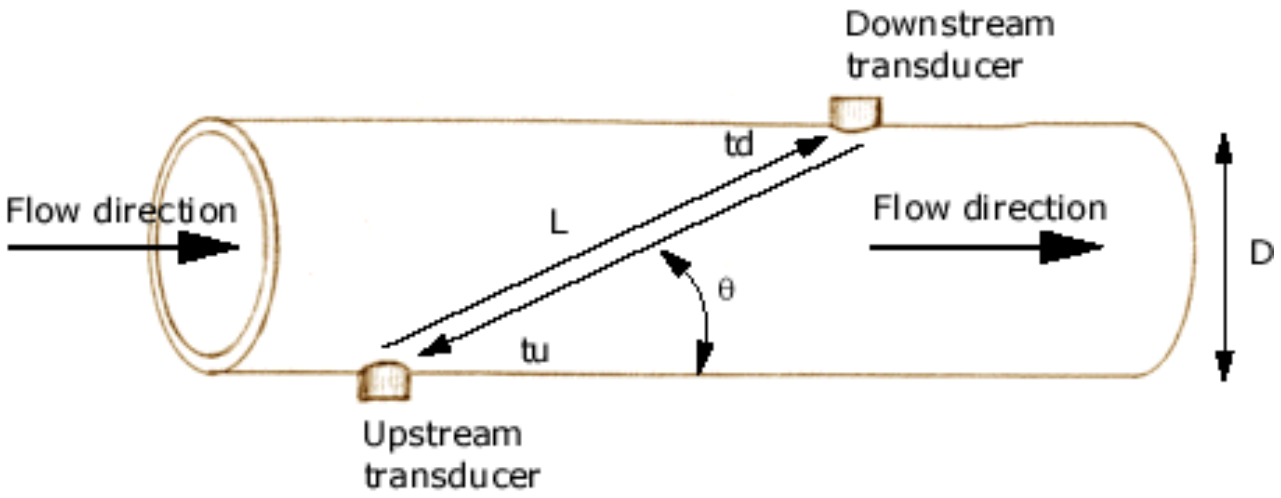
Meter Basics and Failure Modes

Basis for Potential Path Forward Options

Agenda

- Transmit Time Meter Basics
- Failure Modes – NOT like mechanical meters
  - Sneak
  - Conditional
- What do we suspect
  - What do we know
  - What do we NOT know
- Potential Path Forward Options
- Recommendations

Transmit Time Ultra Sonic Flow Meter



$$V = \frac{L^2}{8X}\left[\frac{(t_u + t_d)^2 (t_u - t_d)}{t_u^2 t_d^2}\right]$$

$$\approx \frac{L^2 \Delta t}{2X t_u t_d}$$

Notice the +/- signs

$$\begin{cases} t_d = \dfrac{L}{c + V\cos\theta} \\ t_u = \dfrac{L}{c - V\cos\theta} \end{cases}$$

c is the speed of sound in the fluid, V is the flow velocity, L is the distance between the transducers and theta is the angle between the flow direction and the line formed by the transducers

Design

- Utilizes a pulsed ultrasonic signal – a chirp to measure velocity
- The transducers are really just microphones and speakers (piezo electronic)
- The measured velocity is utilized to calculate the flow volume by using the flow area assuming normalize flow distribution across the area
- To save battery life, only “chirps” at some interval – NOT continuously
  - The integration of the volume must assume the last velocity measurement over the time between the “chirps” to totalize the volume
- At very low flow rates, the delta t (time) between signals is very small
- As the flow rate increases, the difference in transmit time grows much larger
- I suspect, that in order to have relatively high accuracy across the range of flows being measured, Badger may change or modulate the “chirp” interval to improve the metering – adaptive measurement

Key Failure Concept

- A failure to detect the ultrasonic signal has ramifications into the measurement calculations
  - Failure to detect one direction with the other direction still working can result in:
    - Measuring a velocity that is significantly larger – calculated over the transmit time from the next “chirp”
    - Indicating a reverse flow
    - This can be due to a
      - Speaker not working – fail to transmit
      - Microphone not detecting – fail to detect
      - Potentially some noise in the ultrasonic range masking the transmitted signal
    - Certain external conditions may also potentially attenuate the signals
      - Slime in the meter
      - Debris in the meter
      - Air in the meter – Badger has an error detection for this
- This technology has the potential to fail both low AND high
  - Old mechanical displaced flow volume meters could only fail low

