Aquifer Storage and Recovery System Design, Operation and Maintenance Considerations

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Boise, Idaho
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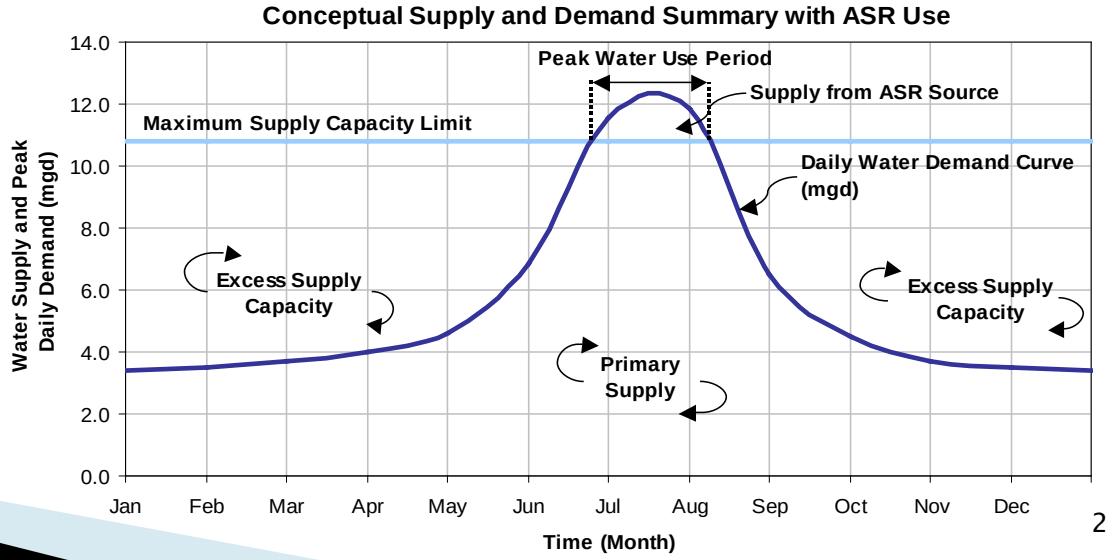
GSI Water Solutions, Inc.
MSA
Murray, Smith & Associates, Inc.
Engineers/Planners

City of Tualatin ASR System

- City wished to develop 2 to 4 MGD additional capacity to meet peak demands
- Supplement wholesale water supply from City of Portland
- Property availability and hydrogeology pointed to upland areas on the south side of Tualatin
- Location of first ASR site at a <u>future</u> reservoir property



ASR Development Chronology

2001 – ASR Feasibility Study

2002 – Exploratory Well

2003 – Limited License Application

2004 – ASR No. 1Production Well

2008 – Well House & Infrastructure

2009 – Cycle 1 and Cycle 2 testing

2010 – Evaluate and Address Operational Challenges

2011 – Resume ASR pilot testing

Tualatin ASR Program Challenges:

- Regulatory

- Infrastructure

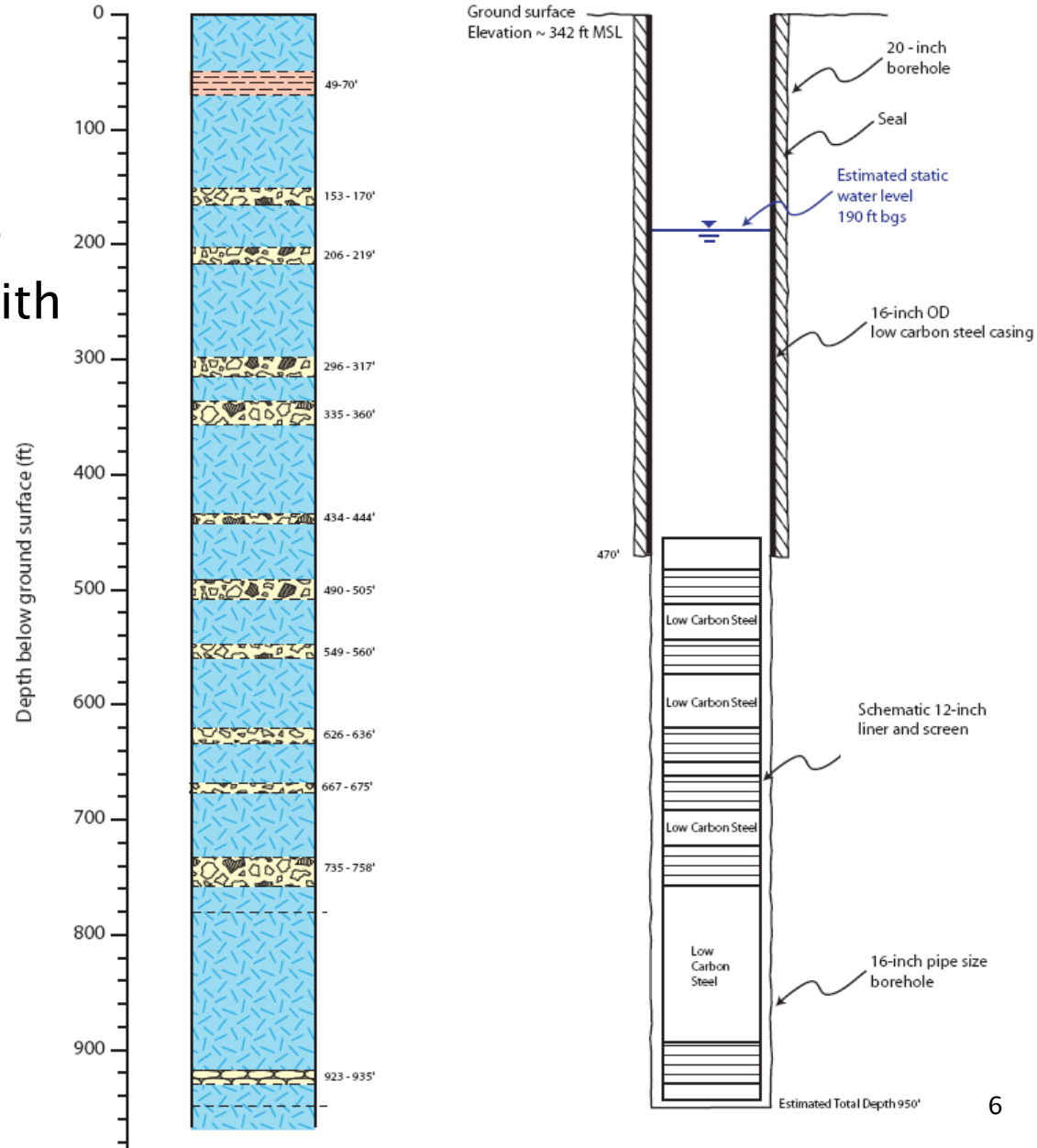
- Water Quality

Regulatory Challenges

- Testing occurs under Limited License
  - OAR 690-350
  - Includes review and input from
    - OWRD – will it work and will it injure other existing users
    - DEQ – will it degrade ground water quality
    - DHS – will it be safe to drink and meet SDWA standards
- Changing Regulatory Criteria (arsenic)
- Existing Native Groundwater Quality (radon)
- Anti-degradation (disinfection by-products or DBPs)
- Public Perception

