Water Treatment Plant Condition Assessment

Department of Public Utilities

City of Richmond, VA

December 2020

Technical Memorandum

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1 Background and Purpose

The City of Richmond Department of Public Utilities' (City) Water Treatment Plant (WTP) is a conventional plant that has been providing City residents and surrounding municipalities with potable drinking water since the early 1900s. Since its construction, the WTP has undergone countless upgrades and changes as drinking water regulations and technologies evolve, and equipment throughout the WTP has continuously been serviced, repaired and replaced in order to provide uninterrupted and reliable service to customers. One of the largest challenges presented to public utilities is not only managing the countless number of assets attributed to their treatment and distribution system, but also maintaining accurate and current information on each asset to better increase efficiency in establishing work orders and prioritizing and budgeting for repairs and replacements. To do this, each individual asset must be documented in a manner that allows it to be easily identifiable by any person wishing to locate it or retrieve information on it.

The City has an existing asset management program for the WTP and distribution system and existing assets have been previously logged and been available to access within the City's computerized maintenance management system (CMMS) software called Mainsaver. Over time the City has discovered that multiple assets have not been logged into the software and those that have been logged in the software often prove challenging for City staff to locate in order to appropriately establish work orders, update maintenance records, and modify asset information. In order to provide a comprehensive update of the asset management system for the WTP the City has engaged Whitman, Requardt & Associates, LLP (WRA) to perform a comprehensive condition assessment of all assets at the WTP, and update the City's Mainsaver software to reflect the most accurate and current information available.

WRA completed a multi-disciplinary walkthrough of the WTP between September 2019 and January 2020 to identify and log each asset with all available, pertinent information, and assign values attributed to each asset's consequence of failure, probability of failure, and overall asset condition. The purpose of this technical memorandum is to describe the walkthrough and the documentation process used during the walkthrough for determining new and existing assets; how the assessment documents were developed; how criticality and asset information was determined and logged; and to describe the risk analysis and the Facility Condition Index (FCI) that was conducted for the assets and how this can be used and incorporated in the development of a 10-Year Repair and Replacement Plan for the City WTP.

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2 Condition Assessment Guidelines

Prior to performing the multi-disciplinary walkthrough, WRA worked with the City to develop a detailed hierarchy at the WTP that illustrates how each location at the WTP is related to another. In addition to the development of a hierarchy based on locations at the WTP (see Section 3.1), two other hierarchies were developed; one for WTP locations outside of the actual boundaries of the WTP (gates, locks, dams, and canal assets), and one and for WTP process affiliations. Along with the hierarchies, a guideline document was created for the inspection team (and for future use by the City) to use in determining and assigning consequence of failure, probability of failure, and asset condition values for each asset. As subsequently outlined in this Section, before commencing the multi-disciplinary walkthrough, key elements of the condition assessment had to be explicitly defined in order to promote standardization across different disciplines and asset types.

2.1 What is an Asset?

In order to implement a successful condition assessment program, the foremost important question to address is "*what is an asset?*" since there are many different interpretations for what assets can be. In order to define the term "asset" for the purpose of this project, WRA and the City identified an asset as a maintenance-managed item down to a level of practical and cost-effective management. This meaning all items that would be readily maintained at the WTP instead of running to failure prior to replacement, should be considered an asset. Examples of items that would not be considered an asset under this definition for the City WTP include electrical conduit and piping/plumbing and appurtenances under 4-inches in diameter.

2.2 Identifying Critical Assets

Once an asset is identified, it requires a criticality classification. Criticality is synonymous with the consequence of failure (CoF) and establishes which assets at the WTP are most critical for maintaining the functionality of the WTP processes, WTP regulatory compliance, and protection of public health. The numerical classifications for CoF range from 1 through 5, with a classification of 5 being the most critical and 1 being the lowest (see **Appendix A** for list of identifying criteria). At the lowest CoF level, asset failure would cause no impact on processes or level of service, no impact on regulatory compliance, and/or multiple assets are readily available as standby units, to take the place of the failed asset. At the highest CoF level, asset failure would cause total WTP loss of service, no redundant asset is available as a standby unit, water conservation/do not use/boil orders would be enacted, and/or the failure of the asset could lead to loss of life. Although each asset is assigned a value for criticality, only those assets at a level 4 or 5 are considered "critical assets" since the WTP would be subjected to regulatory non-compliance and/or a life safety impact in the event of a CoF level 4 or 5 asset failure.

Appropriately identifying and assigning CoF levels can be a challenge for assets that are not directly associated with a WTP process, but instead are indirectly related and have the ability to impact specific processes. This is most notably relevant for electrical assets. To appropriately review and assign CoF classifications to these type of assets, City WTP staff with a strong understanding of WTP operations and controls accompanied WRA team members during the in-field assessment. For assets that were unable to be assigned a CoF in the field, workshops were held between WRA and the City to review assets and more

accurately understand their impact to the WTP if the asset were to fail. A list of all identified Critical Assets at the WTP can be found in **Appendix F**.

2.3 Identifying Probability of Failure and Asset Condition

In conjunction with assigning criticality classifications WRA team members assigned a probability of failure (PoF) and an asset condition value (AC) to each asset, based on visual observations in the field and WTP staff insight. Although the PoF and AC were recorded independently, the two values are largely proportionate to one another in the sense that higher PoF values typically correlate with higher AC values. Like the CoF, the PoF and AC were assigned on a 1 through 5 scale (see **Appendix A** for list of identifying criteria and descriptions). A PoF value of 5 indicates that the asset is either failing, past its useful life, and/or would require parts that are no longer available, and a PoF value of 1 indicates that the asset is either new, exceeds current requirements, has plenty of spare parts available, and/or requires virtually no maintenance. For the AC, a value of 5 designates that the asset has critical defects and should be replaced, whereas an AC value of 1 was given to assets that visually appear new and show no visible signs of defects.

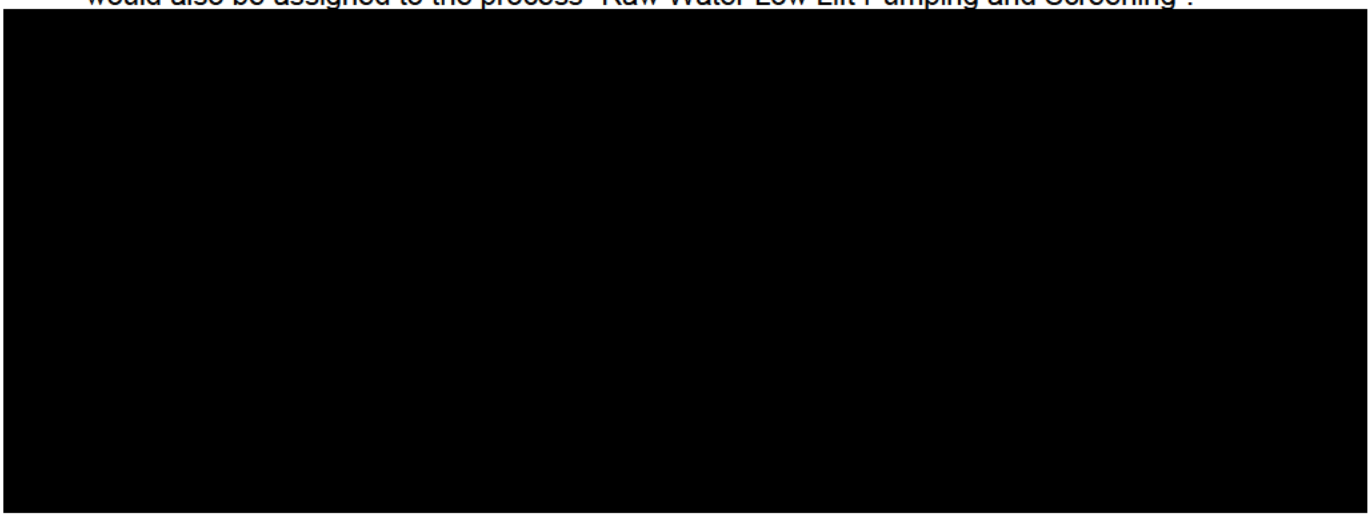
The PoF and AC are entirely independent of the CoF since they do not relate to the consequences pertaining to an asset's failure. However, the PoF is imperative for quantitatively calculating an asset's risk in order to identify assets (specifically those classified as critical) that require immediate repair or replacement. Although not included in the risk calculation, the AC helps identify possible failure modes and is pivotal for establishing a repair and replacement plan. For any assigned AC value greater than 1, a corresponding fault code (FC) was required to be assigned. Unlike the CoF, PoF, and AC, the FC is a numerical value that directly relates to a visually or audibly observed defect, and a higher value is not indicative of a worse defect. A total of 10 FCs were established for the condition assessment which also can be found in **Appendix A**.

3 Asset Logging and Documentation

3.1 Hierarchy Development

The hierarchy that was developed was created so that each asset (once logged) can be assigned to a specific location (room, vault, etc.) allowing for the asset to be quickly and easily identified. Since it was determined with the City that they wish to have Parent-Child relationships established for all assets, each asset will now have the ability to be documented in a manner that allows it to fold into whatever parent asset or location it is directly related to, and any future assets can be systematically assigned to the appropriate location once this hierarchy is integrated in the City's Mainsaver software.

Two separate location hierarchies were developed, namely the WTP location hierarchy (**Appendix B**), and the Water Supply location hierarchy (**Appendix C**) which encompasses sections of the Kanawha Canal, and the pertinent locks and dams. Both of the location hierarchies were developed in parallel with plans (utilizing existing drawings from around the WTP) so that locations on the hierarchy can be easily matched to their identically-named locations on the plans. The process hierarchy (**Appendix D**) differs from the location hierarchies in that it illustrates how WTP processes relate to one another, allowing for assets to be assigned to a WTP process in addition to a location. The purpose of this is to provide the City with the flexibility to establish and track budgets between specific locations at the WTP and process trains. In reference to Figures 1 & 2 below (taken from the established hierarchies), the "Raw Water Pump Station" at the WTP is the direct parent of each individual pump station, and each individual pump station is then the direct parent of each affiliated floor/room location within that given building. For each of the components within those buildings that are affiliated with the operation of the buildings and enclosed equipment, they would also be assigned to the process "Raw Water Low Lift Pumping and Screening".



3.2 Asset Lists

In order to identify which assets at the WTP are already logged within the Mainsaver software, and in order to preserve historical asset information (such as work orders), an initial list was compiled from the City's Mainsaver for all existing assets located at the WTP. This list was used in conjunction with a form developed by WRA to document and log each asset at the WTP during the walkthrough, and to identify assets that were missing from the City's Mainsaver. The Asset Condition Assessment Form was created to provide a simple tool for

data collection that shows what information should be recorded when logging a new asset such as location, manufacturer, model, serial number, etc. The form was not generated for the sole purpose of documenting assets that were found to be missing from the City's Mainsaver during the walkthrough but was created with the intent to be an essential tool to be used by City staff for documenting information of all new assets as they are installed around the WTP in the future. This form is included as **Appendix E**.

3.3 Multi-Disciplinary Walkthrough

In order to document each asset at the WTP, WRA formed a team of inspectors to cover all relevant disciplines of civil, architectural, structural, geotechnical, process mechanical, building mechanical, electrical, and instrumentation & controls. MIN Engineering was subcontracted to perform the building mechanical condition assessment services, and Shah & Associates was subcontracted to perform the electrical and I&C condition assessment work. Throughout the course of a few weeks, the inspection team surveyed the WTP and associated facilities, documenting all new assets ("new" refers to those assets that did not appear in the existing asset log retrieved from Mainsaver and do not necessarily refer to newly installed assets), updating/confirming the information that was shown for existing assets, and performing visual inspections of each asset to determine the asset's CoF, PoF and AC. All of this information was compiled into a master spreadsheet that was used to update the City's Mainsaver software. As part of the data collection services, photos were taken and logged for assets where able.

Photo 1: Inspection Team Member

Following data compilation and sorting, three separate workshops were held with City operational and engineering staff to review the information and provide clarifications as presented by each discipline inspection team. The workshops were essential for incorporating the City's input regarding items to be entered as an asset, identifying missing assets, identifying duplicate entries, and filling in missing information that was unable to be determined during the walkthrough. One such key component of these workshops encompassed the review of criticality for assets that were unable to be classified during the evaluation, including the determination and assignment of the appropriate CoF value.

Photo 2: Drone Inspection of Bosher's Dam

4 Condition Assessment Summary

The existing asset list contained a total of 3,148 assets within the "WP" (Water Plant) Work Area within Mainsaver; 306 of which were classified as deactivated and 621 were associated with distribution system assets (pump stations, storage tanks, etc.), and were excluded from the assessment. Additional assets at the WTP that were not cataloged within the "WP" Work Area were included, bringing the total number of existing WTP assets to 2,312. An additional 1,908 assets were identified and documented as "new" assets as a result of the walkthrough, constituting an increase of 82% and bringing the total number of WTP assets up to 4,220. Of the 4,220 assets documented, 187 have been classified as critical assets (as defined under Section 2.2). Summaries of the asset documentation are presented in Tables 1 through 3.

The condition assessment documentation excluded items that would typically be replaced instead of repaired as well as items that would typically be classified as parts. Each asset was assigned a status identifying the level of service being provided by the asset. The status abbreviations and corresponding abbreviations are as follows:

ISF (In Service Full) – assets that are fully operational and in service.

ISL (In Service Limited) – assets that are not fully operational but are in service.

OSI (Out of Service Inactive) – assets that have been removed from service temporarily, not attributed to maintenance or decommissioning, but are fully operational. This status implies that the asset is temporarily inactive and can be placed back into service at any time.

OSM (Out of Service Maintenance) – assets that have been removed from service for either planned maintenance or unplanned maintenance. This status implies that the asset will be returned to service once the maintenance is complete.

OSP (Out of Service Permanent) – decommissioned assets that are no longer in service but are still on City property in the asset's installed location (i.e. wall-mounted disconnect switch with disconnected wiring). This status implies that the asset has been abandoned or is no longer operational. These assets will not be returned to service.

DEA (Deactivated) – decommissioned assets that are no longer in service and are no longer in the asset's installed location, but the asset is still within the City's possession (i.e. chemical metering pump that has been removed from service and placed in a storage room). This status implies that the asset is no longer needed or is no longer operational. These assets will not be returned to service.

REM (Removed) – decommissioned assets that are no longer in service and no longer located on City property or within the City's possession. This status implies that the asset has been discarded.

NEI (Non-Equipment Item) – identifies non-asset locations (i.e. room within a building) for purpose of employing the location hierarchy in Mainsaver. These items are non-maintainable.

Asset Status	No. of Assets	[redacted]
In Service Full (ISF)	3421	[redacted]
In Service Limited (ISL)	42	[redacted]
Out of Service Inactive (OSI)	90	[redacted]
Out of Service Maintenance (OSM)	31	[redacted]
Out of Service Permanent (OSP)	39	[redacted]
Deactivated (DEA)	80	[redacted]
Removed (REM)	309	[redacted]
Non-Asset (NEI)	208	[redacted]

Table 1: Condition Assessment Summary by Asset Status

Asset Class	No. of New Assets	No. of Existing Assets	TOTAL	[redacted]	[redacted]	[redacted]
P MECH	504	777	1281	[redacted]	[redacted]	[redacted]
B MECH	91	306	397	[redacted]	[redacted]	[redacted]
INST	48	445	493	[redacted]	[redacted]	[redacted]
CONT	257	287	544	[redacted]	[redacted]	[redacted]
ELEC	452	387	839	[redacted]	[redacted]	[redacted]
SEC	17	8	25	[redacted]	[redacted]	[redacted]
STRUC	129	54	183	[redacted]	[redacted]	[redacted]
BUILD	42	6	48	[redacted]	[redacted]	[redacted]
ARCH	108	0	108	[redacted]	[redacted]	[redacted]
CIVIL	24	4	28	[redacted]	[redacted]	[redacted]
LOC	236	33	269	[redacted]	[redacted]	[redacted]
VEH	0	5	5	[redacted]	[redacted]	[redacted]
TOTAL	1,908	2,312	4,220	[redacted]	[redacted]	[redacted]

Table 2: Condition Assessment Summary by Asset Class
[1]Assets Class abbreviations are further outlined and defined in Section 6.2.

