



Modeling the Consequences of Pipeline Risk

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A faint, light gray image of a globe is visible in the background, centered behind the speaker's name and affiliation. The globe shows the continents of North and South America.

PHC Events



Low Probability – High Consequence (LPHC) events dominate the risk picture

- # Top 1% of PHMSA reportable incidents account for 20% of reported property damage
- # Result in significantly higher additional costs
- # Represent 40 – 60% of total risk exposure

Challenges with LPHC Events

- # Because of low frequency, most difficult to address in risk modeling
- # Generally not well quantified
- # Often not considered as possibilities
 - # Not managed

LPHC Events



Understand distribution of LPHC events and what drives them

- # Better address LPHC Events in risk molding and risk management
- # Can be made visible and part of the risk discussion

Key Point



Consequences of pipeline incidents follow a specific distribution

≠ Power Law or Pareto Distribution

Characterizing these distributions and their driving factors provides an important tool for assessing absolute risk and managing risk

Outline



Probability Distributions

Power Law Distributions

Modeling and Managing Risk

Probability Distributions

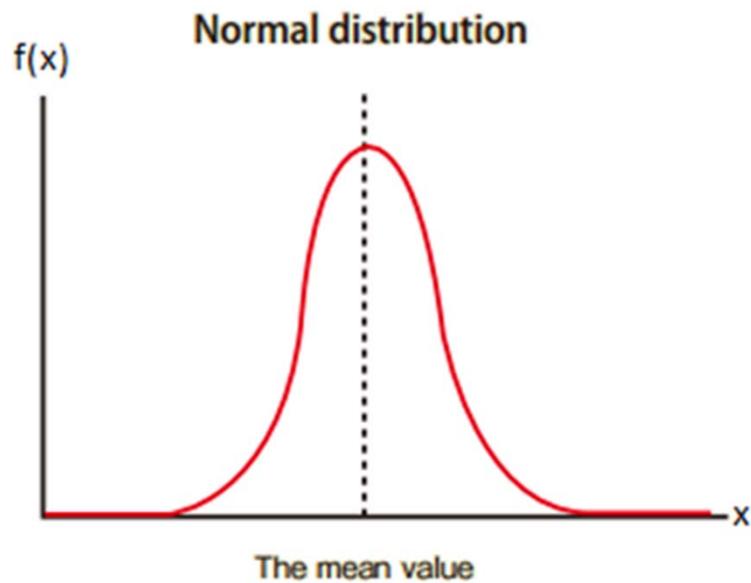


Events probabilistic in nature with the same underlying mechanisms will be part of a population with a specific distribution

Probability Distributions



Normal distribution is most common in everyday life



Power Law Distributions



Pipeline consequences follow a very specific distribution

- # Very different from the normal distribution
- # Similar to fire damage, earthquakes, terrorism, floods and power blackouts

Power Law Distributions



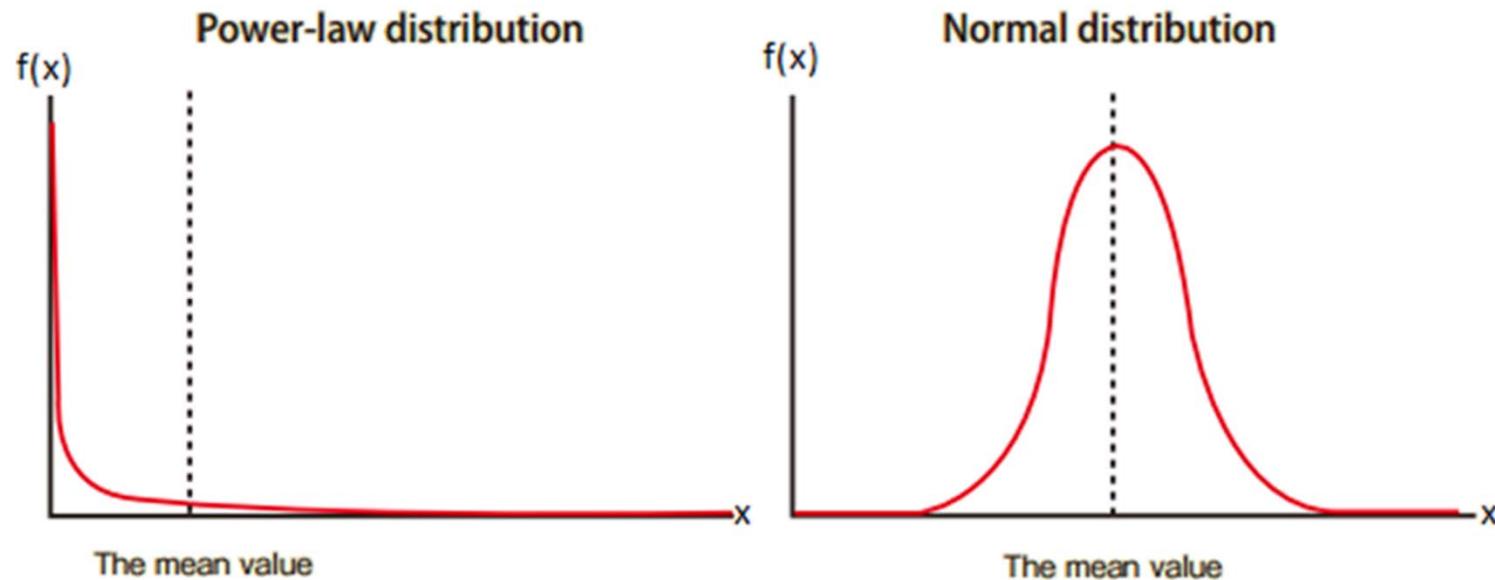
Power Law (Pareto-type) Distribution

- # Small number of incidents account for the majority of the overall damage and risk