Electronics

- Meter does the following actions – basic steps
  - Determines when to send a “chirp” – sends the ultrasonic signal
  - Detects the signal and measures the transmit times
  - Calculates the velocity
  - Calculates the flow (velocity X meter area)
  - Calculates the flow volume (measured flow X time duration between “chirps”)
  - Totalizes (integrates) the flow volume (add up all the flow volumes)
  - Transmits the totalized flow to the external I-Tron data recorder at some interval utilizing some data transfer protocol
- All of this is done with solid state hardware and lines of software code
- The data management and transmittal to external data storage is done utilizing some network type digital protocol

Typical Electronics Failures

- Like all of our computers and other electronic devices, these meters have potential failure modes
- Who has had your keyboard to suddenly have different behavior?
- Who has had their device to lock-up and require down powering and reboot?
- Memory registry over-flow or lock-up?
- Data highway bad connection that intermittently cause signal reflection and cause poor data transfer, dropped bits, errors, etc.

- While the meter is a special purpose computer-based microprocessor that is significantly simpler than a general-purpose computer, it potentially can have problems
  - Designers of such devices typically manage these types of issues by building in mitigating actions – make it reboot at some interval as an example

Sneak Failures

- There is one class of failure modes that may be applicable to the suspected issue
- Sneak failures are unintended current paths (or logic paths) in a design that can cause intermittent or unexplained behaviors
  - Identified by NASA as root cause of some mission failures/unexplained behavior
  - NASA - Ungrounded chip example
  - Steam turbine extraction example
- Sneak failures can be both hardware (intermittent current leakage, intermittent poor connections, conditional – two relays close, etc.) and software (programmed conditional state that when combined with one or more other conditional states takes calculations/actions to behave in a way not intended)
- There are analysis methods and techniques available to identify and flag potential Sneak issues
- The behavior of the meter issue has all the hallmarks of a Sneak Type failure

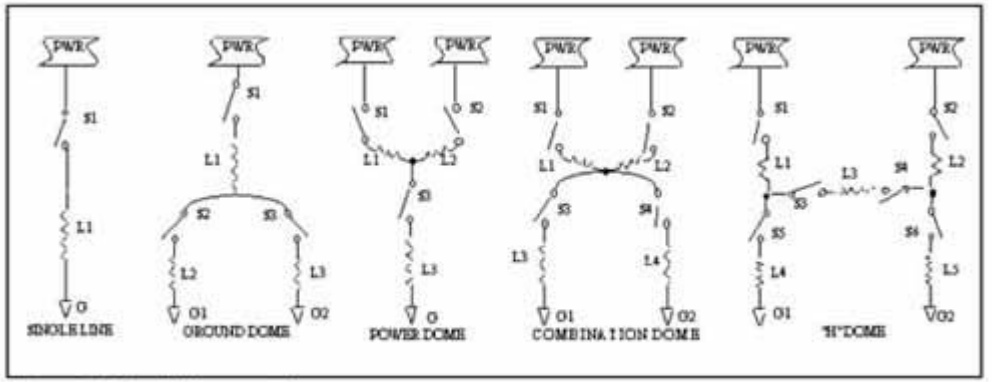
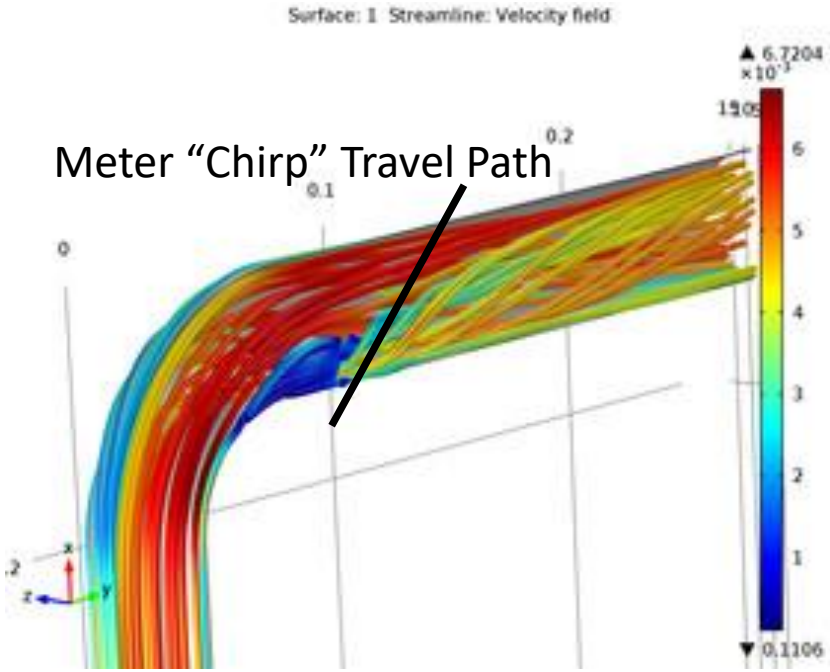