Asset Process	No. of Assets	[redacted]
WATER SUPPLY	146	[redacted]
PRE-SEDIMENTATION	36	[redacted]
RAW WATER LOW LIFT PUMPING AND SCREENING	130	[redacted]
COAGULATION, FLOCCULATION & SEDIMENTATION	476	[redacted]
FILTRATION	813	[redacted]
POST FILTRATION PUMPING & TREATMENT	170	[redacted]
FINISHED WATER PUMPING	225	[redacted]
CHEMICAL FEED AND STORAGE	665	[redacted]
RESIDUALS MANAGEMENT	294	[redacted]
NON PROCESS	1,032	[redacted]

Table 3: Condition Assessment Summary by Asset Process

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5 Risk Analysis

As described in Section 2 with the documentation of each asset's CoF and PoF, a risk score was calculated for each asset by using the equation:

Risk = CoF X PoF

The higher the risk score, the higher the asset's associated risk, corresponding to higher levels of required attention. Although this is an appropriate method for determining risk, the risk scores form a linear relationship which lacks clarity for differentiating between CoF-driven risks and PoF-driven risks as many of the risk scores overlap between categories (See Figure 3 & Table 4). The colors used in Table 4 and Table 5 are indicative of different risk score categories which is further explained in Section 5.2. For example, in using this method a calculated risk of 10 can either be a result of an asset with a CoF and PoF of 5 and 2, or 2 and 5, respectively. In this case, the asset with a CoF of 5 should sensibly carry a higher degree of risk rather than one with a CoF of 2, regardless of the associated PoF. To improve the clarity of the risk analysis, and to further enhance the degree of accuracy in risk score interpretation, the basic risk calculation was modified to better isolate the truly high-risk assets based on higher levels of CoF.

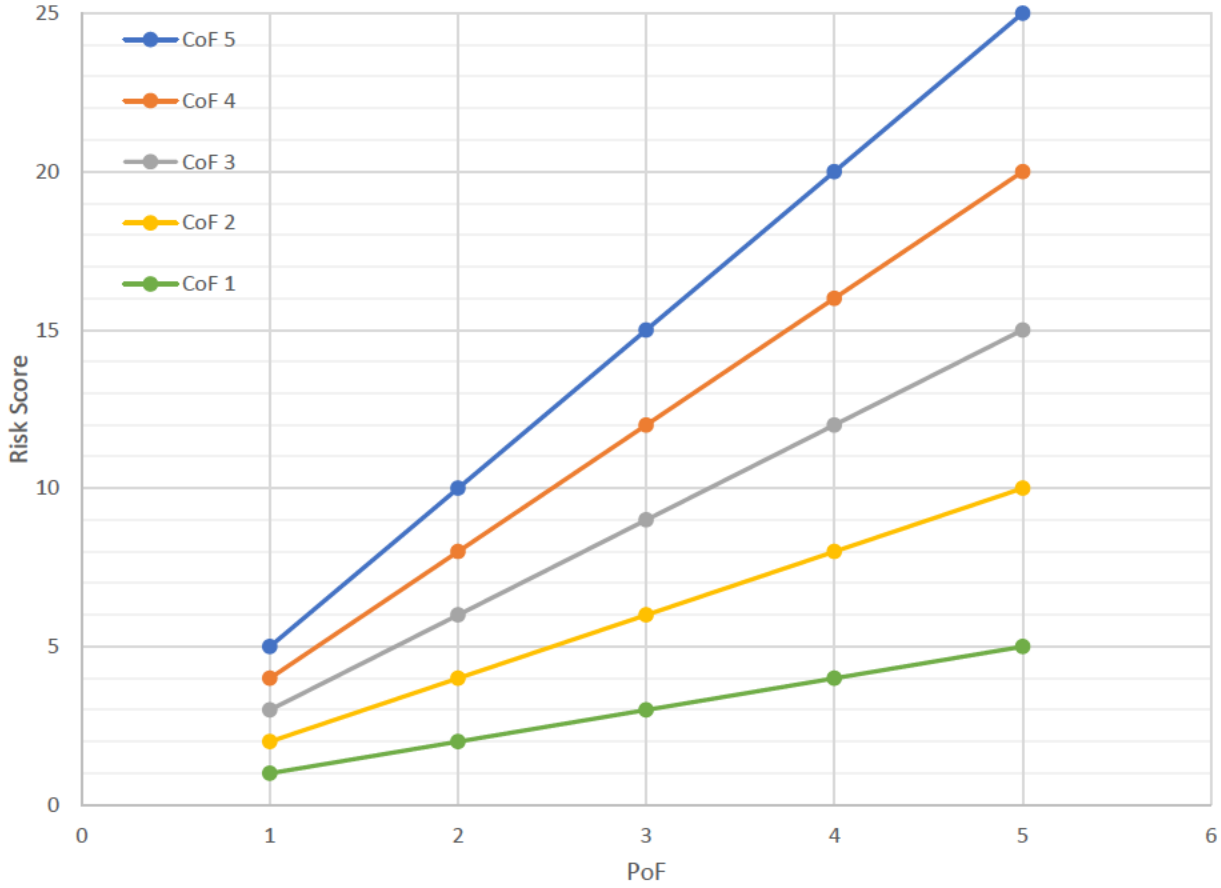


Figure 3: Example of Un-Weighted Risk Score Overlap and Distribution

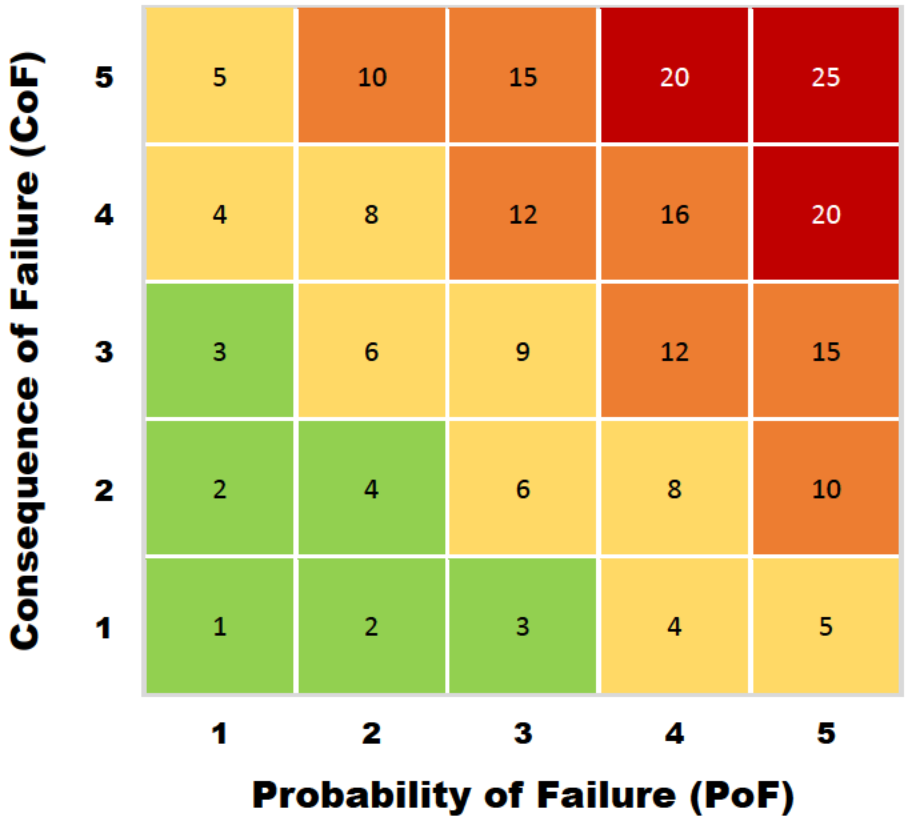


Table 4: Example of Un-Weighted Risk Score Matrix

5.1 Risk Weighting

There are many approaches to calculating risk scores; several of which utilize weighting factors related to an asset's predicted failure mode or, the level of mitigation required in the event of asset failure. For a condition assessment performed on a visual level (such as the one at the WTP), the use of these types of weighting factors would be overly assumptive and would not be appropriately determinable. Additionally, the use of an approach such as Simple Additive Weighting (SAW) would allow for proper distinction between CoF levels, but the resulting values would be subjectively based on the assigned weights, and it assumes that the risk for each level of CoF is linear and maintains the same slope and separation from other levels of criticality. Despite this, the use of a weight in the assessment is appropriate in order to recognize risks based on the asset's criticality.

To maintain the integrity of the traditional risk matrix approach for asset management while simultaneously increasing the accuracy of the results from the condition assessment, an exponential approach to weighting was assumed. At each level of criticality, risk is traditionally visualized as linear in the sense that for each level increase in PoF the risk doubles, and consequentially the slope for risk increases by 50% for each level increase in criticality. Although the slope for risk should increase as criticality increases, with this approach the risk scores at each level of criticality overlap with every other level, blurring the relationship between critical risk and non-critical risk.

By weighting the CoF on an exponential scale it resolves these issues by tiering risk scores in a way that explicitly connects higher risk scores with higher levels of criticality (See Figure 4 and Table 5). The slope for risk continues to increase for each level increase in criticality, but at a steeper slope to account for progressively severe unforeseen/unexpected consequences. Since slight scoring variations are inevitable depending on the individual conducting the assessment, it should be expected that some overlap occurs between successive levels of criticality since an asset with a CoF of 1 and PoF of 5 may not always warrant having a lower risk than an asset with a CoF of 2 and PoF of 1; however, this variance in score assignment does not span the entire CoF spectrum and an asset associated with a non-critical risk (i.e. CoF of 1 and PoF 5) should not be able to be confused with an asset linked to a critical risk (i.e. CoF of 5 and PoF of 1).

To assign the values for the exponential weighting the CoF criterion (1-5) were multiplied by values between 0.25 and 4. This ultimately raised the base risk for each level of criticality and increased the number of unique risk scores from 14 to 23 to allow for a higher level of risk/criticality precision. Ultimately, the highest possible risk score (with exponential weighting) is 100, and the lowest possible risk score is 1.25.

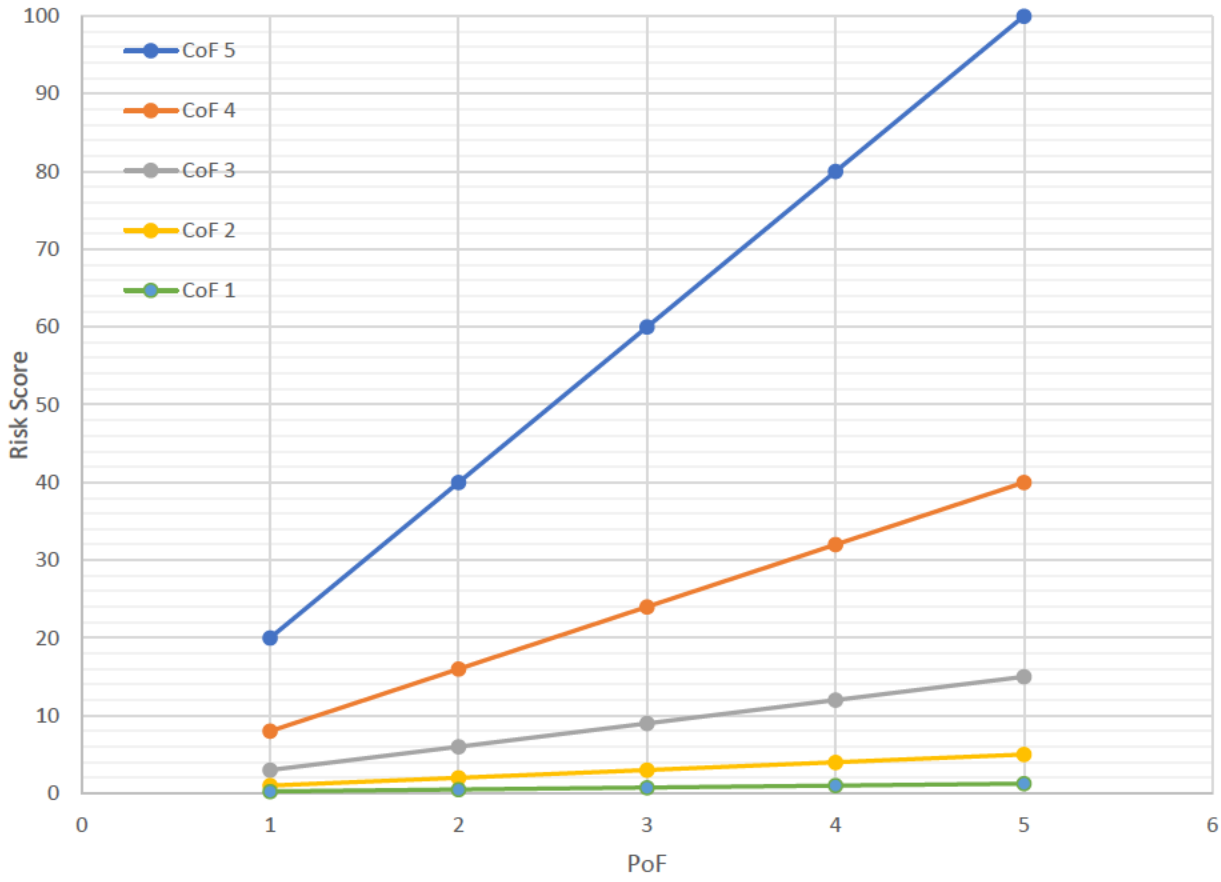


Figure 4: Weighted Risk Score Distributions

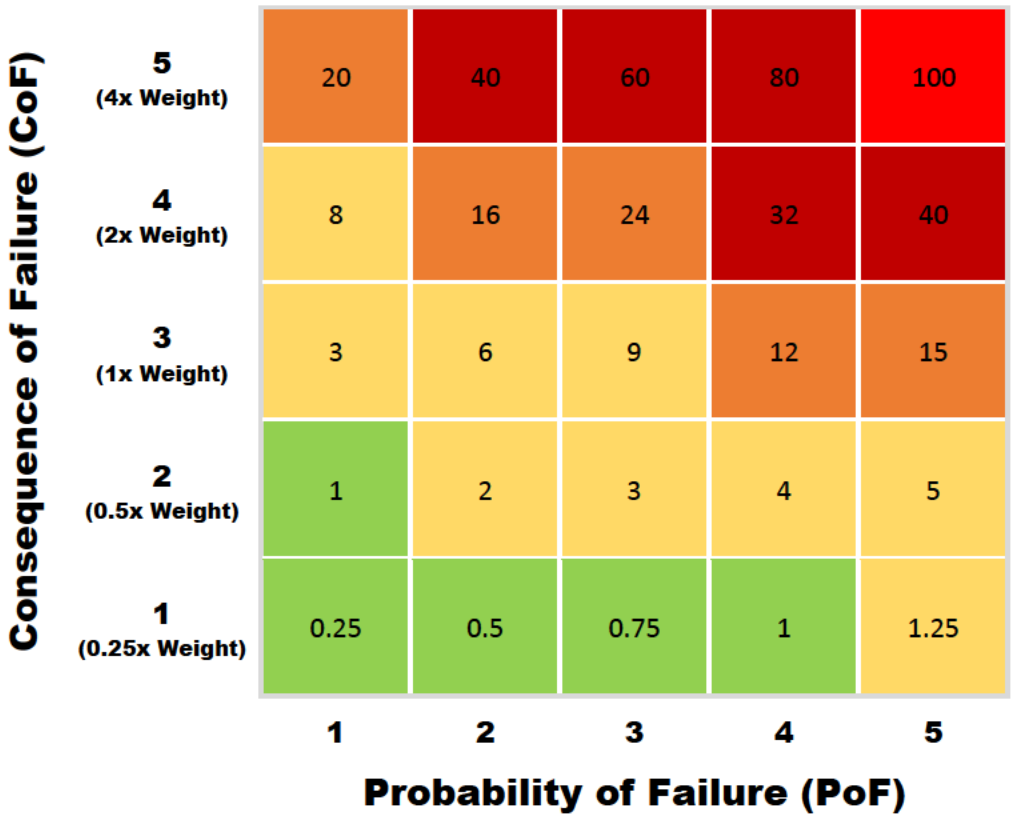


Table 5: Weighted Risk Score Matrix

5.2 Analysis Results

The risk analysis was performed on each asset that was identified as being functionally operational (ISF, ISL, OSI, and OSM) and associated with the WTP. Assets that are known to exist at the WTP but were unable to be located during the walkthrough; assets excluded from the assessment (i.e. vehicles, floodwall, etc.); and assets identified with statuses of NEI, OSP, DEA or REM were excluded from the risk analysis. Of the 4,220 assets documented during the condition assessment, 3,497 were assigned a risk score. As shown in the risk matrix, a color scheme has been incorporated to better visualize the five separate risk categories as shown in Table 6.

Risk Score	Category	Color Scheme
≤1	No Risk	Green
1< to ≤10	Low Risk	Yellow
10< to ≤30	Medium Risk	Orange
30< to ≤99	High Risk	Dark Red
100	Critical Risk	Bright Red

Table 6: Risk Score Categories

In Figure 5, the distribution of weighted risk scores is presented. Of the 3,497 assets, the large majority (63.28%) of the assets have risks scores that place them in the “Low Risk” category, with the second largest majority (29.31%) of the assets falling into the “No Risk” category. The remaining 7.41% of the assets are split up as follows: “Medium Risk” accounts for 6.21%, “High Risk” accounts for 1.14%, and “Critical Risk” accounts for 0.06%.

Based on this methodology for risk score determination, critical assets that have a CoF of 4 are not able to be scored in the “No Risk” category, and critical assets with a CoF of 5 are not able to be scored in either the “No Risk” or “Low Risk” categories. Correspondingly, only critical assets (CoF of 4 or 5) can fall into the “High Risk” and “Critical Risk” categories, and only assets that have both a CoF and PoF of 5 can be classified as a “Critical Risk”.

