Flood Risk on Portfolio of Properties Model Documentation

From the MKM Research Labs

2nd April, 2025

Contents

Legal Notice

1 Document history

Release Date	Description	Document Version	Library Version	Contributor
12-July-2019	Internal beta release	v 1.0	v 1.0 (Beta)	David K Kelly
20-Nov-2024	Internal beta release	v 2.0	v 2.0 (Beta)	David K Kelly, Jack Mattimore
3-Dec-2024	Internal beta release	v 2.1	v 2.1 (Beta)	David K Kelly

2 Introduction

The Flood Risk Model is a comprehensive spatial analysis tool that evaluates property-level flood risk impacts, considering direct physical damage and spatial correlation effects. The model implements a Monte Carlo simulation approach with spatially correlated shocks to estimate portfolio-level impacts.

3 System Overview

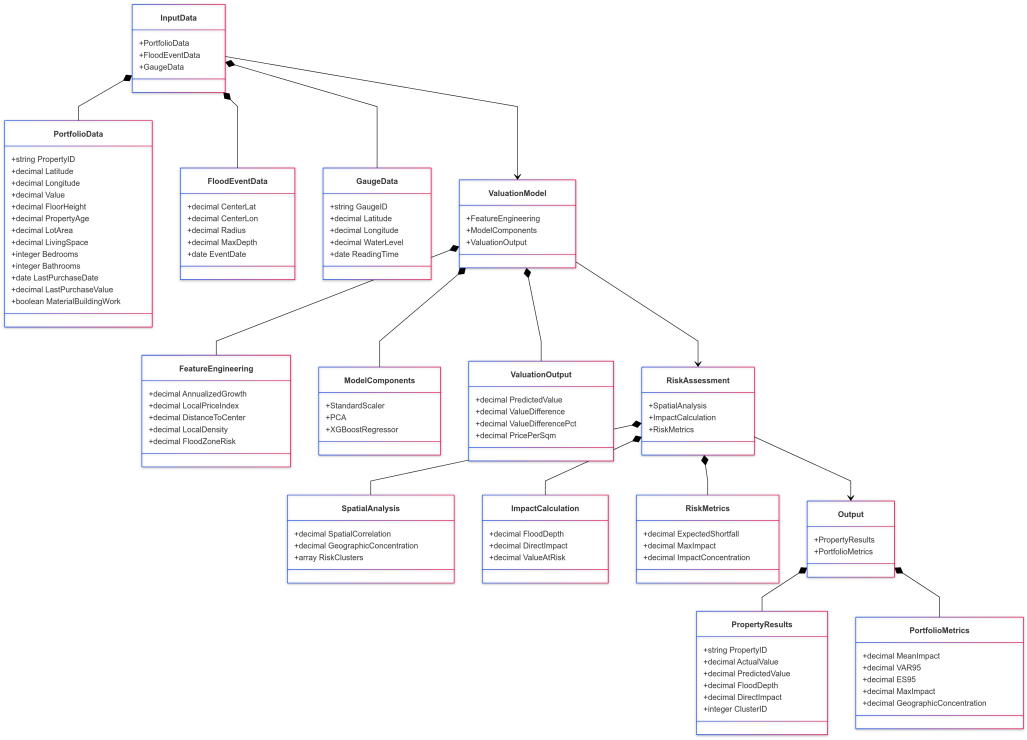

Figure 1: Portfolio Flood Process

The portfolio flood risk assessment system consists of three main components working in sequence:

3.1 Process Architecture

The portfolio flood risk assessment system consists of two primary components:

1. Property Valuation Pipeline
2. Flood Risk Assessment Pipeline

3.2 Data Flow

- Initial property portfolio data ingestion
- Property valuation and feature engineering
- Risk factor calculation and spatial analysis
- Portfolio-level flood impact assessment
- Results aggregation and reporting

3.3 Key Processes

1. Portfolio Data Processing
    - Data validation and cleaning

- Geographic coordinate processing
- Property characteristic normalization

2. Valuation Model Application
   - Feature extraction and transformation
   - Model prediction execution
   - Valuation adjustment calculations
3. Flood Risk Integration
   - Spatial correlation analysis
   - Flood depth calculations
   - Impact assessment computation

3.4 Process Integration

The system integrates property valuation outputs with flood risk assessment through:

- Shared spatial indexing structures
- Unified data formats
- Synchronized calculation pipelines

1. Portfolio Valuation System
   - Property valuation model (portfolio_valuation_flood.py)
   - Portfolio analysis reporting (portfolio_valuation_report.py)
   - Generates portfolio_data.csv as intermediate output
2. Flood Risk Assessment
   - Main flood risk model (portfolio_flood_model_v3.py)
   - Processes portfolio data and generates risk metrics
3. Visualization and Reporting
   - Interactive and static visualizations
   - Comprehensive risk reports
   - Final output as flood_risk.png

4 Core Model Components

4.1 Property Valuation Model

- PropertyValuationModel class
  - Feature preprocessing pipeline
  - XGBoost regression model
  - PCA dimensionality reduction
- Spatial analysis components
- Market factor calculators

4.2 Flood Risk Model

- FloodRiskModel base class
- EnhancedFloodRiskModel extension
- Spatial correlation engine
- Impact calculation system

5 Supporting Components

5.1 Data Management

- ProjectPaths utility
- GeoDataFrame handlers
- Data validation systems

5.2 Analysis Tools

- Spatial clustering engine
- Risk concentration calculator
- Stress testing framework

5.3 Visualization Components

- Interactive mapping system
- Risk heatmap generator
- Correlation visualiser

6 Integration Interfaces

- Portfolio data standardiser
- Risk metric aggregator
- Report generation system

7 Property Valuation Formulae

7.1 Annualized Growth Rate

$$\text{AGR} = \left(\frac{V_{\text{current}}}{V_{\text{purchase}}} \right)^{\frac{1}{t}} - 1$$

where t is years since purchase

7.2 Local Price Index

$$\text{LPI}_i = \text{median}\{V_j : d(i,j) \leq r\}$$

where $d(i,j)$ is distance between properties i and j, and r is radius

8 Flood Risk Formulae

8.1 Flood Depth Calculation

$$D_i = \max\left(0, D_{\max}\left(1 - \frac{d_i}{R}\right)\right)$$

where:

- D_i is flood depth at property i
- $D_{\max}$ is maximum flood depth
- d_i is distance to flood center
- R is flood radius

8.2 Spatial Correlation

$$\rho_{ij} = \rho_0 \exp\left(-\frac{d_{ij}}{d_c}\right)$$

where:

- ρ_0 is base correlation
- d_{ij} is distance between properties
- d_c is correlation distance

8.3 Impact Calculation

$$I_i = V_i \cdot \alpha(1 + \tanh(D_i))$$

where:

- I_i is impact on property i
- V_i is property value
- α is baseline discount
- D_i is flood depth

9 Portfolio Metrics

9.1 Geographic Concentration (HHI)

$$\text{HHI} = \sum_{i=1}^{n}\left(\frac{V_i}{\sum_{j=1}^{n} V_j}\right)^2$$

9.2 Expected Shortfall

$$\text{ES}_\alpha = \mathbb{E}[X | X > \text{VaR}_\alpha]$$

where X is portfolio impact