PLR Machine Learn Based Risk Methodology

Version 3

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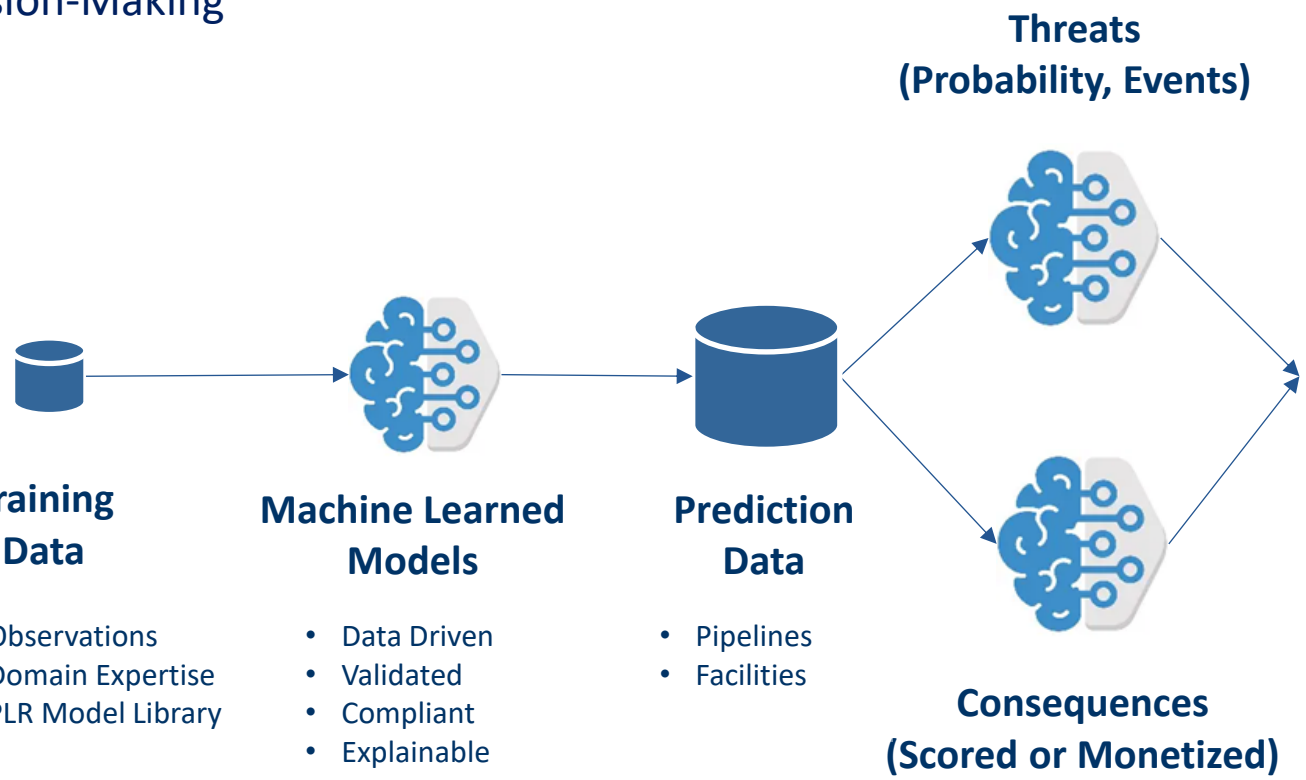
Overview

A Data Driven Machine Learning Based Approach to Integrity & Risk Management Compliance & Decision-Making



- Observations
- Domain Expertise
- PLR Model Library

- Data Driven
- Validated
- Compliant
- Explainable

- Pipelines
- Facilities

Risk

- Predicted Events/Year
- Score or Dollars/Event
- Risk Score or Dollars
- Net Present Value Carried Risk

Objectives

- Compliance
- Inspection Prioritization
- Mitigation Selection
- Improved Reliability, Safety

ML.ai Application

Overview

The purpose of this document is to explain PLR's machine-learned based risk structure for assessing the threats, consequences and risk of pipeline systems.

Machine Learned Models

The risk structure accommodates several approaches to machine learning Individual threat & consequence models in support of integrity & risk management:

- Model learning based on actual observations of the target threat or consequence
- Model learning based on synthetic data created from PLR's model library
- Model learning based on traditional deterministic risk calculations
- Model learning based on a sampling of industry based deterministic structures & studies

Key outputs from the structure include predictions of threat and consequence risks, scored or monetized, prediction explanations and simulations.

ML.ai Software Platform

ML.ai is PLR's secure web platform supporting pipeline & facility risk management through machine learning and advanced analytics.

Value

ML.ai supports a data driven approach to risk, where results are transparent, explainable and can be used to support compliance and resource allocation decision-making:

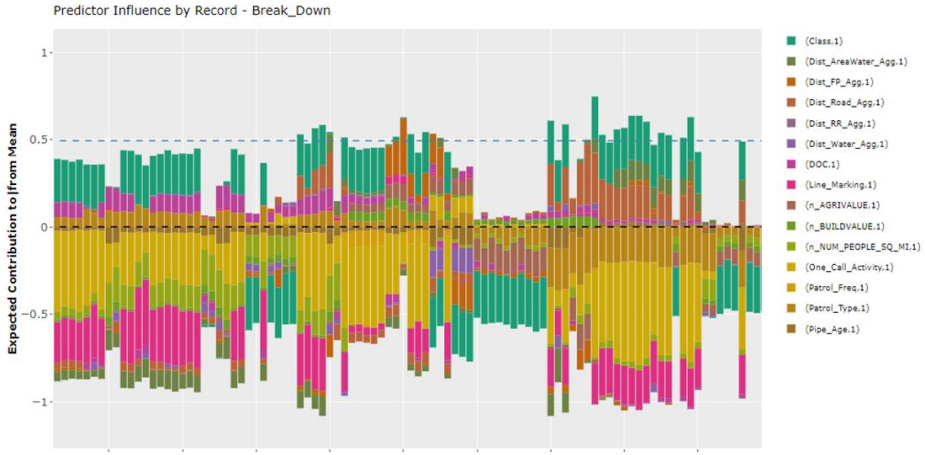
- Models are meta-data driven and can leverage existing data, PLR's geospatial data store & PLR reference models
- Results may be normalized to industry or in-house statistics in support of risk monetization
- Advanced analytics provide methods to understand and explain prediction results in support of relevant action

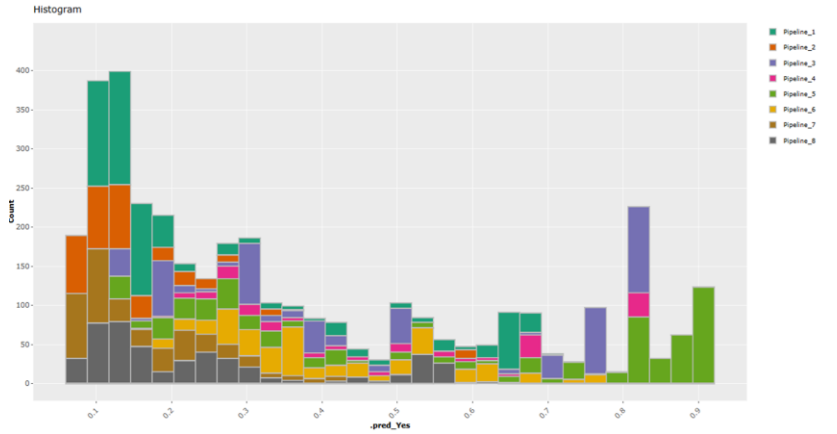
Glossary of Key Concepts & Terms

Key Concepts

Learned models are the foundation of the overall risk analysis supported by ML.ai:

- Threat models support the concept of **POER (probability of event rate)** which is a construct to calculate probabilities for different lengths of pipe or facilities depending on whether the threat is time dependent or time independent. Event rates are based on provided PHMSA statistics or asset owner assumptions, and application of POER results in predicted events per year for each pipe segment over time.
- Consequence models support **risk monetization** and are combined with the results of the threat models to generate risk values for each pipe segment over time for each threat. Risk values are then represented as net present values in support of resource allocation decision-making. Dimensionless scores can be retained if monetization is not required.
- The process provides options for inclusion of the impact of mitigations, threat resistance, recent assessments and repairs, and threat interactions as derived through advanced analytics and simulations.
- Key advantages of a machine learning approach is it is data driven, validated with actual observations, considers threat interactions and non-linearities, fully explainable, compliant and may be continuously improved as new data becomes available.





Glossary of Terms – Time Independent Threats

Time Independent Threats		
Pipe Segment Length	SegLength	Segment Length (Measure_End – Measure_Start)
Threat Prediction	Predict	Machine Learning Prediction (Binary Classification Probability)
Classification Prediction	S	Probability of Threat (Susceptibility: Same as Predict)
Assessment Mitigation	Assess	Assessment & Repair Threat Mitigation (higher % reduces S)
Threat Mitigation	Mitig	Optional Additional Mitigation (higher % reduces S)
Threat Resistance	Resist	Optional Additional Resistance (higher % reduces S)
Probability of Event Rate	POER	POER = S * (1 – Assess) * (1 - Resist) * (1 - Mitig)
Min Boundary	predMin	Sets the Minimum POER Boundary for Scaling
Max Boundary	predMax	Sets the Maximum POER Boundary for Scaling
Event Rate	Event_Rate	Scaled Event Rate for Segment (#/1000 mile – yrs)
Events per Year	Events_yr	Length Adjusted Events per Segment per Year
Analysis Years	Years	Number of Years to Assess Threat

Glossary of Terms – Dependent Threats

Time Dependent Threats		
Pipe Segment Length	SegLength	Segment Length
Threat Prediction	Predict	Machine Learning Prediction (Regression)
Regression Prediction	mpy	Growth Rate (Severity)
Criteria	Criteria	Years for WT to Exceed MAOP (Pressure) or WT Depth (Depth %)
Wall Thickness	WT	Current Wall Thickness of Pipe or Remaining Anomaly
Wall Thickness Required	WT_Req	Two Options: Minimum Pressure or Depth % Criteria
Yrs to Exceed Required WT	WT_Yrs	Number of Yrs to Required WT
Age	Age	Current Age in Years of Pipe
Time to Criteria	TTC	Current Age plus WT_Yrs to Exceed Required WT
Probability of Event Rate	Weibull	Base Probability of Event Rate based on Weibull Curve
Min Boundary	predMin	Sets the Minimum POER Boundary for Scaling
Max Boundary	predMax	Sets the Maximum POER Boundary for Scaling
Assessment Mitigation	Assess	Assessment & Repair Threat Mitigation (higher % reduces POER)
Threat Mitigation	Mitig	Optional Additional Mitigations (higher % reduces POER)
Threat Resistance	Resist	Optional Additional Resistance (higher % reduces POER)
Probability of Event Rate	POER	POER = Probability * (1 – Assess) * (1 - Resist) * (1 - Mitig)
Event Rate	Event_Rate	Scaled Event Rate for Segment (#/1000 mile – yrs)
Events per Year	Events_yr	Length Adjusted Events per Segment per Year
Analysis Years	Years	Number of Years to Assess Threat

Glossary of Terms – Consequences

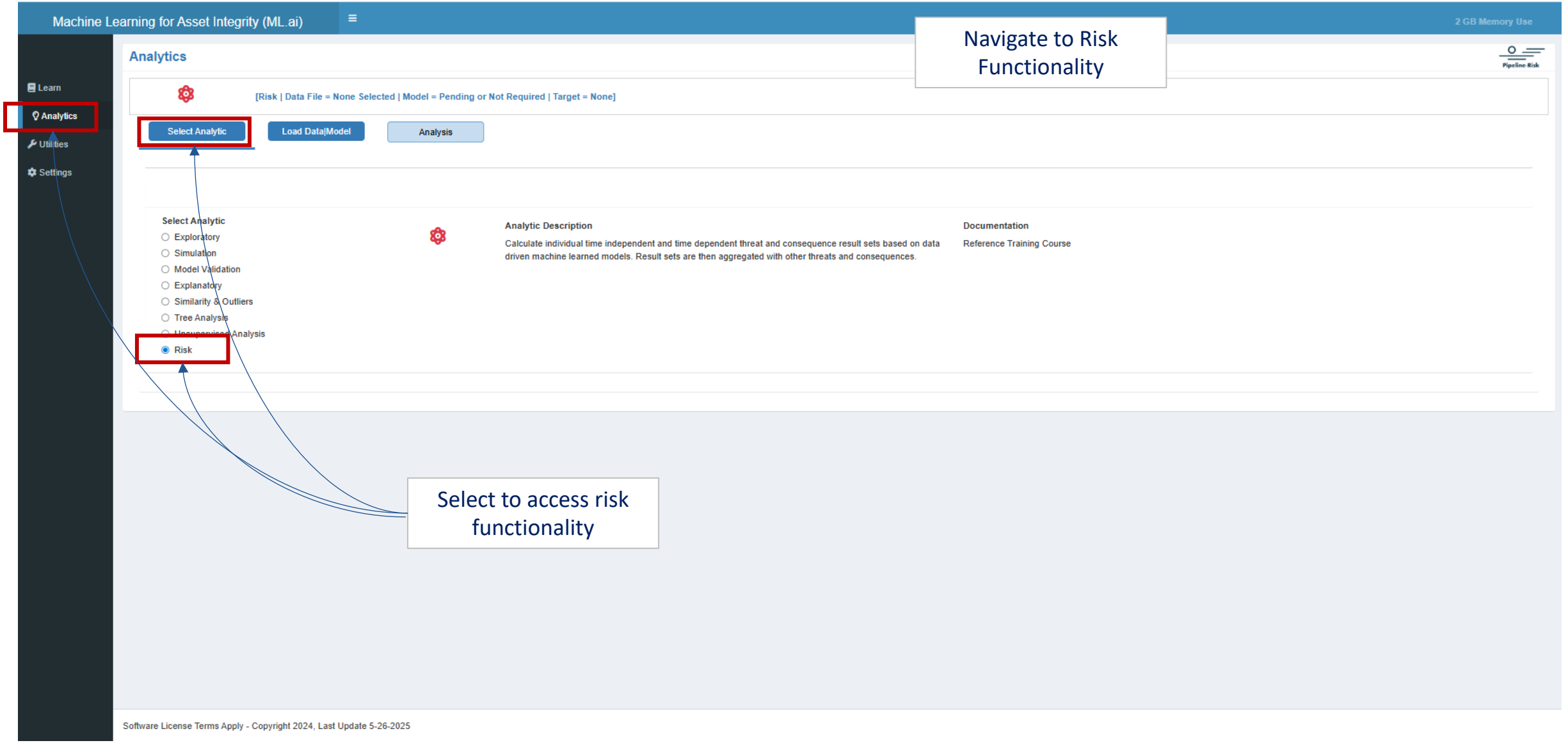
Consequences		
Regression Prediction	Predict	Machine Learning Target (Numerical Value Regression)
Min Boundary	predMin	Sets the Minimum Consequence Boundary for Scaling
Max Boundary	predMax	Sets the Maximum Consequence Boundary for Scaling
Consequence Mitigation	Mitig	Optional Additional Mitigations (higher % reduces Predict)
Regression Prediction	Conseq	Consequence = Predict * (1 – Mitig)
Scaled Consequence	Conseq_Scaled	Scaled Consequence for Segment ($)

Risk		
Total Events per Year	Total_Events_yr	Sum of all Predicted Events
Total Consequences	Total_Conseq	Sum of All Consequences
Total Risk	Total_Risk	Total_Events_yr x Total_Conseq by Threat or All Threats (depends on selected view)
Net Present Value	NPV	Total_Risk discounted to Year 0
Net Present Value per Mile	NPV_mile	NPV Normalized by Mile

- Risk is calculated by multiplying the number of events per year times consequences for each segment and analysis year. The results will show risk for each segment and each analysis year which are then aggregated to a Net Present Value (NPV) for each segment based on an assumed discount rate and number of analysis years. NPV's are further normalized to miles shown as NPV_mile.
- Interactions are an advanced feature, basically if interactions are set as True for a threat the threat POER is increased by the POER of the interacting threats using 1-POER math
- Ensemble model predictions are an advanced feature where the predictions from main threat are multiplied by the ensemble model predictions

EXAMPLE

ML.ai Navigation



Navigate to Risk Functionality

Select to access risk functionality

Prerequisites – Models

Threat and consequence models are required for the risk process. The example shows three typical model types, learned as part of PLR's industry-based reference model library:

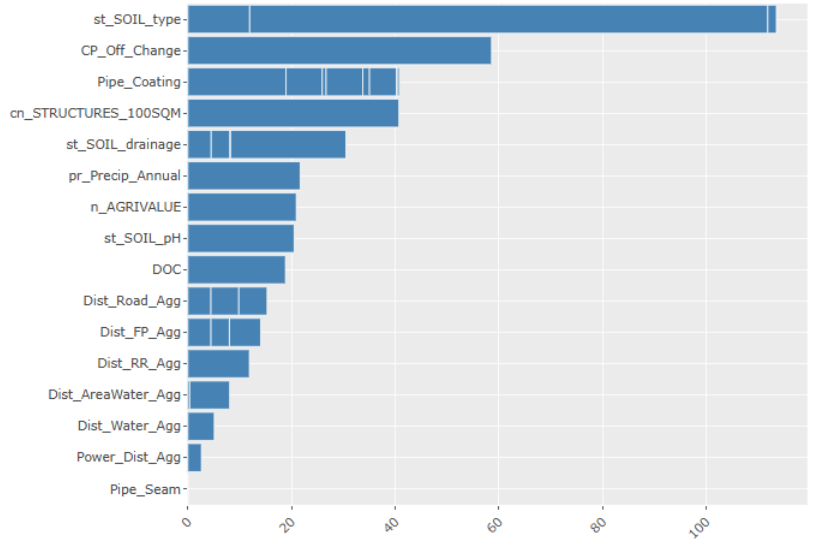
EC_mpy – external corrosion growth rate model (time dependent)

TPD – third party damage susceptibility model (time independent)

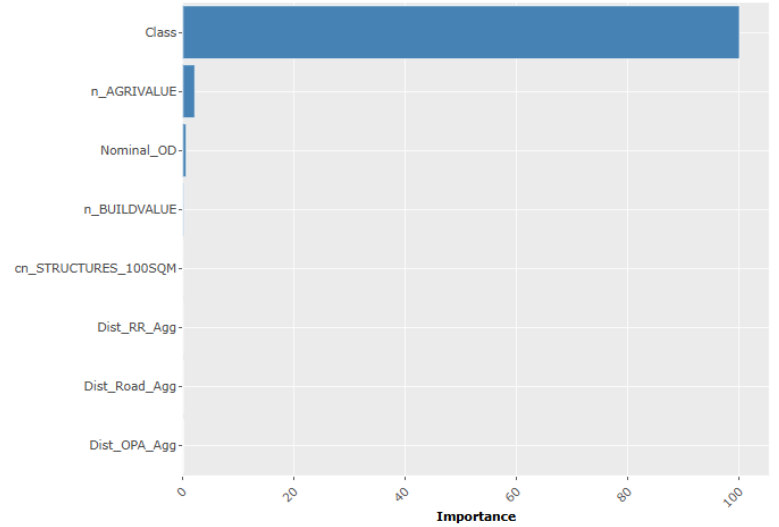
Consequence – impact on population model (consequence)

- Additional models may be added to the process
- The model learning process is automated through ML.ai and is not presented in this document
- The models used in this example are simply previously learned digital objects loaded into the risk process to demonstrate the different types of models

