MHFD Flood Risk Program Implementation Plan

July 10, 2026 *(final draft)*

MHFD Project: 110355

MHFD
MILE HIGH FLOOD DISTRICT

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INTERNATIONAL

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List of Acronyms

1D	one-dimensional
2D	two-dimensional
AALs	average annualized losses
AE	Zone AE (FEMA flood zone designation)
AEP	annual exceedance probability
CCD	City and County of Denver
CIP	Capital Improvement Program
CPI	Cost Performance Index
CUHP	Colorado Urban Hydrograph Procedure
DCM	Design, Construction, and Maintenance
DRCOG	Denver Regional Council of Governments
DxV	depth times velocity (flood force)
FEMA	Federal Emergency Management Agency
FHAD	Flood Hazard Area Delineation
FIRM	Flood Insurance Rate Map
G&A	Green and Ampt
H&H	hydrology and hydraulics
HEC-RAS	Hydrologic Engineering Center's River Analysis System
ICM	Innovyze InfoWorks Integrated Catchment Modeling
IGA	Intergovernmental Agreement
LCCE	Lifecycle Cost Estimate
LG	local government
LOMC	Letter of Map Change
LiDAR	Light Detection and Ranging
MHFD	Mile High Flood District
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NSI	National Structure Inventory
PSS	pseudo-steady state
QA/QC	quality assurance/quality control
RFQ	Request for Qualifications
ROI	return on investment
RoM	Rain-on-Mesh
sq. mi.	square miles
SEMSWA	Southeast Metro Stormwater Authority
SPI	Schedule Performance Index
SST	stochastic storm transposition
SWMM	Storm Water Management Model
TAC	Technical Advisory Committee
USGS	United States Geological Survey
WSE	water surface elevation

Executive Summary

The Mile High Flood District (MHFD) is advancing a new initiative termed the Flood Risk Program (Program) to establish a standardized, Districtwide framework to quantify flood hazard and risk information for use in various end applications that protect people, property, and the environment. This Program has grown out of progressive pilots and explorations since 2022 and seeks to leverage the latest advancements in both technology and methodology to enhance decision making, investments, and management practices by taking a people-centric approach to flood impacts. Central to Flood Risk is a transformation from today's riverine mapping of binary hazard to a future focused on a watershed-wide graduated risk assessment that measures impacts to people.

The Program will continue to evolve as additional learnings take place, but the near-term initiative is well-chartered and involves developing Districtwide coverage of flood hazard and risk for existing conditions by 2029. Subsequent applications being considered that build upon this foundation are numerous and still conceptual at this time, and are therefore not covered here. One primary application whose framework has been established and is included in this Program Implementation Plan (Plan) is to better support the Capital Improvement Program (CIP) decision-making process by modeling post-project conditions and evaluating risk reduction per dollar spent. Although this Program will develop models that could be leveraged as a solid starting point for other applications, the Program does not establish regulatory floodplain boundaries, replace FEMA Flood Insurance Rate Maps (FIRMs), override local land use authority, or produce detailed design information.

Program Content

This Plan defines how flood risk is calculated, compared, documented, and how it could be applied for various end uses. The Plan outlines the management structure, identifies appropriate use cases, and provides guidance for implementation, including sequencing of work, and data development processes such as modeling, risk scoring, and project ranking. The Plan also addresses data management, deployment considerations, performance metrics, contracting mechanisms, and program management procedures needed to build and sustain the Flood Risk Program over time.

Program Implementation begins with establishing foundational data that can later be applied for end applications. Establishing foundational data includes a single concerted effort to develop flood hazard and risk products for existing conditions across the District, beginning in late 2026 and concluding in 2029. The data development methodology has been created and refined through pilot projects, technical review, and stakeholder engagement, and is considered sufficiently mature for Districtwide application. Foundational data will provide significant standalone value by delivering consistent hazard and risk information to support decision making, project prioritization, and communication of flood risk.

Once Districtwide foundational data are developed, subsequent end use applications can leverage and build off this information including objectively prioritizing capital improvement projects based on effectiveness and cost-efficiency, assisting with maintenance priorities, informing the flood warning program, alternative hydrology approaches, supporting planning and floodplain management, and more applications. Many of these future applications are still conceptual, and are not detailed in this Plan.

One primary application whose framework has been initially crafted is estimating risk reduction by evaluating post-project conditions and ranking mitigation projects to improve CIP prioritization. This CIP prioritization end use is outlined in this Plan, whereas other considered applications are still conceptual and are not presented in this version of the Plan. While the overall framework for CIP prioritization has been established and is detailed in this Plan, the scope, methodology, and implementation approach will continue to be refined as the Program evolves and additional funding priorities are defined.

MHFD anticipates that technical guidance, modeling workflows, and production approaches will continue to evolve over time. As more watersheds are analyzed and lessons are learned, opportunities for refinement—such as increased standardization, automation, and broader application—will be incorporated through a continuous improvement process.

Program Vision

The Flood Risk Program establishes a technically consistent approach for quantifying flood hazard across the District and translating it into measurable flood risk to inform future actions that protect people, property, and the environment.

Flood hazard describes the physical condition of flooding— where water flows, how deep it is, how fast it moves, and how often it occurs. **Flood risk** reflects the consequences of that hazard on people, property, and infrastructure. Hazard exists regardless of development; risk occurs when people and assets are exposed to the hazard.

When fully implemented, the Program will enable MHFD and its local government (LG) partners to:

- Provide consistent, Districtwide flood hazard and risk information, including pluvial flooding.
- Communicate flood risk clearly and drive risk-informed action.
- Identify the most beneficial projects and optimize mitigation strategies.
- Adopt a portfolio-based approach of risk ranking that considers the entire District rather than individual watersheds in isolation.
- Maximize risk reduction for each dollar invested.
- Track estimated risk reduction and losses avoided following project completion.

The Program is intended to function as an ongoing decision-support system, not a one-time study. Hazard and risk information will be updated as major projects are completed and as modeling inputs evolve, ensuring that CIP prioritization reflects current conditions.

Program Need

The Flood Risk Program addresses two primary challenges:

Supporting Data Limitations

- Existing hazard data vary in coverage and methodology.
- Pluvial flooding is largely absent from regulatory mapping.
- Floodplain mapping is binary (in or out), limiting insight into relative severity.
- Datasets are aggregated using inconsistent schemas and statistical approaches.

Decision-Making Limitations

- Project selection may be influenced by political priorities, public pressure, or isolated high-value assets.
- Budget constraints often drive near-term needs over long-term strategy.
- There is limited ability to compare cost-effectiveness across watersheds.

The Flood Risk Program replaces this fragmented approach with a single, standardized framework applied across the District, using shared data sources and consistent analytical procedures. One primary end application that this Program is designed to meet is optimizing CIP investments. As of 2025, more than 2,400 drainage and flood problems have been identified across the 1,600-square-mile District, resulting in a CIP backlog exceeding $3 billion. With an annual budget of approximately $60 million, addressing current needs alone would take more than 50 years-- without accounting for future development and emerging challenges. The current project selection process varies across LGs, changes from year to year, and often lacks a clear quantitative basis. Comparing projects across basins is especially difficult, as evaluations are typically conducted without a standardized framework, leading to inconsistent, “apples-to-oranges” comparisons.

Technical Framework

The Flood Risk Program is built upon four primary data components:

1. **Receptors** – A Districtwide, authoritative dataset of people-proxy receptors (e.g. buildings, roads and trails) with assigned impact factors representing relative human consequences.
2. **Hazard** – Two-dimensional rain-on-mesh (RoM) hydrologic and hydraulic models developed using the Hydrologic Engineering Center's River Analysis System (HEC-RAS) or the Innovyze InfoWorks Integrated Catchment Modeling (ICM), where appropriate. These models produce gridded outputs for depth, velocity, and flood force across 13 recurrence intervals.
3. **Risk** – Translation of hazard into flood risk scores by intersecting hazard outputs with receptors, applying hazard thresholds, multiplying by impact factors, and annualizing using probability weights. Flood risk scores are **people-centric** and intentionally independent of property value. Simplistic economic losses are generated as supplemental reference data but do not influence project ranking.
4. **Mitigation (Post-Project Conditions)** – Modeled representation of proposed mitigation projects to quantify risk reduction by comparing pre- and post-conditions. Projects are ranked based on the ratio of risk reduction to project cost, enabling consistent comparison across projects and watersheds. Final project selection remains a LG decision and may incorporate additional considerations such as equity, community values, environmental co-benefits, and policy commitments. This aspect supports CIP prioritization in particular, but other aspects may be further developed as additional applications are evaluated.

Implementation Strategy

The Program is implemented in multiple phases:

Foundational Data: Districtwide Data Development (Existing Conditions)
Target completion: 2029

- Establishes baseline hazard and risk across approximately 170 watersheds.
- Organized into 55–80 modeling domains across 7 geographic regions.
- Provides consistent, Districtwide coverage.
- Estimated at $5.5 million (2025 dollars).

Applied End Uses: Watershed or Location-Specific
Timeframe and cost varies by application - can begin once foundational data and funding are available

- CIP prioritization that evaluates risk reduction for mitigation alternatives.
- Assisting with maintenance priorities with additional data on erosion potential.
- Evolution of planning and floodplain management through alternative data.
- Informing watershed responses for the flood warning program and alternative hydrology.
- The end use application may focus on priority areas rather than Districtwide coverage.

Program Management

The Flood Risk Program is overseen by MHFD leadership and managed by the Flood Risk Program Manager, with support from LG partners and other key contributors at MHFD in planning, floodplain management, GIS, and executive leadership.

LGs participate through:

- Workshops, reviews, and feedback.
- Cost-sharing partnerships.

- Application of results in capital planning.

Pillars of program management include:

- Transparent technical standards.
- Alignment with CIP processes.
- Planning-level (non-regulatory) use.
- Quantifiable people-centric risk metrics.

1 Program Purpose and Background

The Mile High Flood District (MHFD) Flood Risk Program (the Program) establishes a standardized, Districtwide framework to quantify flood hazard and risk information for use in various end applications that protect people, property, and the environment. Having Districtwide information brings significant value and enables numerous applications, of which one that has been fleshed out is evaluating the effectiveness of mitigation investments to optimize capital investments by maximizing risk reduction for each dollar spent. This Program supports risk communication, investment decisions, planning, floodplain management, and assists the Capital Improvement Program (CIP) decision-making process to be data-driven when prioritizing projects across local government (LG) programs.

Although there are many applications of high-resolution flood information, most are still conceptual and not included herein. This Program Implementation Plan (Plan) focuses solely on the Program aspects of:

1. Establishing foundational data, which is a necessary baseline before any other application can be implemented, and the methodology for data development has been thoroughly explored, is well-understood, and has been vetted by MHFD and its LG partners. This foundational dataset will be developed Districtwide through one concerted effort beginning in late 2026 and concluding in 2029.
2. CIP prioritization of future flood mitigation projects by evaluating risk reduction against expenditures. Risk reduction modeling will be conducted at a watershed level upon request and funding from a LG. The details of this application are still evolving, but the framework is generally established.

It is anticipated that this Plan will be occasionally updated as the Program unfolds, the methodology is refined, and additional end use applications are better defined. This Plan defines how flood risk is identified, calculated, compared, documented, and consulted to inform capital planning decisions. This section describes the Program vision, need, desired end state, and guiding principles, beginning with a concise summary in Table 1.

Table 1. Program Intent Summary

The Program Informs	The Program Produces	The Program Does Not
• CIP prioritization and project selection • Basin Master Plan updates • Major system planning efforts • Grant strategy alignment • Strategic long-term financial planning	• Districtwide baseline flood hazard and risk information (under existing conditions) • Flood hazard and risk information at the watershed level (under post-project conditions) • Risk reduction estimates and efficacy per mitigation project • Defensible documentation for investment decisions	• Establish regulatory floodplain boundaries • Replace FEMA Flood Insurance Rate Maps (FIRMs) • Override local land use authority • Produce detailed design information

1.1 Program Vision

The Program establishes a consistent, technical approach to quantify flood hazards across the District and translate them into measurable flood risk. Flood hazard represents the physical characteristics of flooding (where it occurs, and how deep, fast, and frequent it is). Flood risk, on the other hand, reflects the potential impact of that hazard on people, property, or infrastructure. While flood hazards will always exist, risk only occurs when people or assets are placed within those hazardous areas, as illustrated by Figure 1.

The MHFD Flood Risk Program takes a "people-centric" approach in defining risk as the impacts to people as measured by the likelihood of their presence, the threat to their safety, and the disruption of their lives. The presence and susceptibility of people is estimated through people-proxy datasets of buildings (residences, businesses, services, schools, etc.) and transit (roads and trails) layers that place equal value on all people irrespective of property values, income, or demographic characteristics. In this manner, the Program depicts risk and supports CIP prioritization in a fair and equal way.

Figure 1. Hazard vs Risk

Upon successful implementation of the initial Program (foundational data and CIP prioritization), MHFD and its LG partners will be able to:

- Provide consistent, Districtwide flood hazard and risk information, including pluvial flooding.
- Communicate flood risk clearly and drive risk-informed action.
- Identify projects that reduce the greatest amount of risk with the most efficient use of funding.
- Implement a portfolio-management approach that considers the full District or LG jurisdictions, rather than individual watersheds in isolation.
- Right-size investments by balancing risk reduction and cost.
- Track estimated risk reduction and losses avoided after project construction.

The Program aligns with MHFD's mission to reduce flood risk and protect people, property, and the environment. It complements basin master planning by adding a quantitative evaluation layer to support planning recommendations. It also supports major system planning by enabling a comparison between corridor-scale projects and local mitigation efforts. Rather than a one-time study, the Program functions as an ongoing decision-support tool. Hazard and risk information will be refreshed following major project completions and model input changes, so the CIP portfolio reflects current data.

1.2 Program Need

The goal of this Program is to support clear, defensible decisions about which CIP projects to prioritize for funding, which is a challenging task today. There are significantly more proposed projects than available funding. As of 2025, more than 2,400 problems have been identified across the 1,600 sq. mi. District, representing a CIP backlog exceeding $3 billion. With an annual budget near $60 million, this would take more than 50 years to address current needs —without considering future demands. Given these constraints, one primary application of the Program is to best steward limited resources by identifying the most cost-effective projects for prioritization in funding — maximizing risk reduction with the available funding.

The current project selection process is often subjective, varies from year to year, differs between LGs, and does not always clearly tie to supporting information. While prioritization can be challenging within a single watershed, it becomes even more difficult across-basins and local jurisdictions, where projects are often compared without a consistent framework. The main offering of the Flood Risk Program to assist in a data-driven CIP prioritization is to provide a robust dataset to draw upon, as contrasted with today's variable datasets in Table 2.

Table 2. Supporting Data for Decision Making: Today vs. Flood Risk Program

Today's Environment	Flood Risk Program
Limited insights, capabilities, consistency, and coverage	***Robust, consistent, objective, and informational***
• Developed inconsistently over multiple decades using varying methodologies and evolving base inputs • Presented and aggregated using different schemas, approaches, and statistical frameworks • Incomplete coverage, limited to select riverine reaches and does not include pluvial flooding • Zone-based, binary hazard floodplain mapping	• Developed using a single, standardized method applied Districtwide within a focused timeframe, using shared data sources and inputs • Presented and aggregated in a unified schema with pre-defined, consistent statistics • Districtwide coverage, including both recent pluvial and fluvial information • Site-specific graduated hazard and risk information

1.3 Description of Program Capabilities

At full maturity, Flood Risk data will be accessible through an intuitive, interactive viewer (described further in Section 4.5). Key findings, recommendations, and resulting actions will be summarized in an annual report and supporting data bundle. The Flood Risk Program will serve as a source of consistently derived flood information across the District for MHFD project managers and LG partners. It will support estimation of risk reduction from proposed projects, enable informed project selection to optimize mitigation, and allow measurement of overall Program effectiveness. Ultimately, this Program and its data will enable decision-makers to objectively prioritize funding for the most effective investments in flood risk reduction. The core operational components of the Flood Risk Program are listed in Table 3.

While the primary purpose of the Program is to support flood risk-informed decision making and CIP prioritization, MHFD anticipates that lessons learned through Flood Risk may also inform future planning, mapping, and modeling programs. The nature of those relationships will continue to be evaluated as the Program matures.

Table 3. Summary of Program Components

Foundational Data (Existing Hazard & Risk)	Project-Level Risk Reduction Analysis	Capital Prioritization	Data and Documentation Deliverable
Interactive web viewer layer for full District	Interactive web viewer layers per project	Investment analysis reporting	Basin-Level Data Bundle
• Receptors (people as estimated by buildings and transit) • Flood hazard products • Flood risk products • Aggregated scores	• Project footprints • Post-project hazard • Post-project risk • Relative risk reduction • Supporting datasets as overlays (community values)	• Risk reduction per dollar invested by project • Highest to lowest flood risk project list • Annual report on total risk, prior year investments and risk reduction, and forecast.	• Technical Memorandum • Receptor dataset • Centralized geodatabase for existing conditions • Centralized geodatabase for post-project conditions • Ranked projects by relative risk reduction

1.4 Guiding Principles

Program implementation will adhere to the following guiding principles, which MHFD jointly developed with its LGs partners (further described in Section 2.3):

1. **Clarity, Accessibility, and Transparency** – flood risk information shall be clear, visual, and accessible to all audiences. Methods, assumptions, and findings should be openly available and easy to interpret to support informed community decision-making.
2. **Integrated, Multi-Dataset Decision Support** – the Program shall be designed to integrate with existing systems (e.g. emergency response, planning, and design) and incorporate relevant datasets such as transportation, land use, development, equity, safety, and community priorities to support holistic decision-making.
3. **Consistent and Defensible Technical Standards** – the Program shall establish and publish consistent standards for hydrologic and hydraulic modeling, mapping, and risk assessment at a regional scale, including documented assumptions, level of detail for pluvial and fluvial flooding, level-of-service criteria, and appropriate factors of safety for regulatory applications.
4. **Define Policy and Regulatory Flexibility** – regulatory authority shall remain at the state and/or local level. Pluvial flood risk data shall not be regulated as FEMA floodplains but may be regulated locally, while

fluvial data could become FEMA regulatory if desired. Communities retain decision-making authority, with MHFD providing guidance and optional template ordinances (pluvial is local only, fluvial is case-by-case).

5. **Lifecycle Management and Program Sustainability** – the Program shall include clear procedures for model maintenance, data updates, and revisions to ensure information remains current, reliable, and responsive to changing conditions and community needs. Continuous improvement shall be achieved through structured review cycles and documented decision tracking.
6. **Adaptive Implementation and Continuous Improvement** - The Flood Risk Program shall be implemented using the best available methodologies and guidance while recognizing that technical approaches, workflows, and tools will continue to evolve. Lessons learned through implementation, validation, technological advancement, and stakeholder feedback shall be incorporated through structured review and continuous improvement processes. Additional applications beyond the current plan (foundational data and CIP prioritization) may be incorporated into this Plan as they take shape and the Program continues to mature.

2 Program Administration and Outreach

Program administration establishes the management framework, authority structure, and communication protocols needed to execute the Flood Risk Program. Given the Program's scale and multi-year duration, centralized oversight and documented decision-making are essential to ensure consistency and maintain institutional continuity. The Program also includes a deliberate focus on building organizational buy-in through change management and stakeholder outreach. A key part of this effort is ensuring a clear understanding of the applications or use-cases this Program supports, as well as those it does not.

2.1 Program Stakeholders and Responsibilities

The Flood Risk Program involves multiple stakeholders and partners responsible for its development, implementation, and ongoing execution, as shown in Figure 2 and described below.

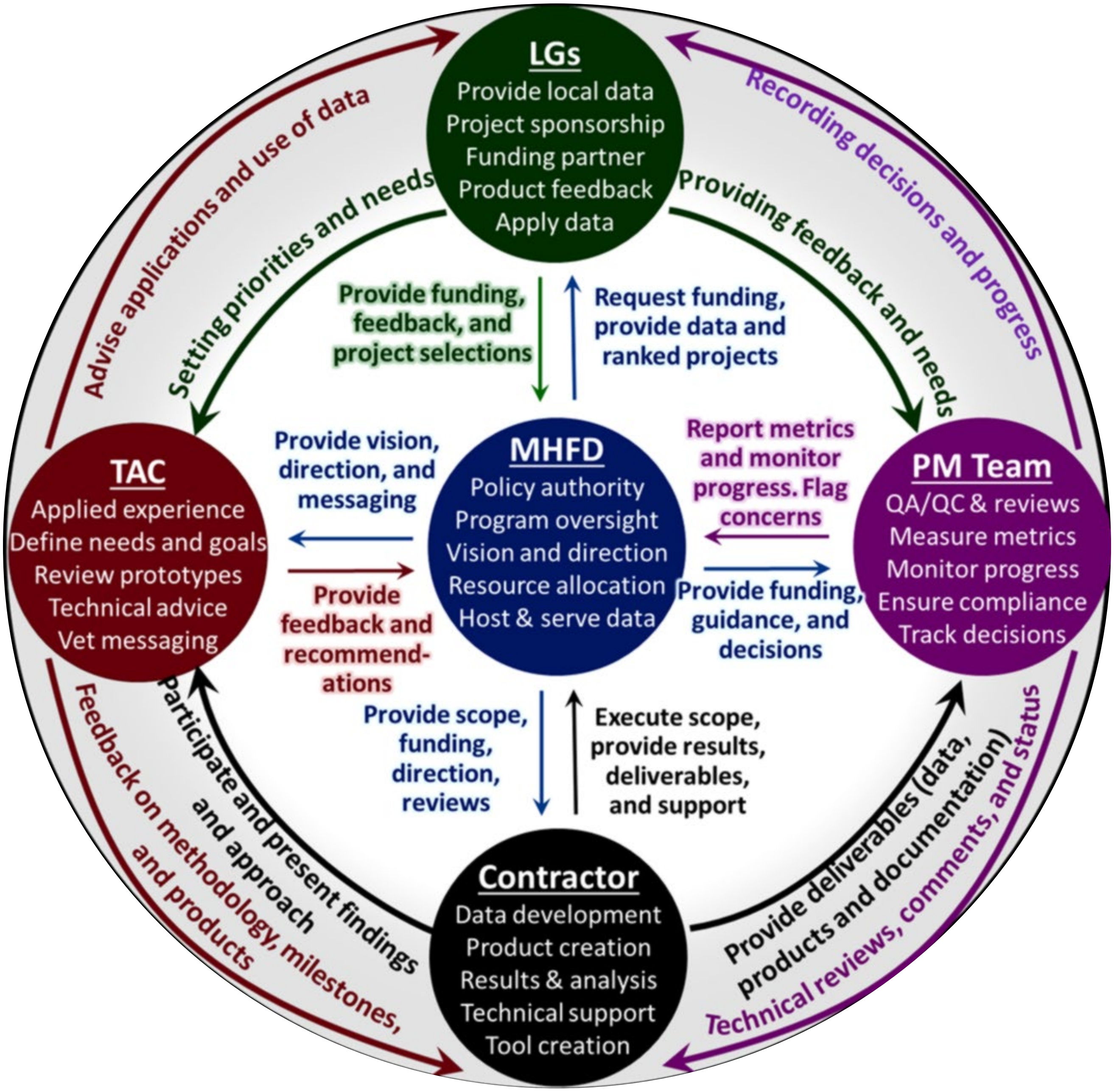


Figure 2. Program Stakeholders, their Roles, and Interactions

The Program is overseen and implemented by MHFD, with primarily leadership from the Program Manager and support from executive leadership, planning, floodplain management, and project managers. LGs play a key role throughout the Program. They help vet major components of methodology and guidance, identify end use applications, contribute funding and oversight for studies, prioritize projects for funding, and ultimately translate results into risk reduction outcomes.

Much of the Program is carried out by contractors. Their work focuses on data development and framework implementation, guided by MHFD direction, with additional support in testing and refining Program components. Flood Risk contractors also assist MHFD with operational oversight, organization, and quality assurance/quality control (QA/QC), as described further in Section 5.3. Technical Advisory Committees (TAC) may provide strategic input on an as-needed basis for targeted issues, including reviewing methods, results, and messaging at key milestones. The TACs are a voluntary collaboration team comprised of experienced staff from MHFD, LGs, and Contractors.

2.2 Change Management and Organizational Buy-In

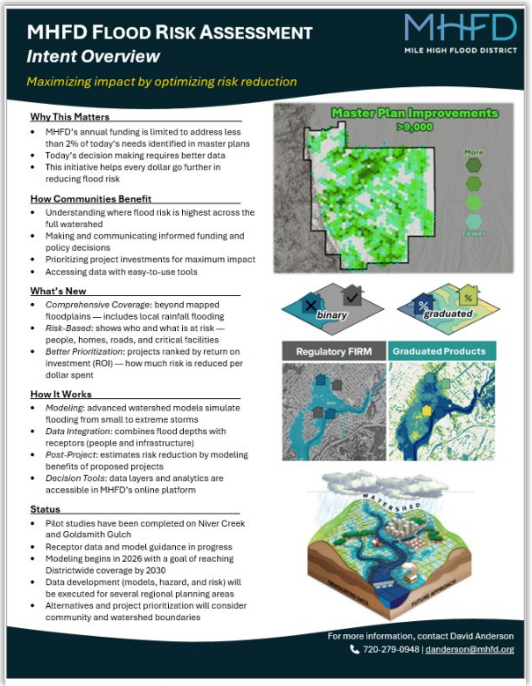
The Flood Risk Program represents a significant shift from traditional, watershed-specific studies with varied methods and products to a unified, quantifiable, risk-informed investment approach. This transition is not only technical but programmatic, and its success depends on strong organizational alignment across MHFD and participating LGs. Effective change management must be intentional and structured to ensure the Program is understood, trusted, and meaningfully applied.

While the approach for developing foundational data is well established and documented in this Plan, the applications of that data will continue to evolve through open engagement, collaboration, and feedback. As described in Section 2.4, this will require ongoing Program outreach through meetings, surveys, workshops, and other stakeholder interactions.

Each engagement should emphasize the specific benefits and values the Program provides to that stakeholder. Communication should also clearly distinguish between what is changing (and when) and what remains the same. Major changes to the current framework should be supported by a clear rationale tied to improved outcomes, increased efficiency, or enhanced capabilities; an “improved technical approach” is not sufficient justification for change.

Internally, the Program requires coordination across project managers and key disciplines, including planning, engineering, floodplain management, IT, design/construction/maintenance, flood warning, and GIS and Data Analysis. To support this alignment, regular cross-disciplinary meetings will reinforce shared terminology, clarify methodology, review metrics, track progress, and evaluate how the Program products integrate with existing workflows (e.g., basin master planning and design). Ongoing leadership engagement is also essential, with periodic briefings for Directors and senior managers that highlight the Program vision, expected outcomes, and resource implications. At each touchpoint, communications should clearly articulate “why” the Program exists—maximizing risk reduction per dollar invested—before describing “how” it works.

For District project managers and technical staff, building buy-in requires transparency and active participation. Internal discussions, concise fact sheets, and open forums create opportunities to surface concerns, identify challenges, and refine guidance. Training and demonstrations should focus on practical application rather than abstract concepts, showing how risk scores support defensible project recommendations. Feedback mechanisms, such as comment logs and lessons-learned workshops, ensure staff input is captured and incorporated where appropriate.



MHFD FLOOD RISK ASSESSMENT

Intent Overview

Maximizing impact by optimizing risk reduction

Why This Matters
- MHFD's annual funding is limited to address less than 2% of today's needs identified in master plans
- Today's decision making requires better data
- This initiative helps every dollar go further in reducing flood risk

How Communities Benefit
- Understanding where flood risk is highest across the full watershed
- Making and communicating informed funding and policy decisions
- Prioritizing project investments for maximum impact
- Accessing data with easy-to-use tools

What's New
- *Comprehensive Coverage*: beyond mapped floodplains — includes local rainfall flooding
- *Risk-Based*: shows who and what is at risk — people, homes, roads, and critical facilities
- *Better Prioritization*: projects ranked by return on investment (ROI) — how much risk is reduced per dollar spent

How It Works
- *Modeling*: advanced watershed models simulate flooding from small to extreme storms
- *Data Integration*: combines flood depths with receptors (people and infrastructure)
- *Post-Project*: estimates risk reduction by modeling benefits of proposed projects
- *Decision Tools*: data layers and analytics are accessible in MHFD's online platform

Status
- Pilot studies have been completed on Niver Creek and Goldsmith Gulch
- Receptor data and model guidance in progress
- Modeling begins in 2026 with a goal of reaching Districtwide coverage by 2030
- Data development (models, hazard, and risk) will be executed for several regional planning areas
- Alternatives and project prioritization will consider community and watershed boundaries

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Figure 3. Example Flysheet Resource

External buy-in from LGs is equally important and should emphasize alignment rather than compliance. Messaging should reinforce that the Program informs decision-making but does not replace local authority or policy discretion. Workshops and annual briefings can demonstrate how risk metrics support CIP, strengthen grant applications, and improve communication with elected officials. Early, tangible examples—such as side-by-side project comparisons—help translate methodology into actionable insight.

Program materials should be developed as standardized, layered communication tools that make technical concepts accessible while maintaining technical defensibility. Core materials should include concise, graphics-based fact sheets (one or two pages) similar to Figure 3, covering topics such as hazard versus risk, risk reduction per dollar, appropriate use and limitations, core methodology components, and example applications. A dedicated webpage should host reports, products, data, FAQs, glossaries, and annual updates. All materials should use consistent terminology, graphics, align with MHFD branding, and clearly state planning-level intent and regulatory limitations to avoid misinterpretation. The content should be tailored to specific audiences—executive summaries for decision-makers, technical briefs for practitioners, and plain-language summaries for the public— and updated at least annually to reflect new data, methodological updates, and documented outcomes.

Ultimately, the success of the Program's change management efforts will be measured not by awareness alone, but by adoption and integration into routine decision processes, as outlined in Section 5.1. Sustained communication, consistent leadership messaging, transparent methodology, and visible integration into capital planning cycles will be key to long-term adoption.

2.3 Summary of Prior Outreach and Feedback

This Plan builds on extensive coordination and stakeholder input, particularly related to policies, decision-related thresholds, and technical requirements. The Flood Risk Program has been shaped by LGs, internal MHFD staff, and technical stakeholders through a structured series of coordination efforts, technical workshops, pilot applications, and stakeholder engagements conducted between 2024 and 2026. These efforts were designed to test the methodology, clarify Program objectives, gather feedback from LG partners, and align expectations prior to formalizing this Plan.

Initial outreach focused on building awareness by introducing high-level concepts at venues such as CASFM and the MHFD Symposium. Engagement then shifted to targeted feedback from LGs through specific informational sessions, surveys, interactive meetings, and structured LG workshops. In parallel, MHFD conducted internal coordination sessions with leadership and study managers to evaluate how the Program aligns with and supports related District initiatives. Collectively, these activities informed the policies, management approach, and technical direction reflected in this Plan.

Across these efforts, consistent feedback emphasized the need for the Flood Risk Program to:

- Integrate with local capital planning processes,
- Provide technically defensible modeling results,
- Improve communication of flood risk and mitigation benefits; and
- Support project justification to decision-makers.

2.3.1 Surveys and LG Meetings

As part of early Program development, MHFD conducted targeted surveys of LG partners to better understand how graduated flood risk data could be used and where gaps exist in current flood hazard and communication tools. Three surveys were distributed based on roles, with responses received from:

- 17 decision-makers (e.g., stormwater managers, engineers, CIP managers, planning staff, and public works leadership)
- 11 floodplain managers
- 4 emergency managers.

The surveys focused on:

- Current uses of flood hazard information
- Challenges in project prioritization and risk communication
- Potential applications of an MHFD-developed Flood Risk Program.

Results are summarized in Table 4, which outlines feedback themes and corresponding Program implications by category.

Table 4. Summary of LG Survey Feedback

Category	Current Management Challenges	Flood Risk Program Implication
Communication and Terminology	A consistent theme across responses was the challenge of communicating flood risk to the public. Respondents pointed to overly technical language, inconsistent terminology across agencies, and confusion caused by overlapping flood products. Floodplain managers noted that limited public awareness and misunderstanding of floodplain concepts remain ongoing barriers to effective communication. Communicating flood risk outside FEMA-mapped floodplains was identified as especially difficult.	The Program must clearly distinguish between hazard and risk, use consistent terminology, and provide accessible communication-ready outputs that address flooding both within and beyond FEMA regulatory areas.
Conflicting Information Sources	Respondents highlighted confusion stemming from multiple sources of flood information, including FEMA maps, local 2D studies, pluvial analyses, and third-party tools that may present inconsistent risk levels. This complexity makes it harder for professionals to make informed decisions and for the public to clearly understand flood risk.	The Program must establish a consolidated, defensible, and clearly documented methodology that reduces ambiguity, creates intuitive products, and supports consistent messaging across jurisdictions. The Program must differentiate its non-regulatory products and decision-support intent from FEMA's regulatory.
Capital Planning and Project Prioritization	Survey questions directed to decision-makers and CIP managers focused on challenges in project prioritization and the potential value of tracking losses avoided. Responses showed interest in risk-based tools that support capital investment decisions, help justify projects to elected officials, and quantify the benefits of mitigation in measurable terms.	The Program should provide quantifiable metrics—such as risk reduction per dollar invested—that can be directly incorporated into CIP discussions and used to communicate return on investment.
Emergency Management Applications	Although emergency manager responses were limited, the available feedback highlighted the value of flood estimates for extreme weather events, integration of gage data, and tools that support early detection and emergency response planning.	While the primary purpose of the Program is capital prioritization, its outputs should be structured to also support operational planning where feasible and appropriate.
Resource Constraints for Public Engagement	Respondents noted limited staffing and resources for proactive flood risk communication and engagement. Even where risk information is available, agencies face challenges in delivering it effectively and consistently to the public.	The Program should emphasize usability, standardized reporting templates, and communication-ready products that reduce the burden on local staff.