ASR Well No. 1

- 950 feet deep
- Seal depth to 470 feet to limit interference with nearby wells
- Completed in CRBG
- Located 400 feet from exploratory well
- Static water level was ~250 feet bgs
- Decreased to 190 feet bgs in 2009



City of Tualatin South Distribution System – ASR Well Vicinity

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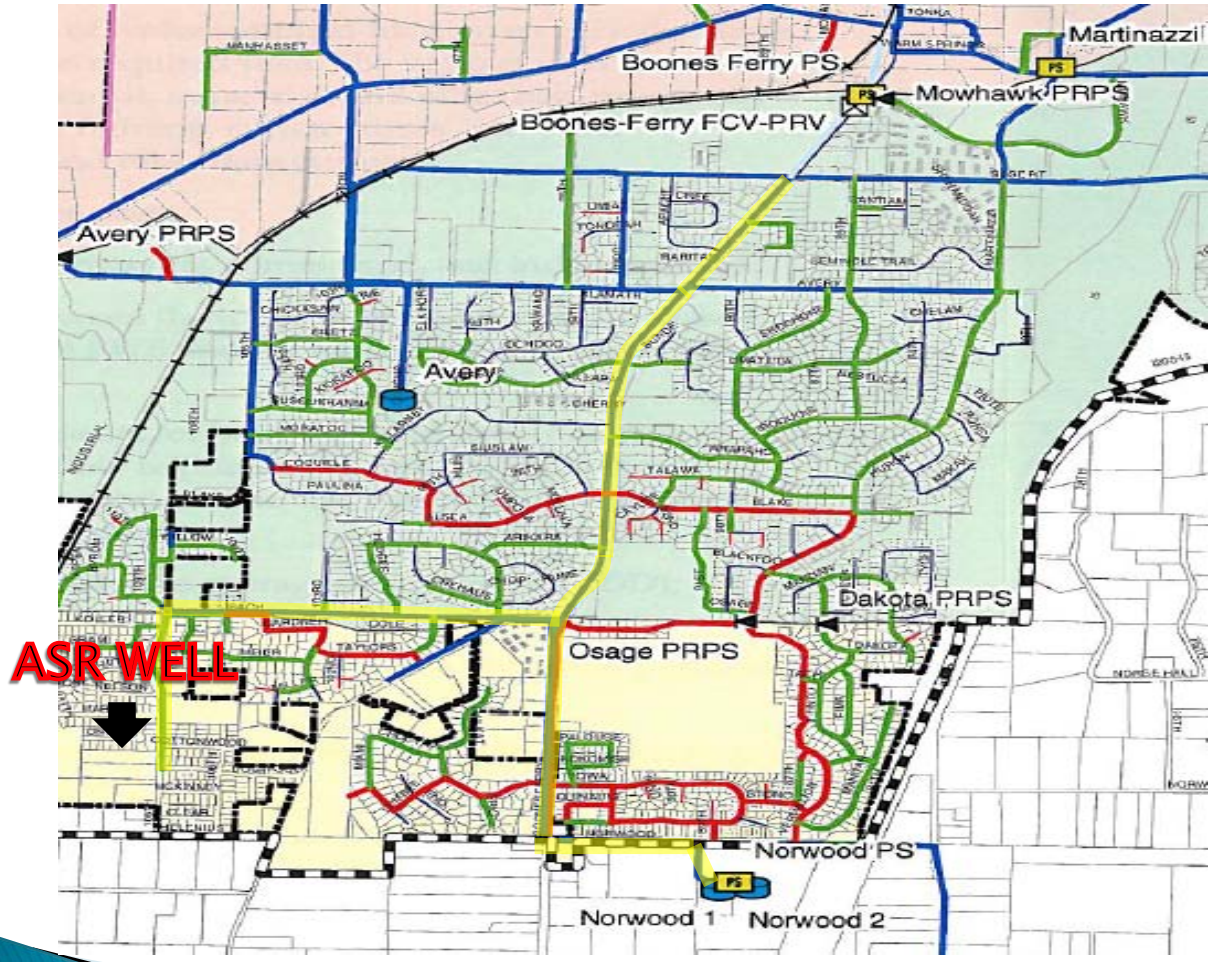


Legend

Facility
- FCV-PRV
- PRPS
- PS
- Emergency Intertie
- Reservoir

Service Level
- A
- B
- C
- City Boundary

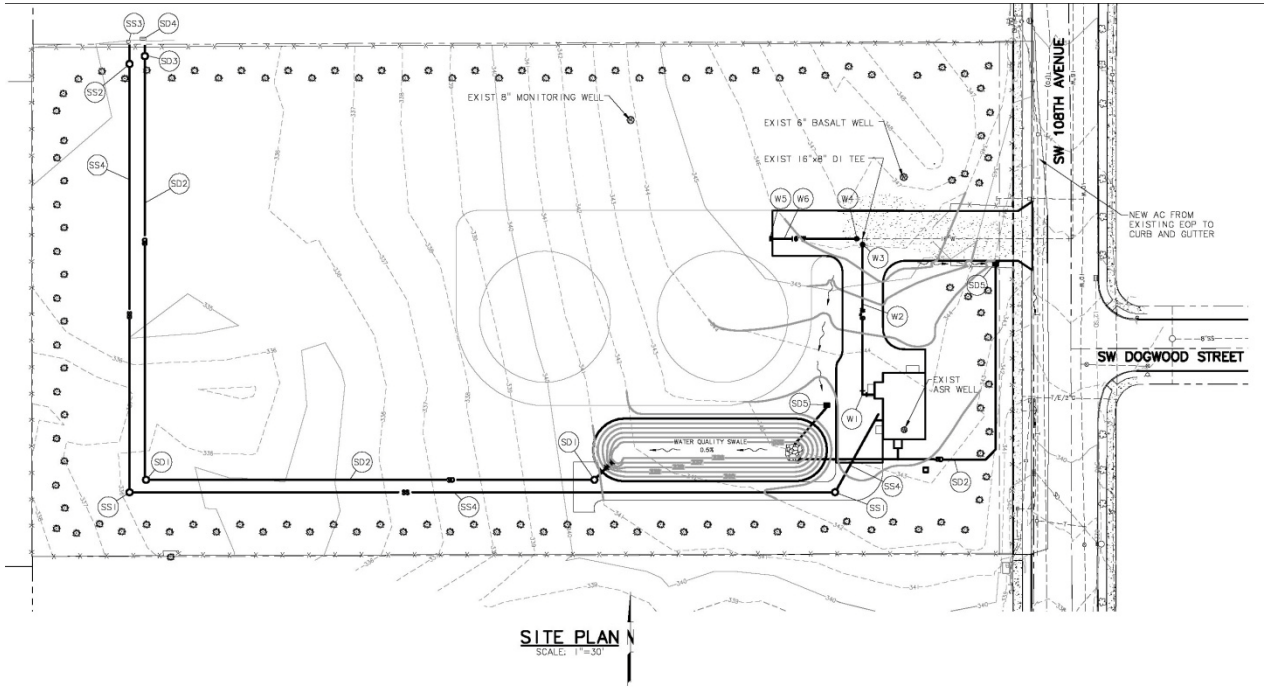
Pipe (in)
- 4
- 6
- 8
- 10
- 12
- 16
- 18
- 24
- 36