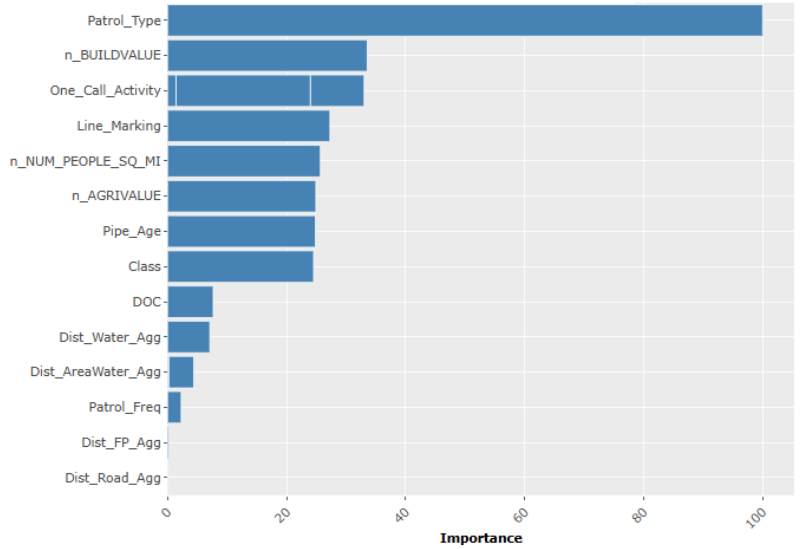
EC_mpy Predictors & Weights



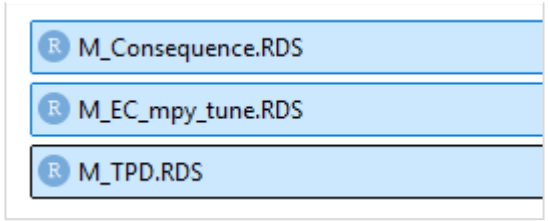
Consequence Predictors & Weights



TPD Predictors & Weights

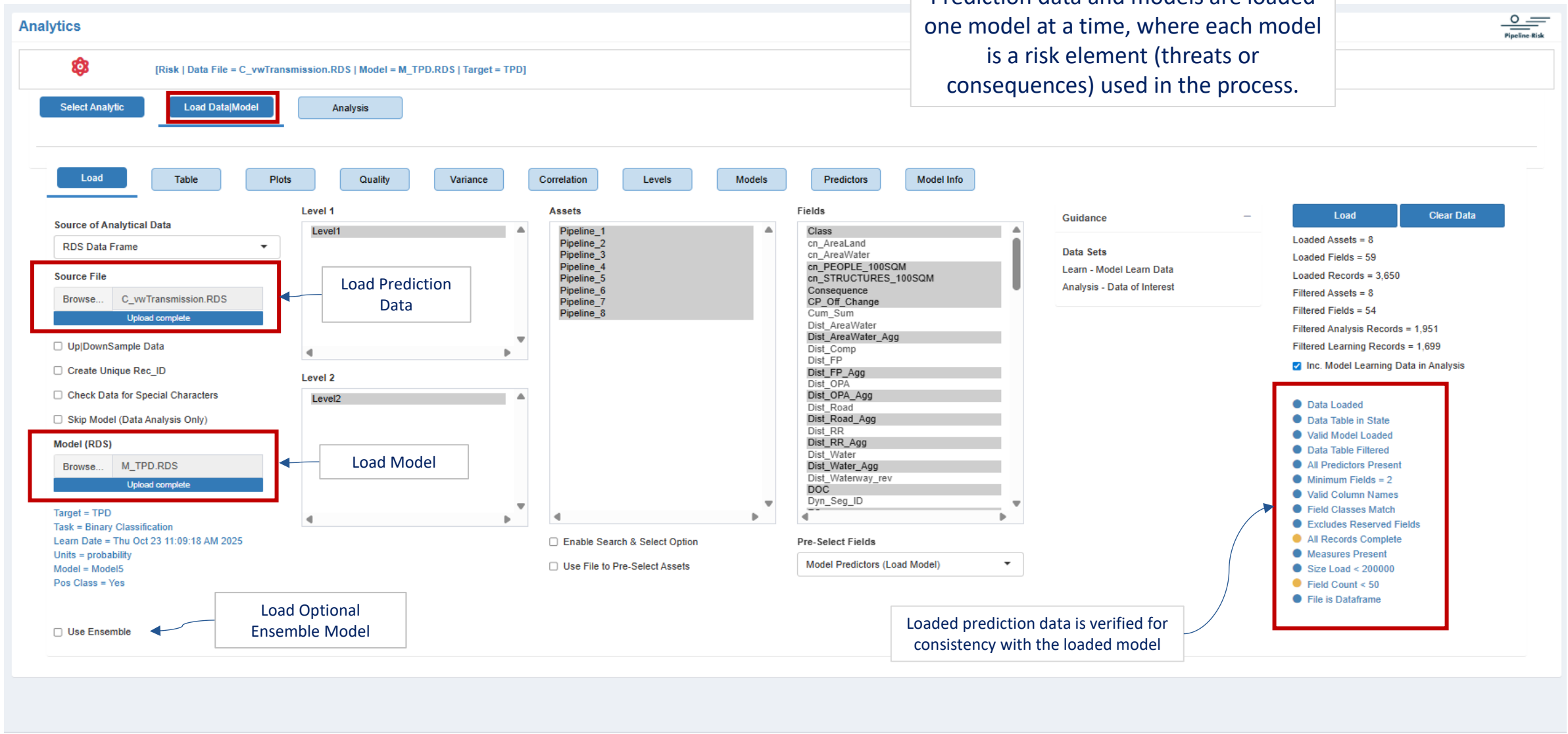


Saved Model Files:



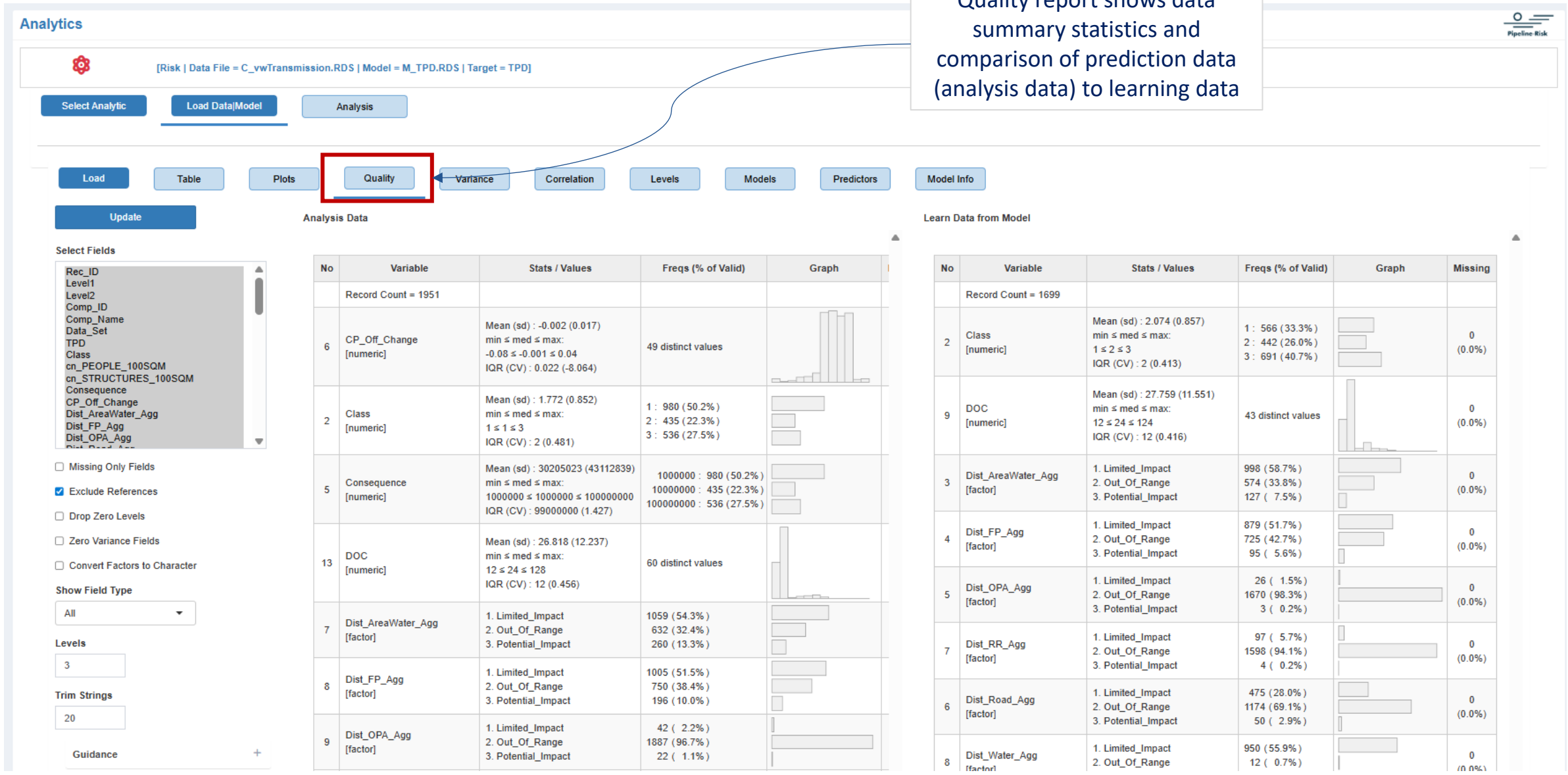
Prerequisites – Prediction Data

Prediction data and models are loaded one model at a time, where each model is a risk element (threats or consequences) used in the process.



Prerequisites – Prediction Data

Quality report shows data summary statistics and comparison of prediction data (analysis data) to learning data



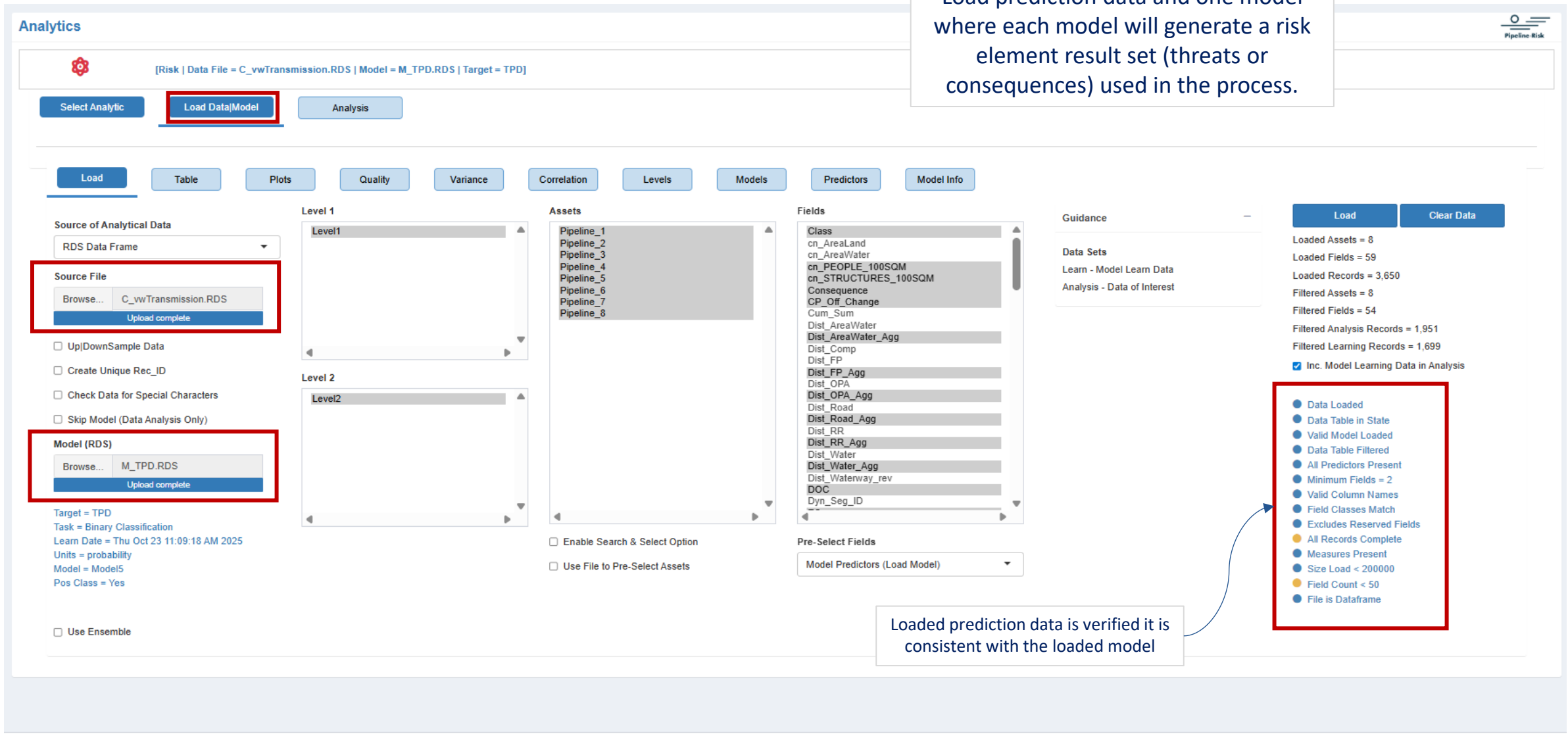
No	Variable	Stats / Values	Freqs (% of Valid)	Graph
	Record Count = 1951			
6	CP_Off_Change [numeric]	Mean (sd) : -0.002 (0.017) min ≤ med ≤ max: -0.08 ≤ -0.001 ≤ 0.04 IQR (CV) : 0.022 (-8.064)	49 distinct values	
2	Class [numeric]	Mean (sd) : 1.772 (0.852) min ≤ med ≤ max: 1 ≤ 1 ≤ 3 IQR (CV) : 2 (0.481)	1 : 980 (50.2%) 2 : 435 (22.3%) 3 : 536 (27.5%)	
5	Consequence [numeric]	Mean (sd) : 30205023 (43112839) min ≤ med ≤ max: 1000000 ≤ 1000000 ≤ 100000000 IQR (CV) : 99000000 (1.427)	1000000 : 980 (50.2%) 10000000 : 435 (22.3%) 100000000 : 536 (27.5%)	
13	DOC [numeric]	Mean (sd) : 26.818 (12.237) min ≤ med ≤ max: 12 ≤ 24 ≤ 128 IQR (CV) : 12 (0.456)	60 distinct values	
7	Dist_AreaWater_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	1059 (54.3%) 632 (32.4%) 260 (13.3%)	
8	Dist_FP_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	1005 (51.5%) 750 (38.4%) 196 (10.0%)	
9	Dist_OPA_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	42 (2.2%) 1887 (96.7%) 22 (1.1%)	

No	Variable	Stats / Values	Freqs (% of Valid)	Graph	Missing
	Record Count = 1699				
2	Class [numeric]	Mean (sd) : 2.074 (0.857) min ≤ med ≤ max: 1 ≤ 2 ≤ 3 IQR (CV) : 2 (0.413)	1 : 566 (33.3%) 2 : 442 (26.0%) 3 : 691 (40.7%)		0 (0.0%)
9	DOC [numeric]	Mean (sd) : 27.759 (11.551) min ≤ med ≤ max: 12 ≤ 24 ≤ 124 IQR (CV) : 12 (0.416)	43 distinct values		0 (0.0%)
3	Dist_AreaWater_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	998 (58.7%) 574 (33.8%) 127 (7.5%)		0 (0.0%)
4	Dist_FP_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	879 (51.7%) 725 (42.7%) 95 (5.6%)		0 (0.0%)
5	Dist_OPA_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	26 (1.5%) 1670 (98.3%) 3 (0.2%)		0 (0.0%)
7	Dist_RR_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	97 (5.7%) 1598 (94.1%) 4 (0.2%)		0 (0.0%)
6	Dist_Road_Agg [factor]	1. Limited_Impact 2. Out_Of_Range 3. Potential_Impact	475 (28.0%) 1174 (69.1%) 50 (2.9%)		0 (0.0%)
8	Dist_Water_Agg [factor]	1. Limited_Impact 2. Out_Of_Range	950 (55.9%) 12 (0.7%)		0 (0.0%)

Third Party Damage - TPD
(Time Independent Threat)

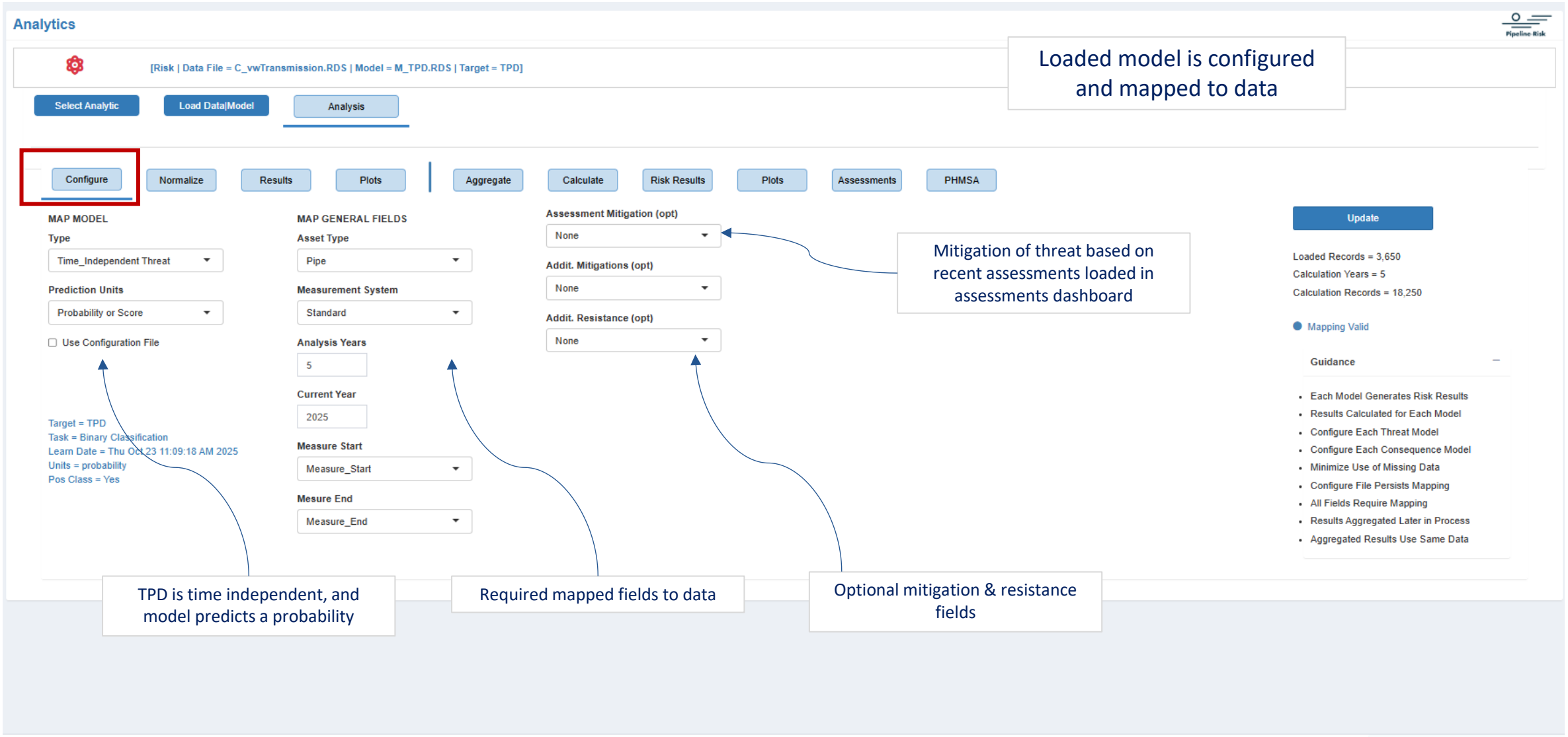
Load Prediction Data & Model

Load prediction data and one model where each model will generate a risk element result set (threats or consequences) used in the process.