Although the majority of WTP assets are primarily within the no risk/low risk categories, the 42 assets having risks scored in the “High Risk” and “Critical Risk” categories should be monitored diligently by the City. The two assets classified as “Critical Risks” are those that should be addressed immediately. These assets are [redacted]

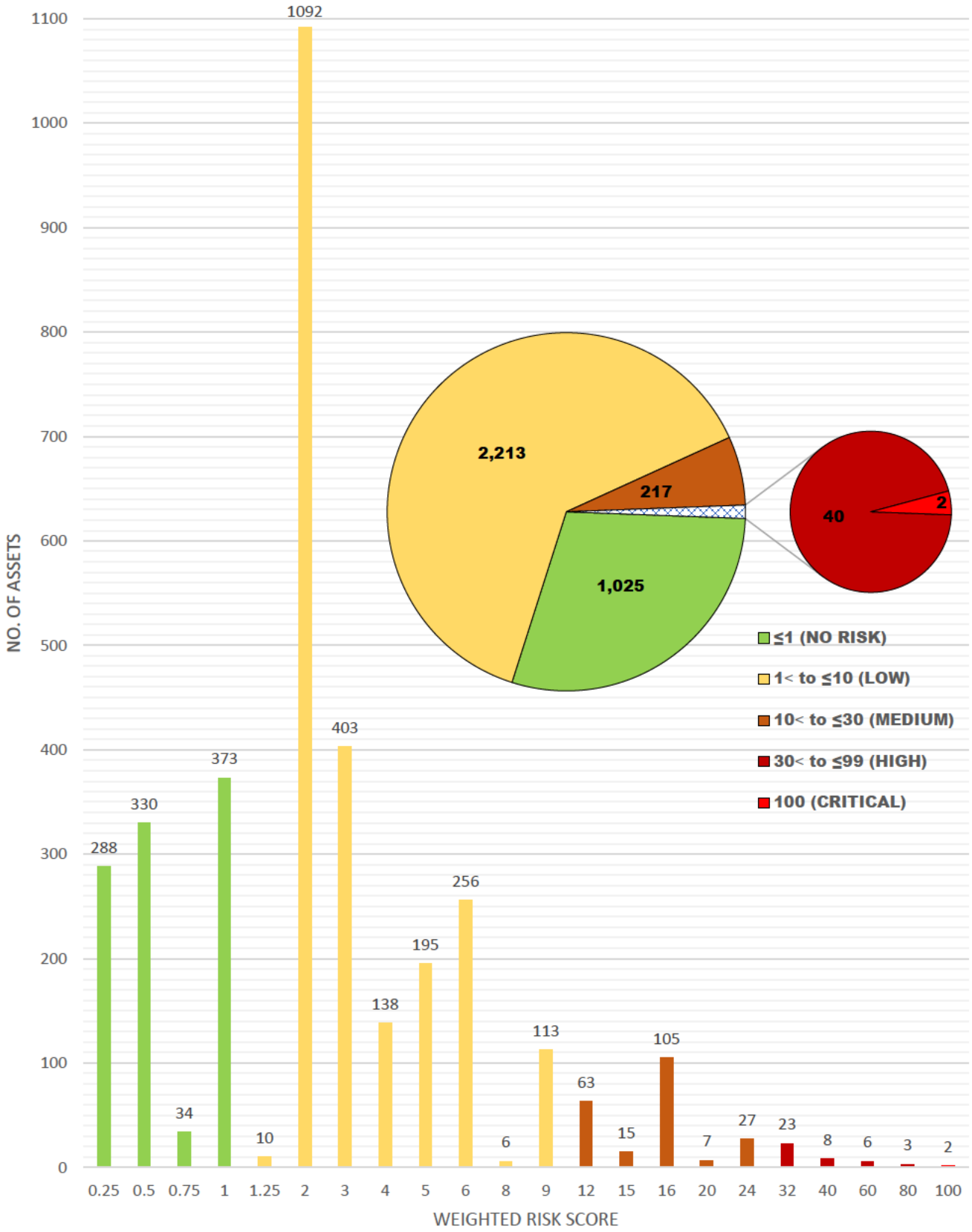


Figure 5: Weighted Risk Score Distribution

5.3 Risk Score Distribution

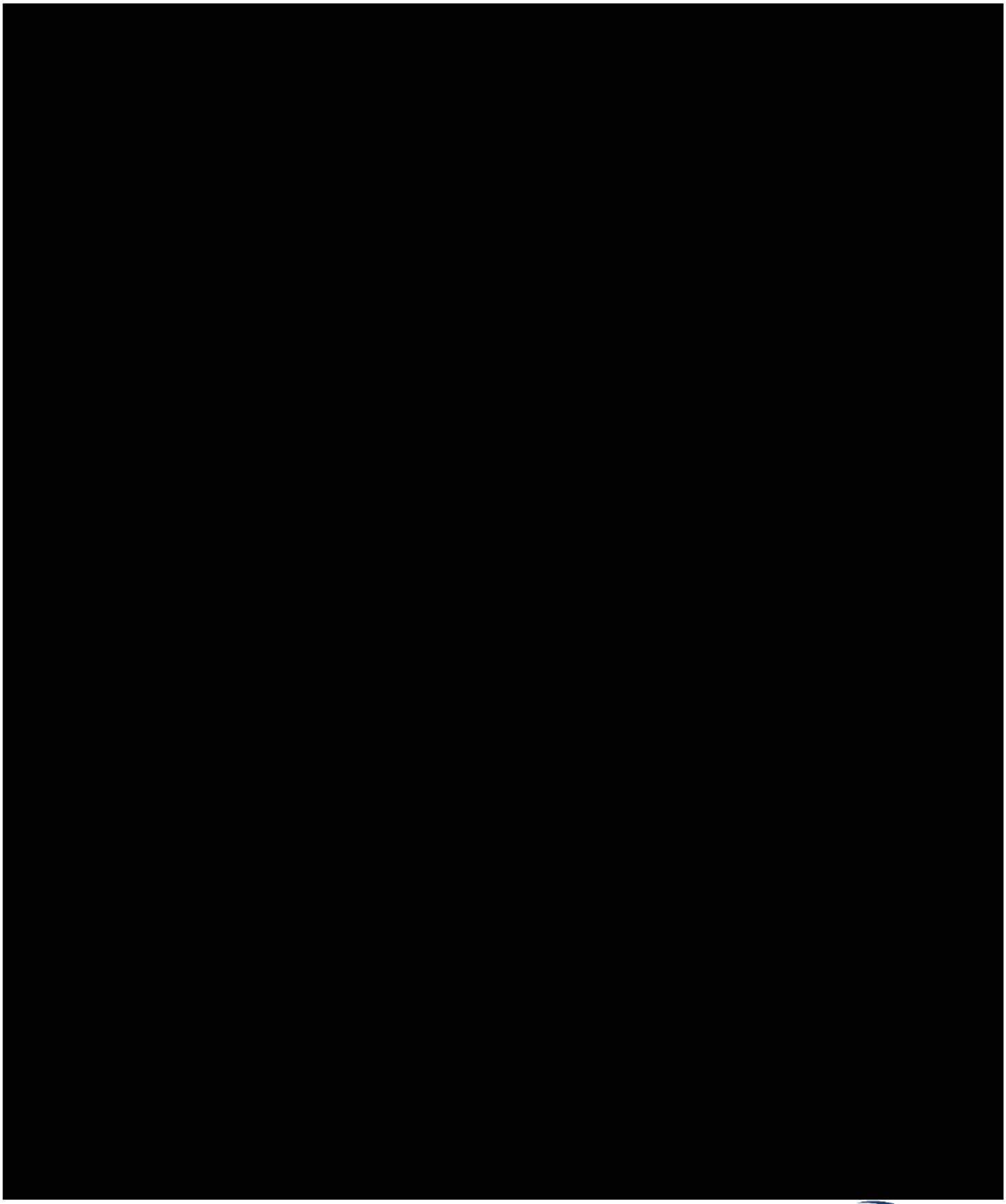
Table 7 lists the number of assets associated with each level of PoF for each asset class. Figure 6 and Table 8 display the distribution of risk scores for all assets within a particular structure or building.

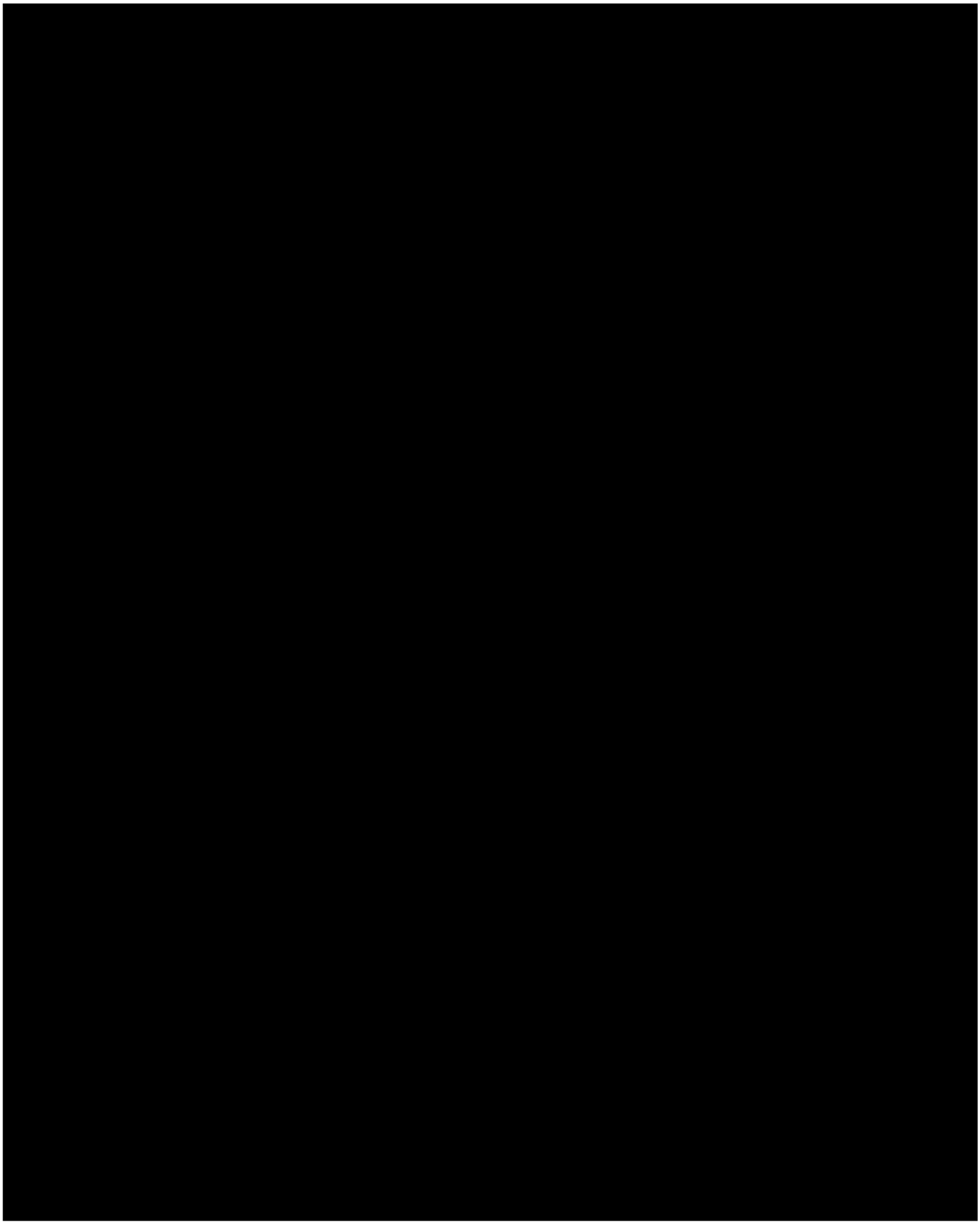
As shown in Figure 6, the maximum and minimum risk assets associated with each structure or building are illustrated by the circular black markers, separated by a vertical black line which represents the spread of risks associated with all assets for that location. Since the number of assets associated with each location is not constant and varies between 1 documented asset (i.e. Residuals Settling Lagoon), up to 505 documented assets (Plant 2 Corridor), the locations have been separated into two categories within the figure: "blue" bars indicate that the location contains an overall total of less than 5 assets, whereas an "orange" bar indicates that the location contains overall total of more than 5 assets. The purpose of this distinction is to help associate a location's level of risk with respect to the number of assets at that location. Key findings and observations include:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted] of the 57 total buildings, structures, and facilities have an average risk categorized as medium risk. The other [redacted] have average risks that fall in to the low or no risk category.
- The average PoF for assets at the WTP is 2.31.
- [redacted]

	PoF 1	PoF 2	PoF 3	PoF 4	PoF 5	Average
P MECH	105	723	215	70	4	2.23
B MECH	51	217	61	22	3	2.18
INST	51	91	82	59	54	2.92
CONT	112	174	59	27	141	2.83
ELEC	284	301	130	70	23	2.07
SEC	6	13	1	3	0	2.04
STRUC	45	116	7	0	1	1.79
BUILD	7	27	3	6	1	2.25
ARCH	0	108	0	0	0	2.00
CIVIL	6	16	1	1	0	1.88
TOTAL	**667**	**1786**	**559**	**258**	**227**	**2.31**

Table 7: Asset Class PoF Distribution





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6 Facility Condition Index (FCI)

6.1 FCI Analysis Overview

A Facility Condition Index (FCI) is an asset management benchmark that compares deferred maintenance and repair costs to current replacement values for assets and their associated building or facility. Low FCI's are preferred since they indicate that the costs associated with repairs are economical in comparison to the replacement costs. The following equation was used for calculating the FCI at the WTP:

$$FCI\ for\ Facility\ or\ Process\ "n" = \frac{\sum Deferred\ Maintenance\ for\ Assets\ in\ "n"}{\sum Current\ Replacement\ Value\ for\ Assets\ in\ "n"}$$

As defined by Facility Management Association (FMA), and as shown in Table 9, there are four tiers of FCI values that are used to associate an FCI value to a qualitative indicator.

	FCI Range
Good	0 to 5%
Fair	5 to 10%
Poor	10 to 30%
Critical	30% <

Table 9: FCI Condition Tiers

In-line with determining the FCI, a Process Condition Index (PCI) has been established for the assets associated with different treatment processes and a Class Condition Index (CCI) has been established for the assets associated with different asset classes. The condition indexes were all determined using the same assumptions and methods.

Although the FCI is a beneficial tool to help asses the relative condition of a building based on deferred maintenance costs, it assumes that an accurate record exists for each asset's historical repair/maintenance costs, and it provides limited insight on an asset's risk in association with its actual condition. The large majority of existing WTP assets, as documented in the City's Mainsaver program at the time of this assessment, did not contain historical cost records (repair/maintenance costs or purchase costs). Additionally, for all newly documented assets collected as part of the assessment, historical cost information was not provided and/or not available. Due to this, in order to determine the FCI, the following assumptions were established and conferred with the City in order to estimate the deferred maintenance costs for individual assets.

1. If no historical maintenance cost records are available for an asset it is assumed that no maintenance has been performed on the asset, and correspondingly all maintenance for that asset has been deferred.
2. The FCI will disregard deactivated, removed, and non-equipment assets, in addition to assets that do not independently have a value outside of the individual components that make up the overall asset (i.e. systems, switchgears, etc.)
3. If the asset records do not include purchase dates for assets, the deferred maintenance start-date is assumed to be the difference between the expected useful life of the asset, minus the remaining useful life.

a. Unless available through any available product warranty or operation manuals, an asset's useful life is estimated and assigned to the "Asset Group" (i.e. Motors, Pumps, etc.).
b. The remaining useful life of an asset is a function of the asset's assigned PoF.
    i. PoF of 1 = 90% life remaining
    ii. PoF of 2 = 70% life remaining
    iii. PoF of 3 = 50% life remaining
    iv. PoF of 4 = 30% life remaining
    v. PoF of 5 = 10% life remaining

6.2 FCI Metrics and Definitions

The following metrics were generated for each applicable asset with regard to the assumptions stated above in Section 6.1:

Remaining Service Life – *The estimated remaining time (in years), that the asset should reliably serve its purpose.*

For example, if an asset has an expected service life of 30 years, and has a record PoF of 4, it is assumed that the remaining service life would equal 9 years (30 years X 0.3).

Expected Service Life – *The estimated total time (in years), that the asset is expected to reliably serve its purpose; otherwise known as Estimated Useful Life.*

Preventative Maintenance Hours – *The estimated annual manhours required by the City to perform preventative maintenance tasks on an asset in order to maximize an asset's design life, and to ensure optimal performance and reliability while doing so.*

These hours were established for each asset based on manufacturer warranty requirements and/or statistical data for similar items, components, and/or manufacturers if no information was explicitly available for the selected asset. If data was unavailable for an asset, the preventative maintenance (PM) hours were estimated using the same methods described under the "Replacement Cost" description. The primary assumption for establishing PM hours was how long it would take for a reasonably-skilled employee in this field to complete the maintenance tasks outlined in the manufacturer's warranty guidelines. The basis for a skilled employee was personnel who have worked in this position for at least 3 years, a general apprenticeship program length. A Performance, Fatigue, and Delay (PFD) allowance was not factored into this determination since the City does not currently assume any additional burden rate factor – the factor that compensates for interruptions the worker has during a shift. If the City wishes to include a burden rate factor, due to the nature of the work and the environment, an elevated 20% factor would be reasonable to use over the standard 15% for PFD. This allows for additional compensation for areas of work that could be difficult to reach, work in, or have other environmental factors involved. All estimated hours are comprehensive for all trades and were determined on an annual basis for each asset.

