BEYOND RISK: A COMMUNITY RETURN ON INVESTMENT APPROACH TO PIPE REHABILITATION

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ABSTRACT

American water resource agencies are increasingly turning to risk analysis to prioritize replacement and rehabilitation (R&R) activities, especially for distribution and collection system piping. Risk is commonly evaluated using a two-dimensional matrix, and pipes scoring highest in both dimensions (failure likelihood and failure consequence) are scheduled for attention first.

This approach is an improvement over traditional methods but still has two shortcomings: It ignores the cost of the rehabilitation as compared with its benefits, and it does not help utilities identify those activities that are worth undertaking from a community value point of view—and those that are not. A number of agencies, including the Orange County Sanitation District (OCSD), are developing more comprehensive approaches to address both of these shortcomings and to identify which R&R activities are truly in the public's interest.

KEYWORDS

Pipe rehabilitation, economic useful life, return on investment, community value, asset management.

BACKGROUND

OCSD is a large regional treatment agency in Orange County, California. It serves 22 cities, two special districts, and the portions of the County of Orange with a total population of 2.4 million within a 470-square-mile area. It treats an average daily flow of 243 million gallons and produces over ten million gallons daily of reclaimed water. Among its major assets are:

- Two large treatment plants
- 17 pumping stations of various capacities
- 620 miles of both large- and small-diameter pipe
- Two ocean outfalls, one of which is five miles long.

OCSD has been developing an asset management program for several years. The work described in this paper was influenced by that program and by OCSD's continuing efforts to provide the best value for the communities it serves.

OCSD's service area is shown in Figure 1 on the following page.

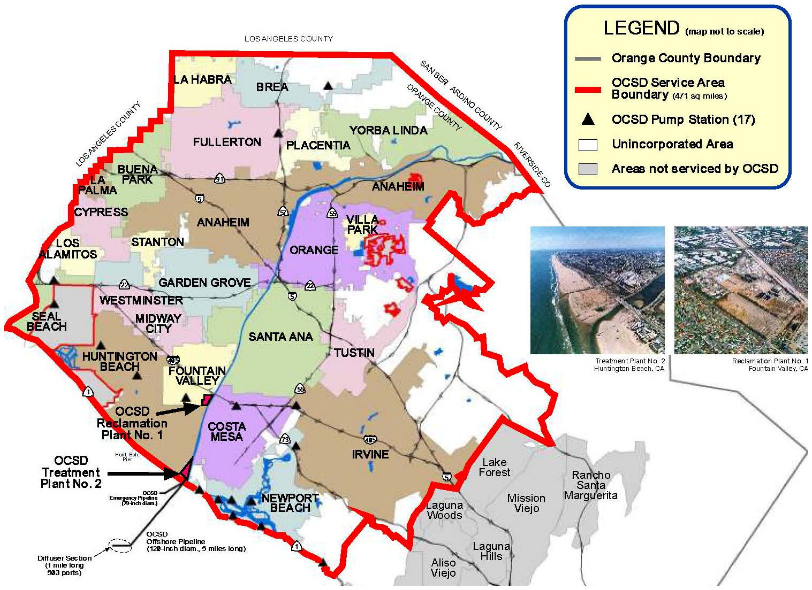

Figure 1: Service area of the Orange County Sanitation District

OCSD was asked by its local regulator, the Santa Ana Regional Water Quality Control Board, to help its member agencies develop a more structured and uniform approach to pipe inspection and rehabilitation. The concepts and tools described in this paper grew out of OCSD's work with its member agencies.

BASIC CONCEPTS IN RISK

The replacement or rehabilitation of a sewer collection pipe is usually undertaken to address perceived risk. A pipe in poor condition, while perhaps still functioning properly, is at risk of structural failure. Such a failure may result in a sanitary sewer overflow leading to regulatory action, excessive costs of emergency response, inconvenience to the community, and a hazard to public health.

The risk is commonly analyzed using a "risk matrix" that considers the probability and consequence of failure, each derived from a number of parameters. A typical risk matrix is shown in Figure 2, below.