Power Law Distributions



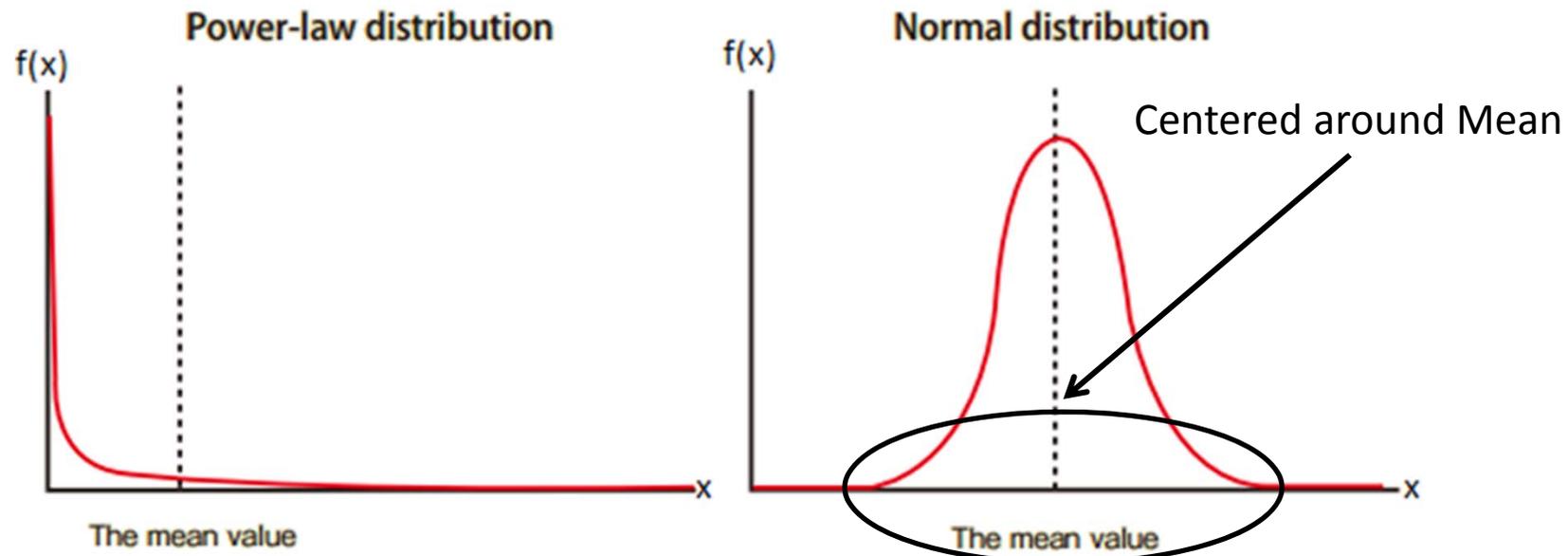
Power Law vs Normal Distributions



Power Law Distributions



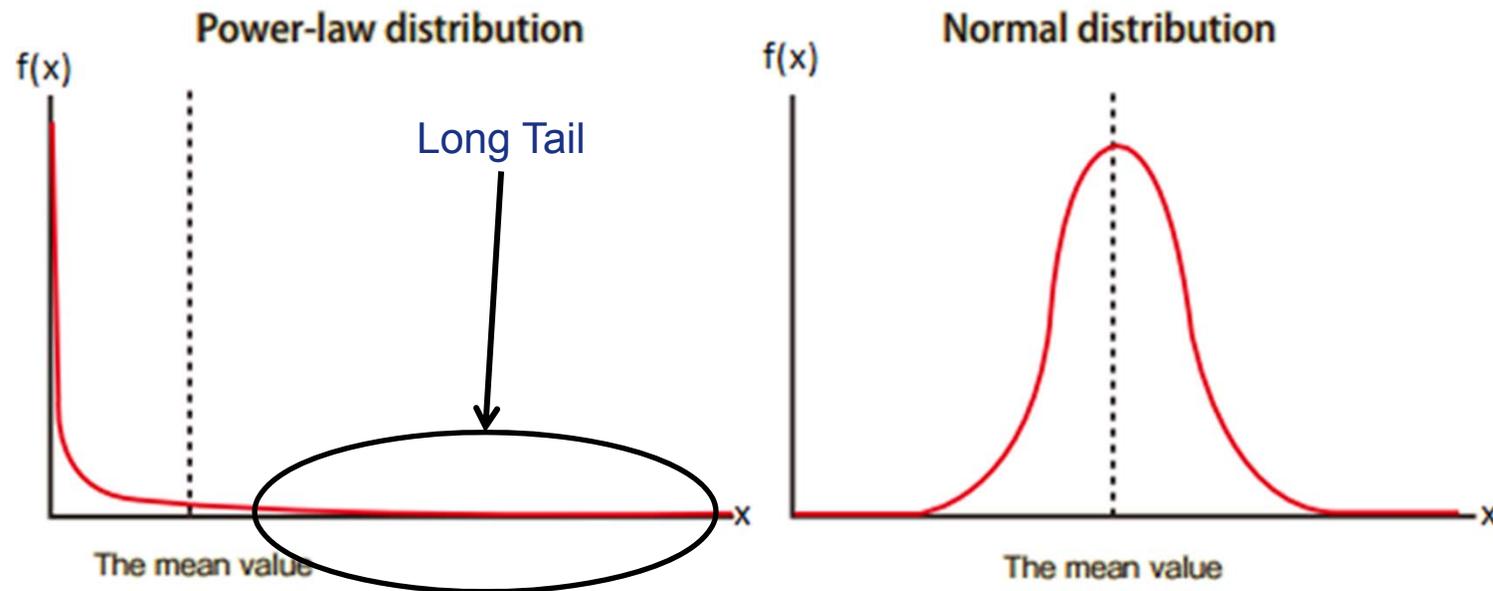
Power Law vs Normal Distributions



Power Law Distributions



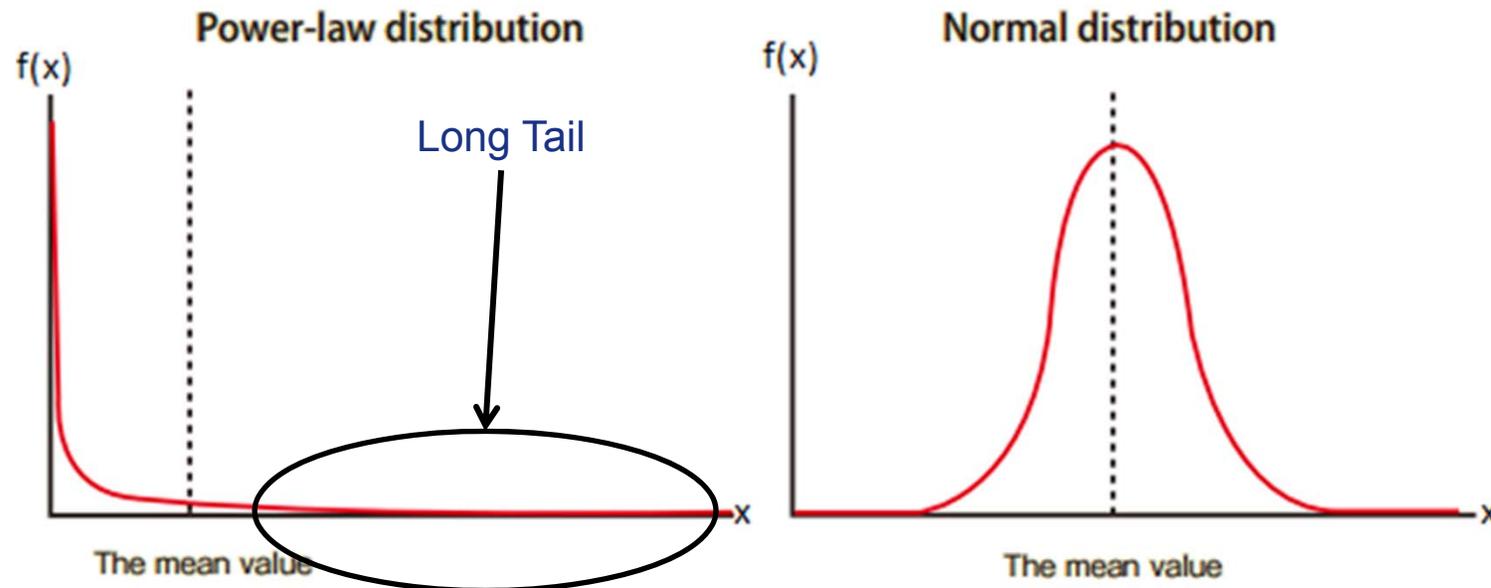
Power Law vs Normal Distributions



Power Law Distributions