Estimated Annual Maintenance Cost – *The estimated annual dollars required by the City to perform preventative maintenance tasks on an asset in order to ensure optimal performance and reliability.*

These costs were estimated for each asset by multiplying the asset's preventative maintenance hours by the average employee compensation rate. This compensation rate was determined using an average hourly employee compensation rate for a machine maintenance worker in the state of Virginia, as sourced by the Bureau of Labor Statistics from their 2019 data on Occupational Employment and Wages. A burden rate was not applied to this compensation rate since the City uses un-loaded compensation metrics for budgeting purposes. The hourly rate used for the analysis is $26.27/hour.

Deferred Maintenance Cost *– The total dollars that were not spent on preventative maintenance tasks, based on the required dollars (estimated annual maintenance cost) that should theoretically be budgeted for performing such tasks.*

For example, if an asset has an estimated annual maintenance cost of $500, but only $300 was documented throughout the year as going towards the preventative maintenance for that asset, then the asset's deferred maintenance cost for that year is equal to $200. Having a positive deferred maintenance cost for an asset is indicative that the preventative maintenance tasks for that asset are insufficient, or not entirely being performed.

Replacement Cost *– The total material price in dollars required to replace an asset.*

This was determined in one of three ways, depending on the asset.

1. The first method was to utilize current cost data sourced from the manufacturer. This was done for as many assets as feasible for the analysis. If the exact model was not available, a comparable model (determined by the manufacturer) was used instead.
2. The second method of assigning replacement costs was the incorporation of asset group-specific weighting factors within a linear regression formula. This method was used to estimate costs based on a delineating factor for the asset group along with an independent variable that was calculated from other known replacement costs. An example of a delineating factor used is valve size for the "valves" asset group.
3. The final method of assigning costs was used only if it was not possible to generate a delineating factor for the asset group. In this situation, the average replacement cost across the asset group was applied to the asset.

As used throughout this analysis, the following asset classes are defined below:

STRUC *– Structural assets including items such as building foundations/structural components, basins, dams & locks, vaults, stairs, mezzanines, and berms.*

LOC *– Location assets typically include rooms (i.e. Plant 2 Control Room – an identifier for a specific location within Plant 2 East Headhouse) or facilities (i.e. Plant 1 Building – an identifier for an overarching location that further breaks down and is the highest-level parent asset for all assets within that location).*

1. *LOC assets are further broken down by the Asset Group FACILITY LOC (Facility location assets - rooms) and FACILITY (Facility assets – Plant 1 Building).*

ARCH *– Architectural assets including doors, windows, louvers, ceilings, floors, and wall partitions.*

BUILD *– Building assets (architectural components) including building roofs and overall exterior building architectural components.*

B MECH *– Building Mechanical assets including items such as HVAC components and non-process mechanical components (sump pumps, eyewash stations, etc.)*

P MECH *– Process Mechanical assets including any mechanical items that relate directly to any treatment processes at the WTP (filter pumps, process valves & gates, chemical system components, etc.)*

CONT *– Controls assets associated with control systems (control panels, actuators, logic controllers, etc.).*

INST *– Instrumentation assets that typically relay data or information to assist with system controls (flow meters, level transducers, pressure gauges, etc.).*

ELEC *– Electrical assets that include items such as breakers, transformers, motors, switches, VFDs, etc.*

SEC *– Security assets including access gates, surveillance cameras, card readers, etc.*

CIVIL *– Civil assets that include comprehensive groups of infrastructure-supporting assets (plant water mains, electrical ductbanks, plant pavement, etc.)*

VEH *- Vehicles*

6.3 FCI Evaluation Considerations

Of the 103 individual asset groups that were cataloged during the condition assessment, 67 asset groups are associated with in-service assets and were able to be incorporated within the analysis. Each asset was assigned a current replacement cost value, an expected service life value (constant across each asset group), and a preventative maintenance hours value. Using the assumed hourly rate of $26.27/hour for WTP maintenance staff, estimated yearly maintenance costs and deferred maintenance costs were able to be calculated for each asset. The sum of the deferred maintenance costs and the sum of the current replacement costs for all assets located in each respective facility/building associated with the WTP were used to determine each FCI.

Each individual building and structure was assigned a total replacement value (inclusive of the building structure, wall partitions, electrical, and plumbing); buildings, structures and basins on the basis of square feet and dams & locks on the basis of linear foot. Similarly, architectural components associated with each building were individually assigned replacement costs based on the estimated total or estimated square footage of each asset.

6.4 Analysis Results

6.4.1 FCI Results

A total of fifty-two (52) facilities were assigned an FCI: twenty-nine (29) of the facilities were found to be in “Good” condition (FCI 0% to 5%), ten (10) were found to be in “Fair” condition (FCI 5% to 10%), thirteen (13) were found to be in “Poor” condition (FCI 10% to 30%), and none were found to be in “Critical” condition (FCI >30%). The FCI results are shown in Table 10, in order of decreasing FCI value. The assets associated with the Civil class were largely unable to be assigned replacement costs or estimated deferred maintenance costs in a way that would yield accurate results, and as such this class has been excluded in this analysis.

1. The average FCI for assets located outside of the limits of the WTP floodwall is 7.0%. The three highest calculated FCIs outside of the floodwall are for:
    a. Haxall Gates & Spillway at 18.3%
    b. Residuals Settling Lagoon at 17.4%

c. 3 Mile Lock Dam & Gates at 9.7%

2. The average FCI for assets located within the limits of the WTP floodwall is 3.2%. The three highest calculated WTP FCIs within the floodwall are for:
   a. Flash Mix House at 16.4%
   b. WTP Yard (excluding civil assets) at 16.32%
   c. Plant 1 Filtered Water Vault at 15.68%

	Sum of Deferred Maintenance Cost	Sum of Replacement Cost	FCI
HAXALL GATES & SPILLWAY	$25,219.20	$137,500.00	18.34%
RESIDUALS SETTLING LAGOON	$9,000,000.00	$51,702,200.00	17.41%
FLASH MIX HOUSE	$23,415.73	$143,114.17	16.36%
WTP YARD	$40,555.97	$248,436.87	16.32%
PLANT 1 FILTERED WATER VAULT	$8,987.25	$57,334.41	15.68%
KORAH 1 PS	$190,668.28	$1,255,545.09	15.19%
PLANT 2 FILTERED WATER VAULT	$12,700.65	$99,851.04	12.72%
SUBSTATION	$165,097.33	$1,330,936.34	12.40%
BASIN SLUDGE PS	$16,628.91	$137,466.87	12.10%
PLANT SWITCHGEAR BUILDING	$38,955.19	$339,716.26	11.47%
LAGOON SLUDGE PS	$46,626.43	$420,384.33	11.09%
BASIN 1 & 2 CONTROL STATION	$46,372.68	$422,889.64	10.97%
BASIN 3 & 4 CONTROL STATION	$39,245.69	$378,438.33	10.37%
3 MILE LOCK DAM & GATES	$50,438.40	$520,000.00	9.70%
RAW WATER PUMP STATION	$292,795.13	$3,109,343.36	9.42%
9 MILE GATES & DAM	$39,694.49	$510,293.42	7.78%
LIME HOUSE	$63,985.47	$893,403.28	7.16%
SUBSIDING BASIN INTAKE GATES	$35,619.49	$503,482.60	7.07%
NORTH ACCESS WELL	$27,112.17	$419,202.53	6.47%
GARAGE & PAINT LOCKER	$5,793.28	$93,491.67	6.20%
WEST CHEMICAL BUILDING	$203,873.66	$3,311,673.43	6.16%
KORAH 2 & 3 PS	$261,139.14	$4,879,247.76	5.35%
SOUTH ACCESS WELL	$33,756.79	$640,110.68	5.27%
PLANT 2 BUILDING	$991,105.83	$20,520,360.30	4.83%

NORTH SUBSIDING BASIN (NEXT TO LAGOON)	$3,006,241.75	$65,522,580.30	4.59%
PLANT 1 BUILDING	$734,143.72	$17,750,431.25	4.14%
BYRD PARK SPILLWAY & GATE	$43,072.29	$1,122,369.20	3.84%
5 MILE LOCK DAM & GATES	$52,712.84	$1,424,077.40	3.70%
CORRIDOR BETWEEN PLANTS	$7,355.60	$254,630.00	2.89%
SETTLED WATER CONDUIT	$53,952.17	$2,031,700.00	2.66%
6 MILE SPILLWAY	$25,219.20	$1,170,000.00	2.16%
CANAL LOCK SOUTH (DOWNSTREAM CANAL CLOSURE)	$24,960.45	$1,384,795.16	1.80%
BASIN 2	$167,628.94	$9,698,046.36	1.73%
BASIN 3	$160,658.94	$9,696,751.36	1.66%
BASIN 1	$154,226.71	$10,487,513.36	1.47%
CANAL LOCK NORTH (UPSTREAM CANAL CLOSURE)	$14,557.92	$1,044,514.76	1.39%
RAW WATER CONDUIT	$8,385.38	$643,506.22	1.30%
FLUORIDE STORAGE VAULT	$2,164.78	$179,060.25	1.21%
BASIN 4	$124,700.35	$10,494,746.36	1.19%
GUARD HOUSE	$535.39	$53,265.80	1.01%
FINISHED WATER BASIN NORTH	$31,385.94	$4,618,043.70	0.68%
WILLIAMS ISLAND DAM & GATES	$36,707.65	$6,899,905.60	0.53%
"Z" DAM	$30,611.43	$9,167,293.33	0.33%
FINISHED WATER BASIN SOUTH	$31,341.42	$10,891,773.31	0.29%
NORTH INTAKE BASIN	$17,294.97	$6,415,560.00	0.27%
BOSHER'S DAM & FISH LADDER	$31,265.43	$12,262,440.00	0.25%
FEEDER CHANNEL	$52,540.00	$26,650,000.00	0.20%
TRAILER & SHED	$110.62	$78,100.00	0.14%
SOUTH INTAKE BASIN	$605.85	$1,525,100.00	0.04%
LAGOON SLUDGE SAMPLING STATION	$0.00	$6,800.00	0.00%
LIME SLURRY STRUCTURE	$0.00	$116,000.00	0.00%
MECHANICAL BUILDING	$0.00	$60,000.00	0.00%

Table 10: FCI Results Summary

6.4.2 PCI Results

A total of ten (10) process affiliations were assigned a PCI: five (5) were found to be in "Good" condition, four (4) were found to be in "Fair" condition, one (1) was found to be in "Poor" condition, and none were found to be in "Critical" condition. (Assets that are not directly affiliated with any process at the WTP were documented as being affiliated with "Non Process"). The PCI results are shown in Table 11, in order of decreasing PCI value.

The three highest calculated WTP PCIs are for:

1. Residuals Management at 17.3% (excluding the residuals settling lagoon this value decreases to 13.8%).
2. Non Process at 9.7%
3. Chemical Feed and Storage at 8.4%

	Sum of Deferred Maintenance Cost	Sum of Replacement Cost	PCI
RESIDUALS MANAGEMENT	$9,248,150.68	$53,578,877.40	17.26%
NON PROCESS	$896,417.84	$9,242,752.78	9.70%
CHEMICAL FEED AND STORAGE	$448,831.58	$5,377,497.37	8.35%
RAW WATER LOW LIFT PUMPING AND SCREENING	$256,328.94	$3,439,472.57	7.45%
FINISHED WATER PUMPING	$383,230.17	$6,476,343.23	5.92%
POST FILTRATION PUMPING & TREATMENT	$221,987.29	$4,865,571.36	4.56%
PRE-SEDIMENTATION	$3,020,830.46	$67,043,138.63	4.51%
FILTRATION	$896,025.49	$27,136,310.77	3.30%
COAGULATION, FLOCCULATION & SEDIMENTATION	$647,175.12	$41,519,101.70	1.56%
WATER SUPPLY	$472,432.28	$62,761,160.47	0.75%

Table 11: PCI Results Summary

6.4.3 CCI Results

A total of ten (10) classes were assigned a CCI (excluding Civil), however, as discussed in Section 6.2 the individual classes for both structural & location, and building & architectural are largely interrelated and share some common costs. For this reason the "STRUC" and the "LOC" asset classes have been combined, and the "BUILD" and the "ARCH" classes have been combined as part of this analysis. Two (2) classes were found to be in "Good" condition, two (2) were found to be in "Fair" condition, four (4) were found to be in "Poor" condition, and none were found to be in "Critical" condition. The CCI results are shown in Table 12, in order of decreasing CCI value.

The three highest calculated WTP CCIs are for:

1. Electrical at 24.8%.
2. Controls at 22.8%
3. Instrumentation at 21.9%

	Sum of Deferred Maintenance Cost	Sum of Replacement Cost	CCI
ELECTRICAL (ELEC)	$1,543,507.96	$6,219,466.63	24.8%
CONTROLS (CONT)	$467,386.68	$2,052,612.18	22.8%
INSTRUMENTATION (INST)	$185,775.65	$849,046.90	21.9%
BUILDING MECHANICAL (BMECH)	$254,839.34	$2,392,097.51	10.7%
SECURITY (SEC)	$1,690.77	$23,400.00	7.2%
PROCESS MECHANICAL (P MECH)	$1,686,839.14	$30,533,653.19	5.5%
STRUCTURAL (STRUC) [1]	$12,351,370.32	$259,973,093.47	4.8%
ARCHITECTURAL (ARCH) [2]	$0.00	$1,882,812.00	0.0%

Table 12: CCI Results Summary
[1] Structural and Location classes have been combined as "STRUC" for the purpose of this analysis. Both individual classes relate to structural components.
[2] Architectural and Building classes have been combined as "ARCH" for the purpose of this analysis. Both individual classes relate to architectural components.

6.4.4 Condition Index Summary

Based on the results from the FCI analysis, the WTP facilities are generally in fair condition with an average FCI of 5.4%. No WTP facilities were found to have FCI values that indicate a facility is in critical condition. However, particular assets at the WTP significantly impact this value. The two primary outliers are the residuals settling lagoon and the north subsiding basin. Both of these basins have large capital costs that may not be practical given that the basins are not necessarily replaceable, but only maintainable. By ignoring the replacement costs and estimated deferred maintenance costs (based on dredging contract costs) for both of the basins, it provides a higher level of clarity for interpreting the overall condition of WTP facilities. In doing so, the average FCI for WTP facilities decreases to 2.4% and the following condition indexes would change:

- the PCI for Residuals Management would decrease from 17.26% to 13.22%
- the PCI for Pre-Sedimentation would decrease from 4.51% to 0.96%
- and the CCI for Structural would decrease from 4.8% to 0.24%

Individual FCI results are illustrated in Figure 7.

With regard to the analysis results, it is important to recognize that an asset with a high or critical risk score may be located within a facility that has an overall "Good" condition, in relation to the FCI. It should not be assumed that all assets within each facility are in good condition, solely based off the respective facility's FCI. As the City continues to document asset replacement and maintenance costs in the coming years, the accuracy of the facility condition index values will increase and allow for additional clarity in benchmarking each facility's overall condition.

Although the FCI provides valuable insight into the overall condition of a facility, asset replacements should be determined on an individual basis, and the FCI should not be used as the primary determining factor whether to repair or replace assets within a facility. It is important that individual asset criticality and risks be accounted for in order to accurately

determine repair and replacement schedules. Along with the FCI analysis, a 10-Year Repair and Replacement Plan has been developed and is included as **Appendix G**.