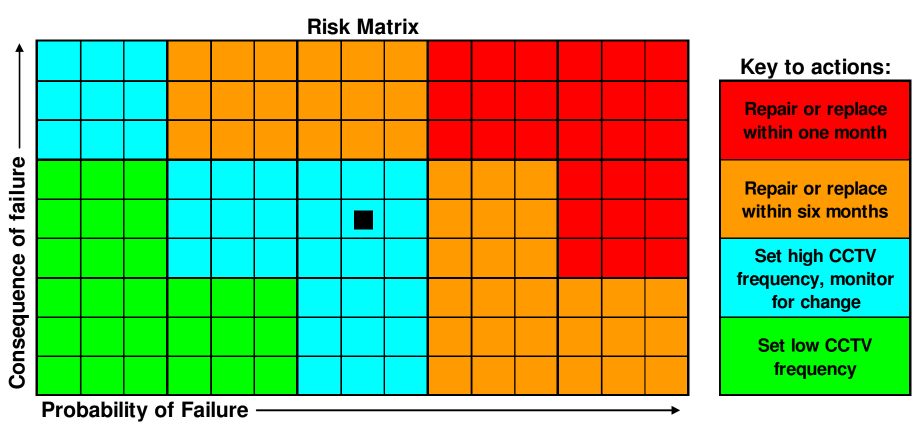

Figure 2: Typical risk analysis matrix

While there is obviously some subjectivity in play here, the matrix approach seems to give a clear and easy-to-understand way of prioritizing pipe work. The message is, "Set a higher priority on those pipes that have the highest probabilities and consequences of failure." This certainly *sounds* right. But is it?

In fact, the matrix when used alone leads to a prioritization of work based solely on the magnitude of risk avoided. But that "benefit" is only one side of the benefit/cost analysis. It does not consider the *cost* of the work. For example, consider two pipes, one with a slightly higher magnitude of risk than the second but with a rehabilitation cost twice the second. Addressing the slightly less "risky" pipe is obviously the best use of public funds, but the matrix alone suggests spending available funds on the first pipe, even though that is of less value because it requires far more funds for only a small increment of benefit.[1]

The solution is obviously to consider both benefits and costs, so that the work can be prioritized according the value delivered, not merely the risk avoided.

BENEFITS AND COSTS OF PIPE REHABILITATION

As is often found in asset management, a rigorous consideration of the benefits and costs of proposed actions leads to improved clarity in making decisions.[2] Both the benefits and costs of pipe rehabilitation are discussed below.

Benefits of rehabilitation—The primary benefit of pipe rehabilitation is the deferral of failure. If a pipe is replaced, the deferral may be 80 years or more (the expected life of the new pipe). If a pipe is relined, the deferral may be on the order of 50 years. If spot repairs are feasible, the deferral may be shorter, perhaps in the neighborhood of twenty years.

Figure 3, below, is a graphical example of risk deferral brought about by relining a failing pipe where the mean failure year is deferred about 55 years. The expected failures, both current and after sliplining, are expressed as distributions around the mean failure years. This is because of the uncertainties concerning actual years of failure that always exist. Note that the areas under the two curves are always the same, equal to the total cost of pipe failure, although the height and width of the distributions may be very different.

