point.	Used by the system to trigger the display of stream reach or leveed area layers.
ReferencePoint	ReferencePointDatum	Datum of the elevation value.	Used by the system to trigger the display of stream reach or leveed area layers.

Table 4.3. Data Model Field Requirements for Loading Event Map Source Data into the System

Data Model Fields			**Event Map Source Types**				
Feature Table	**Model Name**	**Forecast Crest Map**	**Forecast Time Map**	**Stream Reach Map**	**Leveed Area Map**	**EAP Map**	**Historical Map**
Library	UseRestrictionType	Required	Required	Required	Required	Required	Required
Library	Status	Required	Required	Required	Required	Required	Required
Inundation	InundationID	Required	Required	Required	Required	Required	Required
Inundation	EventStartDate	Required	NA	NA	NA	NA	NA
Inundation	EventEndDate	Required	NA	NA	NA	NA	NA
Inundation	ForecastPublishDate	Required	Required	NA	NA	NA	NA
Inundation	MapPurposeType	Required	Required	Required	Required	Required	Required
ReferencePoint	ReferencePointStage	NA	NA	Required	Required	NA	NA
ReferencePoint	ReferencePointElevation	NA	NA	Required	Required	NA	NA
ReferencePoint	ReferencePointDatum	NA	NA	Required	Required	NA	NA

4.8.4 Declaring the Event Map through IWRSS Services

Event map declaration will occur as the data that has been staged in the system is activated or converted into an event map. Table 4.4. displays the typical field values for the event map source types that would be populated prior to event map conversion. Once maps have been converted, several of the fields are populated, and the system identifies the map as an event map. The changes that occur between Table 4.4 and Table 4.5 are underlined in Table 4.5. Table 4.5 thus presents the field content necessary to identify an event map within the logical data model. Note that the forecast crest map and forecast time map types are ready to deploy

as event maps, as soon as they are loaded into the system, while other even map source types have to be converted to event maps by editing the necessary fields.

Table 4.4. Data Model Field Values Prior to Event Map Conversion

Data Model Fields			**Event Map Source Types**				
Feature Table	**Model Name**	**Forecast Crest Map**	**Forecast Time Map**	**Stream Reach Map**	**Leveed Area Map**	**EAP Map**	**Historical Map**
Library	UseRestrictionType	unrestricted	unrestricted	unrestricted	unrestricted	FOUO	unrestricted
Library	Status	Critical Rapid Deploy-ment	Critical Rapid Deployment	Complete	Complete	Complete	Complete
Inundation	InundationID	Unique ID	Unique ID	Unique ID	Unique ID	Unique ID	Unique ID
Inundation	EventStartDate	UTC Date/Time	NA	null	null	null	null
Inundation	EventEndDate	UTC Date/Time	NA	null	null	null	null
Inundation	ForecastPublishDate	UTC Date/Time	UTC Date/Time	null	null	null	null
Inundation	MapPurposeType	Forecast Crest Map	Forecast Time Map	None	None	Emergency Plan Map	Historical Flood Documentation Map
Reference Point	ReferencePointStage	NA	NA	Stage (ft)	Stage (ft)	NA	NA
Reference Point	ReferencePointElevation	NA	NA	Elevation (ft)	Elevation (ft)	NA	NA
Reference Point	ReferencePointDatum	NA	NA	Datum	Datum	NA	NA

Table 4.5. Data Model Field Values While Event Mapping Is In Effect With Changes Underlined

Data Model Fields			**Event Map Source Types**				
Feature Table	**Model Name**	**Forecast Crest Map**	**Forecast Time Map**	**Stream Reach Map**	**Leveed Area Map**	**EAP Map**	**Historical Map**
mLibrary	UseRestrictionType	unrestricted	unrestricted	unrestricted	unrestricted	unrestricted	unrestricted
mLibrary	Status	Critical Rapid Deployment	Critical Rapid Deployment	Complete	Complete	Complete	Complete
Library	LibraryID	Unique ID	Unique ID	Unique ID	Unique ID	Unique ID	Unique ID

Library	EventStartDate	UTC Date/Time	NA	UTC Date/Time *	UTC Date/Time *	UTC Date/Time	UTC Date/Time
Library	EventEndDate	UTC Date/Time	NA	UTC Date/Time *	UTC Date/Time *	UTC Date/Time	UTC Date/Time
Library	ForecastPublishDate	UTC Date/Time	UTC Date/Time	UTC Date/Time	UTC Date/Time	UTC Date/Time	UTC Date/Time
Library	MapPurposeType	Forecast Crest Map	Forecast Time Map	Forecast Crest Map OR Forecast Time Map	Forecast Crest Map OR Forecast Time Map	Forecast Crest Map	Forecast Crest Map
ReferencePoint	ReferencePointStage	NA	NA	Stage (ft)	Stage (ft)	NA	NA
ReferencePoint	ReferencePointElevation	NA	NA	Elevation (ft)	Elevation (ft)	NA	NA
ReferencePoint	ReferencePointDatum	NA	NA	Datum	Datum	NA	NA

UTC Date/Time * = Only required for crest maps.

