RIVERSIDE PUBLIC UTILITIES

Water Committee

BOARD OF PUBLIC UTILITIES - WATER COMMITTEE **DATE:** OCTOBER 13, 2021

SUBJECT: BUSINESS RISK EXPOSURE MODEL UPDATE

ISSUE:

Receive an update on the Business Risk Exposure Model.

RECOMMENDATION:

That the Board of Public Utilities Water Committee receive the update on the Business Risk Exposure Model.

BACKGROUND:

Riverside Public Utilities has over 990 miles of pipeline, of which, over 800 miles comprises distribution pipeline which delivers water from RPU's transmission mains, reservoirs, pump stations and pressure reducing stations to over 66,000 service connections within RPU's 74 square mile service area. With over 72 miles of RPU's pipelines 80 years or older, distribution infrastructure replacement remains one of the highest priorities for RPU to ensure reliable water service to our customers. Replacement dollars are limited and with much of RPU's pipelines at or beyond their service life, the need for a method to identify and prioritize segments for replacement is critical to ensure that CIP funds are used in a cost-effective and impactful manner. For the past 10 years, RPU has been utilizing a data-driven, risk-based model to identify high-risk segments of distribution pipeline for replacement. This model has proven to be an effective tool and has helped to mitigate the impact of aging infrastructure on RPU's customers.

DISCUSSION:

In 2008, multiyear rate increases for Water were approved by the City Council. The rate case identified a need for increased replacement of water distribution main. The selection methodology at that time for identifying water mains for replacement entailed visual selection of mains from printed maps depicting leaks and consideration of pipeline age. Due to the lack of a set process and the manual nature of visual selection, the selection of pipes was not reproducible, susceptible to human biases, and lacked transparency. During that time, the concept of advanced asset management (AAM) was beginning to be adopted by the water and wastewater industry in the United States. At the core of the AAM program was the implementation of a data driven, triple-bottom-line, risk-based capital and maintenance approach to planning for water infrastructure. The key emphasis of the AAM program is to make smart asset management decisions such that the risk of operating the asset is reduced while level of service provided by the assets stays the same or increases.

Utilizing the working experience of a staff member who implemented an AAM program at Orange County Sanitation District, Water Engineering developed a pipeline selection methodology that utilized AAM principles and informally began using it to make more informed decisions in the selection of pipelines for replacement.

At the heart of the methodology lies the basic risk management equation that risk posed by an event equals the likelihood of the event happening times the consequence of the event. This equation has been adopted for pipeline failure as 'Business Risk Exposure' (BRE) equals Probability of Failure (PoF) multiplied by the Consequence of Failure (CoF). Written as an equation, this would be expressed as $BRE = PoF \times CoF$. The adopted terminology has its origins in the asset management framework developed by the Water Research Foundation for the United States Water and Wastewater Industry based on the AAM principles written in the International Infrastructure Asset Management Manual.

The first step in the BRE model is to identify various risks posed by the failure of distribution pipelines to the bottom line of the water utility. The bottom line is not purely economic, and is a combination of three factors: economic factors, environmental factors, and social factors. The concept of Triple Bottle Line (TBL) accounting originated in the 1990s and is slowly gaining wider acceptance. In fact, the City Council's recent adoption of cross-cutting threads could be considered an analogous adoption of the TBL concept. During 2008 to 2011, Water Engineering staff had internally identified the risk factors and was using the methodology to select pipelines for replacement. During this period the use of the BRE model gained more acceptance. In 2011, Water Engineering staff conducted internal risk management workshops and interviews to identify a more comprehensive set of risk factors and assign weightings to each risk factor.

The risk factors, their justifications, and weightings are summarized in the table below.

Table 1: Consequence of Failure (CoF) Risk Factors and Weightings

Risk Factor	Justification	Weighting
Traffic	Impact to traffic flows, businesses, and the community. Traffic is used as a proxy for economic activity	Max 0.45
Un-encased Railroad Crossing	Leak could jeopardize integrity of railroad	0.4
Within Median	Difficult to repair, long repair times	0.15
Proximity to Structure	Chances of damage to private property is high	0.15
Undersized for Fire Flow	Poses risk due to deficient fire flow	Max 0.3
Within Sidewalk	Difficult to repair, long repair times	0.1

The listed risk factors were calculated for approximately 40,000 pipeline segments in the Geographic Information System (GIS) database and each segment given individual CoF values.

The probability of failure (PoF) was calculated for each pipe segment based on its age and leak history. An S-Curve similar to the Weibull cumulative probability curve was used to assign PoF values for the age component. (Weibull probability curves are often used to model binary outcomes such as equipment failures in reliability engineering, outage forecasting in electrical engineering, survival analysis in life sciences, etc.) To account for the autoregressive nature of leaks, i.e., the fact that once a pipe has experienced a leak, it is more likely to leak in the near future than a pipe with no leaks, PoF was increased based on the number of leaks on a pipe. Staff also tried to correlate material type, soil corrosivity and leaks, but statistically significant correlations were not found at that time. It is likely that the lack of good quality of data for soil types was responsible for the lack of correlations.

BRE scores were then calculated for each pipe segment by multiplying CoF and PoF values. A prioritized list with pipeline segments in descending order of BRE score was used to select pipes for replacement. Staff believes that since 2011, RPU has benefitted from the BRE model in multiple ways. Some of the key benefits include:

- ***Transparent and justifiable***: The BRE model is built from the ground up such that each factor is calculated at the pipe segment level. Each pipe replacement project is justifiable based on the risk it poses to the system.

