Willamette Water Supply
Our Reliable Water

Laying A Solid Foundation For The Willamette Water Supply Program's Seismic Resiliency

May 4, 2016

Mike Britch,
Mark Havekost,
John Plattsmier

MAY THE SOURCE BE WITH YOU

American Water Works Association
Pacific Northwest Section

Outline

Safety Moment

Program Overview

Geologic & Geotechnical Conditions

Steel Pipe Considerations

Safety Moment

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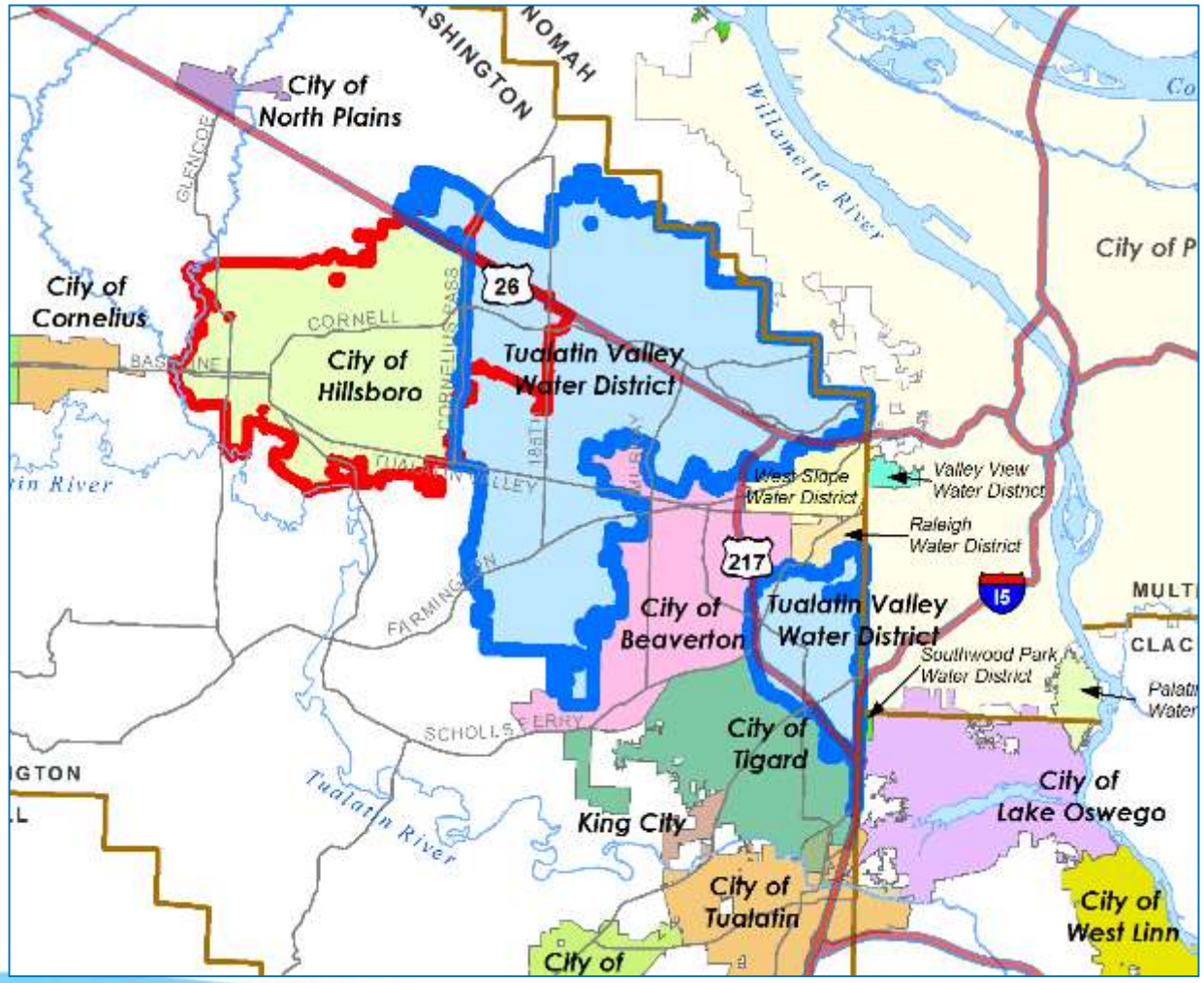
Water Supply Partners



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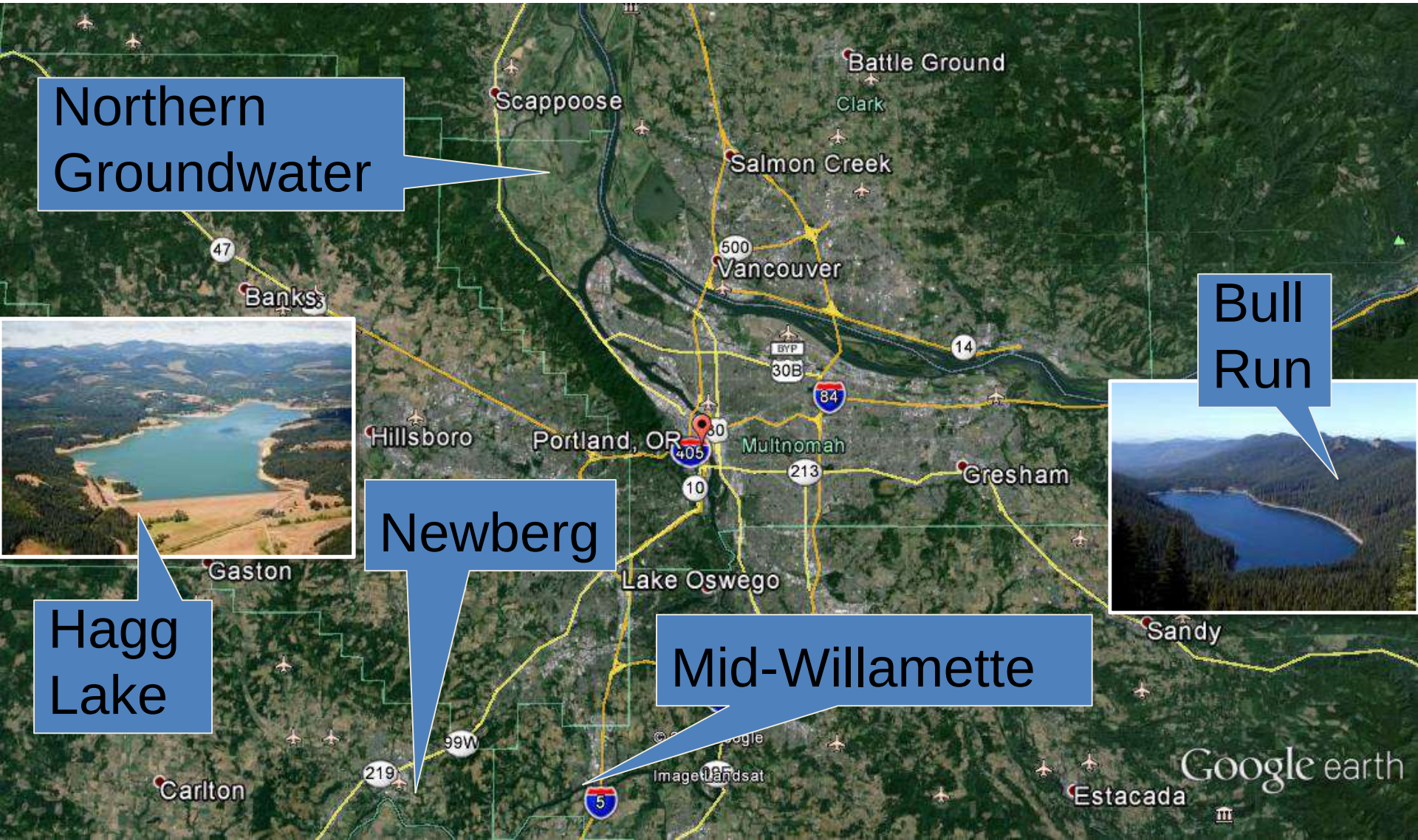
Regional Supply Alternatives Evaluated



Mid-Willamette Supply Selected in 2013

Willamette Water Supply Program (WWSP)

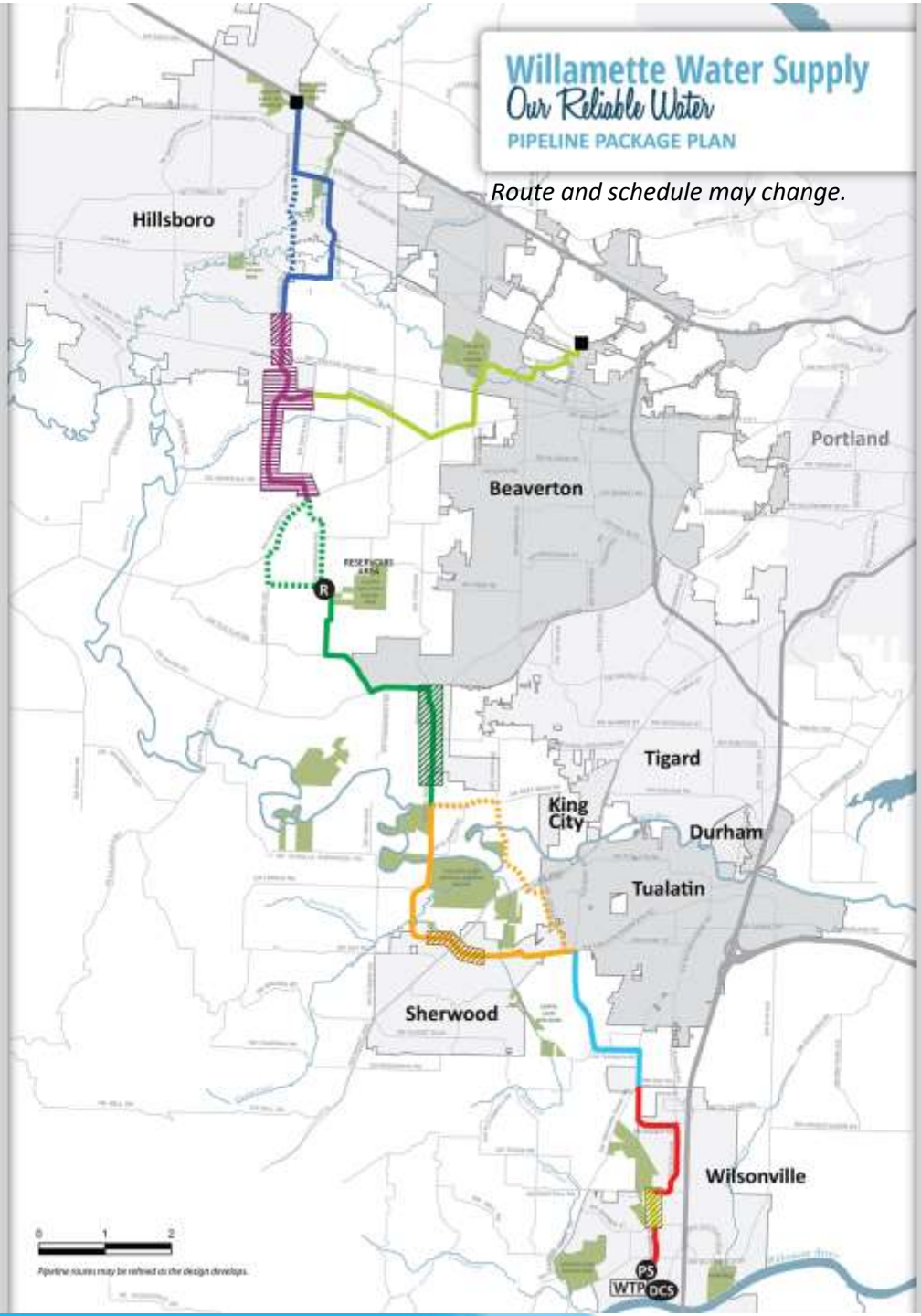
- Lowest cost to implement
- Excellent water quality
- Ownership
- Reliability
- Regional benefits

WWSP Mission Statement

To provide a cost-effective, reliable and resilient water supply system by 2026, that benefits current and future generations of the communities we serve and supports a vibrant local economy.