Power Law vs Normal Distributions



Low Probability – High Consequence Events

Power Law Distributions



Power Law

$$P(X=x) = f(x) = C \cdot x^{-\alpha}$$

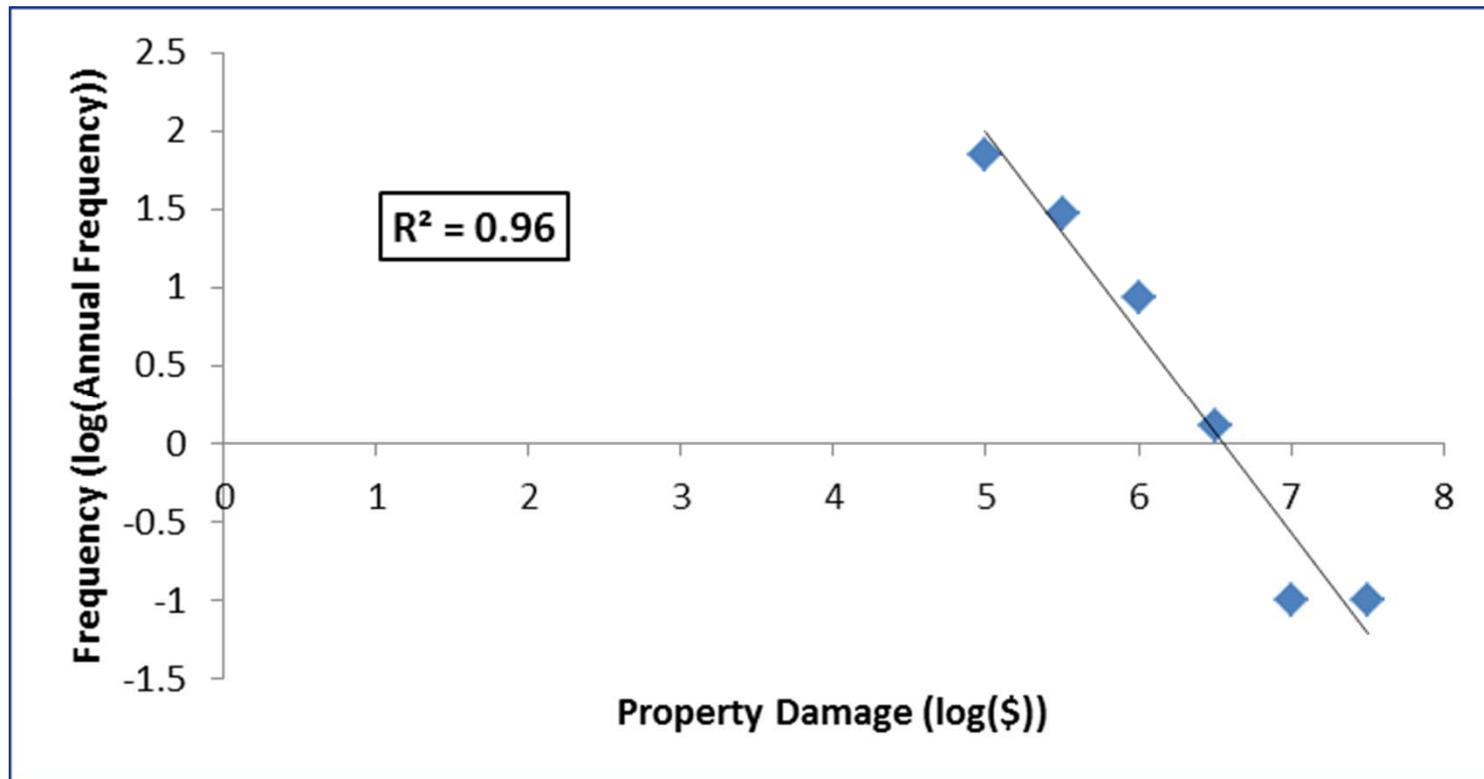
C = Normalizing Constant

α = Scaling Parameter, rate of decay

Power Law Distributions



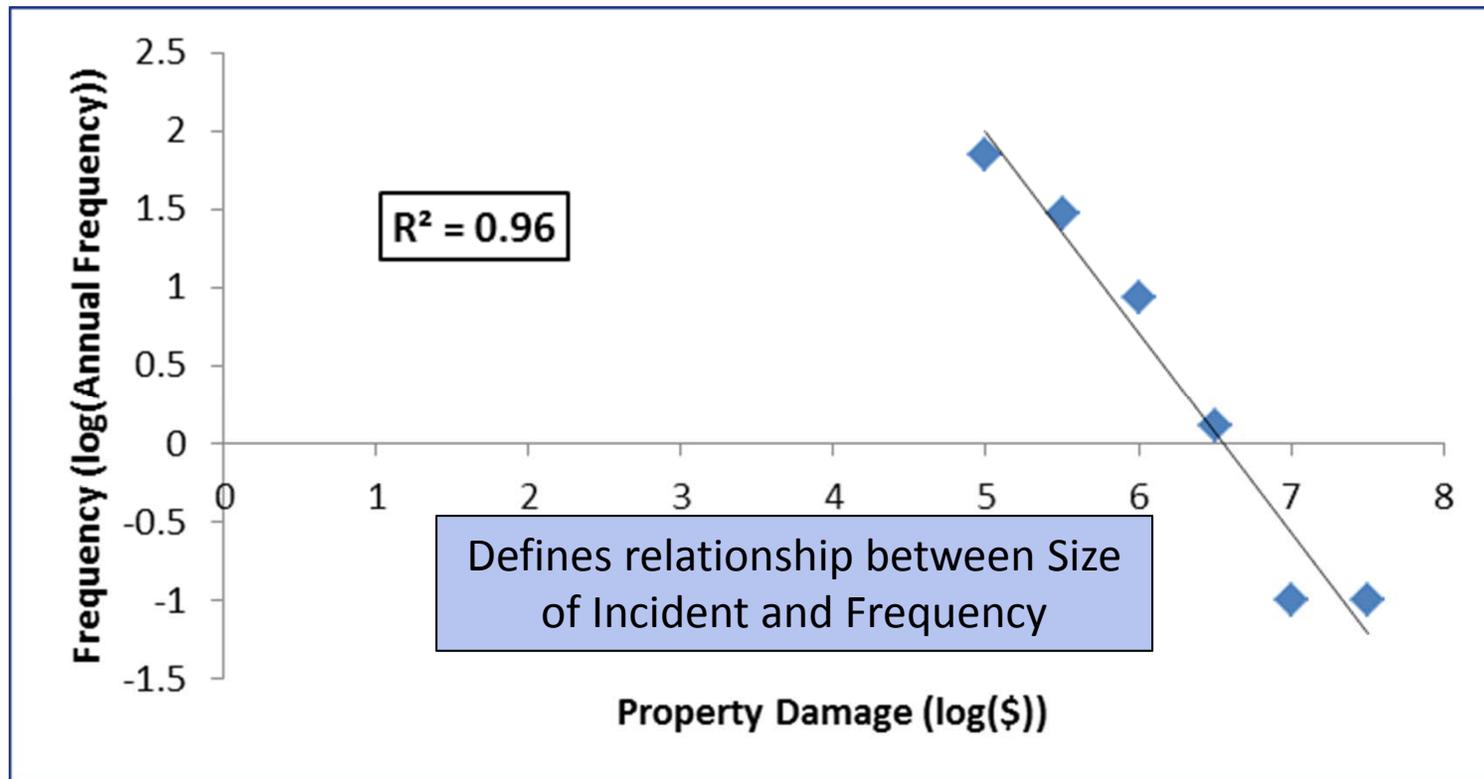
PHMSA Reported Gas Distribution Incidents