The LG survey responses reinforce several key design criteria for the Flood Risk Program:

- A clear distinction between hazard and risk;

- Consistent, defensible technical standards;
- Transparent, communication-ready outputs;
- Applicability beyond FEMA-mapped floodplains;
- Quantifiable metrics to support capital prioritization;
- Consideration of emergency planning applications; and
- Sensitivity to local resource constraints.

2.3.2 Local Government Workshops

In addition to community-specific meetings and surveys, MHFD convened LG workshops on November 18, 2025 and on March 10, 2026. Attendees included representatives from Adams County, Arvada, Aurora, Boulder, Boulder County, Commerce City, City and County of Denver (CCD), Jefferson County, Lakewood, Littleton, Southeast Metro Stormwater Authority (SEMSWA), and Westminster, along with MHFD leadership and contractors. Both workshops were designed to gather feedback and align LGs and MHFD on the Flood Risk Program's objectives, implementation approach—including scope, schedule, and cost sharing—and high-level methodology for modeling and risk scoring.

These workshops addressed core Program components including:

- Communicating Program objectives, recent progress, and current status.
- Jointly crafting the guiding policies (see Section 1.4).
- Selecting a phased implementation approach for Districtwide production, rather than watershed-specific studies (see Section 3.3).
- Reporting out on the schedule and contributions of ongoing work in the validation basins.
- Discussing technical aspects of the modeling methodology, including calibration, mesh resolution, structure representation, land cover assumptions, and storm sewer representation.
- Formulating the risk scoring methodology, including appropriate values for receptor impact factors and hazard thresholds (Sections 4.1.1 and 4.1.3, respectively).
- Identifying the communications needs, engagement structure, and levels of participation (e.g., Inform, Consult/Involve, and Collaborate).

2.3.3 Community Preference on Modeling Software

Several discussions have taken place with select LGs (Boulder, CCD, Lakewood, SEMSWA, and Westminster) regarding the choice of modeling software within their jurisdictions, specifically between HEC-RAS or InfoWorks ICM. While many of these were informal conversations, the topic was discussed in depth during a portion of the March 10, 2026 LG Workshop and at a dedicated meeting on April 1, 2026. Overall, there was broad agreement that recent improvements to HEC-RAS—particularly in modeling underground sewer systems— are sufficient to meet MHFD Flood Risk objectives. In contrast, the more advanced sewer capabilities available in ICM were determined to be unnecessary for this Program and would result in increased cost and schedule impacts if fully implemented. This conclusion was supported with the release of HEC-RAS v6.7 and is even more applicable following the release of HEC-RAS v7.0 on April 17, 2026.

MHFD established a preference for HEC-RAS as the default modeling platform. However, the Program will support the development and integration of ICM models where preferred by individual communities provided that transitions between modeling domains are logical and do not disrupt Program objectives. In cases where MHFD develops ICM models, they will be built to a level of detail appropriate for Flood Risk objectives. This level of detail is less granular than typical ICM applications, which are typically designed to evaluate local stormwater system capacity and support design decisions. MHFD will oversee development of these models to this Program-specific level and then deliver them to the LGs, who may choose to further refine the models at their own discretion and expense. Additional discussion on the use of ICM, including a map of proposed model coverage, is included in Section 4.1.2.

2.3.4 Summary of Key Takeaways

Engagement through Spring 2026 yielded the following key takeaways that directly inform this Plan:

1. Strong support for transparent and defensible technical standards, both for modeling and risk scoring.
2. The need for essential alignment with LG CIP processes and clear, communicable benefits to support project justification.
3. The importance of modeling fidelity, particularly in representing storm sewer systems and their influence on pluvial flooding.
4. Sensitivity to regulatory implications, with Flood Risk remaining a planning-level tool; regulatory adoption should be limited to major drainages (fluvial) where appropriate and voluntary.
5. The value of measurable, people-centered flood risk scores, supplemented by simplistic economic loss metrics.
6. The importance of ongoing, structured engagement, including a supporting TAC as needed and regular communication forums.

2.4 Proposed Ongoing Program Outreach

The Flood Risk Program is a multi-year initiative that will influence capital planning, intergovernmental coordination, and potentially regulatory applications across the District. Sustained, proactive engagement is therefore essential to maintain alignment, reinforce transparency, manage expectations, and ensure consistent implementation. This section establishes a structured stakeholder communication plan, including engagement tiers, communication cadence, formats, and key messaging objectives.

Stakeholders and Involvement

Several stakeholder groups support the Program, as described in Section 2.1 and Figure 2. These include:

- <u>*LG staff*</u>: floodplain administrators, public works directors, CIP managers, planning directors, stormwater utility managers, technical modeling staff, emergency managers, and when appropriate, elected officials.
- <u>*MHFD staff*</u>: planning, DCM, project management, GIS, Data Analysis, and senior leadership.
- <u>*Contractors*</u>: production and data development, program management support and QA/QC, and strategic advisory.

Following the March 10, 2026 LG workshop, participants identified their preferred level of engagement:

- <u>*Inform*</u>: receive deliverables and communication updates.
- <u>*Consult/Involve*</u>: participate in quarterly progress meetings, workshops, and surveys.
- <u>*Collaborate*</u>: actively participate in the TAC when needed, consensus building, and participatory decision-making, with potential for delegated input.

These levels determine the degree and frequency of engagement. Participants may adjust their level on a quarterly basis.

Engagement Objectives

In addition to regular communication between MHFD and its LG partners, MHFD will provide program updates on a semi-annual or annual basis to cover implementation status (completed, active, upcoming, and on-hold basins); updates to foundational datasets (e.g., new terrain or land cover); recent methodological clarifications key challenges and examples of how results inform CIP decisions. These updates are intended to keep stakeholders informed of progress and technical developments. Ongoing engagement is intended to:

1. Promote a consistent understanding of how flood risk is defined, calculated, and applied in capital prioritization.
2. Maintain alignment between MHFD's risk-based approach and LG CIP processes.
3. Ensure transparency in methodology updates, scoring changes, and recalculation triggers.
4. Equip LGs with tools to communicate flood risk and mitigation benefits to decision-makers and the public.
5. Establish structured feedback loops that support program refinement without compromising consistency.

Communication Formats

A range of formats will be used to meet diverse stakeholder needs:

- *Presentations*: for major updates, annual summaries, and CIP alignment discussions. These briefings will include visual graphics, ranking tables, and clear explanation of scoring logic.
- *Technical Memoranda and Pre-Reads*: concise documentation distributed in advance of workshops or TAC meetings.
- *Executive Summaries and Fact Sheets*: designed for use by MHFD project managers and LGs when communicating with elected officials and the public.
- *Program Dashboard and Resource Library*: a centralized repository for methodology documents, FAQs, reports, products, and data files.

Core Messaging Themes

To ensure consistency, all communications should reinforce the following:

1. The Program includes a suite of products for existing flood hazard and risk information that are non-regulatory and provide considerable value in supporting planning, floodplain management, CIP prioritization, and other end use applications.
2. Risk reduction per dollar is a comparative metric to inform CIP prioritization decisions, but may not be the primary driver and does not replace policy judgement or other LG factors.
3. MHFD Flood Risk is human-centric, prioritizing people over property and focusing on safety and life disruption rather than only economic loss.
4. The methodology is consistent Districtwide to support comparable and defensible results.
5. Outputs are planning-level and should be refined as needed for other applications, such as design.

Use Case Demonstrations

At least annually, the Program will present use case demonstrations that highlight how the data and products can be applied to typical planning tasks. Initially this might focus on how the foundational data can be used to evaluate flood hazard and risk outside of the SFHA. Once more mature, a simple demonstration of CIP prioritization might be comparing two candidate projects in the framework of risk reduction per dollar paired with additional decision factors for a LG (e.g., development plans, open space, community values, etc.). Once further fleshed out, additional applications can be illustrated, such as flood warning, alternate hydrology, and design.

When possible, examples should be tailored to different stakeholder perspectives, such as:

- *City engineers*: technical rigor, defensibility, mitigation impact.
- *Elected officials*: return on investment, community benefit, and public visibility.

- *Planning directors*: integration with land use and shared spaces.

2.5 Fit for Use Applications and Regulatory Considerations

The MHFD Flood Risk Program has focused most of its past development on risk identification, screening-level planning, and CIP prioritization, but the Program is likely to support additional future applications, as shown in Table 5. As these additional end uses are identified, explored, and developed, this Plan or other documentation may be expanded to include their methodology and approach.

While the Program is not part of the regulatory process and does not automatically lead to regulatory mapping, it provides foundational models that could be modified for such purposes. Table 6 summarizes key differences between the MHFD Flood Risk modeling approach and FEMA's regulatory protocols. Pluvial mapping (overland flooding) should remain a non-regulatory, locally referenced dataset. In contrast, fluvial (riverine) mapping may be considered for regulatory use on a case-by-case or opt-in basis depending on community needs and data maturity, using pseudo-steady state (PSS) riverine models (see Section 4.1.2). This approach allows the Flood Risk Program to remain flexible and focused on its primary role as a planning and capital prioritization tool, while also enabling potential regulatory updates in the future with relatively minimal additional effort.

Table 5. Fit for Use Applications and Program Considerations

<table>
<tr><th colspan="2">Intended Planning Applications</th></tr>
<tr><td>• Identify high-risk areas: Identify flood risk hot spots and problem areas using elevated scores and mapping outputs.
• Inform capital prioritization: Inform CIP prioritization by comparing risk reduction per dollar invested across a portfolio of potential projects.
• Support project justification: Support justification of property acquisition and flood mitigation projects by demonstrating reductions in flood risk and estimated economic losses avoided.</td><td>• Guide planning and studies: Guide master planning and prioritize areas for future study based on high hazard and risk.
• Assess flood risk across jurisdictions: Enable LG officials to assess flood risk both within and beyond regulatory floodplains, which may be outdated or overly conservative.
• Evaluate mitigation alternatives: Evaluate conceptual mitigation alternatives for select watersheds to identify and optimize the most effective options for risk reduction.
• Strengthen grant applications: Support grant applications with additional cost-benefit metrics and supporting modeling.</td></tr>
<tr><th colspan="2">Peripheral Applications with Caution</th></tr>
<tr><td>• Communicating flood hazard and risk: The Program must clearly convey flood hazard and risk both within and beyond regulatory floodplains. A key challenge is that MHFD Flood Risk results may differ substantially from regulatory information, which could lead to confusion or frustration among users without sufficient context.
• Support project design: Provide hydrologic and hydraulic insights that can inform design. These models are based on best available data but include assumptions where data gaps exist. While the modeling resolution and mesh is defensible, assumptions related to structures may need refinement depending on the specific application and data availability.</td><td>• Support emergency planning and response: Provide generalized flood conditions to inform flood warning and emergency response planning. Actual flood events will vary based on rainfall distribution, intensity, and field conditions such as clogged inlets and openings, debris, and channel migration.
• Local adoption of fluvial (riverine) flooding: PSS models are defensibly developed for this specific use case and are compatible with current regulatory framework. However, differences from existing regulatory floodplains should be anticipated if the PSS models are used to develop floodplains, and especially floodway delineations. Often 2D-dervied floodways are expanded, which may be more technically defensible than 1D-derived floodways, but their extension into existing infrastructure can be highly contentious.</td></tr>
</table>

Assessing storm sewer capacity: MHFD Flood Risk models do not represent every pipe or inlet and rely on assumptions to fill data gaps (e.g. invert elevations), which can be extensive. As a result, their use for detailed storm sewer capacity assessment should be approached with caution.	**Inform site development decisions:** Support location selection by illustrating relative flood risk across a parcel (e.g. identifying lower-risk areas). However, results may not reflect current site-specific conditions and may need to be supplemented with updated or local data.
Not Suitable for	
Detailed hydraulic studies for permitting: Not appropriate for development permitting if the model is not regulatory or approved by a local jurisdiction. Even when it is, the model may first need to be updated (e.g., a corrected effective) to reflect current conditions. **Regulatory modifications:** The model should not be used to modify regulatory floodplains or ordinances unless it has gone through the required review, approval, and the adoption process. **Local adoption of pluvial (overland) flooding:** Not recommended for regulatory use, as assumptions are often made in representing the local storm sewer system.[1] Additionally, most agencies (e.g., FEMA, CWCB, MHFD, LGs) do not have established frameworks for regulating pluvial hazards.	**Storm sewer system sizing and design:** Not suitable for detailed system design, as the models include assumptions and simplifications of the storm sewer network. This limitation could be addressed through detailed model refinement if needed. **Property valuations and insurance:** Not intended for use in estimating property values or setting insurance rates under any circumstances. **Non-flood-related demographic analysis:** Receptor data should not be used for unrelated applications (e.g. transportation or general planning), as it was developed specifically to evaluate flood exposure. **Site-specific engineering and grading:** Not appropriate for detailed, site-scale design. These analyses should be conducted at a local scale (acres) rather than watershed-scale models.

Overarching model limitations and considerations for design and development applications include:

- The models represent a snapshot in time, coincident with land cover and LiDAR collection, which may be several years in the past. As a result, they may not reflect current conditions particularly for areas with recent or ongoing (re)development.
- The models rely on best available information but do not include field survey collection and incorporate assumptions to address data gaps. Examples include estimated invert elevations and slopes for storm sewer systems; bridge/culvert dimensions derived from street view and orthoimagery; and/or elevations and stationing from structure inventories (e.g., a note of “two 10’ x 6’ RBCs”).
- A restart file is used to consume unconstructed watershed storage that may be eliminated with future development activities. This is a preferred conservative approach for risk identification, but may unreasonably overestimate peak flows used in design projects. Flood Risk models should be examined and refined before being adopted for other uses cases, such as stream design.

These first two concerns are typically localized to specific areas. Projects located within data-rich areas—particularly those without structural assumptions—can generally proceed using the MHFD Flood Risk models as-is. For projects within areas with data gaps and assumptions, models can be readily refined through targeted, site- or project-specific updates prior to design.

Table 6. High Level Contrast of MHFD Flood Risk and FEMA Regulatory Modeling

Model Components	MHFD Flood Risk	FEMA Regulatory
Structures	Mix of approximations, field measurements, and survey	Every structure surveyed by a professional land surveyor (PLS)
Mesh	Designed for Level E in urban areas and Level C in rural areas (LGs can refine upon own funding and discretion)	Depends on the desired designation: Zone A (Level C) or AE (Level D or E)

Model Components	MHFD Flood Risk	FEMA Regulatory
Floodway	Not developed	Required for most Zone AE reaches
Events	13 design storms from 1 to 1,000 year with use of a restart/hot-start file	6 design storms from 10 to 500 year
Stormwater	All digitized pipes are included with planning level accuracy	Excluded
Receptors	Included as a primary input for decision making	Not included except occasionally as a structure count for reference data
Products	Several bespoke hazard and risk products	Standard floodplains with optional gridded products
Pluvial Flooding	Retained and influential	Excluded from map, provided as supplemental information
Flood Risk Scores	The main focus of the Program and used for CIP decision making	Not considered

3 Implementation Planning

This section addresses important aspects for planning implementation, beginning with a summary of the need for a new approach and what contributions have been made toward program development, and then turning to an overview of what the scope entails, how it will be executed (phased and sequenced), at what cost, by whom, and over what period of time. This section is about planning out the work, whereas how to execute the work (implementation methodology) is covered in Section 4. This section begins with what has been done to date as foundational context for the Plan and then focuses the remainder on the typical key management aspects: scope, cost, resources, and schedule.

3.1 A Revised Hydrologic and Hydraulic Approach

In order to achieve the program vision and functionality outlined in Section 1, as well as the applications and desired capabilities summarized in Section 2, a revised hydrologic and hydraulic approach was needed beyond the traditional workflows. Core to these desired end uses is having a consistent approach to defensibly derive seamless, watershed-wide coverage of depth, velocity, and flood force estimates due to both pluvial flooding (localized overland flooding from rainfall) and fluvial flooding (concentrated flow in drainages greater than 130 acres for the purpose of this Program).

Developing gridded products with watershed wide coverage including pluvial flooding necessitated a new approach different from the traditional workflows used for Flood Hazard Area Delineation (FHAD), which typically derives excess runoff from rainfall via the Colorado Urban Hydrograph Procedure (CUHP), estimates peak flows when routed through the Storm Water Management Model (SWMM), and applies flows to one-dimensional (1D) HEC-RAS models. The traditional approach does not capture pluvial flooding, is reach-specific (not watershed wide), and does not readily produce gridded outputs for the desired variables. Technology advances and an evolving regulatory framework has opened the door to two-dimensional (2D) rain-on-mesh (RoM) modeling. 2D RoM modeling provides insights on pluvial flooding, it reduces the number of assumptions and judgements a modeler needs to make by representing the hydraulics, terrain, and watershed characteristics in higher detail, and readily produces gridded outputs for the desired variables to assess risk. This shifts the focus from a binary "in or out" floodplain designation to a more graduated depiction of flood risk.

To understand the capabilities of RoM modeling in HEC-RAS, starting in early 2023 the District launched a pilot project for RoM modeling in Niver Creek. The Niver Creek Pilot entailed a comprehensive sensitivity study to establish recommended applied approaches for RoM models, assess their potential regulatory use, and evaluate resulting gridded data to inform project prioritization and risk reduction. The study provided clear guidance for RoM modeling regarding mesh construction, resolution and sources for foundational layers, bathymetry, calibration approaches, model equations and tolerance settings, and approaches for hydraulic structures. Significant differences were observed between a prior FHAD approach and the newly constructed RoM model. Additional aspects were further explored in a subsequent RoM pilot in Goldsmith Gulch between mid-2024 through late 2025. Goldsmith Gulch further refined the RoM methodology, particularly for infiltration and underground stormwater infrastructure, and validated some of the fundamental differences in results between the prior FHAD approach and new RoM modeling.

Following these two pilots, the initial H&H guidance document was produced in March 2026 based on early learnings. At that same time, two additional studies were initiated to further refine the methodology at a much larger scale, including Ralston Creek at 90 sq. mi., and Second and Third Creek at 60 sq. mi. The intent was to implement the methodology as developed thus far without additional testing, thus serving as "validation basins". Both basins introduced new conditions, such as steep terrain, heavy regulation, ongoing development, flat terrain with complex flow paths, and significant storm drain systems. These learnings helped shape the revised draft H&H guidance document issued in July 2026. These activities and other key contributions are further described in the Section 3.2.

3.2 Contributions to Methodology and Program Development

The Flood Risk Program has progressively developed through a phased series of investigations, pilot applications, technical refinements, stakeholder coordination efforts, and resource developments largely conducted between 2023 and 2026. These efforts were intentionally structured to test feasibility, refine methodology, validate assumptions, and establish institutional alignment prior to initiating Districtwide production.

The activities completed to date have established the technical foundation and operational scope for full implementation. They also demonstrate a progression from exploratory pilots toward a standardized, production-ready methodology. As noted in Section 2.3, the findings, framework, and Program development to date have been vetted with partners.

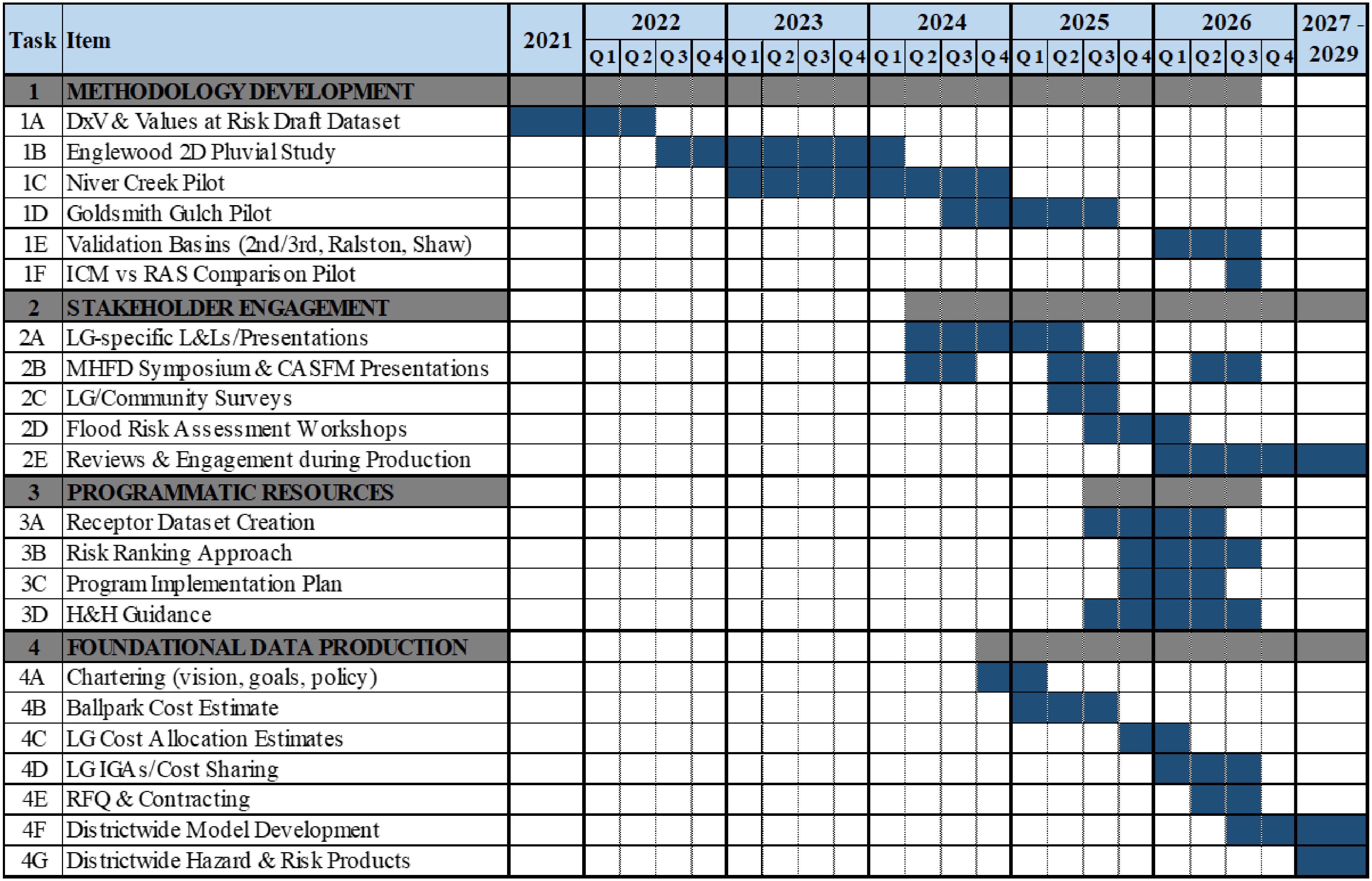
The Program methodology and framework will continue to evolve as MHFD gains implementation experience and evaluates broader applications. This Plan and its supporting guidance documents represent a snapshot in time of the current approach, recognizing that validation efforts and ongoing learning will continue to drive incremental improvements.

As elaborated in Section 3.3, the approach for developing Districtwide existing conditions flood hazard and risk information is more mature than the approach for potential future applications and end uses that may build upon this foundational data. However, sufficient work has been completed to confidently move forward with establishing consistent Districtwide baseline data while continuing to explore future applications..

As detailed in Section 2.5, this Program supports a data-driven decision making framework with numerous future applications, including CIP prioritization, maintenance planning, flood warning enhancements, probabilistic hydrology, planning, floodplain management, and more. The methods for applying this foundational data to future uses are still emerging and will continue to be refined as the Program matures.

The primary development activities supporting the Flood Risk Program are illustrated as a timeline in Figure 4, and are briefly summarized in the following subsections with task references back to line items in Figure 4. The intent is to provide enough context for the remainder of this section (planning) and the next section (methodology) from a programmatic standpoint, but not to adequately summarize technical details. Nearly each effort detailed in this subsection has a standalone technical report with its own executive summary should additional details be of interest.

Figure 4. Flood Risk Program Development Timeline



Task	Item	2021	2022				2023				2024				2025				2026				2027 - 2029
			Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
1	**METHODOLOGY DEVELOPMENT**	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
1A	DxV & Values at Risk Draft Dataset	■	■	■																			
1B	Englewood 2D Pluvial Study				■	■	■	■	■	■	■												
1C	Niver Creek Pilot						■	■	■	■	■	■	■	■									
1D	Goldsmith Gulch Pilot												■	■	■	■	■						
1E	Validation Basins (2nd/3rd, Ralston, Shaw)																		■	■	■		
1F	ICM vs RAS Comparison Pilot																				■		
2	**STAKEHOLDER ENGAGEMENT**											▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
2A	LG-specific L&Ls/Presentations											■	■	■	■	■							
2B	MHFD Symposium & CASFM Presentations											■	■			■	■			■	■		
2C	LG/Community Surveys															■	■						
2D	Flood Risk Assessment Workshops																■	■	■				
2E	Reviews & Engagement during Production																		■	■	■	■	■
3	**PROGRAMMATIC RESOURCES**																▨	▨	▨	▨	▨		
3A	Receptor Dataset Creation																■	■	■	■			
3B	Risk Ranking Approach																	■	■	■	■		
3C	Program Implementation Plan																	■	■	■			
3D	H&H Guidance																■	■	■	■	■		
4	**FOUNDATIONAL DATA PRODUCTION**													▨	▨	▨	▨	▨	▨	▨	▨	▨	▨
4A	Chartering (vision, goals, policy)													■	■								
4B	Ballpark Cost Estimate														■	■	■						
4C	LG Cost Allocation Estimates																	■	■				
4D	LG IGAs/Cost Sharing																		■	■	■		
4E	RFQ & Contracting																			■	■		
4F	Districtwide Model Development																				■	■	■
4G	Districtwide Hazard & Risk Products																						■

3.2.1 Methodology Development

The core of the methodology has been progressively developed through testing, iteration, and refinement across multiple pilots, beginning in late 2021, with a larger focus between 2023 and 2025, and concluding with validating key approaches in 2026 before scaled production. The significant activities include:

1A: DxV & Values at Risk Draft Dataset (Jacobs 2022). MHFD began exploring alternative metrics to characterize flood hazard and methods to assess risk posed to infrastructure. This began with extracting depth times velocity (DxV, or flood force) values from 1D studies and a 2D pilot, to evaluate differentiated hazard zones and infrastructure vulnerability. This study reinforced the value behind flood force and that the traditional binary assessment of inundation (dry vs wet) is insufficient and limiting for decision making.

1B: Englewood 2D Pluvial Study (Dewberry 2022). The prior study (1A above) demonstrated the importance of flood force, which is more readily and defensibly developed using a 2D model with watershed-wide mesh yielding gridded outputs than a 1D model that interpolates between averaged values at cross-sections. Therefore, this study explored the use of 2D and expanded beyond traditional fluvial (riverine) flooding to explore the importance of pluvial flooding (shallow overland flow and ponding). This study revealed that pluvial flooding is a significant driver, but also that pluvial modeling standards were lacking and highly subjective.

1C: Niver Creek Pilot (Michael Baker 2024). By this time, MHFD knew they wanted to account for pluvial flooding through RoM models and so the District launched a comprehensive sensitivity study in Niver Creek (Figure 5) to establish recommended applied approaches for RoM models, assess their potential regulatory use, and evaluate resulting gridded data to inform project prioritization and risk reduction. The study provided clear guidance on mesh construction, resolution and sources for foundational layers, calibration approaches, model equations and tolerance settings, and approaches for hydraulic structures. The sensitivity study suggested that bathymetry is generally insignificant (with exceptions) and that it is important to capture underground storm sewer, which cannot be crudely approximated. The study evaluated various hazard and risk products, and assessed how social vulnerability could be integrated into the analysis.

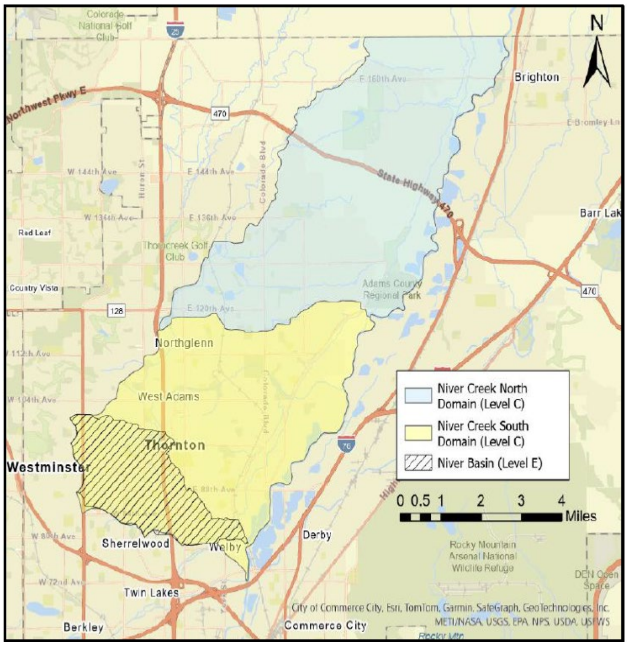


Figure 5. Niver Creek Pilot Study Domain

Major findings that led to additional study included:

- A significant difference in peak flows between RoM modeling and the traditional FHAD hydrologic approach deriving excess runoff from rainfall via CHUP and developing flow hydrographs when routing through SWMM. While the runoff volume was similar, RoM accounted for overland flow paths that muted the response with a longer hydrograph of lower magnitude, as opposed to SWMM which followed channel alignments with lower roughness values that rapidly routed flows to produce fast and flashy hydrographs. These hydrologic differences are further exacerbated in hydraulics when the FHAD takes the high peaking flashy flows and applies them to 1D steady state models (infinite volume over infinite duration), compared to RoM whose hydrology and hydraulics (H&H) are coupled in an unsteady simulation (finite volume over finite duration). This compounding difference was material enough to warrant additional testing in the next pilot (Goldsmith, Item 1D below) and raised questions about the feasibility of using RoM for regulatory applications in the District.
- Recommending the development of a District-specific receptors dataset, custom to the Flood Risk Program's needs (Item 3A) that would have a people-centric approach, not focused on property value.
- Identifying a need for a risk scoring approach (Item 3B), Program Implementation Plan – this document (3C), an H&H Guidance Document (Item 3D), and a Lifecycle Cost Estimate (LCCE) (Item 4B).

- Recommending different infiltration methods be tested, such as Green-Ampt (G&A) and Initial Deficit/Constant Loss, as tested during the Goldsmith Pilot (Item 1D)

1D: Goldsmith Gulch Pilot (Michael Baker 2026a). MHFD selected the Goldsmith Gulch watershed (Figure 6) to selectively test various aspects to address the above recommendations stemming from the Niver Creek project. The primary purpose was to assess whether there would be a similarly significant difference in peak flows from the FHAD (as observed in Niver) and to further refine the RoM methodology, particularly for infiltration and underground stormwater infrastructure. Key takeaways and advancements included:

Figure 6. Goldsmith Gulch Study Domain

- A similar hydrologic difference was observed, confirming the challenge that RoM might present in a regulatory framework along with how to handle other concerns (inadvertent storage, model maintenance, and mapping updates).
- A recommendation to use the CN method for short-duration design storms, and the G&A method for long or continuous events.
- Representing storm sewer in the model has a meaningful impact on estimating pluvial hazard. This project also tested pipes in HEC-RAS, which was released as a beta capability between Niver's end and Goldsmith's start.
- This project was nearly wrapped up around the same time that the initial receptors dataset (Item 3A) was produced, and so this pilot served as a testing ground to evaluate receptor attributes and the flood scoring approach (Item 3B).

1E: Validation Basins (Second/Third, Ralston, Shaw). Due to the considerable number of explorations made and recommendations stemming from Niver, Goldsmith, and programmatic work (Items 2C, 2D, and 3A-3D), a study involving three basins was initiated to implement the Flood Risk methodology as developed thus far with an intent to validate or make final refinements prior to launching Districtwide production. This involved a fast-paced execution of the full methodology to calculate Flood Risk scores in three carefully selected basins, each bringing their own unique aspects to stress test the methodology developed thus far. At the time of this writing, this validation work is anticipated to conclude in July 2026, but has already identified some methodological refinements based on challenges, circumstances, and processes not previously encountered in Niver and Goldsmith.

Second and Third Creek (Figure 7) comprised a combined basin that was notably bigger than prior pilots (at ~60 sq. mi.) and presented very flat terrain involving complex flow paths, which indicated a need for domain expansions and intentional overlaps. Another unique aspect was the mixed land use (agricultural and suburban), which involved a fair amount of irrigation ditches and diversions not previously encountered. Lastly, Second and Third Creek both are experiencing rapid development in the upper portions of their watersheds, proving to be a challenge with reflecting a single snapshot in time. This study leverages several prior and ongoing studies and revealed a challenge in having diverse and at times conflicting datasets across several models and eight storm drain datasets, each from a different LG in a different format. This validation basin helped stress test and refine data hierarchy, metadata, domain boundaries, and how to handle canals and non-levee embankments.