Loaded prediction data is verified it is consistent with the loaded model

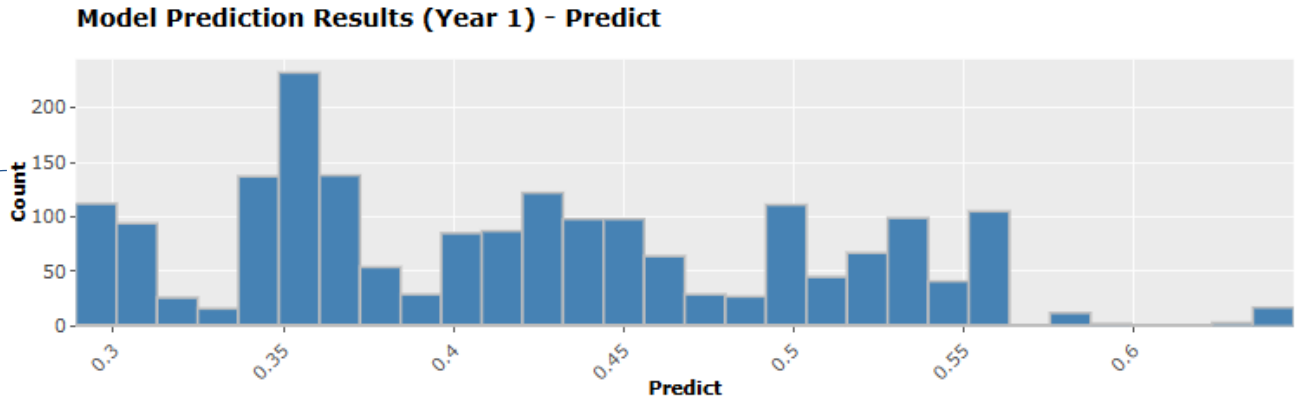
Apply TPD Model to Data



Apply TPD Model to Data

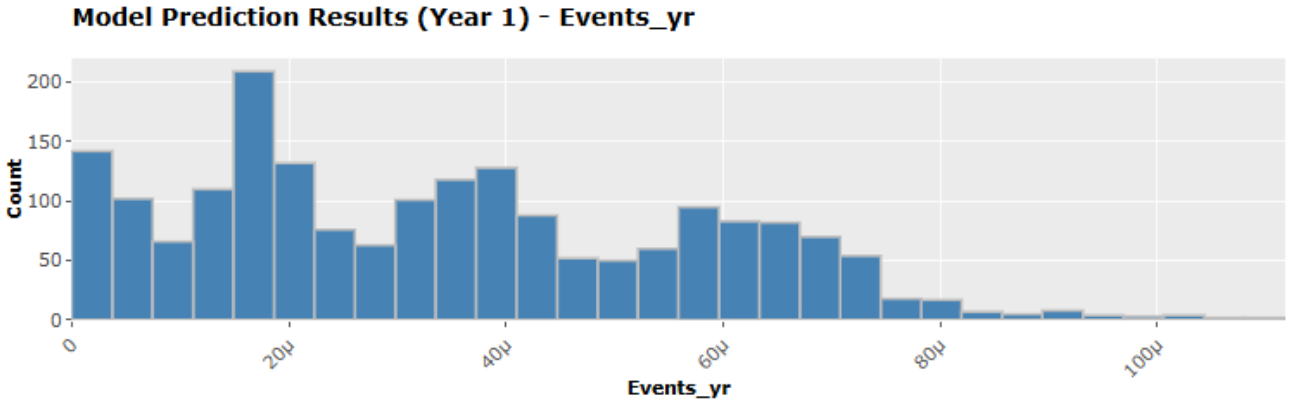
Normalization Concept

Predicted Probability of Event



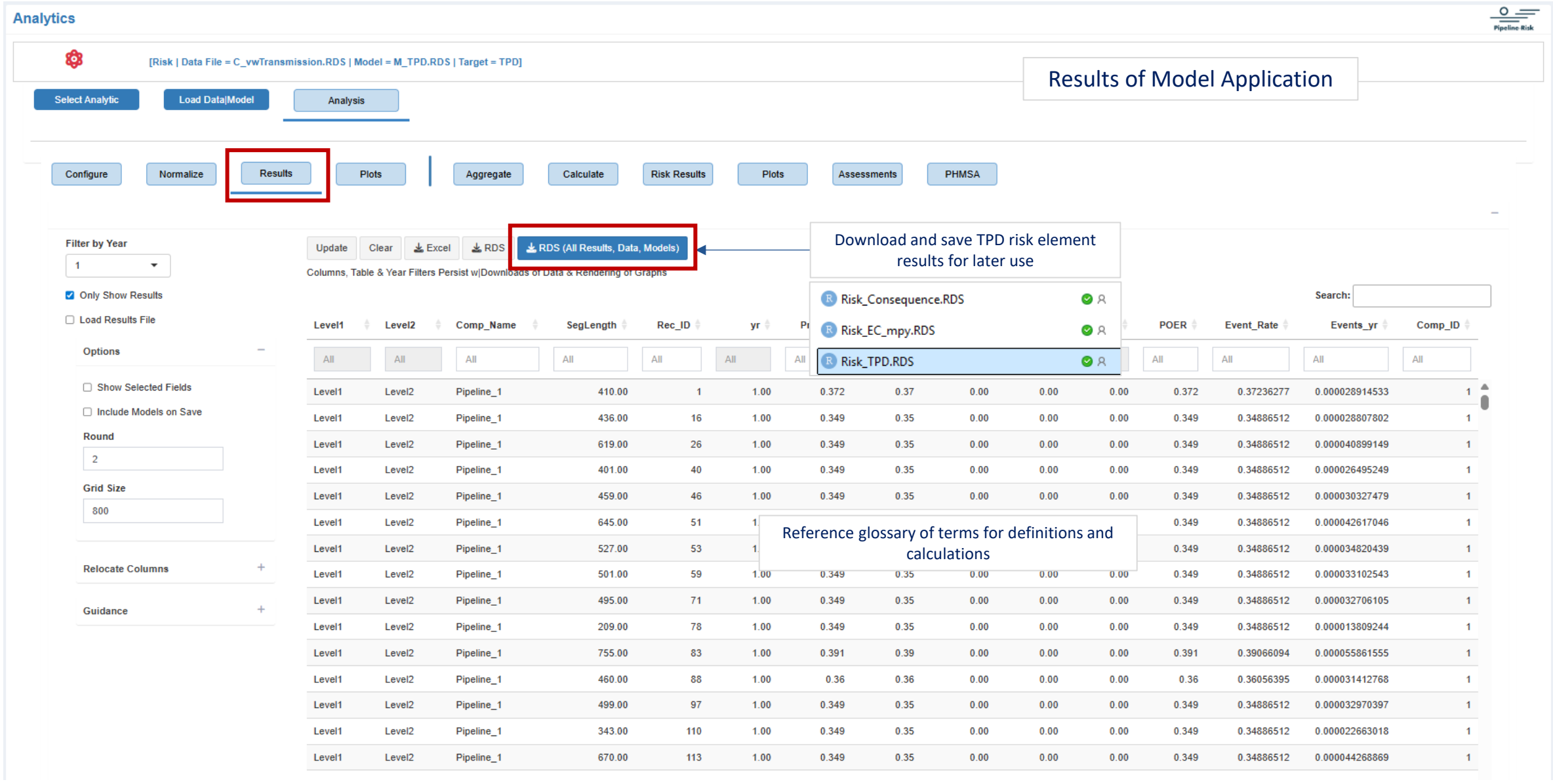
Machine Learned Predictions

Predicted Events per Year



Statistical Normalized Predictions

Results



Level1	Level2	Comp_Name	SegLength	Rec_ID	yr						POER	Event_Rate	Events_yr	Comp_ID
All	All	All	All	All	All	All					All	All	All	All
Level1	Level2	Pipeline_1	410.00	1	1.00	0.372	0.37	0.00	0.00	0.00	0.372	0.37236277	0.000028914533	1
Level1	Level2	Pipeline_1	436.00	16	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000028807802	1
Level1	Level2	Pipeline_1	619.00	26	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000040899149	1
Level1	Level2	Pipeline_1	401.00	40	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000026495249	1
Level1	Level2	Pipeline_1	459.00	46	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000030327479	1
Level1	Level2	Pipeline_1	645.00	51	1.						0.349	0.34886512	0.000042617046	1
Level1	Level2	Pipeline_1	527.00	53	1.						0.349	0.34886512	0.000034820439	1
Level1	Level2	Pipeline_1	501.00	59	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000033102543	1
Level1	Level2	Pipeline_1	495.00	71	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000032706105	1
Level1	Level2	Pipeline_1	209.00	78	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000013809244	1
Level1	Level2	Pipeline_1	755.00	83	1.00	0.391	0.39	0.00	0.00	0.00	0.391	0.39066094	0.000055861555	1
Level1	Level2	Pipeline_1	460.00	88	1.00	0.36	0.36	0.00	0.00	0.00	0.36	0.36056395	0.000031412768	1
Level1	Level2	Pipeline_1	499.00	97	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000032970397	1
Level1	Level2	Pipeline_1	343.00	110	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000022663018	1
Level1	Level2	Pipeline_1	670.00	113	1.00	0.349	0.35	0.00	0.00	0.00	0.349	0.34886512	0.000044268869	1

Results

Pipeline-Risk

Analytics

[Risk | Data File = C_vwTransmission.RDS | Model = M_TPD.RDS | Target = TPD]

Select Analytic | Load Data|Model | Analysis

Configure | Normalize | Results | Plots | Aggregate | Calculate | Risk Results | Plots | Assessments | PHMSA

Perform interactive analysis of results data

Update

Graph: Histogram

X (numeric): Predict

Legend: Comp_Name

Intervals: 3

Plot Height: 800

Use Axis Tics & Disable Format

Special Plots
- None
- Profile Base Predictions (Probability)
- Profile Probability of Event Rate (POER)
- Profile Event-Rate (Mile-Year)
- Profile Events (per Segment-Year)
- PHMSA Incidents (Industry 2010-23)

Position: Stack

Histogram Type: Regular

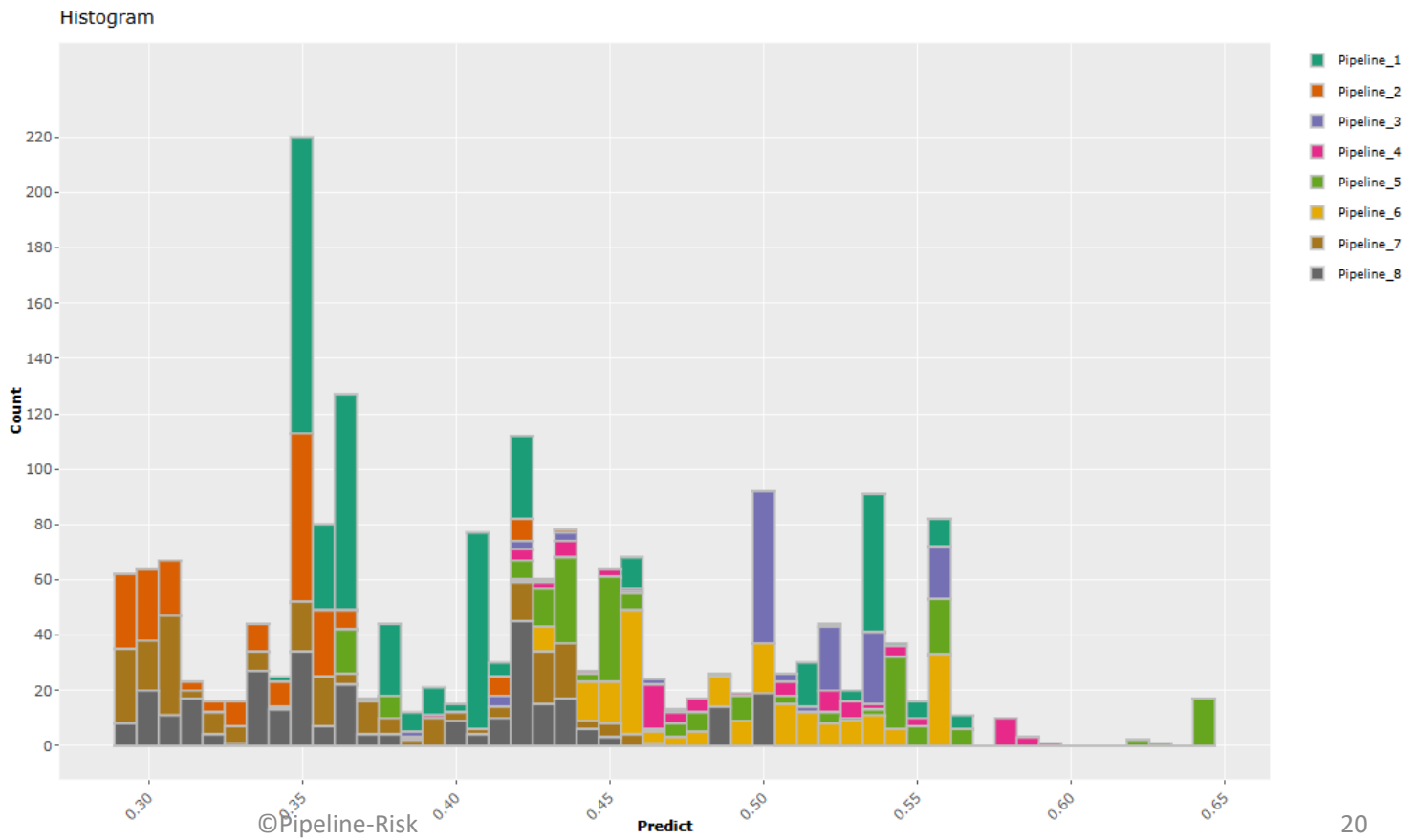
Log10 Y: identity

X Numeric Format: comma

Y Numeric Format: comma

Show Stats

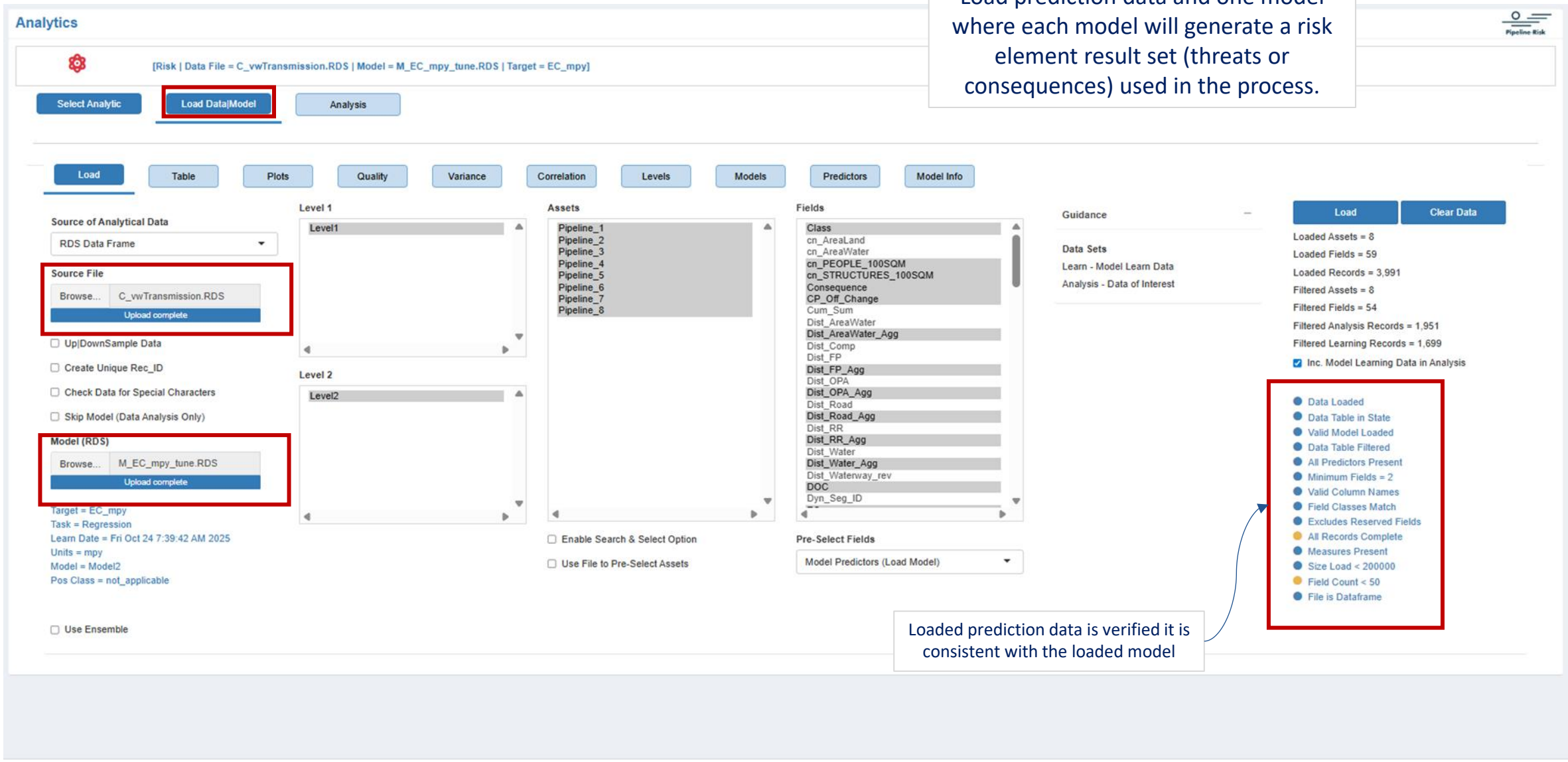
Bins: 50



External Corrosion Growth Rate – EC_mpy (Time Dependent Threat)

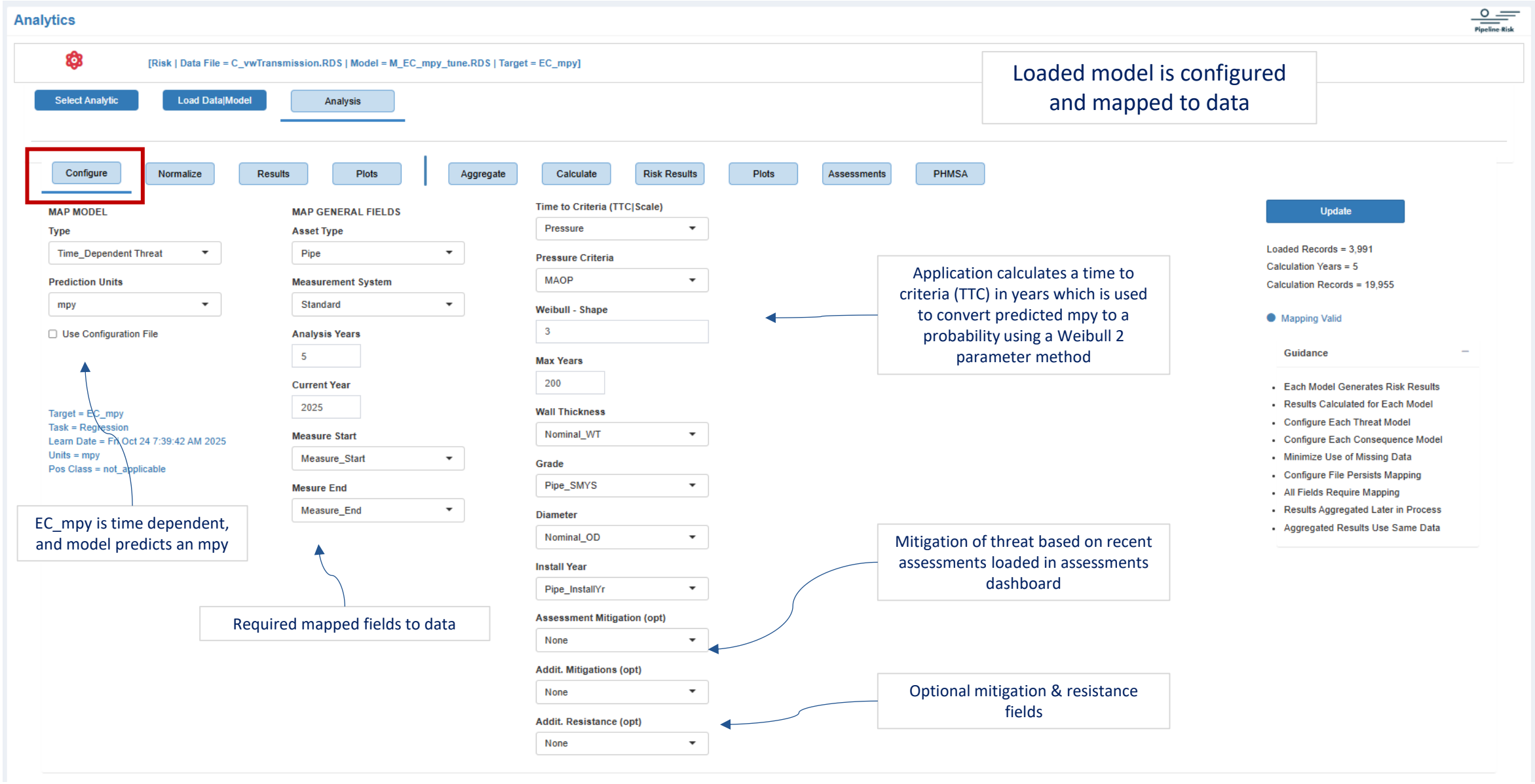
Load Prediction Data & Model

Load prediction data and one model where each model will generate a risk element result set (threats or consequences) used in the process.