Power Law Distributions



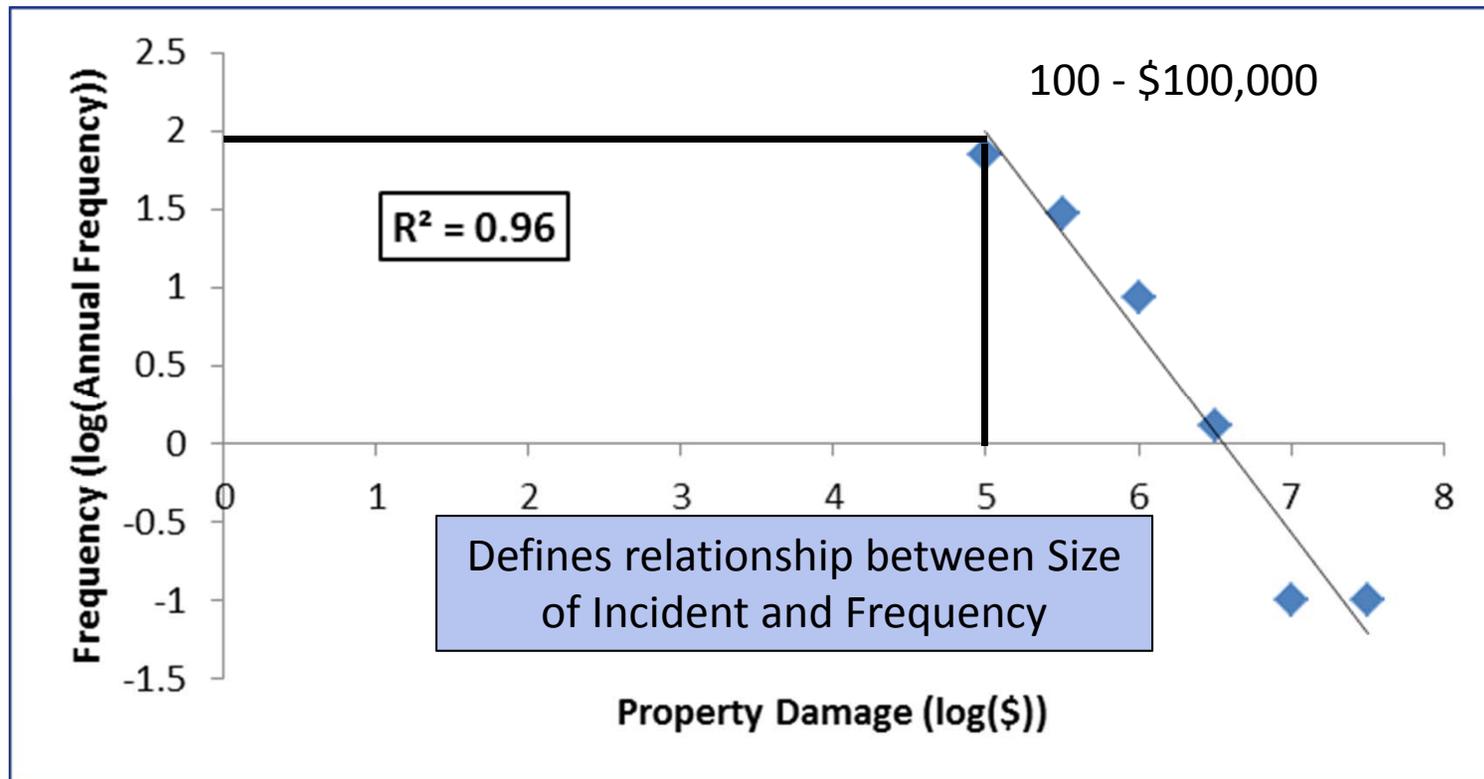
PHMSA Reported Gas Distribution Incidents



Power Law Distributions



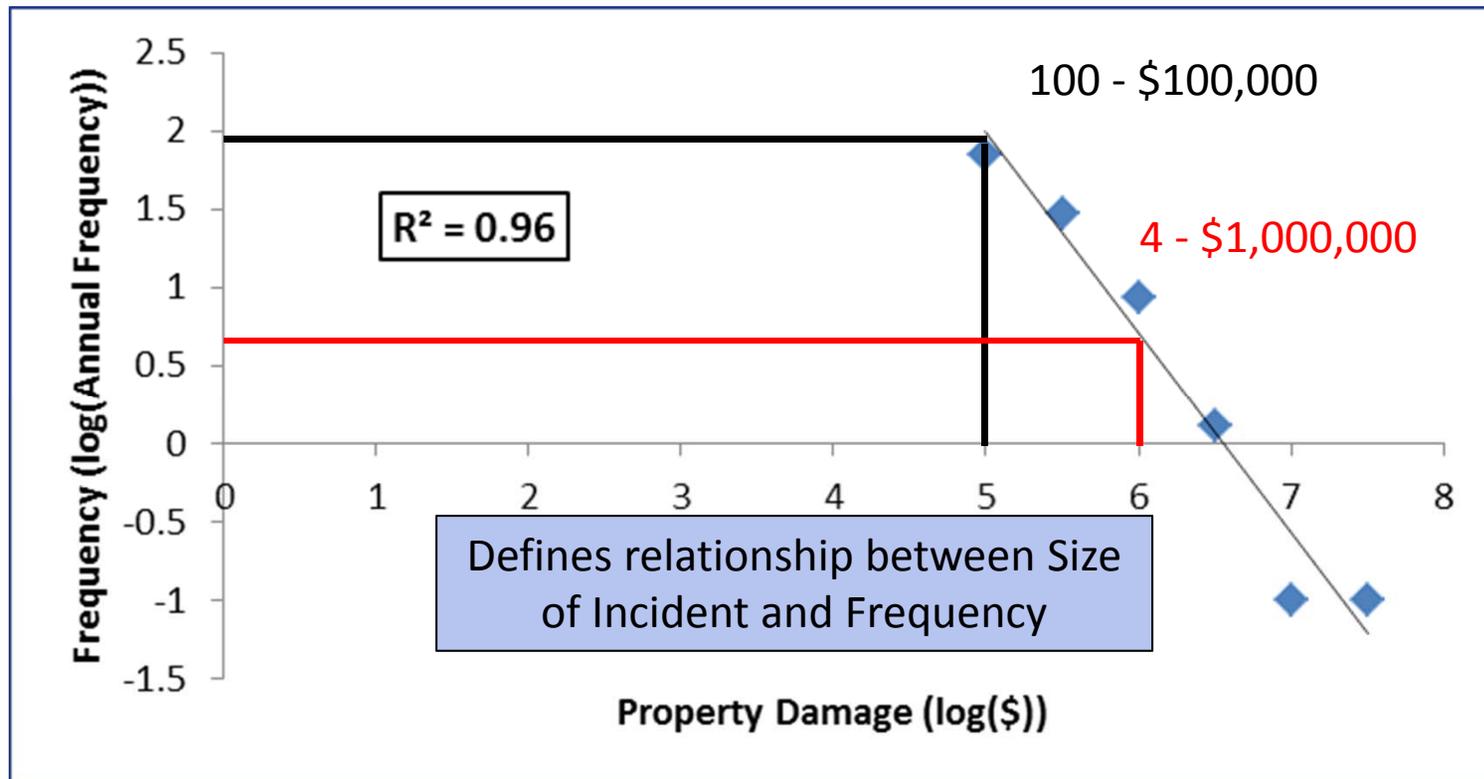
PHMSA Reported Gas Distribution Incidents