"Washington County is one of the economic engines for the State, and that engine runs on water"

(Washington County Chair Andy Duyck, May 2013).


Willamette Water Supply
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PIPELINE PACKAGE PLAN
Route and schedule may change.
Hillsboro
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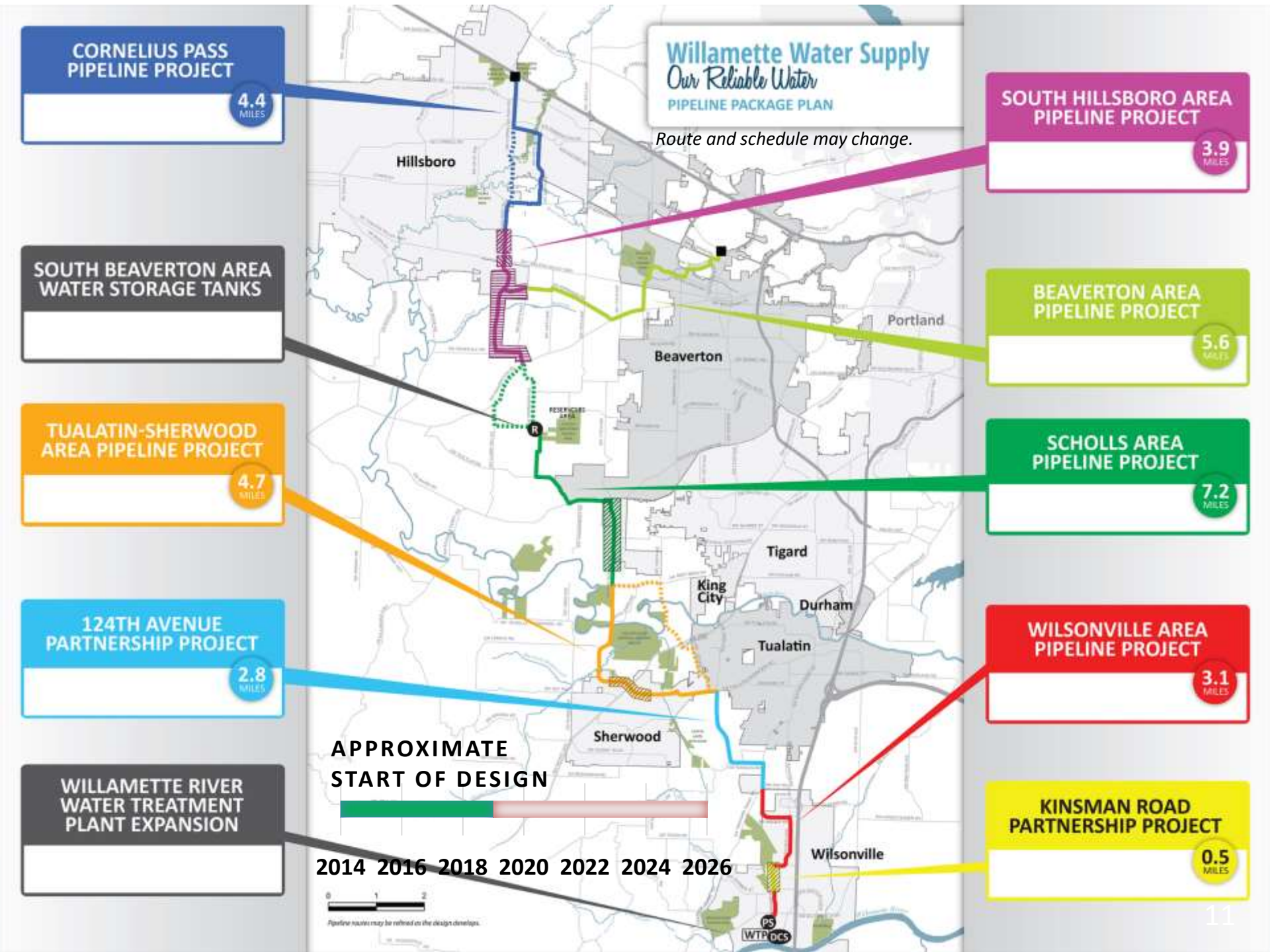
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Overview of today's presentation

- Identifying a level of service goal for the transmission system
- Geohazards along the pipeline route
- Seismic issues specific to steel pipelines

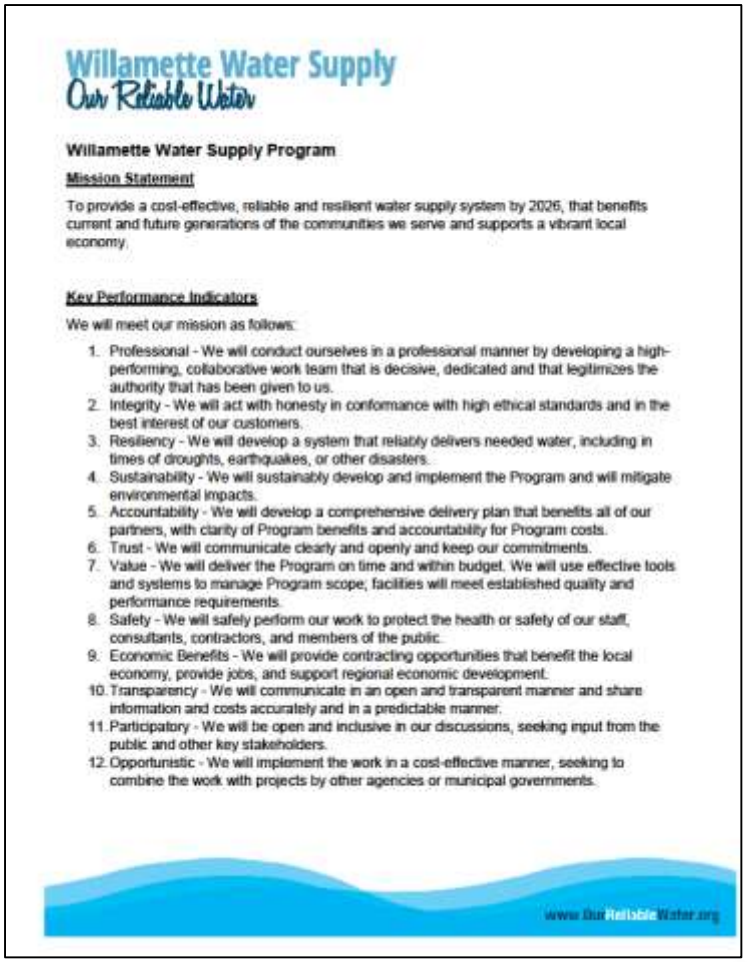
WWSP Performance Goals

Mission Statement

To provide a cost-effective, reliable and resilient water supply system by 2026, that benefits current and future generations of the communities we serve and supports a vibrant local economy.

12 Performance Goals Identified

3. **Resiliency** - We will develop a system that reliably delivers needed water, including in times of droughts, earthquakes, or other disasters.



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Willamette Water Supply Program

Mission Statement

To provide a cost-effective, reliable and resilient water supply system by 2026, that benefits current and future generations of the communities we serve and supports a vibrant local economy.

Key Performance Indicators

We will meet our mission as follows:

1. Professional - We will conduct ourselves in a professional manner by developing a high-performing, collaborative work team that is decisive, dedicated and that legitimizes the authority that has been given to us.
2. Integrity - We will act with honesty in conformance with high ethical standards and in the best interest of our customers.
3. Resiliency - We will develop a system that reliably delivers needed water, including in times of droughts, earthquakes, or other disasters.
4. Sustainability - We will sustainably develop and implement the Program and will mitigate environmental impacts.
5. Accountability - We will develop a comprehensive delivery plan that benefits all of our partners, with clarity of Program benefits and accountability for Program costs.
6. Trust - We will communicate clearly and openly and keep our commitments.
7. Value - We will deliver the Program on time and within budget. We will use effective tools and systems to manage Program scope; facilities will meet established quality and performance requirements.
8. Safety - We will safely perform our work to protect the health or safety of our staff, consultants, contractors, and members of the public.
9. Economic Benefits - We will provide contracting opportunities that benefit the local economy, provide jobs, and support regional economic development.
10. Transparency - We will communicate in an open and transparent manner and share information and costs accurately and in a predictable manner.
11. Participatory - We will be open and inclusive in our discussions, seeking input from the public and other key stakeholders.
12. Opportunistic - We will implement the work in a cost-effective manner, seeking to combine the work with projects by other agencies or municipal governments.

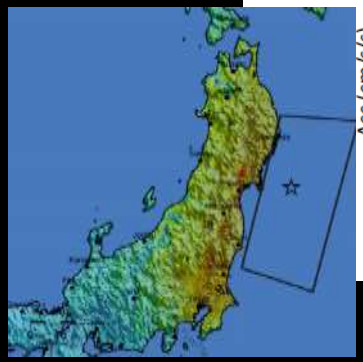
www.OurReliableWater.org

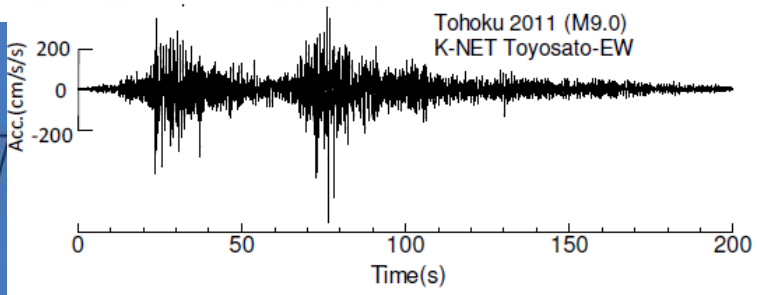
Cascadia Subduction Zone Earthquake Expected to be Similar to Tohoku Japan

M9.0 Earthquake (March 11, 2011)

FEMA

- 16,447 Deaths
- 4,787 Missing
- 5,888 Injured
- 430,000 Homeless
- 111,944 Buildings destroyed
- 637,277 Buildings damaged
- Honshu Island moved 7.8 feet West
- Nuclear power meltdown
- Cost could exceed $300 billion