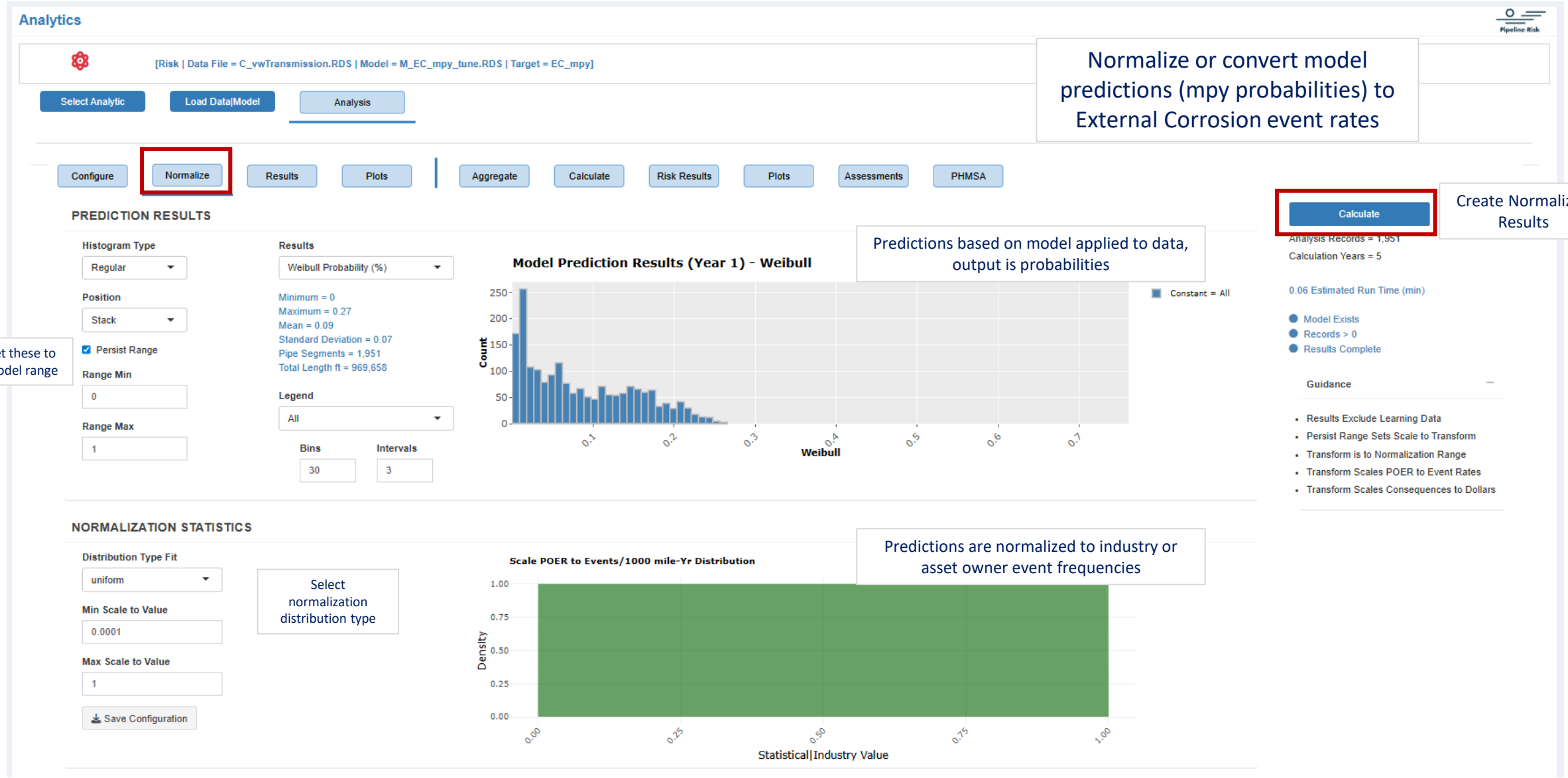


Loaded prediction data is verified it is consistent with the loaded model

Apply EC_mpy Model to Data



Apply EC_mpy Model to Data

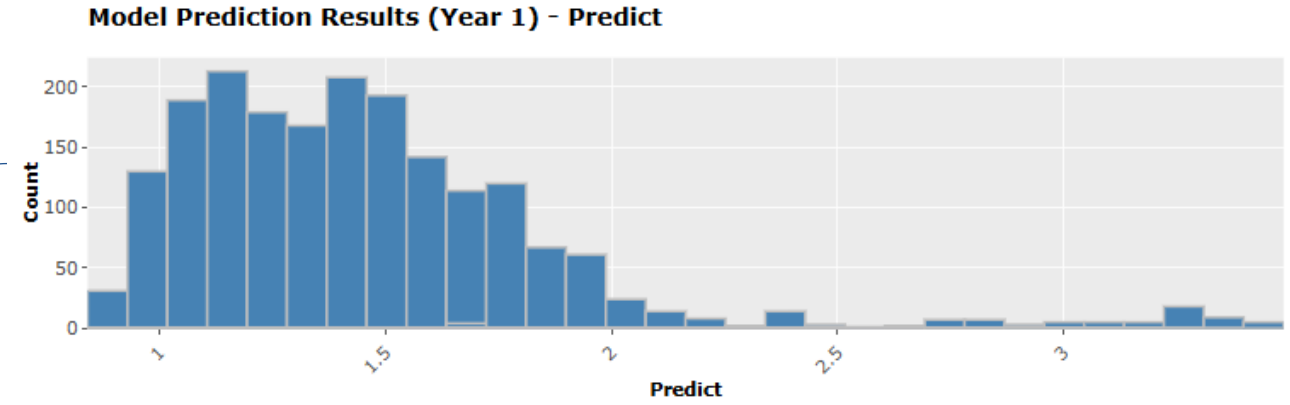


Normalization Concept

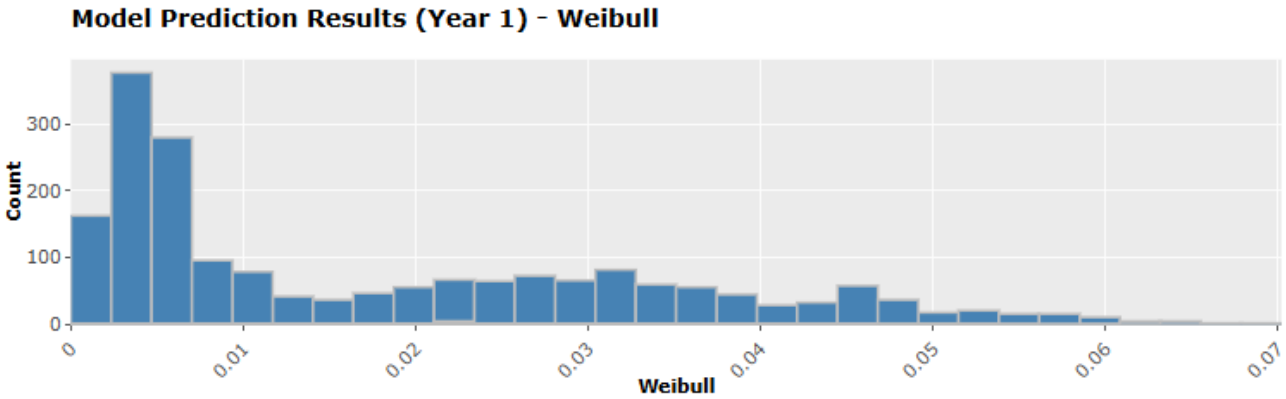
Predicted Corrosion Growth Rate

Probability of Exceeding Criteria (Pressure, % Depth)

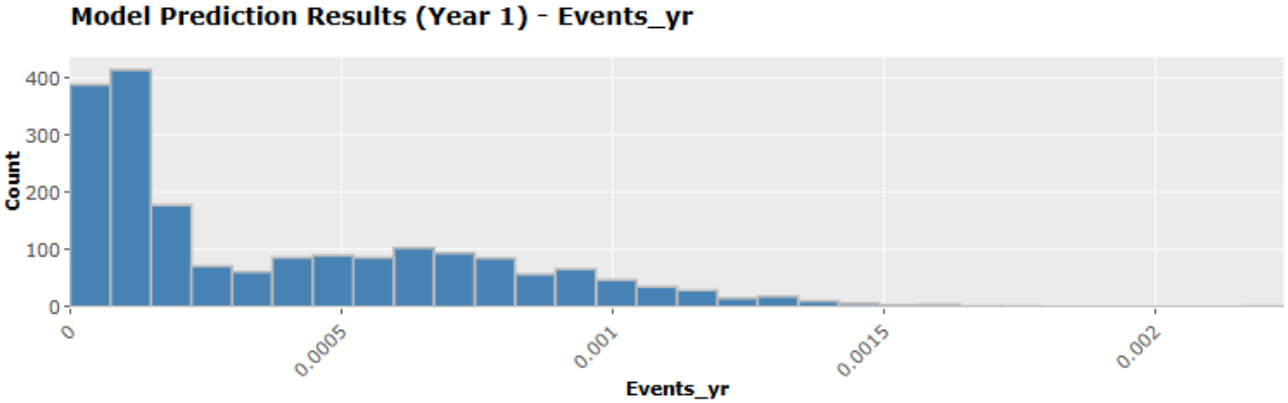
Predicted Events per Year



Machine Learned Predictions (mpy)

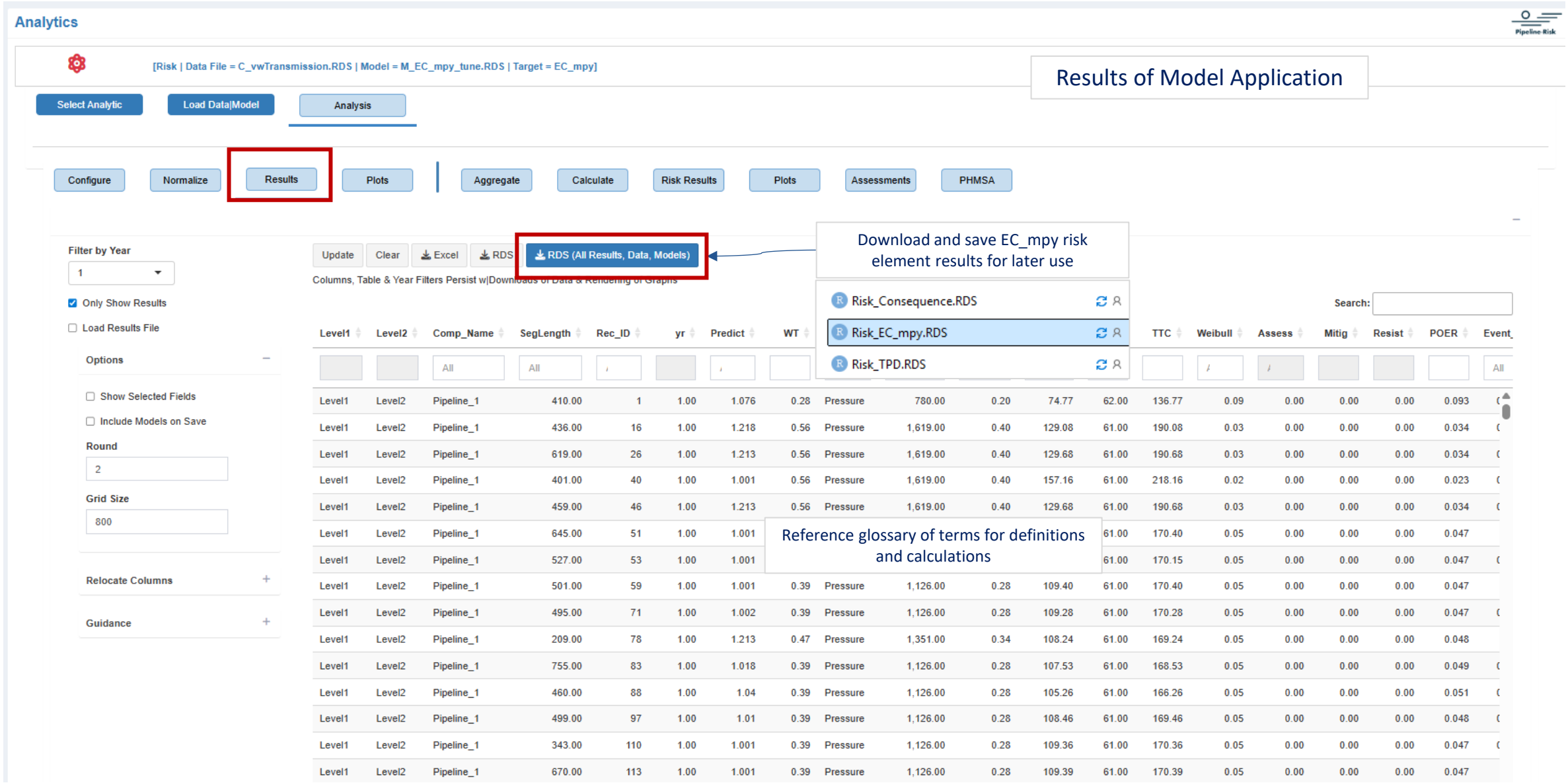


Reliability Curve



Statistically Normalized Predictions

Results



Level1	Level2	Comp_Name	SegLength	Rec_ID	yr	Predict	WT					TTC	Weibull	Assess	Mitig	Resist	POER	Event
		All	All															All
Level1	Level2	Pipeline_1	410.00	1	1.00	1.076	0.28	Pressure	780.00	0.20	74.77	62.00	136.77	0.09	0.00	0.00	0.00	0.093	
Level1	Level2	Pipeline_1	436.00	16	1.00	1.218	0.56	Pressure	1,619.00	0.40	129.08	61.00	190.08	0.03	0.00	0.00	0.00	0.034	
Level1	Level2	Pipeline_1	619.00	26	1.00	1.213	0.56	Pressure	1,619.00	0.40	129.68	61.00	190.68	0.03	0.00	0.00	0.00	0.034	
Level1	Level2	Pipeline_1	401.00	40	1.00	1.001	0.56	Pressure	1,619.00	0.40	157.16	61.00	218.16	0.02	0.00	0.00	0.00	0.023	
Level1	Level2	Pipeline_1	459.00	46	1.00	1.213	0.56	Pressure	1,619.00	0.40	129.68	61.00	190.68	0.03	0.00	0.00	0.00	0.034	
Level1	Level2	Pipeline_1	645.00	51	1.00	1.001						61.00	170.40	0.05	0.00	0.00	0.00	0.047	
Level1	Level2	Pipeline_1	527.00	53	1.00	1.001						61.00	170.15	0.05	0.00	0.00	0.00	0.047	
Level1	Level2	Pipeline_1	501.00	59	1.00	1.001	0.39	Pressure	1,126.00	0.28	109.40	61.00	170.40	0.05	0.00	0.00	0.00	0.047	
Level1	Level2	Pipeline_1	495.00	71	1.00	1.002	0.39	Pressure	1,126.00	0.28	109.28	61.00	170.28	0.05	0.00	0.00	0.00	0.047	
Level1	Level2	Pipeline_1	209.00	78	1.00	1.213	0.47	Pressure	1,351.00	0.34	108.24	61.00	169.24	0.05	0.00	0.00	0.00	0.048	
Level1	Level2	Pipeline_1	755.00	83	1.00	1.018	0.39	Pressure	1,126.00	0.28	107.53	61.00	168.53	0.05	0.00	0.00	0.00	0.049	
Level1	Level2	Pipeline_1	460.00	88	1.00	1.04	0.39	Pressure	1,126.00	0.28	105.26	61.00	166.26	0.05	0.00	0.00	0.00	0.051	
Level1	Level2	Pipeline_1	499.00	97	1.00	1.01	0.39	Pressure	1,126.00	0.28	108.46	61.00	169.46	0.05	0.00	0.00	0.00	0.048	
Level1	Level2	Pipeline_1	343.00	110	1.00	1.001	0.39	Pressure	1,126.00	0.28	109.36	61.00	170.36	0.05	0.00	0.00	0.00	0.047	
Level1	Level2	Pipeline_1	670.00	113	1.00	1.001	0.39	Pressure	1,126.00	0.28	109.39	61.00	170.39	0.05	0.00	0.00	0.00	0.047	

Results

Analytics

[Risk | Data File = C_vwTransmission.RDS | Model = M_EC_mpy_tune.RDS | Target = EC_mpy]

Select Analytic | Load Data|Model | Analysis

Configure | Normalize | Results | Plots | Aggregate | Calculate | Risk Results | Plots | Assessments | PHMSA