Figure 7: FCI Results Summary

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Appendix A

Condition Assessment Criteria

Probability of Failure (PoF)

Asset Age	New	≤ 25% of Useful Life	≤ 50% of Useful Life	≤ 90% of Useful Life	Past Useful Life
Parts Availability	Stocked on site. Always operational.	Available Locally. Minimal downtime, easy to return to service	Not readily available, must order. Out of service for moderate periods,	Difficult to find/obtain. Extensive downtimes, difficult to return to service.	Parts obsolete/no longer available. Virtually impossible to return to service once down.
Maintenance & Repair Issues	Virtually none. Basic OEM maintenance.	As expected. PM required with few, basic CM. Minor work orders established.	Average. PM needed frequently with minor CM. Work orders common.	Substantial. Mainly CM, close monitoring required for asset. Constant work orders established. Costs starting to outweigh the benefit of maintaining/repairing.	Asset failure imminent. Exhibits recurrent patterns of failure and requires constant monitoring.
Performance	Exceeds current requirements.	Meets current requirements.	Meets requirements but needs Improvement. Becoming increasingly more costly to maintain and operate	Inefficient and becoming ineffective. Struggles to meet requirements	Asset failing. No longer capable of meeting performance requirements.
	1	**2**	**3**	**4**	**5**

Consequence of Failure (CoF)

1	**2**	**3**	**4**	**5**
• Asset failure causes no impact on processes or level of service. • Multiple redundant assets on standby. • Water service available. No regulatory impact. • Asset failure would not lead to injury.	• Asset failure may negatively impact some processes but causes no loss of service. • Multiple redundant assets available, at least one is on standby. • Compliance impact anticipated. • Asset failure would not lead to injury.	• Asset failure negatively impacts other processes and could lead to short term loss of service. • Significant corrective action would be required. Single redundant asset on standby. • Low probability of injury from asset failure.	• Asset failure would cause loss of service for major processes, decreasing WTP regulatory capacity below 132 MGD. • Process recovery would be required. Redundant asset available, but not on standby. • Do not drink order. • High probability of injury from asset failure.	• Asset failure would cause total WTP loss of service. • Asset has no redundancy. • Do not use order. Citation/Consent Order. • Boil water order, water conservation order. • Asset failure could lead to loss of life.

Asset Classes

Asset Class	**BUILD** *Buildings*	**ARCH** *Architectural*	**STRUCT** *Structures*	**CIVIL** *Civil/Site*	**ELEC** *Electrical*	**P MECH** *Process Mech*	**B MECH** *Building Mech*	**SEC** *Security/Safety*	**CONT** *Controls*	**INST** *Instrumentation*	**LOC** *Location*	**VEH** *Vehicle*

Fault Codes (FC)

Fault Code	**1** – *Loose*	**2** – *Worn/Aged*	**3** – *Broken*	**4** – *Leaking*	**5** – *Missing*	**6** – *Dirty*	**7** – *Corrosion*	**8** – *Sagging*	**9** – *Noise/Vibration*	**10** – *Unknown*

Structural and Architectural Asset Condition

1	2	3	4	5
New construction, no visible defects	Minor/superficial repairs needed. No cracking, spalling, sagging, corrosion, drainage issues, and/or shifting visible.	Needs some repairs. Some surface cracking, corrosion, drainage issues, shifting, and/or spalling visible. Structure is in fair condition and within useful life	Substantial repairs needed. Significant cracking, sagging, corrosion, drainage issues, shifting, and/or spalling visible. Functional but past useful life	Critical defects visible. Structure cannot be repaired and should be replaced.

Mechanical Asset Condition

1	2	3	4	5
New asset, no visible defects	Minor superficial deterioration and wear/tear. No functional defects, corrosion, and/or leaks. May be slightly outdated, but still meets needs with minimal maintenance.	Needs some repairs. Deterioration evident with defects, corrosion, and/or leaks. Functioning as designed.	Substantial repairs needed. Defects are widespread and the asset no longer meets needs and requires partial replacement.	Critical defects visible. Issues appear beyond repair and asset should be replaced.

Electrical & I&C Asset Condition

1	2	3	4	5
New asset, no visible defects	Minor deterioration. May be slightly outdated, but still meets needs with minimal maintenance.	Needs some repairs. Deterioration evident with defects. Limited flexibility for improvement. System meets requirements and is within useful life.	Substantial repairs needed. Defects are widespread and the asset no longer meets needs and requires partial replacement.	Critical defects visible. Issues appear beyond repair and asset should be replaced.

Civil/Site Asset Condition

1	2	3	4	5
New construction, no apparent defects	Minor cosmetic deterioration such as pavement cracks, damaged signage, etc.	Needs some repairs. Deterioration evident with defects such as signs needing replacement, pavement cracks larger than 2” wide, corroded fire hydrants, etc.	Substantial repairs needed. Defects are widespread Pavement contains potholes, signage, fences, inoperable hydrants, etc. appears outdated/broken and need replacement.	Critical defects visible. Site defects inhibit WTP function including ingress/egress.

Site Security/Safety Asset Condition

1	2	3	4	5
New asset, no apparent defects	Minor cosmetic deterioration. Equipment may be slightly outdated, but meets safety requirements.	Needs some repairs. Deterioration evident with defects. Security finding requiring immediate corrective action.	Substantial repairs needed. Asset requires substantial repairs/maintenance for required level of security. Security breach.	Critical defects visible. Asset is well past its useful life, places the WTP at risk, and should be replaced. Security failure.

Appendix B

WTP Location Hierarchy

Appendix C

WTP Water Supply Location Hierarchy

CITY OF RICHMOND WATER SUPPLY
LOCATION HIERARCHY

Appendix D

WTP Process Hierarchy

CITY OF RICHMOND WATER TREATMENT PLANT PROCESS HIERARCHY

Appendix E

Asset Condition Assessment Form

CITY OF RICHMOND DEPARTMENT OF PUBLIC UTILITIES

ASSET CONDITION ASSESSMENT FORM

Photo ID No. _____

Assessor Name: _____ **Date of Assessment**: _____

Location: _____

Location (ie. Building/structure/Zone) Sub-Location(s) (Floor, Room, Parent Asset, etc.)

Process: _____

Process (ie. Filtration, Finished Water Pumping, etc.)

Asset Description:

Asset Class:

Asset Group:

Manufacturer:

Model Number:

Serial Number:

Manufactured Date:

Acquisition Date:

Estimated Asset Acquisition Cost:

Asset Status:

Refer to the Condition Determination Tables for Scoring Criteria	**Score (1 through 5)** Best ◄——► Worst				
	1	**2**	**3**	**4**	**5**
Consequence of Failure (CoF):	☐	☐	☐	☐	☐
Probability of Failure (PoF):	☐	☐	☐	☐	☐
Asset Condition (AC):	☐	☐	☐	☐	☐

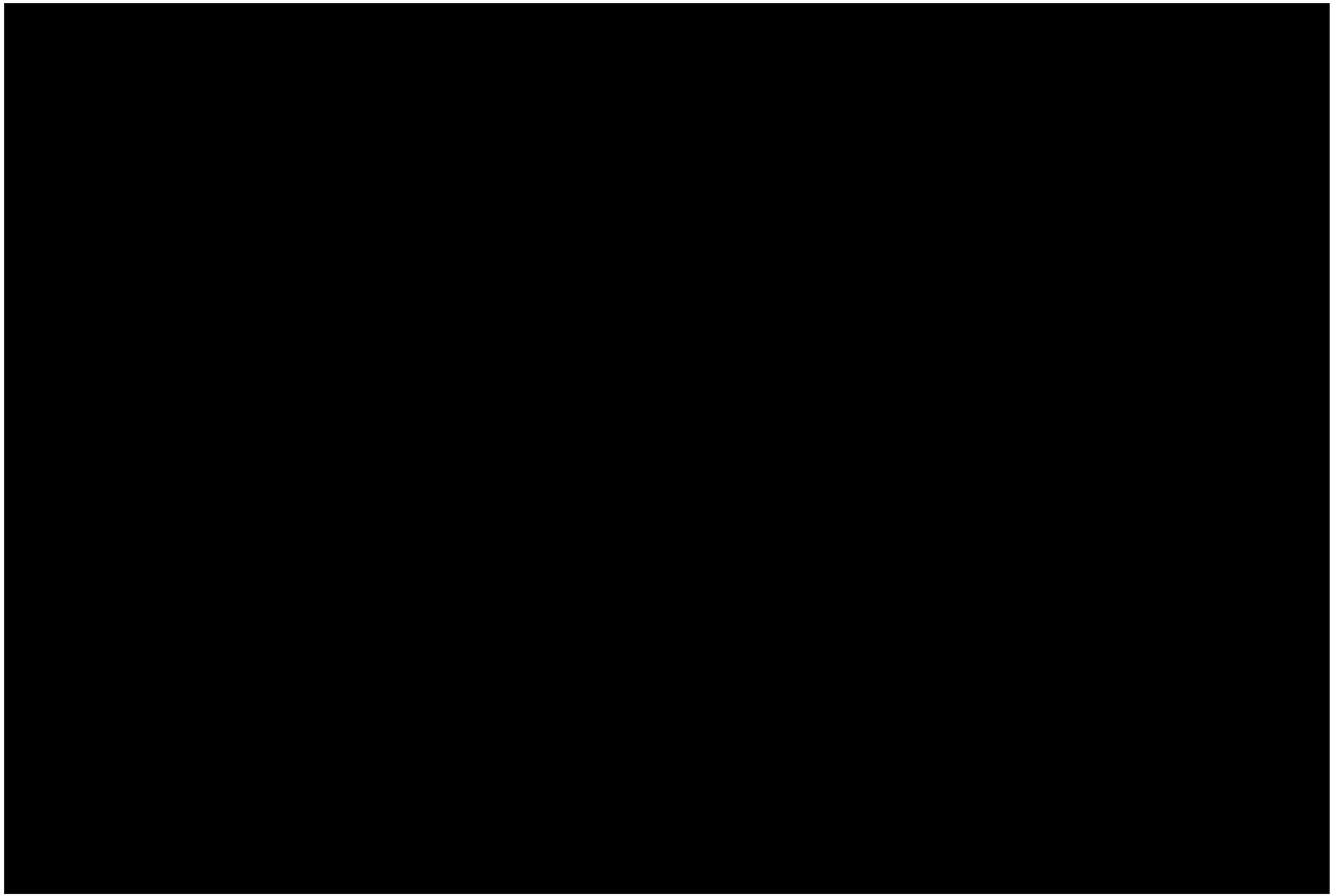
***If Asset Condition (AC) is greater than 1*, Fault Code(s) (FC):**

1 *Loose*	**2** *Worn/Aged*	**3** *Broken*	**4** *Leaking*	**5** *Missing*	**6** *Dirty*	**7** *Corrosion*	**8** *Sagging*	**9** *Noise/Vibration*	**10** *Unknown*
☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Comments: _____

Appendix F

Critical Asset List



Appendix G

10-Year Repair and Replacement Plan

City of Richmond, Virginia
Department of Public Utilities

Water Treatment Plant
10-Year Repair and Replacement Plan

December 2020

Whitman, Requardt & Associates, LLP
9030 Stony Point Parkway, Suite 220, Richmond, VA 23235

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Figures

Tables

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1 Background and Overview

This 10-Year Repair and Replacement Plan is provided as an Appendix to the City of Richmond (City) Water Treatment Plant (WTP) Condition Assessment project Technical Memorandum. The results documented in this plan were collected and cataloged as part of the WTP Condition Assessment project completed in December 2020. Asset replacement costs and condition determinations were conducted using the information gathered and calculated as part of the Facility Condition Index (FCI) and the risk analyses that were performed along with the condition assessment tasks.

Using this data, it is possible to forecast the needs related towards equipment maintenance and replacement tasks for FY 2021 through 2031. This forecast does not take into account WTP expansion/improvements, or available City budget, and is solely established based on the visual assessment on the condition of assets at the WTP and their associated risks. The intent of this plan is to provide the City with information that can be used to assist in budgeting, planning, and prioritizing WTP asset repair and replacement work.

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2 Plan Development

2.1 Identifying Asset Degradation

Before prioritizing assets for repair or replacement, it should be identified that repairs are corrective maintenance tasks, and are different from preventative maintenance, rehabilitation or replacement tasks. As referenced in the Condition Assessment project's Technical Memorandum, assets have time-based indicators that are used to assume the lifespan (time period in years) of an asset from the moment of the asset's installation or commencement. In reference to the definitions outlined in the 2018 AWWA Asset Management Definitions Guidebook and the 2015 International Infrastructure Management Manual, an asset's lifecycle typically accounts for six (6) primary "life" classifications:

Service Life – Often used interchangeably with useful life, the service life is the estimated total time period that the asset is expected to reliably and effectively serve its purpose.

Useful Life – Often used interchangeably with service life, the useful life is most normally recognized as the estimated total time period that an asset is expected to remain practical or available for use by the owner. This is the minimum of the service, design, physical, and economic life cycle periods. The reason that service life and useful life often relate to the same time period is due to the fact that the service life of an asset is normally assumed to be the minimum time period for any asset's life. The time period from any current day to the end of the useful life is known as the Remaining Useful Life.

Design Life – The assumed total time period that the asset's manufacturer expects the asset to function without rehabilitation. (AWWA, 2018)

Economic Life – The total time period in which an asset (when compared to other alternatives) is the most economical option for achieving specific level-of-service goals.

Physical Life – The total time period in which an asset's physical condition is deemed to be acceptable by the asset's owner.

Maximum Potential Life – The total time period from asset installation until asset replacement, including asset life-cycle extensions through rehabilitation tasks.

In referencing the different asset life definitions, the following key asset management terms can be defined with respect to their contributions to sustaining, maximizing, restoring, or replacing an asset's life:

Unplanned Maintenance – Maintenance that is not predetermined and includes corrective measures to restore an asset's functionality in the short-term; typically emergency work.

Planned Maintenance – Maintenance that is predetermined and includes typical maintenance that is performed while the equipment is still in working condition.

Preventative Maintenance – A form of planned maintenance that is typically enacted based on maintenance manuals or manufacturer recommendations. This form of maintenance is not condition-based and does not extend the life of an asset, but instead is used to sustain an asset's service life and maximize an asset's design life. Preventative maintenance is assumed to be necessary in order to meet the design life for the asset.

Without preventative maintenance, it is assumed that an asset's useful life would be shorter than the design life. (AWWA, 2018; IIMM, 2015)

Corrective Maintenance – Maintenance that is usually performed on an asset in order to rectify an asset's failure and restore the asset to its required level of service. This form of maintenance is not always reactive, but can be both planned or unplanned.

Repairs – A form of corrective maintenance and includes maintenance tasks that are performed in response to an asset's deficiencies, failures or faults, and/or to make up for planned maintenance neglect. Repairs do not elongate an asset's useful life, but instead restore an asset's useful life.

Rehabilitations – Restorative tasks such as rebuilding or upgrading individual asset components to meet new demands or, replacing individual asset components to partially renew overall asset performance. Rehabilitations are typically made in order to extend an asset's useful life beyond the asset's physical life, in order to reach the asset's maximum potential life.

Replacements – Renewal tasks that require full asset replacement with a brand-new asset at the end of the asset's useful life.

Once the asset has been in-service for a few years and is no longer covered by manufacturer warranty, degradation of asset components or performance becomes more likely. A common model that is used to conceptualize equipment degradation is known as the P-F Interval Model.

As shown in Figure 1, the point in an asset's life at which degradation becomes evident (visible defects, decreased performance, higher maintenance costs, etc.) can be interpreted as the point of *potential failure* (point P); however, identifying point P in an asset's lifecycle is often not a simple task without enforcing structured periodic inspections or testing. As the asset continues to operate past point P, the rate of degradation is assumed to increase until the asset's useful life has expired, theoretically known as the point of *functional failure* (point F). If the asset continues to operate past the expiration of its design life (past point F), preventative measures to avert asset failure are mostly unsuccessful and the asset needs to be replaced.

The time between point P and point F is referred to as the P-F interval, and within this interval is where assets are usually located within their lifecycle when they have a remaining useful life of 10 years or less (specifically for assets associated with the WTP), and is notably associated with the time-period in which asset rehabilitation would help extend point F past the design life. The asset condition (AC) values that were defined and assigned during the Condition Assessment project are overlain on the P-F interval model shown in Figure 1 for reference.