1,000 500 0 1,000 2,000 Feet

Infrastructure – How Does ASR Design Differ from a Water Supply Well?

- Pump to waste discharge for pipeline flushing and
  - Onsite detention pond sized for routine and extended pump-to-waste cycles
- Adjustable Downhole Control Valve
  - Controls flow during injection
  - Prevents air entrainment
- Pump and Motor Selection
  - Pumping under various hydraulic conditions
- Pressure and water level measurement
  - Larger range of fluctuation in water levels during injection and recovery
- Flowmeters – Bi-directional (injection and recovery)
- Automated Pump-to-Waste Cycle

Infrastructure

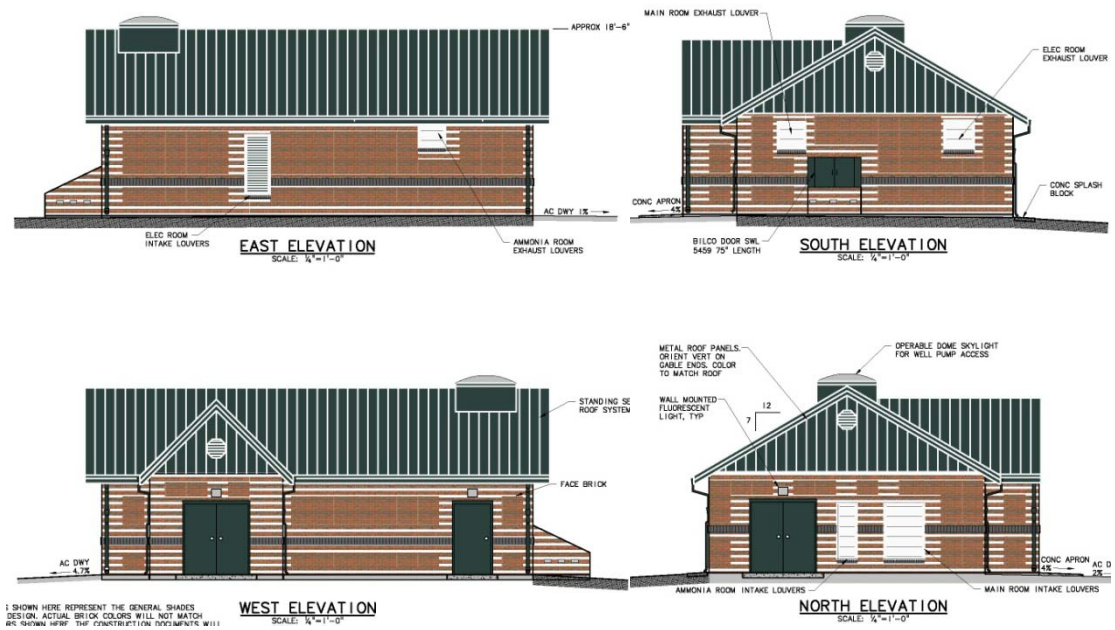


Design and Construction

- Integration with Future Site Plan
- Transmission Piping for ASR Injection/Recovery
- Making the Neighbors Happy…

Infrastructure

- Reliable source of injection water
- Booster chlorination
- Ammonia addition
- Wellhouse design
- Downhole control valve – Baski ™



Testing the Design

- Short duration "Shake-down" testing
  - Test the equipment
  - Identify any adjustments to controls
  - Develop a baseline for the well operation (i.e. verify specific capacity and yield)