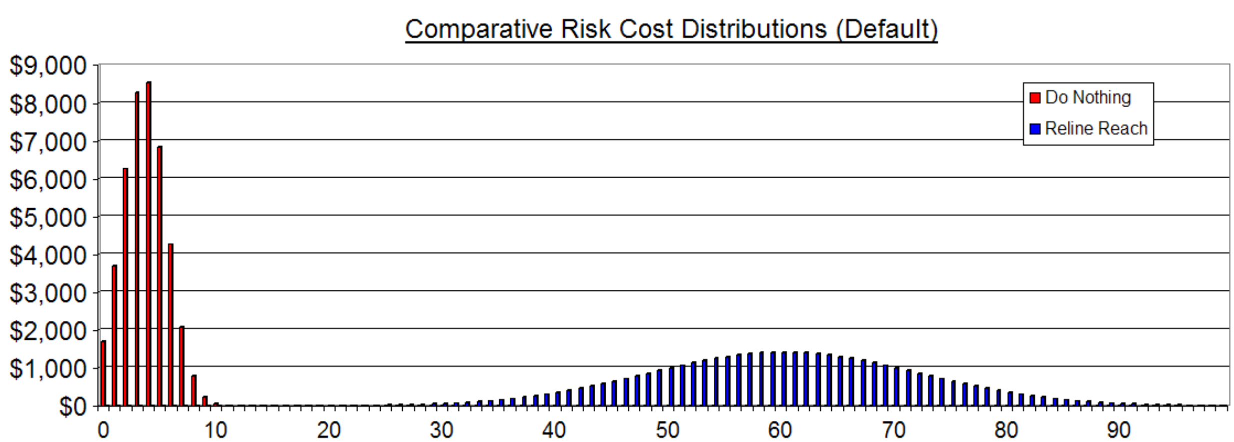

Figure 3: Distributed pipe failure costs, without and with rehabilitation

As can be seen from the graph, the cost of failure is expressed in dollars. This is because the probabilities of failure have been converted to risk costs. This allows the measurement of the benefit of a pipe rehabilitation in dollars:

> *"The benefit of a pipe rehabilitation is the difference between the present value of failure costs if no action is taken and the present value of failure costs if the pipe is rehabilitated."*

Also note that the costs of failure, in keeping with triple-bottom-line analysis, include not only the direct costs of responding to failure but other financial, social, and environmental costs as well.[3]

Costs of pipe rehabilitation—The costs associated with pipe rehabilitation are easier to address. They are simply the direct costs of addressing the problem pipe, typically through replacement, re-lining or similar technology, or one or more spot repairs.

Benefit/cost analysis—The form of the benefit/cost analysis is simply the comparison of the benefit of the rehabilitation as defined above with the cost of the rehabilitation. If the present values involved in calculating the benefit use a discount rate equal to the cost of money, then any pipe rehabilitation with a benefit/cost ratio greater than one will be in the interest of the community. Otherwise, it will not.

Through this type of analysis, two things are achieved:

1. By considering the cost as well as the benefit of a rehabilitation action, better value is assured than if the benefit alone (risk deferral) is used in the decision.

2. By quantifying both the cost and the benefit of the rehabilitation, return on investment analysis makes it immediately apparent whether the rehabilitation should be undertaken at all.

The second point is of crucial importance. As an example, the CCTV program at one large California sewer collection agency had been generating numerous pipe rehabilitation work orders for several years, most of which were not undertaken due to lack of funds. Management directed that an economic model be prepared so that the type of analysis described in this paper could be applied to the work orders. As a result of the analysis, many of the unfunded work orders were found to not meet community value standards and, accordingly, were removed from immediate consideration. The pipe R&R program of this utility suddenly became far more rational—and affordable.

PISCES AND PIPE REHABILITATION

OCSD has incorporated these principles into a simple software tool named PISCES for evaluation by its member agencies. To use PISCES, the analyst first selects the type of defect, each of which is linked to a Pipeline Assessment and Certification (PACP) code. The defect selection screen is shown on the next page.