Figure 2. Basic Topographs

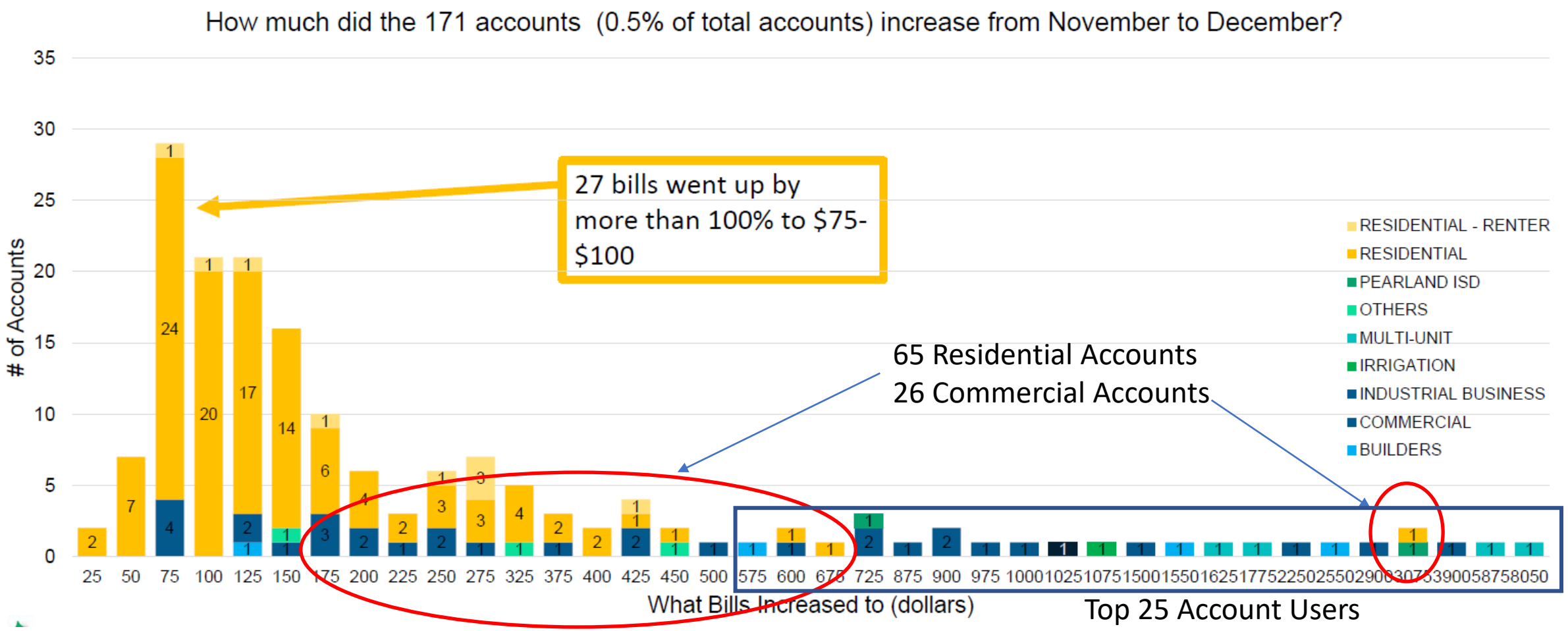
Physical Arrangement

- One potential item that may be a source of some of the reported behavior is:
  - Immediately upstream of the meter is a service manifold that contains the shutoff valve and makes necessary changes in direction to bring the water into the meter
  - My manifold has mine and my neighbor's meters attached.
    - 3 changes in direction into my meter
    - Right angle plug valve directly attached to the meter
  - These changes in direction are less than 5 diameters upstream of the meter
- For larger meters – 1” and above, Badger recommends that for calibration, the meter be provided 7-10 diameters of straight pipe before the meter
  - Flow redistribution after a flow disturbance takes 7-10 diameters as a MINIMUM to recover the normal flow regime
  - This becomes increasingly important as the flow rate increases
- I am unsure if a flow disturbance at some intermittent to high flow regime isn’t affecting the velocity measurement (maldistribution or eddy shed) that could potentially cause high velocity measurement