Perform interactive analysis of results data

Update

Graph: Box Plot

X (numeric): POER

Y (character): Comp_Name

Legend: Level1

Intervals: 3

Plot Height: 800

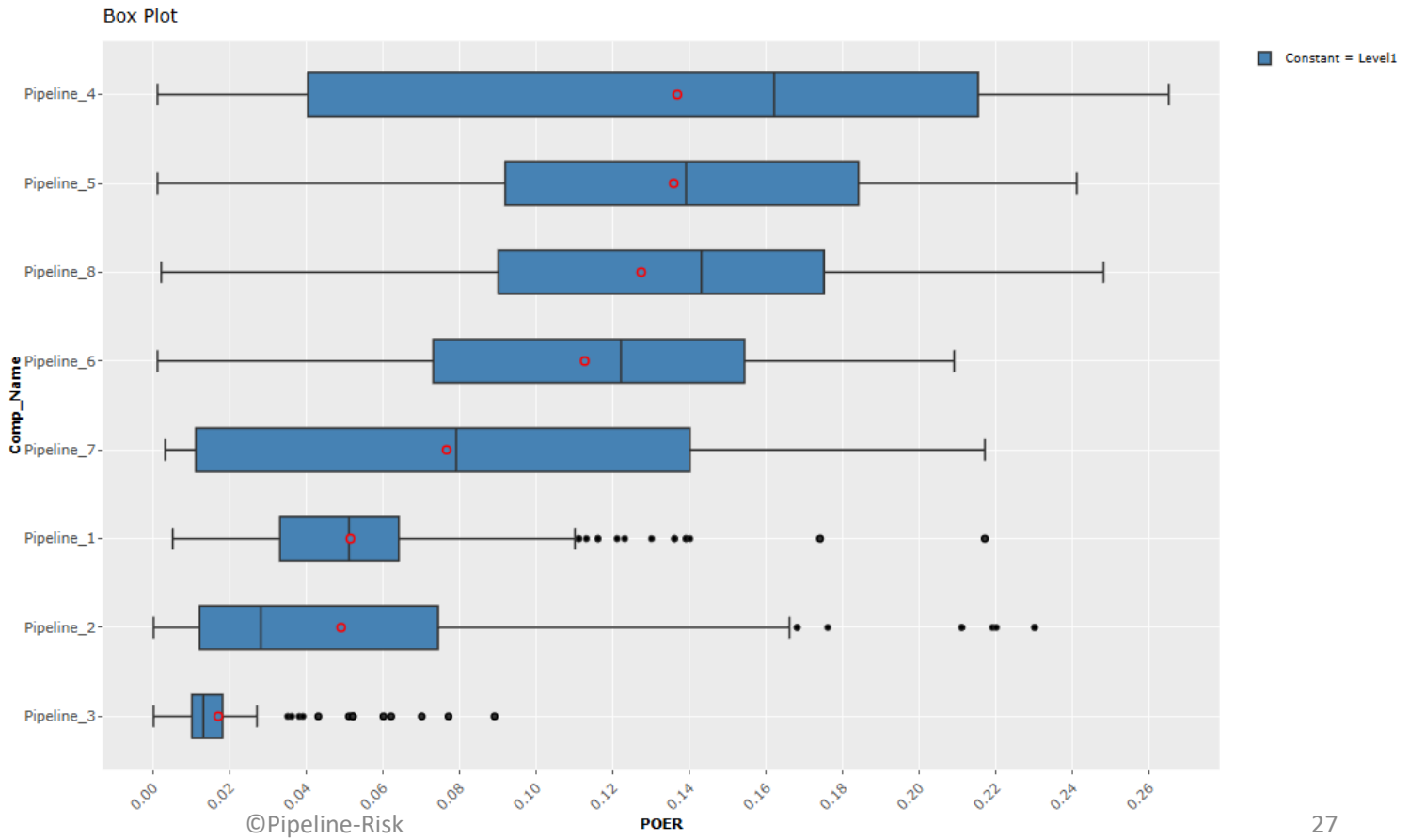
Use Axis Tics & Disable Format

Special Plots
- None
- Profile Base Predictions (mpy)
- Profile Probability of Event Rate (POER)
- Profile Event-Rate (Mile-Year)
- Profile Events (per Segment-Year)
- Profile Weibull
- PHMSA Incidents (Industry 2010-23)

Flip Coordinates

Y Numeric Format: comma

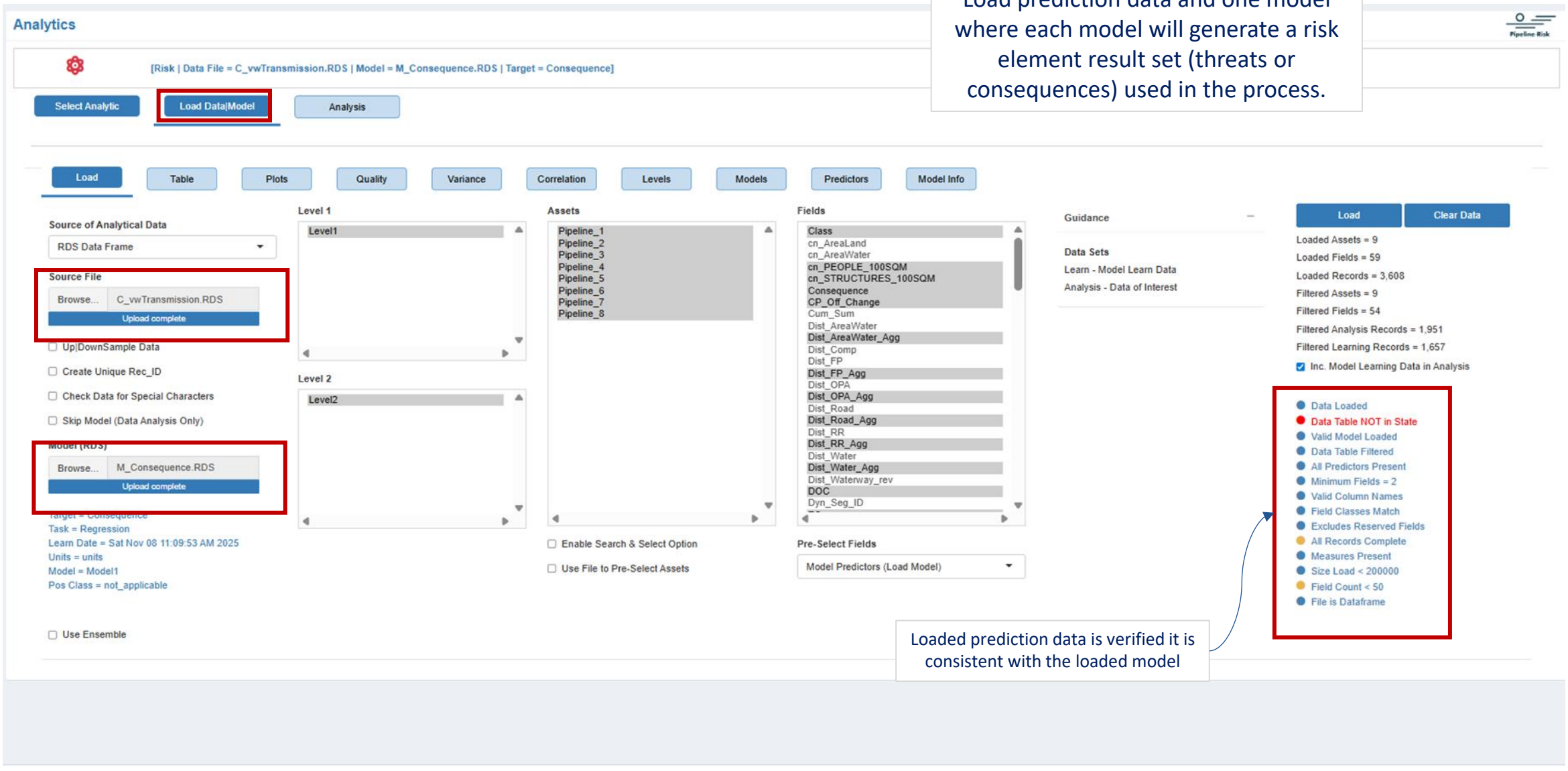
Show Violin



Impact on Population (Consequences)

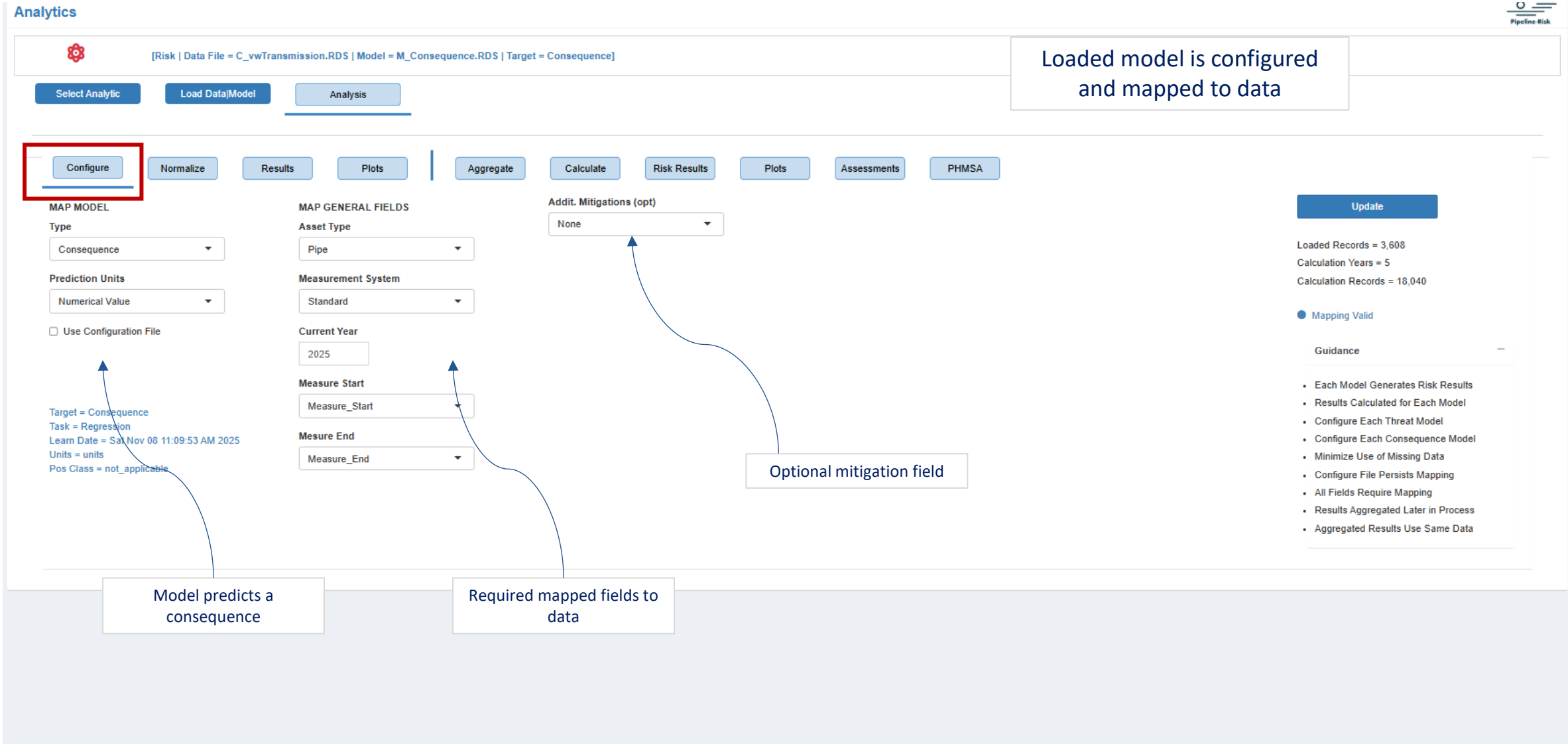
Load Prediction Data & Model

Load prediction data and one model where each model will generate a risk element result set (threats or consequences) used in the process.

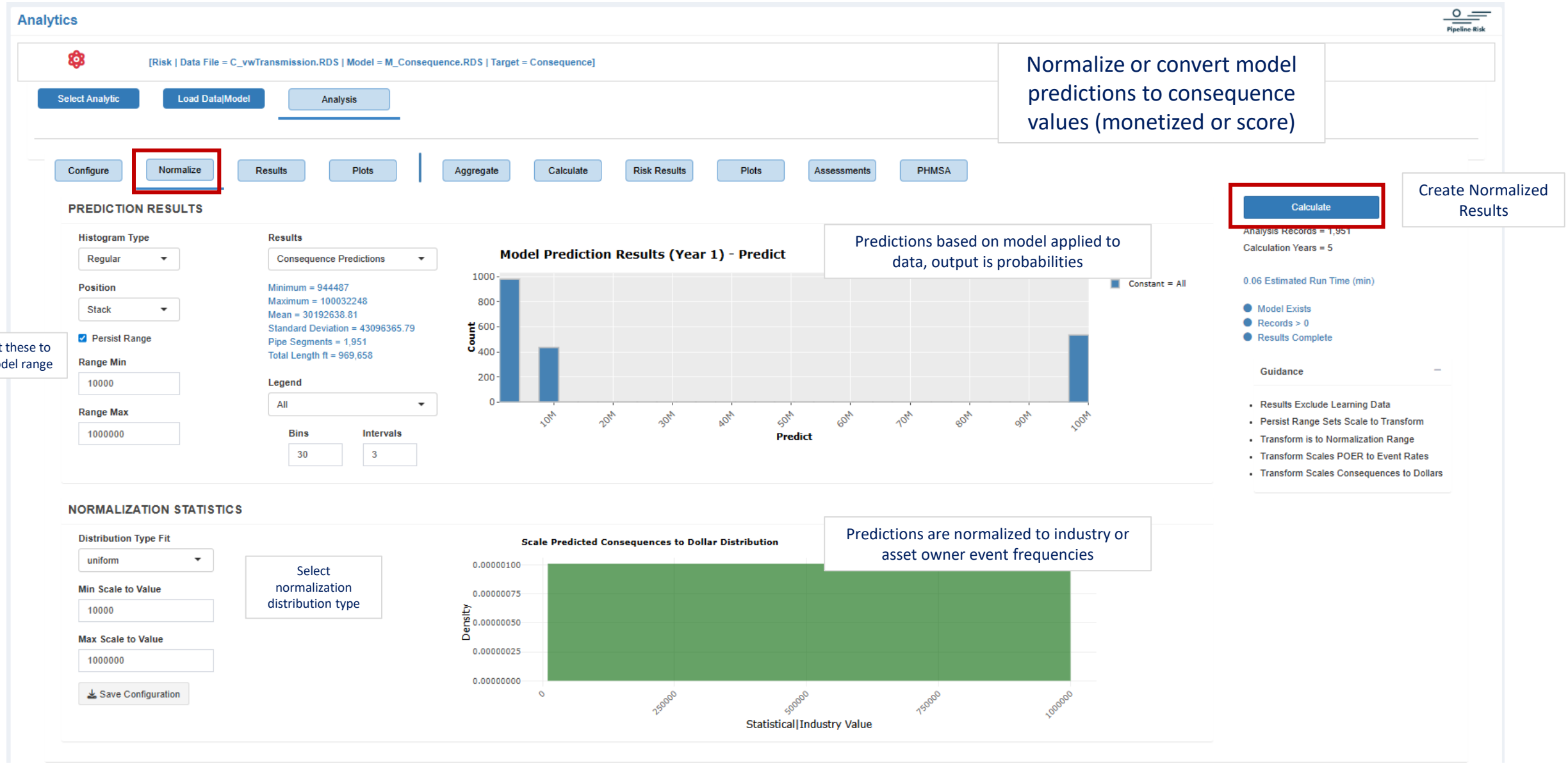


Loaded prediction data is verified it is consistent with the loaded model

Apply Consequence Model to Data



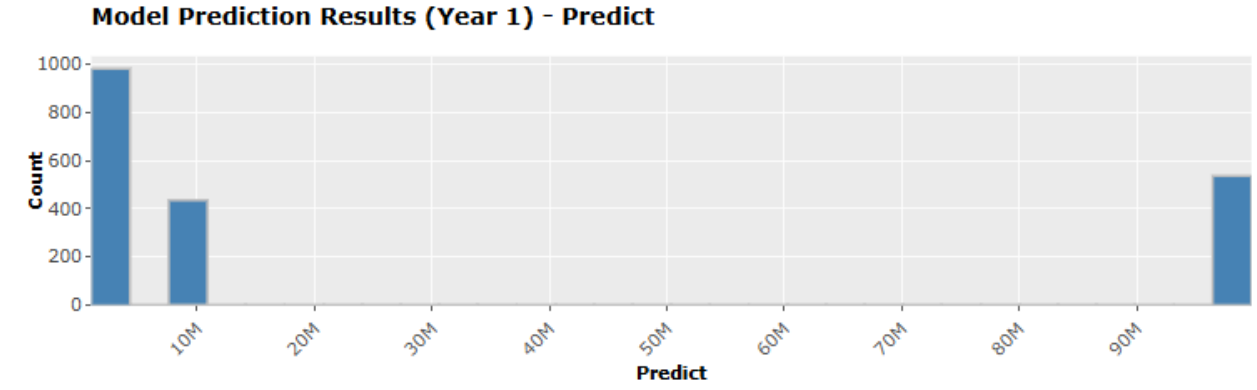
Apply Consequence Model to Data



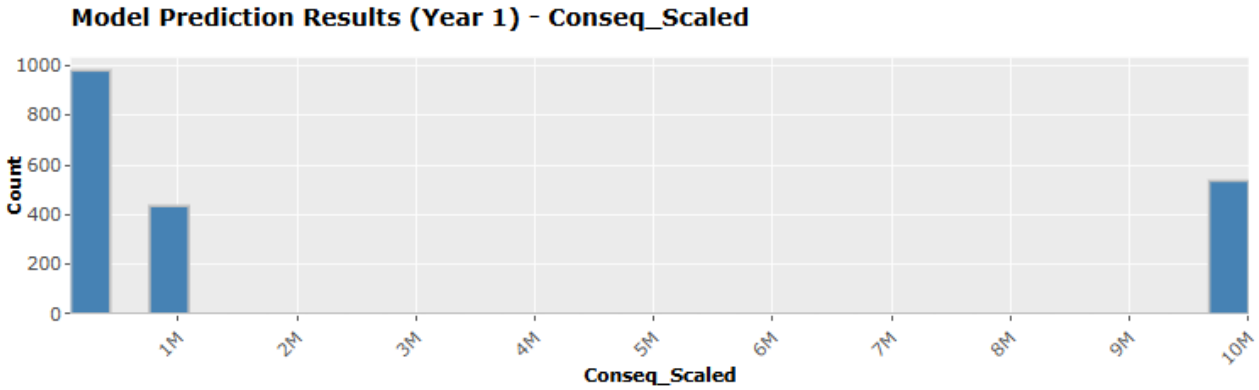
Normalization Concept

Predicted Consequence
(Score or Monetized)

Consequences
(per Event)