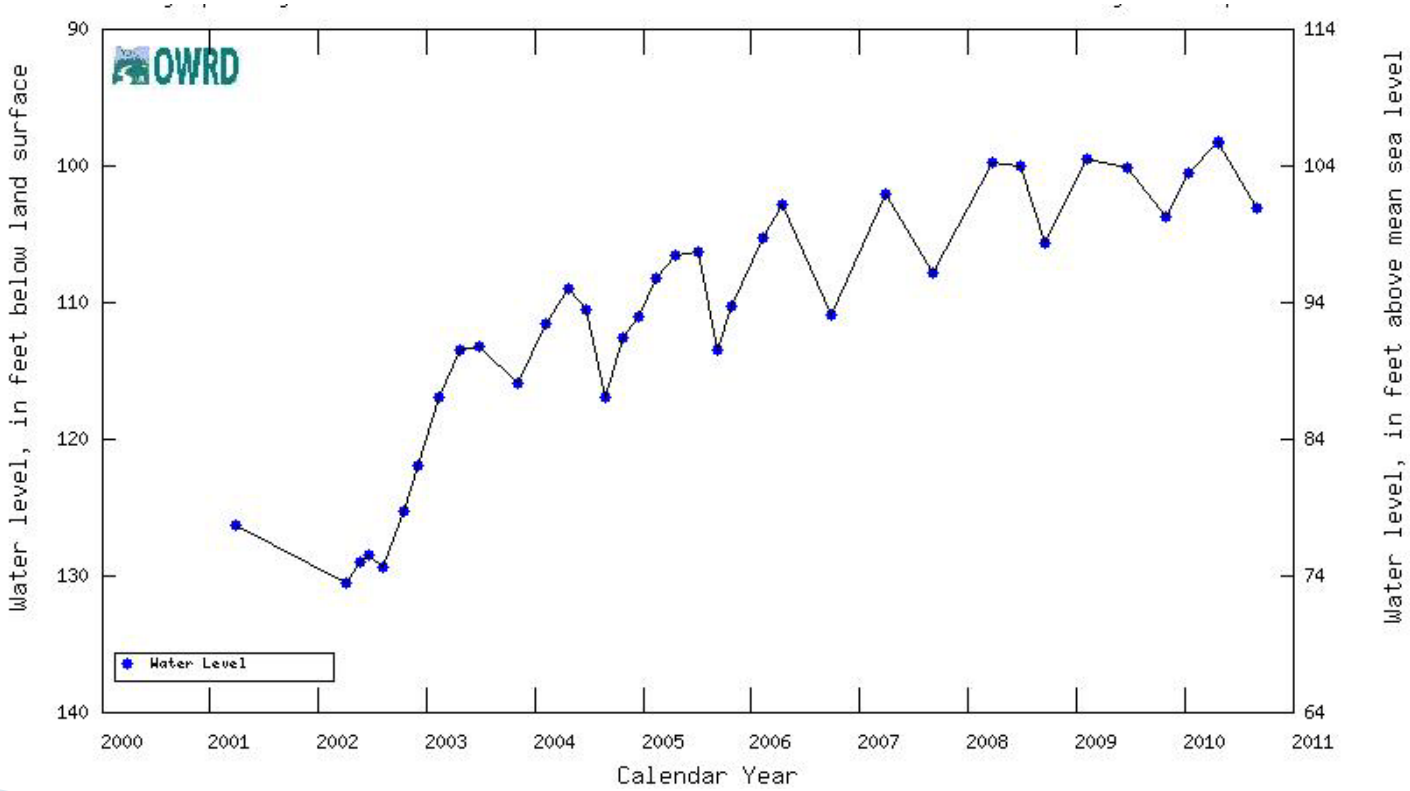
- Cycle Testing
  - Operation under longer term operation
  - Increase operation time to full scale
  - Evaluates the well performance, aquifer hydraulic response, water quality and "the whole system"

Infrastructure Observations

- System Pressure Fluctuations
  - Varying water supply modes of operation
  - ASR Injection Demand on System
  - Slow Response of Downhole Control Valve

Well Performance Observations

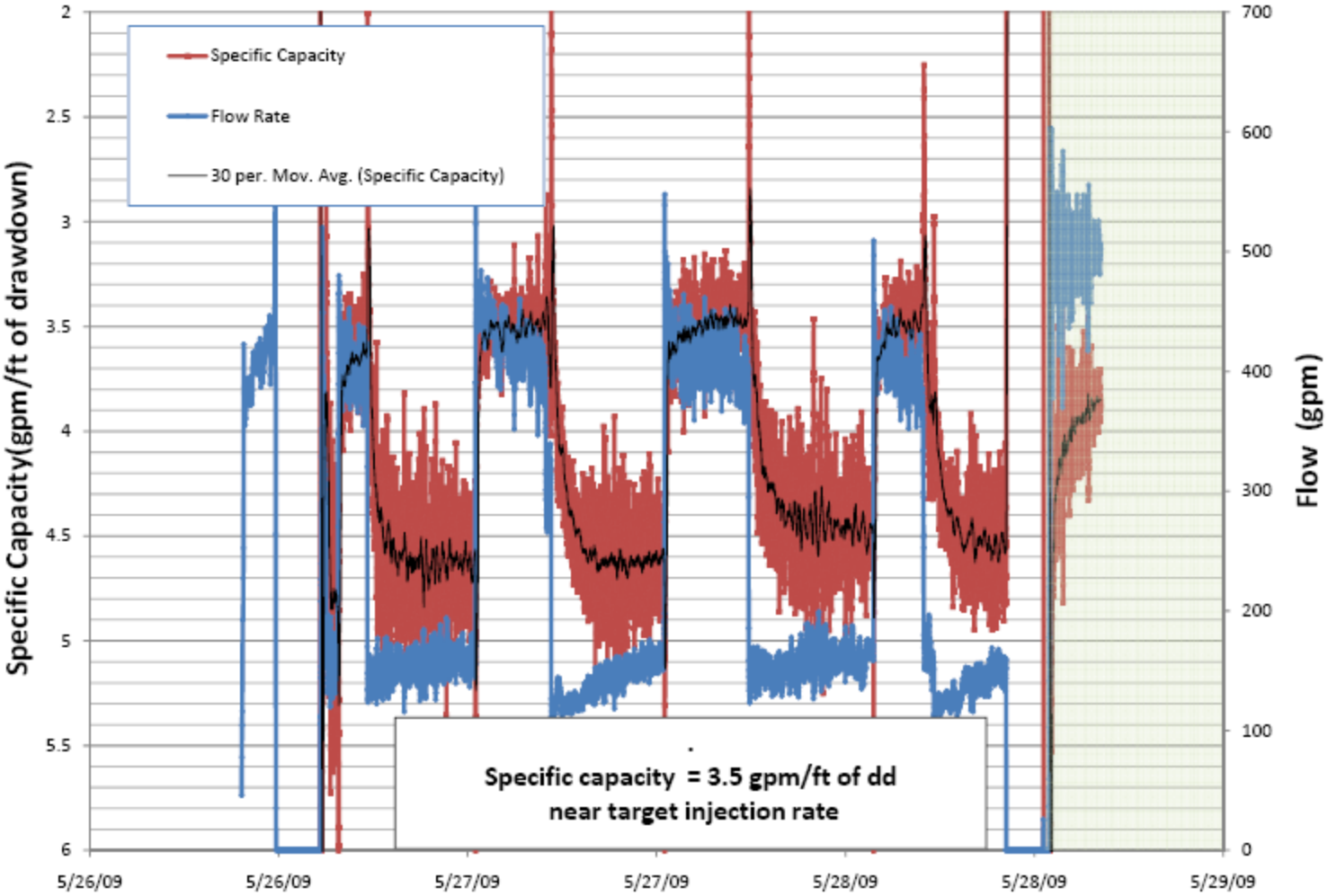
- Static water level in well had rebounded in the aquifer approximately 50 feet at the ASR Well since testing in 2003 due to decreases in water use by the City of Wilsonville (changed to a surface water source)



Well Performance Observations (cont.)