What do we know

- When tested, meters seem to function and match the reported accuracy – they work correctly almost all the time
  - Note that I suspect the test rig has a nice straight entrance into the meter
- The reported high consumption events are a very small percentage of all meter reads
- The numbers of meters that have the reported high readings are a fraction of a percentage of the meter fleet
- The reported high consumption events seem to be randomized and not consistently repeatable (there is no small set of bad meters identified)
- The City should have available the historical consumption by account that could be utilized statistically in identifying abnormal meter data
- We know other municipal users seem to be having similar issues


How much did the 171 accounts (0.5% of total accounts) increase from November to December?
# of Accounts
What Bills Increased to (dollars)
27 bills went up by more than 100% to $75-$100
65 Residential Accounts
26 Commercial Accounts
Top 25 Account Users
RESIDENTIAL - RENTER
RESIDENTIAL
PEARLAND ISD
OTHERS
MULTI-UNIT
IRRIGATION
INDUSTRIAL BUSINESS
COMMERCIAL
BUILDERS

What do we NOT know

- We don’t know anything about how the meter is designed or programmed
- We don’t know if Badger has encountered this before or if they have a fix
- Of the high consumption events, we don’t know (currently) which are within the normal usage profile for that account and which are not (potentially bad meter data)

Path Forward Options – not mutually exclusive

- Do nothing
- Investigate “root-cause” of high meter readings
- Double up metering
- Implement mitigating City actions to minimize or eliminate use of high (“suspected bad”) meter readings for billing

Do Nothing – Wait for AMI

- Pro's
  - Easiest to implement
- Con's
  - Continues to foster citizen mistrust and discontent
  - IF we truly think there is a potential metering issue – then to continue to bill for such events could be construed as being complicit in the failure
  - While AMI may ease the generation of supporting billing data, it will do nothing to indicate or to resolve a meter issue IF that is what is occurring
  - Inaction has likely legal implications in terms of potential litigation and liability for over billing if that is determined
    - Some of the proposed mitigation actions are steps that are likely to be required in mounting a defense in the event of litigation
    - The account-by-account meter usage analysis and determination of any meter error is likely to be the litigation path for proving or disproving the existence of meter failures

Investigate Root-Cause

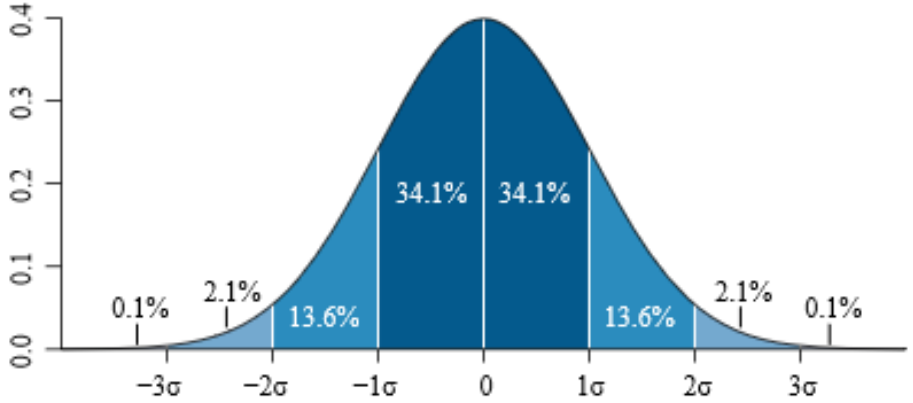
- Pro’s
  - Potentially can identify the cause of the high meter readings and with Badger, take corrective changes to eliminate the cause
- Con’s
  - Will take Badger assistance – they must be willing to undertake
  - Will take substantial time and resources to accomplish
    - Both internally and externally (need a meter engineering consultant)
  - May not, at the end of the day, be able to fully identify and mitigate the causes
    - Likelihood of successfully finding and correcting this issue is far from certain

Double Meter

- Pro’s
  - Provides a check meter (assuming using a different technology) of the current meter
  - Should be able to identify any discrepancies
- Con’s
  - Only a fraction of the meters will be provided with the check meter – others may continue to have one-off high readings
    - So doesn’t really help in mitigating the issue for accounts that do not have a second meter
  - Requires capital investment
  - Citizens may feel that they are paying for more – having to fix a City issue
  - Only propagates the notion that the new meters have problems and cannot be trusted to deliver an accurate result while at the same time requiring more money for second meters