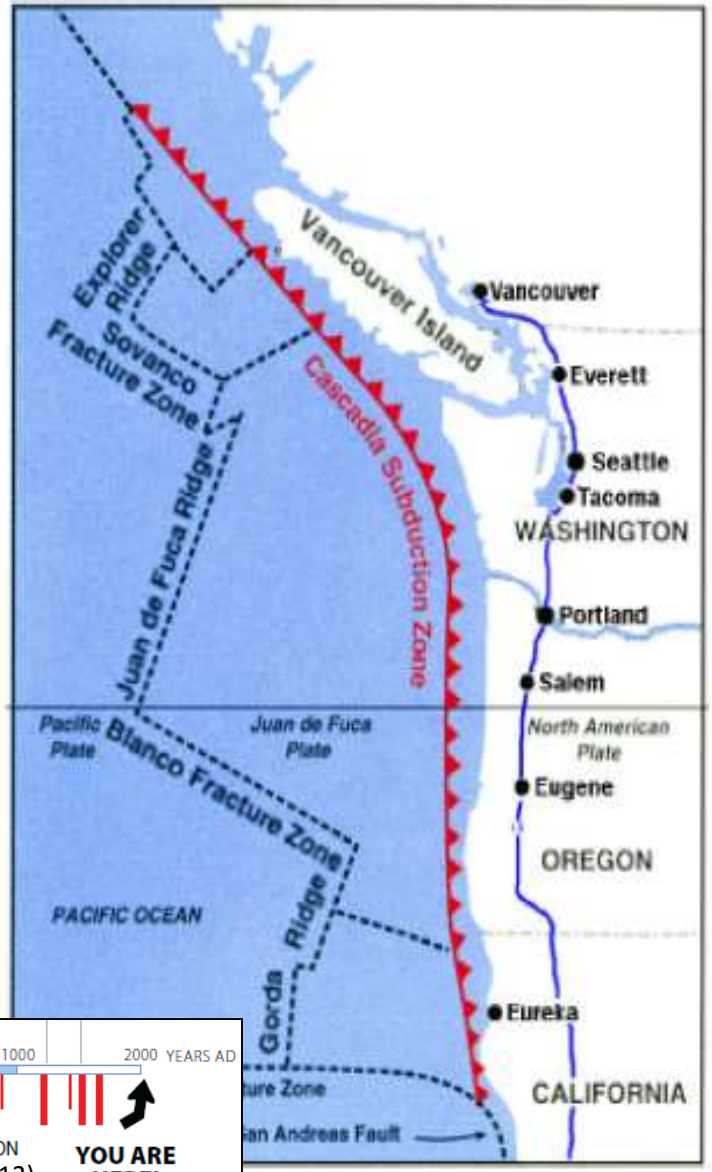


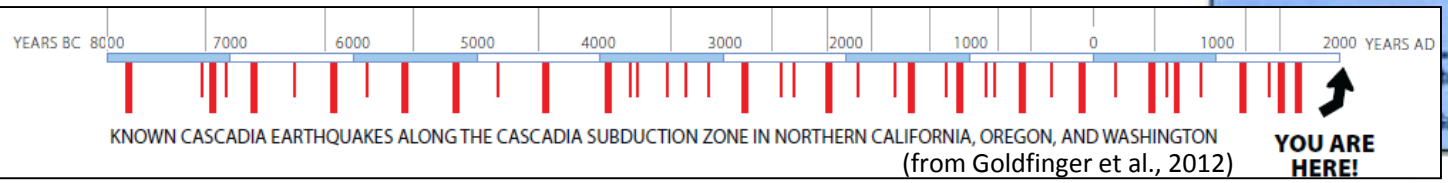


Planning Scenario

FEMA

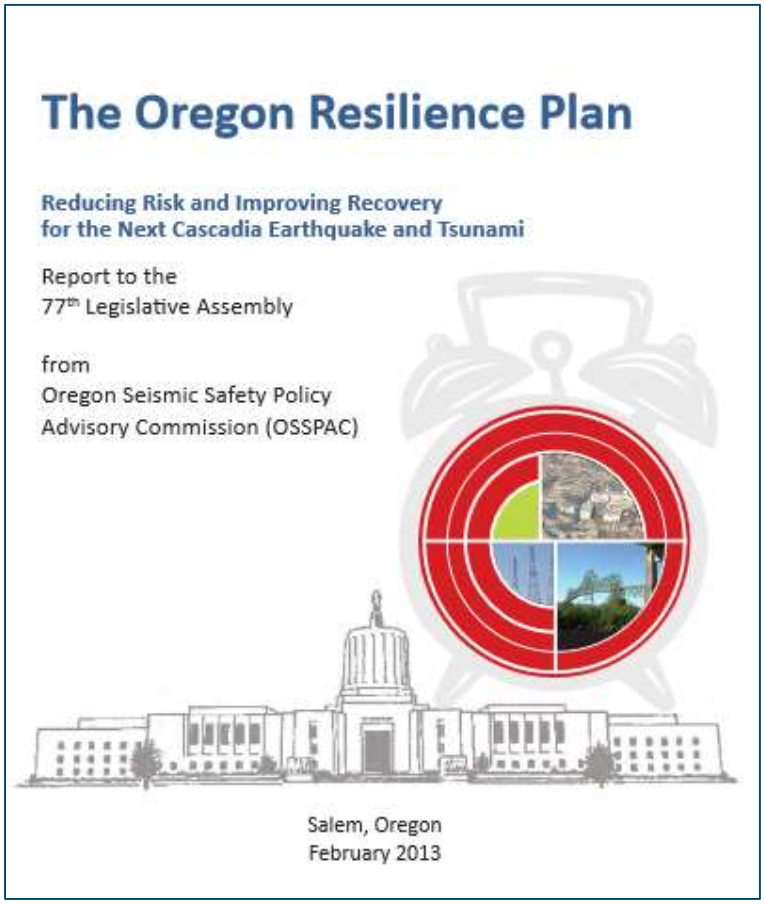
- 9.0 m. Earthquake
- February 6, 2012 at 9:41 AM PST
- Direct Impact to 3 States, 2 FEMA Regions
- Complete rupture of the 800 Mile Fault Line
- Impacts affecting over 140,000 sq. mi.
- Ground shaking lasts up to 5 minutes
- Numerous aftershocks with several of M7.0+
- 1,100+ Deaths From Earthquake 24,000+ injuries
- 10,600+ Deaths from tsunami & 2,600 injuries





(from Goldfinger et al., 2012)

Level of service goals provide the targets for infrastructure performance



"The backbone water system would be capable of supplying key community needs, including fire suppression, health and emergency response, and community drinking water distribution points, while damage to the larger (non-backbone) system is being addressed."

(Oregon Resilience Plan)

Infrastructure Systems Support the Social & Economic Functions of the Community

Figure 1-3: The social functions of a community define the functional requirements of a community's buildings and infrastructure systems.

The problem we need to solve is a *"social-technical problem"*

Desired performance

The pipe must continue to convey water after the design event

FUNCTIONAL

NOT ACCEPTABLE

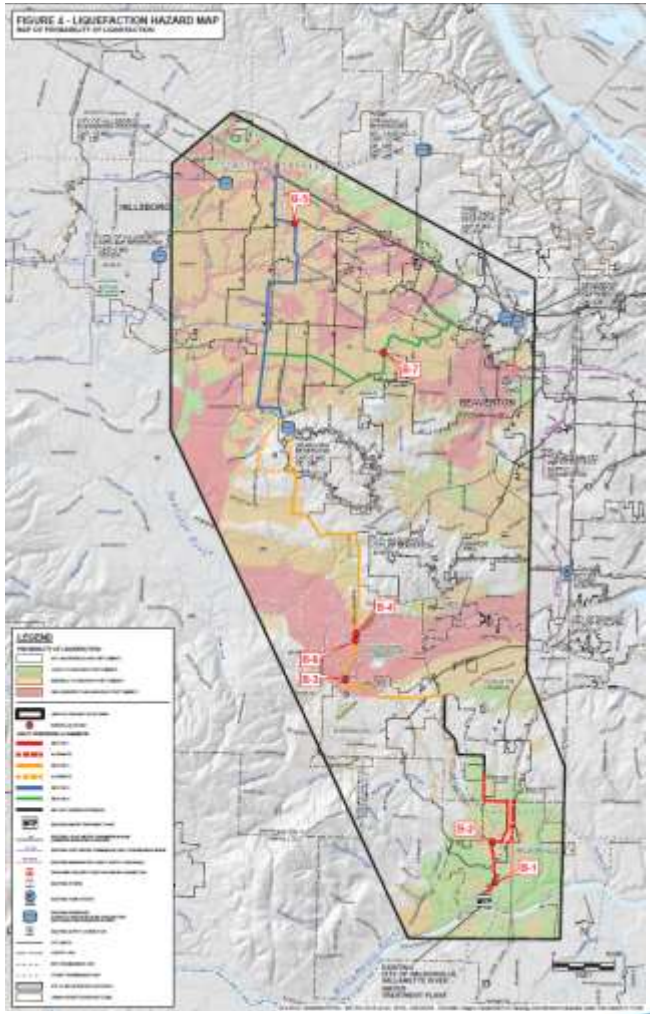
Overview of today's presentation

- Identifying a level of service goal for the transmission system
- Geohazards along the pipeline route
- Seismic issues specific to steel pipelines

Determining seismic forces requires geohazard area understanding

Soils Hazard Map

- Soils affect resiliency
- Geotech studies helps us understand where soil types occur



1964 Alaska Earthquake

- **Alaska 9.2 M Earthquake**
- **March 27, 1964, at 5:36 p.m.**

"Alaska Quake-Fourth Ave" by U.S. Army - http://libraryphoto.cr.usgs.gov/

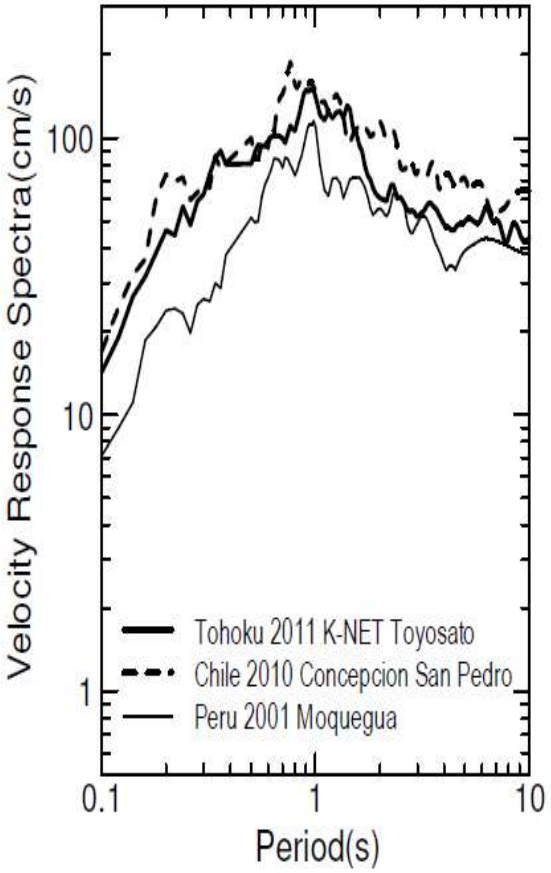
Project design earthquake recommendations

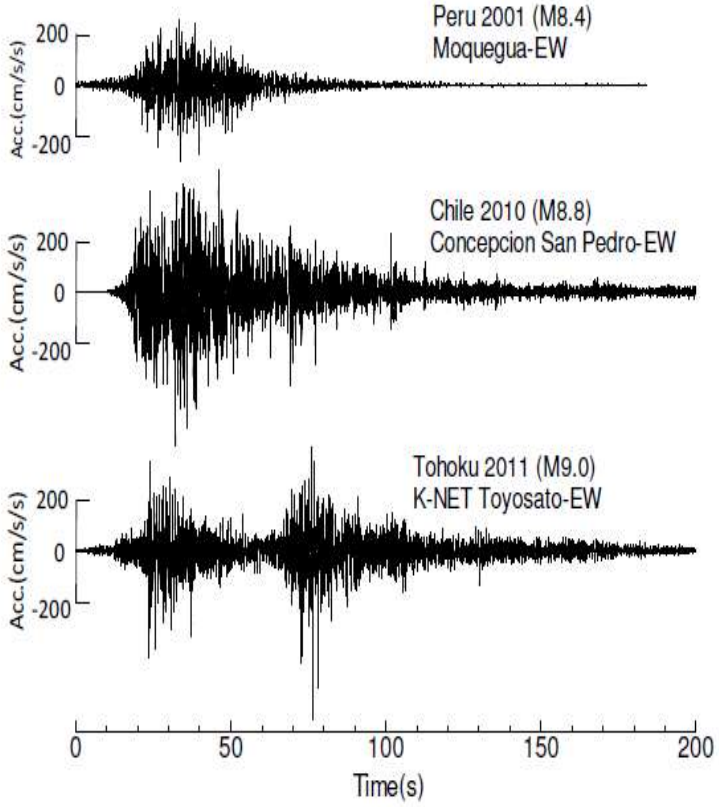
Seismic Sources: Local Faults, CSZ, Intraslab

1. Shallow-focus Crustal Earthquakes (Mw = 5 to 7)
2. Deep-focus, Intraplate Earthquakes (Mw = 6 to 7.5)
3. CSZ Interface Earthquakes (Mw = 8 to 9.2)

What events are we planning for? + What level of performance do we want from the pipeline?