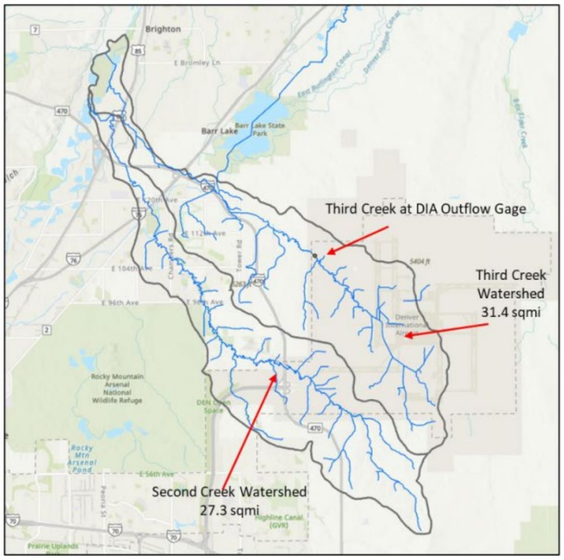


Figure 7. Second/Third Creek Study Domain

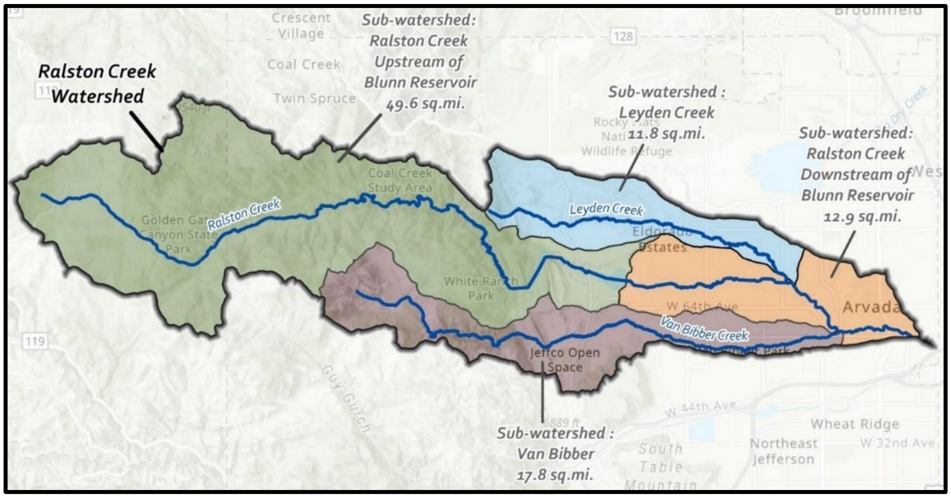


Figure 8. Ralston Creek Study Domain

Ralston Creek (Figure 8) was also much bigger than prior pilots (at ~90 sq. mi.) and as such introduced a number of new aspects including interconnected basins where the overall study was split into five domains. The upper portion of the basin also extends well outside of the District; therefore, accounting for external inflows was a new approach for Flood Risk. Additionally, this basin added another new aspect of accounting for the impact of multiple heavily regulated reservoirs and ponds. This basin also contains a significant number of storm sewer features, steep terrain, and a complex approach to calibration that involves synchronizing responses across several gages on different tributaries. Ralston Creek is the most complex H&H system that Flood Risk has yet modeled and some of the learnings are still in progress. One that is already apparent is the need to make simplified assumptions for type of channel crossing is worthy of a hydraulic structure, as there are multiple greenways and golf courses where small undocumented structures abound.

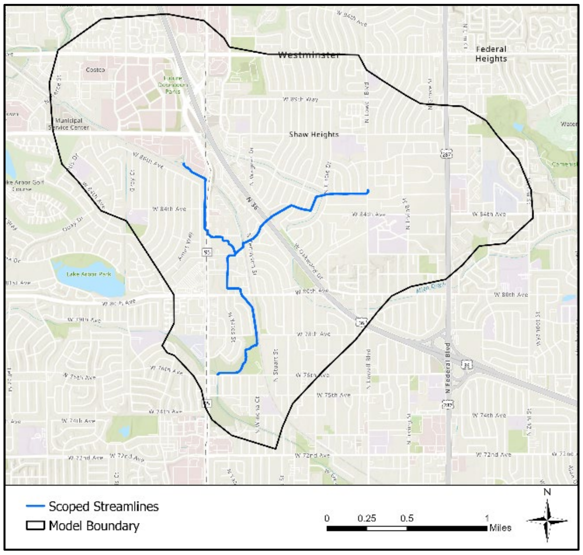


Figure 9. Shaw Heights Study Domain

Shaw Heights (Figure 9) was added as its timing coincided well with a concurrent alternatives analysis project to be informed by the Flood Risk approach. This small basin is heavily urbanized with very large sewer features and "hard engineering" infrastructure not previously modeled in Flood Risk pilots. It is also the only study domain analyzed thus far without any historical records to use for calibration.

1F: ICM vs RAS Comparison Pilot. A recurring discussion topic at workshops and coordination meetings was an interest from some LGs to use InfoWorks ICM as an alternate RoM approach, in lieu of HEC-RAS. This is allowable for the Flood Risk Program as long as the same minimum modeling standards are upheld, and that any extra refinement for expanded use is not borne by MHFD. This pilot is presently underway using a small (<2 sq. mi.) portion of Foursquare Mile watershed (downstream of Cherry Creek Reservoir) to evaluate the incremental cost and benefits realized between varied levels of detail (no sewer, basic sewer, full sewer) and modeling platforms (ICM vs RAS).

3.2.2 Stakeholder Engagement

The Flood Risk Program has been significantly shaped by feedback from and interaction with its LG partners. Section 2.3 thoroughly summarizes this content; therefore, the significant activities from Figure 4 are only briefly captured as follows:

- **2A: LG-specific L&Ls/Presentations.** Many LG-specific meetings were held to build awareness and collect initial feedback in the early stages to help inform objectives and priorities ahead of chartering (Item 4A).
- **2B: MHFD Symposium & CASFM Presentations.** Progressive updates were given at large gatherings of the engineering and floodplain management community with LGs, agencies, and contractors. These included report outs on the Niver and Goldsmith pilots, the overall objectives to and framework for Flood

Risk, how CIP project prioritization might work, and previews of scoring. These are likely to continue with presentations already planned for ASFPM in June 2026 around modeling with storm sewer in the validation basins and on for project prioritization; and then for CASFM in September 2026 around outreach and flood risk scoring methodology.

- **2C: LG/Community Surveys.** These targeted surveys focused on desired functionality, needs, and potential applications to help define Program requirements ahead of chartering and to inform this Plan.
- **2D: Flood Risk Assessment Workshops.** These LG workshops took place on November 18, 2025 and March 10, 2026 to craft governing principles, socialize and vet the overall approach, and achieve alignment on the technical methodology. Notable takeaways included developing the guiding principles (Section 1.4), arriving at a phased approach (Section 3.3), crowdsourcing values for receptor impact factors (Section 4.1.1), and jointly refining hazard thresholds (Section 4.1.3).
- **2E: Reviews & Engagement during Production.** These will take place with greater focus and regularity during future production phases, but have begun in some fashion with the TAC or collaboration team (Section 2.4) and project status reviews associated with the validation basins (Item 1E).

3.2.3 Programmatic Resources

One of the guiding principles (Section 1.4) to the Flood Risk Program is consistency, which necessitates a programmatic structure and accompanying resources that foster standardization and support reproducibility. Significant contributions in this realm include:

3A: Receptor Dataset Creation. A single authoritative dataset of receptors was developed from people-proxy sources including buildings (structures and critical facilities) and transit (roads and trails), as detailed in the receptor methodology memorandum (Michael Baker 2026b) and briefly summarized in Sections 4.1.1 and 4.1.3. In short, the MHFD Flood Risk receptor datasets (buildings and transit) were created by extracting attributes across several public datasets and amalgamating point and polygonal data to arrive at a comprehensive dataset comprised of relevant information for the likely presence of people, and the degree to which they might be impacted. This dataset (Section 4.1.1) is intersected with flood hazard (Section 4.1.2) to arrive at flood risk (Section 4.1.3).

3B: Risk Ranking Approach. The risk scoring and project ranking approach has been progressively developed from the following incremental tests:

- <u>Niver Creek</u>: existing risk scores were developed solely from depth values at buildings and then from a combination of depth, velocity, and flood force for transit receptors. Hazard values were extracted at buildings by centroids and perimeter methods (max value and lowest adjacent grade) and the sensitivity observed. Centroid values were problematic, so the perimeter max was recommended. Buildings were not elevated in the terrain (represented as bare earth), so rendering was not an issue. Hazard values were extracted within road polygons between edges of pavement. Due to noise and rendering, it was deemed best to grab values along the centerline, which also is more realistic in that people can avoid deeper flooded road sides and drive along the crown center of a road when experiencing shallow flooding.

  The scoring approach was simplistic with binned integers of 0, 1, 2, or 3, and there was no use of impact factors. The approach was being developed and so was not yet automated, but fairly manual with spreadsheet calculations. Mitigation projects were identified from the Master Drainage Plans and screened against baseline results for the presence of an existing risk that could be mitigated. The eight retained projects were modeled as hypothetical post-project conditions and the risk scores were recalculated for the full watershed for each project. The difference between existing and mitigated risk (pre- vs post-project) was tabulated and compared to ballpark capital costs for each project to determine which project was most impactful. This process was relatively straightforward and nicely illustrated the desired concept and outcome. This is the only instance of testing or piloting the mitigation modeling approach and risk reduction aspect of the Program thus far. Further testing is recommended prior to beginning risk reduction modeling to better define processes and standards.

- *Highline Canal*: the next test of the scoring and ranking approach was applied to the Highline Canal Stormwater Transition and Management Plan results that were created from a 2D riverine model under a separate project. This leveraged depth, velocity, and flood force rasters for a smaller subset of design storms. Buildings were not elevated in the terrain and the model was riverine (not RoM), so rendering was not an issue. The risk scoring workflow was further built out and implemented in a largely automated fashion. Instead of evaluating mitigation projects, breach areas had been identified, and these were ranked by order of greatest impact off risk scores alone.
- *Goldsmith Gulch*: this pilot afforded significant testing and refinement of risk scoring with several key decisions made. (1) Buildings were initially elevated in the terrain, which introduced rendering issues (cupping) that could not be fully resolved with post-processing. Ultimately it was decided to use bare earth in the RoM models. (2) Sampling at buildings was expanded to include the maximum result residing within a 4-foot buffer from the building footprint, rather than along direct intersection of the footprint. (3) Impact factors were assigned to buildings to account for their relative importance (e.g., a garage being the minimum vs a hospital being the maximum). Initially this was assigned to buildings based on the estimated number of occupants, but ultimately was determined by occupancy type and professional judgement from LGs (see Section 4.1.1). Impact factors were assigned to roads based on estimated traffic. (4) Multiple occupancy types represented within a single building footprint were encountered, evaluated, and addressed by summing impact factors. (5) Scoring values were modified with input from LGs and ultimately changed to linear correlations producing decimals rather than fixed bins with integers.
- *Validation Basins:* data development for this work is still underway, but the final approach used in Goldsmith will be employed here and either validated as-is or further refined. The final approach resulting from testing upon the three basins (Second/Third, Ralston, and Shaw) will be documented and operationalized for full-scale implementation via a shareable notebook or python-based tool.

3C: Program Implementation Plan. The work to produce this document involved considerable iteration, solicitation of input from LGs, workshops, and brainstorming sessions as described throughout this Plan.

3D: H&H Guidance. This provides detailed guidance and step-by-step processes for standardized 2D RoM modeling for the MHFD Flood Risk Program. This was produced following completion of the Goldsmith Gulch work and is currently being revised based on technical review comments (MHFD, LGs, and other contractors) along with recent learnings from the Validation Basins project that is underway.

3.2.4 Foundational Data Production

The following activities assisted in established a structure, cost estimate, and plan for producing Districtwide flood hazard and risk information for existing conditions (see Section 3.3):

- **4A: Chartering (vision, goals, policy).** A few sessions were held with MHFD leadership to identify the Program charter. This helped solidify the Program vision, desired end state, and guiding policies that support and direct subsequent data development activities. This step drew upon prior learnings and observations from pilot projects and crafted a programmatic charter to direct the remainder of Program development, including the commissioning of this Plan.
- **4B: Ballpark Cost Estimate.** This exercise helped distinguish what was ideal from what was feasible, and then to plan for necessary funding by associating approximate costs with Program activities. This process went through a few iterations, with an initial draft in November 2024 to get a sense of what might be reasonably possible. After feedback on what to prioritize, a second draft at the program level was presented to MHFD executive leadership to garner Program support. Following additional feedback, a third draft was presented with options regarding the level of required detail and Program implementation methods. Once detailed assumptions were determined, a fourth and final version was delivered in September 2025 and was structured by Program phase (model build, problem definition, and alternative assessment) grouped by large geographies used as planning areas. This helped visualize how the Program might be operationalized and incrementally funded, as detailed in Section 3.6.

- **4C: LG Cost Allocation Estimates.** Following District budget approval, the production costs from the September 2025 ballpark cost estimate were distributed across the LGs based on their jurisdictional boundaries intersecting the underlying watersheds. Production costs were presented in a detailed spreadsheet with pivot tables in January 2026, and were used to formulate cost sharing requests with LGs (see Section 3.6.3 for details).
- **4D: LG IGAs/Cost Sharing.** The District used the above cost allocation estimate to request a 50% funding match from 31 of the 42 LGs for developing foundational data. The remaining 11 LGs had cost allocations below an established $9,000 threshold and so funding was not requested. MHFD began approaching LGs to establish Intergovernmental Agreements (IGAs) in February 2026 with hopes of finalizing IGAs and securing funding throughout the duration of data development, which is still underway.
- **4E: RFQ & Contracting.** MHFD will issue a Request for Qualifications (RFQ) in July 2026 to contract multiple consultants to begin foundational data production work by September 2026, as further described in Section 5.2. The RFQ will be accompanied by reference resources, including this Plan, a revised 2D H&H Modeling guidance document for HEC-RAS, and the Denver Innovyze ICM Modeling Guidelines for areas with ICM modeling.
- **4F: Districtwide Model Development.** Once contracted, 2D RoM models will be generated in HEC-RAS or ICM across the full District to represent existing conditions with a target completion in 2029, as described in Section 4.1.2.
- **4G: Districtwide Hazard & Risk Products.** Following on the heels of model development, hazard and risk products will be created from model outputs for each watershed, as described in Section 4.2. This will mark the completion of the concerted Districtwide foundational data development push (existing conditions), after which mitigation modeling (post-project) and risk reduction will be handled on a watershed basis per LG request.

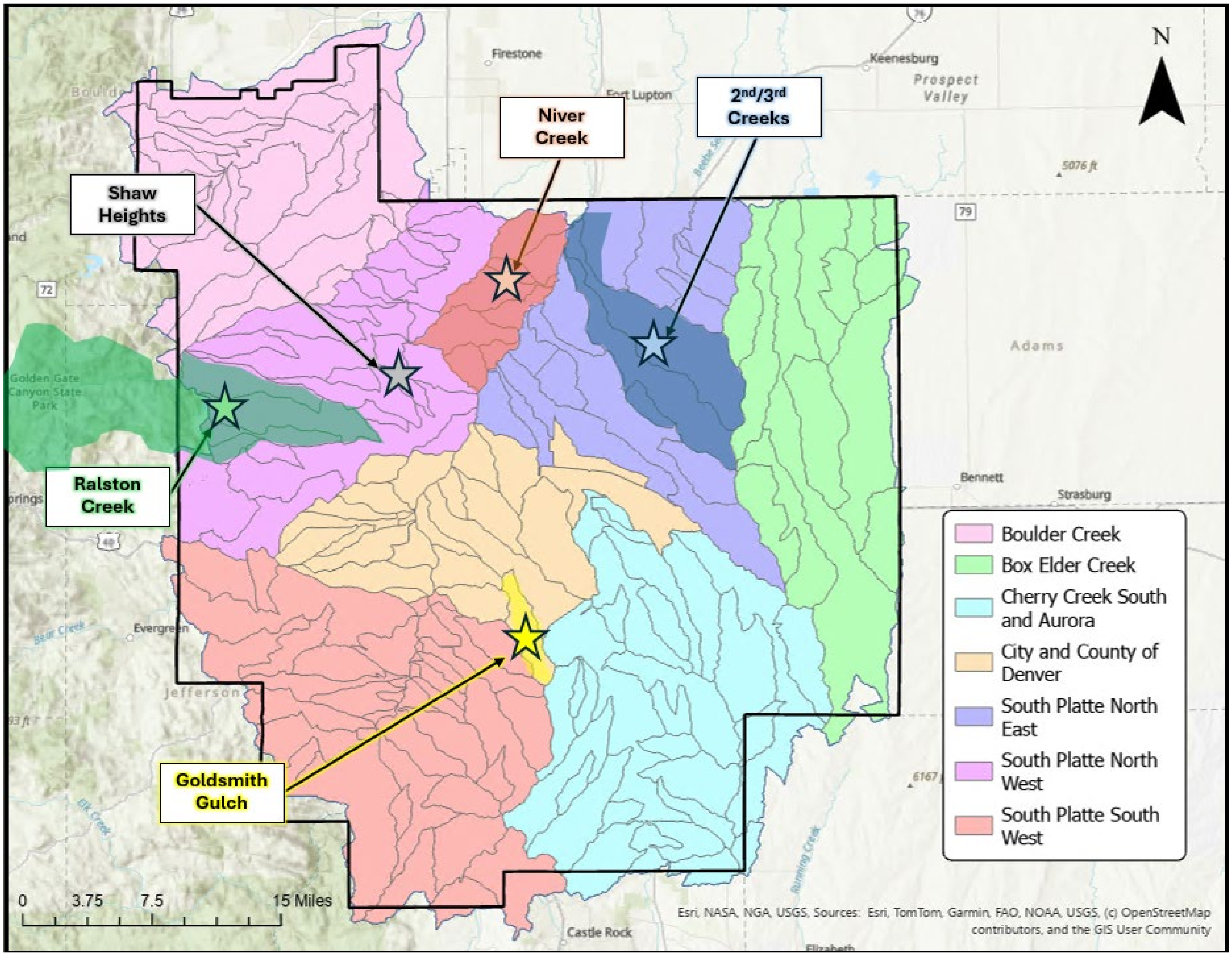
3.3 Summary of Production Scope and Coverage

This section describes the current production plan, which includes a well-established approach for producing foundational data, and a general framework for estimating risk reduction to inform CIP prioritization. Potential subsequent applications (e.g., flood warning, design, enhanced hydrology) are still in the early stages of consideration and premature to include at this time.

- **Foundational Data Development (late 2026 through 2029)**: creating hazard and risk information for existing conditions Districtwide in one concerted effort across approximately 3 years. This produces valuable information to inform planning decisions and improve risk communication, and concludes with an analysis of hotspots for problem area identification and future consideration of potential proposed projects. This foundational dataset also serves as baseline conditions (pre-project) to assess risk reduction (next paragraph) or to leverage for other applications or regulatory updates, as detailed in Section 2.5. The approach for developing foundational data is fairly established based on prior pilots and engagement; however, the initial production will be at a slower pace to allow for intentional learning, methodology refinement, and overall alignment as multiple teams begin work across varied watersheds. Lessons learned from these earlier watersheds will be incorporated into the evolving guidance and workflows, after which production speed can increase in pace with greater efficiency and a lower risk of rework or inconsistency.
- **Risk Reduction for Informed CIP Prioritization (2028+)**: this effort begins with leveraging the foundational data to evaluate proposed projects and screen potential mitigation projects for modeling. The primary focus of this effort is to create hazard and risk information for mitigated conditions (post-project) at select watersheds based on LG interest and funding. These post-project conditions will be compared against the baseline conditions (pre-project) to calculate risk reduction and then divided by project cost to rank mitigation projects by their cost effectiveness. Projects eligible for evaluation under this Program include structural and non-structural measures that produce measurable change in H&H conditions or hazard. Examples include regional detention facilities, channel widening or stabilization

where capacity increases, or bridge or culvert replacements, as further detailed in Section 4.1.4. In contrast to the concerted Districtwide effort for foundational data, this risk reduction modeling is advanced on an as-needed basis and may begin once foundational data are available, additional funding is secured, a clear direction is established, and interest exists for a specific watershed. This might begin for a subset of watersheds in 2028 at the soonest, and may gradually initiate across a portion of watersheds over several years and possibly focus only on particular locations or problem areas and is unlikely to reach Districtwide coverage in the near term. This phase is only generally outlined at this time and subject to considerable change.

Foundational data will be produced at a basin level grouped across several planning geographies to realize economies of scale, as depicted in Figure 10.



Esri, NASA, NGA, USGS, Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, (c) OpenStreetMap contributors, and the GIS User Community

Figure 10. Past Pilots and Planned Production Geographies

Where possible, the modeling domain size should be larger than 5 sq. mi. to avoid too many small basins and to reduce the number of times that modeling tasks are required (setup, refinement, calibration, etc.). This may necessitate collocating several adjacent watersheds in the same model geometry mesh as there are a number of isolated small watersheds. Modeling domains should aim to not exceed 3000 pipe features to avoid cumbersome functionality and excessive run times (i.e., keeping it below 30 hours). Where conditions allow, ideal domain sizes should target between 20 and 30 sq. mi. to produce manageable models that benefit from efficiencies without becoming difficult to work with, except for select circumstances that simplify simulations (e.g., domain expansions outside the District for linked inflows), complex calibration (e.g., integrated reaches with gages), or interconnected flow paths (e.g., like braided channels converging across flat terrain between adjacent domains). With this approach, there are approximately 170 watersheds delineated across the District, beginning with MHFD's watershed delineation areas (last updated January 2024) as shown in Figure 10, that could be grouped together to form somewhere between 55 and 80 independent RoM models depending on balancing model size and functionality/run times.

The full scope of production work will be executed in each of the watersheds, which is detailed in Section 4.1, illustrated in Figure 17, and briefly summarized to include:

- *Receptors*: this dataset has already been developed Districtwide, but may be refreshed/upgraded with local data based on LG preference and funding.
- *Hazard Models*: this constitutes the most significant focused effort of the Program and involves developing 2D RoM models at a watershed level. The majority will be created in HEC-RAS7.0 with a few LG jurisdictions covered by ICM. The existing model inventory will be leveraged, particularly for hydraulic structure information, and recent 2D models will be reused where possible. Table 7 lists 2D models within the District that have already been identified for potential reuse, being relatively recent and larger in coverage. However, this table is incomplete and building a model inventory (including 1D models) should be an early-stage step following the kickoff for each future basin study.
- *Products*: hazard and risk information and products will be developed for existing conditions from post-processed model outputs and hot spots identified. This marks the conclusion of the Districtwide foundational data production effort, but at the outset of risk reduction modeling, these products will be used to evaluate whether additional mitigation projects might be needed, and will form the baseline to compare mitigated conditions (post-project). Risk information will be people-centric; however, simplistic economic losses will be generated as supplemental data for reference purposes, but will not influence risk scores. No regulatory information will be generated and models will not undergo regulatory review as part of the Program, but may be advanced through other initiatives based on LG interest and funding.
- *Risk Reduction*: hazard and risk information will be created for modeled mitigation scenarios (post-project) at particular locations or watersheds based on LG interest and funding. This will be compared to existing conditions (foundational data), to evaluate the net risk reduction per scenario, which will be divided by project costs for an effectiveness ratio that assists with CIP prioritization.

Table 7. Known Recent 2D Models within the District Identified for Reuse

Effort or Entity	Software	Geographies & Watersheds
City of Boulder	ICM	Goose /Twomile Canyon
CCD	ICM	DFA 0064, DFA 0065, North Sanderson Gulch, and Sanderson Gulch
		Weir Gulch Basin
		Valverde Basin (ongoing MHFD OSP)
		Montclair Basins (City Park Basin, Park Hill – Colfax Basin, Park Hill – 6th Avenue Basin)
		I-70 and York Basin
		Central Platte Valley Basin + Central Business District Basin west of Cherry Creek (ongoing study)
		1st and Federal Basin (ongoing study)
		Quebec Corridor Basin (ongoing study)
		Lower Platte Valley Basin (upcoming study)
		36th and Downing Basin (upcoming study)
		Central Business District Basin east of Cherry Creek (upcoming study)
		Harvard Gulch Basin (upcoming study)
		West Harvard Gulch and Ruby Hill Basins (upcoming study)
Goldsmith RoM Pilot	RAS	Goldsmith Gulch

Effort or Entity	Software	Geographies & Watersheds
2nd/3rd RoM Validation Basin	RAS	Second Creek, Third Creek, Airport Drain, and Grass Valley Gulch
Niver RoM Pilot	RAS	Brantner Gulch and Tributary 2
		DFA 0052, 0054, 0056, 0057 and basin 4100
		Grange Hall Creek, Niver Creek, Todd Creek
Ralston RoM Validation Basin	RAS	Leyden Creek, Ralston Creek, Ramstetter Creek, and Van Bibber Creek
Lakewood	RAS	Dry Gulch, Lakewood Gulch, Sloan Lake (upcoming studies)
SEMSWA	ICM	Four Square Mile, Midtown Centennial
		Little Dry Creek Tribs, Dove, Windmill, Lone Tree (ongoing study)

Note: while any prior model should be inventoried and reviewed as a potential data source for new model construction, this table seeks to list only RoM models that are recent and large enough to be readily used without much modification.

3.4 Watershed Study Sequencing

As shown in Figure 10, the District is divided into seven geographies that are hydraulically independent as the larger basin outflows are not inflows for subsequent downstream basins. The exception to this is the major stream network (i.e., South Platte, Bear Creek, and Cherry Creek) whose flows will be determined by other means and are not a direct model linkage for reasons like heavily regulated dams, joint probability, and stream gage records. Therefore, these seven geographies can be executed concurrently without model linking.

Within these geographies, there are instances where upstream basins flow into downstream basins without much alteration (e.g., detention ponds or infrastructure) and without stream gages to inform flows. Therefore, the outflow from the upstream basin will often become the inflow to the downstream basin, adjusted for joint probability as laid forth in the 2D RoM H&H Modeling Guidance (Michael Baker 2026c). This section presents considerations for study sequencing, where modeling should prioritize completion of headwater basins knowing that the downstream receiving basins are dependent on information from upstream basins. Figure 11 presents the individual basins by a suggested order of completion based on hydrologic continuity and uses the terminology "wave" to reflect the order in which a model simulation must be completed. Figure 12 also presents basins by wave, but within the context of geographies to better illustrate basin division.

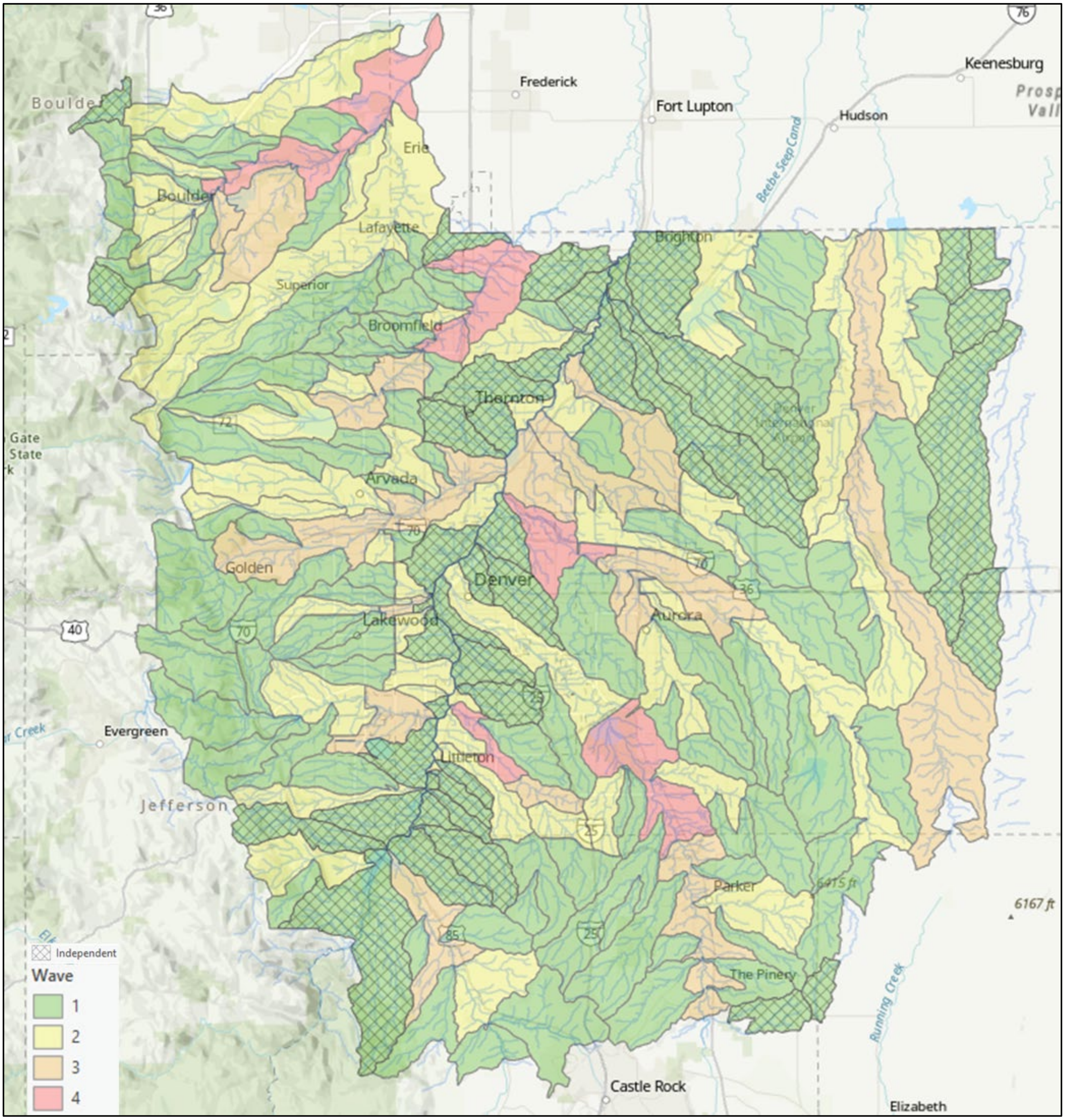


Figure 11. Basins by Production Wave (Reflecting Hydrologic Dependence)

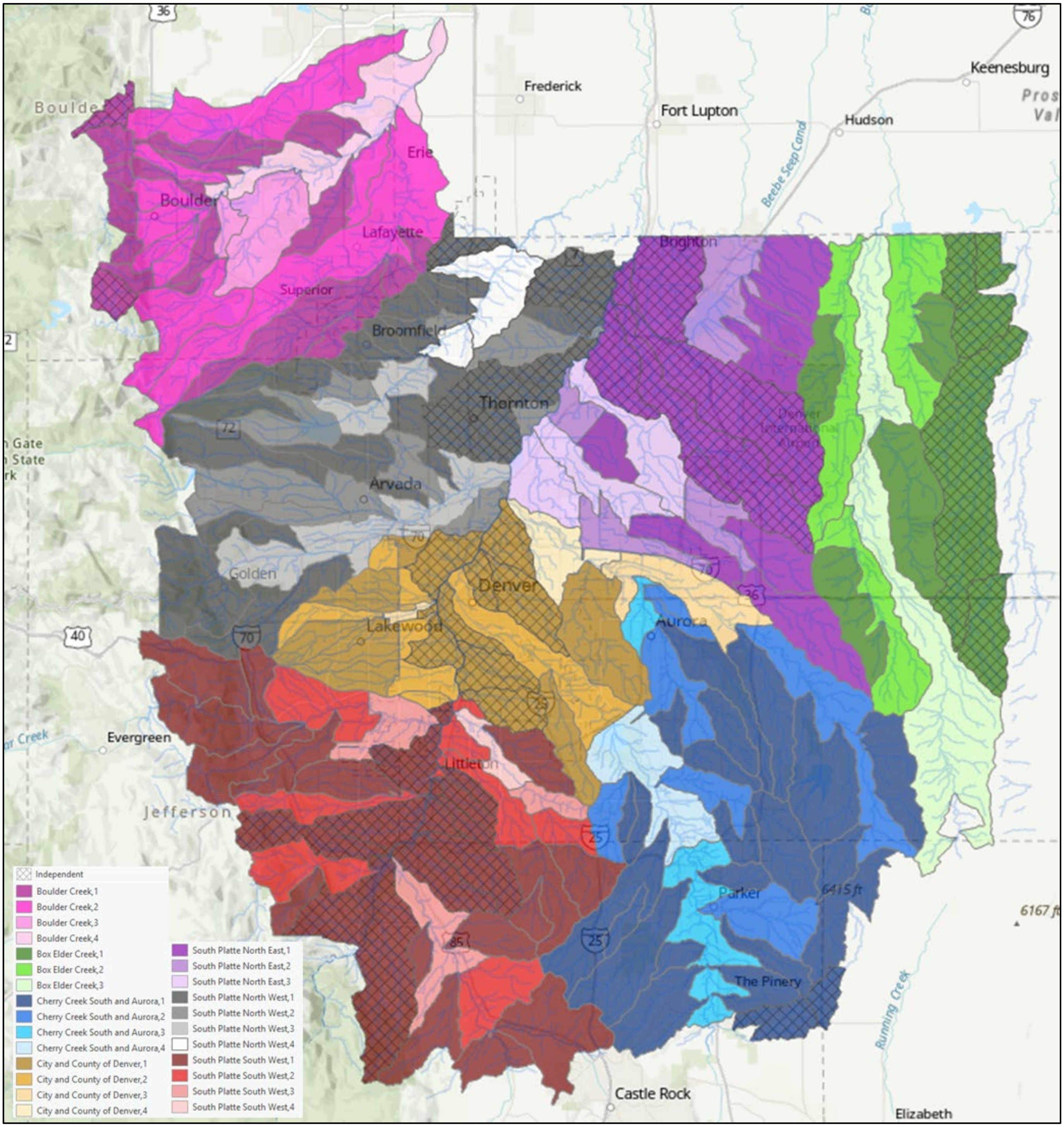


Figure 12. Basins by Geography and Production Wave (Reflecting Hydrologic Dependence)

Wave 1 basins are not dependent on RoM-generated inflows, where Wave 2 basins use Wave 1 outflows as inflows, Wave 3 basins use Wave 1 and 2 outflows, and Wave 4 basins use outflows from Waves 1, 2, and 3 and are the most dependent on upstream completion. Some Wave 1 basins are “independent” in that no downstream RoM basin depends on their outflows, as indicated by cross-hatching in Figure 11, and so these could be completed at any time as they are not on the critical path. Some of these “independent” basins are along the District perimeter and so drain outside of the District, but most drain directly to the South Platte River, which is heavily regulated by Chatfield Dam and has multiple stream gages such that the flow modeled for the South Platte River in these RoM domains will not be meaningfully informed by upstream RoM results.