4.8.5. Resolving Conflicts and Geographic Overlap between Event Map Libraries

Conflicts will inevitably occur when multiple libraries are published fora reach of river. The IWRSS system should be built to help the agencies identify and reconcile the conflicts that occur. Tools may be developed to monitor and alert for conflicts; however, all conflicts should be manually reconciled by the agencies. Fields in the data model such as the Inundation.ForecastPublishDate, Inundation.EventStartDate and Inundation.EventEndDate can be used to identify and reconcile the differences between overlapping layers.

4.8.6. Defining When to Trigger the Event Map

The IWRSS agencies should develop a policy to define the impact level to trigger the event map. This policy could be as simple as a “stage based” approach, where the NWS flood stage is the trigger for the event map or there could be more complex criteria involving flood frequency flows or damage curves.

4.9. Rules For Rapid Deployment Maps During Emergency Events

The “RapidDeployment” Library.Status should be used sparingly. In a situation where libraries have to be shared on an FOUO basis during an event, and there is insufficient time to fully document the library and complete the review process, this status allows for minimal documentation and a capability to disseminate the mapping for broad visibility and interagency emergency planning and response coordination. If a “RapidDeployment” library is intended to be released with an “Unrestricted” UseRestrictionType, all IWRSS Standards will apply and the Library.Status should follow the Draft – Complete – Archive workflow.

4.9.1. Removing the Event Map from the Display

When the event map needs to be removed, the data fields are changed back to their initial states found in Table 4.4. This can be done manually by changing the field or via expiration, as the system automatically cleans up expired products. The system will function to automatically

remove event maps as they expire. The system should be programmed to look backwards (2 to 3 days) and forward (5 to 7 days) in time a number of predetermined days. Event mapping products that age out of this moving time window will expire and be removed by the system. The extents of this rolling time window should be kept flexible in order to adapt to the situation. Variations in the date\times used to consider the event map should be defined by the agencies.

4.9.2. Archiving the Event Map

The system will function to track and log all mapping that has been reclassified as an event map. The event map parameters, identified as required in the Table 4.2, should also be logged for each case an event map is declared for. In addition, any mapping library may be converted to an archive library by changing Library.Status to archive.

Section 5: Service and Tool Implementation

Currently, each IWRSS member agency has existing FIM data, services and tools to provide maps, data and documentations for their users including IWRSS partners, non-IWRSS partners and stakeholders. Existing FIM services and tools that are utilized by each member agency, may or may not meet the common IWRSS map and data standards that were mentioned in Section 3 for sharing FIM data and for visualizing flood inundation maps.

In order to deploy and implement FIM services and tools that are compliant to the common IWRSS FIM map and data standards, a strategy was recommended for an IWRSS FIM design that begins with a decentralized implementation phase where all member agencies endorse common IWRSS standards, each member agency deploys independent FIM services, and member agencies collaborate to develop and deploy FIM tools through existing agency IT infrastructure.

This section explores following topics:

- The current status of existing FIM services and tools used by each member agency;
- A conceptual data flow diagram showing how all agencies are hosting and sharing data and metadata between agencies;
- The possible implementation plans of listed FIM services and tools by each member agency; and
- A timeline summary showing how proposed agency implementations align.

5.1. Current Status of IWRSS Member Agency FIM Services and Tools

Capabilities of existing flood inundation mapping services and tools employed by each member agency were evaluated and compared to the common IWRSS FIM standards. Though IWRSS FIM tools are not a priority design requirement, the IWRSS FIM IWRSS POCs did request that the design team consider tools and recommend a path forward for tool development. Member agencies could be sharing tools and co-developing tools to help facilitate more efficient and user-friendly data sharing, data consuming, and data exchanging. The design team's tool evaluations and comparisons are presented in the subsections below. For each table, the column headings below the "Status of Current Capability" label describe capabilities of each service and/or tool; where appropriate, the IWRSS FIM requirement number(s) are included along with a capability description. They symbols in the table represent:

- ● Fully Implemented to IWRSS levels
- ◉ Partially Implemented
- ○ Not Started Implementation

For the Rough Order of Magnitude (ROM) Cost, the following guidelines were used to scale across different agency budgets:

$	Can be completed within current operating budget
$$	No additional staff needed, but more hours/funding needed for something
$$$	Outside the annual scope of personnel and budget but maybe feasible within the larger team's operations
$$$$	Up to roughly double the annual operating budget and will need additional teams/resources
$$$$$	Needs a budget initiative and Senior Leadership/significant resources (4+X annual operating budget