Comparison of three recent subduction EQ ground motions





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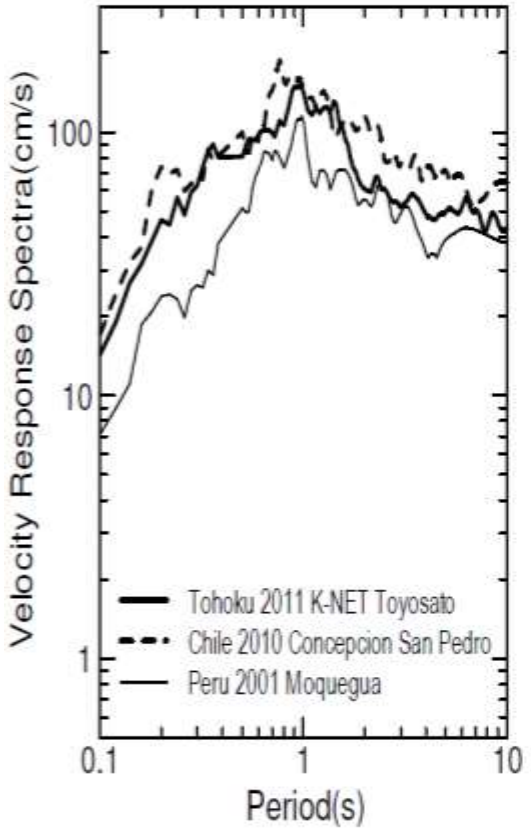
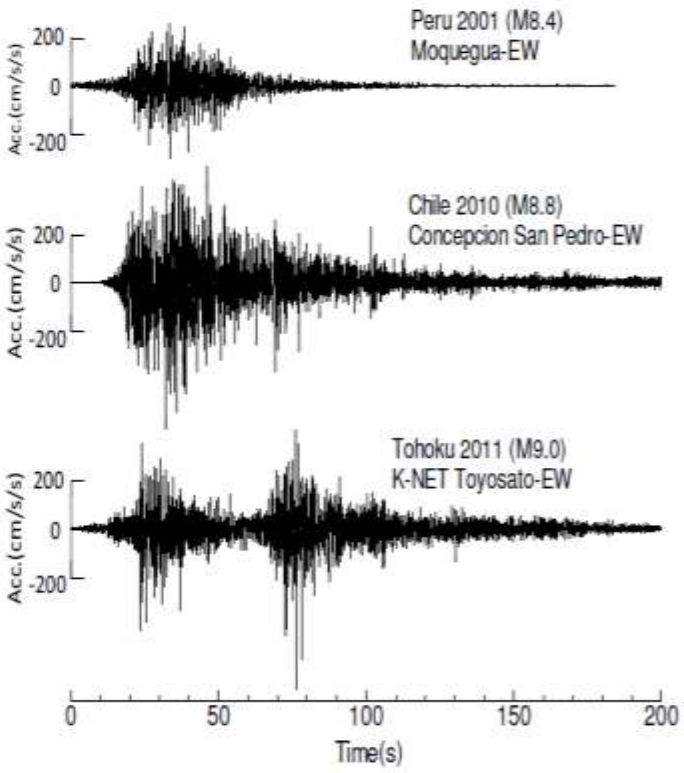
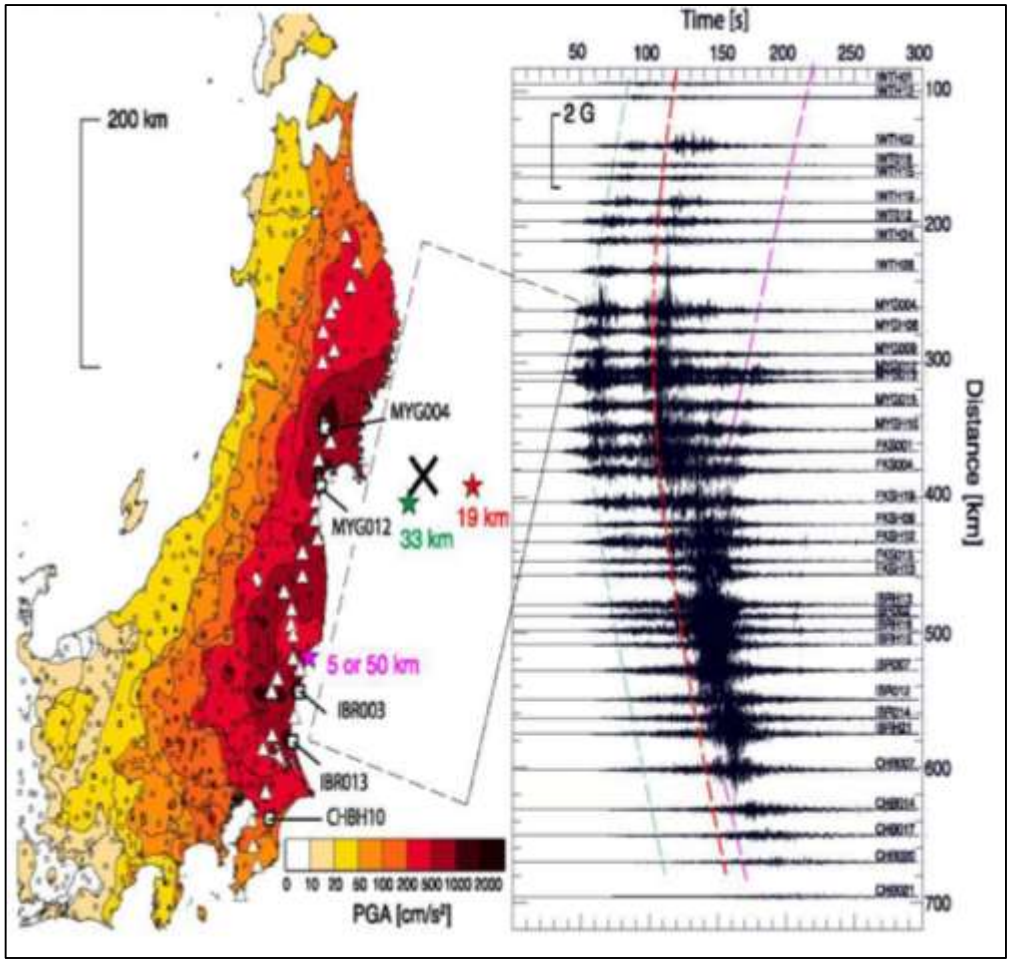




Patterns associated with CSZ events

- Extended period of ground shaking
- Larger area affected

More stress on infrastructure



2011 Japan EQ ground motion distribution

Project design earthquake recommendation

- Recommended design parameters
  - USGS 2014 map with minor adjustment for future updates

  (last update added more seismic zone around Portland area and considered more recurrence distribution for CSZ earthquakes)
  - 2475 year event
    - PGA - 0.40 to 0.45 g
  - Site-specific analysis using EQ ground motions for critical pieces of project (WTP, reservoir, PS, major crossings)

Overview

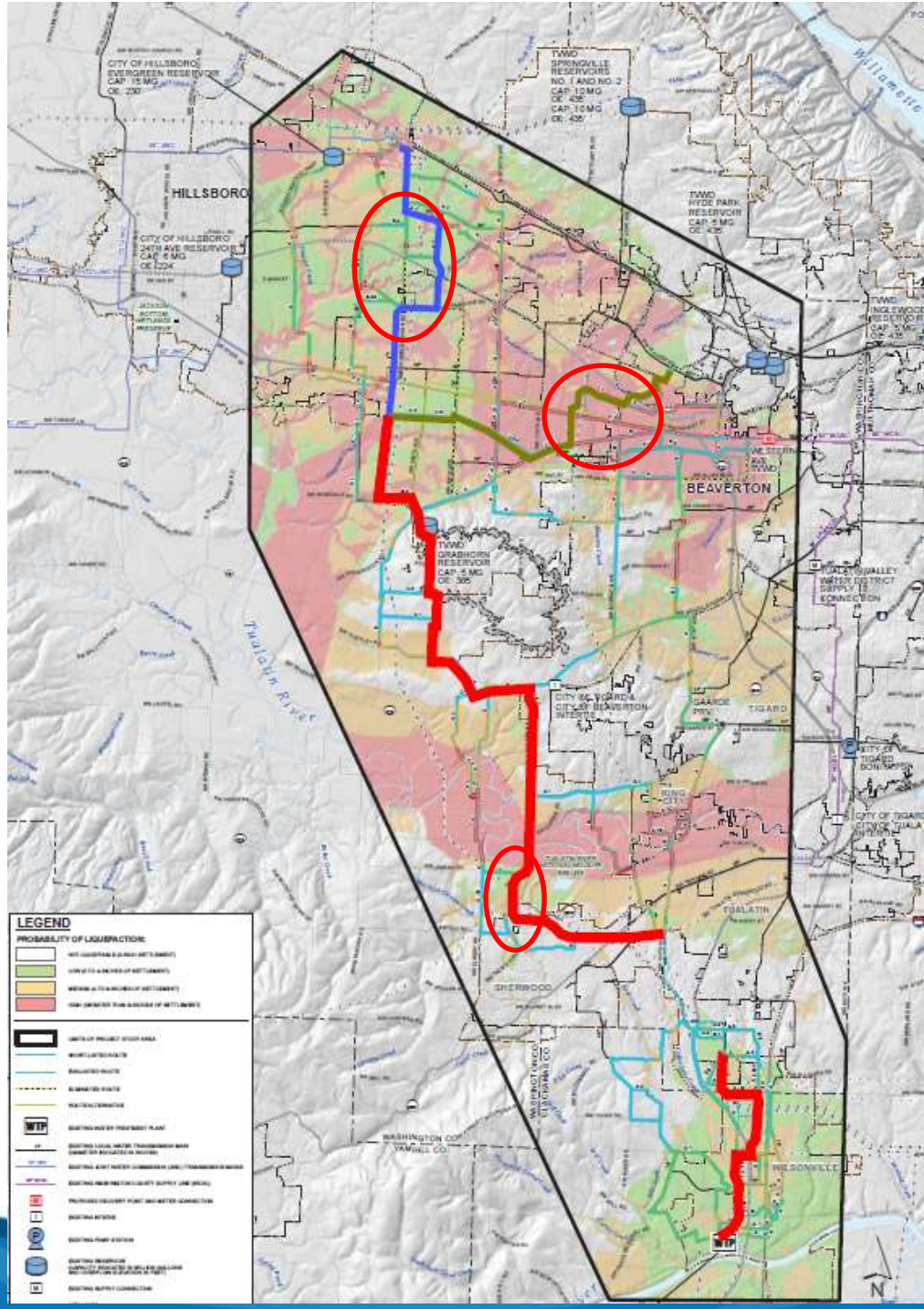
- Identifying a level of service goal for the transmission system
- Geohazards along the pipeline route
- Seismic issues specific to steel pipelines