Most Wave 1 basins are headwater basins without inflows, but several do have inflows external to the District that will be generated from other means (e.g., flow frequency analysis on a stream gage, regional regression equations, effective study, or other) but would not be receiving RoM-generated inflows from upstream basins included in this effort. It should be noted that these "waves" are assigned based on RoM interactions, but that all basins will contribute to riverine domains (further discussed in Section 4.1.2).

A few additional notes about sequencing apart from the hydrologic considerations above:

- The model geometry can be fully developed and troubleshooted for all basins concurrently irrespective of "production wave", which only designates the hydrologic connectivity. Even Wave 4 models can be fully constructed and stress tested with test hydrographs apart from progress on upstream basins. The wave progression only applies when executing design storms and passing upstream outflows into downstream inflows.
- Among the Wave 1 basins, it may be advantageous to prioritize "high-readiness" basins (e.g., those with recently updated H&H models and/or mature GIS datasets) or basins where LGs are interested in accelerated data for near-term CIP decision making. At the time of this writing (July 2026), the following basins were requested for acceleration: Little Dry Creek (through Englewood/SEMSWA), Lakewood Gulch, Irondale Gulch, East Toll Gate, and Slaughterhouse Gulch.
- The sequences shown in Figure 11 and Figure 12 represent one approach based on basin delineations; however, if grouped differently, the order could change notably. For example, one project team may choose to group a Wave 1 and 2 basin together, executing them in a single domain rather than two separate domains with linked boundary conditions. Conversely, a large Wave 1 basin might be split, forming a downstream Wave 2 basin. These decisions are best made on a basin-specific basis by the responsible project team after reviewing the watershed in detail. Therefore, Figure 11 and Figure 12 do not dictate how production must take place, but should be seen as a reference starting point for understanding macro-scale basin interactions.
- Initial production will start in September 2026 and begin with three to five priority watersheds at a slower pace to solidify a united approach and build alignment between newly onboarded contractors. This will help foster consistency, collaboration, and quality in the modeling between contractors. Once the methodology is vetted and synchronized between contractors, the production pace can increase as operations scale up.

3.5 Watershed Characteristics and Modeling Factors

Model complexity and level of effort are influenced by basin characteristics and components, including but not limited to:

- *Area*: the size of the domain.
- *Degree of urbanization/development*: this was calculated as the zonal mean for each basin from the National Land Cover Database (NLCD) impervious layer dated 2024. This dictates the degree of mesh refinement needed and assumed underground sewer infrastructure associated with a basin.
- *Structures*: this was estimated by the number of times a road (from Open Street Maps layer) intersected a stream centerline at or greater than 130 acres. Recognizing that some structures are not connected to the road network (trail crossings, pedestrian bridges,) or occur in smaller drainages <130 acres, this method tends to underpredict structures by approximately 30% based on a comparison of structures modeled in the Goldsmith Gulch pilot versus those estimated geospatially. The number or density of structures has a significant impact on modeling level of effort, as incorporating and troubleshooting structures is one of the more time-consuming tasks.
- *Gages*: the number of gages affects the level of effort as more gages means a more robust and complicated calibration effort. Estimated counts were determined by the number of United States Geologic Survey (USGS) or MHFD Alert gages within a basin.

- *Stream length*: this was calculated from stream centerlines to 130 acres in drainage area. This has a minor effect on mesh refinement requirements.

Table 8 summarizes these above watershed characteristics by basin, which were used to estimate modeling level of effort, as described in Section 3.6.2.

Table 8. Basin Characteristics Affecting Modeling Level of Effort

Geographies & Watersheds	Gages	Area (sq. mi.)	% Developed	Stream Length (mi)	Structure Estimate
Boulder Creek Geography	**25**	**213.0**	**15%**	**418.0**	**664**
Bear Canyon Creek	1	5.1	17%	11.8	46
Boulder Creek	3	17.5	5%	27.0	16
Boulder Creek & Sunshine Canyon Creek	5	9.2	24%	17.6	45
Boulder Creek Drainageway A, and Phelps Drainage	0	3.5	16%	7.4	20
Bullhead Gulch	2	6.4	21%	10.1	22
Coal Creek and South Boulder County Drainage	4	41.6	21%	85.6	149
Dry Creek (North) and Foothills Highway Creek	1	25.4	8%	48.6	45
Dry Creek and Valmont Reservoir Drainage	0	16.6	7%	27.6	21
Fourmile Canyon Creek	1	6.3	13%	12.6	19
Goose /Twomile Canyon	0	5.1	33%	10.7	54
Gun Barrel North and Soth	0	5.4	3%	7.6	8
Martin Gulch	1	3.7	1%	6.1	4
Pony Estates Drainage	0	2.6	14%	5.4	0
Prince Lake No. 2 Drainage	0	4.8	19%	7.0	12
Rock Creek	1	18.5	19%	49.6	60
Rock Creek Basin D Outfall	0	3.1	30%	6.9	8
Sixmile Canyon	0	3.0	2%	5.7	6
Sixmile Reservoir Drainage	0	5.1	18%	8.2	10
Skunk Creek	0	2.7	22%	7.7	35
South Boulder Creek, Marshall Gulch, and Doudy Draw	6	19.1	5%	38.7	16
Tri-County Airport Drainage	0	1.9	36%	3.6	7
Viele Lake Channel	0	3.7	41%	6.9	40
Wonderland Creek	0	2.7	33%	5.5	21
Box Elder Creek Geography	**0**	**229.5**	**2%**	**401.3**	**199**
Bear Gulch	0	19.6	1%	29.5	19
Blue Collar Draw, White Collar Gulch, and Splits Draw	0	7.0	0%	9.9	6
Coyote Run and Woodrat Gulch	0	16.1	1%	34.0	11
Crooked Run, Thistle Gulch, Newcomb Gulch, Henry David, and Flat Drainage	0	38.2	1%	68.7	41
Dogbane Draw	0	7.0	0%	11.1	6
Ethan Gulch	0	3.9	0%	4.9	2
Glory Run and Clover Draw	0	5.2	1%	7.6	3
Horse Creek and Workmans Gulch	0	18.4	1%	31.5	28
Lynne Creek	0	8.6	8%	15.5	12
Patton Creek	0	19.7	5%	35.6	17
Prairie Dog Draw, Muskrat Gulch, and Rat Run	0	12.3	2%	17.3	3
Running Cemetery and Box Elder Creek	0	63.0	1%	117.0	43
West Sand Creek and Morning Draw	0	10.6	2%	18.6	8
Cherry Creek South and Aurora Geography	**35**	**259.4**	**21%**	**519.3**	**792**
Antelope Creek and Saddle Rock Ranches	0	4.5	24%	10.2	10
Badger Gulch	0	2.9	5%	6.1	3
Baldwin Gulch	0	3.7	13%	7.2	19
Cherry Creek South	10	37.4	26%	85.0	165
Coal Creek	0	21.1	3%	40.5	20

Geographies & Watersheds	Gages	Area (sq. mi.)	% Developed	Stream Length (mi)	Structure Estimate
Coal Creek Tributary	0	1.3	2%	2.4	3
Cottonwood Creek	0	8.1	38%	16.3	33
East Toll Gate Creek	3	10.8	28%	22.7	31
Granby Ditch	1	1.8	47%	3.4	11
Happy Canyon Creek	1	14.5	21%	32.4	55
Kersten Gully, Walrush Gulch, Dreamers Draw, and Leberl Draw	0	11.5	0%	19.8	2
Kinney Creek and Fonder Draw	1	6.3	12%	12.2	16
Lemon Gulch and Scott Gulch	0	10.3	8%	19.7	12
Llama Draw and Corner Drainage	0	1.8	2%	3.1	5
Lone Tree Creek	0	1.8	48%	3.8	6
Meadowood Drain	1	3.1	49%	3.7	10
Moonshine Gulch	0	5.7	8%	9.6	10
Murphy Creek	1	12.6	13%	28.9	18
Newlin Gulch	1	15.1	16%	32.4	29
No Name Creek	1	6.0	49%	11.5	46
Oak Gulch	0	2.8	11%	6.7	7
Piney Creek and Sampson Gulch	2	17.5	27%	30.4	69
Sable Ditch	1	2.0	47%	3.3	18
Senac Creek and Mutchie Creek	3	18.2	10%	34.7	23
Sulphur Gulch and Sara Gulch	2	12.2	17%	26.6	52
Tallman Gulch	1	5.0	11%	9.0	8
Toll Gate Creek	1	3.8	48%	6.6	26
West Toll Gate Creek	5	14.4	46%	24.4	71
Windmill Creek	0	3.2	39%	6.7	14
City and County of Denver (CCD) Geography	**43**	**147.9**	**50%**	**299.6**	**2073**
Cherry Creek North	8	17.6	52%	43.7	299
DFA 0060	2	5.6	59%	15.7	89
DFA 0061	2	6.8	57%	12.5	121
DFA 0062	1	3.0	65%	6.4	81
DFA 0063	1	3.7	63%	8.2	63
DFA 0064	1	4.8	56%	7.4	71
DFA 0065, North Sanderson Gulch, and Sanderson Gulch	2	9.5	48%	17.0	135
Goldsmith Gulch	3	7.9	51%	12.0	52
Harlan Drain	0	3.8	48%	6.2	58
Harvard Gulch	4	6.5	43%	9.2	104
Interstate 25 Drainage	1	6.6	51%	14.5	95
Montbello Drainage	0	5.7	50%	15.1	98
Park Hill Drain	3	8.6	44%	13.2	156
Sand Creek	6	25.7	44%	55.2	178
Sloan Lake	1	4.8	44%	9.1	90
Weir Gulch	0	7.5	47%	14.8	80
West Harvard Gulch	0	1.4	48%	2.2	26
Westerly Creek	8	18.3	49%	37.2	277
South Platte Northeast Geography	**18**	**208.4**	**17%**	**407.5**	**714**
Beebe Draw	0	15.8	13%	25.8	30
DFA 0051	1	14.7	25%	24.7	79
DFA 0053	2	9.5	23%	23.3	70
DFA 0055	0	10.8	19%	23.6	24
DFA 0058	1	7.5	45%	16.8	83
Dupont Drainage	0	4.6	38%	10.7	27

Geographies & Watersheds	Gages	Area (sq. mi.)	% Developed	Stream Length (mi)	Structure Estimate
Eagles Run	0	6.6	5%	11.6	12
First Creek	4	35.0	14%	66.9	95
First Creek Tributary T	0	8.7	9%	14.1	15
Irondale Gulch	9	17.9	25%	46.1	100
Robins Run, Finch Creek, Mockingbird Run, Osprey Creek, and Beeble Seep CO2	0	12.5	3%	24.1	27
Second Creek	0	24.3	14%	50.2	55
Third Creek, Airport Drain, and Grass Valley Gulch	1	31.4	18%	52.4	74
West Fork Second Creek	0	3.0	18%	5.4	12
Wren Creek	0	6.1	1%	11.8	11
South Platte Northwest Geography	**43**	**252.1**	**32%**	**503.0**	**1490**
Airport Creek	0	2.3	51%	4.0	19
Big Dry Creek (ADCO)	1	35.5	27%	77.7	139
Brantner Gulch	0	8.1	46%	16.0	56
Brantner Gulch Tributary 2	0	2.3	35%	6.8	17
City Park Basin	0	3.1	56%	6.5	37
Clear Creek	2	28.2	41%	62.7	254
Clear Creek, Tucker Gulch, West Fork Kenneys Run, Kenneys Run and Clear Creek	2	17.5	12%	37.6	80
DFA 0052	0	4.6	15%	10.0	15
DFA 0054	0	4.3	23%	7.0	41
DFA 0056	0	2.1	28%	3.8	29
DFA 0057 and basin 4100	0	4.3	47%	9.7	76
DFA 0059	0	4.2	63%	7.2	43
Grange Hall Creek	3	8.9	46%	16.7	44
Hidden Lake	1	2.2	46%	2.5	13
Hylands Creek	0	3.5	42%	5.8	22
Kalcevic Gulch	0	1.7	51%	3.7	16
Lena Gulch	8	13.5	31%	27.7	83
Leyden Creek	2	12.0	13%	20.9	14
Little Dry Creek	1	10.3	48%	18.0	78
Little Dry Creek (ADCO) Tributary	0	2.8	45%	4.6	17
McKay Lake	0	2.9	29%	5.6	13
Mount Olivet Drainage	0	2.9	29%	5.4	17
Nissen Reservoir Basin	1	2.4	39%	4.6	18
Niver Creek	1	6.6	51%	12.4	43
Preble Creek	0	3.8	22%	7.3	9
Quail Creek	0	5.1	39%	7.9	25
Ralston Creek	4	16.3	35%	31.0	136
Ramstetter Creek	0	2.6	13%	4.2	7
Ranch Golf Course Drainage	0	2.5	43%	3.7	5
Shay Ditch	0	2.0	29%	2.8	5
Todd Creek	0	7.9	19%	13.5	22
Van Bibber Creek	3	6.2	28%	12.2	23
Walnut Creek	7	10.8	18%	26.3	57
West Lake Basin	0	2.7	41%	5.8	15
Woman Creek	7	5.8	3%	11.7	2
South Platte Southwest Geography	**43**	**306.6**	**22%**	**644.6**	**1307**
Bear Creek and Henry's Lake	7	33.5	22%	72.9	141
Big Dry Creek	2	16.4	37%	30.0	75
Big Dry Creek (ARAPCO) Branch 1	1	3.1	19%	6.7	6

Geographies & Watersheds	Gages	Area (sq. mi.)	% Developed	Stream Length (mi)	Structure Estimate
Coon Creek and Lilley Gulch	0	7.8	46%	16.0	37
Dad Clark Gulch	0	9.2	40%	17.9	23
Deer Creek	1	10.1	4%	22.1	18
DFA 0066	6	14.5	39%	29.2	160
Dry Gulch	0	3.7	53%	11.0	89
Dutch Creek	1	7.2	24%	21.6	24
East Plum Creek, Cohens Drainage, Haskins Gulch, East Plum Creek, Angela Draw, and Emery Run	1	13.2	11%	23.4	13
Greenwood Gulch	1	7.4	32%	14.6	38
Jarre Creek and West Plum Creek	0	6.2	2%	14.1	0
Lakewood Gulch	2	5.1	45%	13.3	55
Lee Gulch	0	2.5	44%	5.7	9
Lehigh Gulch, Rainbow Creek, and Indian Creek	1	9.0	1%	18.4	7
Little Dry Creek	2	8.4	41%	16.6	55
Little's Creek	0	2.8	44%	4.2	63
Massey Draw	0	9.6	20%	21.1	33
McIntyre Gulch	1	5.3	44%	16.2	60
Mill Creek	0	3.7	2%	5.8	0
Mt. Vernon Creek, and Sawmill Gulch	4	11.7	4%	22.3	17
Oxide Draw	0	7.0	1%	13.0	1
Plum Creek	2	11.5	9%	21.5	8
Plum Creek, Daniels Park Drain, and Ingot Draw	1	11.5	3%	23.1	8
Rooney Gulch	0	4.3	11%	12.0	9
SJCD(N and S)	0	6.1	41%	14.2	60
Slaughterhouse Gulch	2	2.2	48%	4.9	61
South Lakewood Gulch	0	2.0	44%	3.3	15
Spring Gulch and Marcy Gulch	1	11.3	38%	25.6	35
Sterling Gulch	0	2.4	17%	5.8	10
Turkey Creek and Parmalee Gulch	4	9.8	5%	18.3	25
Weaver Creek	0	7.0	24%	14.1	48
Willow Creek	1	9.4	45%	19.9	70
Willow Creek, Arrowhead Gulch, Little Willow Creek, Brush Creek, and Hogback Creek	2	31.8	6%	66.0	34
Grand Total (Districtwide)	**207**	**1616.8**	**21%**	**3193.3**	**7239**

3.6 Program Costs

This section overviews the anticipated cost for Program execution, which is also used to estimate necessary resources (Section 3.7) and a likely schedule (Section 3.8). A detailed cost estimate is included in this section with approximate costs for developing foundational data (±20%) that can be used for planning purposes; however, costs for future efforts beyond data development were not estimated as the scope and approach remain undefined with high uncertainty on the scale and level of detail. There are a number of applications that could be applied in future efforts with highly varied levels of effort based on the selected application and geographic scope. The most common future end use is estimating risk reduction across potential projects to inform CIP prioritization. In this application, the foundational model for a watershed produced under the Districtwide effort would be modified and run for selected scenarios, in which the cost will largely depend on the assumed number of problem areas and mitigation projects modeled. Further testing and methodology development is required to estimate risk reduction costs, but for a moderately sized watershed (e.g., between 5 and 15 sq. mi.), the effort is somewhere in the ballpark of $2,500 to $4,000 per evaluated potential project depending on economies of scale.

In general, the data development production cost was mostly developed by scaling costs incurred for the Goldsmith Gulch pilot relative to basin attributes (Table 8). As briefly summarized in Section 3.2.4, there were four iterations before arriving at the final cost estimate provided in September 2025. Prior versions considered alternate scenarios including (1) a conservative and thorough process that executed the full process for each watershed individually; (2) a streamlined portfolio approach where tasks were executed concurrently across large geographies realizing economies of scale; and (3) an exclusive focus on data production without outreach, application, or programmatic support. After multiple meetings and correspondence, the approach was finalized to develop detailed models that meet regulatory requirements (without regulatory products) for project prioritization and to implement the plan in phases across larger regions, rather than fully executed the whole process on an individual watershed basis.

The September 2025 cost estimate is the focus of this section and formed the foundation for cost sharing requests allocated to LGs calculated in January 2026, as documented through IGAs in the Spring and Summer of 2026. This section summarizes costs by task, phase, and geography; explains notable cost drivers; and concludes with an overview of how costs were allocated to individual LGs.

3.6.1 Summary of Costs

The foundational data production effort is estimated at approximately \$5.55M (2025 dollars) at ±20% confidence. This is based on the original estimate of approximately \$5M, as detailed in Table 9, which was later increased due to the additions of PSS modeling and simplistic economic losses.

The following assumptions apply to the production costs for developing foundational data in the September 2025 Program-level estimate:

- Production assumes continuous, concurrent production at a geography level to leverage economies of scale. This will be fully funded upfront with a target of a 50/50 match between the District and LGs via IGAs. The goal is to complete coverage by 2029.
- Costs do not include field survey collection, analyses upon or updates to other forms of study (FHADs, MDPs, LOMCs), floodway analysis, developing regulatory products, nor going through regulatory reviews.
- Costs are for initial Program development but do not include future enhancements, data updates, nor routine maintenance.
- Costs were developed based on prior projects, most notably Goldsmith Gulch, and reflect HEC-RAS modeling as outlined in the 2D H&H modeling guidance. While it does not affect the Program cost, it should be noted that developing Flood Risk models in ICM versus HEC-RAS should be comparable in cost as long as the expected level of detail and representation is similar. However, ICM models typically are used for applications meriting a greater level of detail and therefore typically incur greater model development costs. In such cases, those incremental costs above the Flood Risk estimate would be borne by the LG, as the MHFD is co-funding the piece related only to Flood Risk.
- Costs represent fully developing the Program from scratch and do not account for savings or offset expenditures from existing investments. While this Program does leverage existing inventory for structure information, the cost estimate presents a complete build-out scenario. Specifically, the cost represented includes the level of effort to build models and develop hazard and risk information for every basin inside the District, including areas that have already been studied, such as the pilots, validation basins, and prior investments by LGs (Table 7). This enables a complete picture of the full development cost to assist in understanding relative expenditures per geography and LG without conflating prior development costs, which were notably higher in the pilots due to sensitivity testing and methodology development. Cost allocation agreements ought to consider a reduced level of effort based on the existing inventory, as discussed in Section 3.6.3.

Table 9. Planning Level Cost Estimate for Districtwide Data Development

Phase	Aspect/Task	Boulder Creek	Box Elder Creek	Cherry Creek South and Aurora	City and County of Denver	South Platte Northeast	South Platte Northwest	South Platte Southwest	Total	Comment/Assumption
General Study Info	Modeled Area (sq. mi.)	221	232	273	172	204	261	286	1,648	
	# of watersheds	23	13	28	24	15	36	30	169	See accompanying figure
	# of domains	8-10	5-10	10-12	6-10	6-9	10-15	11-12	56 - 78	Avg size of 25 sq. mi. and 2-3 combined watersheds
	% Developed	15%	2%	19%	50%	16%	32%	20%	21%	
	Stream:Road Intersects	625	191	733	2090	666	1342	905	6,552	See accompanying figure
	Stream Length (mi)	425	404	539	357	395	525	586	3,231	
	# Gages	26	0	34	47	18	45	39	209	
Model Build	Mesh Development	$167,469	$96,877	$230,597	$291,482	$129,036	$337,011	$246,833	$1,499,304	Driven by size, % development, and stream miles
	Structure Integration	$81,464	$25,830	$95,656	$266,532	$85,722	$173,714	$118,080	$846,997	Driven by stream-road intersections
	Storm Sewer Integration	$72,381	$11,070	$117,512	$183,081	$72,807	$180,526	$128,157	$765,533	Driven by developed area
	Calibration & Sims	$37,808	$8,856	$46,664	$57,905	$26,227	$65,058	$51,774	$294,292	Driven by number of gages
	QC	$19,708	$7,827	$26,914	$43,847	$17,220	$41,505	$29,900	$186,922	4.5% of the total effort
	Documentation	$28,467	$11,306	$38,876	$63,335	$24,874	$59,951	$43,189	$269,998	6.5% of the total effort
	PM & Coordination	$30,657	$12,176	$41,866	$68,207	$26,787	$64,563	$46,511	$290,767	7% of the total effort
	Subtotal	**$437,954**	**$173,942**	**$598,085**	**$974,388**	**$382,673**	**$922,327**	**$664,442**	**$4,153,812**	
Hazard Data	D, V, DxV Grids (cleaned)	$6,300	$5,250	$7,700	$5,600	$5,250	$8,750	$8,050	$46,900	Per domain: 2 hr export, 3 hr clean
	Floodplains (cleaned)	$10,440	$8,700	$12,760	$9,280	$8,700	$14,500	$13,340	$77,720	Per domain: 6 hr clean, 2 hr convert to poly
	QC	$7,830	$6,525	$9,570	$6,960	$6,525	$10,875	$10,005	$58,290	Per domain: 2 hr spot check, 4 hr manual fixes
	Documentation	$11,400	$10,500	$12,600	$10,800	$10,500	$13,500	$12,900	$82,200	Metadata, geodatabases, shared memo
	Data Delivery/Deploy	$9,360	$7,800	$11,440	$8,320	$7,800	$13,000	$11,960	$69,680	Submit and upload to Confluence by domain
	PM & Coordination	$1,810	$1,550	$2,160	$1,640	$1,550	$2,430	$2,250	$13,390	4% of the above effort
	Subtotal	**$47,140**	**$40,325**	**$56,230**	**$42,600**	**$40,325**	**$63,055**	**$58,505**	**$348,180**	

Phase	Aspect/Task	Boulder Creek	Box Elder Creek	Cherry Creek South and Aurora	City and County of Denver	South Platte Northeast	South Platte Northwest	South Platte Southwest	Total	Comment/Assumption
Baseline Risk	Consequence Scoring	$15,660	$13,050	$19,140	$13,920	$13,050	$21,750	$20,010	$116,580	Per domain: 12 hr for scripted process
	QC	$14,355	$11,963	$17,545	$12,760	$11,963	$19,938	$18,343	$106,865	Per domain: 8 hr review, 25% re-run w/revised inputs
	Documentation & Analytics	$19,500	$17,250	$22,500	$18,000	$17,250	$24,750	$23,250	$142,500	Geodatabases, analytics/stats, shared memo
	Data Delivery/Deploy	$7,020	$5,850	$8,580	$6,240	$5,850	$9,750	$8,970	$52,260	Submit and upload to Confluence by domain
	PM & Coordination	$5,650	$4,810	$6,780	$5,090	$4,810	$7,620	$7,060	$41,820	10% of the above effort
	Hotspot Analysis, New Areas	$3,568	$1,870	$5,247	$6,578	$3,546	$7,047	$5,647	$33,503	Review domain at 20sq. mi./hr rural & 2 sq. mi./hr urban
	Subtotal	**$65,753**	**$54,793**	**$79,792**	**$62,588**	**$56,468**	**$90,854**	**$83,279**	**$493,528**	
GRAND TOTAL		**$550,847**	**$269,060**	**$734,106**	**$1,079,576**	**$479,467**	**$1,076,236**	**$806,227**	**$4,995,519**	

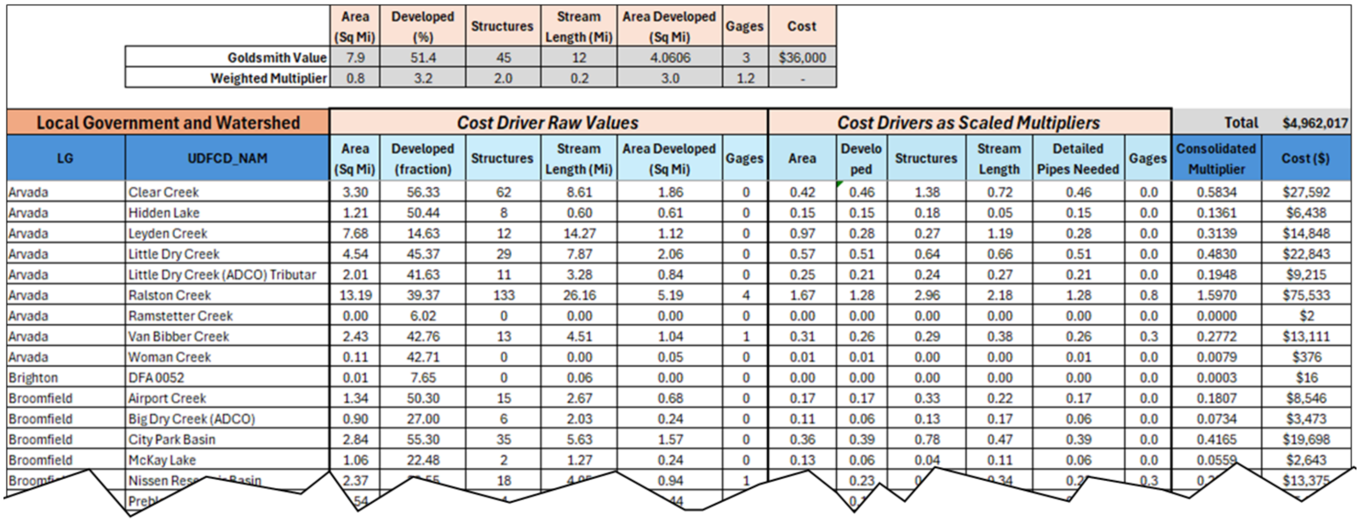
Note: Costs are not included for floodway analysis, regulatory products, nor future maintenance cycles. This original September 2025 estimate did not include creating PSS models nor loss calculations (estimated separately).

The following two scope additions came after the September 2025 cost estimate, which are not reflected in Table 9, and raise the approximate production cost to $5.55M:

- The development of PSS riverine only models (Section 4.1.2). This has not been evaluated in detail across the District, but was estimated for the Validation Basins to increase costs for the modeling effort by approximately 15% or around 10% of overall project costs. The basin-specific cost is dependent on the stream network and also varies depending on whether HEC-RAS or ICM is used for the RoM model. Ballpark estimates include a $480,000 to $540,000 increase for developing foundational data.
- Calculating simplistic economic losses using unmodified national datasets (Section 4.1.3) at approximately $40,000 Districtwide during data development.

3.6.2 Modeling Cost Drivers

As noted in Section 3.5, there were five basin attributes used as cost drivers that were populated for all watersheds, as listed in Table 8. These basin attributes were then compared to those of Goldsmith Gulch to arrive at a proportional effort relative to Goldsmith Gulch to derive modeling costs. This was done with ratios between individual factors paired with a weighted multiplier that represented the relative impact between drivers on the Goldsmith Gulch cost. With this approach, a consolidated multiplier was developed that effectively represented the level of effort relative to Goldsmith Gulch, where a value of 1.1 is 10% more involved and a value of 0.9 is 10% less involved than modeling was for Goldsmith Gulch. These consolidated multipliers were then applied against the actual costs incurred for modeling Goldsmith Gulch to develop basin-specific modeling costs. This process is illustrated for a dozen basins in Figure 13.



	Area (Sq Mi)	Developed (%)	Structures	Stream Length (Mi)	Area Developed (Sq Mi)	Gages	Cost
Goldsmith Value	7.9	51.4	45	12	4.0606	3	$36,000
Weighted Multiplier	0.8	3.2	2.0	0.2	3.0	1.2	-

Local Government and Watershed		***Cost Driver Raw Values***						***Cost Drivers as Scaled Multipliers***						**Total**	**$4,962,017**
LG	**UDFCD_NAM**	**Area (Sq Mi)**	**Developed (fraction)**	**Structures**	**Stream Length (Mi)**	**Area Developed (Sq Mi)**	**Gages**	**Area**	**Developed**	**Structures**	**Stream Length**	**Detailed Pipes Needed**	**Gages**	**Consolidated Multiplier**	**Cost ($)**
Arvada	Clear Creek	3.30	56.33	62	8.61	1.86	0	0.42	0.46	1.38	0.72	0.46	0.0	0.5834	$27,592
Arvada	Hidden Lake	1.21	50.44	8	0.60	0.61	0	0.15	0.15	0.18	0.05	0.15	0.0	0.1361	$6,438
Arvada	Leyden Creek	7.68	14.63	12	14.27	1.12	0	0.97	0.28	0.27	1.19	0.28	0.0	0.3139	$14,848
Arvada	Little Dry Creek	4.54	45.37	29	7.87	2.06	0	0.57	0.51	0.64	0.66	0.51	0.0	0.4830	$22,843
Arvada	Little Dry Creek (ADCO) Tributar	2.01	41.63	11	3.28	0.84	0	0.25	0.21	0.24	0.27	0.21	0.0	0.1948	$9,215
Arvada	Ralston Creek	13.19	39.37	133	26.16	5.19	4	1.67	1.28	2.96	2.18	1.28	0.8	1.5970	$75,533
Arvada	Ramstetter Creek	0.00	6.02	0	0.00	0.00	0	0.00	0.00	0.00	0.00	0.00	0.0	0.0000	$2
Arvada	Van Bibber Creek	2.43	42.76	13	4.51	1.04	1	0.31	0.26	0.29	0.38	0.26	0.3	0.2772	$13,111
Arvada	Woman Creek	0.11	42.71	0	0.00	0.05	0	0.01	0.01	0.00	0.00	0.01	0.0	0.0079	$376
Brighton	DFA 0052	0.01	7.65	0	0.06	0.00	0	0.00	0.00	0.00	0.00	0.00	0.0	0.0003	$16
Broomfield	Airport Creek	1.34	50.30	15	2.67	0.68	0	0.17	0.17	0.33	0.22	0.17	0.0	0.1807	$8,546
Broomfield	Big Dry Creek (ADCO)	0.90	27.00	6	2.03	0.24	0	0.11	0.06	0.13	0.17	0.06	0.0	0.0734	$3,473
Broomfield	City Park Basin	2.84	55.30	35	5.63	1.57	0	0.36	0.39	0.78	0.47	0.39	0.0	0.4165	$19,698
Broomfield	McKay Lake	1.06	22.48	2	1.27	0.24	0	0.13	0.06	0.04	0.11	0.06	0.0	0.0559	$2,643
Broomfi	Nissen Res	2.37		18		0.94	1		0.23			0.2	0.3	0.2	$13,375
	Prebl	54				44			0.1						

Figure 13. Illustrative Snippet of Basin-Specific Cost Calculations

The attribute ratios were primarily used for developing cost, as described above, but are also helpful descriptors for Districtwide characterization. For example, Figure 14 depicts the structure density and degree of development across the District relative to Goldsmith Gulch. As expected, the greatest concentration of structures and development is found within CCD, with very little along the eastern third of the District. Although Goldsmith Gulch is more developed than most, it is about middle of the pack for structure density likely due to a smaller stream network than most basins in the District.