Power Law Distributions



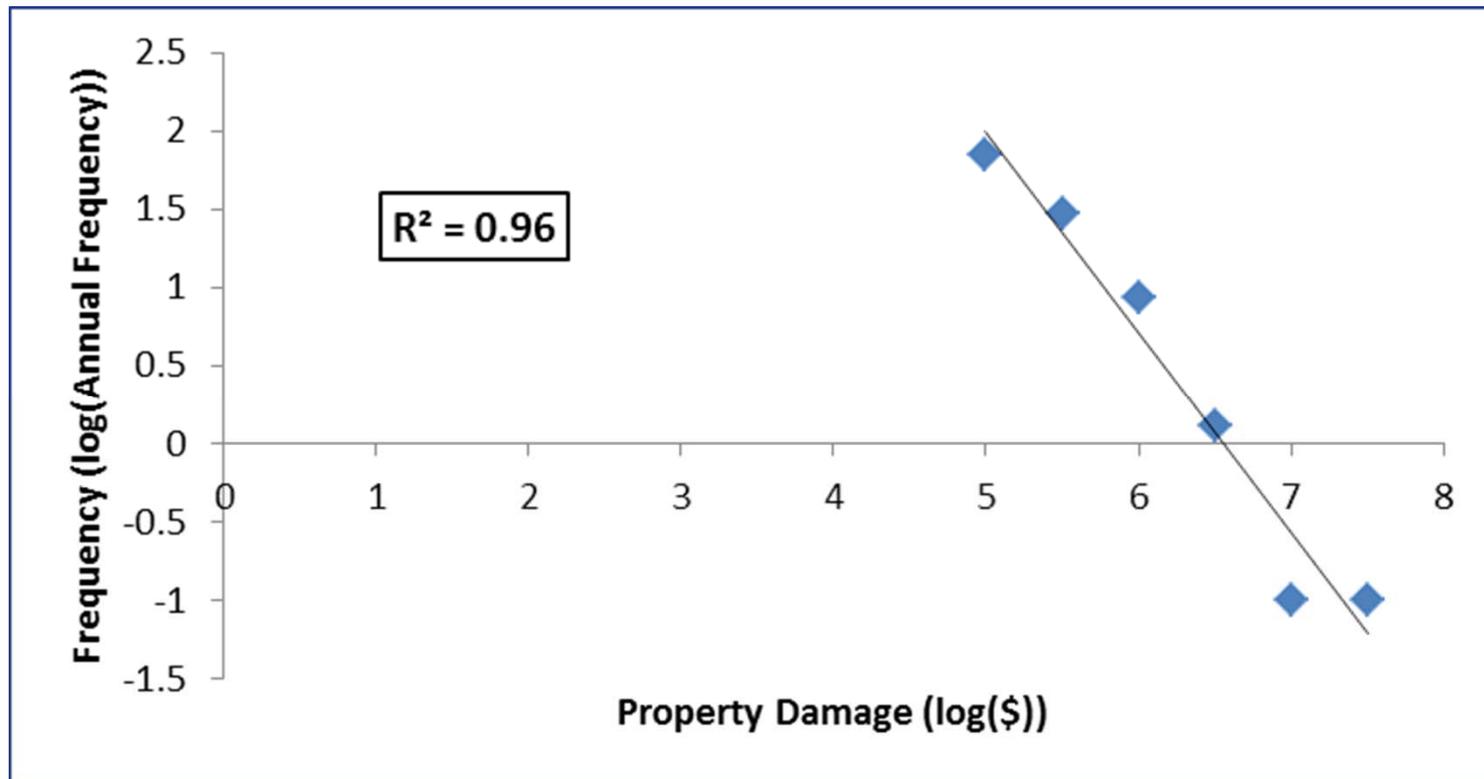
PHMSA Reported Gas Distribution Incidents



Power Law Distributions



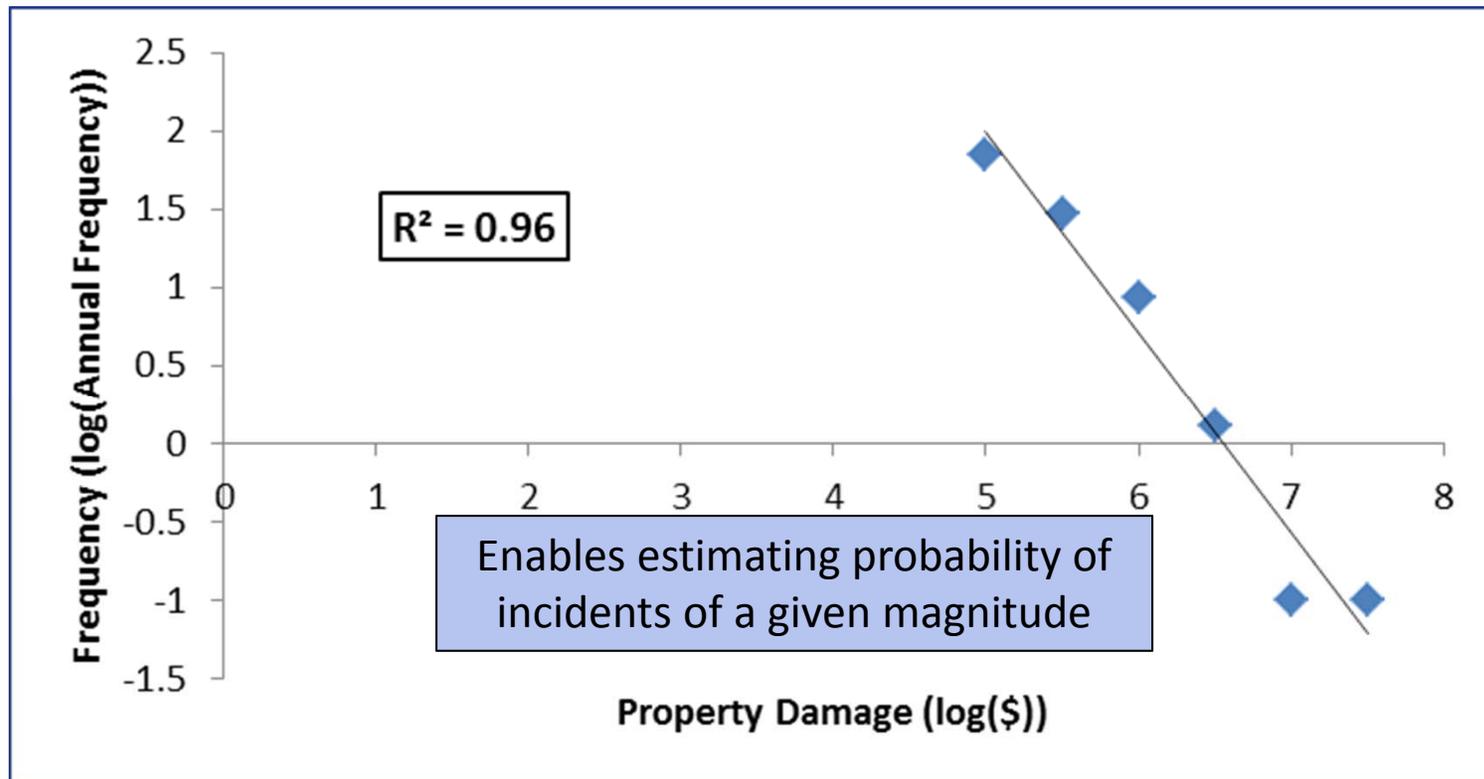
PHMSA Reported Gas Distribution Incidents