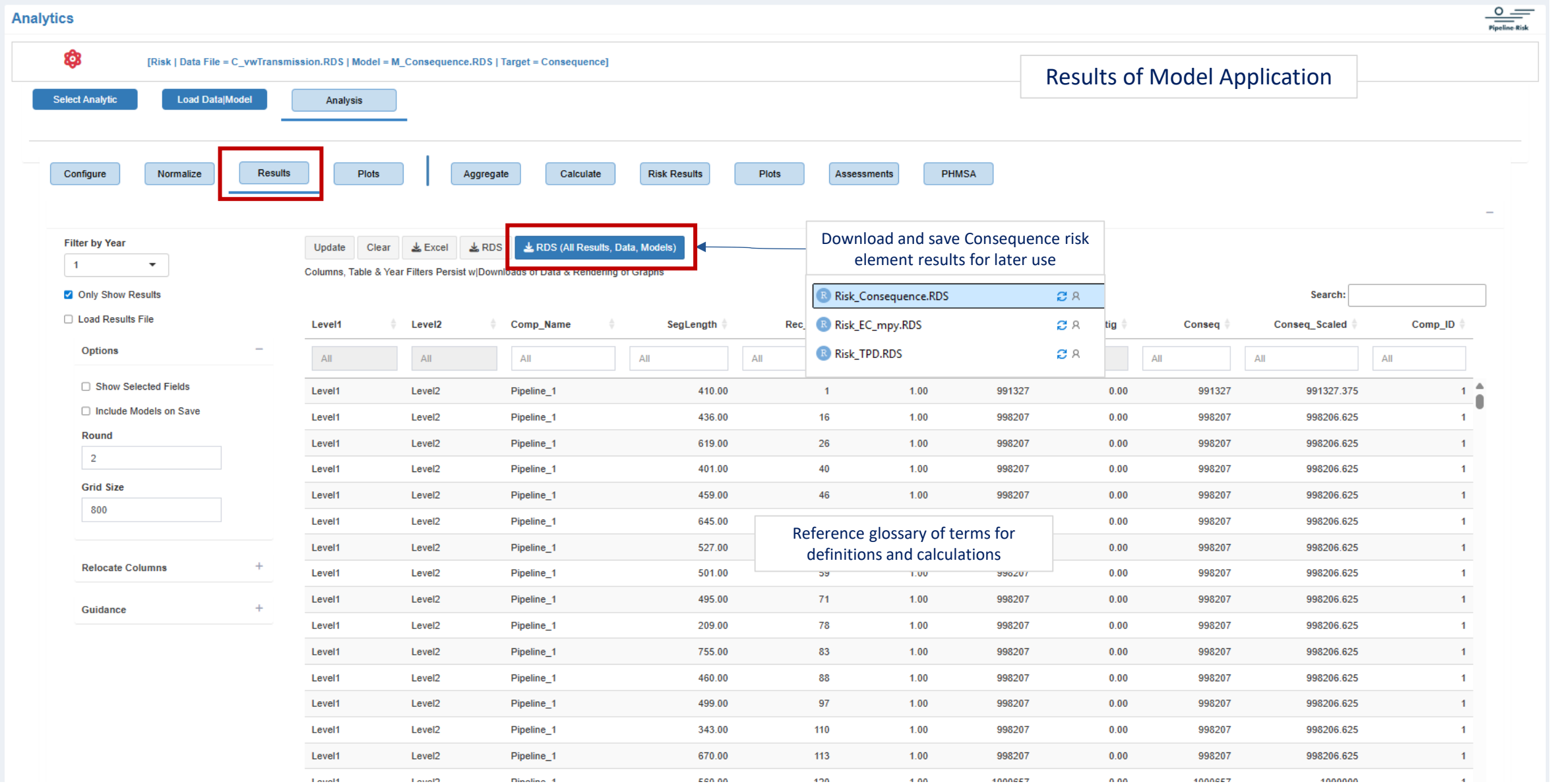


Machine Learned
Predictions



Statistically
Normalized
Predictions

Results



Level1	Level2	Comp_Name	SegLength	Rec_			tig	Conseq	Conseq_Scaled	Comp_ID
All	All	All	All	All				All	All	All
Level1	Level2	Pipeline_1	410.00	1	1.00	991327	0.00	991327	991327.375	1
Level1	Level2	Pipeline_1	436.00	16	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	619.00	26	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	401.00	40	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	459.00	46	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	645.00				0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	527.00				0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	501.00	59	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	495.00	71	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	209.00	78	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	755.00	83	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	460.00	88	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	499.00	97	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	343.00	110	1.00	998207	0.00	998207	998206.625	1
Level1	Level2	Pipeline_1	670.00	113	1.00	998207	0.00	998207	998206.625	1

Results

Pipeline-Risk

Analytics

[Risk | Data File = C_vwTransmission.RDS | Model = M_Consequence.RDS | Target = Consequence]

Select Analytic | Load Data|Model | Analysis

Configure | Normalize | Results | Plots | Aggregate | Calculate | Risk Results | Plots | Assessments | PHMSA

Perform interactive analysis of results data

Update

Graph: Histogram

X (numeric): Predict

Legend: Comp_Name

Intervals: 3

Plot Height: 800

Use Axis Tics & Disable Format

Special Plots
- None
- Base Predictions (Numerical Value)
- Scaled Consequences (dollars)
- PHMSA Consequences (Industry 2010-23)