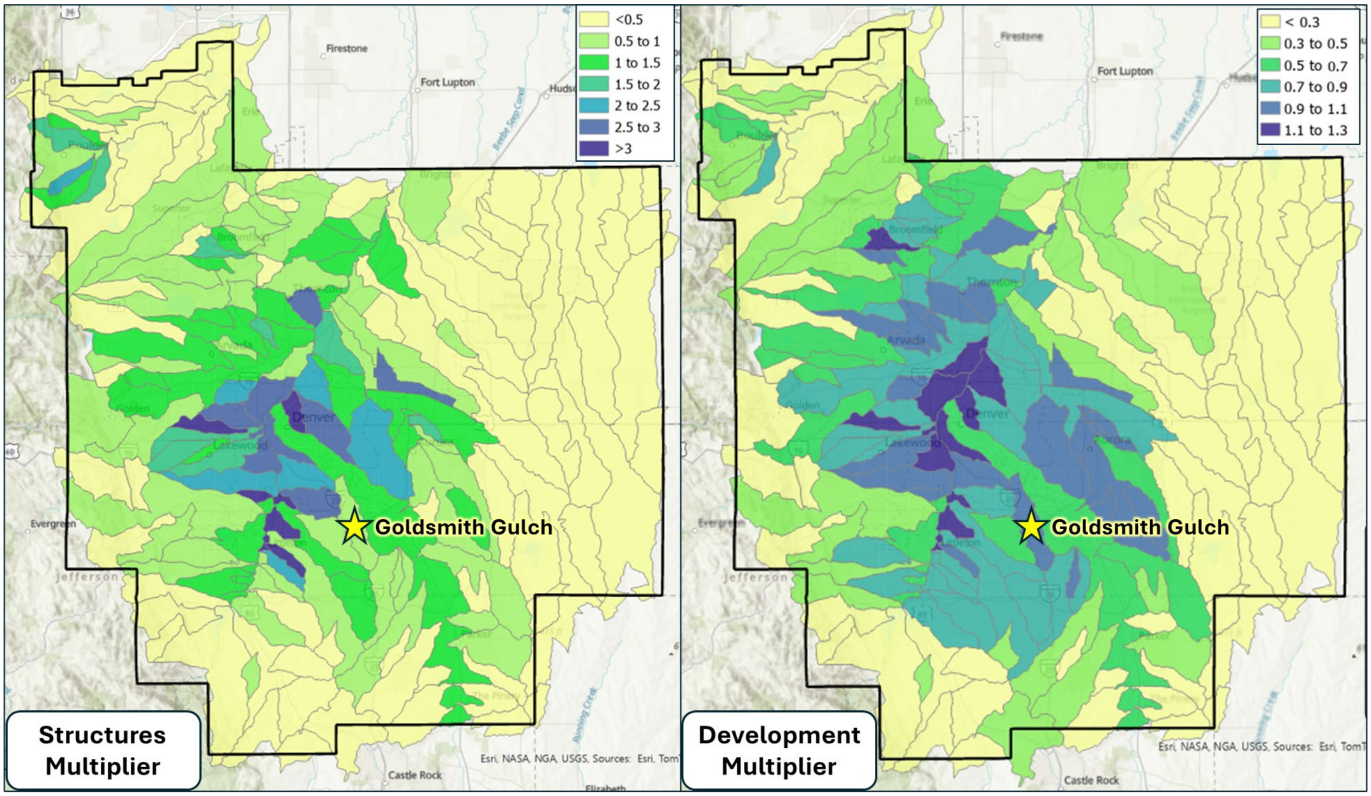


Figure 14. Structure Density (left) and Development Relative to Goldsmith Gulch

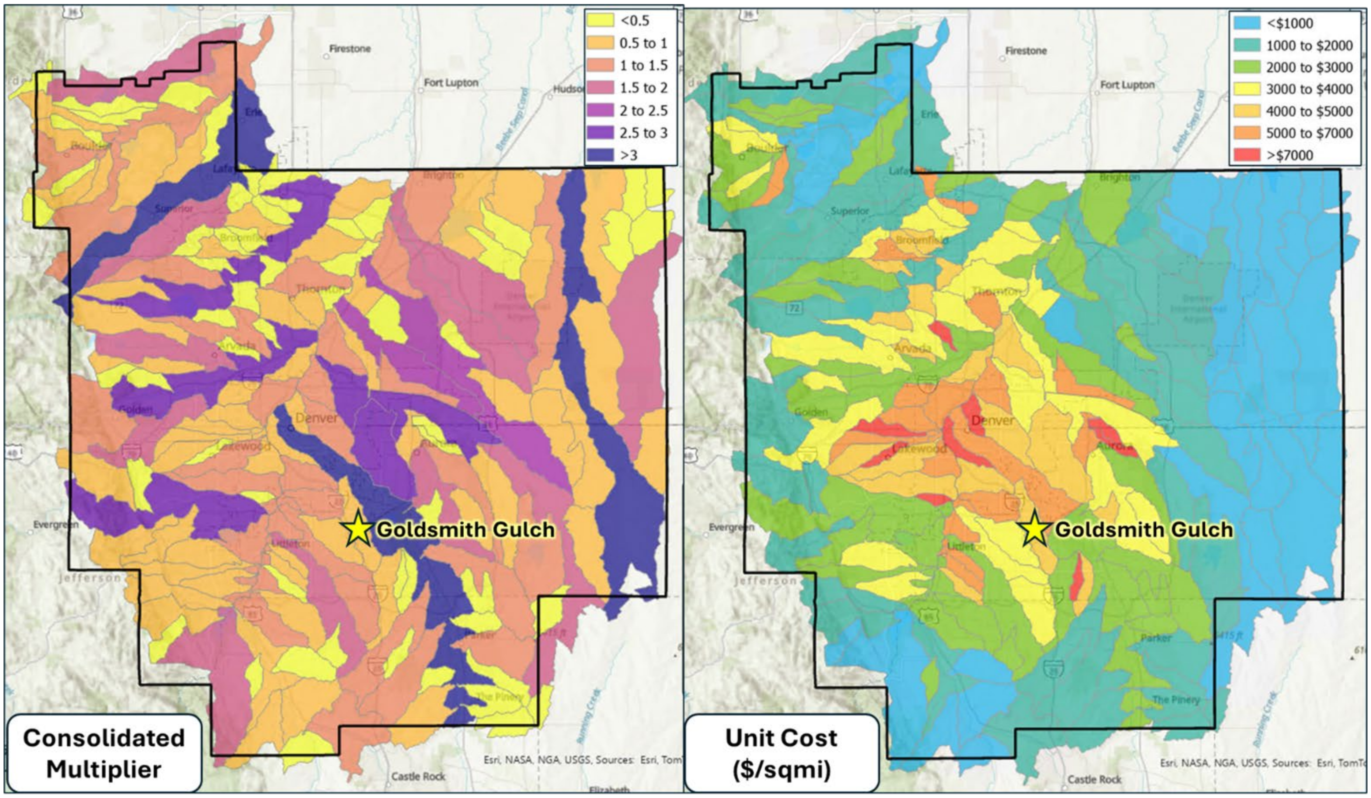


Figure 15. Consolidated Multiplier (left) and Unit Cost (right)

The left side of Figure 15 depicts the relative level of effort at a basin scale relative to Goldsmith Gulch, where darker pink and purple basins are anticipated to have a greater total cost for model development. This is a net effect and does not necessarily mean that these basins are more complex, but could just be related to their sheer size, as is the case for a few large basins in the eastern and northeastern portions of the District. The right side of Figure 15 depicts the estimated unit cost, which is the total cost (estimated by multipliers) divided by area to arrive at $/sq. mi. This is the simplest form of viewing model development complexity, which shows that most basins will be simpler than Goldsmith Gulch and the greatest complexity will be in CCD with relatively simple basins along the eastern, southern, and western edges of the District.

Figure 16 plots six cost drivers as a relative percentage of total basin modeling cost for all 169 basins that were originally delineated for the initial cost estimate. The sixth driver added is pipes, which was assumed to be proportional to developed area. This helps identify the relative influence of cost drivers as the basin cost changes. For inexpensive basins (e.g., <$10,000), area is the primary driver, indicating these are likely rural basins where development is not a significant driver and there are few to no structures identified; thus, being an inexpensive basin. Conversely, expensive basins (>$50,0000) show primary cost drivers as structures and incorporating sewer, which is a reflection of urbanized basins. Gages captures the calibration effort, so even if no gages are present within a basin, it still has an associated cost with other means of validation (e.g., regional regression equations).

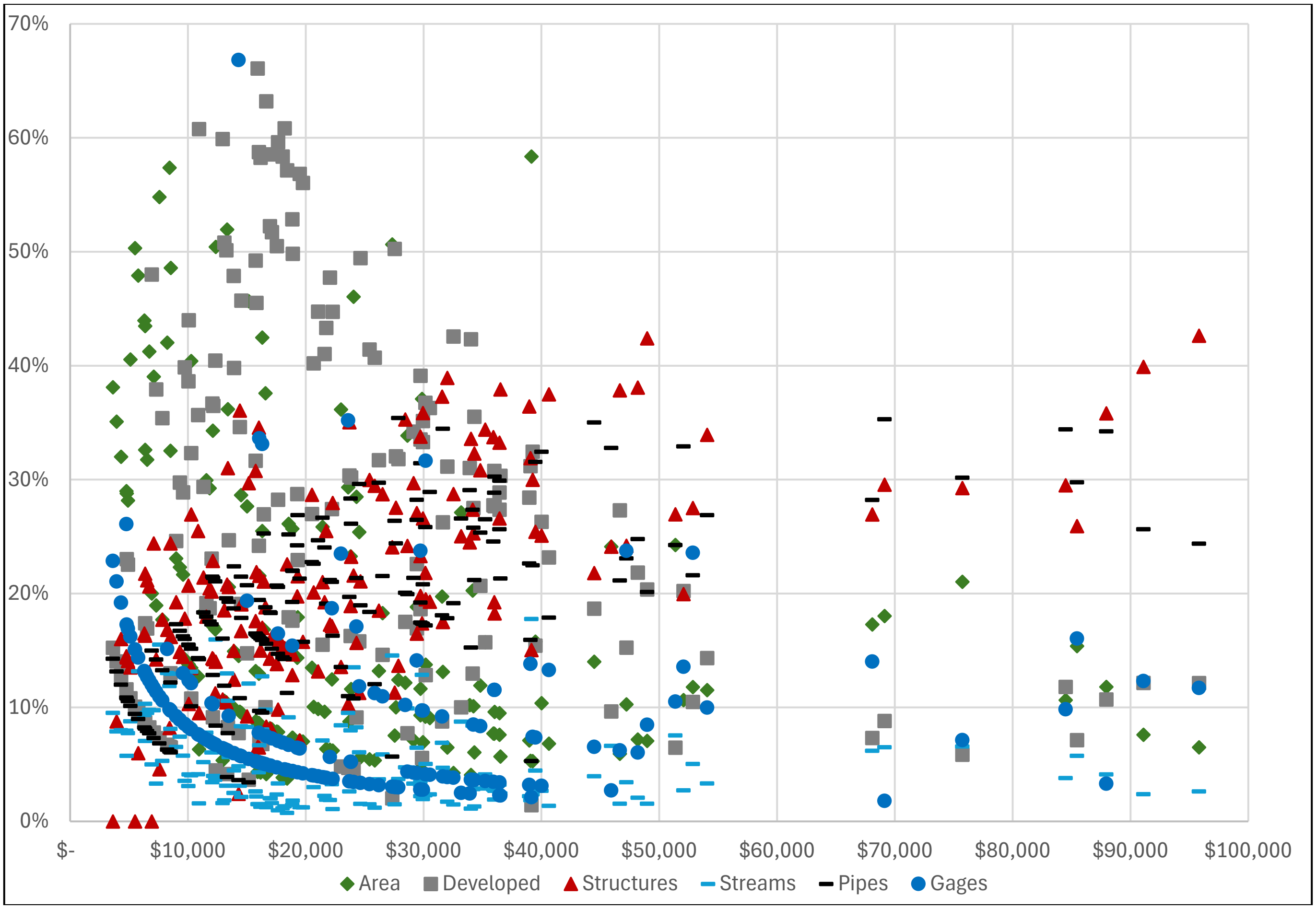


Figure 16. Relative Influence of Drivers by Basin Modeling Cost

3.6.3 Cost Allocations to Local Governments

After finalizing the cost estimate, the data development costs were allocated across the 42 LGs. This involved subdividing basins with LG boundaries and re-calculating characteristics for the subdivided basins and applying the same cost driver logic. This approach was determined to be more representative than simple area-weighted calculations by LG coverage as the degree of urbanization varies by LG. For example, if half of a basin was covered by the City of Aurora and the other half by Arapahoe County, the portion in Aurora will certainly account for well over half of the estimated modeling level of effort, likely due to the number of structures and development.

Table 10 presents allocated costs for all 42 LGs, of which 11 LGs fell below the contribution threshold, so their total portion ($20,500) was proportionally redistributed across the remaining 31 LGs. The primary purpose of Table 10 is to calculate the *relative* cost allocation by LG if a uniform RAS 2D RoM effort were to be implemented Districtwide from scratch and does not reflect the reductions associated with leveraging existing inventory.

Table 10. Data Development Costs and Relative Contributions by Local Government

Local Government	Total Modeling Cost ($)	Modeled Area (sq. mi.)	Requested Contribution ($)	% of Cost	% of Area
City and County of Denver	$894,965	154.7	$452,900	18.3%	9.6%
Aurora	$531,318	159.9	$268,900	10.8%	9.9%
Unincorporated Adams County	$412,189	244.2	$208,600	8.4%	15.1%
Unincorporated Jefferson County	$344,935	165.5	$174,600	7.0%	10.2%
SEMSWA (includes Centennial)	$279,682	91.8	$141,500	5.7%	5.7%
Unincorporated Douglas County	$255,073	167.0	$129,100	5.2%	10.3%
Lakewood	$218,192	44.2	$110,400	4.5%	2.7%
Unincorporated Boulder County	$187,841	127.8	$95,100	3.8%	7.9%
Arvada	$184,300	38.5	$93,300	3.8%	2.4%
Thornton	$183,314	37.4	$92,800	3.7%	2.3%
Westminster	$155,874	33.9	$78,900	3.2%	2.1%
Boulder	$150,598	27.3	$76,200	3.1%	1.7%
Commerce City	$138,864	36.1	$70,300	2.8%	2.2%
Broomfield	$121,329	29.0	$61,400	2.5%	1.8%
Parker	$97,752	22.2	$49,500	2.0%	1.4%
Highlands Ranch Metro District	$73,507	20.7	$37,200	1.5%	1.3%
Unincorporated Arapahoe County	$72,239	68.8	$36,600	1.5%	4.3%
Wheat Ridge	$67,551	9.6	$34,200	1.4%	0.6%
Brighton	$66,639	18.9	$33,700	1.4%	1.2%
Littleton	$61,042	13.7	$30,900	1.2%	0.8%
Erie	$56,378	16.2	$28,500	1.1%	1.0%
Englewood	$54,222	6.6	$27,400	1.1%	0.4%
Golden	$48,005	9.7	$24,300	1.0%	0.6%
Lafayette	$41,934	9.5	$21,200	0.9%	0.6%
Louisville	$39,667	8.1	$20,100	0.8%	0.5%
Northglenn	$39,089	6.5	$19,800	0.8%	0.4%
Greenwood Village	$32,442	8.3	$16,400	0.7%	0.5%
Lone Tree	$30,105	9.8	$15,200	0.6%	0.6%
Superior	$22,815	4.3	$11,500	0.5%	0.3%
Castle Pines	$22,447	9.6	$11,400	0.5%	0.6%
Cherry Hills Village	$18,434	6.3	$9,300	0.4%	0.4%
Sheridan	$18,236	2.3	$0	0.0%	0.1%
Glendale	$8,520	0.6	$0	0.0%	0.0%
Federal Heights	$8,098	1.8	$0	0.0%	0.1%
Edgewater	$7,137	0.7	$0	0.0%	0.0%
Morrison	$5,045	1.6	$0	0.0%	0.1%
Foxfield	$4,778	1.3	$0	0.0%	0.1%
Columbine Valley	$3,246	1.0	$0	0.0%	0.1%
Bow Mar	$1,384	0.8	$0	0.0%	0.1%
Mountain View	$1,217	0.1	$0	0.0%	0.0%
Lakeside	$1,155	0.3	$0	0.0%	0.0%
Lochbuie	$460	0.2	$0	0.0%	0.0%
Districtwide Grand Total[1]	**$4,962,017**	**1,616.8**	**$2,481,200**	**100%**	**100%**

[1] The total of $4,995,519 in Table 9 is $33,503 higher than shown here due to the inclusion of the hotspot analysis component that was recently moved to the data development phase, but was not included in earlier communications with LGs; therefore, Table 10 and Table 11 have been preserved to match what was previously presented.

Table 11 summarizes LG contributions, showing that nearly half of the Program (45%) is funded and spatially covered by 4 LGs. Most LGs contribute at minor levels comprising less than one fifth of the Program funding.

Table 11. Local Government Contribution Summary

Contribution Levels	*Amount*	*Funding Portion*	*Area Covered*	*Count*
Exempt (<$5k)	$ -	0%	1%	11
Minor ($5k-50k)	$ 427,200	17%	15%	17
Moderate ($50k-150k)	$ 949,000	38%	39%	10
Major (>$150k	$ 1,105,000	45%	45%	4
Total	***$ 2,481,200***	**100%**	**100%**	***42***

3.7 Resources

This section overviews the people resources anticipated to implement and maintain the Flood Risk Program, involving leadership and participation among MHFD, LGs, and contractors.

3.7.1 MHFD Staff

This Program requires considerable investment from MHFD staff as it is a significant undertaking in a new initiative to develop strategic capabilities. This includes the following involvement:

- *Flood Risk Program Manager*: a role at nearly full-time to manage the planning, messaging, implementation, and operation of the Flood Risk Program. This role focuses on three realms:
    - *MHFD*: includes internal engagement, building consensus, chartering, educating, collecting requirements, training for adoption, and reviewing/communicating programmatic metrics. Also coordinating tasks and objectives among other MHFD contributors.
    - *LGs*: stakeholder engagement, collecting requirements, understanding pain points and end uses, and building user-friendly platforms. Also coordinating studies, IGAs, and project planning.
    - *Contractors*: planning and directing scope, providing direction and resolving outstanding issues, monitoring and managing progress, and assigning new tasks.
- *Planning Program Manager*: a supporting role to the Flood Risk Program Manager at perhaps 8 to 16 hours per week to shape the structure of the Program, providing valuable perspective and institutional knowledge.
- *Planning and Floodplain Management Director*: a supporting role to the Flood Risk and Planning Program Manager at perhaps 1 to 2 hours per week to shape the Program and keep the Executive Leadership in the loop.
- *Research and Development Director*: a supporting role to the Flood Risk and Planning Program Manager at perhaps 1 to 2 hours per week to shape the Program and keep the Executive Leadership in the loop.
- *Floodplain Manager*: a supporting role to the Flood Risk Program Manager at perhaps 1 to 2 hours per week in considering core values and policies for the Program, especially with relation to alternate end uses and applications.
- *Senior H&H Engineer*: a supporting role to the Program on an as-needed basis to weigh in on technical matters during methodology development, result review, or when determining the approach for complex circumstances. Providing technical review of guidance documents and perhaps occasionally select models and results.

- *GIS and Data Manager*: a supporting role to the Program on an as-needed basis to intake, review, and host datasets, especially in relation to final product uploads to the web viewer (see Section 4.5).
- *Design, Construction, and Maintenance (DCM) Liaison*: a supporting role to the Program on an as-needed basis to collaborate with the Flood Risk Program Manager and others to facilitate the use of Flood Risk on DCM projects.
- *Executive Leadership Team:* having a working familiarity with the Program vision, structure, and products to help rally policies, processes, and people around contributing to and benefiting from the Flood Risk Program.
- *Information Technology (IT):* a supporting role to the Program on an as-needed basis. This includes understanding the end products to determine requirements for data storage, user interfaces, and security protocols needed to ensure the long-term management and integrity of Flood Risk Program data.

3.7.2 Local Government Partnerships

As with nearly every MHFD program, partnerships with LGs are important for planning, funding, execution, and effective outcomes. For the early stages of the Flood Risk Program, this involves executing IGAs to secure funding and scope with most of the communities. Representatives from a subset of communities (Denver, SEMSWA, and Lakewood) volunteered to participate in biweekly collaboration meetings to help craft Program direction. After the Program has completed the initial data development phase and matured in its operation, LG coordination will likely become streamlined to more of a task-by-task consultation with a regular focus on planning projects.

In this initial start-up phase, the Program would benefit from collaboration meetings that meet biweekly to review program elements, methodology, and status. The ideal size is between 8 to 12 people, so as to have a representative sample of experience and differing perspectives, without being encumbered by a large dynamic that can hinder consensus and creativity. These meetings should proceed at a regular cadence understanding that group attendance will fluctuate, rather than trying to align schedules. Understanding that a biweekly commitment may pose a large cumulative contribution, the group should be structured so that members can onboard and offboard on a quarterly basis, but should be committed to consistent contribution during the quarter. Ideally the group would have continuous representation from a few of the major LGs (e.g., Adams County, Aurora, CCD, and Jeffco) with a couple mid-sized LGs having rotational representation (e.g., Arvada, Thornton, Westminster).

3.7.3 Contractor Teams

The Districtwide scale of this Program necessitates a heavy reliance on multiple contractors. Districtwide data development follows grouped geographies and is set to commence in late 2026 and conclude in 2029, as detailed in Section 3.3. The initial production will be at a slower pace to allow for intentional learning and methodology refinement as multiple teams begin work across varied watersheds. Lessons learned from these earlier watersheds will be incorporated into the evolving guidance and workflows, after which production speed can increase in pace with greater efficiency and a lower risk of rework or inconsistency.

Developing Districtwide foundational data is estimated to cost roughly $5.55M in contracting (Section 3.6), which when spread over the 3 years equates to a monthly burn rate of approximately $150,000 once in full production, following initial learnings. Using typical industry billing rates for a team mix reflected in Table 12, this would comfortably coincide with two teams of moderate size; however, team composition can vary significantly based on the experience and availability of staffing. A third production team could be enlisted to either accelerate the completion timeframe (finishing a majority by late 2028) or if there is a concern about sustained capacity from the other two teams. Unless there is a desire to notably accelerate the schedule, it is recommended to not overly spread the work across too many contractors as there may be diminishing returns on efficiency that comes with streamlined decisions, familiarity, and collaboration in a smaller and more focused project team.

Table 12. Simplified Example of Team Composition and Monthly Expenditures

Per Team				Monthly Burn ($/month)		
Resource	$/hr	Staff	Total hrs/wk	1 Team	2 Teams	3 Teams
PM	$ 250	1	14	$ 14,350	$ 28,700	$ 43,050
Engineer III	$ 180	1	20	$ 14,760	$ 29,520	$ 44,280
Engineer II	$ 145	2	48	$ 28,536	$ 57,072	$ 85,608
Engineer I	$ 130	2	64	$ 34,112	$ 68,224	$ 102,336
Total	**$ 151**	**6**	**146**	**$ 91,758**	**$ 183,516**	**$ 275,274**

Table 12 is a reasonable approximation of the team composition and efforts expended to complete the validation basin work (Ralston Creek and Second/Third Creek – see Section 3.2.1) over 4.5 months. An ideal team mix is subjective and will differ between contractors and their project managers, but general rules of thumb include:

- *Project Manager*: should focus on management and technical advisement, whose involvement should amount to about 15% of total costs. Less than 10% is likely too hands off, and more than 20% is likely too expensive.
- *Engineer III (Senior)*: this role should be more focused on review, advisement, troubleshooting, and complex tasks, but is too expensive for a lead production role when the methodology is fairly prescriptive. Therefore, this is largely a supporting role to the rest of the team and it's ideal to have their time typically amount to 15% to 20% of the cumulative time across mid and junior levels. If the team is mostly junior, then 25% would be appropriate. In Table 12's example, this is one individual at half-time, representing 15% of the lower categories as the team is well supported by two mid-levels.
- *Engineer II (Mid)*: this role tends to be the primary modeler in terms of responsibility, delegation, and overall organization – but not perse with hours as more of the work is still completed by a junior modeler paired with a mid-level. Generally mid-level engineers are highly sought after and it is difficult to secure more than 3 days per week of their time, so Table 12 assumes two mid-level engineers at 24 hours per week each rather than one full-time.
- *Engineer I (Junior)*: this role tends to be assigned most of the production work, given autonomy with straightforward tasks, but closer direction and only pieces of complex tasks that might be executed more often by a mid-level engineer. If the work is explorative and uncertain, most hours should fall under the mid-level category (as in pilots and sensitivity studies), but when the work has been well defined and documented (as is for production), this labor category should have more hours than other categories.

As noted, a team mix is subjective, especially with regards to size or the number of hours per staff member; however, the general ratios and support structures reflected in Table 12 should be generally adhered to (e.g., 10-15% PM, 15-20% Senior, 30-35% Mid-Level) for well-guided and cost-efficient execution.

3.8 Schedule

This section discusses Program schedule considerations, including primary drivers and potential risks, sequencing considerations, and an example data development production schedule.

3.8.1 Drivers and Risks

Apart from the volume of work, the schedule is most influenced by the following drivers, listed as perceived from most to least influential:

- *Stakeholder involvement*: varying opinions, differing levels of understanding, and extended reviews can lead to rework, iterations, or delays awaiting feedback, approval, and input data. It is important to align the Production work around the Flood Risk Program objectives and not to conflate it with other initiatives or agendas. Review durations should be established in advance and adhered to. If delivery deadlines for input data are missed, the work should continue or the schedule be adjusted.

- *Storm Sewer*: the quality and format of the storm sewer data proved to be a significant influence on schedule (and cost) during the validation basins, as was specifically the case for Second and Third Creek that aggregated data from seven LGs, all in different formats, with differing fields and degrees of information. Joining and standardizing this information was laborious, as was debugging and "correcting" the linework. Ralston on the other hand came in relatively seamlessly from a single source; therefore, this component is a variable in schedule impact depending on its quality and format. Considerable efficiency could be gained in schedule and cost savings if there were a single concerted effort to obtain storm sewer data across the District and consolidate it into a single schema that can be readily ingested into the hydraulic models. This would also increase consistency and reduce the level of effort needed to make subjective judgements about pipe attribution.

- *Number of Models/Sources*: the Flood Risk Program leverages existing information and does not include separate field survey collection efforts. Therefore, existing model inventory is important, but can considerably differ between basins. Collecting and sorting through model inventory can be a lengthy process, where even tracking down and attaining the correct models may add several weeks to the schedule. Once the information is in hand, it may take another week or two to deconflict information between overlapping models. Once basins are assigned to contractors, contractors should create an inventory of all data sources for all the basins they are assigned to obtain the information at the onset of the project and mitigate delays as much as feasible.

- *External QC Model Reviews:* large programs can have a tendency of becoming heavily focused on compliance, and external reviews (one contractor reviewing another contractor's work) can become nitpicky with multiple rounds of QC. Given that the Flood Risk Program is not regulatory and provides relative risk scores, the QC should be focused on influential aspects of the model that would notably affect results, and not on minutia or precision in extraneous values.

- *Number of Structures*: large models in urban areas with many structures tend to introduce more instabilities that require iterative troubleshooting. It is best to incorporate structures in small batches and then run and troubleshoot before continuing on to the next batch; otherwise, it can be difficult to pinpoint the source(s) of instability in the model.

- *Calibration*: calibration can vary from one to several weeks depending on the number of gages, whether there are multiple interconnected streams, and if regulation (reservoirs, ponds) has an impact. Experience has shown that gage datums often require examination and even field verification at times. These components are compounded when datums shift or changes occur in the field (structure replacements, outlet modifications, etc.) making it difficult to decipher differences between modeled and observed conditions. MHFD will develop a list of adjustments for Alert gages to avoid production delays.

- *Compute time*: for larger models with many structures and pipes, the run times can become cumbersome, especially with iterative calibration and then 13 design events. While it is best to keep run times under 30 hours, combined models are sometimes necessary (e.g., complex braided flow paths between basins or interconnected calibration) and can exceed 50 hours, as was the case with the Ralston Creek model at 90 sq. mi. having over 200 structures and more than 8,000 pipes. It is suggested to manage design storm simulations to 30 hours or less. Consider splitting a basin at a logical break point when basins have excessive simulation durations for design storms, as further discussed in the 2D RoM modeling guidance.

3.8.2 Sequencing and Grouping

As described in Section 3.4, each basin has been assigned a "production wave" based on the necessary order of completion for hydrologic continuity. This signifies when an upstream basin's outflow becomes the downstream basin's inflow and will be a controlling factor for sequencing and the critical path for schedule. Table 13 summaries the number of basins and their cost by wave for each geography, leveraging the September 2025 cost estimate. These costs are used to calculate the months to complete model development using a monthly burn rate of $91,758 (from Table 12) assuming one team is assigned per geography and able to continuously advance without notable interruption after the initial ramp up following the learnings from the early production basins.

Table 13. Basin Counts and Cost by Production Wave per Geography (Modeling Only)

Wave & Geography	Count	Total Cost ($)	Months to Model
Boulder Creek	**23**	**$ 437,954**	**4.8**
Independent	2	$ 9,104	0.1
1	10	$ 151,892	1.7
2	9	$ 237,392	2.6
3	1	$ 16,581	0.2
4	1	$ 22,985	0.3
Box Elder Creek	**13**	**$ 173,942**	**1.9**
Independent	5	$ 51,335	0.6
1	4	$ 39,635	0.4
2	3	$ 43,823	0.5
3	1	$ 39,150	0.4
Cherry Creek South and Aurora	**28**	**$ 598,085**	**6.5**
Independent	2	$ 13,812	0.2
1	20	$ 374,054	4.1
2	6	$ 210,219	2.3
City and County of Denver	**24**	**$ 974,388**	**10.6**
Independent	8	$ 315,381	3.4
1	9	$ 414,623	4.5
2	6	$ 222,335	2.4
3	1	$ 22,050	0.2
South Platte Northeast	**15**	**$ 382,673**	**4.2**
Independent	5	$ 152,862	1.7
1	6	$ 68,227	0.7
2	2	$ 72,796	0.8
3	2	$ 88,788	1.0
South Platte Northwest	**36**	**$ 922,327**	**10.1**
Independent	7	$ 152,342	1.7
1	20	$ 394,304	4.3
2	7	$ 218,596	2.4
3	1	$ 87,958	1.0
4	1	$ 69,127	0.8
South Platte Southwest	**30**	**$ 664,442**	**7.2**
Independent	9	$ 236,354	2.6
1	15	$ 287,827	3.1
2	5	$ 125,238	1.4
3	1	$ 15,023	0.2
Districtwide Grand Total	**169**	**$ 4,153,812**	**45.3**

Table 13 reflects 48 total months to completion for one team, or 24 months for two teams, to complete District wide modeling coverage. The quickest geography is Box Elder Creek as it is mostly undeveloped and straightforward, where the longest geography is CCD at almost a year given the complexity and urbanization.

The month estimates in Table 13 represent best case scenarios and do not consider coordination delays with stakeholders or when staggering flow transactions between waves (1→2→3→4) for calibration and design storm simulations (for 13 events). If properly planned, these transactional delays can be minimized by accelerated wave 1 (dependent) basins and finishing wave 2 geometries as wave 1 simulations are finalizing. Then finishing wave 3 geometries as wave 2 simulations are underway, and so forth. The independent basins (wave 1 without downstream basins) should be given lowest priority and be advanced while other basin models are running (calibration or design storms).

Section 5.2.1 recommends performance-based contracting; however, if there were to be an even distribution of assignments, then the following options from Table 13 could be considered for contracting:

- With two teams
    - Boulder Creek, Cherry Creek/Aurora, and CCD totaling $2.0M and 22 months
    - Box Elder and the three South Platte geographies totaling $2.1M and 24 months
- With three teams
    - Boulder Creek and South Platte Northwest totaling $1.4M and 15 months
    - Box Elder, Cherry Creek/Aurora, and South Platte West totaling $1.4M and 16 months
    - CCD and South Platte Northeast totaling $1.4M and 15 months

3.8.3 Example Production Schedule

Table 14 reflects an example optimized production schedule (post-learnings after the initial ramp up) for the South Platte Northwest geography, following the sequencing logic presented above. The Table 14 schedule is not meant to be a planning metric nor does it reflect the slower ramp up, but is included here as an illustration of how production coordination can be optimized if development is partly staggered in parallel. For example, base layers are created for all basins at once and then model development is prioritized for Wave 1 basins, only moving to Wave 2 model development when Wave 1 models are in QC at Week 14 (finishing in Week 16). Similarly, Wave 3 model development begins after Wave 1 is complete and Wave 2 begins calibration. Wave 4 and the independent basins begin once Wave 3 is in QC. This staggered approach prioritizes the critical path, while putting tasks in parallel to optimize the overall schedule.

Table 14. Example Data Development Production Schedule (South Platte Northwest Geography)

Item	Finish Week by Wave					If 9/1/26 NTP	
	1	2	3	4	Ind	Start	End
Base Layer Creation	2	2	2	2	2	09/01/26	09/15/26
Model Setup & Mesh	4	16	28	35	35	09/29/26	05/04/27
Structure Incorporation	8	19	30	36	37	10/27/26	05/18/27
Sewer/Pipes	12	22	32	37	39	11/24/26	06/01/27
Internal QC & Revisions	14	24	34	38	41	12/08/26	06/15/27
Calibration	18	28	37	41	43	01/05/27	06/29/27
External QC & Revisions	22	31	40	43	45	02/02/27	07/13/27
Simulations & Post-Process	24	34	43	46	47	02/16/27	07/27/27
Hazard Products	26	36	45	48	49	03/02/27	08/10/27
Risk Products & Scores	28	38	47	50	51	03/16/27	08/24/27
Data Delivery	30	40	49	52	53	03/30/27	09/07/27
Documentation	34	44	53	56	57	04/27/27	10/05/27
Management, Mtgs, Comms	36	46	55	58	59	05/11/27	10/19/27

Schedules similar to Table 14 ought to be developed shortly after contract execution and reflect the desired end schedule, the contractor team, the awarded geographies, and their planned sequenced. Schedules like these can help form a baseline for measuring progress and performance, as elaborated on in Sections 5.1 and 5.3.