Power Law Distributions



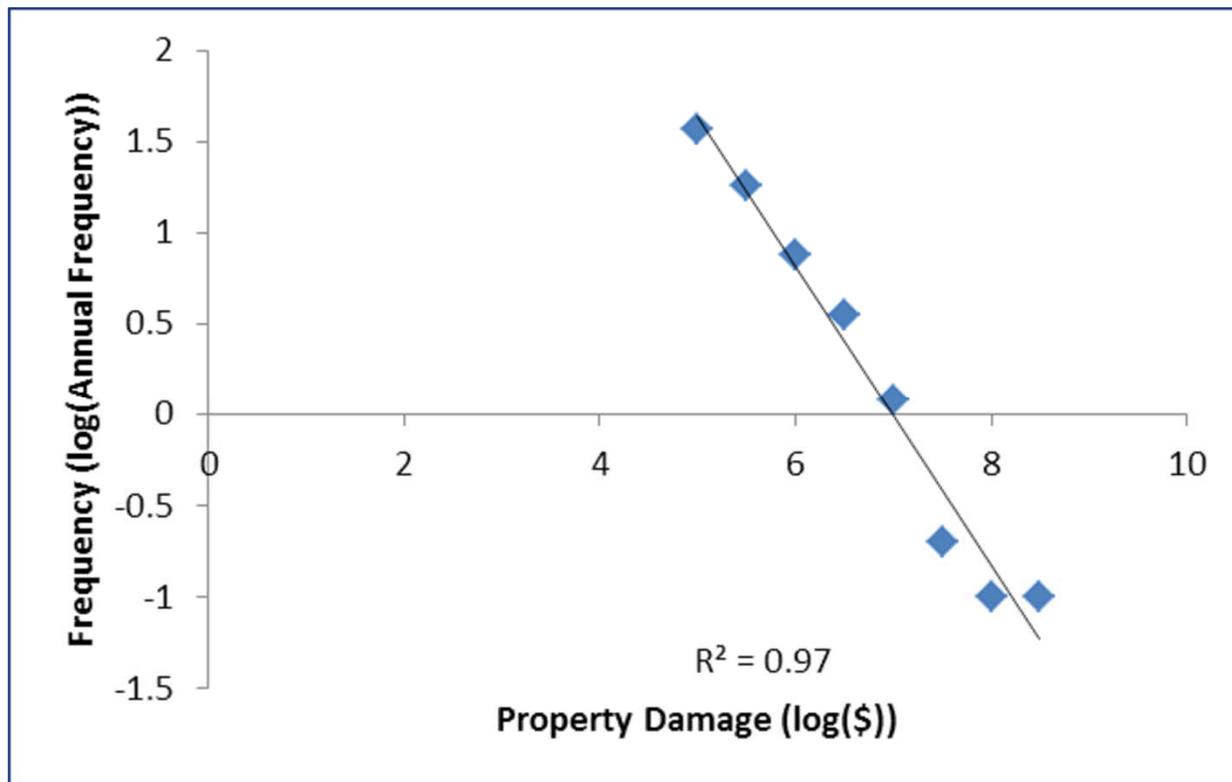
PHMSA Reported Gas Distribution Incidents



Power Law Distributions



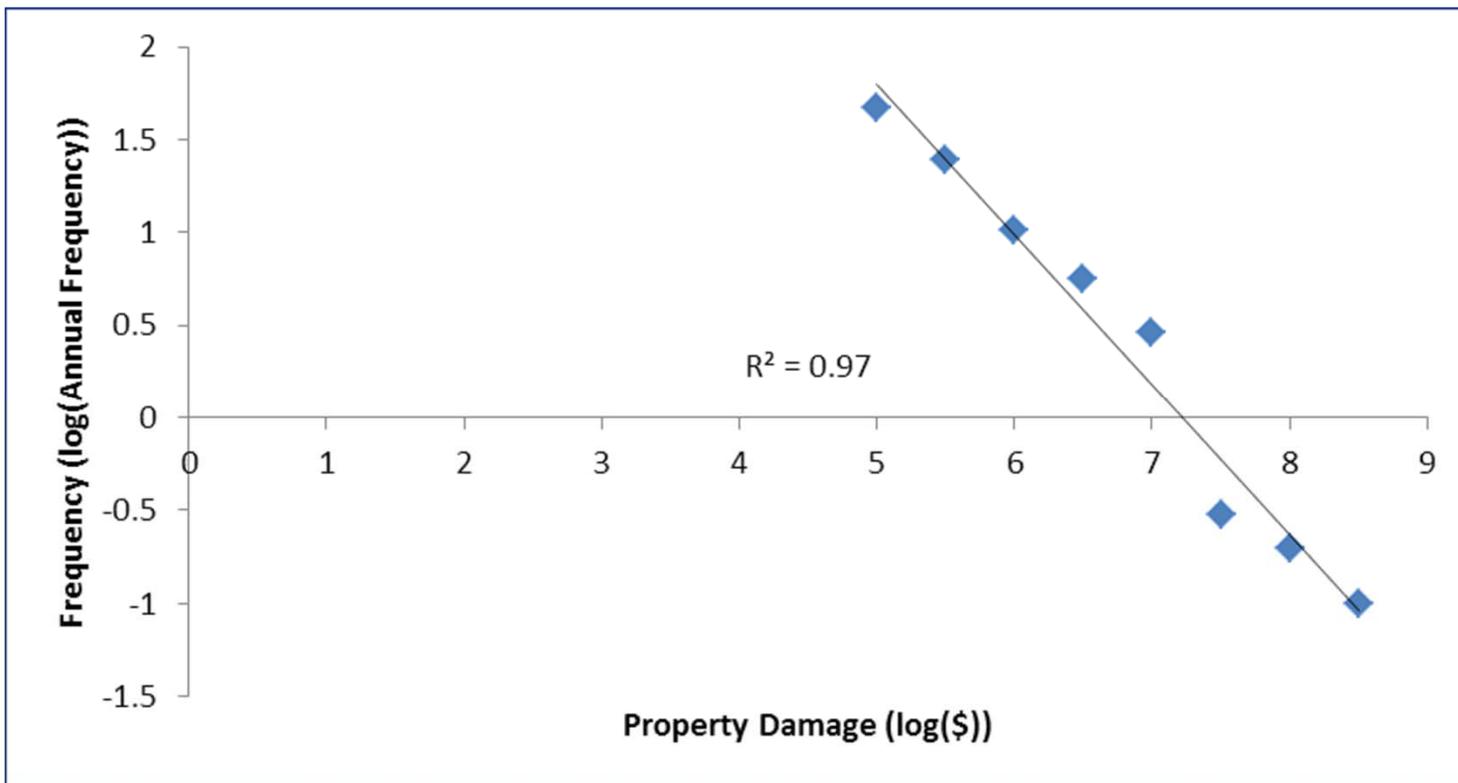
PHMSA Reported Gas Transmission Incidents