- Well performance (i.e. specific capacity) under injection and pumping was decreasing indicating that plugging was occurring
- Significant turbidity and color observed during back-flushing
- Injection rate had to be reduced to maintain injection level 40 feet below ground surface
- Suspected that bio-fouling was the cause for the loss of well performance

Specific Capacity Trends During Cycle 2



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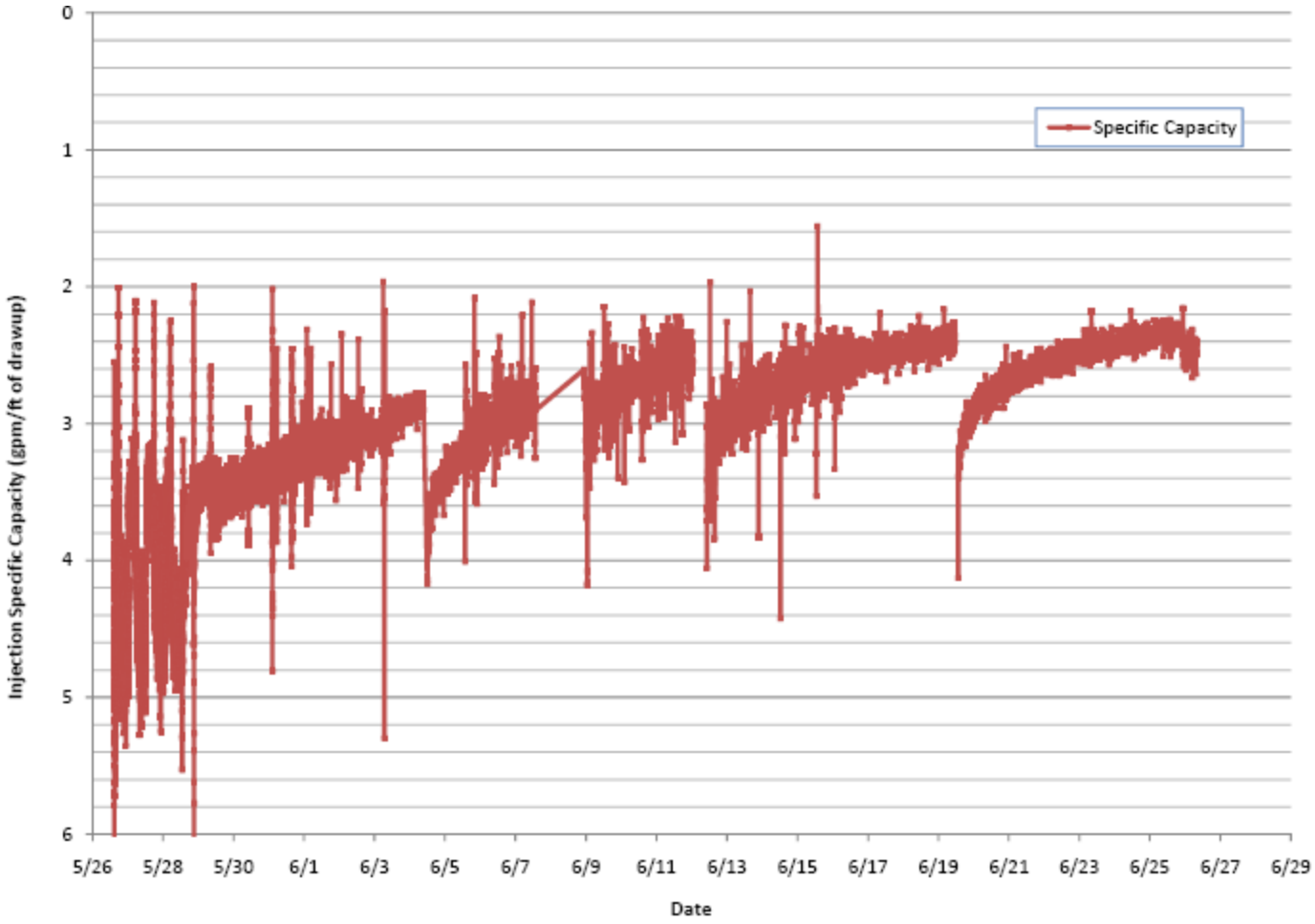


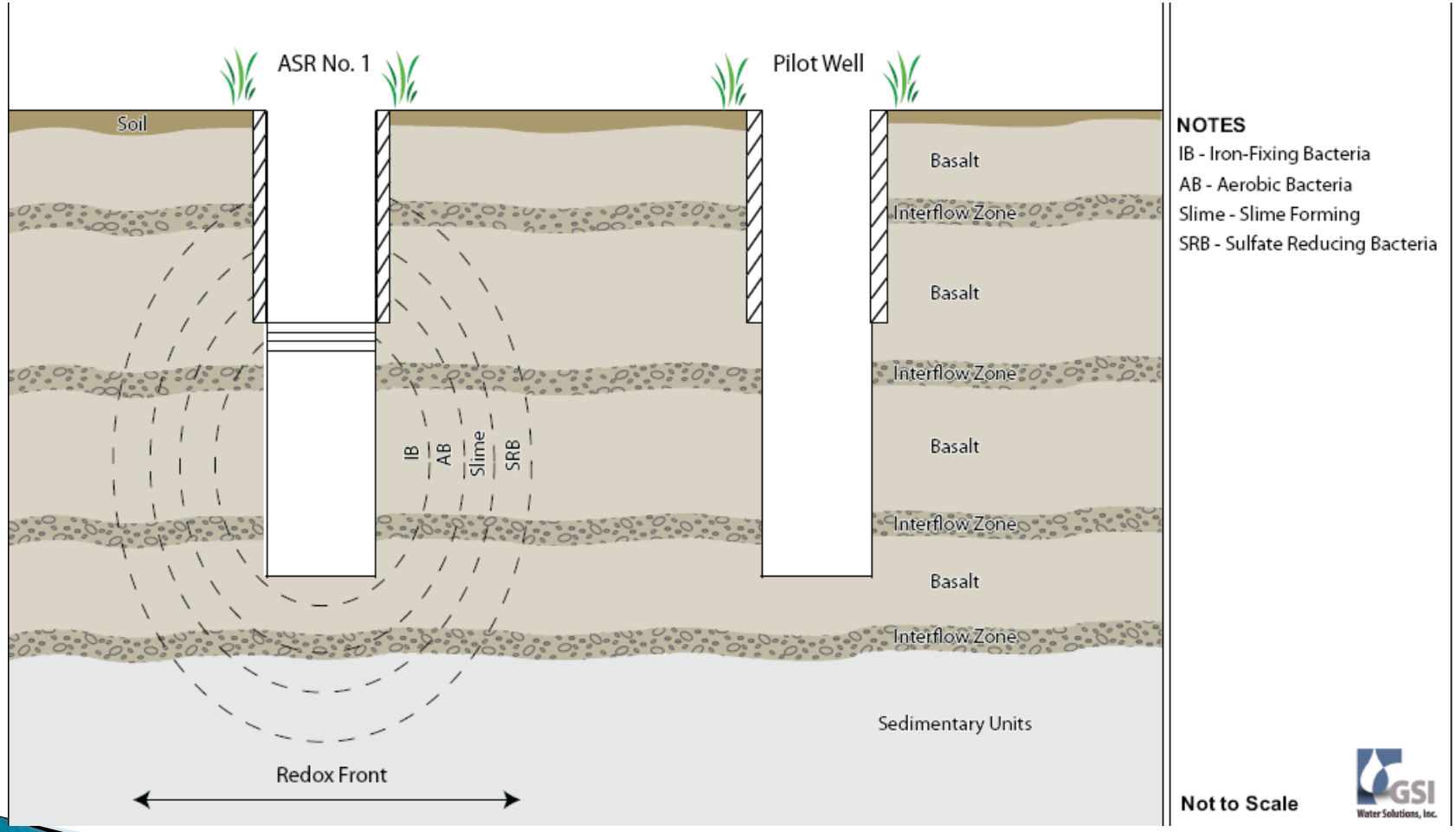
Initial Steps Taken to Improve ASR System Performance