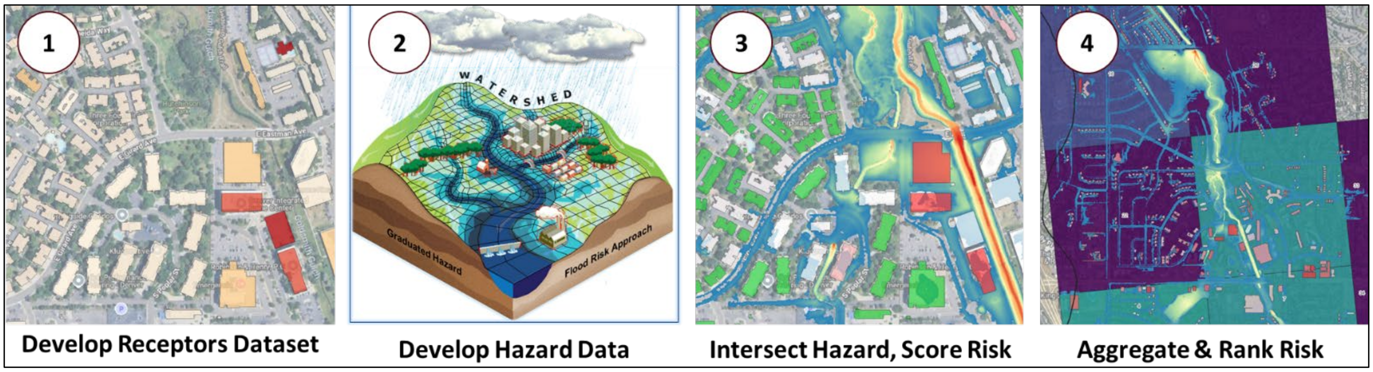
4 Implementation Methodology

This section overviews the Implementation Methodology to develop data (receptors, hazard, risk, and reduction estimates), rank projects for CIP prioritization, manage data, deploy products, and maintain the datasets. This section concludes with documenting sources of technical uncertainty. The section aims to provide enough information for a manager or user to adequately understand the process, but not enough detail for a contractor to execute the process. Additional details are provided in separate documents such as the receptors web-documentation, 2D H&H Modeling Guidance, and risk scoring workflow.

4.1 Data Development

The Flood Risk Program is built upon four data development phases, which are illustrated in Figure 17 and include:

1. **Receptors**: building and transit layers as people-proxy datasets to estimate the likely presence of people and the degree to which they would be impacted by flooding. This has already been completed for the full District and should require little to no modification prior to use in translating hazard to risk.
2. **Hazard**: the physical condition of flooding as estimated by 2D RoM models and represented by spatially-varied parameters such as depth or water surface elevation (WSE), velocity, and flood force (DxV). The hazard data development methodology was created through a series of pilots (see Section 3.2.1) and has been standardized as defined in the 2D H&H modeling guidance. Hazard data has been developed in select pilot watersheds and will be produced Districtwide by 2029 for existing conditions through a sustained regional production effort that this Plan informs.
3. **Risk**: represents the impact of flooding on people, through intersecting receptors with hazard data to develop risk data. This is developed from the hazard data and will also be produced Districtwide by 2029 for existing conditions through regional production per this Plan.
4. **Mitigation**: this phase evaluates the mitigation effect of hypothetical post-project conditions. This will be implemented on a watershed or LG-specific basis upon LG-request and funding. The mitigation effect will be assessed by modeling a modified geometry/condition, as if the project had been implemented, and compared the risk scores to the existing conditions to measure reduction.



Develop Receptors Dataset **Develop Hazard Data** **Intersect Hazard, Score Risk** **Aggregate & Rank Risk**

Figure 17. The Four Primary Components of Data Development

4.1.1 Receptors

A single authoritative dataset of receptors was developed for the entire District from people-proxy sources and organized into two layers: transit (roads and trails) and buildings (structures and critical facilities), as simply illustrated in Figure 18 and shown for a representative sample in Figure 19. These layers estimate the likely presence of people and their susceptibility to impact from flooding, which is captured through impact factors assigned to each receptor to represent threat to safety and general life disruption. Receptor development and impact factor assignments are summarized in the subsections below, and described in detail in the receptor methodology memorandum (Michael Baker 2026) with additional web-based documentation available HERE.

Figure 18. People-Proxy Receptor Datasets

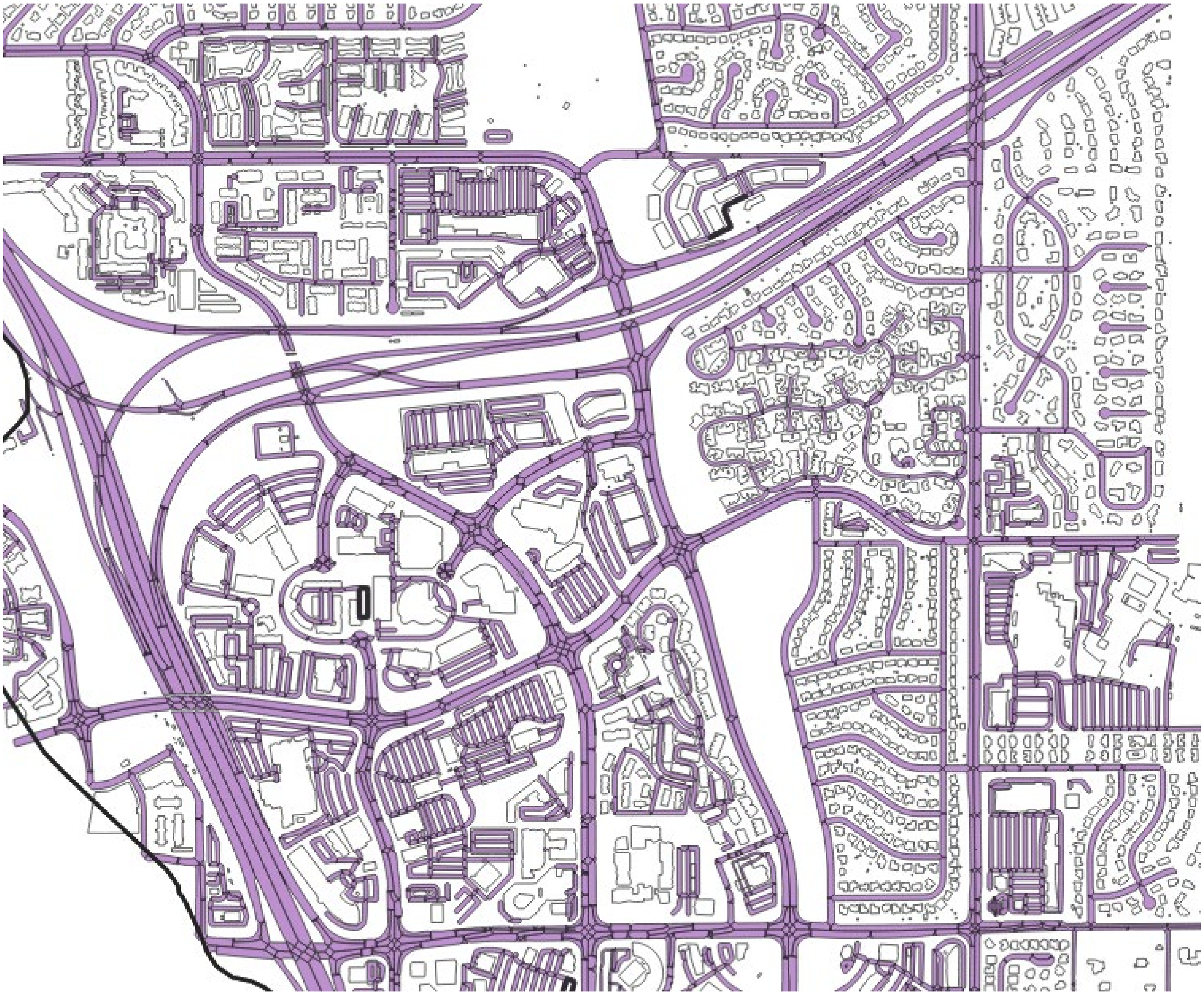


Figure 19. Representative Sample of Receptors (near I-25 and I-225 exchange)

In general, this receptor dataset is meant to be used "as-is" without the need for additional refinement prior to developing risk data (Section 4.1.3). Targeted modifications, including additions and subtractions, can be made where there may be misclassifications, missing data, or assets no longer in use. However, it might benefit from a future refresh if notable time has elapsed or national datasets were enhanced since its development in early 2026, or if a LG funded a targeted supplement from local datasets. Note that the date that the receptor dataset was generated should closely match the model source data to avoid discrepancies between model topography and receptor datasets.

Transit Layer

The transit layer was developed across three road and one trail datasets, aggregating linework and attributed as appropriate to arrive at a single transit layer in the form of road and trail segments (Figure 20).

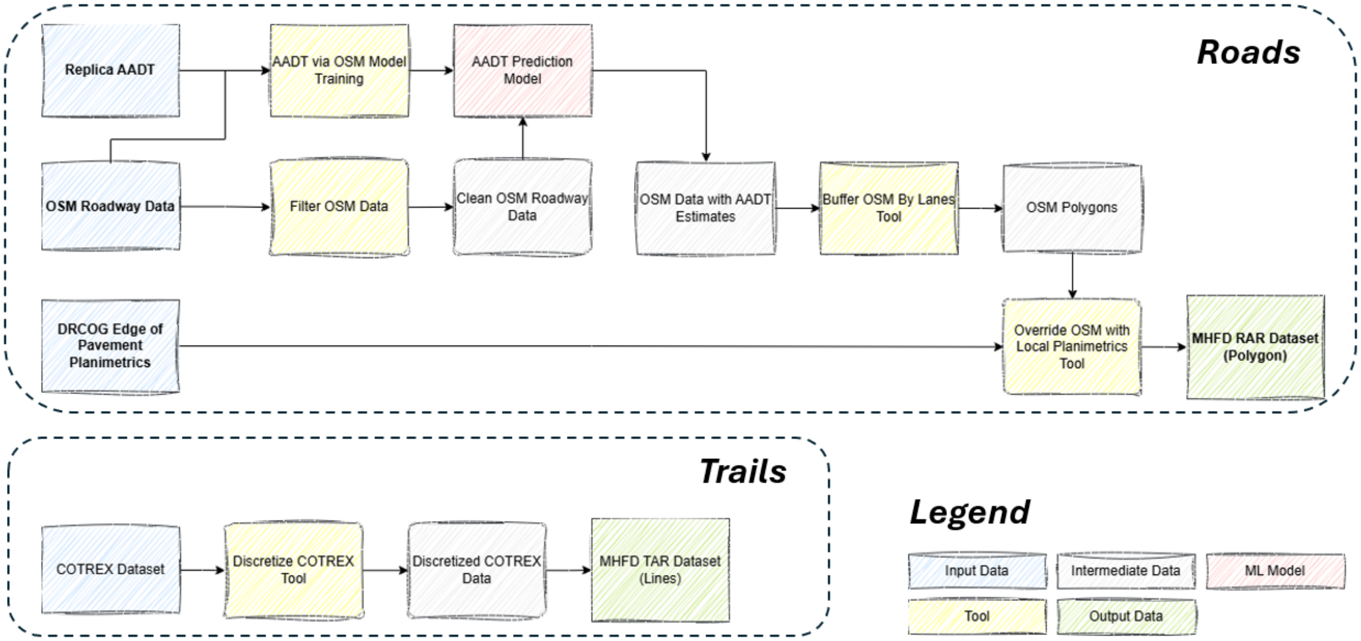


Figure 20. Developing the Transit Receptors Layer Across Various Data Sources

Impact factors for roads were assigned to individual road segments linearly based on the Average Annualized Daily Traffic (AADT) count, which is predicted based on a statistical model developed from Replica, a proprietary traffic model, and estimates the amount of people traveling along a road. Therefore, road segments with greater traffic have greater impact on people. All trails received an impact factor of 1 (lowest on the scale).

Transit Impact Factor = AADT/2600 + 3.5 (*cannot exceed 40*)

As a reference point, Table 15 shows impact factors for several examples and classifications from the Goldsmith Gulch pilot, along with some better-known roads to give the reader a sense of how this equation might translate to relatable impact factors.

Table 15. Transit Impact Factors for Representative Examples from Goldsmith Gulch

AADT	Description	Representative Examples	Count in Domain	Impact Factor
Trails	All recreational and access trails (500’ segments)	Goldsmith Gulch Trail	1,643	1
< 1,800	Local Street, Parking, Service Roads	E. Jewell @ S. Holly St.	6,280	4
< 4,600	Minor Collectors	S. Monaco St. Parkway	554	5
< 7,500	Major Collectors	E. Yale Ave.	456	6
< 16,000	Minor Arterial	E. Hampden Ave (east of I-25)	107	10
< 62,200	Freeway	I-225 @ DTC Blvd.	3	27
< 89,700	Freeway	I-25 @ Belleview Ave.	7	38
< 100,000	Interstate	I-25 @ Arapahoe Rd.	9	40

Buildings Layer

The buildings layer was developed across four datasets (two with footprints and two with points), aggregating attributes as appropriate to arrive at a single polygon building layer with attributed footprints (Figure 21).

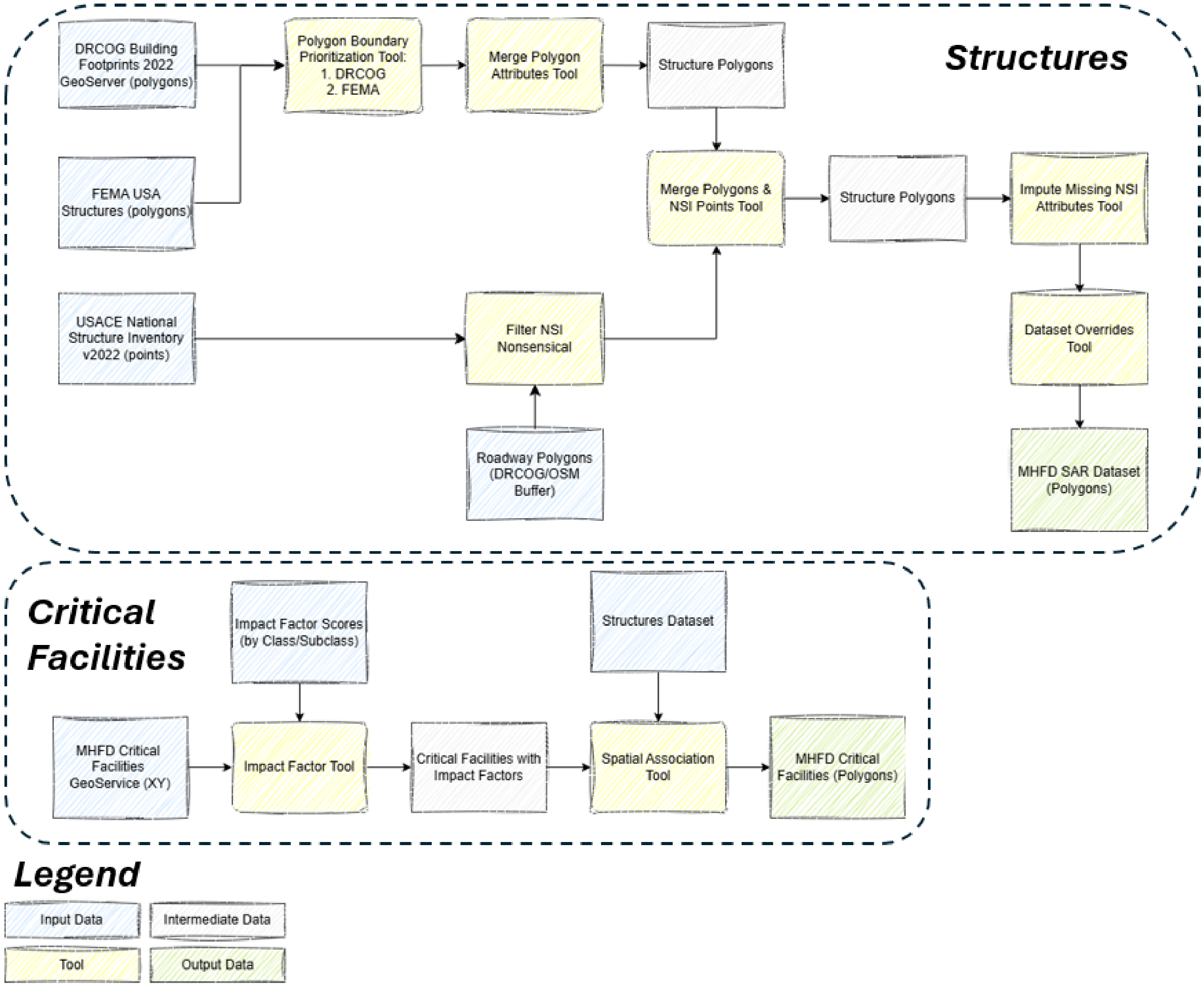


Figure 21. Developing the Structures Receptors Layer Across Various Data Sources

The process of combining building datasets created over 70 attributes, many of which were duplicative or irrelevant; therefore, the delivered building dataset is limited to a dozen relevant attributes, as shown in Table 16. The building footprints were taken from the Denver Regional Council of Governments (DRCOG), and most building attributes were carried over from the National Structure Inventory (NSI). The MHFD Critical Facilities dataset was used to identify structures with elevated importance.

Table 16. Relevant Attributes for Building Receptors

Field Name	Source	Description
receptor_id	Generated	Unique ID for each feature
occtype	NSI	Occupancy type
est_total_pop	NSI derived	Estimated total population
impact_factor	LGs, MHFD	Impact Factor based on professional judgment
found_type	NSI	Foundation type (basement, slab, crawlspace)

Field Name	Source	Description
sqft	NSI	The estimated total floor area in square feet of the structure across all above-ground levels, not just the footprint
num_story	NSI	number of stories
val_struct	NSI	Value in dollars of the structure
med_yr_blt	NSI	Describing the median year built of structures within the Census Block
PROP_ADDR	FEMA USA	Address of the property parcel intersected by the NSI point
LAT (Y)	Generated	Latitude (location)
LONG (X)	Generated	Longitude (location)
FR_score_P	Generated	Flood risk score from pluvial hazard (added upon completion of risk analysis)
FR_score_F	Generated	Flood risk score from fluvial hazard (added upon completion of risk analysis)

The likelihood of people being present and the degree to which they might be affected by flooding was represented through Impact Factors assigned for each occupancy type. This impact factor was developed in conjunction with LGs using professional judgment and past experience of perceived impact based on occupancy type with consideration given to the likely number of people present, their duration or frequency of occupying the structure, and their activity when doing so (e.g., work, recreation, sleep, medical care, etc.). As emphasized in Section 1, the Flood Risk Program prioritizes people over property, and as such, the impact factors are intentionally independent of asset value but do take workplace environments into account as a source of income. The perceived degree that people would be impacted was estimated first in terms of safety and then with regard to general disruption of life, including personal finance or ability to recover loss.

For example, a single-family residence may only average four people, but it is where people sleep (highest risk during an event), is their only living space, and is their primary economic asset. In contrast, a church may host hundreds of people but only for several hours a week and is able to temporarily close without significant disruption to people's lives. Furthermore, a home with a basement has significantly more risk to safety than a home without a basement. Table 17 summarizes the building Impact Factors by occupancy type.

Table 17. Building Impact Factors by Occupancy Type

occtype	Description	Impact Factor	occtype	Description	Impact Factor
AGR1	Agriculture Buildings	4	REL1	Church	6
COM1	Retail	6	RES1-1SNB	1 story no basement	20
COM2	Wholesale	10	RES1-1SWB	1 story with basement	45
COM3	Personal and Repair Services	6	RES1-2SNB	2 story no basement	25
COM4	Professional or Technical	6	RES1-2SWB	2 story with basement	45
COM5	Bank	6	RES1-3SNB	3 story no basement	30
COM6	Hospital	100	RES1-3SWB	3 story with basement	45
COM7	Medical Office	20	RES2	Mobile Home	30
COM8	Entertainment or Recreational	6	RES3A	Multi-Family (2-4u)	30
COM9	Theater	6	RES3B	Multi-Family (3-4u)	32
COM10	Parking Garage	4	RES3C	Multi-Family (5-10u)	36
EDU1	School	80	RES3D	Multi-Family (10-20u)	40
EDU2	College, University	30	RES3E	Multi-Family (20-35u)	40
GOV1	Government Services	15	RES3F	Multi-Family (35-50u)	40
GOV2	Emergency Response Services	100	RES4	Hotel or Motel	30
IND1	Heavy Industrial	10	RES5	Institutional Dormitory	60
IND2	Light Industrial	10	RES6	Nursing Home	100

occtype	Description	Impact Factor	occtype	Description	Impact Factor
IND3	Food, Drug, Chemical	10	Garage/Shed		1
IND4	Metals or Minerals	10			
IND5	High Technology	10			
IND6	Construction	10			

Note: for detailed information on types of structures and attributes by occupancy type, see the NSI User Attribute Guide.

4.1.2 Hazard

Hazard is the physical condition of flooding as modeled by 2D RoM with gridded outputs of depth, WSE, velocity, and flood force (DxV). At this time, most of the District (approximately 85%) will be modeled using HEC-RAS 7.0 (or later), with the remaining 15% being modeled with InfoWorks ICM driven by LG preference and generally following the jurisdictional footprints for Boulder, CCD, and SEMSWA, as shown in Figure 22. The planned modeling software was determined following the decision logic in Figure 23, and mostly followed watershed boundaries with some modifications. This is for planning purposes, where actual model domain divisions and software selections are subject to change and will be revisited prior to production kickoff.

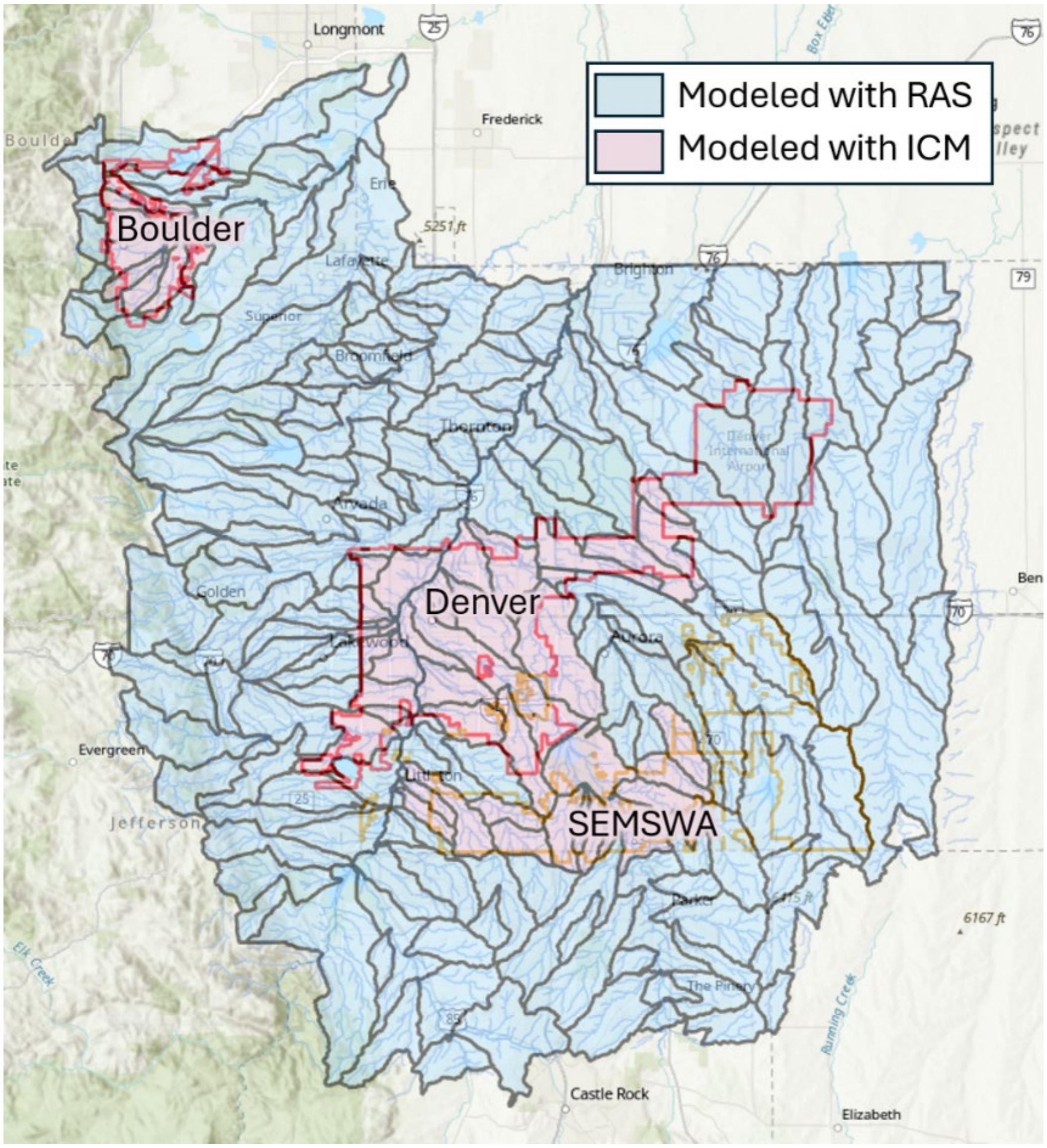


Figure 22. Planned Division of RAS vs ICM Modeling (subject to change)

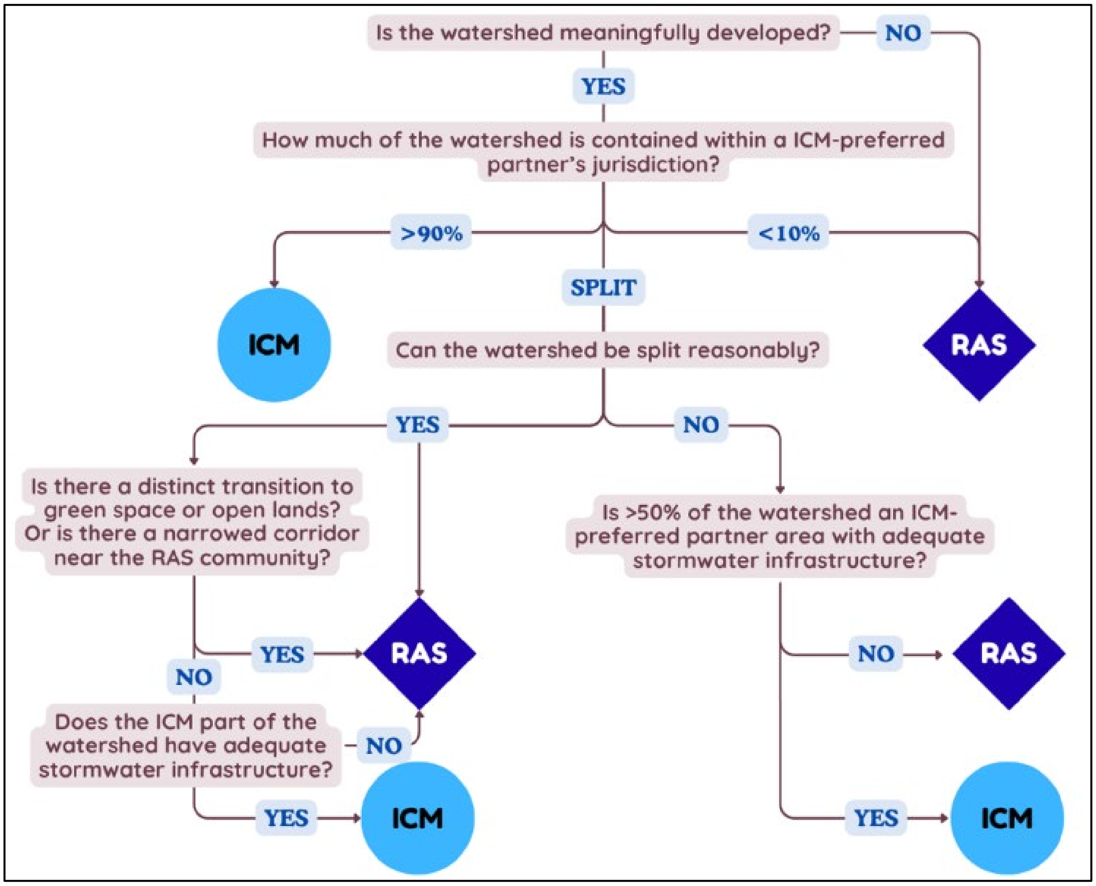


Figure 23. Decision Logic for RAS vs ICM Model Assignment

Hazard data have been developed in select pilot watersheds and will be produced Districtwide by 2029 for existing conditions through a sustained regional production effort that this Plan informs (see Section 3.3). The hazard data development methodology was created through a series of pilots (see Section 3.1.1) and has been standardized as defined in the 2D RoM H&H modeling guidance (Michael Baker 2026c). The main highlights for the H&H methodology are briefly summarized below:

- **Software baseline:** unless approved for InfoWorks ICM, 2D RoM models shall be developed and maintained in HEC-RAS7.0 (or later versions), including updates to legacy models, to support required capabilities such as pipe network representation.
- **Design storms:** include 13 recurrence intervals (1-, 2-, 5-, 10-, 25-, 50-, 100-, 200-, 300-, 400-, 500-, 750-, and 1000-year), using NOAA Atlas 14/15 precipitation with CUHP procedures (with interpolation for non-Atlas intervals as needed).
- **Conservative initial conditions:** Current RoM guidance utilizes restart files to reduce the influence of micro-storage and better represent long-term watershed conditions consistent with the objectives of the Flood Risk Program. MHFD will continue to evaluate and refine this approach as additional watersheds are modeled and validation efforts are completed.
- **Domain sizing and run-time targets:** delineate domains to balance stability and efficiency with target runtimes below 30 hours for design storms. Urban domains should generally range between 5 and 25 sq. mi., keeping the total pipes under 3,000. Larger rural domains may exceed 100 sq. mi.
- **Typical mesh guidance:** nominal mesh of 50 feet in urban areas (and 100 to 200 feet in lower-development areas), with refinements (generally 25 to 50 feet) along channels, floodplains, structures, and key breaklines.

- **Stormwater systems:** represent underground stormwater networks using HEC-RAS pipe features; including all inlets and pipe subsystems that have been digitized in a geospatial format.
- **Stability expectations:** keep total volume accounting error ≤2%; document and justify any main-channel cell water surface elevation error >0.2 foot.
- **Mapping and post-processing:** export maximum value rasters at a 0.1-foot threshold; remove disconnected islands and fill small holes; filter nuisance pluvial flooding; and classify fluvial vs pluvial using a 130-acre (0.20 sq. mi.) drainage threshold.

Pseudo-Steady State Riverine Models

The primary purpose for model development will be to create hazard data and then risk data; however, the finalized 2D RoM models will also be used to develop pseudo-steady state (PSS) riverine models that are more compatible with a regulatory framework. A PSS model is one that uses lateral inflow hydrographs to input a constant flow, which given sufficient time reaches a steady state condition in the 2D simulation.

This approach allows for a differentiation between pluvial and fluvial flooding and effectively decouples fluvial hydrology and hydraulics. While this adds a layer of complication to data development, it considerably simplifies the potential regulatory use and maintenance of riverine models. Program benefits to this decoupled PSS approach include:

1. Allows for riverine hazard to become regulatory and its models remain manageable, while pluvial hazard remains locally adopted or best available data.
2. Can hard-code flows into PSS models to avoid the mitigative effects of inadvertent storage (e.g., flow reductions at undersized culverts).
3. Minor changes to infrastructure or grading would not have a downstream propagation, as riverine flows would remain hard-coded and unchanged within a tolerance threshold.
4. Allows for multiple models and subbasins to feed into one larger RAS model spanning several domains/inflows; therefore, having a regulatory inventory comprised of fewer domains.

The process to develop a PSS model is described in the 2D H&H modeling guidance, but is briefly summarized as follows:

1. Developing a “structures removed” interim geometry from a copy of the final RoM geometry. Adding reference lines, deleting structures, blowing out residual embankments in the terrain, and running all 13 recurrence intervals.
2. Extracting flow hydrographs at reference lines from the “structures removed” plan, summarizing peak flows, and calculating flow change differences for all 13 recurrence intervals to develop incremental PSS hydrographs moving downstream.
3. Developing a PSS geometry by copying the final RoM geometry, adding inflow boundary conditions at corresponding reference lines, applying PSS incremental inflow hydrographs throughout, and running all 13 recurrence intervals.
4. Iteratively comparing PSS modeled flows against target flows (from “structures removed”) and adjusting as needed.

4.1.3 Risk

As emphasized in Section 1, the MHFD Flood Risk Program prioritizes people over property, and as such, the flood risk scores developed herein do not reflect economic losses but are representative of impacts to people. Risk scores capture the impact of flooding on people and are developed from intersecting receptors with hazard data through a series of custom tools in a mostly automated process. These tools are available <placeholder> with detailed documentation HERE and implement the following process:

1. *Gridded Outputs:* maximum depth, velocity, and flood force grids are exported from the RoM models and are post-processed, as described in Section 4.2.
2. *Filtered Buildings*: the receptor dataset is filtered to exclude buildings more recent than the terrain and landcover captured within the hazard model. This is done using the "med_yr_blt" field (Table 16), which represents the median year that buildings were constructed within that census block. Recognizing that terrain and landcover are captured usually within the last 2 to 5 years (via LiDAR and planimetrics on satellite imagery), most watersheds in the District will have had little to no "newer" development and will not have buildings removed through this process. However, some portions, particularly near the Denver Airport, Aurora, and Parker may have a reduced receptor dataset from the process. The purpose of this step is to avoid attributing hazard to a built environment whose infrastructure is not reflected in the hazard model.
3. *Hazard Intersect:* values are attributed to individual receptors across all 13 design events for depth, velocity, and flood force. The maximum value for each parameter is assigned to the receptor as found within a 4-foot buffer of footprints for buildings; within the polygon segments for roads; and along the trail linework (no width or buffer).
4. *Hazard Scores:* the maximum values for the 3 parameters are then translated to scores for each of 13 design storms based on the receptor-specific hazard thresholds using the linear relationships shown in Figure 25. The scores range from 0 to 3 and are based on professional development in conjunction for building depths, with the remaining 5 parameters (depth for transit, along with velocity and force for both buildings and transit) based on grouping hazard categories H1 to H6 from the often cited Australian study (Smith et al, 2014) that produced Figure 24.