Seismic hazards assessment

- Existing knowledge

(based on map review and regional experience)

  - Fault Rupture Potential: very low
  - Strong Shaking/Ground Amplification: low to medium
  - Liquefaction Settlement: low to high
  - Lateral Spreading: high (mainly along creek and river banks)



Predesign geotechnical exploration program

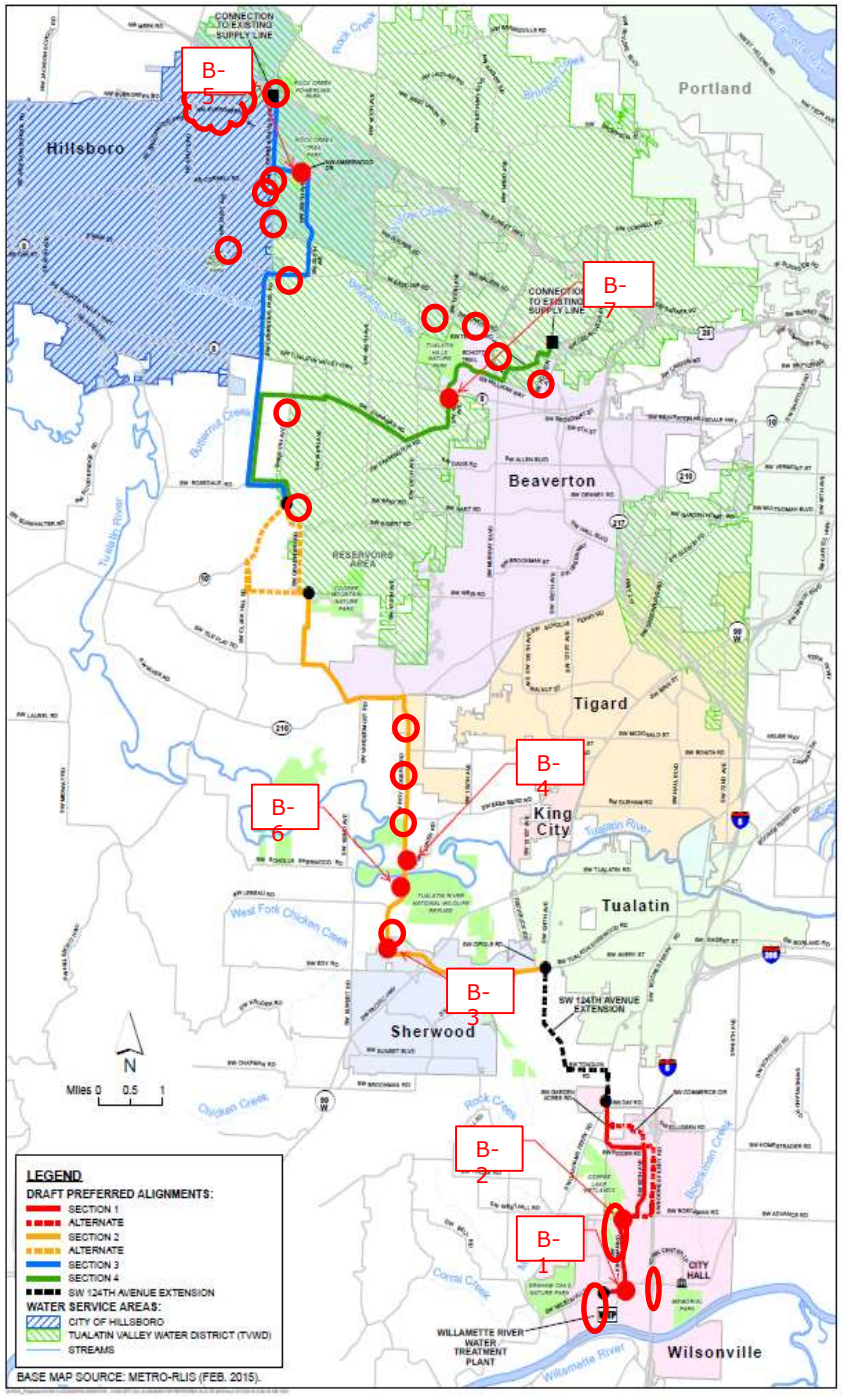
- **Current exploration borings along preferred pipeline route**
  - 7 borings at depths of 65 – 125’
  - Located mostly at major crossing locations

+

- Existing geotechnical information
  - ~ 20 relevant locations
  - Local bridges & roadways; TriMet; TVWD reservoir; WTP existing and new sites; Intel

+

- Specialized Testing



Tualatin Valley Water District

Differential settlements in liquefaction zones are significant

Location	Boring	Liquefaction Layer Depths	Estimated Settlement
Wilsonville Road Crossing	B-1	None	N/P
Beckman Road Crossing	B-2	28-34′	3″
Chicken Creek Crossing	B-3	20-30′ & 38-48′	10″
Tualatin River Crossing	B-4 B-6	20-38′ & 48-53′ 23-48′	6 to 7″
Rock Creek Crossing	B-5	15-25′ & 43-55′	7″
TV HWY Crossing @ Beaverton	B-7	10-30′ &	6″

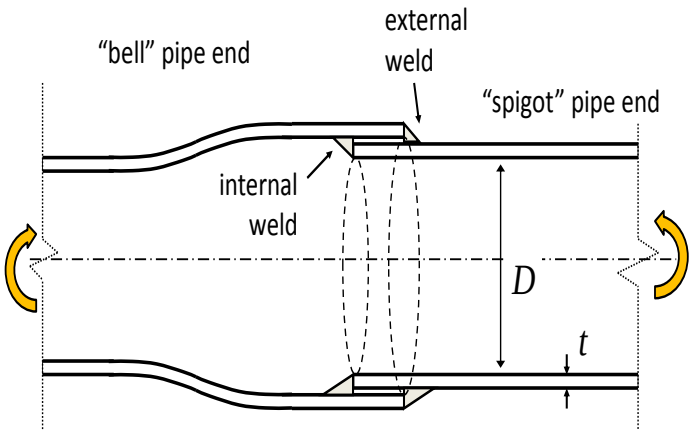
Overview

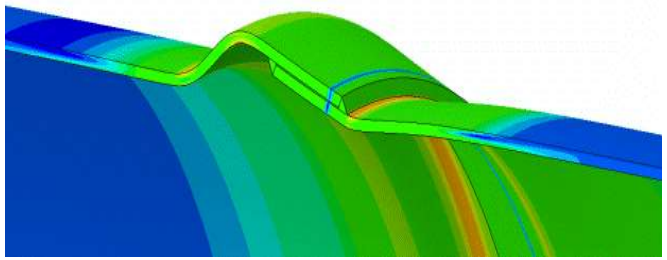
- Identifying a level of service goal for the transmission system
- Geohazards along the pipeline route
- Seismic issues specific to steel pipelines

With seismic forces defined, we are determining design stresses

However lap welded joints can pose a challenge

"Compressive deformation… represents the most severe type of loading imposed on welded steel pipelines during an earthquake" (O'Roarke and Jones, 2006) [Photo: Smith, 2006]





Karamanos, Keil & Card, ASCE Pipelines Conference, 2015, Baltimore

Behavior of steel pipeline under permanent ground deformation

- A 2% strain level is more than 10 times higher than the one corresponding to the yield strain of pipe material
- Tensile strain capacity depends on
  - Pipe base material
  - Weld material (always "overmatched"),
  - Type, size and location of discontinuities in the weld and HAZ,
  - Ductility of the weld metal and the HAZ.

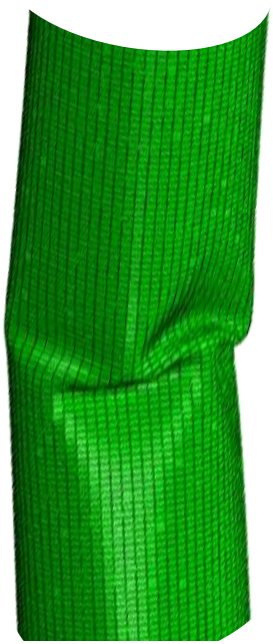
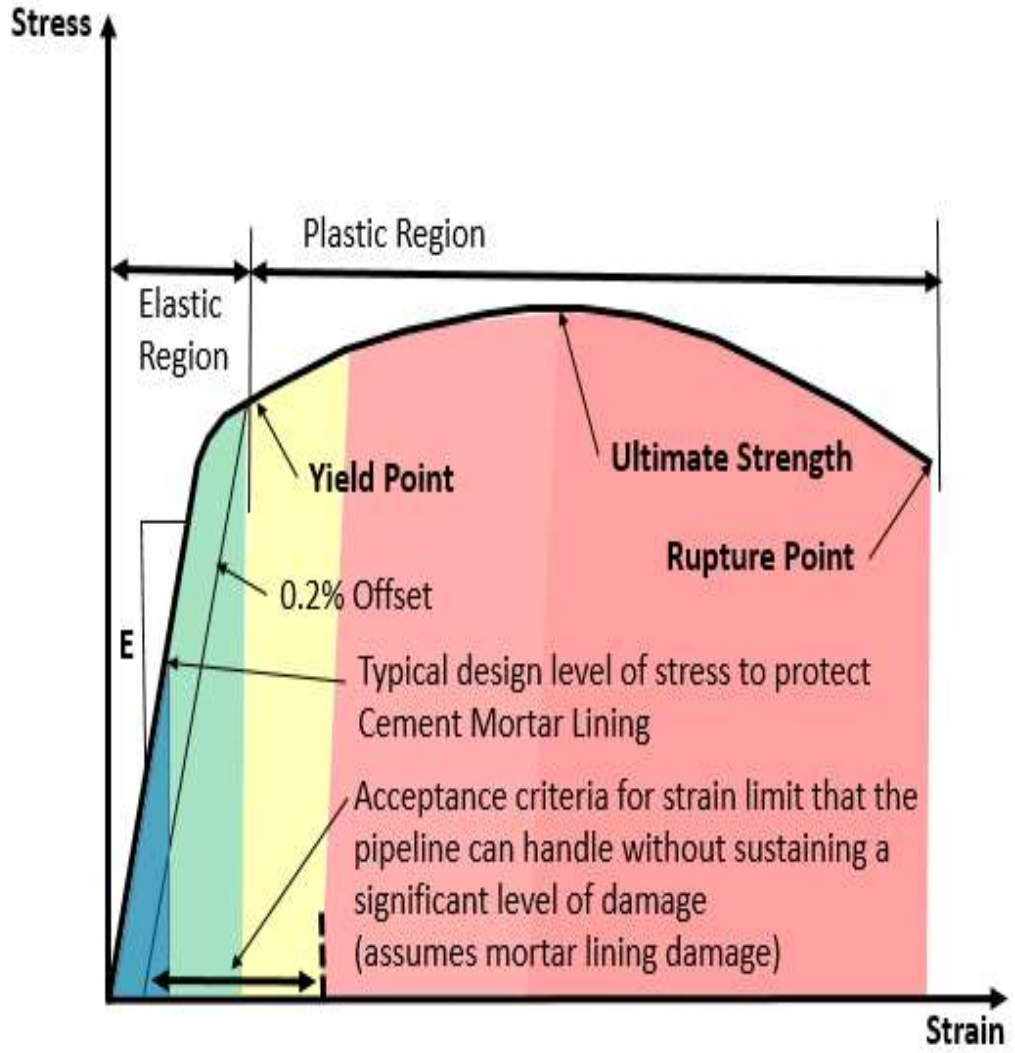