Position: Stack

Histogram Type: Regular

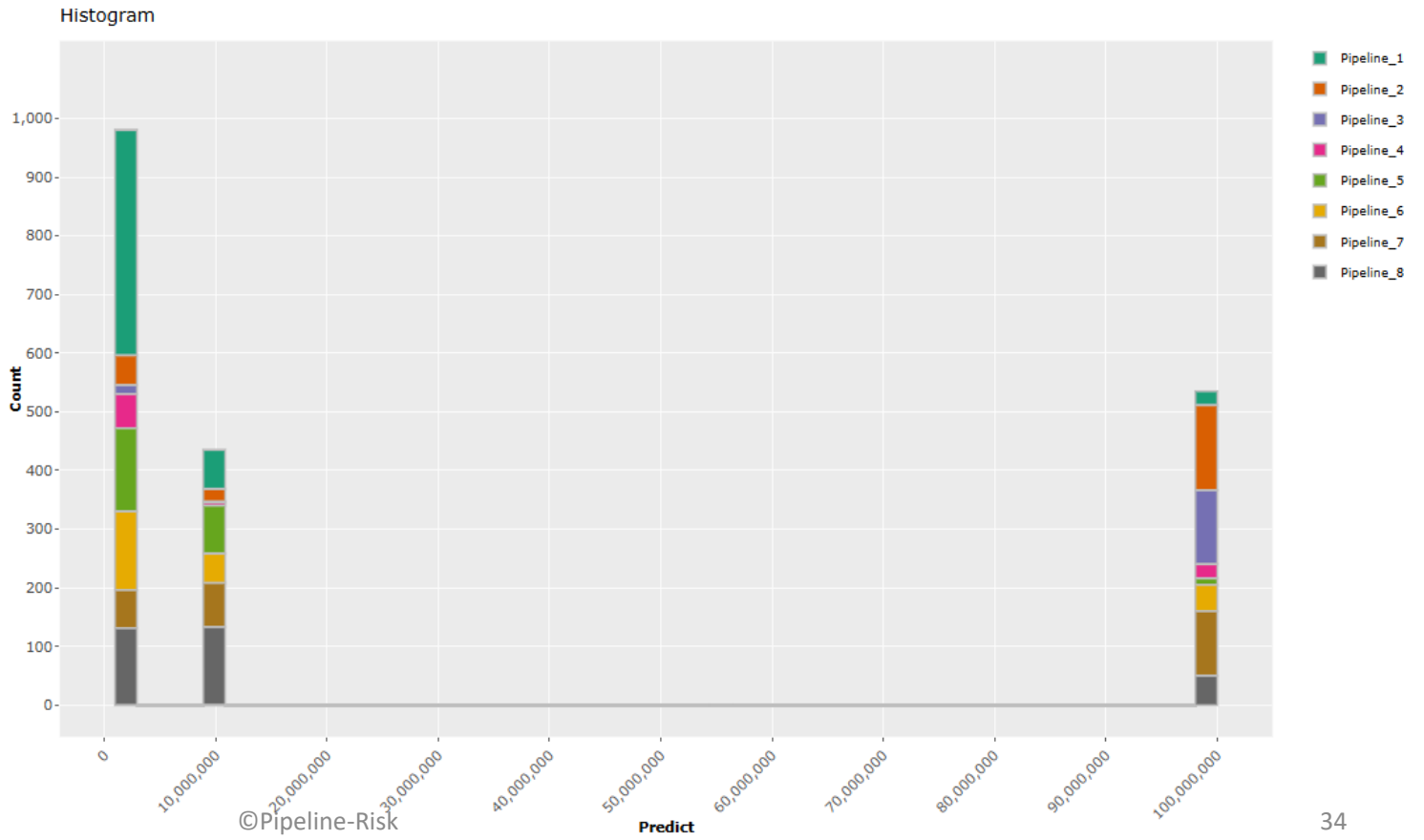
Log10 Y: identity

X Numeric Format: comma

Y Numeric Format: comma

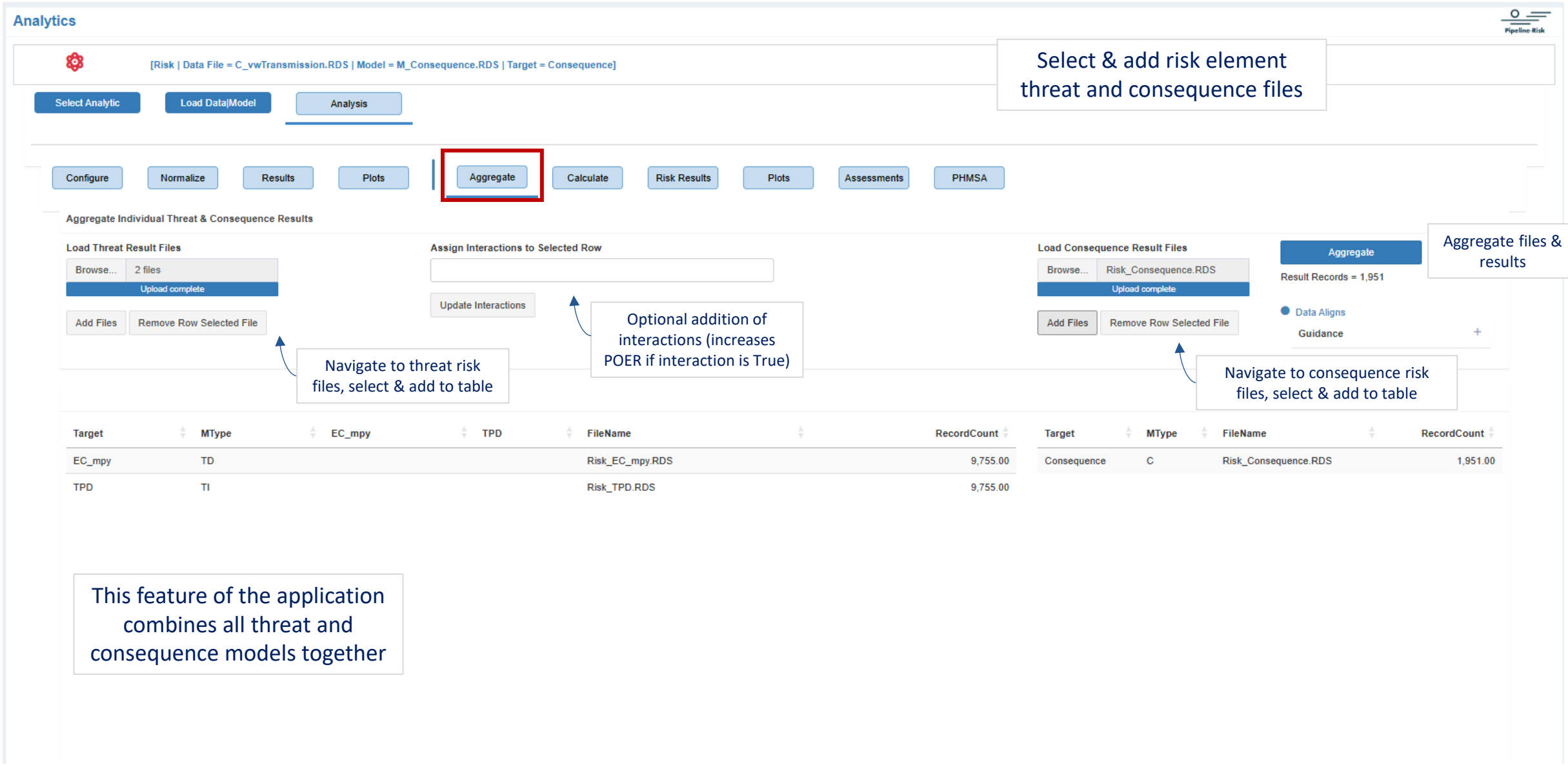
Show Stats

Bins: 50

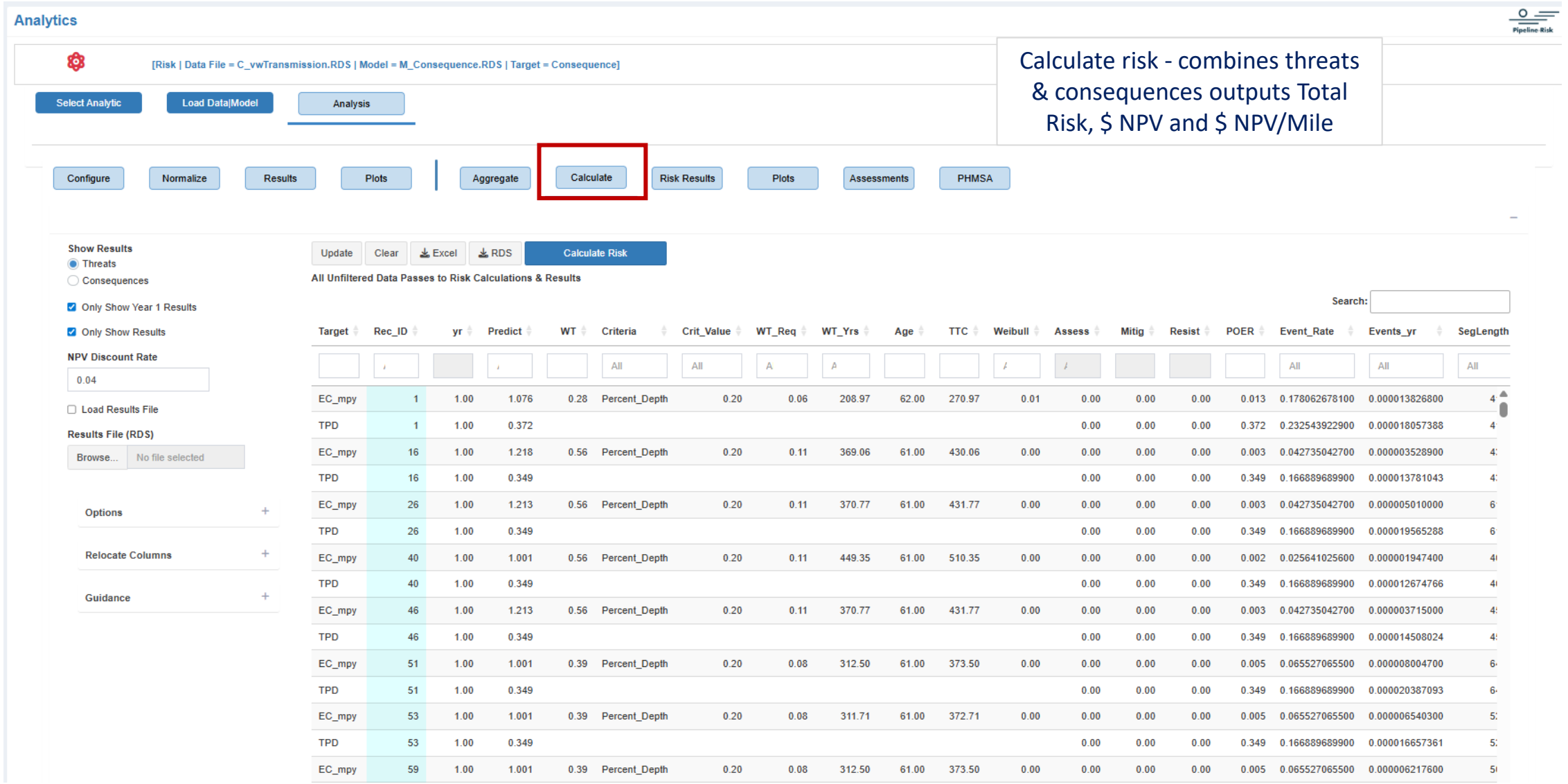


Aggregate Risk Elements to Overall Risk

Aggregate Risk Elements

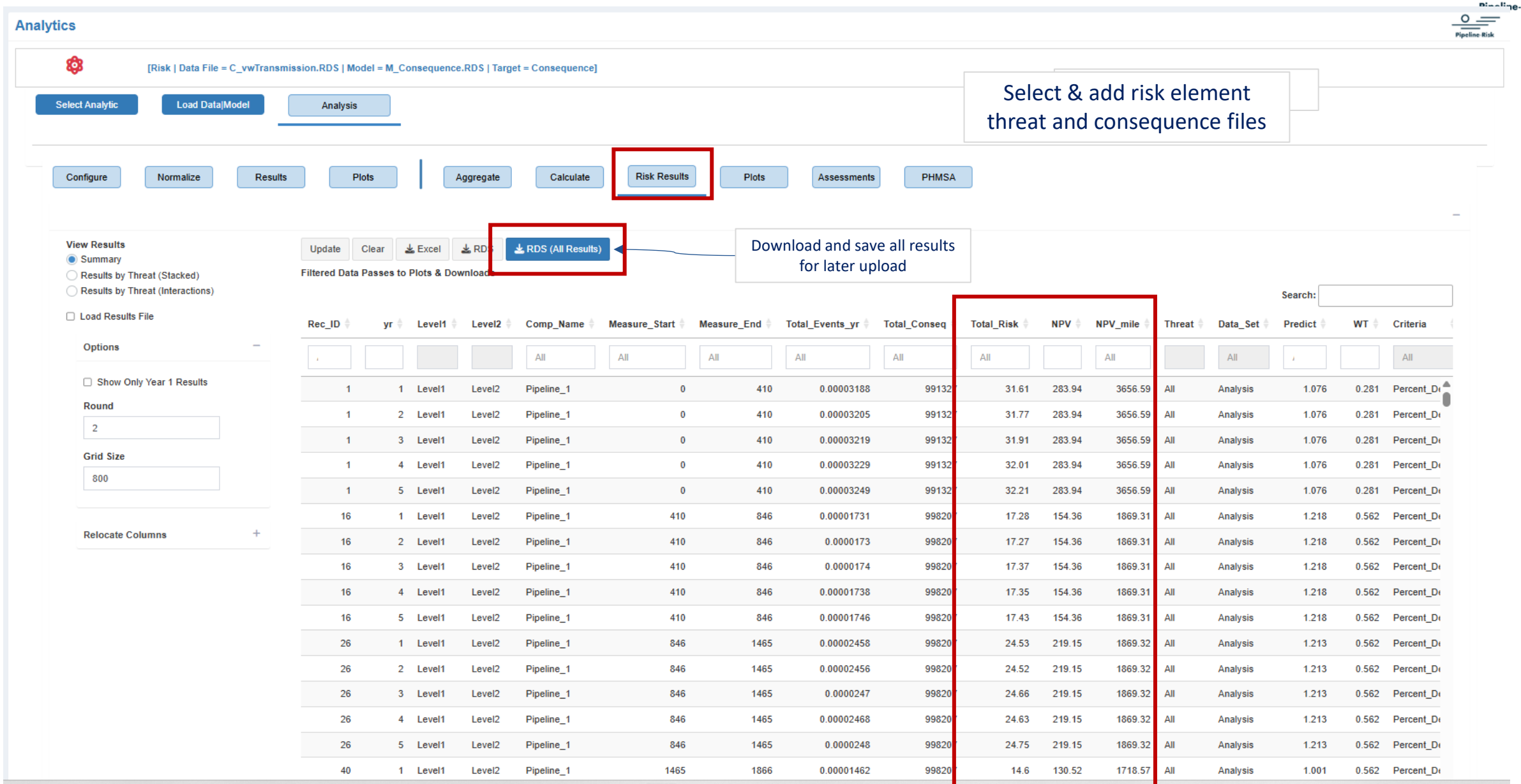


Calculate Risk



Target	Rec_ID	yr	Predict	WT	Criteria	Crit_Value	WT_Req	WT_Yrs	Age	TTC	Weibull	Assess	Mitig	Resist	POER	Event_Rate	Events_yr	SegLength
EC_mpy	1	1.00	1.076	0.28	Percent_Depth	0.20	0.06	208.97	62.00	270.97	0.01	0.00	0.00	0.00	0.013	0.178062678100	0.000013826800	4
TPD	1	1.00	0.372									0.00	0.00	0.00	0.372	0.232543922900	0.000018057388	4
EC_mpy	16	1.00	1.218	0.56	Percent_Depth	0.20	0.11	369.06	61.00	430.06	0.00	0.00	0.00	0.00	0.003	0.042735042700	0.000003528900	4
TPD	16	1.00	0.349									0.00	0.00	0.00	0.349	0.166889689900	0.000013781043	4
EC_mpy	26	1.00	1.213	0.56	Percent_Depth	0.20	0.11	370.77	61.00	431.77	0.00	0.00	0.00	0.00	0.003	0.042735042700	0.000005010000	6
TPD	26	1.00	0.349									0.00	0.00	0.00	0.349	0.166889689900	0.000019565288	6
EC_mpy	40	1.00	1.001	0.56	Percent_Depth	0.20	0.11	449.35	61.00	510.35	0.00	0.00	0.00	0.00	0.002	0.025641025600	0.000001947400	4
TPD	40	1.00	0.349									0.00	0.00	0.00	0.349	0.166889689900	0.000012674766	4
EC_mpy	46	1.00	1.213	0.56	Percent_Depth	0.20	0.11	370.77	61.00	431.77	0.00	0.00	0.00	0.00	0.003	0.042735042700	0.000003715000	4
TPD	46	1.00	0.349									0.00	0.00	0.00	0.349	0.166889689900	0.000014508024	4
EC_mpy	51	1.00	1.001	0.39	Percent_Depth	0.20	0.08	312.50	61.00	373.50	0.00	0.00	0.00	0.00	0.005	0.065527065500	0.000008004700	6
TPD	51	1.00	0.349									0.00	0.00	0.00	0.349	0.166889689900	0.000020387093	6
EC_mpy	53	1.00	1.001	0.39	Percent_Depth	0.20	0.08	311.71	61.00	372.71	0.00	0.00	0.00	0.00	0.005	0.065527065500	0.000006540300	5
TPD	53	1.00	0.349									0.00	0.00	0.00	0.349	0.166889689900	0.000016657361	5
EC_mpy	59	1.00	1.001	0.39	Percent_Depth	0.20	0.08	312.50	61.00	373.50	0.00	0.00	0.00	0.00	0.005	0.065527065500	0.000006217600	5

Risk Results



Risk Results

Pipeline-Risk

Analytics

[Risk | Data File = C_vwTransmission.RDS | Model = M_Consequence.RDS | Target = Consequence]

Select Analytic | Load Data|Model | Analysis

Configure | Normalize | Results | Plots | Aggregate | Calculate | Risk Results | Plots | Assessments | PHMSA

Update

Graph: Histogram

X (numeric): NPV_mile

Legend: Comp_Name

Intervals: 3

Plot Height: 800

Use Axis Tics & Disable Format

Position: Stack

Histogram Type: Regular

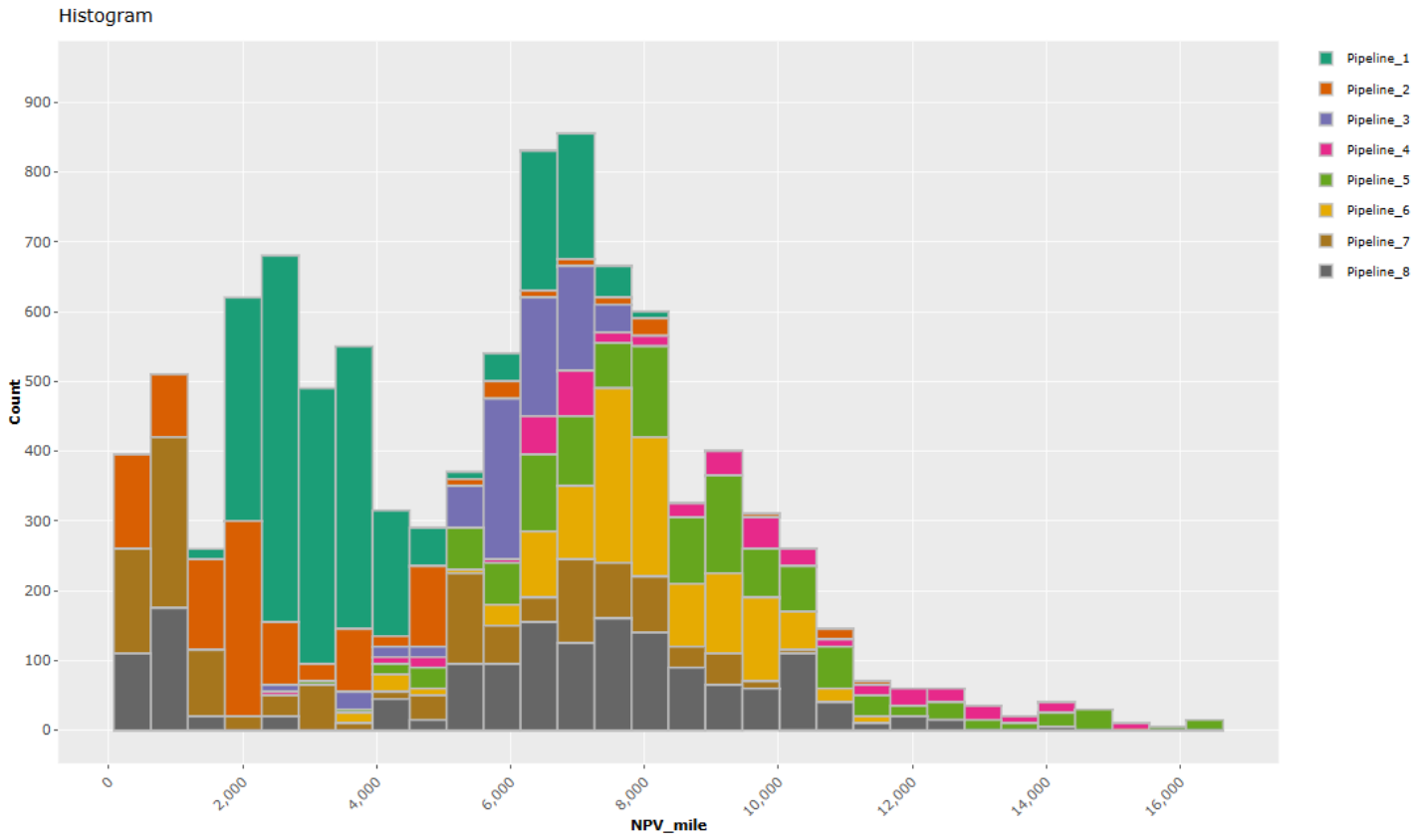
Log10 Y: identity

X Numeric Format: comma

Y Numeric Format: comma

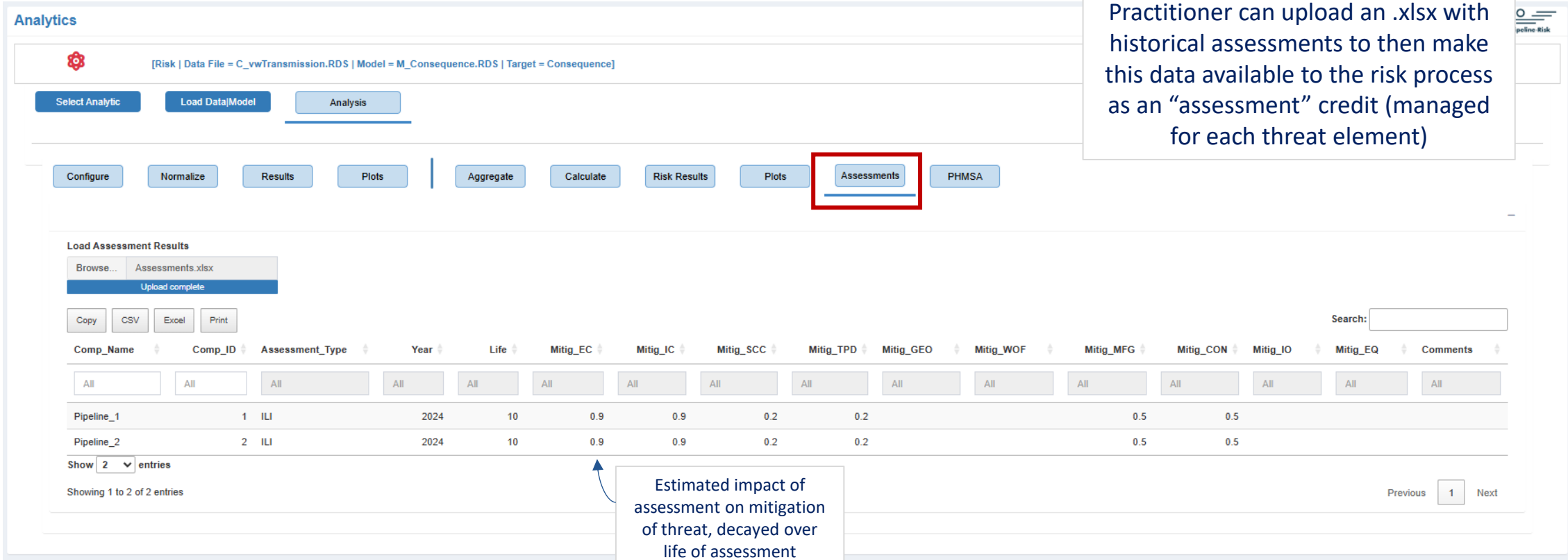
Show Stats

Bins: 30



Special Features

Assessments

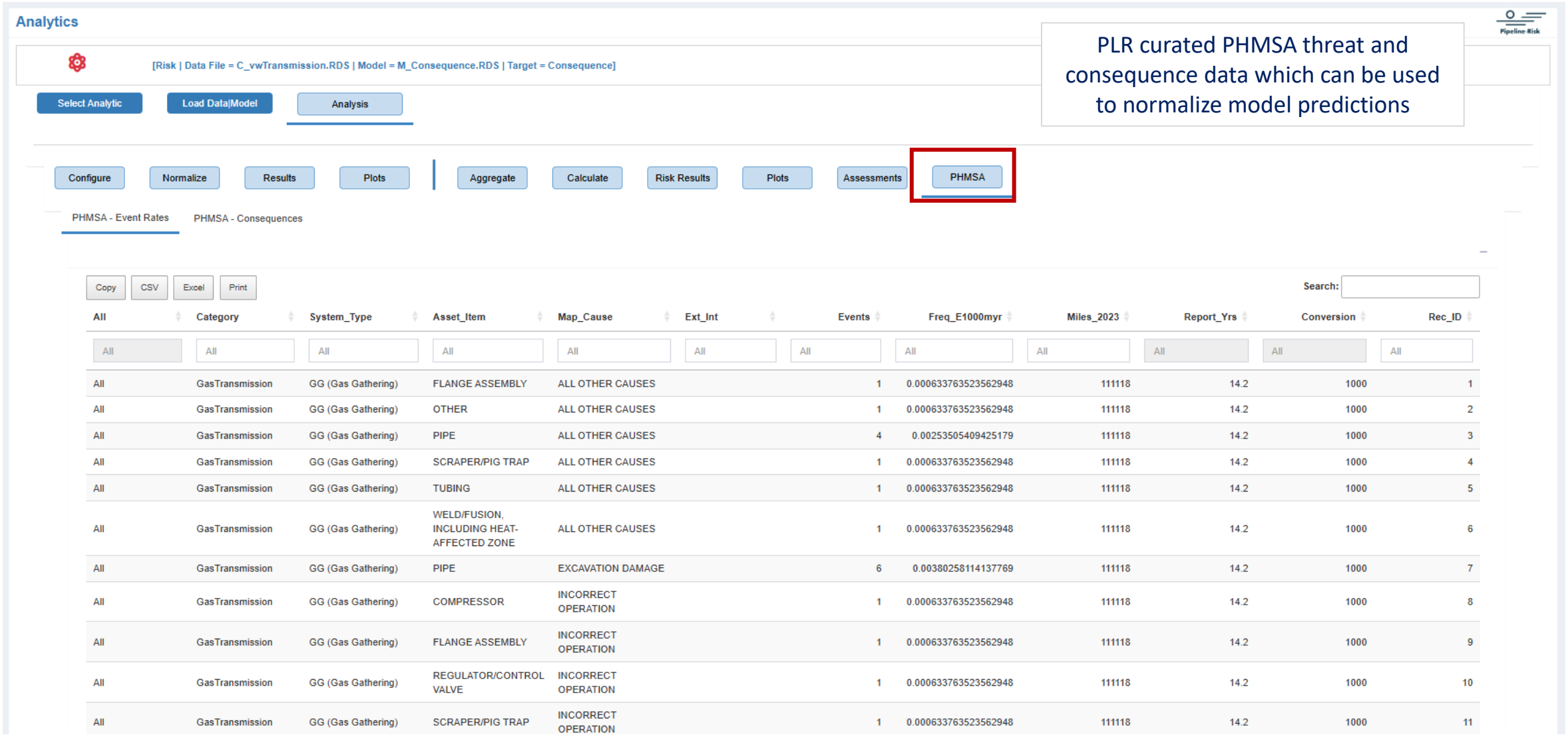


Practitioner can upload an .xlsx with historical assessments to then make this data available to the risk process as an "assessment" credit (managed for each threat element)

Estimated impact of assessment on mitigation of threat, decayed over life of assessment

Concept is asset owner will mitigate all critical defects for a threat(s) after an assessment and the risk for that threat would be expected to be impacted over some time (straight line decay) during the life of the assessment

PHMSA Stats



PLR curated PHMSA threat and consequence data which can be used to normalize model predictions

All	Category	System_Type	Asset_Item	Map_Cause	Ext_Int	Events	Freq_E1000myr	Miles_2023	Report_Yrs	Conversion	Rec_ID
All	All	All	All	All	All	All	All	All	All	All	All
All	GasTransmission	GG (Gas Gathering)	FLANGE ASSEMBLY	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	1
All	GasTransmission	GG (Gas Gathering)	OTHER	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	2
All	GasTransmission	GG (Gas Gathering)	PIPE	ALL OTHER CAUSES		4	0.00253505409425179	111118	14.2	1000	3
All	GasTransmission	GG (Gas Gathering)	SCRAPER/PIG TRAP	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	4
All	GasTransmission	GG (Gas Gathering)	TUBING	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	5
All	GasTransmission	GG (Gas Gathering)	WELD/FUSION, INCLUDING HEAT-AFFECTED ZONE	ALL OTHER CAUSES		1	0.000633763523562948	111118	14.2	1000	6
All	GasTransmission	GG (Gas Gathering)	PIPE	EXCAVATION DAMAGE		6	0.00380258114137769	111118	14.2	1000	7
All	GasTransmission	GG (Gas Gathering)	COMPRESSOR	INCORRECT OPERATION		1	0.000633763523562948	111118	14.2	1000	8
All	GasTransmission	GG (Gas Gathering)	FLANGE ASSEMBLY	INCORRECT OPERATION		1	0.000633763523562948	111118	14.2	1000	9
All	GasTransmission	GG (Gas Gathering)	REGULATOR/CONTROL VALVE	INCORRECT OPERATION		1	0.000633763523562948	111118	14.2	1000	10
All	GasTransmission	GG (Gas Gathering)	SCRAPER/PIG TRAP	INCORRECT OPERATION		1	0.000633763523562948	111118	14.2	1000	11