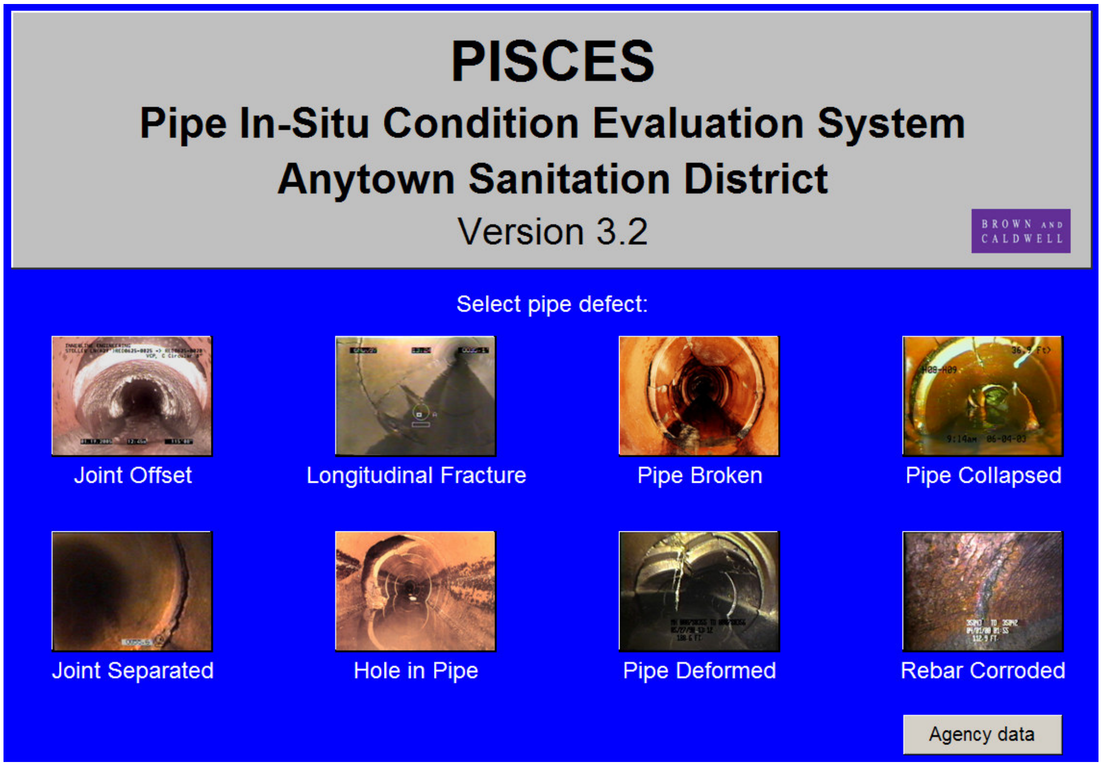

Figure 4: PISCES defect selection screen

Specific information concerning the pipe, in this case with a PACP code of "BP" or "broken pipe," is entered on the main entry screen.