Table 4.2 Recommended Maximum Tensile Strain for PGD – Onshore Steel Pipe with Good Quality Butt Welds

Newmark & Hall (1975)	1984 ASCE Guideline	2001 ALA Steel Pipe Guideline	2004 PRCI Guideline	Wijewickreme et al. (2005)
4%	3 to 5%	4% – (pressure integrity goal) 2% – (normal operability goal)	2 – 4% (pressure integrity goal) 1 – 2 % (normal operability goal)	3% (10% probability of tensile rupture) 10% (90 % probability of tensile rupture)

Strain-based design decreases conservatism by allowing deformation but not failure

- Remain in service without need for repair
- Limit strain to tolerable levels
  - Low level – **may require repair to linings**
  - High level without rupture - **require repair to pipe**

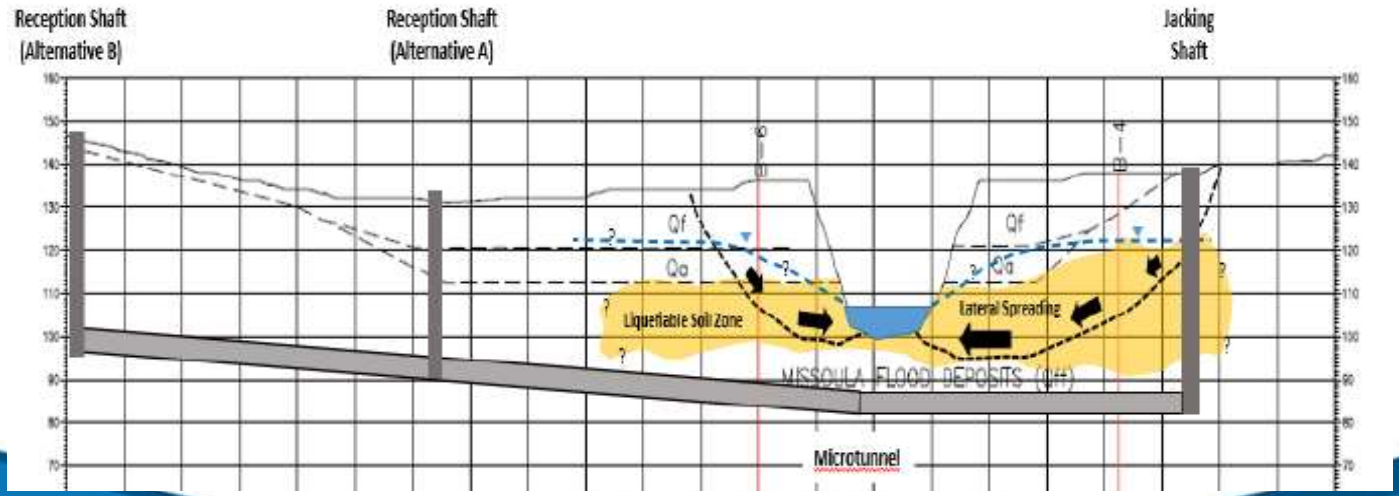


Three main categories to address

Strong ground shaking → Standard design (joint and material selection) is sufficient to address

Lateral spreading zones (mainly in creek/river areas) → Minimize impact through trenchless or special profile

Liquefaction and transition areas with differential settlements → Toolbox of options applied specific to each site



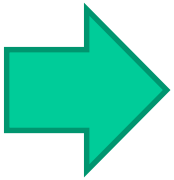
Mitigation for areas with permanent ground deformation

General Approach	No.	Specific mitigation measure	Cost to implement
Increase pipe capacity to resist deformation	1	Localized increase pipe wall thickness	$
	2	Use special joints (e.g., butt joints) and alternative pipe linings	$$
Reduce soil loading on the pipeline	3	Use select granular trench backfill or other deformable material to accommodate movement in the trench	$-$$
	4	Use low-friction pipe-wrapping systems to reduce axial friction	$$
	5	Orient pipeline parallel with movement and maintain the pipeline straight through deformation zone for as long as possible	$-$$
	6	Bridge differential settlement zones with reinforced trench base	$$
	7	Locate pipeline and shaft to stay outside extents of movement	$-$$$
Isolate pipeline	8	Locate beneath the zone of ground deformation	$$$
	9	Bridge or pile support pipeline through deformation zones	$$$
	10	Ground improvement	$$$$
	11	Earth retention systems to resist deformation	$$$-$$$$

Next steps

- Move from planning to design!

Design level geotechnical exploration program for each segment



Identification of specific permanent deformation profiles and develop appropriate mitigation

Questions

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Willamette Water Supply
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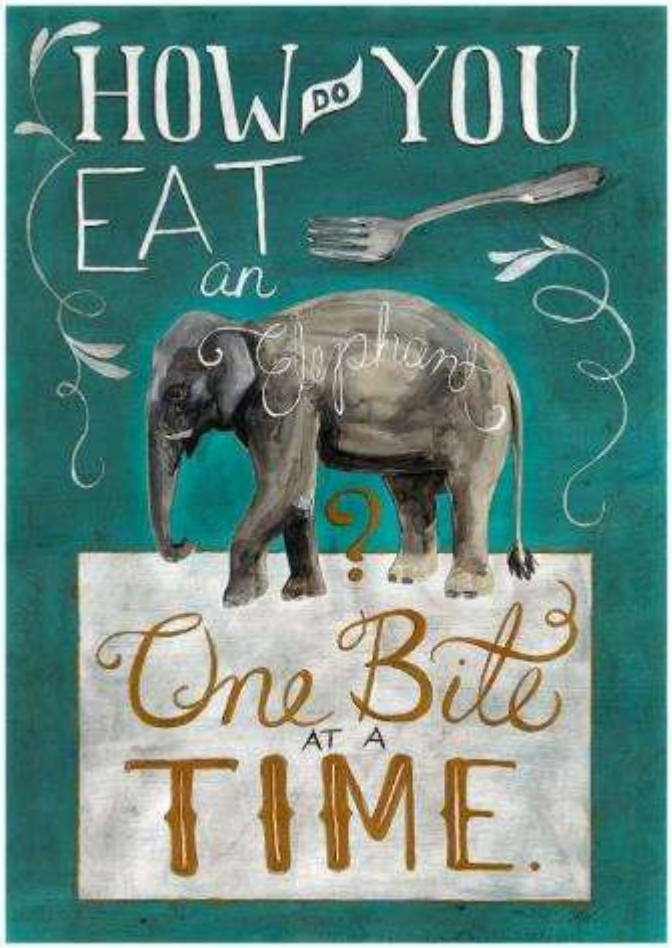
How Do You Deliver a $1 Billion Water Supply Program?

- The answer is similar to the question, “how do you eat an elephant?”
- Answer: One bite at a time
- In our case, it’s about the ***Work Packages***



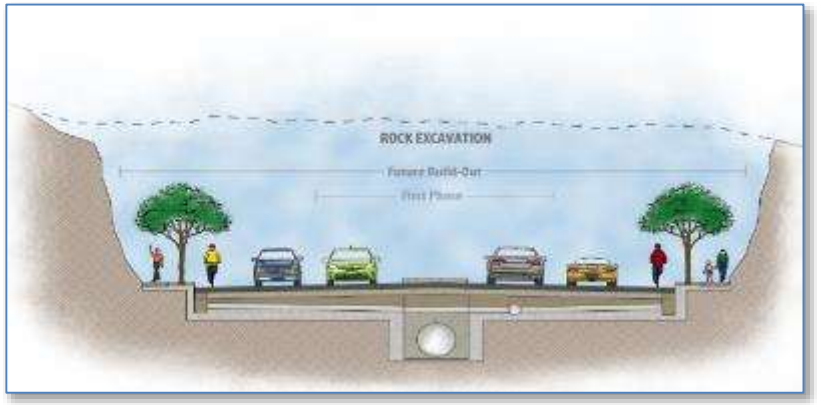
Four main considerations for development of work packages

- **Boundary** – jurisdictional/service areas, turnouts, opportunity projects
- **Economic** – sizing of packages in relation to contracting community and maintaining competition
- **Environmental** – sensitive areas, land use
- **Technical** – complexity of construction, geotechnical/seismic, system pressures & pipe diameters

When do we build the work packages?

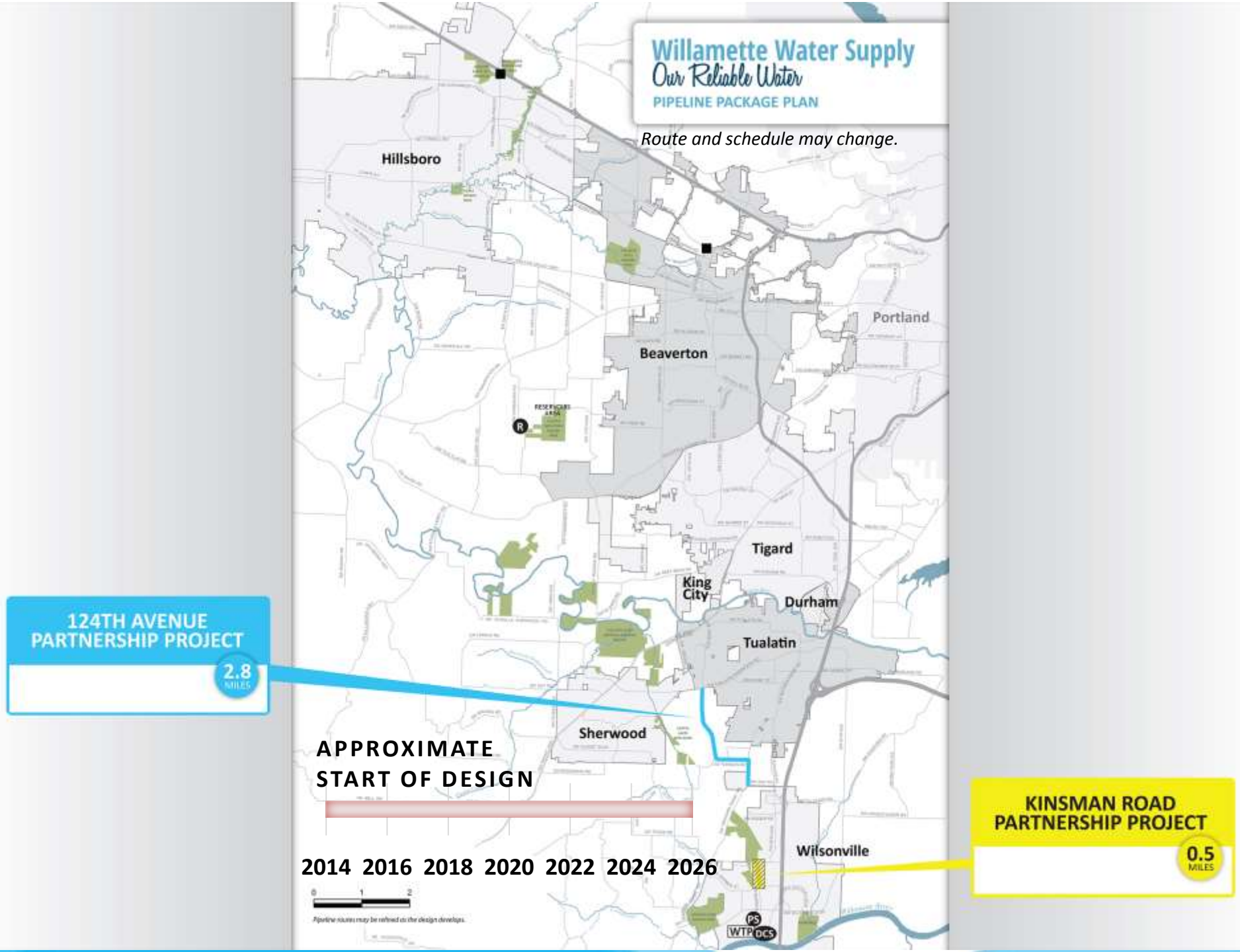
Depends on:

- Cash flow and finances
- Opportunity projects and timing
- Environmental permitting
- Overall schedule to complete on time



SW 124th Avenue Project

South Hillsboro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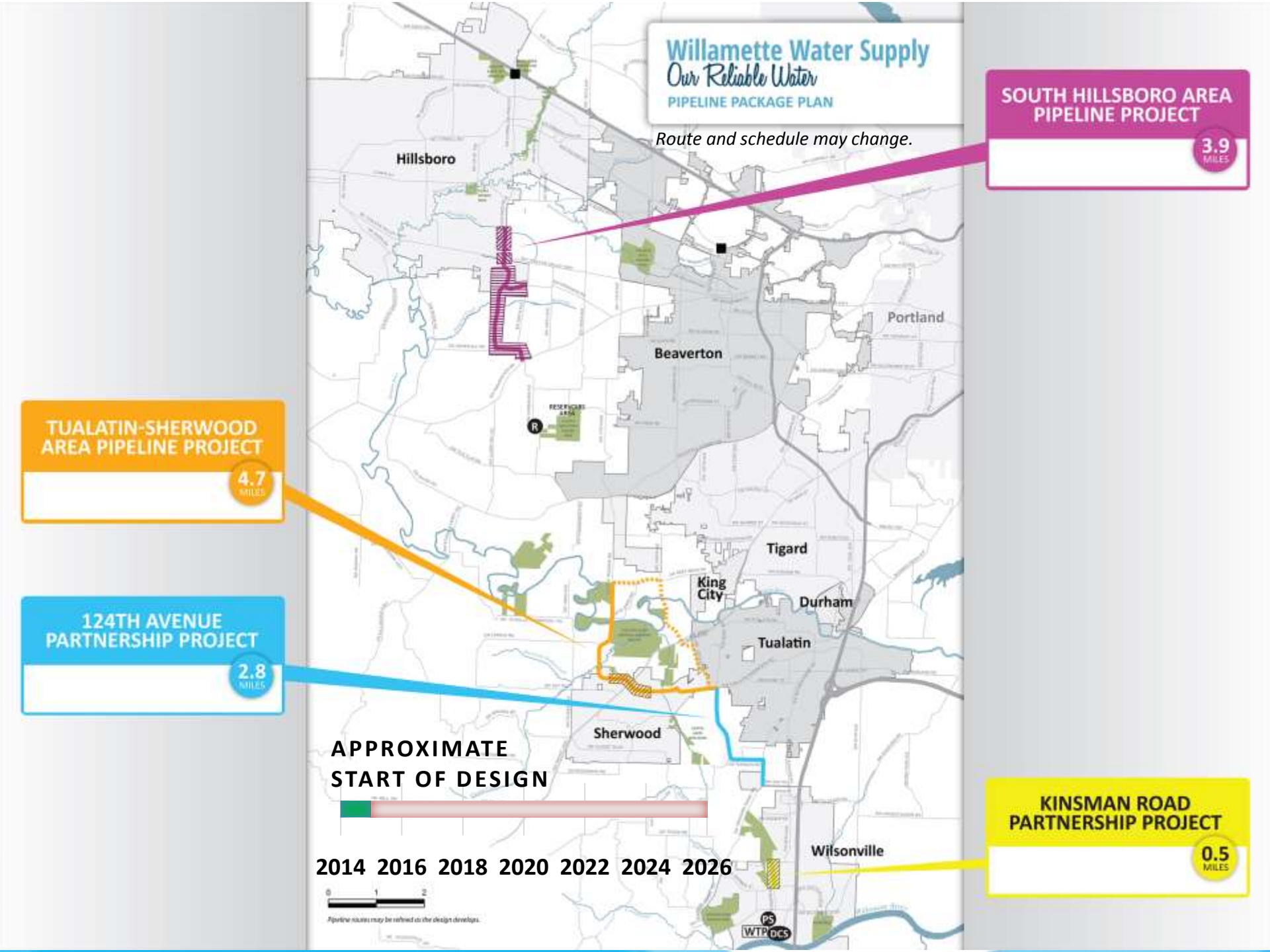
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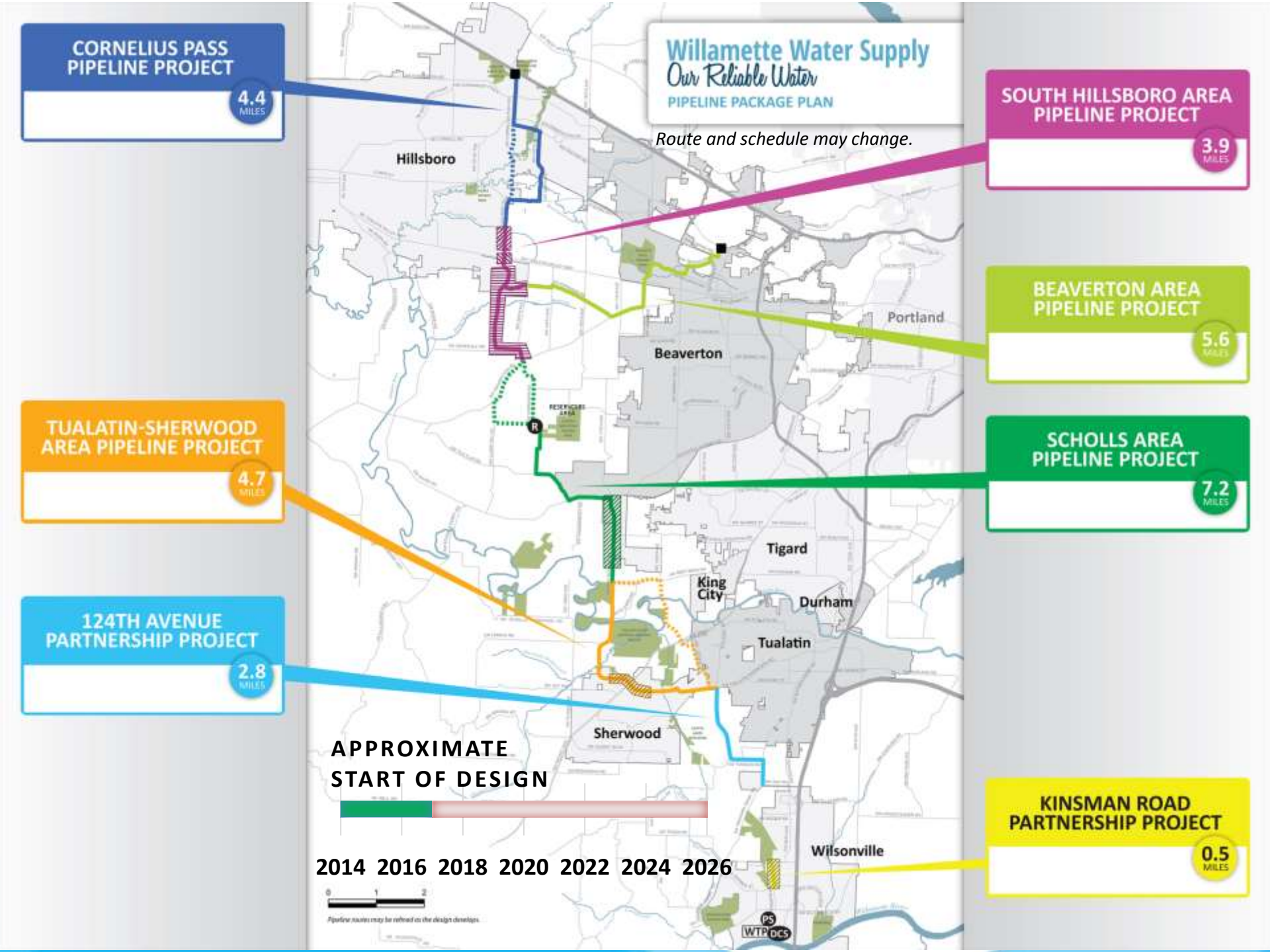
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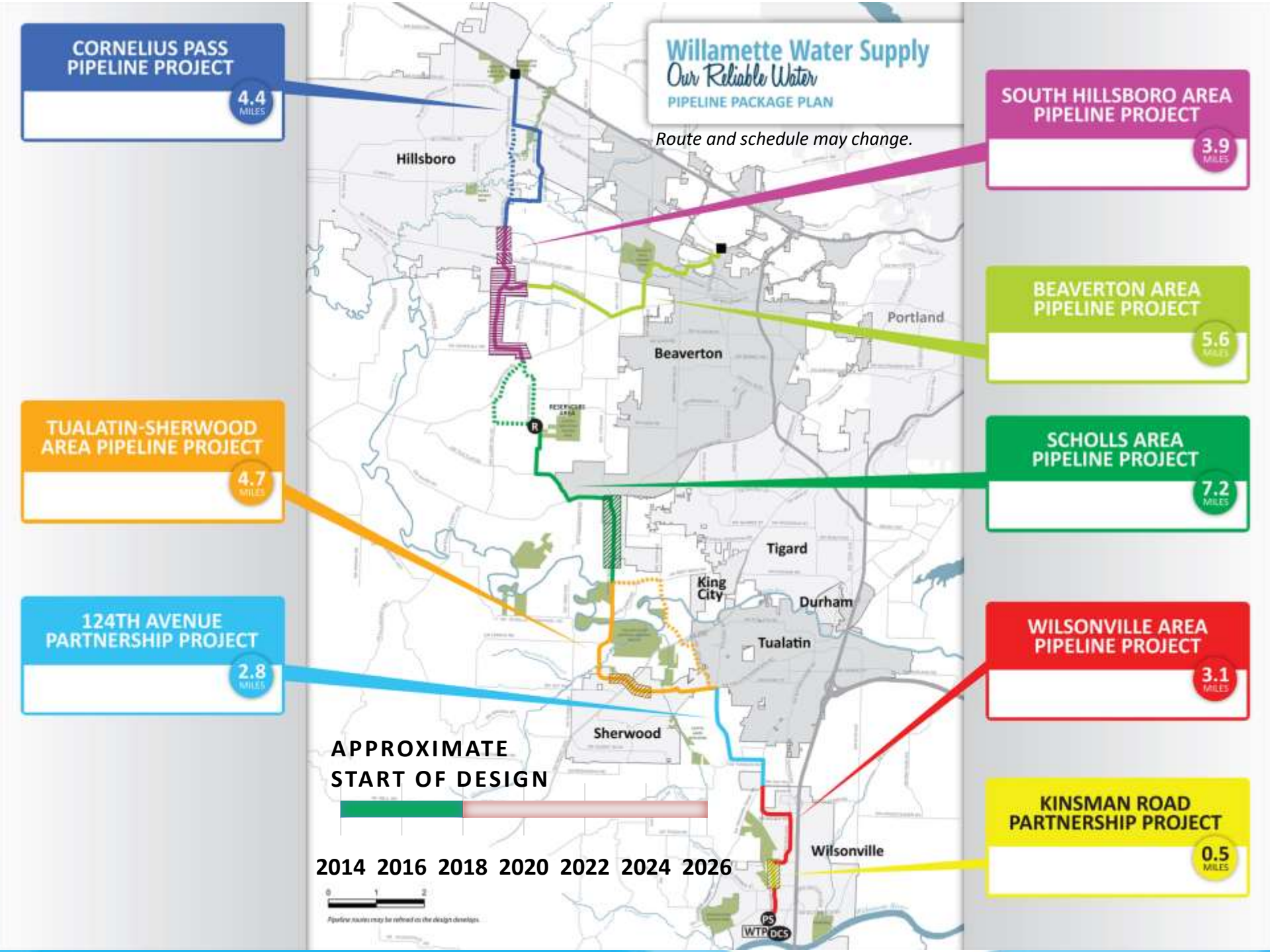
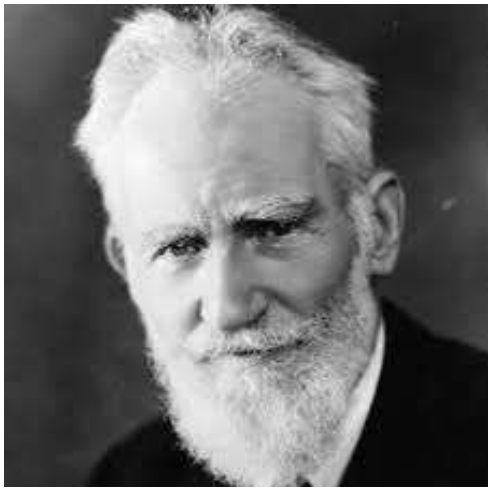