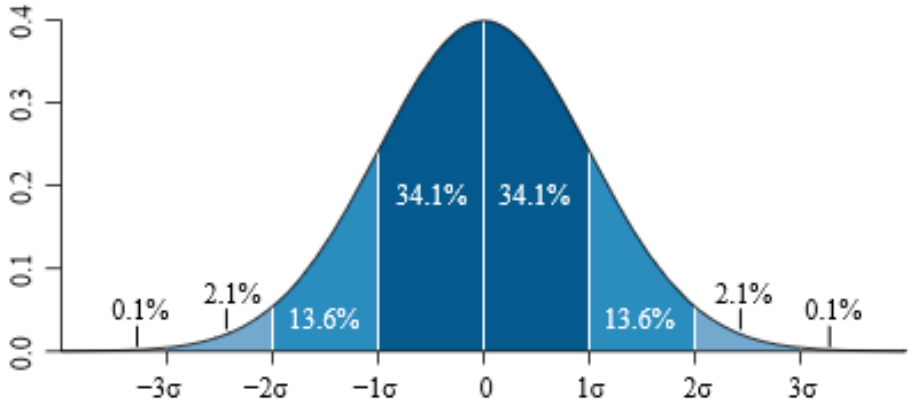
Implement Mitigating Actions - Immediate

- Move from the policy that customer must prove the meter usage is wrong – “you have a leak”…. TO the City must prove the high usage is correct…..
  - Reflects the reality that these meters potentially can fail high as compared to the old mechanical displacement meters which fail low
- Expand the flagged accounts past top 25
  - > 100% increase ???…. And
  - More than $150 dollars???
  - Certainly, ask about a large usage – fill a pool, etc.
- Immediately implement a policy, that if a high usage event is flagged - complaint, to bill at some estimated usage (the average of the last three previous meter readings, etc.)
  - Do this until the long-term mitigating actions are implemented
  - Based on the provided data, this is only a small fraction of the accounts – not a significant dollar amount - ~$36k for the two months evaluated



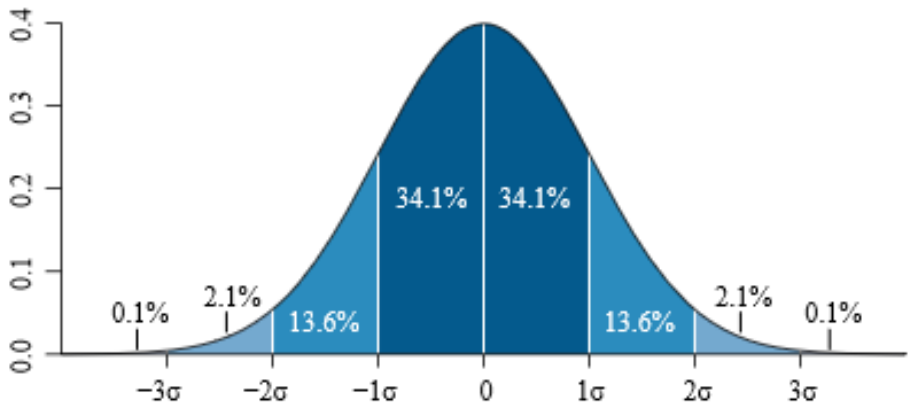
Implement Mitigating Actions – Long Term

- For the below actions to work; Billing cycle MUST be current with the latest meter readings – do meter data analysis and generate the bill in under a week
- City has historical account usage data
  - Using past water usage; implement a data historian (data warehouse) to:
    - Do a retrospective water usage analysis going back ~5 years if possible
    - Execute mean and standard deviation analysis (seasonally adjusted – average rainfall for the month)
    - Utilize the historical usage to determine if the current meter reading is within the statistical range (two or three standard deviations)
    - Utilize this information by providing historical usage plots and data via the new AMI portal
- IF a high usage event is detected
  - Bill at the historical mean for the reporting period – seasonally adjusted
  - Immediately remove the meter and return to Badger as a bad meter – change out with new meter – Warranty Claim
- All these actions are executed by the meter reading system and ONLY confirmed good data is loaded for billing