5.1.1 Database Design and Storage (Required)

Current status of database design and storage for each member agency was evaluated for readiness to meet the common IWRSS FIM standards including IT standards described in Section 3.7. Each member agency will need to maintain a database and deploy data services that will accept, store and serve FIM data in formats that comply with the IWRSS FIM standards and that will be accessible by other member agencies, optionally by the public subject to FOUO designations. Compliance of current systems with National Institute of Standards and Technology D 4.1 Disaster Monitoring and Prediction Information Type from the National Institute of Standards and Technology Special Publication 800-60 was partially evaluated.

- For NWS, existing Advanced Hydrologic Prediction Service (AHPS) FIM site, which currently does not fully meet the IWRSS FIM requirements, will transition to NOAA Integrated Dissemination Program (IDP). A new database will be constructed in NOAA IDP, which is the storage and service dissemination plan for NWS. When NWS will have to reformat 133 existing FIM libraries, storage space may be an issue.
- For USACE, the analysis assumes update of Modeling, Mapping and Consequences (MMC) database and corporate CorpsMap database. MMC Production Center FIM database is close to meeting the FIM data standard, but will require modification to fully meet the standard. Once completed, the MMC FIM physical data model (Oracle RDBMS) will serve as the 80% solution for update of the corporate CorpsMap database. Once the CorpsMap database is updated, interfaces can be developed to post FIM data to CorpsMap from the MMC database, from CWMS deployments and from USACE projects utilizing HEC RAS 5.0 models.
- For USGS, existing FIM services are very similar to the IWRSS standards since USGS already meets the reporting storage and delivery minimums. The data model would need to be upgraded to include more map types and event-based choices.

Table 5.1. Status of Current Capability for Database Design and Storage (Required)

	Status of Current Capability							
Agency/Tool name	Meets IWRSS IT Standards (R033)	Meets IWRSS Data Model Standards (Multiple Requirements)	Data Accessible; separates Public and FOUO access (R035)	IT system available to host database	Identify and coordinate the event maps (R30, R161, R163, R164)	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS	●	○	◎	◎	◎	20	Jan 2016 - Dec 2019	$$$$
USACE	●	◎	○	◎	○	0	Dec 2015 - May 2017	$
USGS	●	○	●	●	○	70	Dec 2015 - Dec 2016	$$

5.1.2 Web (Cartographic and Data) Services (Required)

Current status of cartographic and data services for each member was evaluated to readiness to meet the IWRSS FIM cartographic and the data standards. The web map and web feature services should be available to other member agencies and optionally to the public subject to FOUO designations. The IWRSS web services must segregate publically available data from FOUO data.

- For NWS, NOAA IDP will function as the IWRSS service plan.
- For USACE, the analysis assumes that the services will be deployed through the existing geospatial DMZ. Solution will be deployed using similar technologies to NLD and other geospatial systems providing services accessible outside USACE firewall.
- For USGS, minimal updates are needed to make new layers and other services available.

Table 5.2. Status of Current Capability for Web (Cartographic and Data) Services (Required)

	Status of Current Capability										
Agency/Tool name	Service based (R034, R036)	Meets IWRSS standards	Public and FOUO defined (R035)	Uptime/IT requirements	Public	Defined cartography (R037)	Platform independent	Identify and coordinate the event map display (R30, R161, R163, R164)	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS	◎	○	○	●	●	○	●	○	10	Jan 2016 - Dec 2020	$$$$
USACE	◎	○	◎	◎	●	◎	●	○	25	Dec 2015 - May 2017	$
USGS	●	◎	●	●	●	●	●	○	70	Dec 2015 - Dec 2016	$$

5.1.3 Service Viewer Mapping Application (Required)

Current status of mapping applications, which allow users to interact with FIM data, was evaluated for readiness to meet the common IWRSS standards and to consume IWRSS-compliant web services.

- For NWS, AHPS FIM is capable of consuming WMS services. NWS AHPS would need to be modified to consume the IWRSS services, similar to how AHPS now consumes FEMA's National Flood Hazard Layer (NFHL). Updates would include the Coordinated Management System (CMS) modifications to allow Hydro Program Managers (HPM) to setup IWRSS FIM; it would require funding for Orion to modify the interface.
- For USACE, the analysis assumes use of CorpsMap platform with custom tools. Completion status is based on existing MMC Production Center data viewer. There are likely to be multiple viewers ultimately deployed inside USACE; this analysis proposes the schedule for first viewer that can serve as a model for additional viewers.
- For USGS, the review Mapper is publically available but designated for facilitating peer-review of FIM libraries; USGS is considering password protecting the review process although USGS Fundamental Science Practices (FSP) doesn't require it. Additional capability is available through a USGS mapping application where a user can control the viewing of FIM libraries with multiple control site locations and display many possible FIM scenarios based on the multiple combinations of conditions available at multiple sites; other member agencies can take advantage of this capability and apply to their own mapping application.