Willamette Water Supply
Our Reliable Water
PIPELINE PACKAGE PLAN
Route and schedule may change.
CORNELIUS PASS PIPELINE PROJECT
4.4 MILES
SOUTH HILLSBORO AREA PIPELINE PROJECT
3.9 MILES
BEAVERTON AREA PIPELINE PROJECT
5.6 MILES
TUALATIN-SHERWOOD AREA PIPELINE PROJECT
4.7 MILES
SCHOLLS AREA PIPELINE PROJECT
7.2 MILES
124TH AVENUE PARTNERSHIP PROJECT
2.8 MILES
WILSONVILLE AREA PIPELINE PROJECT
3.1 MILES
KINSMAN ROAD PARTNERSHIP PROJECT
0.5 MILES
Hillsboro
Beaverton
Portland
Tigard
King City
Durham
Tualatin
Sherwood
Wilsonville
APPROXIMATE START OF DESIGN
2014 2016 2018 2020 2022 2024 2026
PS
WTP
DCS

Technical challenges we are solving to provide the reliable water supply

- Establishing level of service goals
- Identifying geohazard areas
- Analyzing stresses in infrastructure
- Selecting appropriate mitigation methods to achieve goals

How Do You Solve the Problem?



George Bernard Shaw

Willamette Water Supply
Our Reliable Water

Safety Moment

Program Overview

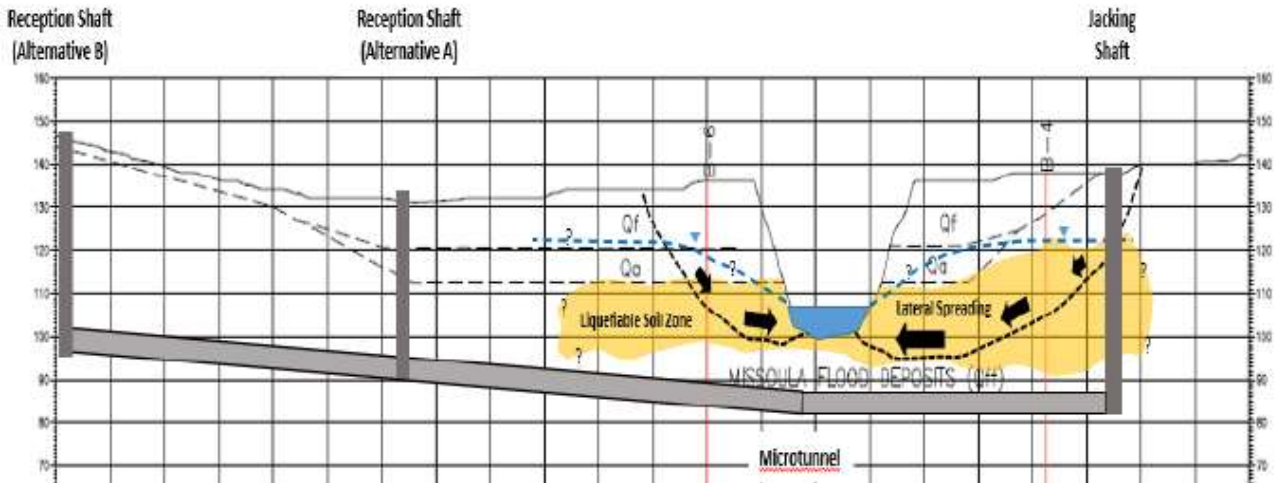
Geologic & Geotechnical Conditions

Steel Pipe Considerations

Geohazards range from rock to liquefiable soils

Rock along SW 124th compared to liquefiable soils along the Tualatin River (and other areas)

Strategy to avoid geohazard areas



Willamette Water Supply
Our Reliable Water

Overview of today's presentation

- Identifying a level of service goal for the transmission system
- Geohazards along the pipeline route
- Seismic issues specific to steel pipelines

Updated seismic hazards map

Hillsboro area

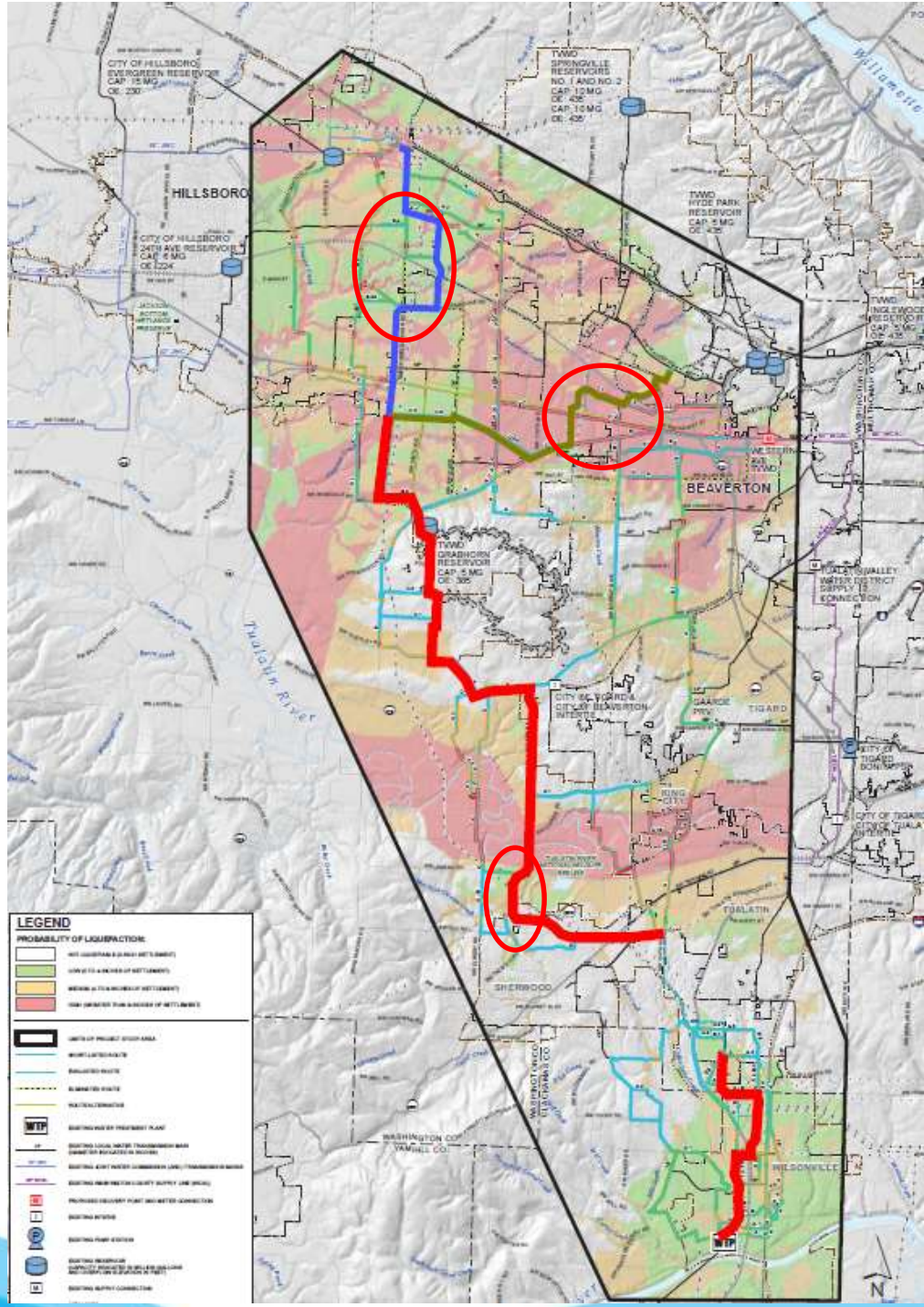
- medium risk along Cornelius Pass (previously considered low)

Beaverton area

- medium risk in TV HWY to Hocken area (previously considered high)

Chicken Creek/Sherwood North

- high risk (previously considered medium risk)



Safety Moment

Program Overview

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John’s slides

There are three main options for mitigating

Significant portions of the alignment are affected by liquefaction and localized permanent ground deformation (1 to 12 inches)

- Avoid the hazard
  - Routing, tunnel depth and shaft placement
- Reduce the hazard to an acceptable level
  - Ground improvements, pile foundations
- Accommodate the hazard
  - Flexible joints, stiffened pipe, alternate materials (Kubota)

Compressive Forces are Key:

"Compressive deformation… represents the most severe type of loading imposed on welded steel pipelines during an earthquake" (O'Roarke and Jones, 2006) [Photo: Smith, 2006]