Power Law Distributions



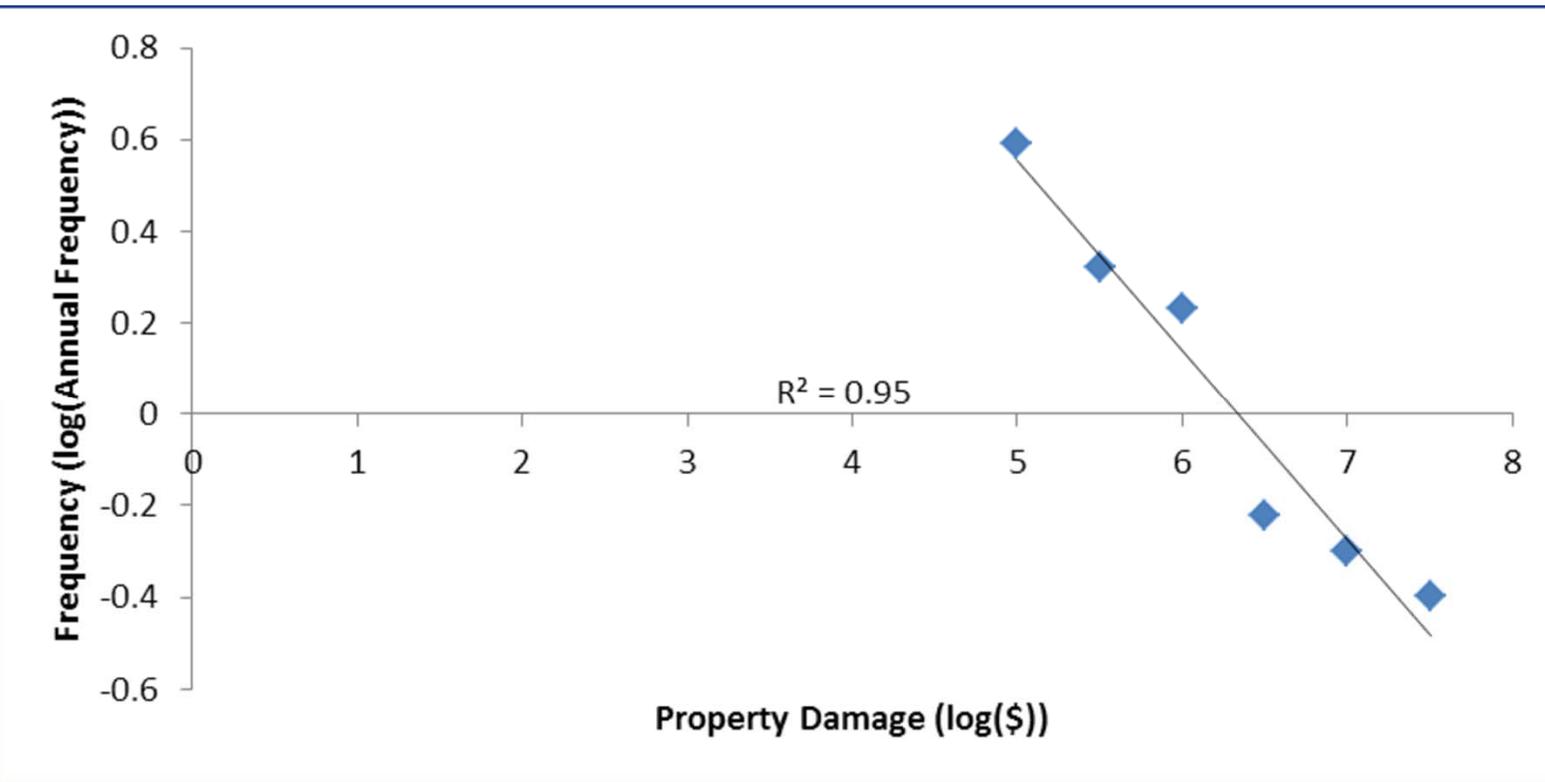
PHMSA Reported Hazardous Liquid Pipeline Incidents



Power Law Distributions



PHMSA Reported Gas Gathering Pipeline Incidents



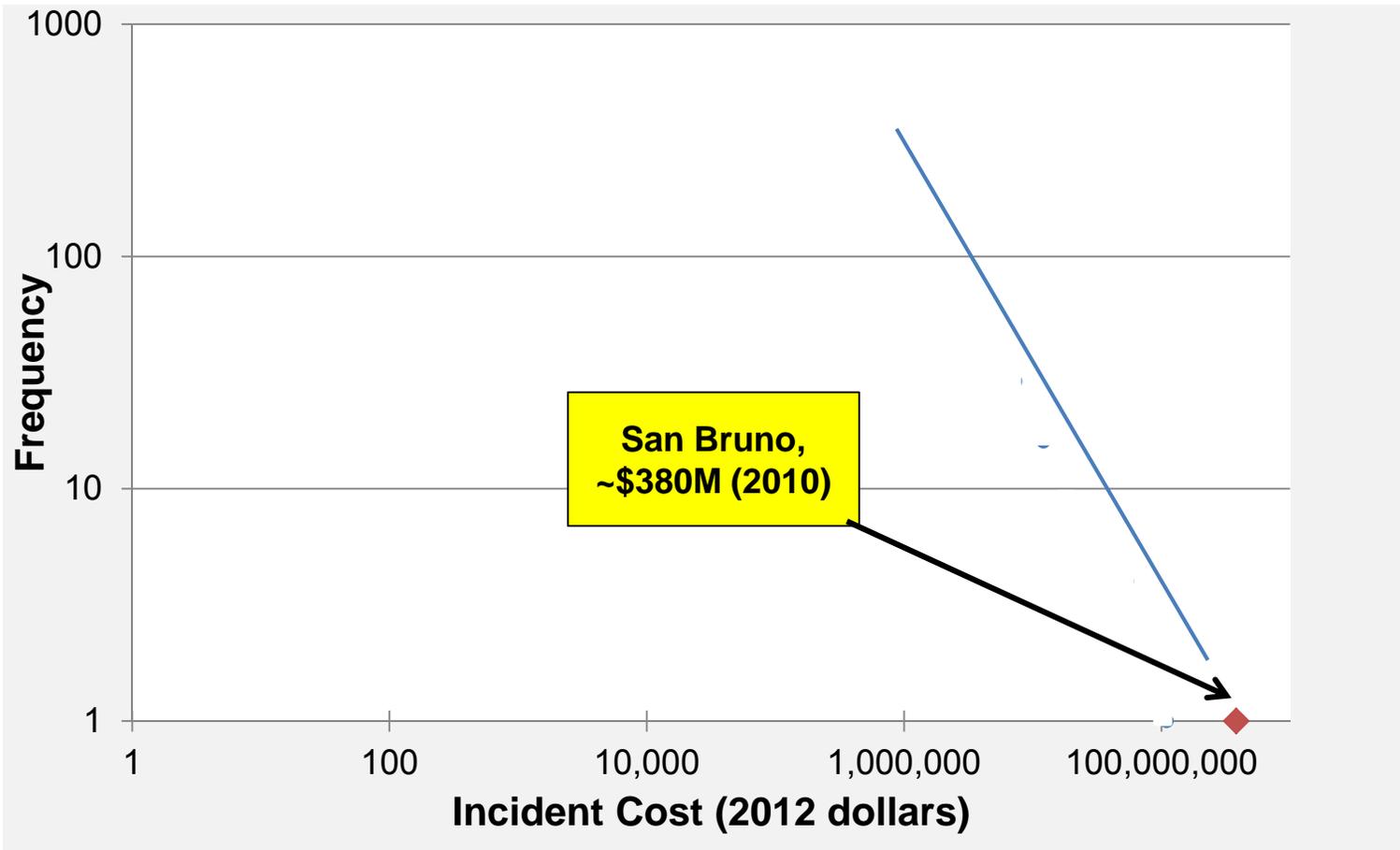
o What?