Table 5.3. Status of Current Capability for Service Viewer Mapping Application (Required)

	Status of Current Capability											
Agency/Tool name	Service based	Consumes IWRSS FIM services	Consumes external services	Public	FOUO or password	Appropriate display for each IWRSS FIM type	Download available	Platform independent (R39)	Multiple control point (optional)	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS - AHPS mapping	●	○	◎	●	○	◎	◎	◎	○	25	Jan 2016 - Dec 2020	$$$$
USACE - CorpsMap	○	○	●	●	●	◎	○		○	25	Dec 2015 - Oct 2018	$$$
USGS - FIM Mapper	●	○	◎	●	○	◎	●	◎	●	80	Dec 2015 - Dec 2016	$$
USGS - Review Mapper	●	○	◎	○	●	◎	○	○	●	100	NA	NA

5.1.4 Data Accessibility Tool (Required)

Current status and capability of tools to navigate FIM data libraries for accessing source data were evaluated for readiness to meet the common IWRSS standards. Capability requires providing access to external FOUO and optionally public users to retrieve data and supporting documentation from FIM databases/systems.

- NWS will have to develop this capability from scratch, since supporting data is stored locally offline.
- USACE presently relies upon HSIP to provide geospatial data accessibility to other federal agencies and has no tools for searching holdings. There is no mechanism for providing FIM data to the public. The MMC Production Center data viewer workflow provides a list of libraries to the user, user selects library of interest, library is loaded and the library's map layers are displayed. Multiple libraries can be displayed at once, when needed. Minor modification needed to enter this workflow through a spatial query and to allow for data exports.

- USGS uses publications warehouse (http://pubs.er.usgs.gov/) as our ftp repository for full reports, shapefiles and grids of products and metadata. Terrain and hydraulic models are available via the Water Science Center (WSC) archive policy (i.e. business card). The mapper does produce a minimum report (Page One) with the pdf maps tool.

Table 5.4 Status of Current Capability for Data Accessibility Tool (Required)

	Status of Current Capability								
Agency/Tool name	Meets IWRSS format standards	Standard formatted metadata (R056)	Minimum report available (R056, 061)	Geospatial zip file available (R031)	Terrain model data available (R055)	Hydraulic model data available (R055)	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS	○	◎	○	●	○	○	20	Apr 2016 - Mar 2021	$$
USACE	○	○	○	○	○	○	0	Dec 2016 - Mar 2018	$
USGS	◎	●	●	●	●	●	90	Dec 2015 - Dec 2016	$

5.1.5 Map Atlas Generation Tool (Optional)

There is a standalone service developed by USACE that returns a Map Atlas in PDF format from a FIM library using standard page sizes based on the U.S. National Grid (USNG) (Appendix H). Source code will be shared. With limited development, it could be deployed by USACE or another IWRSS member agency for use by all IWRSS member agencies.

Table 5.5. Status of Current Capability for Map Atlas Generation Tool (Optional)

	Status of Current Capability								
Agency/Tool name	Service based	Meets IWRSS cartographic standards	Auto formatting	Includes report	Public	Internal	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS	○	○	○	○	○	○	0	Jan 2016 - Sep 2020	$$$$
USACE	◎	●	●	○	○	●	50	Dec 2015 - June 2016	$$
USGS	○	○	○	○	○	○	0	TBD	$$$$

5.1.6 Single Map View Generation Tool (Optional)

There is a standalone Service by USGS that returns a single map in PDF format from a FIM library using user defined areas and a single map level (Appendix I). This USGS tool is available and works on web service that would be easy to make available to partners.

Table 5.6. Status of Current Capability for Single Map View Generation Tool (Optional)

	Status of Current Capability							
Agency/Tool name	Service based	Meets IWRSS cartographic standards	Auto formatting	Includes report	Public	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS	●	○	●	○	●	20	Jan 2016 - Sep 2020	$$$
USACE	○	◎	◎	○	○	10	Oct 2015 - Dec 2015	$$
USGS	●	●	●	●	●	100	NA	NA

5.1.7 FDGC Metadata Generation Tool (Optional – Future Collaborative Tool)

This tool should be collaboratively developed by member agencies. It would support user creation of FGDC-compliant metadata that would be loaded with FIM data. Automated reports could then produce structured metadata for viewing in FIM applications and downloading with FIM data. Because of the high value the IWRSS FIM design places on the importance of metadata, the analysis assumes that a custom library data population interface may be necessary in the future. Industry standard metadata creation tools must be evaluated to ensure proper integration into a solution that will meet the IWRSS-specific requirements currently beyond the industry definition of metadata.

