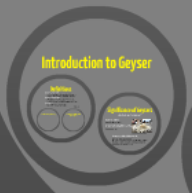
Towards Predicting the Occurrence of Geysers and CSOs in Combined Sewer Systems

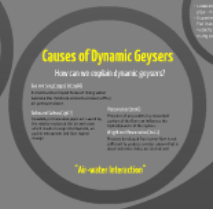
Recent developments and future perspectives

Arturo Leon[1], Assistant Professor
YunJi Choi[1], PhD Student
[1]Oregon State University
2/27/2013

Research Questions

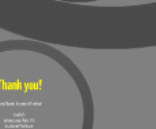
Q1: Is there any waterhammer push effect from the flow in the horizontal pipe when air pocket enters the vertical shaft?
Q2: What causes air pocket to accelerate in vertical shaft?
Q3: What air-water interaction mechanisms occur in vertical shaft during the air pocket rise?

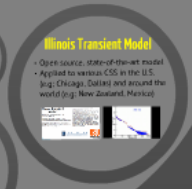


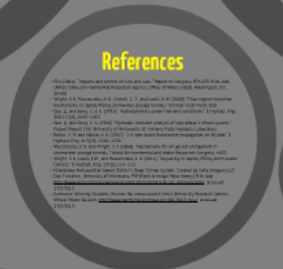


Research Goals

- Mechanistic understanding of dynamic geysers and non-dynamic CSO events in complex Combined Sewer Systems
- Determining relationships for quantifying CSO discharges and implementing these into an open source model: Illinois Transient Model (ITM)







Towards Predicting the Occurrence of Geysers and CSOs in Combined Sewer Systems

Recent developments and future perspectives

Arturo Leon[1], Assistant Professor
YunJi Choi[1], PhD Student
[1]Oregon State University
2/27/2013

This presentation was developed under Grant number R835187 awarded by the U.S. Environmental Protection Agency. It has not been formally reviewed by EPA. The views expressed are solely those of Arturo Leon and YunJi Choi. EPA does not endorse any products or commercial services mentioned.

Introduction to Geyser

Definitions

Combined Sewer System (CSS)
A wastewater collection system designed to collect and convey sanitary wastewater and stormwater through a single system
Combined Sewer Overflow (CSO)
When collection system (CSS) capacity is exceeded, sanitary wastewater and storm water discharge directly to surface waters
Dynamic Geyser
Dynamic CSO event (air-water interaction)

EPA (2004)

Combined Sewer System (CSS)

Combined Sewer Overflow (CSO) "Dynamic Geyser"

Significance of Geysers

why should we study geysers?

Impact on Society
Public health and safety

Interest of Municipalities and EPA
Minimizing CSOs

Interests of Scientific Community
Why do dynamic geysers occur?
How can geysers be reproduced in a laboratory setting?
Development of numerical models for predicting the occurrence of geysers and CSOs

Guo and

It must
becaus
air pres

Bellos a

Instabil
the rela
which r
pocket
change

Definitions

Combined Sewer System (CSS)

A wastewater collection system designed to collect and convey sanitary wastewater and stormwater through a single system

Combined Sewer Overflow (CSO)

When collection system (CSS) capacity is exceeded, sanitary wastewater and storm water discharge directly to surface waters

Dynamic Geyser

Dynamic CSO event (air-water interaction)

EPA (2004)

Combined Sewer System (CSS)

Combined Sewer Overflow (CSO) "Dynamic Geyser"

Combined Sewer System (CSS)

Milwaukee Metropolitan Sewer District's
Deep Tunnel System, Suite Imagery LLC

Milwaukee Metropolitan Sewer District's
Deep Tunnel System, Suite Imagery LLC

Combined Sewer Overflow (CSO) "Dynamic Geyser"

Stormwater Tunnel in Minneapolis, Minnesota
Recorded by St. Anthony Falls Hydraulics Laboratory, University of Minnesota
Wright et al. (2008)


7-03-99 SAT A03
5*19*36A *06 L

Definitions

Combined Sewer System (CSS)

A wastewater collection system designed to collect and convey sanitary wastewater and stormwater through a single system

Combined Sewer Overflow (CSO)

When collection system (CSS) capacity is exceeded, sanitary wastewater and storm water discharge directly to surface waters

Dynamic Geyser

Dynamic CSO event (air-water interaction)

EPA (2004)

Significance of Geysers

why should we study geysers?

Impact on Society

Public health and safety

Interest of Municipalities and EPA

Minimizing CSOs

Photo Courtesy to Duluth Deluge 2012 - the torrential flooding of June 2012 Blog

Interests of Scientific Community

Why do dynamic geysers occur?
How can geysers be reproduced in a laboratory setting?
Development of numerical models for predicting the occurrence of geysers and CSOs

r

ers

- Laboratory studies are
  pipe - no complex pip
- Experiments performe
  For instance, experim
  velocity field informat
  rising pocket

Causes of Dynamic Geysers

How can we explain dynamic geysers?

Guo and Song (1991) & (1988)

It must be the impact force of rising water because the manhole cannot be blown off by air pressure alone.

Bellos and Sakkas (1967)

Instability in horizontal pipes are caused by the relative motion of the air and water which results in surge development, air pocket entrapment and flow regime change.

Vasconcelos (2006)

Presence of air pockets in pressurized portion of the flow can influence the hydrodynamics of the system.

Wright and Vasconcelos (2011)

Pressure developed from sewer flow is not sufficient to produce a water column that is observed in the video. Air is involved!