Conceptual

Risk Management - Distribution

Pipeline-Risk

Risk Models

Risk Results

Analysis

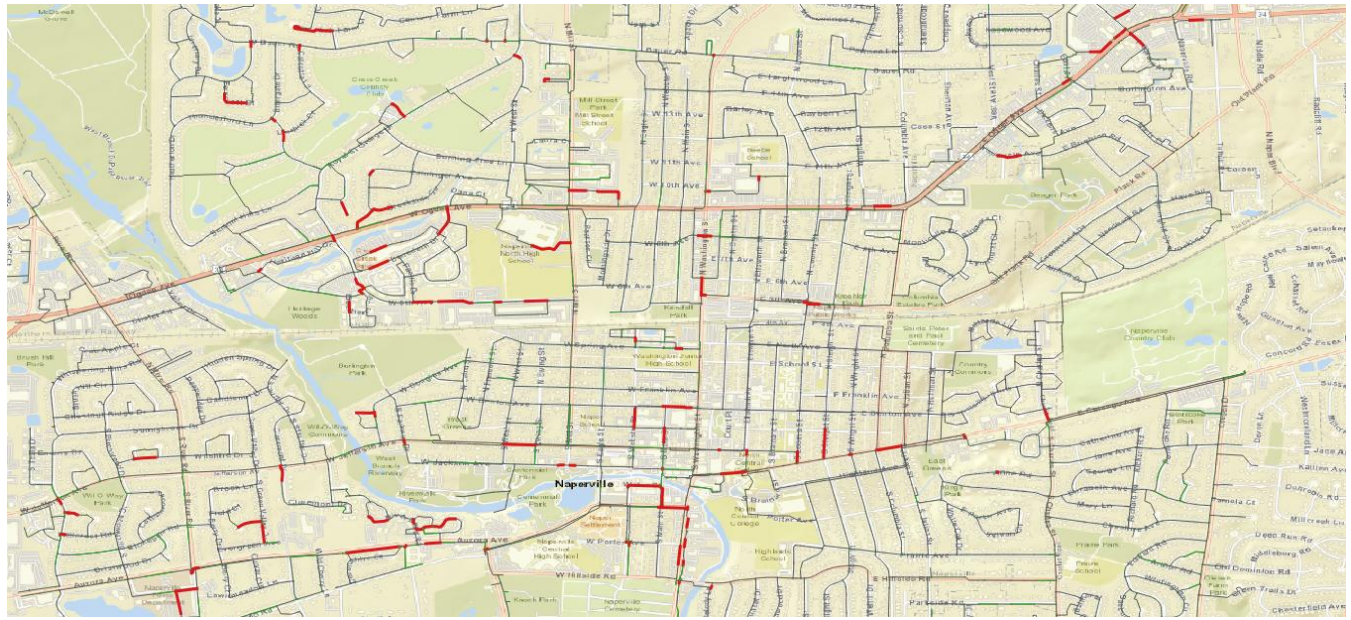
Data

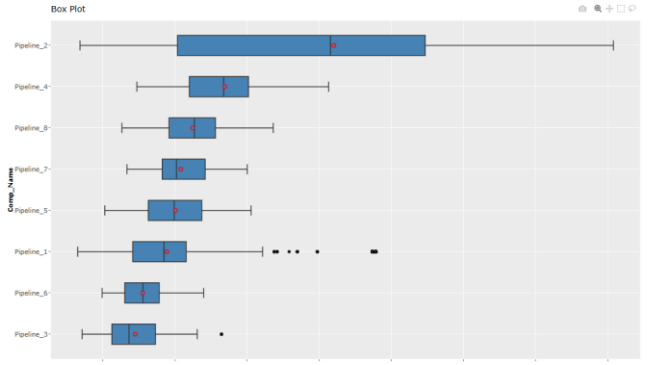
Threat Models

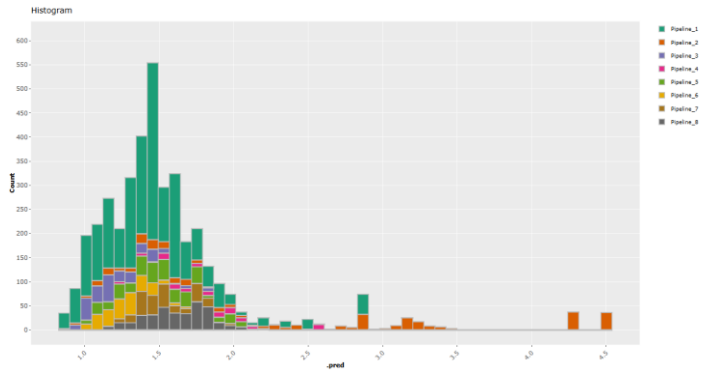
Consequence Models

Missing Data Models

Data Quality Models







Risk Management - Transmission

Pipeline-Risk

Risk Models

Risk Results

Analysis

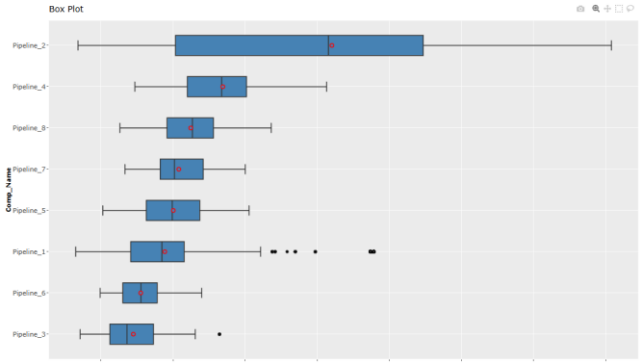
Data

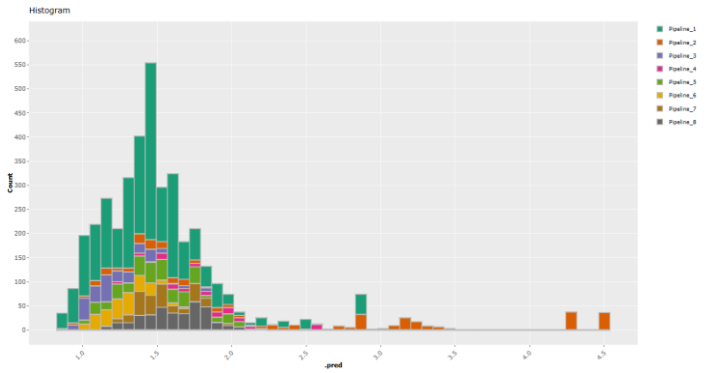
Threat Models

Consequence Models

Missing Data Models

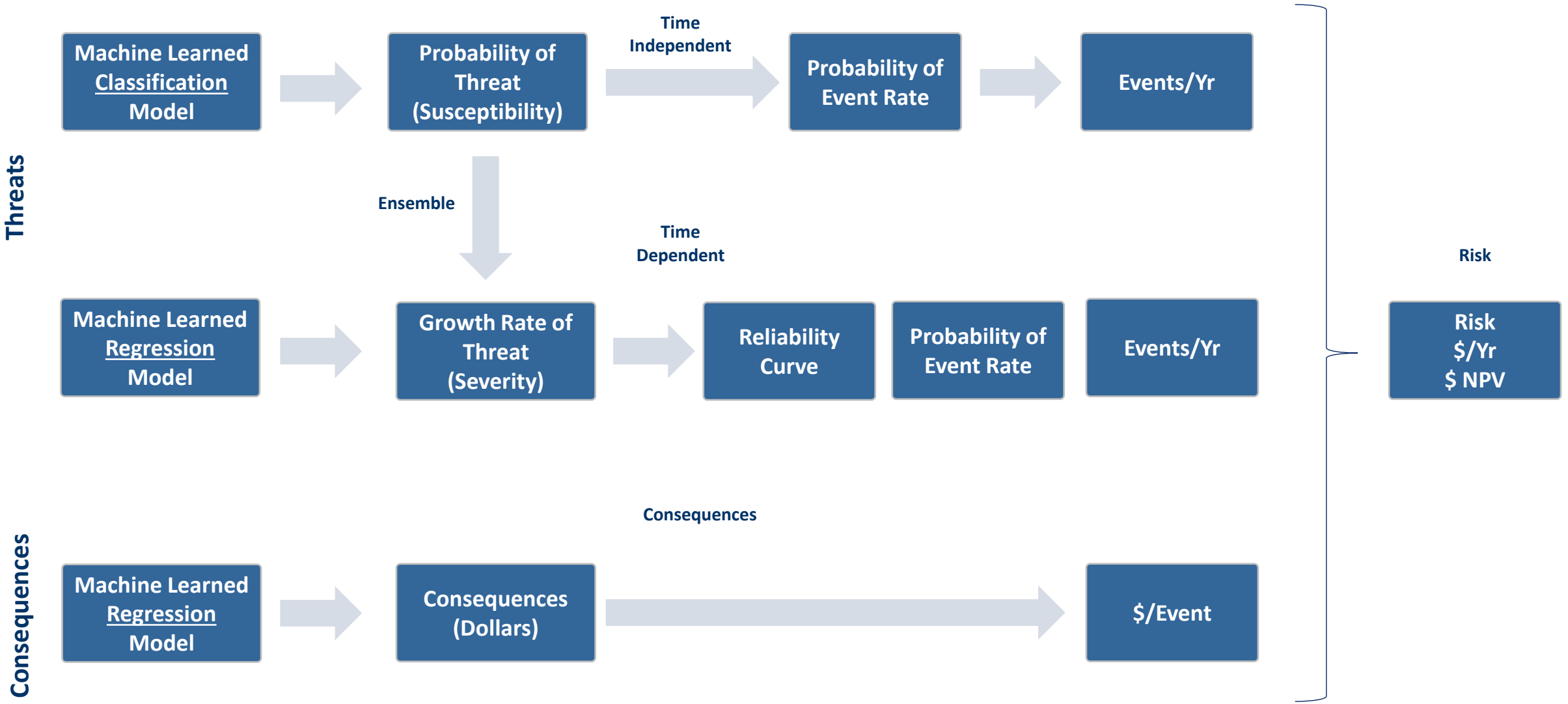
Data Quality Models





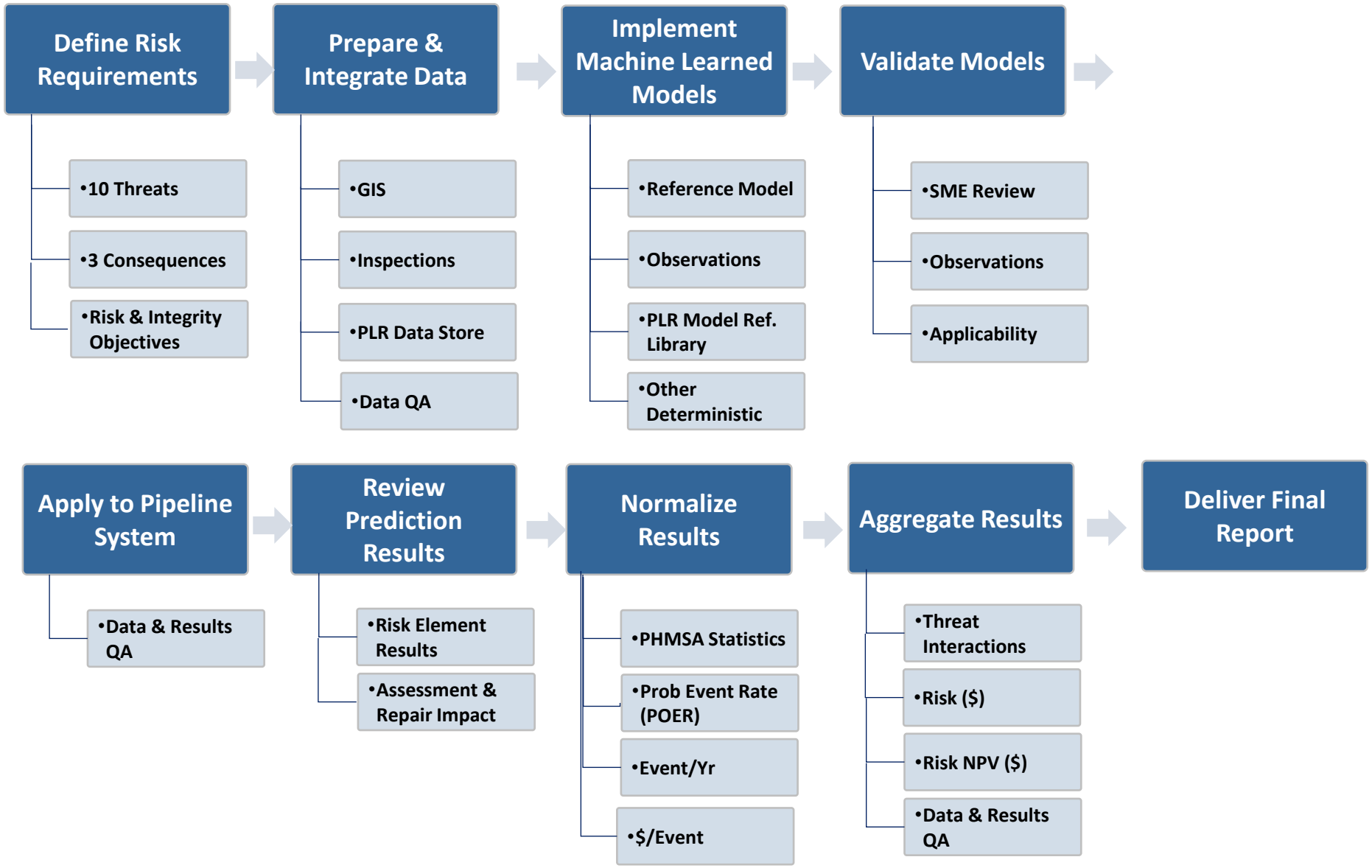
Work-Flows & Structures

Intuition



Process

- Data-Driven Machine Learned Based Risk Assessment Process
- Leverage Existing Client Data & PLR Geospatial Data Store
- Manages 10 Threats & 3 Consequences (flexible depending on use case)
- Supports Risk Monetization thru Use of Industry Statistics



Details

Threat Analysis

- Initial data driven machine learned models are based on PLR reference & other client learned models
- Models are then tuned to Client observations & domain expertise
- Primary output is a **POER (Probability of Event Rate)** for each segment of pipe
- Time independent threats have stable POER over time
- Time dependent threats have changing POER over time based on predicted growth rates & exceedance criteria
- Results are fully traceable to raw input data
- POERs are normalized to industry event rates to arrive at potential events per yr per segment of pipe

Consequence Analysis

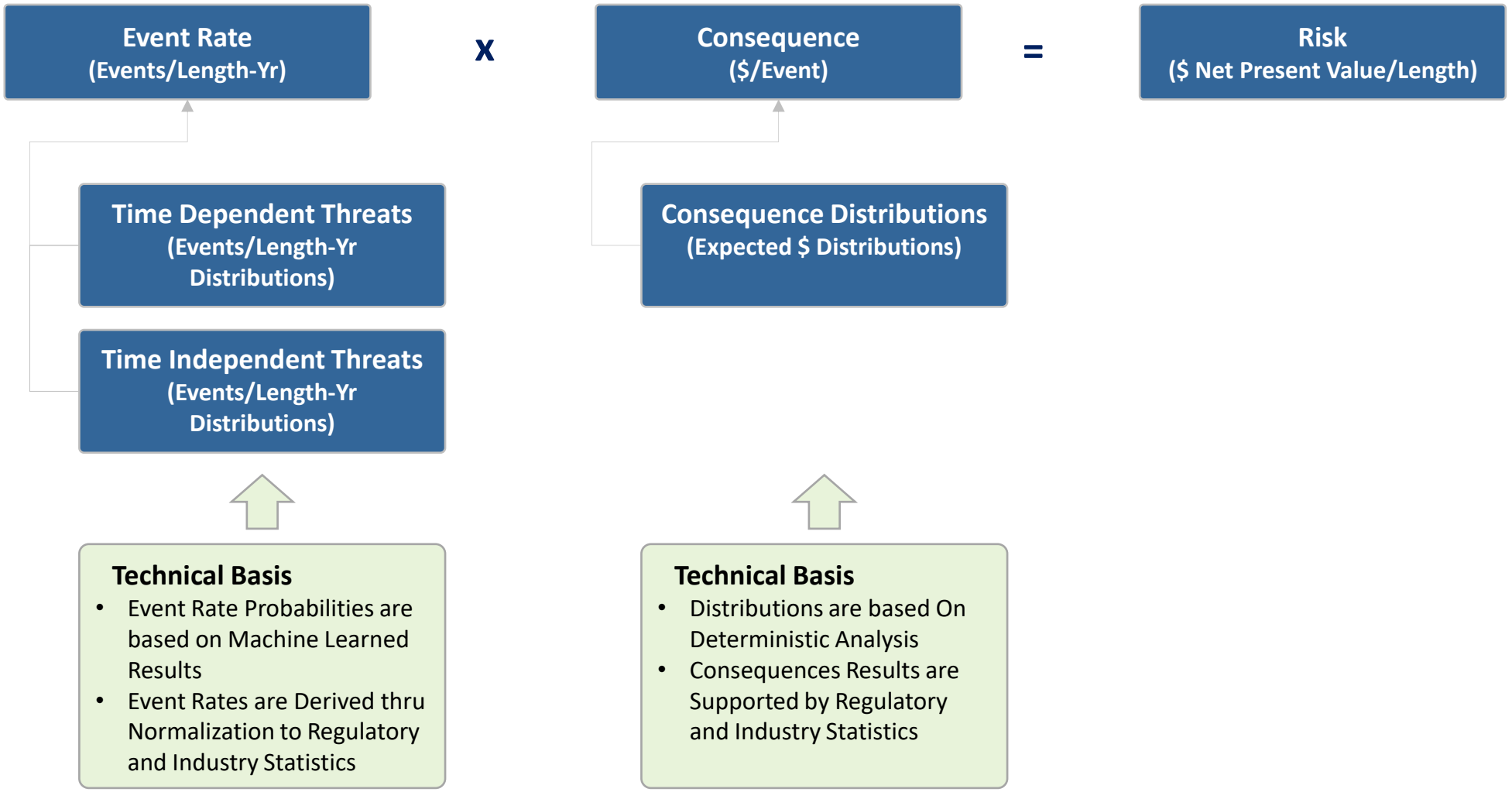
- Initial data driven machine learned models are based on PLR reference & other client learned models
- Models are then tuned to Client observations & domain expertise
- Results are fully traceable to raw input data
- Result is a scaled Consequence number (monetized) normalized to Industry statistics in terms of potential **$/event**

Risk Analysis

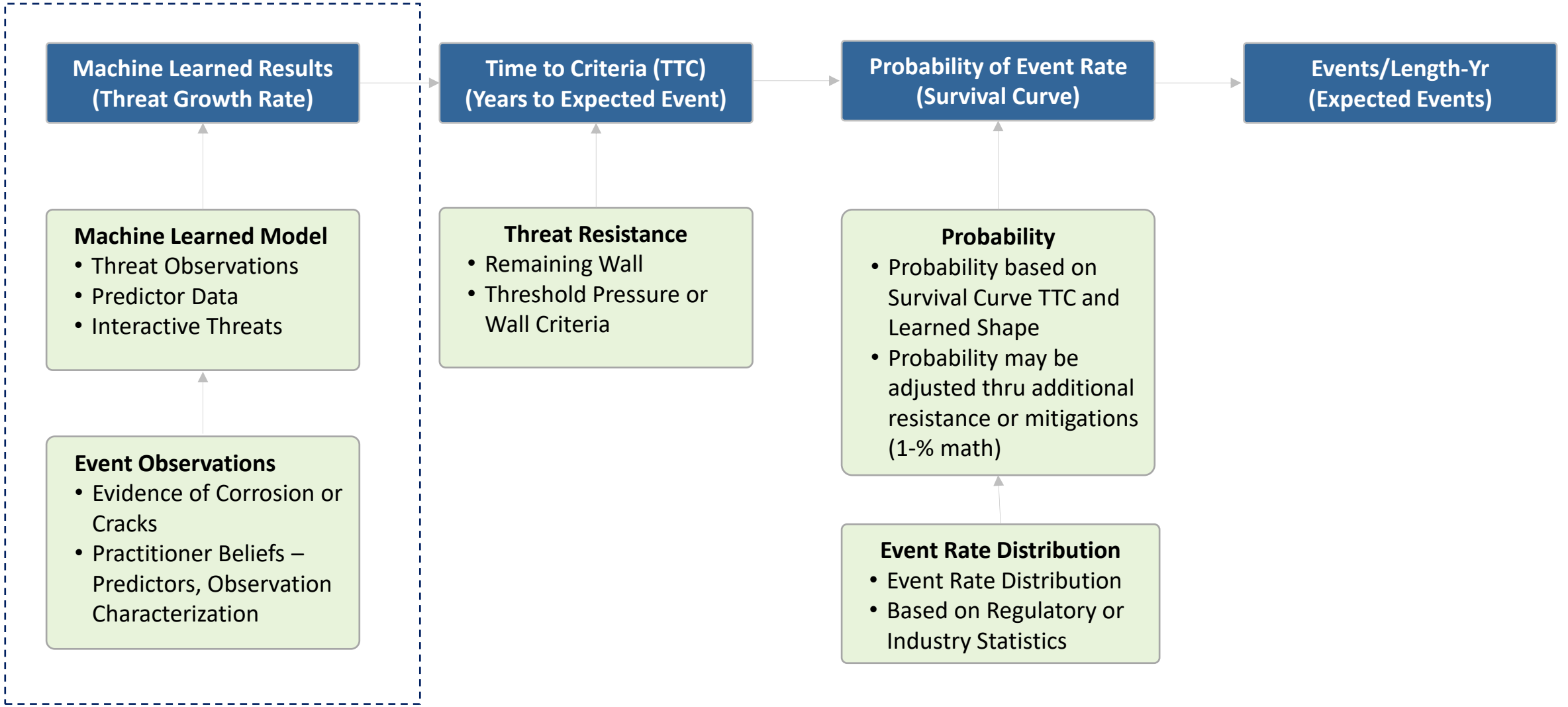
- Predicted Events/Yr x $/Event outputs $ Risk for each pipe segment per yr
- Risk is reduced by assessment & repair activity
- Interactive threats are considered
- Outputs include potential **$ Risk, $ Net Present Value and $ Net Present Value/mile for each segment of pipe**

- Risk is calculated by multiplying the number of events per year times consequences for each segment and analysis year. The results will show risk for each segment and each analysis year which are then aggregated to a Net Present Value (NPV) for each segment based on an assumed discount rate and number of analysis years. NPV's are further normalized to miles shown as NPV_mile.
- Interactions are an advanced feature, basically if interactions are set as True for a threat the threat POER is increased by the POER of the interacting threats using 1-POER math
- Ensemble model predictions are an advanced feature where the predictions from main threat are multiplied by the ensemble model predictions

Risk Structure - Monetization



Risk Structure – Time Dependent Threats



Risk Structure – Time Independent Threats