- NOAA has a system called MERMAID but not used by NWS; instead NWS uses ESRI Tools. IDP has a layerinfo service that may be used to serve this purpose. See NOWCoast example (http://new.nowcoast.noaa.gov/help/#!section=layerinfo)
- For USACE, MMC Production Center workflows support the need for IWRSS-compliant data loading and metadata creation for a limited subset of IWRSS data and metadata.
- USGS provides the XML file with downloadable data but has no plans to turn that into services.

Table 5.7. Current Status of FGDC Metadata Generation Tool (Optional - Future Collaborative Tool)

	Status of Current Capability									
Agency/Tool name	Meets IWRSS standards	Service based	Upload template	Dowload data	Auto formatting	Internal	Public	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS	◎	○	○	○	○	○	●	10	Mar 2016 - Dec 2019	$$
USACE	○	○	○	○	○	○	○	0	TBD	$$$
USGS	○	●	●	●	○	○	●	70	Dec 2015 - Dec 2016	$$

5.1.8 Registry Tool for Current and Planned FIM Libraries (Optional – Future Collaborative Tool)

A registry tool to provide current, planned, and status of a FIM library would be beneficial. The tool would register incoming FIM libraries and provide mechanisms for searching libraries based on data and metadata content. This requirement may be met through a catalog service.

- For NWS, the immediate need for a registry could be implemented quickly using Google Sheets; A catalog service providing more robust search capabilities would be deployed at a later date.
- USGS Sharepoint site can be made available to cooperators or publically available to meet immediate registry needs. An advanced public version could be made in the Federal Toolbox or USGS FIM Toolbox or other location to meet this need.

Table 5.8. Current Status of Registry Tool for Current and Planned FIM Libraries (Optional - Future Collaborative Tool)

	Status of Current Capability					
Agency/Tool name	List exists (R060)	Supports IWRSS collaboration	Public and FOUO defined (R054)	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS	◉	○	○	10	Jan 2016 - June 2016	$
USACE	○	○	○	0	TBD	$$$
USGS	●	◉	●	95	Dec 2015 - April 2016	$$

5.1.9 Guidance for submitting data to the IWRSS FIM member agencies

This is a future collaborative guidance to be developed by member agencies that would provide format guidelines, easy to use templates, and instructions for submitting data to agency proponents for incorporation into FIM services.

- For NWS, this is a collaborative activity in which IWRSS agencies should be sharing documents, templates, and tools.
- For USACE, MMC Production Center workflow requires use of geospatial data templates to ensure standards compliance for work performed by production teams. MMC templates, once modified to be IWRSS standards-compliant will benefit the broader IWRSS community.
- USGS have templates that match our current data and service architecture and when that gets updated to meet the IWRSS standards, new guidance and templates will have to be issued. A blank geodatabase may be part of that update if needed.

Table 5.9. Status of Current Capability for Guidance for Submitting Data to the IWRSS FIM Member Agencies

	Status of Current Capability						
Agency/Tool name	Available to public or to select group of users (R113)	Meets IWRSS standards (R032, R102)	Geodatabase	Template provided (R112, R114)	**Percent Completion**	**Completion Timeline (Start Date - End Date)**	**ROM Cost**
NWS	◉	◉	○	○	20	Jan 2016 - Mar 2018	$
USACE	○	○	○	○	0	TBD	$
USGS	●	◉	◉	●	80	Dec 2015 - Dec 2016	$

5.2. Conceptual Data Flow Diagram - Data Flow & Interfaces

5.2.1 Current Status

Currently, each member agency has independent FIM workflows, services and tools. Sharing of FIM data through these tools without modification would be cumbersome, because they do not follow a common standard. Data sharing processes (the arrows in the diagram) are inconsistent or non-existent.