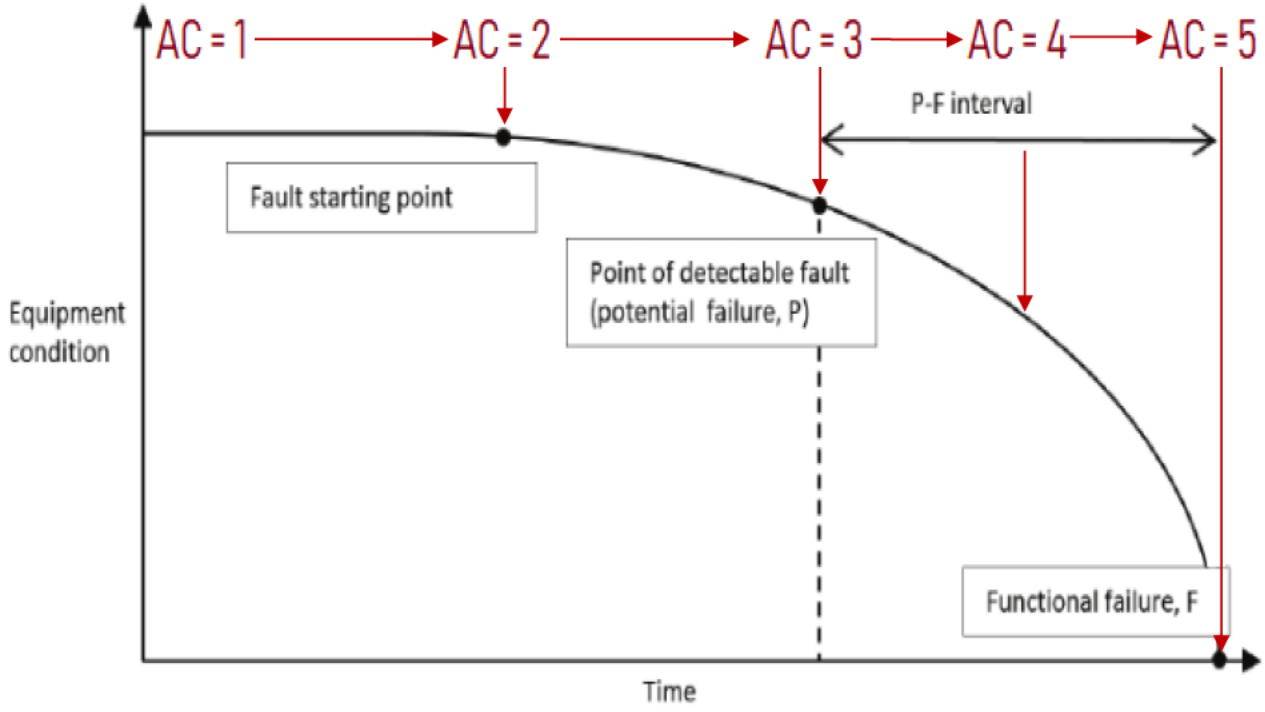

Figure 1: Degradation Curve Example
Source: 'Down Time Terms and Information Used for Assessment of Equipment Reliability and Maintenance Performance' by J. Selvik & E. Ford (2017)

2.2 Ranking of Assets for Repair and Replacement

The two primary criteria used to determine repair and replacement considerations for assets associated with the WTP are the AC (asset condition) and the remaining service life (actual or estimated as determined during the FCI analysis – based on the asset's assigned PoF). In all instances, the remaining service life of the asset is required to be ≤10 years in order to be included in this plan. To differentiate the level of attention required by each asset, the asset condition (AC) values were used to assign assets to one of four replacement groups, as listed below:

Group A – Asset requires immediate replacement within next 1-2 years (FY 2021-2022): *Asset has a remaining useful life of ≤10 years, AC is 5.*

Group B – Asset requires immediate repair and should be replaced within 5 years (FY 2023-2025): *Asset has a remaining useful life of ≤10 years, AC is 4.*

Group C – Asset requires timely repair and should be replaced within 10 years (FY 2026-2030): *Asset has a remaining useful life of ≤10 years, AC is 3.*

Group D – With repairs, asset should be capable of lasting 10 years and should be replaced in 10 years (FY2031): *Asset has a remaining useful life of ≤10 years, AC is less than 3*

An AC of 3 was chosen as the basis for the lowest level of attention since a score of 3 is indicative of the point of potential failure, point P, and is the lowest level at which repairs would most likely start being needed.

Within each group, assets were further sorted based on their calculated level of risk as determined by the risk analysis that was conducted along with the WTP Condition Assessment project. An asset's risk is defined as being equal to the consequence of asset failure (CoF) multiplied by a weighting factor, multiplied by the probability of asset failure (PoF). From the risk analysis, the following levels of risk were established:

Risk Score	Category
≤1	No Risk
1< to ≤10	Low Risk
10< to ≤30	Medium Risk
30< to ≤99	High Risk
100	Critical Risk

Table 1: Risk Score Categories

The higher the asset's risk score, the higher its rank within the replacement group. This ultimately allows for increased precision by prioritizing assets not just by their physical condition and not just by their remaining service life, but also by the asset's criticality to the WTP.

2.3 Results of Determination

A total of 635 assets have been identified as having remaining life of ≤ 10 years, which accounts for 15.0% of the total number of assets associated with the WTP (currently 4,220 following the Condition Assessment). Table 2 shows the distribution of these assets based on their Group (outlined above), and by their asset class. The majority of assets identified for replacement within 10 years are instrumentation assets or controls assets. No architectural (interior – doors, wall partitions, etc) or civil assets were determined to need replacement within 10 years; however, it should be assumed that normal repairs (asphalt patching, interior painting, etc.) should be anticipated during the plan period.

	P MECH	B MECH	INST	CONT	ELEC	SEC	STRUC	BUILD	ARCH	CIVIL	Total
Group A	4	2	20	4	19	0	0	1	0	0	**50**
Group B	19	23	2	4	34	0	1	0	0	0	**83**
Group C	46	35	24	139	33	0	0	0	0	0	**277**
Group D	24	14	116	54	11	4	0	2	0	0	**225**
Total	**93**	**74**	**162**	**201**	**97**	**4**	**1**	**3**	**0**	**0**	**635**

Table 2: Summary of Assets by Class for 10-Year Repair and Replacement

In order to further prioritize certain assets within each Group, we can compare the risk associated with each asset in each Group. A summary of the number of assets associated with each level of risk within each Group is shown in Table 3.

	Group A	Group B	Group C	Group D
No Risk	0	9	26	19
Low Risk	35	46	217	194
Medium Risk	12	20	23	8
High Risk	2	7	11	4
Critical Risk	1	1	0	0

Table 3: Summary of Assets by Risk for 10-Year Repair and Replacement

Of the 635 assets identified for repair or replacement within this plan:

- Two (2) critical-risk assets are identified. Both assets are recommended for immediate repair or replacement.
- Twenty-four (24) high-risk assets are identified. Nine (9) of which are recommended for immediate repair or replacement.
- Sixty-three (63) medium-risk assets are identified. Thirty-two (32) of which are recommended for immediate repair and replacement.
- Four hundred ninety-two (492) low-risk assets are identified. Eighty-one (81) of which are recommended for immediate repair and replacement.
- Fifty-four (54) no-risk assets are identified. None of these assets require immediate replacement, but nine (9) of the assets are recommended for immediate repair.

The eleven (11) critical and high-risk assets that are recommended for immediate repair or replacement (Group A and B assets) are listed in Table 4. Based on the City's available budget and manpower, it should be recognized that it may be in the City's best interest to prioritize higher risk assets in lower replacement groups over lower risk assets in higher replacement groups.

Section 3 includes the full list of all 635 assets. This table includes each individual asset's location, estimated replacement cost in 2020 dollars, risk, and field-identified fault code(s). The table also lists each asset in order of priority, with the highest priority assets at the top and the lowest priority assets at the bottom. Since this plan assumes that all assets will need to be replaced by FY 2031 regardless of the Group, all estimated costs are representative of full asset replacement costs, and do not include estimated repair costs.

A summary of the estimated replacement costs for each asset class and each of the four replacement groups is summarized in Table 5.

Table 4: Top 11 Critical and High Risk Assets Recommended for Immediate Repair or Replacement
[1]Replacement Cost (as defined in the Condition Assessment project's Technical Memorandum) is the estimated total material price in dollars required to replace the asset.
[2]Replacement Cost shown for [redacted] does not include additional and incidental tasks that would need to be determined during replacement. Such tasks include the [redacted] With consideration to these costs, the estimated replacement cost may be closer to $100,000/each.

2.4 Summary of WTP Needs

The priority and cost information that has been compiled as part of this plan should be used to assist in budgeting and prioritizing capital renewal projects in association with the City's existing capital improvements plan.

Since the existing City records largely do not contain maintenance cost information, it is recommended that preventative cost records are diligently accounted for in the coming years in order to track maintenance costs as a percentage of replacement values or costs for each asset. For example, if $1,000 is spent on maintenance for an asset each year, and that asset

has a replacement value of $10,000, the maintenance costs would be 10% ($1,000/$10,000) of the replacement asset value (RAV). At this rate, the total maintenance cost would outweigh the total replacement cost over the course of 10 years. If the asset has a useful life of 15 years, then it could be interpreted that too much is being spent on preventative and/or corrective maintenance for that asset. This benchmark is commonly used in the private industry where 2-4% of RAV is ideal and often expected. Unfortunately, this is not a practical benchmark for the majority of public utilities, but tracking the RAV still provides beneficial data that can be used to identify if an asset is beginning to exhibit premature failure, or if the annual asset maintenance costs are high enough to warrant the asset's rehabilitation or replacement.

The grand total replacement cost identified for all 3,584 functional and in-use assets at the WTP (in service full [ISF], in service limited [ISL], out of service inactive [OSI], and out of service maintenance [OSM] as defined in the Condition Assessment Technical Memorandum), in the James River, and in the Kanawah Canal is estimated at approximately $303.7 million. As estimated during the FCI analysis, and as based on the assigned preventative maintenance hours at an hourly, unburdened maintenance rate of $26.27/hour, the WTP should expect to budget $1.7 million for annual preventative maintenance tasks. This compensation rate was determined using an average hourly employee compensation rate for a machine maintenance worker in the state of Virginia, as sourced by the Bureau of Labor Statistics from their 2019 data on Occupational Employment and Wages. At the time of this analysis, the City's total documented lifetime-to-date maintenance costs within Mainsaver for these assets is equal to $9.43 million.

For assets identified in this repair and replacement plan, the asset class has been assigned a grand total replacement value for each of the four replacement groups (A-D). This data is summarized by asset class and replacement group in Table 5 below. The combined, rounded replacement cost for all 635 assets included within this plan is estimated at $12,374,158.

	Group A	Group B	Group C	Group D	Class Total
P MECH	$36,103	$1,850,774	$6,000,076	$219,882	**$8,106,836**
B MECH	$9,399	$69,628	$173,108	$79,143	**$331,277**
INST	$100,598	$3,700	$103,567	$273,806	**$481,671**
CONT	$8,200	$19,833	$681,870	$322,023	**$1,031,927**
ELEC	$130,179	$1,276,170	$660,883	$77,854	**$2,145,086**
SEC	$0	$0	$0	$6,300	**$6,300**
STRUC	$0	$260,000	$0	$0	**$260,000**
BUILD	$1,257	$0	$0	$9,805	**$11,062**
ARCH	$0	$0	$0	$0	**$0**
CIVIL	$0	$0	$0	$0	**$0**
TOTAL	**$285,736**	**$3,480,105**	**$7,619,504**	**$988,812**	**$12,374,158**

Table 5: Summary of Estimated Replacement Costs by Class and Group

Process mechanical assets that require repair and replacement under this plan account for approximately 66% of the total estimated replacement costs, whereas the total number of process mechanical assets only accounts for approximately 15% of the 635-total assets. Electrical assets follow; accounting for approximately 17% of the total estimated replacement costs and approximately 15% of the total number of assets.

With respect to high-value Facilities at the WTP:

1. [redacted] This is largely attributable to the anticipated replacement costs for filter components such as underdrains, integral media support caps, and washwater troughs. These assets will most likely be accounted for in the upcoming filter media, and filter actuators replacement project (anticipated within 2 years).
2. The Raw Water Pump Station and associated assets [redacted] are planned to be replaced/upgraded during the WTP's upcoming pump station upgrades project (anticipated within 2 years).
3. The assets associated with the Lime House are anticipated to be removed, deactivated, or replaced as part of the WTP's lime storage and feed improvements project (anticipated within 4 years).

Figure 2 shows the individual asset class costs and combined replacement costs for each Facility (as outlined in the FCI analysis).

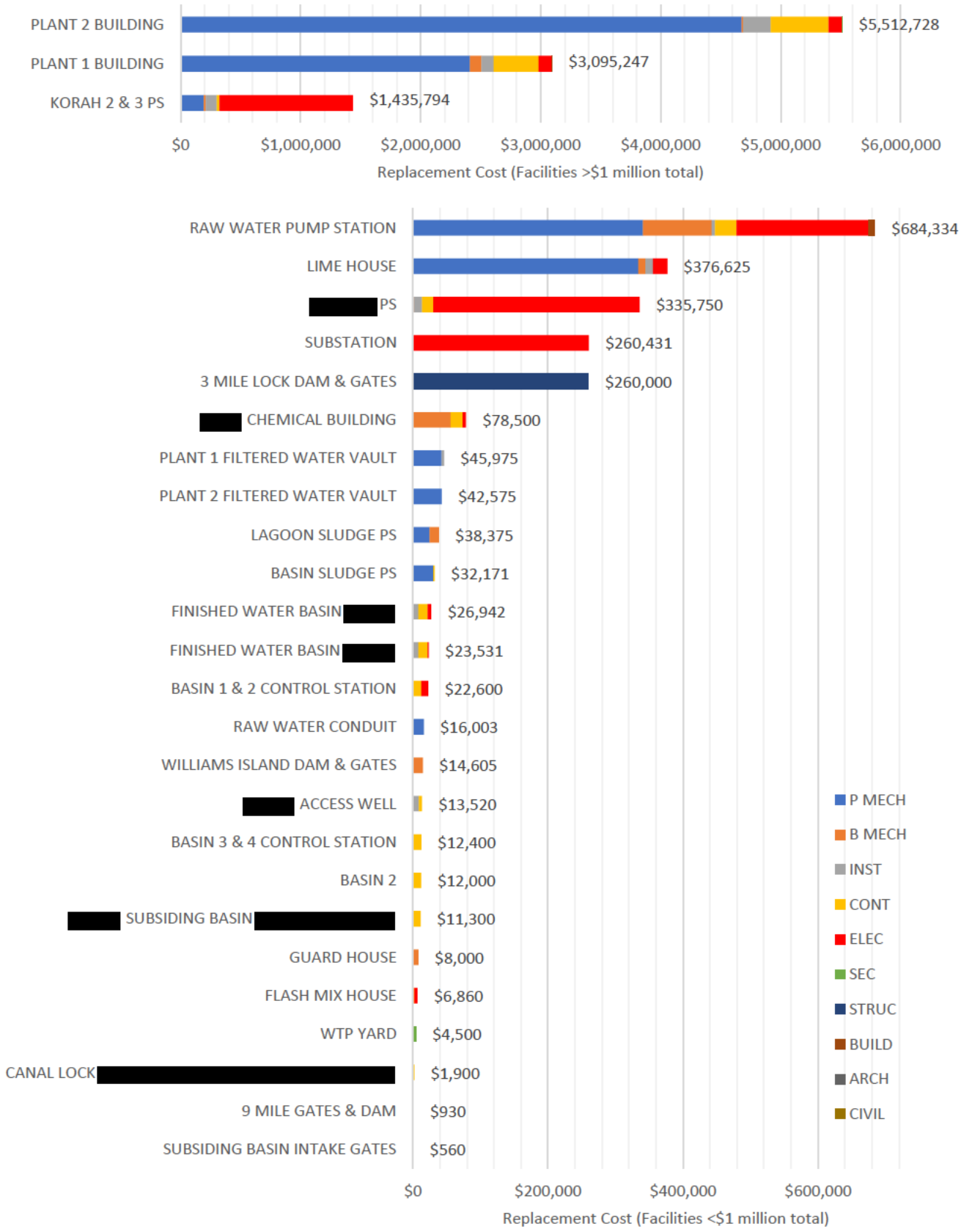

Figure 2: Cumulative 10-Year Replacement Costs by Facility

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3 Comprehensive 10-Year Repair and Replacement Asset List

The following table includes all assets identified for repair and replacement within the next 10 years. The assets are tabulated in order of priority. The primary location (Facility) of each asset is included, but the exact location (building/floor/room) may not be shown.