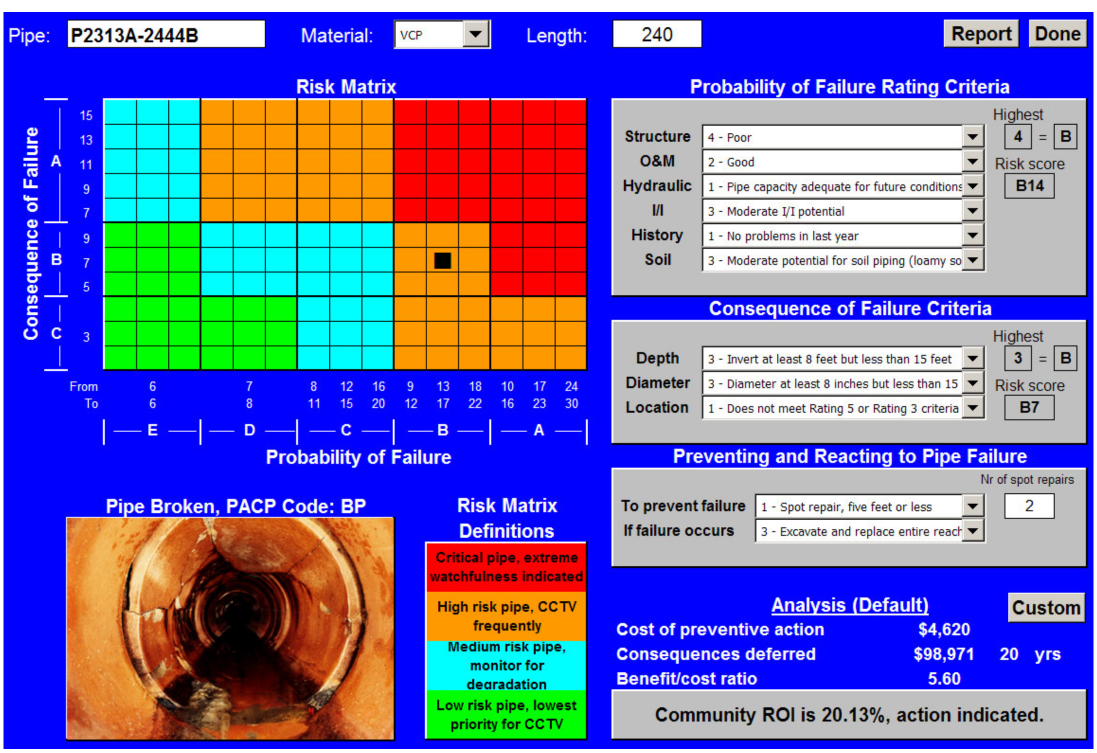

Figure 5: PISCES main entry screen

As can be seen, a risk matrix is used in PISCES. However, the probability of failure is converted to mean years until failure and the consequences of failure are converted to dollar terms as discussed above. This supports a fully-quantified evaluation of the rehabilitation decision. Some additional notes:

- The probability of failure is based on this pipe being in poor structural condition with moderate I&I potential and moderate potential for soil piping.

- The consequence of failure is based on pipe depth (neither shallow nor deep), pipe diameter, (8- to 15-inch), and pipe location (low environmental and social sensitivity).

- Failure can be deferred an estimated 20 years through two spot repairs.

- If actual failure results from further deterioration, all 240 feet of the pipe will need to be replaced.

The last two points are important because the actions required to defer failure may be quite different from those needed if failure occurs, and they are usually less costly.

The various attributes of pipe failure, including costs and deferrals, are derived from look-up tables in PISCES that are unique to each agency. PISCES presents the entire analysis on a screen that allows “fine tuning” of results based on estimates of the actual numbers that can be provided by the analyst performing the evaluation. This screen, matching the previous figure, is shown below.

Return

Customize Benefit/Cost Ratio

Reset

Resets custom values to defaults

Use custom

Change entries in yellow cells only

	Default	Custom
Likely years to failure	16.4	25.0
Consequences, direct (dig/replace reach)	$83,160	$60,000
Consequences, social and environmental	$15,811	$24,000
Total consequences of failure	$98,971	$84,000
Proactive measure (spot repair(s))	$4,620	$6,500
Failure deferral, years	20.0	25.0
Results of Analysis		
PV of risk amelioration	$25,887	$16,480
Benefit/cost ratio	5.60	2.54
Community ROI	20.13%	10.29%

Comparative Risk Cost Distributions (Custom)

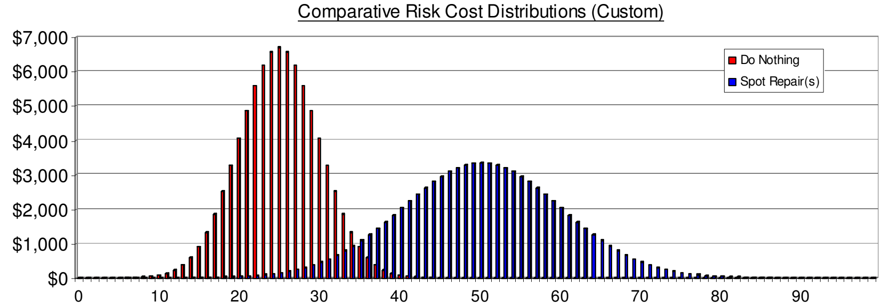

Figure 6: Sample PISCES analysis, with custom values provided by analyst

Here it can be seen that despite changes made by the analyst, which lower the community return on investment, the rehabilitation still shows a positive return on investment and favorable benefit/cost ratio. The cost of the spot repairs is $6,500. This will defer likely pipe failure costs of $84,000 a total of 25 years. The present value of the triple-bottom-line failure costs if nothing is done is $24,338. If the spot repairs are made, the present value of failure costs, now deferred, is $7,858 (these two costs are not shown on the entry screen). The benefit is the difference between these two costs, or $16,480.