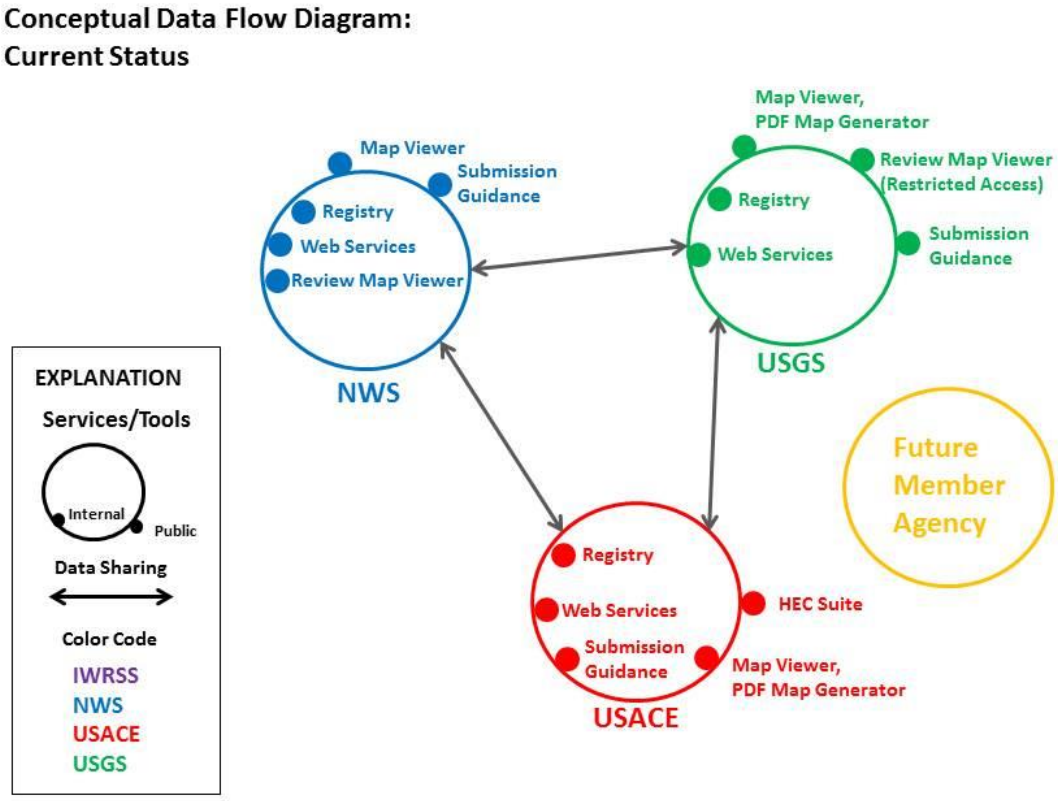

Figure 5.1. Conceptual Data Flow Diagram: Current Status

5.2.2 Implementation in Progress

After completion of the pre-implementation activities recommended in this design, such as formal adoption of IWRSS FIM map and data standards, each member agency would develop, test, and deploy IWRSS standards-compliant FIM services for the purpose of sharing of FIM data seamlessly conforming to the IWRSS FIM map and data standards. Once completed, consistent data sharing mechanisms could function.