- ***Fewer leaks***: Due to the fact that the BRE model ranks pipes higher that have more leaks, the number of leaks on distribution mains have reduced since the use of the BRE model.

- ***Balancing of competing needs***: The BRE model also prioritizes certain risk factors such as pipelines without a protective casing crossing under a railroad track; such pipelines are scored higher for replacement. These risk factors were overlooked prior to the adoption of the BRE model.

- ***Forward looking***: The use of a risk-based, data-driven model that accounts for non-economic impacts to the community was one of the earliest such implementations in the water industry. After a decade, this methodology is more widely used in the water industry. Staff has received acknowledgements from industry experts on RPU's use of the BRE model.

Future Improvements

Since 2011, there have been minor changes in utilizing the GIS system (versus excel spreadsheets) to calculate CoFs and PoFs, but no major changes have been made to the BRE model. Staff sees a few areas of improvement to further enhance the model. A few key changes that staff is exploring include the following:

- ***Improved Forecasting***: Water Engineering staff's previous effort to correlate leaks and soil chemistry did not yield meaningful results due to a lack proper data quality and the lack of access to advanced statistical modeling software such as SAS. However, staff now has access to SAS that can run more specialized types of regression analyses such as logistic regression with large number of variables. Staff plans to map the soil chemistry data from geotechnical reports and assign corrosivity values to each pipe using kriging (a spatial interpolation method). Staff is likely to also use logistic regression in place of linear regression and is optimistic that above mentioned methods will substantially enhance the forecasting of leaks.

- ***Normalization of probability values***: Currently the PoF values can exceed 1 for a pipeline that has had more than 3 or 4 leaks. Staff plans to normalize PoF values on a scale of 0 to 1.

- ***Normalization of BRE scores on linear length of pipe***: Currently, the CoF and PoF values do not account for the length of the pipe segment. As a result, this skewed BRE scores toward longer lengths of pipes. Staff plans to normalize CoF and PoF values which would thus normalize BRE scores for the linear length of pipe.

- ***Project Selection Tool***: Currently, the project selection process is dictated by the highest BRE score pipe in the system. Other nearby pipelines are manually added to the project to take into account better economies of scale in the scope of construction. Staff plans to build a GIS tool to automate the process that not only selects the other pipes but optimizes the selection to reduce the maximum amount of risk per dollar of construction cost.

- ***Implementation of BRE model to other assets***: Currently the BRE model is only applied to distribution mains. Staff plans to extend the application of the model to maintenance decision making for booster stations in the near future in form of Reliability Centered Maintenance (RCM).

Reliability Centered Maintenance (RCM)
Assets that have moving part require regular maintenance and upkeep. RPU owns and operates 44 booster stations and 144 pumps across its service area. The Water Operations Division regularly performs preventative maintenance with an aim to reduce pump failures. With implementation of RCM, RPU can optimize the use of its limited maintenance budget such that preventative maintenance is customized for each pump and booster station based on its risk of failure and condition rating. This type of preventative maintenance is called predictive maintenance. The key steps in implementing RCM as follow:

- Identify risk factors and assign CoF ratings to each pump.
- Identify failure-modes for pumps
- Select the most common failure modes using the pareto rule
- Perform condition assessment and assign PoF rating to each pump
- Develop a predictive maintenance plan customized for each pump

The expected outcome of a future implementation of RCM is a reduction in high-impact failures overtime.

STRATEGIC PLAN ALIGNMENT:

CIP Project coordination supports the City Council Strategic Plan 2025 Priorities and Goals for:

Environmental Stewardship
Goal 4.2. Sustainably manage local water resources to maximize reliability and advance water reuse to ensure safe, reliable and affordable water to our community.

High Performing Government:
Goal 5.2. Utilize technology, data, and process improvement strategies to increase efficiencies, guide decision making, and improve access to and delivery of financially sustainable City services.

Infrastructure, Mobility & Connectivity:
Goal 6.2. Maintain, protect and improve assets and infrastructure within the City's built environment to ensure and enhance reliability, resiliency, sustainability, and facilitate connectivity.

Goal 6.5. Incorporate smart city strategies into the planning and development of local infrastructure projects.

Recycled water site conversions align with the City Council's Strategic Plan 2025 Cross-Cutting Thread themes:

1. **Community Trust** – Development and use of the BRE Model ensures that there is a transparency in the identification and selection process of high priority pipelines to be replaced utilizing limited CIP resources.

2. **Equity** – The use of a BRE model ensures that main replacement dollars are utilized where there is the greatest need and funding can address the weakest, most vulnerable segments of the distribution system.

3. **Fiscal Responsibility** – Utilization of a model helps to maximize the use of limited CIP funding to address the areas of greatest system need, and those areas that would have the greatest consequence of failure. In addition, proactive main replacement reduces the loss of water from unanticipated main breaks along with any associated damage to public and private property.

4. **Innovation** – The use of a model-based approach to main replacement selection is an innovative approach that was developed in-house by RPU staff nearly ten years ago. It has been proven to be an effective risk-based methodology which has helped RPU to maximize the impact of its main replacement funds.

5. **Sustainability & Resiliency** – Infrastructure renewal helps to maintain the reliability and a high level of service to RPU customers; replacing the right mains at the right time helps to mitigate against lost water, damages to property and infrastructure, and ensure that staff and field labor resources are conserved.

FISCAL IMPACT:

There is no fiscal impact for the update on the Business Risk Exposure Model.

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Attachment: Presentation