Bringing Low Probability – High Consequence events into the risk picture

How can we use this to address LPHC events?

Understanding Risk Range



Overall Risk Predictions



Can we use this to predict?

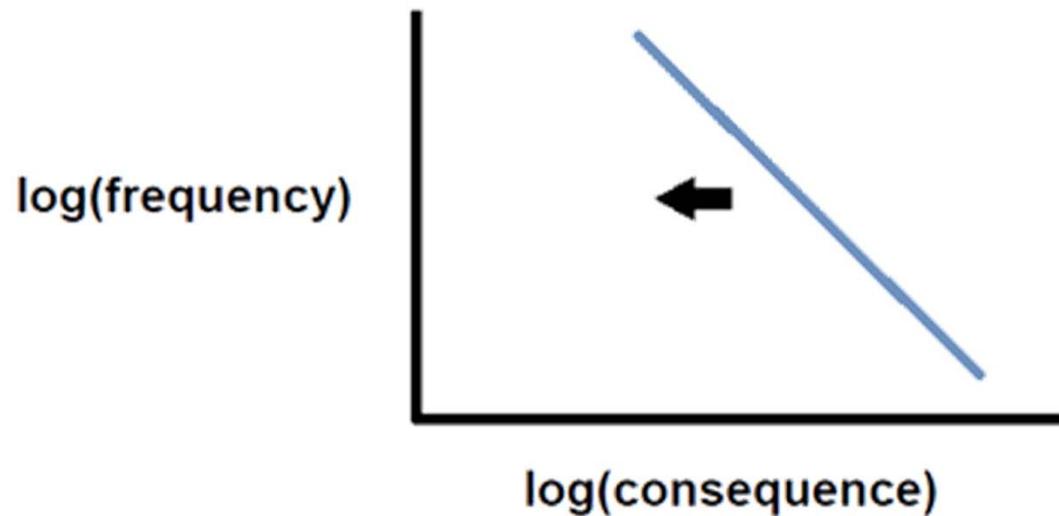
- # Incident of \$380 Million in property damage predicted to be a **once every 40 years event** in gas transmission based on historical performance
- # 96% probability of event of similar or greater magnitude in next 20 years
- # **Not** a highly improbable event

Risk Management Strategies



LPHC Events

// Move curve to the left

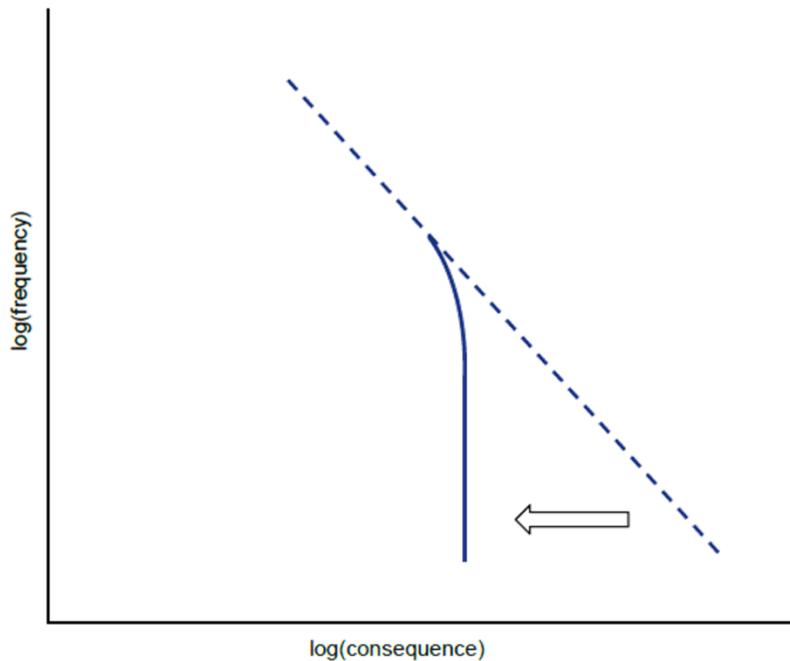


Risk Management Strategies



LPHC Events

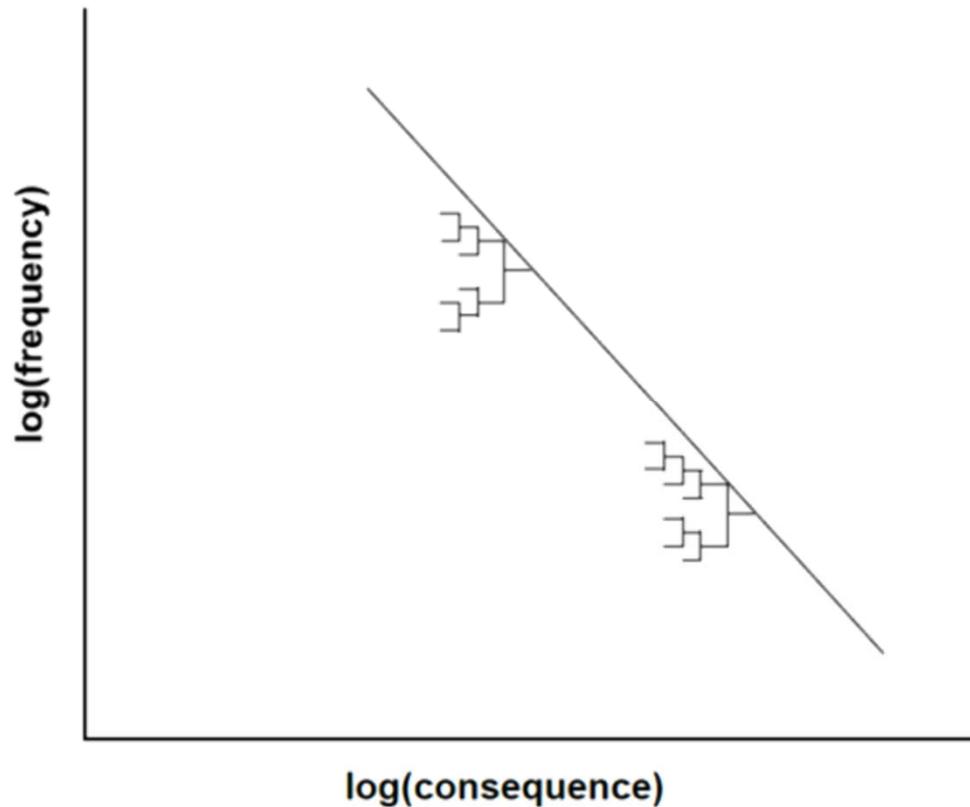
Specific focus on large risks



Risk Management Strategies



Connect Pipeline Event Trees to Power Law



Conclusion



Consequences of pipeline incidents are seen to follow Power Law distributions

- # Direct relationship between frequency of incidents and their size
- # LPHC events dominate risk picture
- # Observed in wide range of applications
 - # Gas distribution, gas transmission, hazardous liquids and gas gathering

Conclusion



Power Law Modeling

- # Provides overall picture of absolute risk based on specific system attributes
- # Provides check of mechanistic-probabilistic models
- # Provides means of optimizing risk mitigation based on understanding driving factors
- # Brings LPHC events into the risk picture