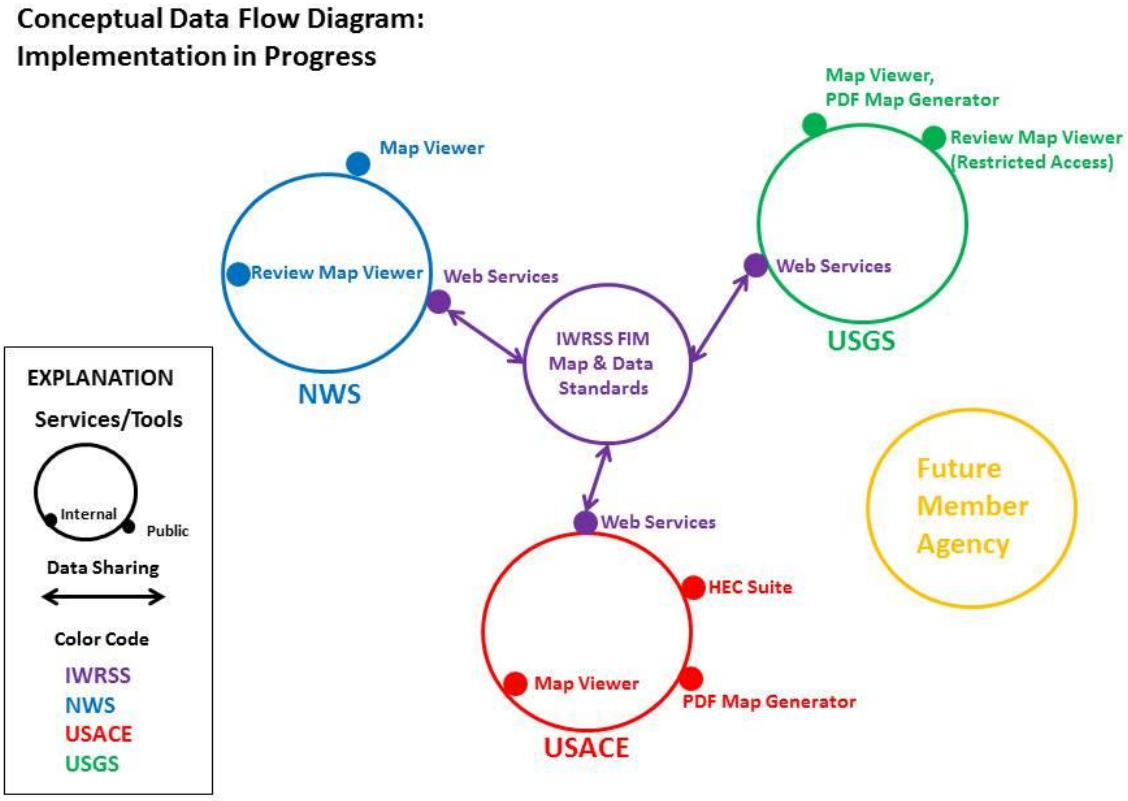

Figure 5.2. Conceptual Data Flow Diagram: Implementation in Progress

5.2.3 Post-Implementation

As each member agency develops and deploys IWRSS FIM services, additional capabilities can be developed and deployed either independently by agencies or centrally by IWRSS. Deployed IWRSS FIM services and tools would include registry tool, metadata generator tool, and submission guidance which are mentioned in Section 5.1.

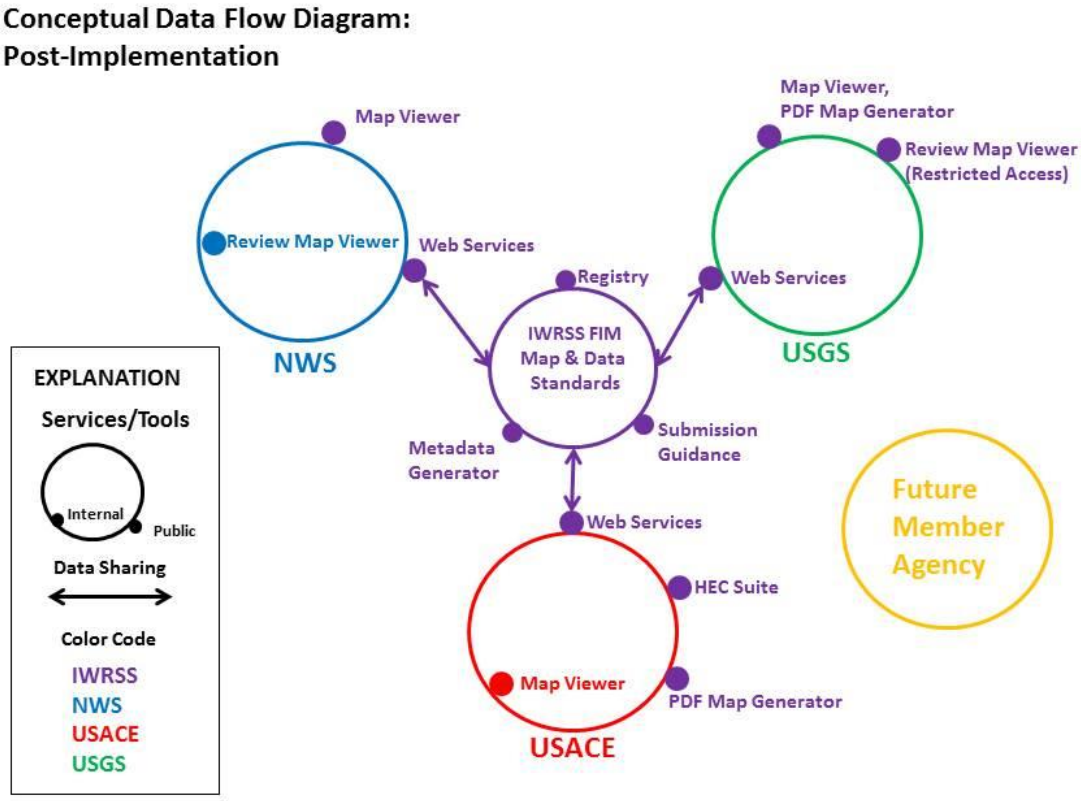

Figure 5.3. Conceptual Data Flow Diagram: Post-Implementation Progress

5.3. Implementation Plan For Each Member Agency

Each member agency will need to convert existing FIM libraries to meet the IWRSS standards presented in this design document. The number of existing FIM libraries will give an indication of level of effort needed to convert and update to meet the standards, including supporting documentation and ancillary data. For example, the existing NWS AHPS FIM libraries, which currently do not meet the IWRSS FIM standards, should be translated to follow the IWRSS FIM Data Model and to leverage spatial data services during their transition to NOAA IDP. Agency implementation plans, available in Appendix G, address:

- Plan for ensuring that all IWRSS services meet performance benchmarks
- Priority of services and tools
- Schedule for implementation
- Resources needed (ROM)

5.4. Timeline Summary Of Agency Implementation Plans

Based on the draft agency implementation plans this is the current general schedule, assuming starting October 2015, the target completion dates for key implementation milestones are below.