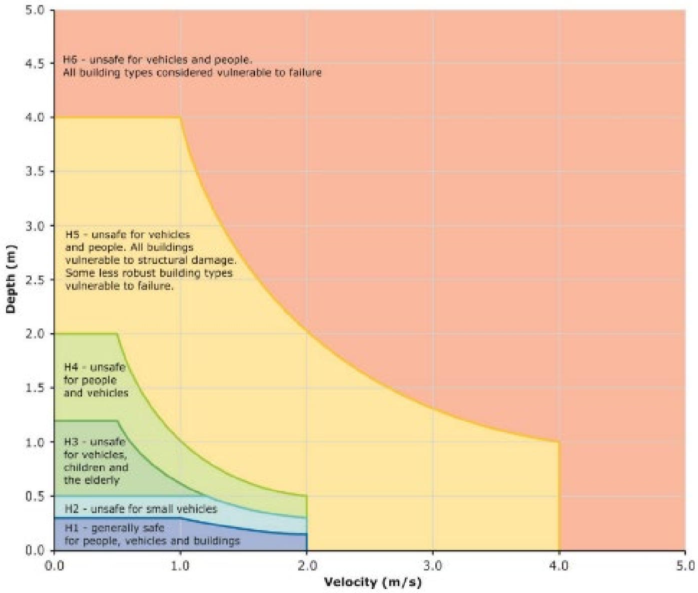


Figure 24. Hazard Categories by Depth and Velocity (Smith et al, 2014)

5. *Max Event Score:* the maximum score is retained across the 3 scores (D, V, DV) for each event, ranging from 0 to 3. Note that the driver for the maximum flood risk score varies between receptors (one building to another) based on its location in the watershed, and may vary across events (e.g., a road's max risk score might be triggered by depth for the frequent events and then velocity for the less frequent events).
6. *Apply Impact Factors:* the maximum flood risk scores by event are then multiplied by the receptor's impact factor, which is always 1 for trails, ranges between 1 and 40 for roads (Table 15), and ranges between 1 and 100 for buildings (Table 17). This allows for a receptor's importance or susceptibility to have a compounding effect that treats flooding differently (e.g., a flooded garage vs a hospital, or a flooded trail vs a highway). These receptor-weighted risk scores can then be evaluated individually or aggregated spatially for a single event (1 of 13 design storms).
7. *Annualized Risk Scores:* the event risk scores are then annualized across the full hydrologic spectrum (1- to 1000-year) through the summation of its event-specific risk score multiplied by its associated probability factor (or bin weight) using values in Table 18. *Note: if an asset is wetted every time, the bin weight sums to 1.*
8. *Exclusion Flagging:* the risk results (scores and threat maps) are reviewed for reasonableness, panning around the full domain but particularly focusing on outliers and irregular or disconnected hot spots. Results are compared against terrain and built-conditions at the time of terrain capture, and results are either deemed legitimate or receive an exclusion flag to override the unsupported risk scores. Exclusion

flag codes are defined in Table 19 and the process of assigning these is further detailed in the web documentation for risk scoring HERE, accompanied by graphics illustrating each example case.

9. *Spatial Aggregation*: once results have been reviewed and indefensible results excluded, the annualized risk scores can be evaluated at individual structures or aggregated spatially by problem area or a gridded overlay that helps highlight where legitimate risk hot spots exist (see Section 4.2 for examples).

This overall process is conducted for both existing conditions (foundational data) and post-project conditions (risk reduction, see Section 4.1.4) and will be performed most often on a watershed basis, but could be performed for individual domains or larger batches.

Table 18. Probabilities and Bin Weights by Recurrence Interval

Recurrence Interval	Probability (AEP)	Bin Weight
1-year	1	0.25
2-year	0.5	0.40
5-year	0.2	0.20
10-year	0.1	0.080
25-year	0.04	0.040
50-year	0.02	0.015
100-year	0.01	0.0075
200-year	0.005	0.003333
300-year	0.00333	0.00125
400-year	0.0025	0.000667
500-year	0.002	0.000583
750-year	0.00133	0.00050
1000-year	0.0010	0.001167

Table 19. Exclusion Flags and Descriptions

Flag Code	Description
-111	The receptor is not captured in the hydraulic model as its development or construction occurred after terrain collection/capture.
-222	The results are suspect due to poor hydroflattening of the terrain.
-333	Anomalies in the terrain capture produce unrealistic estimations of flooding.
-444	Anomalous result is due to constructed low-lying terrain adjacent to the structure, but is managed locally and not anticipated to negatively impact the structure (e.g., loading docks at retail stores).
-555	Controlling localized drainage is not adequately captured (e.g., curb adjacent to a retaining wall).
-666	Rendering issues near abrupt elevation changes (e.g., embankments, retaining walls) produce unrealistic depth artifacts.
-777	Inaccurate building footprint delineated, as it merges with the surrounding features/pavement.
-888	Indefensible results as local hydraulic structure information was not obtained (pipes, culverts, rating curves, etc.)
-999	Erroneous building footprint, as no apparent structure is present.

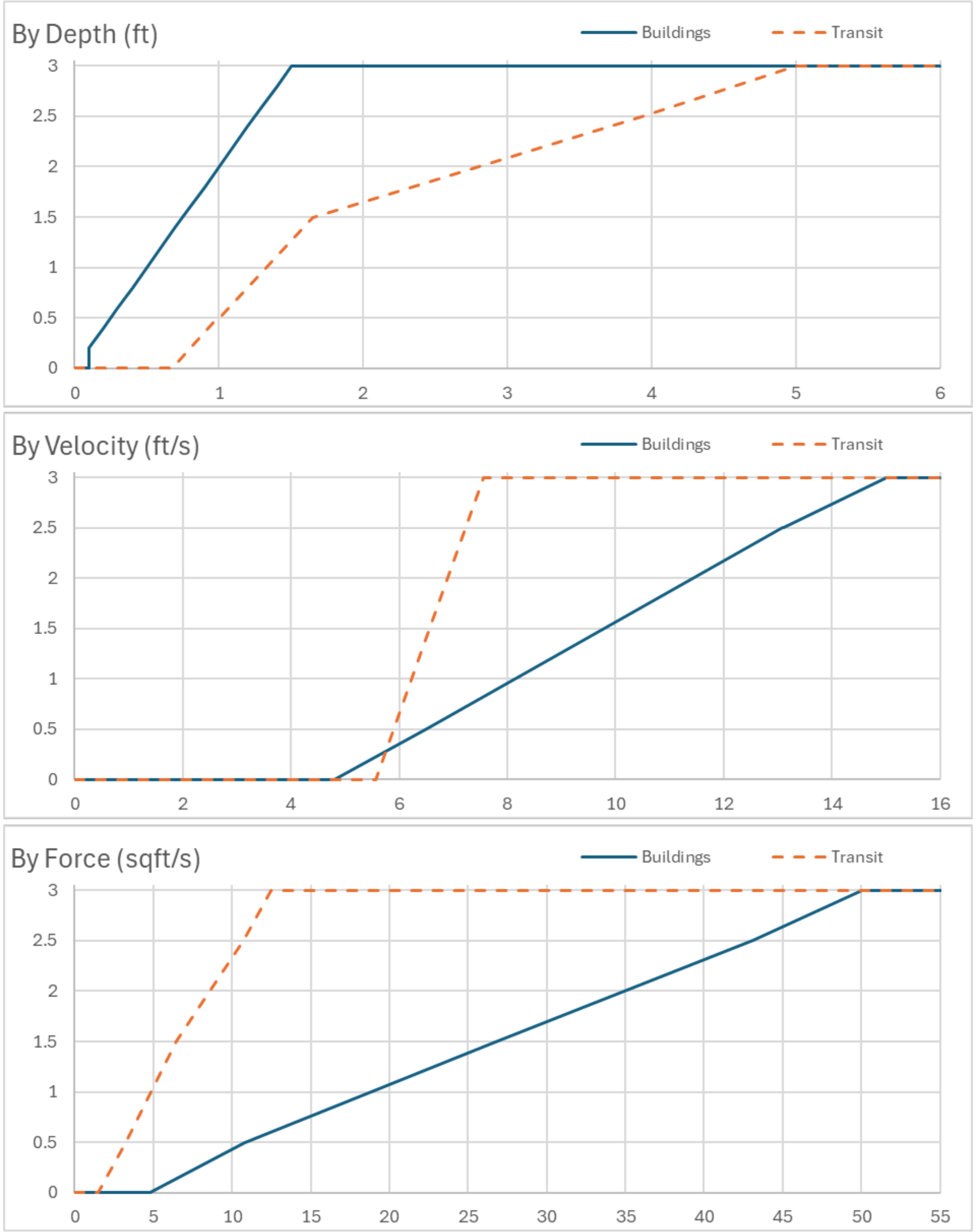


Figure 25. Hazard Thresholds for Risk Scoring

Economic Loss

The risk scoring process is intentionally independent of economic losses to prioritize people over property value; however, LG feedback indicated that estimated losses (e.g., event-specific damages and average annualized losses [AALs]) are still useful reference data for decision making. Even though they are not given primary consideration, they still inform benefit-cost analysis and help with justifying budgets. While cost-agnostic risk scores are sufficient (and unbiased) for justifying how to spend a fixed budget among many good options to "fix the problem", cost-benefit and losses avoided speak to the "magnitude of the problem" and are compelling metrics for justifying how much budget to request or allocate. In other words, loss informs budget setting, flood risk scores inform budget spending.

At this time, simplistic loss estimates will be generated using data as found in the NSI without alteration paired with standard depth-damage functions. Calculating simplistic AALs will be a default portion of the automated workflow using unmodified characteristics of the datasets, assuming default values, and not requiring additional review or user input. It should be noted that these simplistic AALs should be considered only as initial screening level information and should not be used for decision making. Instead, this automated output may assist in determining whether refined calculations should be undertaken to develop more defensible results. If desired, a future end user or LG could develop more defensible loss estimates without additional hazard modeling, as depth rasters will be provided for each recurrence interval.

The two most influential factors in loss estimates are first floor height and the structure value. These are typically derived for the NSI by very generic broad-sweeping assumptions, such as all structures sharing a single first floor height based on foundation type, and are known to be inaccurate at a local scale. Therefore, the two most influential drivers in loss are the two greatest sources of uncertainty when using the NSI-provided data. The primary focus of Flood Risk is “people first” through the use of human-centric flood risk scores and avoids this challenge, as neither attribute is used in the scoring; however, if more defensible economic losses are desired, then considerable effort may be required to refine these building attributes. Additionally, how hazard is attributed to each structure may warrant revision along with reviewing accuracy of building footprints themselves, as opposed to the current method of taking the maximum depth within a 4-foot buffer of the stock building footprints.

Overall, this Program will include fast and simple loss estimates using default values without attribute refinement to provide a screening level dataset, but LG-specific upgrades could be considered upon request and negotiated funding. These may include updating structure value from assessor records (which are known to be more realistic than NSI), revising first floor heights based on a terrain analysis from the building footprint (e.g., highest adjacent grade compared to lowest adjacent grade, and other analytics), updating the presence of basements from assessor records (where available), refining building footprints, modifying hazard attribution methods, and providing user-specified damage functions rather than the standard. Overall, the loss calculations themselves are highly automated and a low lift; however, it can be very costly to refine the building attributes.

4.1.4 Risk Reduction (post-project)

Once foundational data exists, risk reduction can be modeled through mitigation projects, where the RoM hazard models are modified to reflect likely post-project conditions. This is not a Districtwide concerted effort, but may be done for particular locations or select watersheds based on LG interest and funding. Projects evaluated at this stage may be conceptual for planning or alternative evaluation for a CIP. Projects should provide enough information to sufficiently represent its mitigative effects in the RoM model to quantify pre- vs post-project hazard differences. Information includes specifics on the changed condition, the spatial impacts, the proposed year of construction, and a cost estimate. The cost estimate is not required for modeling the impacts, it is to inform a risk reduced per dollar calculation. The risk reduction approach needs further testing, but Figure 26 illustrates an example comparison of what it might look like to model pre- vs post-project conditions.

Observed hot spots of existing Flood Risk may be used to signal where mitigation projects should be considered; however, at this time, the Flood Risk Program does not have a separate phase to implement an alternatives analysis as part of Flood Risk data development. Potential projects will vary in approach and complexity, and might include increased storage (expanding and/or deepening detention ponds, using underground storage, using blue or purple roofs), channel modifications (deepening, re-routing, new alignment, stabilization), structure upgrades (culvert replacements/upsizing or bridge widening), or new infrastructure (crossings, sewer, drop structures, etc.). MHFD’s master planning process will evolve for such modeling to be conducted on a watershed or LG-specific basis upon LG request and funding, but not for the entire District in a coordinated effort, as is the case for establishing the foundational data.

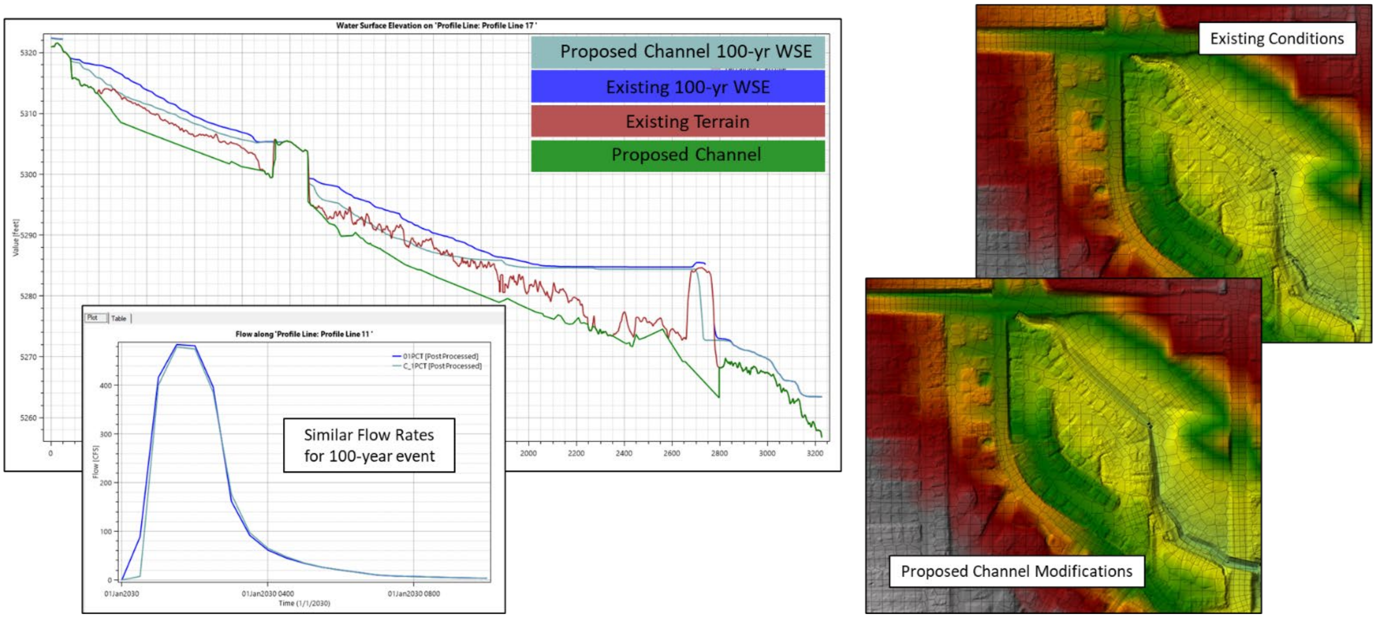


Figure 26. Example Mitigation Modeling of Post-Project Conditions

It is worth noting that post-project conditions will be modeled only in the RoM plans, but not in the PSS models as some mitigation benefits (specifically storage) would not be observed in a PSS model. If storage benefits were to be reflected in a PSS model, it would first need to be modeled in the RoM plan, flow reductions extracted from the RoM plan, modify the PSS model geometry, and then apply the reduced (mitigated) flows to the revised PSS model. However, simply modifying (adding storage to) the baseline PSS geometry without updating the hardcoded flows will reflect no benefit in a PSS simulation where there is infinite volume applied over an infinite duration.

It is also worth emphasizing that having optimized model run times becomes important for this stage, as each mitigation project is run individually for each of the 13 events, which could readily translate to hundreds of simulations. Where possible, some mitigation projects could be grouped into shared post-project simulations depending on their locations and if the watershed conditions did not propagate their mitigative effects downstream to shared reaches. This would reduce the overall computational load, but necessitates careful forethought and aggregation of pre- vs. post-project risk scores to fully capture a project's effects without conflating with a separate and concurrent project effects.

Projects could vary drastically in scale and impact, where the most costly project might not provide the most benefit, or the most affordable projects might not provide commensurate value. That is a central purpose of this exercise – to find the most cost-optimized mitigation project. At its core, this simply compares the rough cost estimate to a risk reduction estimate, as measured through a change in cumulative risk scores (both buildings and transit). The risk scores are summed for the entire watershed, as some project effects may propagate downstream as is frequently observed in RoM modeling, especially those that affect storage and flows. It should be noted that risk reduction measurement is inherently limited to effects on current infrastructure, or more specifically on people as represented through already existing buildings and roads – but not future investments.

4.2 Products and Deliverables

The Flood Risk Program will include various products and deliverables, with suggested initial products as shown in Table 20. These will be delivered as a "Flood Risk Data Bundle", with some of the spatial information hosted on a MHFD web viewer (e.g., Confluence or similar). The products will be refined and shaped by future coordination and iteration with MHFD and are purposed to enable:

- Watershed-scale quantification of existing flood risk for improved transparency and CIP decisions.
- Identification of flood risk inside and outside of FEMA-mapped floodplains.
- Consistent comparison of risk-reduction benefits across proposed projects.

Table 20. Potential Hazard and Risk Products and Data Bundle (initial version to be refined)

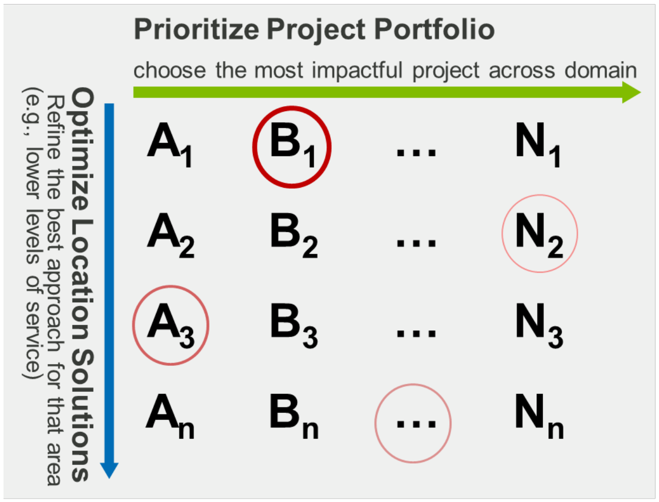
Type	Hazard	Risk
Polygon Data (receptor specific)	• Maximum flood depth values at individual receptors for the 1-, 10-, 100-, and 1000-year events.	• Flood Risk scores at individual receptors. Fluvial scores will be NULL for receptors outside the fluvial floodplain. Pluvial scores will be 0 for receptors that are always "dry". Exclusion override flags applied per Table 19. • AEP of Receptors (inundation or threat) – an intersect of the layers on the built environment itself. • Potential future product: A geodatabase of scored potential mitigation projects with pre- and post-project flood risk scores and their cost-benefit (risk reduction) ratios. • Simplistic AALs based on defaults for screening level purposes only.
Maps/Layers (polygons or rasters)	• Post-processed floodplains for the 1% and 0.2% events (other events available upon request). • Post-processed grids (D, V, and D×V) for all 13 events (other layers available upon request, such as WSE, shear stress, and inundation duration). • A composite AEP map to show the frequency of inundation (irrespective of depth). It has a maximum value of 0.9995 if wetted during each event, such as a stream centerline.	• Flood Risk scores aggregated and ranked by problem areas or tiles. • A threat AEP map for buildings and for transit reflecting annualized threshold scores independent infrastructure location. The threat AEP map shows how frequently and dangerously it floods and is created for both buildings and transit receptors. • Risk driver map indicating whether the maximum score was prompted by depth, velocity, or flood force, for both buildings and transit. This is an insightful layer to consult when considering mitigation alternatives, as the objective could vary (e.g., lessening flood depth versus slowing the velocity).
Other Spatial Information	• An attributed receptor dataset for the basin. • Centerline shapefile for all streamlines within a watershed to the 0.20 sq. mi. cutoff. • Storm sewer inventory geodatabase (post-processed/corrected pipes). • Structure inventory geodatabase (type, opening information, source). • Terrain modification shapefile used for channels, hydroconnectors, culvert inlet/outlets, or any additional terrain adjustments. • A calibrated RoM model with plans and results for calibration events and 13 design storms. • Exclusion area polygons with flags per Table 19.	
Supporting Documentation	• Summary statistics in tables and figures of flood risk scores and ranked projects • A summary master report documenting the overall approach and shared processes, with basin-specific subreports (or appendices) that document basin-specific notes, assumptions, deviations from the overall approach, and key observations. This will leverage a future template report with a tool that generates automated figures and tables from geospatial files and HEC-RAS outputs. • Meeting minutes, presentation materials, and supporting calculations.	

4.3 Risk-Informed Prioritization

While developing the hazard and risk data is fairly involved with a significant level of effort, ranking the projects for risk reduction efficiency is quite simple and straightforward. The process and factors may be refined after future exploration, but the current primary ranking metric is the cost of risk reduction, which is a comparison of the net change in risk scores between pre- and post-project against the estimated cost. The most cost-effective project can be designated either as the lowest cost per risk reduction point ($$$/point) or as the highest risk reduction per unit cost (points/$).

It is important to clarify that the Flood Risk Program is a data-driven approach to objectively rank projects by cost-effective flood risk reduction, but that it does not determine which projects are ultimately selected. Project selection remains a collaborative decision between MHFD and LGs for projects receiving MHFD funding and the Flood Risk ranking is a supporting dataset to assist in that decision, but there are additional factors that carry influence such as equity, losses avoided, economic benefits, environmental co-benefits, community values, synergy with other efforts (parks and recreation), or political commitments.

Figure 27 provides a simplified depiction of how the Flood Risk scores can be used to optimize and prioritize projects for funding. Individual solutions can be optimized for a single problem area with this approach that maximizes the cost-benefit ratio. An example might be evaluating multiple channel alignments to determine which alignment reduces the most risk for the least expenditure. Another example might be when evaluating a culvert replacement, which diameter and/or number of barrels are the best solution. Each problem-specific solution will have an inflection point at which greater effort yields less incremental risk reduction. Running post-project conditions for multiple project variations (e.g., culvert sizes, pond footprints, channel alignments, etc.) allows for identification of the best project option to address that problem area. This is reflected on the y-axis of Figure 27's lefthand diagram where A_3 was the best of "n" options considered.



Aggregated Score by Project	Risk Reduction (Δpts)		Cost	Risk ROI	ROI Rank
	Bldg	Transit	$MM	($/pt)	
1. Expand Pond	-97	-98	$1.4	$7,200	3
2. Upsize Culvert	-62	-92	$0.6	$3,900	1
3. New Basin	-31	-94	$5.3	$42,400	5
4. Deepen Channel	-4	-27	$0.5	$16,100	4
5. Reroute Channel	-19	-160	$11.6	$64,800	6
6. New Channel	-581	-1205	$8.8	$4,900	2

Figure 27. Example Illustration of the Project Prioritization Process

The next step is to then evaluate the most impactful project across the full portfolio of options, which might cover a watershed, service area, or LG boundary. This answers the question of "given many good (optimized) options, which is the best (most bang for buck)?". Moving across the x-axis, this is shown as Project B (specifically alternative B1) of options A through N on Figure 27's lefthand diagram.

The table on the right of Figure 27 shows example details that might be evaluated when identifying the most cost effective risk reduction project across six optimized options, which is the project with the greatest return on investment (ROI) as measured by dollars spent to reduce risk by one point. The best project in this example ends up being the second least expensive project, with the second-best option being the second most expensive project. Without a cost to risk reduction ratio, it might not be readily apparent which project is most impactful.

4.4 Data Management

Flood Risk is a data-rich program that aims to enable data-driven decision-making. This Program generates significantly more quantities and types of data than traditional studies, and for far more scenarios. Therefore, standards, tracking, storage, and QA/QC become key components to data management.

4.4.1 Standardization

As noted in Section 1.4, consistency and standardization are important principles for a few reasons:

1. *Objective Relative Ranking*: the primary goal behind the Flood Risk Program is to rank projects by their total flood risk or degree of optimized impact across watersheds and communities. This relies on a uniform methodology for developing hazard data, risk scores, and estimating risk reduction. CIP prioritization is informed by relative ranking (not absolute scores); therefore, as long as the methodology is consistently applied across the District, the ranked project order should be accurate even if some of the underlying assumptions aren't correct. In other words, proper risk reduction ranking is more reliant upon consistent assumptions than accurate assumptions.
2. *Automation and Data Linking*: large scale implementation presents many challenges that with proper upfront planning become opportunities for standardization that facilitate automation and data linking. The goal is to have seamless handoffs where data generated as outputs in one task become inputs to a subsequent downstream task with as few touchpoints as possible. To accomplish this, file nomenclature, formats, and storage structures must be codified. This is described in the 2D RoM H&H modeling guidance for hazard development (Section 3 of Michael Baker 2026c) and is baked into the tools for risk workflows, but needs to be developed for mitigation scenarios, program storage, and hosting.
3. *Streamlined Implementation and Reduced Review*: standardized practices, schemas, and reporting templates help streamline the effort when modeling dozens of domains, saving on cost and schedule, as well as reducing the review effort and providing a consistent product.
4. *User Experience*: many communities will have several watershed models, some over a dozen; therefore, standardization helps create a consistent look and feel, where an end user can leverage products uniformly without working through basin-specific deliveries.

4.4.2 Data Tracking, Hierarchy, and Storage

When working with large amounts of data and files, it is important to be intentional in how data are stored, tracked, and traced.

Version Control: this Program will have overlapping models in three ways: (1) RoM pre- vs. post-project conditions, which will be within one model project file, but have multiple geometries and plans; (2) RoM vs. PSS models, which are recommended as separate model project files to simplify future PSS use cases; and (3) overlapping domains where some portions are modeled two or three times when intentional domain expansions and overlaps are introduced (this is most common in very flat terrain with complex flow paths). In such cases, clearly labeled and organized file structures are important to ensure that the correct results are ingested in the automated workflows. This is particularly true for overlapping domains, as only one of the multiple datasets must be selected for use to avoid double counting.

Tracking and Traceability: Flood Risk scores are the primary decision driver and their derivation needs to be traceable. The Program is designed in such a way that for a project score an end user could (1) identify the contributing receptors that had changes in risk scores; (2) locate the model plans that were used; (3) review what changes were made to the model to reflect the project; (4) review the relative contributions by each recurrence interval to see where the greatest impact was observed; and (5) determine what parameter drove the risk score (D, V, or D×V). Having inline documentation (fields noting sources and assumptions within the receptors geodatabase) and uniform metadata accompanying deliverables will assist in this process.

Storage: the solution should vary based on what is being stored, its ingestion in use cases, and its end users. Data that needs to be accessed regularly should live in hot storage and be limited to only the minimum necessary datasets. Supporting documentation and models that aren't being queried, but need to be available for download can reside in cold storage at a fraction of the cost. Files that are kept for records retention without need for active access could be archived on external hard drives or backed up to an on-prem server.

Table 21 provides a ballpark estimate of data storage requirements for the full Flood Risk Program for existing conditions (excluding post-project conditions) based on file sizes from the Goldsmith Gulch pilot. This should be revised upon completion of the Validation Basins, which is a more recent reflection of requirements and is narrowly focused on Flood Risk, as opposed to Goldsmith Gulch that also included various sensitivity testing. Regardless of whether this estimate changes notably, it still shows a relatively low storage demand and inexpensive cost. This relies on smart storage with the bulk in cold storage that does not need to be readily accessed by web applications.

Table 21. Estimated Program Data Storage Requirements (existing conditions only)

Datasets	Format	Goldsmith Gulch (8.2 sq. mi.)	Districtwide (1,608 sq. mi.)	Storage Costs (AWS Estimates[2])
HECRAS Model Files	Various	~35 GB	~6.9 TB[1]	$329/yr (S3 Glacier Instant Retrieval)
Hazard Grids (D, V, D×V)	Cloud Optimized GeoTiff (.tif)	0.9 GB	176 GB	$50/yr (S3 Standard)
Derivative Rasters (AEP, classified rasters, floodplains, etc.)	Cloud Optimized GeoTiff (.tif)	0.4 GB	78 GB	$22/yr (S3 Standard)
Flood Risk (Buildings, Transit)	Parquet (.parquet)	0.02 GB	4 GB	$1/yr
Aggregated Risk (by project area or grids)	Parquet (.parquet)	0.0005 GB	0.1 GB	$0.02/yr
Totals		**36.3 GB**	**7.1 TB**	**~$400/yr**

[1] Cold storage of 6.9 TB could be reduced to below 2 TB if only the max profile was saved

[2] Storage is relatively inexpensive, but data transfers and downloads can be much more costly (e.g., 1 TB might equal ~$1,100). Internet uploads are typically free.

4.4.3 Quality Assurance / Quality Control

QA/QC is integrated in each major step of the Flood Risk Program and includes but is not limited to:

- **Receptors**: automated checks of reasonableness thresholds to ensure that stray building footprints are not located in streets, that impact factors match occupancy types, and that cumulative impact factors within a single footprint do not exceed 100 when multiple occupancy types are present. Additional QA/QC steps will be required in cases where local datasets (footprints or assessor data) are integrated.
- **Hazard**: before beginning, watershed domains should be carefully examined and adjusted as needed. Any adjustments need to be coordinated with adjacent watershed boundaries to avoid overlap, unless intentionally desired (e.g., expansions for flat terrain). There are multiple QC steps during model development, which are detailed in Section 13 of the 2D RoM H&H Modeling Guidance and in its accompanying QC spreadsheet (Michael Baker 2026c). Automated checks should be run on draft results to identify values exceeding reasonable tolerances (e.g., velocities > 15 feet per second).

Because these models are not being used for regulatory purposes (see Section 2.5 for fit for use), the QC review will be focused on "influential aspects" of the model that drive results (e.g., runoff, routing, storage, and hydraulics) and continuity of flow (instabilities), rather than verifying every structure dimension, survey shot, and compliance with specifications. Upon completion of hazard data development, a completeness check should be conducted to ensure the necessary outputs are generated and comply with specified nomenclature (see Sections 3 and 13 of the Modeling Guidance).

- **Risk**: following risk scoring, high threshold scores (prior to impact factor application) should be examined. Most of the time, elevated values are legitimate due to flood prone areas; however, at times they may be caused by modeling artifacts (e.g., mesh construction, rendering, or terrain defects) that either need to be corrected or post-processed. Reviewing flood risk scores and spatial patterns to identify outliers can be one of the most effective mechanisms for reviewing model results as oddities in the result tend to be emphasized once applied to receptors. Once finished, a completeness check will be conducted for required products (see Section 4.2).
- **Mitigation**: the main QC focus in this stage is to review whether the modified model geometries reasonably reflect the conceptual design description of the alternative, which at times can be rather subjective. A completeness and compliance check will also be conducted to ensure all files are present and named properly, as automated risk reduction calculations rely on following a prescribed structure.
- **Products & Deliverables**: products will be spot checked and reviewed for outliers or edge cases to ensure that processes did not fail or experience a data gap. The most likely source of error in this step is not that the tool didn't run properly, but that an input or piece of data was improperly named and either omitted or given an incorrect weight (Table 18). Deliverables will be reviewed for clarity and comprehension.
- **Data Delivery**: upon finishing the above steps, the necessary files will be uploaded to their respective repositories for storage, hosting, and deployment (Section 4.5). Prior to uploading the geospatial files (primarily the receptors with flood risk scores and tiled aggregated scores), their schema and metadata will be self-checked via "pass/fail" to ensure they can be uploaded to the web viewer.

At this time, the following levels of review are anticipated:

1. Contractors perform rigorous self-checks that verify many aspects of the model configuration and specific values in their own work.
2. Contractors perform higher-level reviews of one another's work focused on influential aspects and assumptions of modeling that would meaningfully affect the outcome.
3. The program management team conducts a final completeness check of the submittal for necessary files, schema, and documentation.
4. MHFD does spot reviews as needed, as well as cursory reviews of the contractor "peer reviews" to provide accountability and oversight.
5. LGs review hot spots and flood risk scores based on their institutional knowledge of past flooding and problem areas.

Extensive third-party reviews of the hazard models or datasets (receptors, risk, products) are not anticipated, nor reflected in the estimated cost and schedule (Sections 3.6 and 3.8).