In other words, by investing $6,500 for the spot repairs now, the community is gaining a benefit of $16,480. The project should be entered into the utility's pipe rehabilitation schedule and the proposed spot repairs made.

PISCES summarizes the entire analysis on a one-page report for documentation, as shown below.

Return | **Anytown Sanitation District** | Print

Pipe Risk Analysis

Pipe: P2313A-2444B, 240 ft   Date: 7/2/2007
Defect: Pipe Broken   Analyst: Jacobs

1. Probability of Failure

Structure	4 - Poor	
O&M	2 - Good	
Hydraulic	1 - Pipe capacity adequate for future conditions	
I&I	3 - Moderate I/I potential	
History	1 - No problems in last year	
Soil	3 - Moderate potential for soil piping (loamy soils)	
Risk matrix rating	B14	Severity: 7 of 11
Est. years to failure*	25.0	

2. Consequence of Failure

Depth	3 - Invert at least 8 feet but less than 15 feet	
Diameter	3 - Diameter at least 8 inches but less than 15 inches	
Location	1 - Does not meet Rating 5 or Rating 3 criteria	
Risk matrix rating	B7	Severity: 3 of 9
Direct costs*	$60,000	cost of unplanned dig/replace reach
Indirect costs*	$24,000	social/environmental costs
Total failure costs	$84,000	

3. Benefit/cost Analysis

Cost of proactive measure*	$6,500	cost of planned spot repair(s)
Failure deferral (yrs)*	25.0	
PV of avoided risk	$16,480	
Benefit/cost ratio	2.54	

*Custom value used in lieu of default value

Community ROI is 10.29%, action indicated.

4. Default and Custom Values

	Default	Custom
Likely years to failure	16.4	25.0
Consequences, direct	$83,160	$60,000
Consequences, indirect	15,811	24,000
Consequences, total	$98,971	$84,000
Cost of proactive measure	$4,620	$6,500
Failure deferral, years	20.0	25.0

Figure 7: Sample PISCES report, based on the previous figure

SUMMARY AND STATUS OF PISCES

PISCES is still under evaluation by the member agencies of OCSD. The logical next step will be to convert PISCES' logic into an automated program that can process piping lists and generate initial evaluations for each segment.

PISCES may not be uniformly adopted for the following reasons:

- Many agencies resist looking at risk objectively, preferring the traditional approach of intuition or even simply spending all the money available and hoping it will be enough.

- Beyond that, the idea of evaluating asset actions in a rigorous and quantified manner, and especially the concepts of community value and economic end of useful life, are new to the industry in this country and are not yet widely accepted.

Nonetheless, more and more utilities are turning to risk analysis and other techniques of modern asset management to help make difficult and costly decisions on how best to spend their communities' scarce funds. The author believes that the concepts underlying PISCES point the way forward to allocating community funds more effectively and to increasing the effectiveness of R&R efforts in maintaining the service levels our communities want and need.

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Ken Harlow's asset management web page: http://www.bcwaternews.com/AssetMgt/

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[1] Ken Harlow, *The Myth of Deep Pipes: Criticality and Pipe Rehabilitation Strategies*, http://www.bcwaternews.com/AssetMgt/AM19_deep_pipes.pdf (2006)

[2] New Zealand Asset Management Steering Group and Institute of Public Works Engineering of Australia, *International Infrastructure Management Manual*, Wellington New Zealand (2002).

[3] Ken Harlow, *What's a Spill Worth? or, a Brief Look at Community Values,* http://www.bcwaternews.com/AssetMgt/AM16_spillworth.pdf (2005).