- IWRSS Standards Adoption
    - NWS June 2016
    - USACE December 2015
    - USGS September 2016
- Agency Service Deployment
    - NWS December 2022
    - USACE September 2016
    - USGS September 2017
- Tool Deployment (only core agency toolsets are IWRSS standards compliant)
    - NWS December 2022
    - USACE May 2017
    - USGS September 2017

Section 6: Assumptions and Constraints

The FIM Strategic Vision states that *FIM developed and/or hosted by one member agency shall be shareable, exchangeable, and consumed seamlessly by the other*. The intent of this section is to document the key assumptions and constraints which impact the IWRSS FIM Design from sharing, exchanging, and consuming of the data and its map services. There are assumptions implied from the IWRSS FIM Design Charter and constraints to delivering the data and map services. This section also includes recommendations in addressing these constraints.

Assumption 1: Flood Inundation Maps and Data will be shared and seamlessly exchanged amongst IWRSS member agencies.
Constraints: Some information is For Official Use Only (FOUO) and consuming agencies cannot disseminate further. Development and dissemination of derivative products should be coordinated.
Recommendations: Each respective system to ensure FOUO maps and data are not distributed beyond the member agencies. If there is an emergency such as a pending dam breach, levee failure, flash flood, or flooding, the proponent agency may allow release of FOUO products.

Assumption 2: Tools and services, once deployed incur an operation and maintenance cost.
Constraints: No certainty of an O&M budget for IWRSS services and tools
Recommendations: IWRSS Governance Board to develop a budget.

Assumption 3: The design shall include maintaining and sustaining FIM capabilities amongst member agencies.
Constraints: If IWRSS FIM capabilities are to evolve over time, resources are needed to maintain and sustain the FIM capability and capacity.
Recommendations: The IWRSS FIM member agencies will need to collectively agree on the timeframe of FIM capability evolution, work respectively to budget resources to maintain/sustain this capability and ensure maps are continually available for sharing, consuming and exchanging.

Assumption 4: More Flood Inundation Maps will be created that can be stored and shared by this data model and associated systems.
Constraints: Uncertainty of future supply of maps and related data.
Recommendations: IWRSS Governance Board oversee, encourage and track future map development so that resources to address future data needs and expansion.
.
Assumption 5: Data exchange of large datasets presents a large challenge, specifically with terrain and hydraulic models.
Constraints: Bandwidth to seamlessly, electronically download the terrain and hydraulic models.

Recommendations: IWRSS member agencies will need to budget storage capacity or provide pointers to where these data are publically available.

Assumption 6: There are pre-implementation activities which are to be completed prior to or in parallel to the IWRSS FIM Implementation efforts.
Constraints: Resources to tackle pre-implementation activities as described in Section 1 .
Recommendations: IWRSS POC to identify resources, establish a start date and track progress.

Assumption 7: The IWRSS FIM map and data standards are widely used throughout the FIM production community.
Constraints: Lack of industry awareness of the standards.
Recommendations: Each agency to formally adopt the standards through issuance of guidance. IWRSS determine mechanisms to promote the standard.

Assumption 8: The IWRSS FIM design will be implemented.
Constraints: Requires a team, budget and scope of work and schedule.
Recommendations: IWRSS POC to incorporate recommended guidelines listed at end of IWRSS FIM Design Document Section 1 into implementation charter.

Assumption 9: Some future IWRSS efforts will be performed through chartered teams, while some may not need charter teams.
Constraints: Presently no criteria for determining when charters are required.
Recommendations: IWRSS governance board to develop criteria.

Assumption 10: IWRSS member agencies are to evaluate the ROM described in Section 5 to bring respective agencies into the IWRSS FIM Data Standards and Map Services capability.
Constraints: Respective resources to bring member agencies in alignment.
Recommendations: The member agencies to agree to a schedule, acquire resources and complete the unilateral approved activities.

Assumption 11: A broad community of FIM product and tool development is the vision.
Constraints: Closed systems aren't widely adopted.
Recommendations: Open standard, open documentation, APIs, open code base.

Assumption 12: Agency IT systems to allow sharing, consuming and exchanging of IWRSS FIM Services shall follow Federal IT system requirements.
Constraints: The evaluation of IT infrastructure and determination of resources to satisfy the Federal Information Security Management Act of 2002 are beyond the scope.
Recommendations: IWRSS FIM services shall follow IT System standards in accordance to the National Institute of Standards and Technology Special Publication 800-60 D 4.1 Disaster Monitoring and Prediction Information Type for the purposes of infrastructure and security (U.S. Department of Commerce NIST, 2008).