[redacted]	Replace Group	[redacted]	Asset No.	Replace Cost	Risk Score	Asset Class	FC
	Group A		0001271	$2,100	100	INST	8
	Group A		0016183	$1,300	40	BUILD	2, 3, 4
	Group A		0015408	$11,200	40	ELEC	10
	Group A		0001267	$3,400	15	INST	8
	Group A		0001365	$2,600	15	INST	8
	Group A		0001403	$2,400	15	INST	8
	Group A		0001367	$2,600	15	INST	8
	Group A		0015486	$16,000	15	P MECH	10
	Group A		0016093	$5,200	12	ELEC	2, 3, 5, 6
	Group A		0006546	$16,000	12	INST	8
	Group A		0012971	$14,000	12	INST	8
	Group A		0001953	$14,000	12	INST	8
	Group A		0001952	$14,000	12	INST	8
	Group A		0006134	$4,100	12	INST	8
	Group A		0006133	$4,100	12	INST	8
	Group A		0015556	$1,400	5	B MECH	3
	Group A		0011922	$8,000	5	B MECH	10
	Group A		0016385	$2,100	5	CONT	7
	Group A		0016386	$2,100	5	CONT	7
	Group A		0015976	$2,100	5	CONT	7

Group A	[redacted]	0015977	$2,100	5	CONT	7
Group A		0015384	$11,200	5	ELEC	7
Group A		0016674	$3,800	5	ELEC	10
Group A		0015470	$3,800	5	ELEC	7
Group A		0016675	$3,800	5	ELEC	10
Group A		0015473	$3,800	5	ELEC	6, 7
Group A		0016084	$3,800	5	ELEC	7
Group A		0015011	$2,100	5	ELEC	3, 5
Group A		0016282	$2,100	5	ELEC	7
Group A		0016044	$900	5	ELEC	6, 10
Group A		0015503	$4,800	5	ELEC	7
Group A		0015314	$400	5	ELEC	7
Group A		0016673	$27,100	5	ELEC	10
Group A		0015390	$27,100	5	ELEC	10
Group A		0001172	$2,400	5	INST	2, 5
Group A		0001171	$2,400	5	INST	2, 5
Group A		0001177	$2,400	5	INST	2, 5
Group A		0001174	$2,400	5	INST	2, 5
Group A		0001173	$2,400	5	INST	2, 5
Group A		0001175	$2,400	5	INST	2, 5
Group A		0001176	$2,400	5	INST	2, 5
Group A		0001170	$2,400	5	INST	2, 5
Group A		0001404	$2,100	5	INST	8
Group A		0016825	$4,800	4	ELEC	6, 7
Group A		0015371	$4,800	4	ELEC	6, 7

[redacted]	Group A	[redacted]	0015373	$4,800	4	ELEC	6, 7
	Group A		0015372	$4,800	4	ELEC	6, 7
	Group A		0001879	$6,700	1.25	P MECH	6
	Group A		0001881	$6,700	1.25	P MECH	6
	Group A		0001880	$6,700	1.25	P MECH	6
	Group B		0007428	$2,100	100	CONT	7
	Group B		0005404	$250,000	80	ELEC	2, 7, 10
	Group B		0005405	$8,300	40	ELEC	2, 7, 10
	Group B		0015023	$260,000	40	STRUC	4, 8
	Group B		0000975	$45,400	32	P MECH	4, 6
	Group B		0000974	$45,400	32	P MECH	4, 6
	Group B		0015146	$42,600	32	P MECH	6, 7
	Group B		0015148	$42,600	32	P MECH	7
	Group B		0005615	$6,400	15	CONT	6, 7
	Group B		0015016	$10,000	15	ELEC	10
	Group B		0015151	$10,000	15	ELEC	10
	Group B		0006038	$600	15	INST	2
	Group B		0001576	$3,100	15	INST	7

Group B	[redacted]	0016094	$5,200	12	ELEC	5
Group B		0011880	$4,600	12	ELEC	2, 9, 10
Group B		0011879	$4,600	12	ELEC	2, 9, 10
Group B		0015695	$124,000	12	P MECH	10
Group B		0015640	$124,000	12	P MECH	10
Group B		0015645	$124,000	12	P MECH	10
Group B		0015690	$124,000	12	P MECH	10
Group B		0015655	$124,000	12	P MECH	10
Group B		0015700	$124,000	12	P MECH	10
Group B		0015660	$124,000	12	P MECH	10
Group B		0015665	$124,000	12	P MECH	10
Group B		0015670	$124,000	12	P MECH	10
Group B		0015675	$124,000	12	P MECH	10
Group B		0015680	$124,000	12	P MECH	10
Group B		0015650	$124,000	12	P MECH	10
Group B		0006927	$400	9	B MECH	6, 7
Group B		0006925	$400	9	B MECH	6, 7
Group B		0006924	$400	9	B MECH	6, 7

[redacted]	Group B	[redacted]	0006926	$400	9	B MECH	6, 7
	Group B		0006928	$1,400	9	B MECH	6, 7
	Group B		0015819	$14,100	9	P MECH	
	Group B		0000844	$1,400	5	B MECH	2, 9, 10
	Group B		0016672	$27,100	5	ELEC	10
	Group B		0006145	$4,000	4	B MECH	2, 6
	Group B		0007425	$1,400	4	B MECH	6, 7
	Group B		0006146	$4,000	4	B MECH	2, 6
	Group B		0006143	$4,000	4	B MECH	2, 6
	Group B		0006144	$4,000	4	B MECH	2, 6
	Group B		0011865	$8,000	4	B MECH	2, 6, 7
	Group B		0000908	$8,000	4	B MECH	3, 6, 7
	Group B		0011907	$8,000	4	B MECH	2
	Group B		0015824	$0	4	B MECH	6
	Group B		0016649	$4,800	4	B MECH	10
	Group B		0005585	$900	4	ELEC	10
	Group B		0005579	$900	4	ELEC	10
	Group B		0005586	$900	4	ELEC	10
	Group B		0005578	$1,300	4	ELEC	10
	Group B		0005584	$900	4	ELEC	10
	Group B		0005577	$900	4	ELEC	10
	Group B		0005583	$900	4	ELEC	10

[redacted]	Group B	[redacted]	0011259	$1,500	4	ELEC	10
	Group B		0016036	$900	4	ELEC	6
	Group B		0013014	$7,000	4	ELEC	10
	Group B		0016125	$102,900	4	ELEC	10
	Group B		0016823	$1,500	4	ELEC	6, 7
	Group B		0005588	$90,100	4	ELEC	10
	Group B		0005337	$90,100	4	ELEC	10
	Group B		0015267	$1,500	4	ELEC	6, 7
	Group B		0016126	$102,900	4	ELEC	10
	Group B		0005336	$90,100	4	ELEC	10
	Group B		0005335	$90,100	4	ELEC	10
	Group B		0005332	$115,600	4	ELEC	10
	Group B		0005331	$115,600	4	ELEC	10
	Group B		0005330	$115,600	4	ELEC	10
	Group B		0014016	$4,100	3	B MECH	2, 9, 10
	Group B		0014017	$8,000	3	B MECH	2, 9, 10
	Group B		0016902	$4,800	3	ELEC	5, 7
	Group B		0016901	$4,800	3	ELEC	10
	Group B		0016345	$4,800	3	ELEC	5, 7
	Group B		0016344	$4,800	3	ELEC	10
	Group B		0015636	$170,500	3	P MECH	2, 4, 8

[redacted]	Group B	[redacted]	0016379	$5,700	1	CONT	2, 7
	Group B		0016377	$5,700	1	CONT	2, 7
	Group B		0005279	$2,300	1	P MECH	7
	Group B		0000853	$1,400	0.75	B MECH	7
	Group B		0000854	$1,400	0.75	B MECH	2, 7
	Group B		0000856	$1,400	0.75	B MECH	7
	Group B		0000855	$1,400	0.75	B MECH	7
	Group B		0000852	$1,400	0.75	B MECH	7
	Group B		0016396	$4,800	0.75	ELEC	2, 10
	Group C		0001356	$2,100	40	INST	7
	Group C		0016639	$5,700	32	P MECH	6, 7
	Group C		0005488	$12,300	32	P MECH	4, 7
	Group C		0001040	$13,100	32	P MECH	6
	Group C		0005458	$12,300	32	P MECH	4, 7
	Group C		0001045	$42,600	32	P MECH	
	Group C		0006490	$8,700	32	P MECH	4, 7
	Group C		0005278	$6,900	32	P MECH	4, 7
	Group C		0005429	$13,100	32	P MECH	6

[redacted]	Group C	[redacted]	0005451	$6,900	32	P MECH	
	Group C		0001026	$8,700	32	P MECH	7
	Group C		0016638	$1,900	15	CONT	6
	Group C		0015143	$2,100	15	INST	7
	Group C		0001226	$2,100	15	INST	7
	Group C		0011928	$6,700	12	B MECH	7
	Group C		0000798	$6,700	12	B MECH	7
	Group C		0006627	$5,700	12	CONT	10
	Group C		0006039	$11,400	12	CONT	6, 7
	Group C		0006628	$5,700	12	CONT	10
	Group C		0005504	$5,200	12	ELEC	10
	Group C		0005446	$28,400	12	ELEC	10
	Group C		0005445	$28,400	12	ELEC	10
	Group C		0001017	$250,000	12	P MECH	3, 6, 7
	Group C		0015705	$217,000	12	P MECH	10
	Group C		0015685	$217,000	12	P MECH	10
	Group C		0015725	$217,000	12	P MECH	10
	Group C		0015630	$217,000	12	P MECH	10
	Group C		0015635	$217,000	12	P MECH	10
	Group C		0015715	$217,000	12	P MECH	10

[redacted]	Group C	[redacted]	0015735	$217,000	12	P MECH	10
	Group C		0015710	$217,000	12	P MECH	10
	Group C		0015720	$217,000	12	P MECH	10
	Group C		0015730	$217,000	12	P MECH	10
	Group C		0000894	$13,800	12	P MECH	6, 7
	Group C		0015409	$13,700	9	B MECH	6
	Group C		0006885	$1,400	9	B MECH	6, 7
	Group C		0006886	$1,400	9	B MECH	6, 7
	Group C		0006888	$1,400	9	B MECH	6, 7
	Group C		0006887	$1,400	9	B MECH	6, 7
	Group C		0006312	$700	9	ELEC	10
	Group C		0005400	$1,500	9	ELEC	10
	Group C		0006943	$217,000	9	P MECH	10
	Group C		0006942	$217,000	9	P MECH	10
	Group C		0006941	$217,000	9	P MECH	10
	Group C		0006944	$217,000	9	P MECH	10
	Group C		0006938	$217,000	9	P MECH	10
	Group C		0006945	$217,000	9	P MECH	10
	Group C		0006940	$217,000	9	P MECH	10
	Group C		0006946	$217,000	9	P MECH	10
	Group C		0006937	$217,000	9	P MECH	10
	Group C		0006947	$217,000	9	P MECH	10
	Group C		0006948	$217,000	9	P MECH	10

[redacted]	Group C	[redacted]	0006939	$217,000	9	P MECH	10
	Group C		0016088	$900	6	ELEC	7
	Group C		0006770	$5,300	5	CONT	2, 7
	Group C		0015199	$6,400	5	CONT	7
	Group C		0015183	$6,400	5	CONT	7
	Group C		0006097	$4,800	5	CONT	7
	Group C		0015215	$3,100	5	CONT	7
	Group C		0006099	$5,900	5	CONT	7
	Group C		0006778	$4,800	5	CONT	2, 7
	Group C		0006100	$5,900	5	CONT	7
	Group C		0015191	$6,400	5	CONT	7
	Group C		0006101	$3,100	5	CONT	7
	Group C		0015207	$3,100	5	CONT	7
	Group C		0006102	$4,800	5	CONT	7
	Group C		0006766	$5,300	5	CONT	2, 7
	Group C		0006103	$4,800	5	CONT	7
	Group C		0006774	$4,800	5	CONT	2, 7
	Group C		0006104	$5,900	5	CONT	7
	Group C		0006782	$4,800	5	CONT	2, 7
	Group C		0006105	$5,900	5	CONT	7
	Group C		0015187	$6,400	5	CONT	7
	Group C		0006106	$4,800	5	CONT	7
	Group C		0015195	$6,400	5	CONT	7

[redacted]	Group C	[redacted]	0006107	$5,900	5	CONT	7
	Group C		0015203	$6,400	5	CONT	7
	Group C		0006108	$5,900	5	CONT	7
	Group C		0015211	$3,100	5	CONT	7
	Group C		0006109	$3,100	5	CONT	7
	Group C		0006095	$3,100	5	CONT	7
	Group C		0006110	$4,800	5	CONT	7
	Group C		0006768	$5,300	5	CONT	2, 7
	Group C		0006111	$5,900	5	CONT	7
	Group C		0006772	$4,800	5	CONT	2, 7
	Group C		0006112	$5,900	5	CONT	7
	Group C		0006776	$4,800	5	CONT	2, 7
	Group C		0006113	$5,900	5	CONT	7
	Group C		0006780	$4,800	5	CONT	2, 7
	Group C		0006114	$3,100	5	CONT	7
	Group C		0006115	$4,800	5	CONT	7
	Group C		0015185	$6,400	5	CONT	7
	Group C		0006116	$4,800	5	CONT	7
	Group C		0015189	$6,400	5	CONT	7
	Group C		0006117	$5,900	5	CONT	7
	Group C		0015193	$6,400	5	CONT	7
	Group C		0006118	$5,900	5	CONT	7

[redacted]	Group C	[redacted]	0015197	$6,400	5	CONT	7
	Group C		0006119	$5,900	5	CONT	7
	Group C		0015201	$6,400	5	CONT	7
	Group C		0006120	$3,100	5	CONT	7
	Group C		0015205	$6,400	5	CONT	7
	Group C		0006121	$4,800	5	CONT	7
	Group C		0015209	$3,100	5	CONT	7
	Group C		0006093	$5,900	5	CONT	7
	Group C		0015213	$3,100	5	CONT	7
	Group C		0006094	$5,900	5	CONT	7
	Group C		0015217	$3,100	5	CONT	7
	Group C		0006762	$5,300	5	CONT	2, 7
	Group C		0006764	$5,300	5	CONT	2, 7
	Group C		0006122	$4,800	5	CONT	7
	Group C		0006761	$5,300	5	CONT	2, 7
	Group C		0006123	$5,900	5	CONT	7
	Group C		0006763	$5,300	5	CONT	2, 7
	Group C		0006124	$5,900	5	CONT	7
	Group C		0006765	$5,300	5	CONT	2, 7
	Group C		0006125	$5,900	5	CONT	7
	Group C		0006767	$5,300	5	CONT	2, 7
	Group C		0006126	$3,100	5	CONT	7
	Group C		0006769	$5,300	5	CONT	2, 7
	Group C		0006127	$4,800	5	CONT	7

[redacted]	Group C	[redacted]	0006771	$5,300	5	CONT	2, 7
	Group C		0006128	$4,800	5	CONT	7
	Group C		0006773	$4,800	5	CONT	2, 7
	Group C		0006135	$5,900	5	CONT	7
	Group C		0006775	$4,800	5	CONT	2, 7
	Group C		0006136	$5,900	5	CONT	7
	Group C		0006777	$4,800	5	CONT	2, 7
	Group C		0006137	$5,900	5	CONT	7
	Group C		0006779	$4,800	5	CONT	2, 7
	Group C		0006138	$3,100	5	CONT	7
	Group C		0006781	$4,800	5	CONT	2, 7
	Group C		0006139	$4,800	5	CONT	7
	Group C		0006783	$4,800	5	CONT	2, 7
	Group C		0006140	$4,800	5	CONT	7
	Group C		0006160	$5,900	5	CONT	7
	Group C		0015184	$6,400	5	CONT	7
	Group C		0006161	$5,900	5	CONT	7
	Group C		0015186	$6,400	5	CONT	7
	Group C		0006162	$5,900	5	CONT	7
	Group C		0015188	$6,400	5	CONT	7
	Group C		0006163	$3,100	5	CONT	7

[redacted]	Group C	[redacted]	0015190	$6,400	5	CONT	7
	Group C		0006164	$4,800	5	CONT	7
	Group C		0015192	$6,400	5	CONT	7
	Group C		0006165	$4,800	5	CONT	7
	Group C		0015194	$6,400	5	CONT	2
	Group C		0006166	$5,900	5	CONT	7
	Group C		0015196	$6,400	5	CONT	7
	Group C		0006167	$5,900	5	CONT	7
	Group C		0015198	$6,400	5	CONT	7
	Group C		0006168	$5,900	5	CONT	7
	Group C		0015200	$6,400	5	CONT	7
	Group C		0006169	$3,100	5	CONT	7
	Group C		0015202	$6,400	5	CONT	7
	Group C		0006170	$4,800	5	CONT	7
	Group C		0015204	$6,400	5	CONT	7
	Group C		0006171	$4,800	5	CONT	7
	Group C		0015206	$6,400	5	CONT	7
	Group C		0006172	$5,900	5	CONT	7
	Group C		0015208	$3,100	5	CONT	7
	Group C		0006173	$5,900	5	CONT	7
	Group C		0015210	$3,100	5	CONT	7
	Group C		0006174	$5,900	5	CONT	7
	Group C		0015212	$3,100	5	CONT	7
	Group C		0006175	$3,100	5	CONT	7

[redacted]	Group C	[redacted]	0015214	$3,100	5	CONT	7
	Group C		0006176	$4,800	5	CONT	7
	Group C		0015216	$3,100	5	CONT	7
	Group C		0006177	$4,800	5	CONT	7
	Group C		0015218	$3,100	5	CONT	7
	Group C		0006337	$6,400	5	CONT	7
	Group C		0006760	$5,300	5	CONT	2, 7
	Group C		0001633	$2,100	5	CONT	6
	Group C		0016603	$1,100	5	CONT	7
	Group C		0007781	$4,100	5	CONT	7
	Group C		0005349	$4,100	5	CONT	7
	Group C		0005350	$4,100	5	CONT	7
	Group C		0006411	$2,100	5	CONT	7
	Group C		0007031	$1,700	5	CONT	7
	Group C		0007030	$1,700	5	CONT	7
	Group C		0006412	$2,100	5	CONT	7
	Group C		0011658	$3,100	5	CONT	7
	Group C		0006499	$1,700	5	CONT	7
	Group C		0006500	$1,700	5	CONT	7

[redacted]	Group C	[redacted]	0006735	$6,200	5	INST	2, 7
	Group C		0006742	$7,800	5	INST	2, 7
	Group C		0006737	$6,200	5	INST	2, 7
	Group C		0006729	$6,200	5	INST	2, 7
	Group C		0006734	$6,200	5	INST	2, 7
	Group C		0006730	$6,200	5	INST	2, 7
	Group C		0006736	$6,200	5	INST	2, 7
	Group C		0006731	$6,200	5	INST	2, 7
	Group C		0006738	$6,200	5	INST	2, 7
	Group C		0006727	$6,200	5	INST	2, 7
	Group C		0006728	$6,200	5	INST	2, 7
	Group C		0006733	$6,200	5	INST	2, 7
	Group C		0006732	$6,200	5	INST	2, 7
	Group C		0015847	$8,000	4	B MECH	10
	Group C		0011906	$8,000	4	B MECH	2
	Group C		0011918	$8,000	4	B MECH	6
	Group C		0012664	$8,000	4	B MECH	2