1. Modified control valve at the ASR wellhead to reduce injection rate fluctuation
2. Increased periodic back-flushing of the well to improve performance
3. Performed Bacteriological assessments of the ASR Well, nearby pilot well and supply points in the distribution system
4. Compared source water quality with other metro ASR system source water quality

Source Water Quality

- Bull Run source water is unfiltered surface water treated by chloramination
- Chlorine residual is typically >1.0 mg/L at the entrance to the City of Tualatin system decreased to <0.5 mg/L at ASR wellhead
- City of Portland Bull Run water had higher Adenosine triphosphate (an indicator of total viable cellullar material), TOC and DOC compared to other source water which is filtered
- Nutrients for microbial growth – dissolved oxygen, sulfate, nitrate, iron and manganese were similar in all source waters

Microbial Community Evolution at ASR Well No. 1



Conclusions After Year 1Testing

- Changes in the available draw-up (i.e. decreased use of the City of Wilsonville wells) since 2003 will factor into system operation in the future
- A combination of physical plugging and biofouling was the cause of loss of injection performance at ASR Well No. 1
- Distribution system leading to ASR No. 1 had a high chlorine demand based on low chlorine residual, TOC, and DOC results

Recommendations after Year 1 Testing

- Comprehensive water quality testing of the distribution system supplying the ASR well
- Well rehabilitation using both mechanical and chemical treatment methods to address plugging
- Ongoing bacteriological monitoring of the ASR well

Comprehensive Distribution System Evaluation 2010

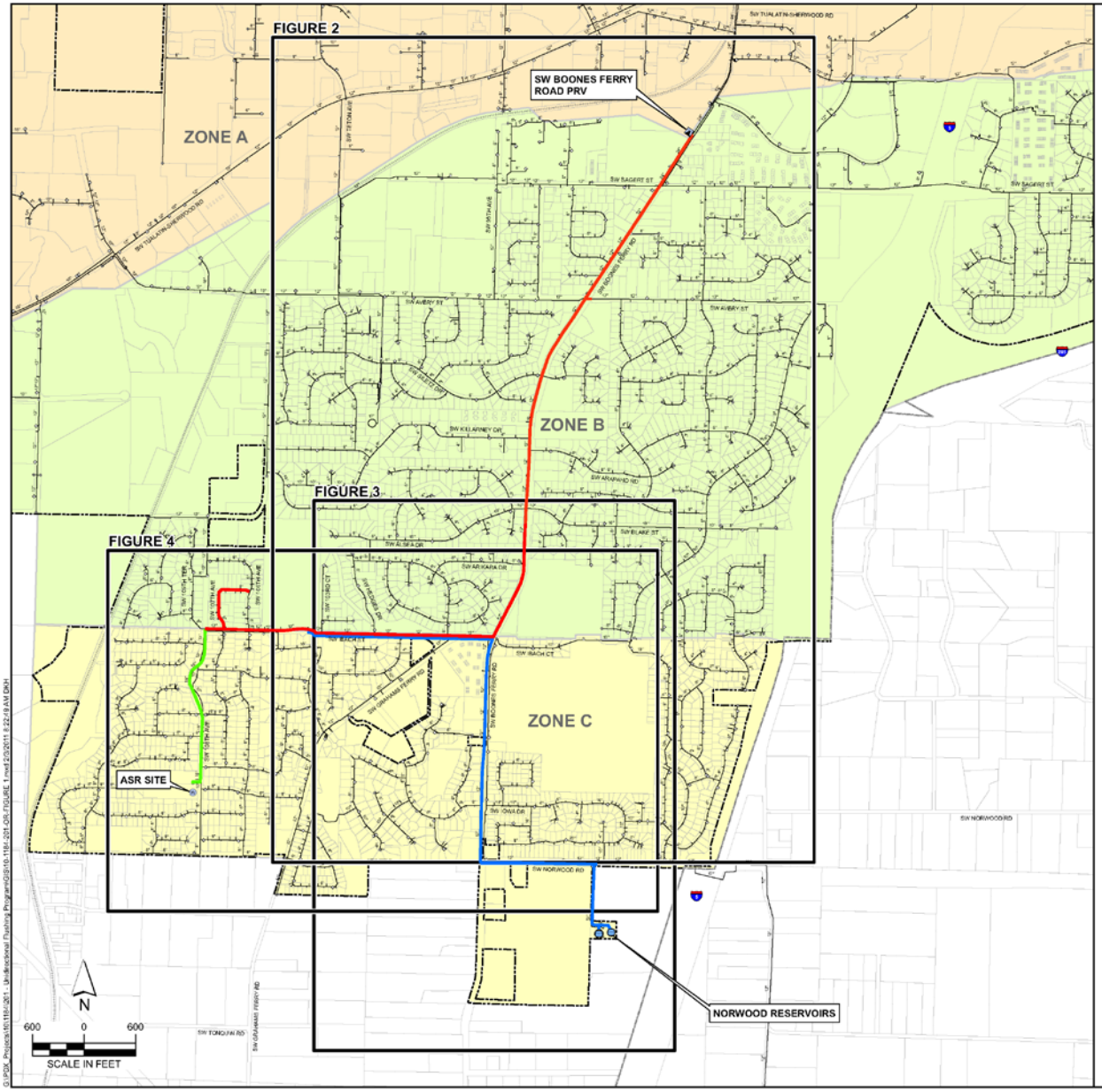
- Performed by Confluence Engineering Group, LLC
- Evaluation of variation in residual chlorine, nitrogen species (Nitrate, Nitrite, and Ammonia) and bacterial populations under various operational modes
- Water quality sampling for DBPs
- Performed hydrant flushing and sediment collection to evaluate biofilm in distribution system