4.5 Deployment & UI/UX

The Flood Risk Program will likely deploy results to a fully functional, intuitive, web-accessible platform that enables consistent interpretation of risk data, project comparison, and reporting. The purpose of a well-designed deployment is not merely to visualize flood maps, but to operationalize Flood Risk as a data-driven decision support system integrated into capital planning workflows. Adoption and uptake require that the platform be useful and intuitive (minimal learning curve) because Flood Risk is a non-regulatory, optional decision support tool. It must improve the end user's experience by making their task easier and more defensible, without complicating the task or increasing the level of effort required. Therefore, a well-designed user interface/user experience (UI/UX) is just as important as a carefully designed methodology for data development.

When planning the deployment and UI/UX, the following should be considered:

- **Applications**: the platform features and interface will vary depending on the desired functionality and supported end uses, which are not well-defined at this time and will likely encompass more than risk identification and CIP prioritization.
- **End User Base**: the primary users will be community officials who are evaluating project selection for CIP prioritization; however, other users will have interest in viewing the dataset corresponding to the number of potential use applications described in Table 5. It is likely that the user base will vary considerably in knowledge, interest, and desired functionality. The platform should be designed with a layered structure allowing different levels of detail and complexity (low, medium, high). This can be accomplished via filters or persona-based portals.
    - Floodplain administrators and CIP managers are likely to be most familiar with flood data and interested in greater levels of detail.
    - Public works directors and planners are likely to have a working knowledge of flood data with interest in the main layers, but not derivative products or detailed data.
    - Elected officials and board members are unlikely to access the data and their exposure might only be to select screenshots and stats provided as justification accompanying funding requests.
    - Although the platform will be accessible to the public, it will not be socialized and the general public is not a target end user.
- **Access**: the platform should be web-based and hosted by MHFD with all required data readily accessible. At this time, the plan is to make the portal public without user login. The portal ought to have a carefully crafted disclaimer as a splash page before accessing the data that clearly lists its appropriate uses, limitations, non-regulatory nature, and that it does not assess property value.
- **Visualization**: LG feedback should be solicited through a workshop and survey on the desired look and feel of the platform including color schema, results visualization, and aggregation mechanisms (tiles, honeycombs, grids, heatmaps, etc.). LGs should be asked what supplemental layers might assist in decision making, such as regulatory mapping, social vulnerability, census economics, or demographics.
- **Training**: following deployment, structured training sessions shall be conducted for system navigation, dataset orientation, interpretation of risk scores, and common misinterpretations to avoid. Training materials shall include a quick user guide with example screenshots.
- **User Acceptance Testing:** prior to Districtwide release, the platform shall undergo formal user acceptance testing including representatives from MHFD, LGs, and contractors. Users ought to evaluate the functionality, visualization, and system performance under multi-user load.
- **Recalibration:** The team should plan to seek feedback on the UI and make adjustments and improvements following an initial period of use, (e.g., after a year of use).
- **Architecture Requirements:** the system will likely be built on an enterprise geospatial architecture compatible with MHFD's existing GIS infrastructure. It shall support multi-user access, role-based permissions, and version-controlled data updates. The deployment environment shall include:
    - A centralized spatial database (enterprise geodatabase or equivalent);
    - Server-side processing capability to calculate aggregated risk metrics dynamically;
    - An application interface accessible through a secure web portal; and
    - Automated backup and version history retention.
- **Core Functions:** the platform shall include the following functionality:

- Toggling between AEP hazard events with the ability to obtain event-specific values from D, V, or D×V grids.
- Switching between "Existing Conditions" and "Post-Project Conditions" (where available) for each evaluated project. Side-by-side map panels shall be available to visually compare hazard extent and depth differences to spatially assess the impact.
- Calculating and displaying metrics dynamically for user-selected areas (e.g., polygon selection tool) to report the number of structures and roads impacted, event-specific flood risk scores, and annualized risk scores.
- Displaying project metadata including cost basis year, contingency assumptions, and modeled domain/project file.
- Generating standardized summary statistics and graphs exported to PDF or graphics.

4.6 Maintenance & Refresh

Although Flood Risk does not need frequent updates, it is not a static dataset and should be checked annually to determine which (if any) watersheds might merit an update. Over the long-term, some maintenance is required to preserve relevance, comparability, and technical defensibility; however, most maintenance should not be a big lift. The Flood Risk Program is designed in a consistent manner that is readily refreshed as most updates should be feasible with minor modifications to geometry/mesh and layer replacements. In other words, a refresh should be a revision, not a rebuild.

The Program will always retain the first model built for each basin as the "baseline condition" for future change metrics. Model revisions may include batched updates based on major changes to watershed conditions (e.g., significant development), updated datasets, implemented CIP projects (e.g., storage, structures, channel alignments), or potentially a Master Drainage Plan. Model updates will require MHFD and LG coordination and funding, and will be made both to the RoM and PSS models. If LGs perform model enhancements via separate efforts, the updated models should be shared back with MHFD for evaluation whether to be incorporated into the Flood Risk Program. Updates to receptors or hazard model inputs will need to be carried through risk scoring.

The following occurrences could merit an update and should prompt a discussion or evaluation:

- Significant changes to receptors, such as the release of a vastly updated NSI dataset. This could prompt recalculating risk, but would still source the same baseline hazard datasets without needing additional modeling.
- Notable watershed alterations either from extensive recent development or completion(s) of large-scale capital project(s) materially altering flood hazard. This can be updated as needed associated with CIP projects, as-built incorporation, or as funded and directed by LGs. Only the altered portions of the mesh need to be updated (new breaklines, structures, and pipes) and associated layers regenerated (terrain and land cover, if applicable); however, depending on the extent of changes and the availability of recent historic storms, recalibration might be prudent.
- Adoption of new Districtwide hydrology or a potential future study deriving hydrology from the District's own gages. The hydrology datasets should first be compared to see whether a meaningful change has occurred (e.g., >10% change in basin-averaged precipitation depth) prior to re-running hazard analyses. This would involve applying new/updated precipitation boundary conditions, but would not require geometry updates nor recalibration; thus, keeping it a pretty low lift.
- Newly available LiDAR/terrain for all or a majority of the basin may merit an update depending on what changes have taken place since the last capture. Whether to update the model could be assessed by a quick review of a difference grid between the two terrains to identify areas of meaningful change. If deemed worth updating the model, the new terrain can be associated with the geometry, breaklines and key mesh features adjusted where needed, and then the model run again. In most situations, little to no revisions will be needed to the geometry, making it a simple update.

- A capital improvement project has been completed by MHFD and the as-built geometry can be incorporated into the model. Incorporating this process into the standard CIP scope is recommended.

Since these updates will be basin specific, the District will maintain a basin-tracking layer that notes the recency and data sources for various fields, as suggested in Table 22, which can be used to create maps that illustrate the flood risk scoring vintage and where updates might be needed. Given the above scenarios, it's likely that most basins will be updated on average every 3 to 5 years. The example shown in Table 22 is hypothetically triggered by the release of new terrain and land cover, which prompts a hazard model refresh. In this example, the latest receptors are updated (assuming a new NSI release), but the pipes and hydraulic structures are left unaltered from baseline and NOAA Atlas 14 is still consulted (sourced 2013), though NOAA Atlas 15 is planned to be released in late 2026.

Table 22. Example of Recency Tracking for Basin Attributes

Component	Data Source(s)	Baseline Year	Last Updated
Transit Receptors	OSM + others	2026	2027
Building Receptors	NSI, DRCOG, USA Structures	2022	2027
Hydrology	NOAA	2013	N/A or 2027
Terrain	USGS	2021	2027
Landcover	DRCOG	2021	2026
Pipes	List LGs	2026	N/A
Hydraulic Structures	List models/survey	2010-2024	N/A

4.7 Sources of Technical Uncertainty

Flood risk quantification inherently includes uncertainty associated with its inputs, with the greatest contributions arising from hydrologic variability and building attribution (informing impact factors). A number of data inputs carry uncertainty, generally listed from greatest to least net impact but can vary by basin depending on data sources available:

- *Hydrology*: most notably the assumption of a static uniform distribution (an AEP [e.g., 1%] applied everywhere evenly without moving) and following a fixed/prescribed intensity-duration frequency. The applied precipitation depth is better understood, but where, when and how quickly that depth is applied is extremely variable and impossible to capture in simple design storms. A related issue is joint-probability for large domains with inflows, where is it educated guesswork at what timing, magnitude, and shape nearby inflows might coincide with local flows. All of these issues are significant oversimplifications which are well understood to certainly be incorrect, but to still provide useful insights with large uncertainty bands. The accuracy of these matters can be significantly improved through sophisticated methods like stochastic storm transposition (SST), which can eliminate concerns like depth-area reduction, joint probability, and unrealistic distributions. However, SST also brings significant complexity and extremely large compute demands (tens of thousands of storms), thus offsetting the technical benefits that it brings.
- *Building Attributes*: if economic loss was a central component to Flood Risk, then this would be at the top of the list, as first floor height and structure value are both the most influential inputs and the least defensibly derived fields. However, these fields are not factored into the flood risk scoring, rather occupancy type is the controlling influence on scores via the impact factor. While the NSI occupancy category assignments are generally credible, the presence of a basement is inferred from a probability based estimate from regional structural attributes. The credibility of these assignments are believed to be fairly high in urban areas like Denver, which pull from tax assessor data that explicitly tracks basements; however, these data can be inaccurate at times and the presence of a basement has a notable effect on assigned impact factors (Table 17). Likely the greatest source of building uncertainty on risk scores is how multistory buildings with multiple occupancy types are handled. For example, if a medical office was on the fourth floor, it likely would have no impact from flooding, but there are no known datasets that currently identify what floor an occupant might reside on, so all points within the building footprint are scored for hazard thresholds as if they were the ground floor. This is

understandably conservative and results in inflated scores for multi-use, multi-story buildings. Also related is the configuration of building footprints and poor hydroflattening that occurs near large structures.

- *Design Storms Aren't Reality*: in addition to rainfall being extremely different in reality, the modeled simulations make assumptions that the channel doesn't change (move, deepen, or avulse), remains clear of debris, and that structures (including pipes) continually experience clear water conditions without blocked openings. This is seldom the case in reality, but difficult to predict. Modeling bulked flow with partly blocked conditions could be considered for specific watersheds and infrastructure based on LG feedback.
- *Modeled Initial Conditions and Storage*: the design storms make assumptions about initial conditions that have notable impacts. Examples include the normal pool elevation for reservoirs (storage), effects of water quality basins, eliminated microstorage that is consumed through a restart file, typical soil moisture for initial abstraction (which can be influential and is impossible to predict), and that canals and ditches are assumed to be full and not conveying flows. Such conditions can be adjusted to mimic reality when calibrating to historic storms from gage information, but need to have generic assumptions for predictive storms.
- *Data Gaps and Structure Assumption*: due to these models being watershed wide yet not involving field survey collection, there are inevitably data gaps that need to be addressed with generic assumptions. Frequently, there are small hydraulic structures (especially pedestrian bridges and small culverts along green space) that can only be vaguely inferred from satellite imagery, but do not appear in a prior hydraulic model nor an LG's structure inventory nor as-builts. Therefore, a generic approach is taken with opening sizes that are typical of the area, but unverified. Additionally, hydraulic structures are incorporated from past models, some of which were built from information that was collected over 20 years ago and is liable to change, especially with regards to the channel bottom beneath the bridge.
- *Pipes*: often datasets have the linework without many attributes, requiring automated pre-processing that adjusts slopes and assigns diameters when data is unknown. Assumed values are noted in the delivered pipes database and could be revisited with improved datasets.
- *Recent Development*: as mentioned above, models are tied to the input datasets, which might be a few years old and not capture recent development. This is not a concern as long as the results are understood to be a snapshot in time and are not meant to reflect today's conditions. Recent development is also constructed to modern regulations which typically provide a minimum of 1 foot of freeboard for the 100-year within the channel. Thus, flood risk scores within recently developed areas should be minor.

Overall, the uncertainty is acceptable for the intended use – understanding the system flood risk to inform CIP prioritization (see Table 5 for other uses). This is particularly true for Flood Risk as the goal is not to capture hazard and risk as accurately as possible, but instead to measure the change in relative risk reduction across various projects all sharing the same underlying assumptions. Therefore, any biases or uncertainties carried into the analysis are reflected in both the baseline (pre-project) conditions and mitigation (post-project) conditions, meaning that the effect is cancelled out. If what is of primary interest is where the greatest risk reduction occurs, as is the case for a Flood Risk ROI, then shared uncertainties in both pre- and post-project conditions do not generally present a concern. However, if the data are to be used for other uses, especially those in the "caution section" of Table 5 like design, then some of the components with greater uncertainty might be given additional attention.

Lastly, it is helpful to remember that uncertainty does not equate to error, but rather to variability and unknowns in datasets, which is acceptable if documented and noted in external facing products and platforms with appropriate disclaimers and limitations. A relevant and oft quoted remark on modeling is that "All models are wrong, but some are useful" and is attributed to statistician George Box. This means that even though no model is ever completely accurate, simple models can still provide valuable insights if applied judiciously.

5 Program Management

Program Management provides the administrative, contractual, oversight, documentation, and adaptive management structure needed to deliver the Flood Risk Program over multiple years, across multiple consultant teams, and with multiple partner jurisdictions.

Given the scale of the effort, program management will be proactive, well-documented, and performance-driven. This will be led primarily by the Flood Risk Program Manager at MHFD, with support from other MHFD staff (planning, floodplain management, and leadership) and MHFD's Flood Risk contractors.

This section describes how work is measured, procured, monitored, controlled, documented, evaluated, and improved. It is intended to promote:

- Consistent execution
- Responsible use of resources
- Contractor accountability
- Transparent decision-making
- Continuous improvement
- Long-term program sustainability

5.1 Metrics & Reporting

As a new program, its development, use, adoption, and impact should be regularly evaluated to identify opportunities for improvements—including additions, removals, or modifications to program elements.

Because this Program is a significant long-term investment, its value must also be demonstrated through clear metrics and stakeholder feedback. Where possible, metrics should be:

- Quantifiable
- Trackable over time (monthly, quarterly, annually)
- Actionable (able to trigger a management response)
- Scalable (applicable at basin, community, geographic, and program-wide levels).

These suggested metrics should be routinely reviewed, measured, and reported to stakeholders. Metrics may be refined as the program evolves.

5.1.1 Program Implementation and Performance Metrics

Program performance and effectiveness can be evaluated using a range of metrics. Proposed metrics are included in Table 23 for developing foundational data that aim to assess how well the program development is executed relative to the plan (schedule, cost, and quality). This helps identify whether delays or cost overruns are systemic (e.g. modeling complexity, scope creep) or tied to specific contractors, LGs, or basins.

Once the Program is further developed and additional end use applications more mature, additional program metrics should be identified that consider the following aspects:

1. *Operations*: Evaluates how well systems function, how usable they are, and how sustainably they are maintained. This should help identify usability barriers and cost predictability
2. *Usage*: Assesses how often and how effectively decision-makers use flood risk information (scores, platform, and products) for both primary and secondary use cases. This should focus on whether the Program is actively used— not just available.
3. *Outcome:* Measures how risk-informed decisions influence capital allocations and reduce flood risk. This should focus on measurable change and risk reduction attributable to the Program

Table 23. Proposed Metrics to Evaluate Performance during Data Production

Category	Metric	Success Target	Measurement Frequency
Schedule	% Complete	<10% variance	Monthly rollups by community and geography. Quarterly program wide assessment.
	Schedule Performance Index (SPI) (actual/planned)	≥ 0.90	
	% Basins Delivered on Time	≥ 90%	Update upon delivery
	Cumulative Delay	≤ 3 months between original plan and final delivery	
Cost	Cost Performance Index (CPI) (actual/planned)	≥ 0.95	Monthly rollups by community and geography. Quarterly program wide assessment.
Quality	Rounds of External QC	1 for ≥80% of basins ≤2 for ≥95% of basins	Cumulative, updated per review
	QC Review Turnaround	Review in 30 days, Revision within 30 days	

5.1.2 End Goal Success Metrics

Table 23 presents a range of potential metrics that can be used as incremental indicators of Program implementation during foundational data development. However, the Program should ultimately define success based on the utility in the end use applications. For CIP prioritization, this could include two key outcomes:

(1) whether this Program influenced CIP decisions, and

(2) whether the improvements meaningfully reduced risk.

<u>*Decision Influence*</u> measures whether risk scores are a major consideration for stormwater CIP project selection based on whether they were consulted and influenced decision making. Flood risk reduction is only one of several decision factors, therefore, the projects ranked to be the most effective in risk reduction may not be the most impactful or desirable project for other reasons.

<u>*Outcome Impact*</u> evaluates whether risk is actually reduced and by how much. In more established programs, this is often measured using losses avoided—the difference between costs that would have occurred under pre-project conditions vs. those that actually occurred after project implementation during real events. This cost includes damages, recovery, and maintenance costs and that total value is then compared to the project costs (capital and maintenance) to assess overall benefit.

However, a cost-based comparison presents two challenges for the Flood Risk Program:

- It prioritizes property value over impacts to people, which does not align with the Program's core values
- It requires detailed building data for damage estimates, which is not a focus for MHFD Flood Risk (see Section 4.1.3).

Instead, the Program emphasizes impacts to people. However, defining a clear, quantifiable success metric is more difficult than a simple "*money saved vs. money spent"* comparison.

One potential metric is "risk avoided," defined as the difference in flood risk scores between pre-project and post-project conditions. This would require maintaining a baseline model and comparing it to an updated model that reflects post-project conditions during real flood events. The limitation of this approach is that risk scores are not inherently meaningful on their own. They are useful for relative comparisons (e.g., identifying higher-risk areas or higher ROI projects), but they are not easily understood or communicated as standalone values.

A more meaningful metric may be the number of people affected, estimated based on buildings and transit. This would compare the number of people impacted under pre-project conditions to those impacted after improvements are implemented. However, clear definitions of "impacted" would be required (e.g., lives threatened, disrupted, or economically affected). Even then, it remains difficult to directly relate "people spared from disruption" to "money spent".

It is recommended for this "net impact reduction" metric to be further refined through discussions with stakeholders (LGs, MHFD staff, and the Board of Directors) to define an outcome-oriented measure of success.

5.1.3 Routine Reporting

An abbreviated Flood Risk summary report should be shared with stakeholders, including the Executive Director and the Board. We recommend the report be published online. Reporting frequency should be determined by MHFD, typically ranging from 2 to 5 years. The report should concisely capture risk distribution and focus on impact, including:

- **Districtwide baseline table** summarizing total quantified risk by basin.
- **Portfolio efficiency metric** showing the average risk reduction per dollar invested for projects initiated or completed during the reporting period.
- **Geographic maps** illustrating where risk reduction investments have occurred relative to baseline high-risk areas.

5.2 Contracting

As noted in Section 3.7.3, the Districtwide data development phase relies heavy on multiple contractors. The recommended approach is two to four teams with a combined monthly burn rate of approximately $180,000 to $275,000 to develop foundational data by 2029.

To support this effort, MHFD plans to issue an RFQ in July 2026 to eligible contractors, with a goal of beginning production in September 2026. The RFQ will include this Plan and the revised 2D H&H modeling guidance, incorporating lessons learned from the Validation Basins work. Subsequent applications (e.g., mitigation and risk reduction ranking) will not be included in the July 2026 RFQ.

In addition to technical qualifications, experience, and fee schedules, the RFQ may request:

- Organizational chart highlighting the key team members having a direct connection to project delivery
- Collaborative approach to similar team efforts
- Strategies for project management support

5.2.1 Contracting Mechanisms

To encourage cost effective and timely delivery, MHFD may use incentive and performance-based contract structures (see Section 5.1). Options include:

- Firm Fixed Price contracts that tend to foster innovation for cost measures. Schedule delay penalties could be included (e.g., $4,000 per month withheld from payment after a grace period) to guard against schedule slippage.
- Performance Based contracts that pay upon achieved outcomes/milestones at variable amounts depending on metrics (quality, schedule).
- Cost-Plus-Incentive-Fee contracts that cover the costs and rather than paying a fixed multiplier for profit, issue an incentive fee that is adjusted based upon metrics, including planned vs. actual costs. This allows for a profit-sharing mechanism where if the project is completed below budget, a portion of the underrun is awarded as pure profit to the contractor and the remainder is recognized as savings to the Program.
- Incremental contracts, where only a portion of the planned work (e.g., 25%) is contracted upfront, and then the remaining work (75%) is awarded in a second contract based on initial performance. This incentivizes each contractor to efficiently deliver quality products in a timely manner and then awards

a greater proportion of the larger remaining work to the best performing contractor. Another advantage is that this approach better leverages available funds as the full funding does not need to be available at the outset in September 2026, but can span multiple funding years and budget requests. This approach could be used with any of the above contract types.

All approaches require clear expectations, defined success metrics, and measurable financial implications. Performance will be monitored by the MHFD Flood Risk Program Manager, with input from other MHFD staff (e.g., Planning and Floodplain Management) and participating LGs.

All alternative contract mechanisms will require explicit agreements between MHFD and the contractor. The incremental approach (performance-based follow-on work) also requires transparent performance tracking across all contractors.

5.2.2 Number of Contractors

As shown in Table 12, the number of "teams" does not necessarily equal the number of contractors, as a single firm may provide multiple teams. However, experience from similar large-scale programs suggests that using multiple contractors generally leads to better outcomes than relying on a single firm.

Multiple contractors bring diverse perspectives, broaden technical expertise, and promote performance through competition. At the same time, collaboration remains essential—teams should jointly develop methodologies, tools, templates, and shared approaches. Success is defined by meeting MHFD's Flood Risk Program goals through coordinated and high-performing teamwork.

However, too many contractors can create inefficiencies, slow collaboration, and complicate decision making without adding commensurate value. Based on past program experience, two to four contractors are likely to provide the best balance of competition, collaboration, and manageability for a Program of this scale. Programs with more than four often become difficult to manage and place unnecessary burden on the Program Manager. This recommended range aligns with the team structure in Table 12 and supports achieving Districtwide foundational data by 2029.

It is also recommended that one of the production contractors provide program management support, rather than hiring a separate, standalone program management (PM) consultant. Standalone PM contracts can introduce unnecessary process, increase costs, slow schedule, and focus on low-value review details. In contrast, peer review among production teams tends to be more practical and focused on meaningful outcomes.

Following contract award, each contractor should submit a concise Production Work Plan using a standard template. The Work Plan should include planned data sources, coordination and data collection with LGs, execution approach, and QA/QC process, watershed sequencing, and a baseline schedule. Plans will be refined in coordination with MHFD, LGs, and the other contractors to establish a consistent baseline for performance tracking.

5.2.3 Program Management Responsibilities

The Flood Risk consultants will be asked to provide select services to support coordination, oversight, and performance tracking across multiple concurrent efforts. In a program of this scale—spanning multiple basins, consultants, and years—the consultants serve as an extension of the Owner (MHFD), supporting consistency, risk management, and alignment.

They do not replace technical leads but focus on integration and accountability across schedule, cost, quality, and stakeholder coordination.

Program Support

The select services by the Flood Risk consultants support management functions by ensuring consistent adherence to processes, decision authorities, and documentation protocols, and that program decisions are documented, traceable, and aligned with approved policies. Typical responsibilities include:

- Support development and maintenance of Production Work Plans and guidance documents.

- Maintain the decision log, lessons learned tracker, and risk register.
- Track approvals at defined stage gates.
- Perform QC reviews to confirm deliverables meet standards and templates.
- Coordinate quarterly LG check-ins, executive briefings, and Board materials.

Schedule Management

For multi-basin programs, schedule integration is a key responsibility focused on maintaining progress, avoiding resource conflicts, and meeting CIP timelines. Typical duties include:

- Develop and maintain the master program schedule.
- Integrate basin schedules into a single timeline.
- Monitor Schedule Performance Index (SPI), which measures planned progress against actual progress based on percent complete.
- Identify critical path risks and delays.
- Develop recovery plans for missed milestones.
- Report quarterly schedule status to leadership.

Cost Management and Controls

Cost oversight is critical for a multi-year program with significant public funding. Special services consultants do not authorize spending but provides oversight and variance analysis to the Owner. Typical responsibilities include:

- Track Cost Performance Index (CPI), which measures planned budget against actual costs based on percent complete.
- Review invoices for consistency with scopes.
- Monitor burn rates by geography and task (see Table 24).
- Identify potential cost overruns.
- Track contingency usage.
- Support annual budget forecasting.

Scope and Change Management

In complex technical programs, scope creep is common. Special services consultants help maintain control and consistency across basins. Scope will be clearly defined and documented upfront in coordination with MHFD and its LG partners. Responsibilities typically include:

- Review and evaluate proposed scope changes.
- Maintaining a formal change log.
- Ensure consistency across basins despite methodological updates.

Technical Coordination and Integration

While technical leads are responsible for engineering decisions, special services consultants ensure integration across teams to prevent inconsistencies between basins as methods evolve. Typical duties include:

- Coordinate across modeling, GIS, and risk teams.
- Ensure consistent use of data sources and inputs.

- Verify standardized data schemas.
- Facilitate lessons learned and cross-basin improvements.
- Monitor adherence to H&H guidance.

Quality Assurance / Quality Control (QA/QC) Oversight

Special services consultants supports quality assurance and serves as the primary reviewer, although independent technical review may also be conducted. Typical responsibilities include:

- Verify documentation completeness and internal QC.
- Independent peer review of models, products, and deliverables for compliance (also supported by MHFD).
- Provide high-value review comments.
- Track review timelines and responses.

Data Management Oversight

In data-driven programs, effective management of geospatial and analytical data is critical to support automation, system integration, and reproducibility. Typical responsibilities include:

- Verify adherence with data schema prior to uploads.
- Ensure version control is followed.
- Confirm proper storage, display, and archival of datasets.
- Coordinate integration with enterprise GIS systems.

Stakeholder Coordination

Supporting structured engagement with LGs and partner agencies. Responsibilities may include:

- Support basin kickoff and review meetings.
- Prepare workshop materials.
- Track and respond to stakeholder feedback.
- Support reporting and briefings.

Reporting and Performance Tracking

Development and use of dashboards and performance reporting tools, with typical responsibilities including:

- Maintain program performance dashboards.
- Prepare program health reports as needed (suggested quarterly and annual).
- Track implementation, operation, usage, and outcome metrics.
- Supporting Board presentations.

5.3 Monitoring & Controlling

Monitoring and controlling are active management practices that detect variance early, maintain comparability across basins, and protect the Program's integrity and credibility over time. This function provides structured oversight to ensure the Program remains aligned with approved scope, schedule, cost, and quality expectations.

It includes continuous tracking of program metrics shown in Table 23. Metrics can be collected through defined processes rather than informal reporting. For example:

- Schedule performance compares current to status to planned progress using an integrated master schedule
- Cost performance compares invoiced amounts to the value of work completed
- Quality metrics are derived from QA/QC review records.

Effective monitoring requires practical tools and repeatable processes. A program dashboard—updated monthly or quarterly—can consolidate performance indicators across geographies and phases. At the program level, the Program Manager can prepare a quarterly financial summary that includes:

- Monthly expenditure to date (overall and by geography, phase, category—e.g. H&H, risk, vs outreach)
- Forecasted costs for upcoming work.

A Program Status Tracker will also be developed to monitor progress at the basin level, tracking interim checkpoints and documenting task completion dates, as shown in Table 24.

Table 24. Basin Progress Tracker for Data Development by Task/Milestone

Category	Milestone	Basin A	Basin B	Basin C	Basin N
Foundational Datasets	Receptor inventory completeness	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Model layers developed	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Structure inventory completeness	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Sewer/pipes dataset compilation	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
Model Development	Foundational mesh	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Structures incorporated	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Pipes incorporated	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Calibration	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Internal QC by Contractor	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	External QC	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
Product Creation	Design storms simulated	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Hazard products developed	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Risk scores and products developed	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Data bundle delivered (model, products, docs)	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Data bundle external review	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy
	Data bundle approved by MHFD and LG/TAC	mm/dd/yy	mm/dd/yy	mm/dd/yy	mm/dd/yy

A Program Risk Register can be used to identify and manage program-level risks (e.g., data gaps, model inconsistencies, resource bottlenecks), with assigned mitigation actions and review dates.

The MHFD Program Manager will conduct quarterly performance reviews with each contractor to assess trends, identify emerging issues, and determine whether corrective action is needed. If performance thresholds shift from acceptable to warning status, a written corrective action plan shall be developed. This may include schedule recovery strategies, scope clarifications, or communication adjustments.

5.4 Continuous Improvement

Continuous improvement should be an intentional and ongoing component of program management, rather than something considered passively during implementation. This multi-year Program will evolve as modeling standards mature, datasets improve, and user needs become better understood.

Continuous improvement includes a structured review of technical methodologies, data workflows, reporting formats, engagement approaches, and integration with stormwater CIP processes. The objective is to refine the Program while preserving Districtwide consistency and comparability. Improvement will be guided by documented performance metrics (Section 5.1), stakeholder feedback, QA/QC findings, and implementation variance analyses to ensure that refinements are evidence-based rather than anecdotal.

MHFD anticipates that modeling workflows, tools, guidance, and production approaches will continue to evolve throughout implementation. As methodologies mature and opportunities for standardization and automation are identified, the scope and nature of consultant support may also change. Consultants should be prepared to adapt to evolving workflows and contribute to ongoing improvements.

Following completion of the validation basin work, the selected production contractors should establish a deliberate learning agenda at the outset of foundational data production. This agenda will identify key questions the Program intends to address and should consider the full spectrum of Program components—from foundational layers (terrain, land cover, receptors) to modeling approaches and risk assumptions. A similar learning agenda should be developed prior to risk reduction modeling. This is particularly important given that “mitigation modeling” has been less extensively tested, with only a limited, accelerated application completed for Niver Creek.

At defined intervals—such as after completion of several basins or at least semiannually—the Program Manager shall lead structured retrospectives with the TAC and contractor leads. These retrospectives will evaluate:

- What approaches and assumptions added value
- What should be added, refined, or removed
- Where rework occurred
- Where bottlenecks emerged
- How outputs were interpreted and applied by end users

End users—including project managers, floodplain administrators, CIP managers, planners, and emergency staff—shall remain central to the improvement process. Feedback will be collected through periodic workshops, short post-deliverable surveys, and facilitated discussions during periodic risk briefings. Particular attention should be given to whether:

- Users understand the expanded capabilities of pluvial and risk information
- Risk reduction per dollar is being applied as intended
- Deliverables are clear and effective for communication with elected officials.

Where confusion or friction is identified, communication materials, platform interfaces, or reporting formats shall be refined. Over time, continuous improvement should reduce user burden, improve clarity, and increase confidence in Program outputs.

To accelerate learning while minimizing programmatic risk, MHFD should consider prioritizing early, end-to-end implementation in a small number of strategically selected watersheds. These “early action” basins should represent a range of conditions and be distributed across the selected contractors. Completed on an accelerated schedule, they will help identify and resolve program challenges early, allowing lessons learned to improve overall implementation quality and efficiency.

5.5 Decision Tracker and Lessons Learned Log

As the Flood Risk Program progresses, lessons will be learned and additional decisions will need to be made related to methodology, policy, implementation, and operations as part of ongoing program improvement. To ensure consistency and maintain a clear record of decisions, MHFD and the Flood Risk contractors should maintain a formal Decision Tracker and Lessons Learned Log. Past decisions and lessons learned should be incorporated into updated templates, guidance documents, or materials following formal approval.

The Decision Tracker serves as the official record of substantive program decisions that influence methodology, management, scope, cost assumptions, sequencing, or reporting standards. It should be updated in real time as decisions are made (not retroactively) and reviewed at least quarterly by the Program Manager. Items requiring future decisions or aspects still under consideration can also be tracked. Beyond documentation, the tracker supports defensibility, promotes consistency across phased implementation, and preserves institutional knowledge through staff or consultant transitions. Entries could include:

- **Decision ID**: for easy reference
- **Date Proposed**: when it was suggested for review
- **Date Finalized**: when it was approved and final
- **Originator**: who added it (for follow up or clarification)
- **Owner**: who is responsible for making the decision
- **Status**: current state of the decision (e.g., Proposed, Under Review, Approved, Rejected)
- **Domain**: for easy filtering or tagging (e.g., hydrology, hydraulics, risk, comms, ops, etc.)
- **Decision Title**: a short descriptive headline
- **Description:** a summary of what was decided – note the alternatives considered where appropriate to avoid re-opening the matter in the future
- **Info Needed:** for future decisions not yet made, note what remaining information/investigation is needed to be able to make a decision (allows for placeholders for aspects still being formed)
- **Rationale:** optional supporting information
- **Reference:** optional hyperlinks to documents related to the decision
- **Impacts:** list affected documents and sections (e.g., Sec 12.2 of H&H guidance)

The lessons learned log serves a slightly different purpose and could include the following elements:

- **Unique ID**: for easy reference
- **Date Captured**: when it was added/discovered
- **Owner**: who added it (for follow up and accountability)
- **Domain**: for easy filtering or tagging (e.g., hydrology, hydraulics, risk, comms, ops, etc.)
- **Type**: success, mistake, best practice, risk avoidance, etc.
- **Occasion**: the project or task in which it was learned on (e.g., validation basins, Goldsmith, receptors, workshops, etc.)
- **Lesson Title**: a short descriptive headline of the observation
- **Description:** what was learned with concise context
- **Root Cause:** why it happened, distinguishing between the symptoms and core issue
- **Impact:** positive or negative outcomes because of it
- **Effects:** what was changed, revised, developed or codified because of it
- **Audience:** who should this be shared with (e.g., just the project team, or other watershed managers, or LGs, or contractors, etc.)

Pending decisions should be logged as “for review”, updated to “in review” once actively considered, and marked “decided” once finalized. The Decision Tracker is to be stored in a shared program repository with version control, accessible to all stakeholders, and retained as part of the permanent program record.

6 References

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