[redacted]	Group C	[redacted]	0012392	$1,100	4	B MECH	3
	Group C		0012176	$1,100	4	B MECH	3
	Group C		0005431	$5,900	4	CONT	6, 7
	Group C		0005430	$5,900	4	CONT	6, 7
	Group C		0015239	$8,000	3	B MECH	10
	Group C		0012559	$8,000	3	B MECH	2, 6
	Group C		0015238	$8,000	3	B MECH	10
	Group C		0016648	$1,200	3	B MECH	3, 10
	Group C		0016647	$1,200	3	B MECH	3, 10
	Group C		0016510	$1,100	3	B MECH	10
	Group C		0012391	$1,100	3	B MECH	10
	Group C		0012390	$1,100	3	B MECH	10
	Group C		0006088	$1,100	3	B MECH	6
	Group C		0006081	$1,100	3	B MECH	10
	Group C		0006080	$1,100	3	B MECH	10
	Group C		0006085	$1,100	3	B MECH	10
	Group C		0012387	$1,100	3	B MECH	7
	Group C		0016907	$2,100	3	CONT	2, 7, 10
	Group C		0005582	$900	3	ELEC	10
	Group C		0005581	$900	3	ELEC	10

[redacted]	Group C	[redacted]	0005580	$900	3	ELEC	10
	Group C		0015568	$1,400	3	ELEC	7
	Group C		0015567	$1,400	3	ELEC	7
	Group C		0007011	$6,000	3	ELEC	10
	Group C		0016820	$1,600	3	ELEC	6, 7
	Group C		0005448	$21,000	3	ELEC	2, 6
	Group C		0005962	$7,200	3	ELEC	2, 6, 7
	Group C		0005333	$130,000	3	ELEC	10
	Group C		0005963	$7,200	3	ELEC	2, 6, 7
	Group C		0005447	$21,000	3	ELEC	2, 6
	Group C		0005964	$7,200	3	ELEC	2, 6, 7
	Group C		0005587	$90,100	3	ELEC	10
	Group C		0007008	$6,000	3	ELEC	10
	Group C		0005334	$130,000	3	ELEC	10
	Group C		0007009	$6,000	3	ELEC	10
	Group C		0005745	$28,000	3	ELEC	2, 6
	Group C		0007010	$6,000	3	ELEC	10
	Group C		0005744	$26,400	3	ELEC	2, 6
	Group C		0016128	$4,800	3	ELEC	7
	Group C		0015656	$170,500	3	P MECH	2, 3, 6

[redacted]	Group C	[redacted]	0015641	$170,500	3	P MECH	2, 3, 6
	Group C		0015651	$170,500	3	P MECH	2, 6, 8
	Group C		0015003	$27,100	1.25	ELEC	2, 10
	Group C		0016830	$27,100	1.25	ELEC	2, 10
	Group C		0016829	$27,100	1.25	ELEC	2, 10
	Group C		0001366	$2,600	1.25	INST	
	Group C		0002126	$2,400	1.25	INST	
	Group C		0001368	$2,600	1.25	INST	
	Group C		0001370	$2,600	1.25	INST	
	Group C		0005595	$900	1	ELEC	6
	Group C		0001933	$1,200	1	INST	6
	Group C		0001932	$1,200	1	INST	6
	Group C		0001930	$1,200	1	INST	6
	Group C		0001931	$1,200	1	INST	6
	Group C		0016077	$5,000	1	P MECH	6
	Group C		0016075	$5,000	1	P MECH	6
	Group C		0016074	$5,000	1	P MECH	6
	Group C		0000916	$75,000	1	P MECH	6
	Group C		0016076	$5,000	1	P MECH	6
	Group C		0000917	$75,000	1	P MECH	6
	Group C		0000915	$75,000	1	P MECH	6

[redacted]	Group C	[redacted]	0000918	$75,000	1	P MECH	6
	Group C		0006014	$6,900	0.75	B MECH	7
	Group C		0006015	$13,700	0.75	B MECH	7
	Group C		0016766	$13,700	0.75	B MECH	6
	Group C		0015019	$13,700	0.75	B MECH	7
	Group C		0015020	$13,700	0.75	B MECH	7
	Group C		0000861	$1,400	0.75	B MECH	6, 7
	Group C		0000860	$1,400	0.75	B MECH	5, 6, 7
	Group C		0000857	$1,400	0.75	B MECH	3, 5, 6, 7
	Group C		0015521	$4,800	0.75	B MECH	
	Group C		0016587	$2,100	0.75	CONT	2, 6, 7
	Group C		0016558	$4,800	0.75	ELEC	2, 6, 7
	Group C		0016397	$4,800	0.75	ELEC	2, 10
	Group C		0016641	$600	0.25	P MECH	6, 7
	Group D		0015175	$6,900	80	P MECH	7
	Group D		0015312	$15,000	60	P MECH	
	Group D		0012127	$3,400	32	INST	7
	Group D		0015487	$16,000	32	P MECH	7

Group D	[redacted]	0011367	$2,100	15	INST	
Group D		0001222	$2,100	15	INST	7
Group D		0001656	$2,300	12	CONT	6
Group D		0001655	$2,300	12	CONT	6
Group D		0001650	$400	12	INST	6
Group D		0001651	$400	12	INST	6
Group D		0001645	$4,100	12	INST	6
Group D		0001644	$4,100	12	INST	6
Group D		0015233	$13,700	9	B MECH	6
Group D		0016755	$5,100	9	CONT	6
Group D		0016746	$5,100	6	CONT	
Group D		0016745	$5,100	6	CONT	
Group D		0005596	$900	6	ELEC	
Group D		0016821	$26,400	6	ELEC	6
Group D		0016822	$26,400	6	ELEC	6
Group D		0011256	$5,600	5	CONT	6
Group D		0011257	$5,600	5	CONT	6
Group D		0007782	$4,100	5	CONT	
Group D		0016284	$2,100	5	ELEC	10
Group D		0016283	$2,100	5	ELEC	10

[redacted]	Group D	[redacted]	0005589	$900	5	INST	7
	Group D		0006395	$1,100	5	INST	2
	Group D		0006179	$1,100	5	INST	2
	Group D		0006217	$700	5	INST	2
	Group D		0006221	$700	5	INST	2
	Group D		0006219	$700	5	INST	2
	Group D		0006211	$700	5	INST	2
	Group D		0006216	$700	5	INST	2
	Group D		0006212	$700	5	INST	2
	Group D		0006218	$700	5	INST	2
	Group D		0006213	$700	5	INST	2
	Group D		0006220	$700	5	INST	2
	Group D		0006214	$700	5	INST	2
	Group D		0006210	$700	5	INST	2
	Group D		0006215	$700	5	INST	2
	Group D		0006048	$2,100	5	INST	7
	Group D		0012713	$8,000	4	B MECH	2, 3, 6
	Group D		0015842	$8,000	4	B MECH	2, 3, 6
	Group D		0016369	$4,900	4	BUILD	2, 3
	Group D		0016365	$4,900	4	BUILD	2, 3
	Group D		0011993	$5,000	4	CONT	2
	Group D		0011992	$5,000	4	CONT	2

[redacted]	Group D	[redacted]	0011990	$8,900	4	CONT	2
	Group D		0011991	$8,900	4	CONT	2
	Group D		0006130	$14,000	4	INST	
	Group D		0006129	$14,000	4	INST	
	Group D		0011656	$3,100	4	INST	6
	Group D		0007766	$400	4	INST	6
	Group D		0007777	$400	4	INST	6
	Group D		0007775	$400	4	INST	6
	Group D		0007767	$400	4	INST	6
	Group D		0007779	$500	4	INST	6
	Group D		0007768	$400	4	INST	6
	Group D		0007774	$400	4	INST	6
	Group D		0007769	$400	4	INST	6
	Group D		0007776	$400	4	INST	6
	Group D		0007770	$400	4	INST	6
	Group D		0007778	$4,100	4	INST	6, 7
	Group D		0009293	$4,100	4	INST	7
	Group D		0009234	$4,100	4	INST	7
	Group D		0007772	$400	4	INST	6
	Group D		0007773	$400	4	INST	6
	Group D		0007771	$400	4	INST	6
	Group D		0012006	$2,100	4	INST	2
	Group D		0011662	$2,100	4	INST	2

[redacted]	Group D	[redacted]	0012016	$2,000	4	INST	2
	Group D		0012017	$2,000	4	INST	2
	Group D		0012005	$2,100	4	INST	2
	Group D		0016011	$2,100	4	INST	
	Group D		0012015	$2,000	4	INST	2
	Group D		0016867	$2,100	4	INST	2
	Group D		0011661	$2,100	4	INST	2
	Group D		0012018	$2,000	4	INST	2
	Group D		0006393	$2,100	4	INST	7
	Group D		0006394	$2,100	4	INST	7
	Group D		0016012	$2,100	4	INST	2
	Group D		0001893	$10,000	4	P MECH	6, 7
	Group D		0001892	$10,000	4	P MECH	6, 7
	Group D		0001894	$10,000	4	P MECH	6, 7
	Group D		0015840	$16,000	4	P MECH	7
	Group D		0016332	$17,600	4	P MECH	7
	Group D		0016328	$17,600	4	P MECH	7
	Group D		0011310	$1,600	4	P MECH	
	Group D		0011322	$1,600	4	P MECH	
	Group D		0016337	$14,100	4	P MECH	7

[redacted]	Group D	[redacted]	0011312	$1,600	4	P MECH	
	Group D		0015841	$16,000	4	P MECH	7
	Group D		0011314	$1,600	4	P MECH	
	Group D		0016330	$17,600	4	P MECH	7
	Group D		0015307	$3,400	4	P MECH	6, 7
	Group D		0016333	$14,100	4	P MECH	7
	Group D		0011318	$1,600	4	P MECH	
	Group D		0011316	$1,600	4	P MECH	
	Group D		0011320	$1,600	4	P MECH	
	Group D		0012379	$1,500	4	SEC	
	Group D		0012381	$1,500	4	SEC	
	Group D		0012380	$1,500	4	SEC	
	Group D		0000843	$1,400	3	B MECH	10
	Group D		0012999	$1,400	3	B MECH	10
	Group D		0000839	$1,400	3	B MECH	6
	Group D		0012919	$8,000	3	B MECH	10
	Group D		0011905	$8,000	3	B MECH	10
	Group D		0007449	$4,800	3	B MECH	10
	Group D		0006330	$12,000	3	CONT	
	Group D		0006328	$12,000	3	CONT	
	Group D		0016753	$6,200	3	CONT	
	Group D		0015740	$6,200	3	CONT	

[redacted]	Group D	[redacted]	0016754	$6,200	3	CONT	
	Group D		0006327	$12,000	3	INST	
	Group D		0001955	$12,000	3	INST	
	Group D		0001954	$12,000	3	INST	
	Group D		0011416	$2,400	3	INST	
	Group D		0011414	$2,600	3	INST	
	Group D		0011377	$2,400	3	INST	
	Group D		0011379	$2,400	3	INST	
	Group D		0011378	$2,400	3	INST	
	Group D		0011381	$2,400	3	INST	
	Group D		0011380	$2,400	3	INST	
	Group D		0011376	$2,400	3	INST	
	Group D		0011389	$2,400	3	INST	
	Group D		0001161	$2,700	3	INST	2
	Group D		0011360	$2,100	3	INST	
	Group D		0001190	$2,700	3	INST	2
	Group D		0001191	$2,700	3	INST	2
	Group D		0011372	$2,100	3	INST	
	Group D		0001192	$2,700	3	INST	2
	Group D		0001165	$2,700	3	INST	2
	Group D		0001193	$2,700	3	INST	2
	Group D		0001158	$2,700	3	INST	2

[redacted]	Group D	[redacted]	0001194	$2,700	3	INST	2
	Group D		0011366	$2,100	3	INST	6
	Group D		0001195	$2,700	3	INST	2
	Group D		0011415	$2,100	3	INST	6
	Group D		0001196	$2,700	3	INST	2
	Group D		0001163	$2,700	3	INST	2
	Group D		0001197	$2,700	3	INST	2
	Group D		0001167	$2,700	3	INST	2
	Group D		0001198	$2,700	3	INST	2
	Group D		0001157	$2,700	3	INST	2
	Group D		0001150	$2,700	3	INST	2
	Group D		0011359	$2,100	3	INST	
	Group D		0001151	$2,700	3	INST	2
	Group D		0011361	$2,100	3	INST	
	Group D		0001201	$2,700	3	INST	2
	Group D		0001159	$2,700	3	INST	2
	Group D		0001152	$2,700	3	INST	
	Group D		0011373	$2,100	3	INST	
	Group D		0001153	$2,700	3	INST	2
	Group D		0001160	$2,700	3	INST	2
	Group D		0001349	$2,100	3	INST	7
	Group D		0001162	$2,700	3	INST	2

[redacted]	Group D	[redacted]	0001350	$2,100	3	INST	
	Group D		0001164	$2,700	3	INST	2
	Group D		0001154	$2,700	3	INST	2
	Group D		0001166	$2,700	3	INST	2
	Group D		0001155	$2,700	3	INST	2
	Group D		0001168	$2,700	3	INST	2
	Group D		0006047	$2,100	3	INST	7
	Group D		0001156	$2,700	3	INST	2
	Group D		0001199	$2,700	3	INST	2
	Group D		0001149	$2,700	3	INST	2
	Group D		0001200	$2,700	3	INST	2
	Group D		0011393	$300	3	INST	
	Group D		0011395	$300	3	INST	
	Group D		0011394	$300	3	INST	
	Group D		0011391	$300	3	INST	
	Group D		0011390	$300	3	INST	
	Group D		0011392	$300	3	INST	
	Group D		0016173	$1,800	3	SEC	6
	Group D		0007422	$0	2	B MECH	
	Group D		0005593	$900	2	CONT	6
	Group D		0015733	$6,200	2	CONT	
	Group D		0016749	$5,100	2	CONT	
	Group D		0015643	$6,200	2	CONT	
	Group D		0015663	$6,200	2	CONT	

[redacted]	Group D	[redacted]	0015723	$6,200	2	CONT	
	Group D		0015668	$6,200	2	CONT	
	Group D		0015843	$5,100	2	CONT	
	Group D		0015673	$6,200	2	CONT	
	Group D		0016747	$5,100	2	CONT	
	Group D		0015678	$6,200	2	CONT	
	Group D		0015658	$6,200	2	CONT	
	Group D		0015683	$6,200	2	CONT	
	Group D		0015628	$6,200	2	CONT	
	Group D		0015688	$6,200	2	CONT	
	Group D		0015638	$6,200	2	CONT	
	Group D		0015693	$6,200	2	CONT	
	Group D		0016404	$4,000	2	CONT	
	Group D		0015698	$6,200	2	CONT	
	Group D		0015648	$6,200	2	CONT	
	Group D		0015633	$6,200	2	CONT	
	Group D		0016748	$5,100	2	CONT	
	Group D		0016757	$6,200	2	CONT	
	Group D		0015653	$6,200	2	CONT	
	Group D		0015713	$6,200	2	CONT	
	Group D		0015718	$6,200	2	CONT	
	Group D		0015703	$6,200	2	CONT	
	Group D		0015708	$6,200	2	CONT	

[redacted]	Group D	[redacted]	0015728	$6,200	2	CONT	
	Group D		0015419	$5,100	2	ELEC	10
	Group D		0012154	$0	2	ELEC	
	Group D		0005995	$21,200	2	P MECH	6, 7
	Group D		0015973	$6,200	1	CONT	
	Group D		0016750	$6,200	1	CONT	
	Group D		0016751	$6,200	1	CONT	
	Group D		0015974	$6,200	1	CONT	
	Group D		0016118	$5,100	1	ELEC	
	Group D		0016117	$5,100	1	ELEC	
	Group D		0000858	$1,400	0.75	B MECH	6, 7
	Group D		0000859	$1,400	0.75	B MECH	6, 7
	Group D		0015969	$8,000	0.75	B MECH	6
	Group D		0016561	$4,800	0.75	ELEC	5, 6
	Group D		0005280	$2,300	0.75	P MECH	7
	Group D		0015471	$13,700	0.25	B MECH	
	Group D		0016752	$6,200	0.25	CONT	
	Group D		0016756	$6,200	0.25	CONT	
	Group D		0016140	$5,100	0.25	CONT	
	Group D		0015844	$6,200	0.25	CONT	

[redacted]		[redacted]					
	Group D		0013023	$0	0.25	ELEC	
	Group D		0001643	$900	0.25	INST	
	Group D		0016642	$900	0.25	P MECH	6

Table 6: 10-Year Repair and Replacement Comprehensive Data List
[1]Replacement Costs are rounded to the nearest $100, and are estimates based on 2020 dollars. All replacement costs were estimated and assigned during the FCI analysis, using the FCI methodology as outlined within the Condition Assessment Technical Memorandum.

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