Distribution System Analysis Summary

- Reservoir operations (fill/draw mode) significantly increases water age which contributes to:
  - Reduced and highly variable chlorine
  - Could be causing nitrification in reservoir
- Accumulated biofilm – may not be severe, but….
  - Does exert chlorine demand
  - Potential source of nutrients and microbes at ASR site
- "Well-behaved" water
- Determine dosages and contact times needed for approach
- DBP Rule requirements (DBP levels and MRDLs) may limit breakpoint free chlorine levels

Strategy to Improve Injection Water Quality

- Apply booster disinfection at ASR well site
  - Use existing equipment
    - Developed dosing control strategy
  - Evaluate biofouling control effectiveness; start with free Cl_2
    - Opportunity for full-scale pilot; address uncertainties with jar tests
    - Start with a short-cycle (~2 wks) to assess DBP and Cl2 fate in aquifer
    - Limit dose to meet MRDL and avoid the need for on-site contact time
- Apply structured high-velocity UDF on high-priority mains near the ASR site
- Explore changes to Norwood reservoir cycling
    - 400 to 500 gpm ASR injection offers an opportunity to cycle reservoirs more quickly



FLUSHING FLOW RATES AND VOLUME OF FLOW

FLOW (GPM)	VELOCITY* (FT/S)	TIME (MIN)	VOLUME (GAL)
1,500	4.2	5 10 15 20 30	7,500 15,000 22,500 30,000 45,000
1,750	5.0	5 10 15 20 30	8,750 17,500 26,250 35,000 52,500
2,000	5.7	5 10 15 20	10,000 20,000 30,000 40,000
2,250	6.4	5 10 15 20	11,250 22,500 33,750 45,000

TARGET FLOW RATE/FLUSHING VELOCITY

* VELOCITY OF FLOW BASED ON FLOWS THROUGH 12-INCH DIAMETER PIPING.

RECOMMENDATIONS FOR UDF PROGRAM AS FOLLOWS:

1. TARGET FLUSHING VELOCITY, APPROXIMATELY 6 FT/S.
2. FLUSH A MINIMUM OF ONE PIPE VOLUME, AS CALCULATED FOR EACH PIPING SEGMENT.
3. MANIPULATE EXISTING VALVES AND HYDRANTS TO INSURE FLUSHING FLOWS ARE UNIDIRECTIONAL AS SHOWN FOR EACH PIPING SEGMENT.
4. FLUSHING FLOWS MAY NEED TO BE RESTRICTED OR STOPPED BASED UPON OBSERVATIONS IN EXISTING STORM DRAIN SYSTEM.
5. IT IS RECOMMENDED THAT CITY STAFF HAVE A MINIMUM OF 40 SAND BAGS OF TYPICAL SIZE ON-HAND DURING FLUSHING ACTIVITIES FOR PROTECTING DRIVEWAYS AND DIRECTING FLOWS TO CATCH BASINS.

LEGEND

- WATERLINE SEGMENTS 1-3, 5
- WATERLINE SEGMENT 4
- WATERLINE SEGMENTS 6
- OTHER WATERLINE
- AIR RELEASE ASSEMBLY
- BLOW-OFF ASSEMBLY
- FIRE HYDRANT
- ASR WELL
- PRESSURE REDUCING VALVE (PRV)
- RESERVOIR
- CITY LIMITS
- RAILROAD
- URBAN GROWTH BOUNDARY (UGB)

PRESSURE ZONES:

- ZONE A
- ZONE B
- ZONE C

City of Tualatin

FIGURE 1

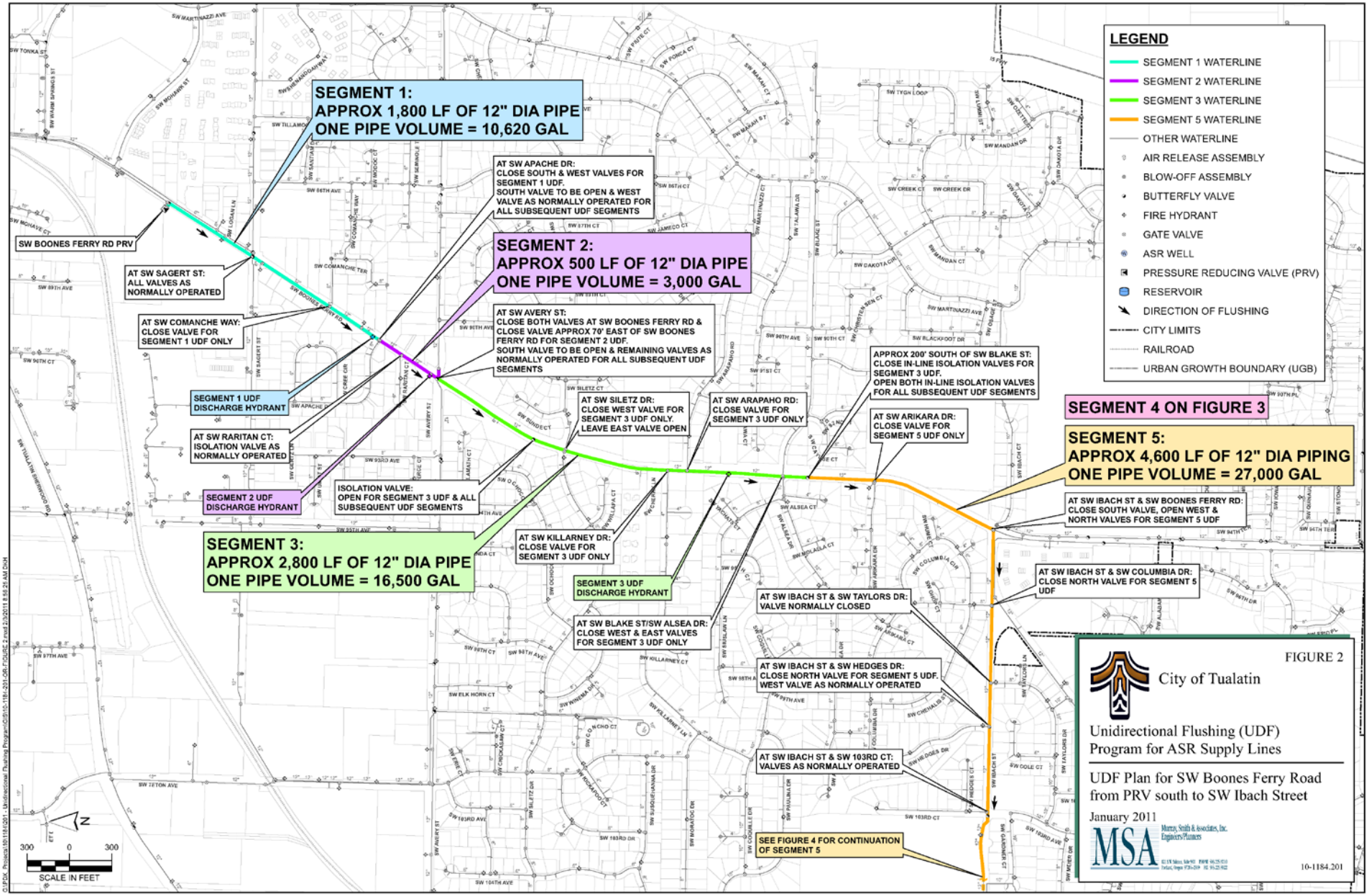
Unidirectional Flushing (UDF) Program for ASR Supply Lines