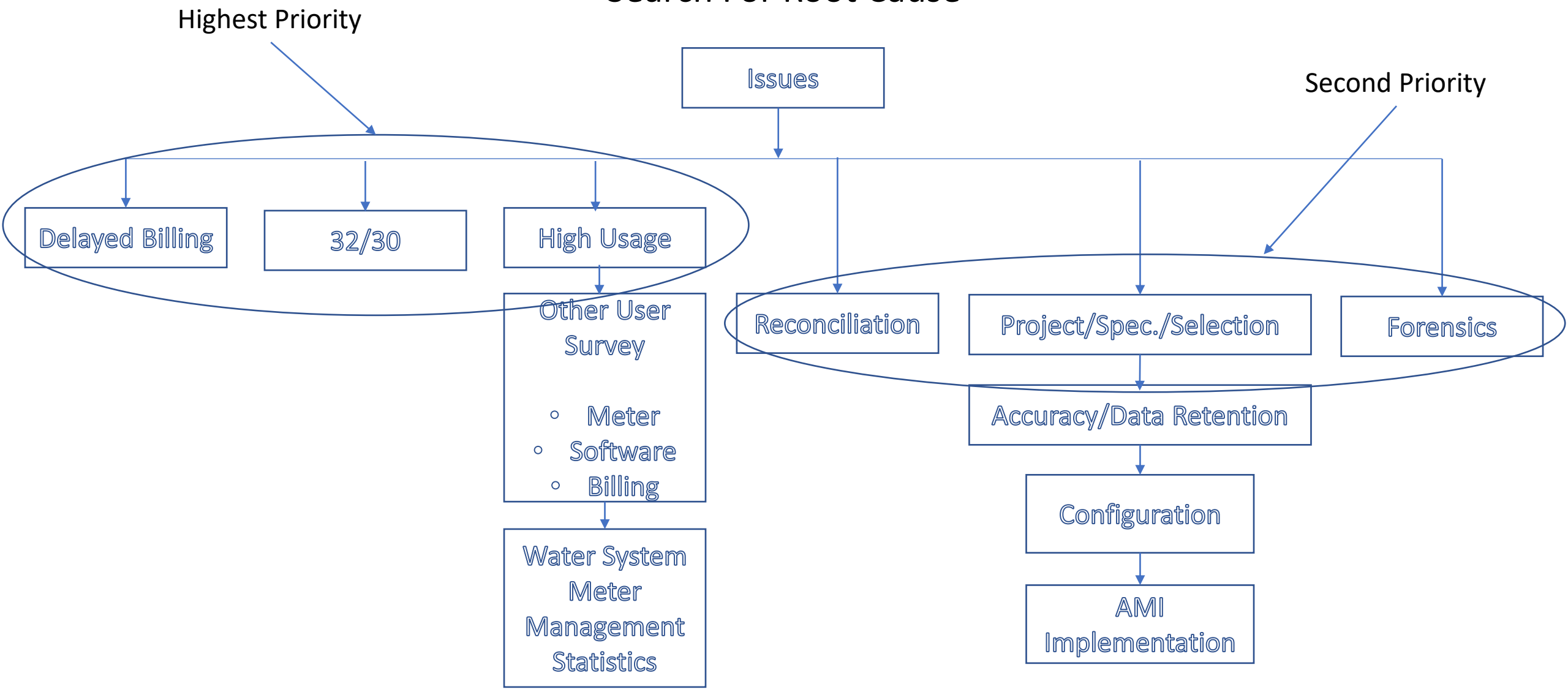
Implement Mitigating Actions

- Pro's
  - Immediately addresses citizens complaints
  - Action is in full control by the City – may require some IT/database support for report generation and calculations
  - No new information or data is required
    - Will require a retrospective analysis of the data to flag any high usages that may have occurred since installing the new meters – prevents incorrectly biasing the analysis with bad meter data
  - Require the AMI portal to report the account analysis with the ability to download the actual data
    - This will enhance City transparency and fosters customer confidence in the meter and billing processes
- Con's
  - Takes Staff resources to accomplish or to oversee contractor support in doing the implementation



Pearland Water Billing

Search For Root Cause



Recommendations For Consideration

- Immediately implement the mitigation actions
- Continue to pursue root cause analysis with Badger – if possible
  - Recommend a subset of committee members meet with City Engineering and Meter personnel to begin discussions internally before bringing in Badger
  - Meet with Badger and lay out the issue and get answers to our questions
  - Continue to gather odd usage information as evidence for the root cause failure analysis
  - If statistical account analysis is executed, utilize the results in executing the root cause failure analysis – look for common denominator conditions
- Committee is then free to focus on the other issues
  - Place on the agenda a workshop meeting to expand and validate the “Issues Chart”
  - Begin to make progress on resolving any identified items

Thoughts? Discussion? Questions?