Key Map

January 2011

MSA Murray, Smith & Associates, Inc. Engineers/Planners

10-1184.201


SEGMENT 1:
APPROX 1,800 LF OF 12" DIA PIPE
ONE PIPE VOLUME = 10,620 GAL
SEGMENT 2:
APPROX 500 LF OF 12" DIA PIPE
ONE PIPE VOLUME = 3,000 GAL
SEGMENT 3:
APPROX 2,800 LF OF 12" DIA PIPE
ONE PIPE VOLUME = 16,500 GAL
SEGMENT 4 ON FIGURE 3
SEGMENT 5:
APPROX 4,600 LF OF 12" DIA PIPING
ONE PIPE VOLUME = 27,000 GAL
SW BOONES FERRY RD PRV
AT SW SAGERT ST: ALL VALVES AS NORMALLY OPERATED
AT SW COMANCHE WAY: CLOSE VALVE FOR SEGMENT 1 UDF ONLY
SEGMENT 1 UDF DISCHARGE HYDRANT
AT SW RARITAN CT: ISOLATION VALVE AS NORMALLY OPERATED
SEGMENT 2 UDF DISCHARGE HYDRANT
AT SW APACHE DR: CLOSE SOUTH & WEST VALVES FOR SEGMENT 1 UDF. SOUTH VALVE TO BE OPEN & WEST VALVE AS NORMALLY OPERATED FOR ALL SUBSEQUENT UDF SEGMENTS
AT SW AVERY ST: CLOSE BOTH VALVES AT SW BOONES FERRY RD & CLOSE VALVE APPROX 70' EAST OF SW BOONES FERRY RD FOR SEGMENT 2 UDF. SOUTH VALVE TO BE OPEN & REMAINING VALVES AS NORMALLY OPERATED FOR ALL SUBSEQUENT UDF SEGMENTS
ISOLATION VALVE: OPEN FOR SEGMENT 3 UDF & ALL SUBSEQUENT UDF SEGMENTS
AT SW SILETZ DR: CLOSE WEST VALVE FOR SEGMENT 3 UDF ONLY. LEAVE EAST VALVE OPEN
AT SW ARAPAHO RD: CLOSE VALVE FOR SEGMENT 3 UDF ONLY
AT SW KILLARNEY DR: CLOSE VALVE FOR SEGMENT 3 UDF ONLY
SEGMENT 3 UDF DISCHARGE HYDRANT
AT SW BLAKE ST/SW ALSEA DR: CLOSE WEST & EAST VALVES FOR SEGMENT 3 UDF ONLY
APPROX 200' SOUTH OF SW BLAKE ST: CLOSE IN-LINE ISOLATION VALVES FOR SEGMENT 3 UDF. OPEN BOTH IN-LINE ISOLATION VALVES FOR ALL SUBSEQUENT UDF SEGMENTS
AT SW ARIKARA DR: CLOSE VALVE FOR SEGMENT 5 UDF ONLY
AT SW IBACH ST & SW BOONES FERRY RD: CLOSE SOUTH VALVE, OPEN WEST & NORTH VALVES FOR SEGMENT 5 UDF
AT SW IBACH ST & SW COLUMBIA DR: CLOSE NORTH VALVE FOR SEGMENT 5 UDF
AT SW IBACH ST & SW TAYLORS DR: VALVE NORMALLY CLOSED
AT SW IBACH ST & SW HEDGES DR: CLOSE NORTH VALVE FOR SEGMENT 5 UDF. WEST VALVE AS NORMALLY OPERATED
AT SW IBACH ST & SW 103RD CT: VALVES AS NORMALLY OPERATED
SEE FIGURE 4 FOR CONTINUATION OF SEGMENT 5
LEGEND
SEGMENT 1 WATERLINE
SEGMENT 2 WATERLINE
SEGMENT 3 WATERLINE
SEGMENT 5 WATERLINE
OTHER WATERLINE
AIR RELEASE ASSEMBLY
BLOW-OFF ASSEMBLY
BUTTERFLY VALVE
FIRE HYDRANT
GATE VALVE
ASR WELL
PRESSURE REDUCING VALVE (PRV)
RESERVOIR
DIRECTION OF FLUSHING
CITY LIMITS
RAILROAD
URBAN GROWTH BOUNDARY (UGB)
FIGURE 2
City of Tualatin
Unidirectional Flushing (UDF) Program for ASR Supply Lines
UDF Plan for SW Boones Ferry Road from PRV south to SW Ibach Street
January 2011
MSA
10-1184.201
SCALE IN FEET
300 0 300

Year 2 ASR Program (2010– 2011)

- Well Rehabilitation was performed to recover well performance
- Installation and testing of booster chlorination system at ASR Well No. 1 wellhead to control biological populations
- Short duration pilot test in Spring 2011 to evaluate fate and decay of DBPs
  - 7 day injection period
  - Approximately 30 day storage period
- Cycle 3 full scale testing – October 2011?

Operation and Maintenance: Lessons Learned

1. Include well redevelopment and rehabilitation in system maintenance budgets
2. Structured uni-directional flushing may be needed to supplement existing line flushing practices
3. Closely monitor turbidity during injection
4. Backflushing is critical to maintaining well performance especially if physical plugging occurs due to turbidity events
5. Evaluate changes in well performance periodically during injection and recovery

Design Considerations for Integration: Lessons Learned

- Know your system
- Know the source water quality
- Know the hydrogeology

Questions?

Thank You!

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