"Air-water Interaction"

Limitations of Current Experimental Studies

- Laboratory studies are restricted to a single pipe - no complex pipe network was used
- Experiments performed were not rigorous. For instance, experiments did not extract velocity field information surrounding the rising pocket

ers

Research Questions

Q1: Is there any waterhammer push effect from the flow in the horizontal pipe when air pocket enters the vertical shaft?

Q2: What causes air pocket to accelerate in vertical shaft?

Q3: What air-water interaction mechanisms occur in vertical shaft during the air pocket rise?

Limitations of Current Experimental Studies

- Laboratory studies are restricted to a pipe - no complex pipe network was

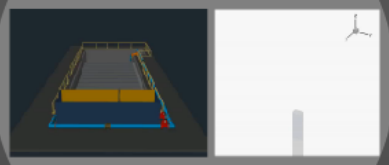
Introduction to Geysers

This presentation was developed under Grant number R835187 awarded by the U.S. Environmental Protection Agency. It has not been formally reviewed by EPA. The views expressed are solely those of Arturo Leon and Yunli Choi. EPA does not endorse any products or commercial services mentioned.

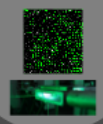
Research Goals

- Mechanistic understanding of dynamic geysers and non-dynamic CSO events in complex Combined Sewer Systems
- Determining relationships for quantifying CSO discharges and implementing these into an open source model: Illinois Transient Model (ITM)

Preliminary Results

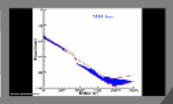


Particle Image Velocimetry (PIV)



Illinois Transient Model

- Open source, state-of-the-art model
- Applied to various CSS in the U.S. (e.g; Chicago, Dallas) and around the world (e.g; New Zealand, Mexico)



CSS of Portland, Oregon

References

...and ssos." Report to Congress EPA 833-R-04-001, ...gency, Office of Water (4203), Washingron, D.C.

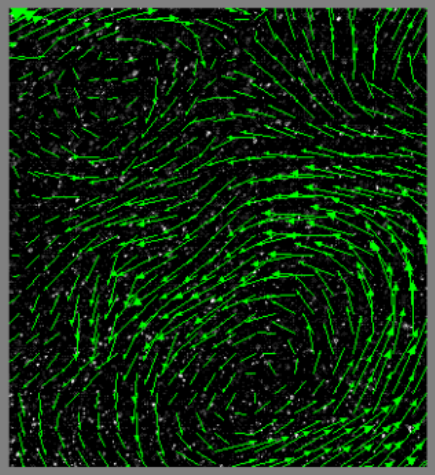
..., T., and Lewis, J. W. (2008). "Flow regime transition ... storage tunnels." Environ Fluid Mech, 8(5)

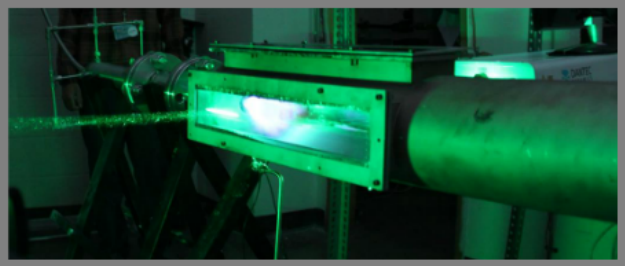
Research Goals

- Mechanistic understanding of dynamic geysers and non-dynamic CSO events in complex Combined Sewer Systems
- Determining relationships for quantifying CSO discharges and implementing these into an open source model: Illinois Transient Model (ITM)

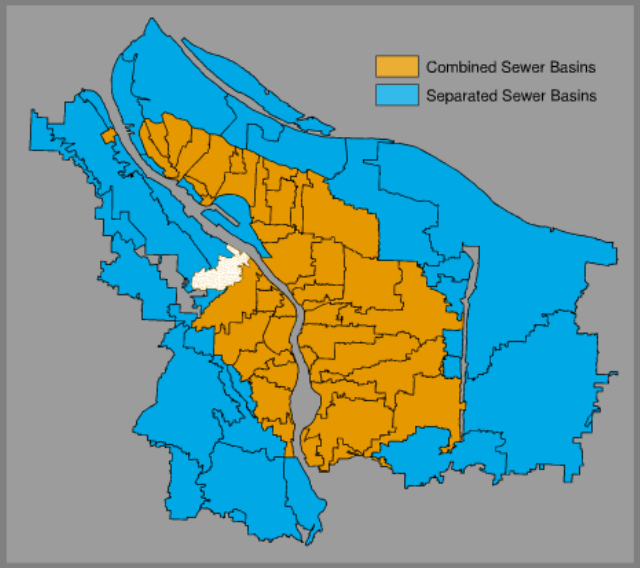
Preliminary Results

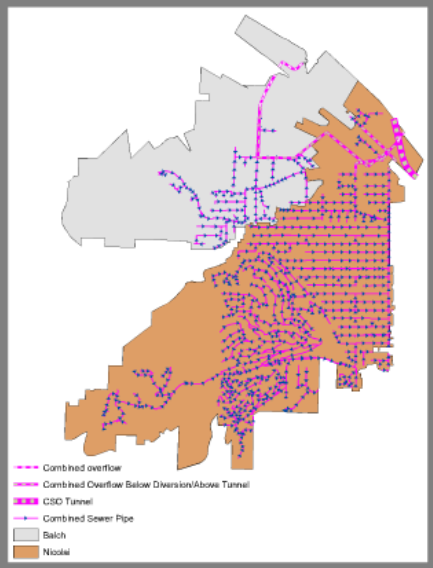
Particle Image Velocimetry (PIV)

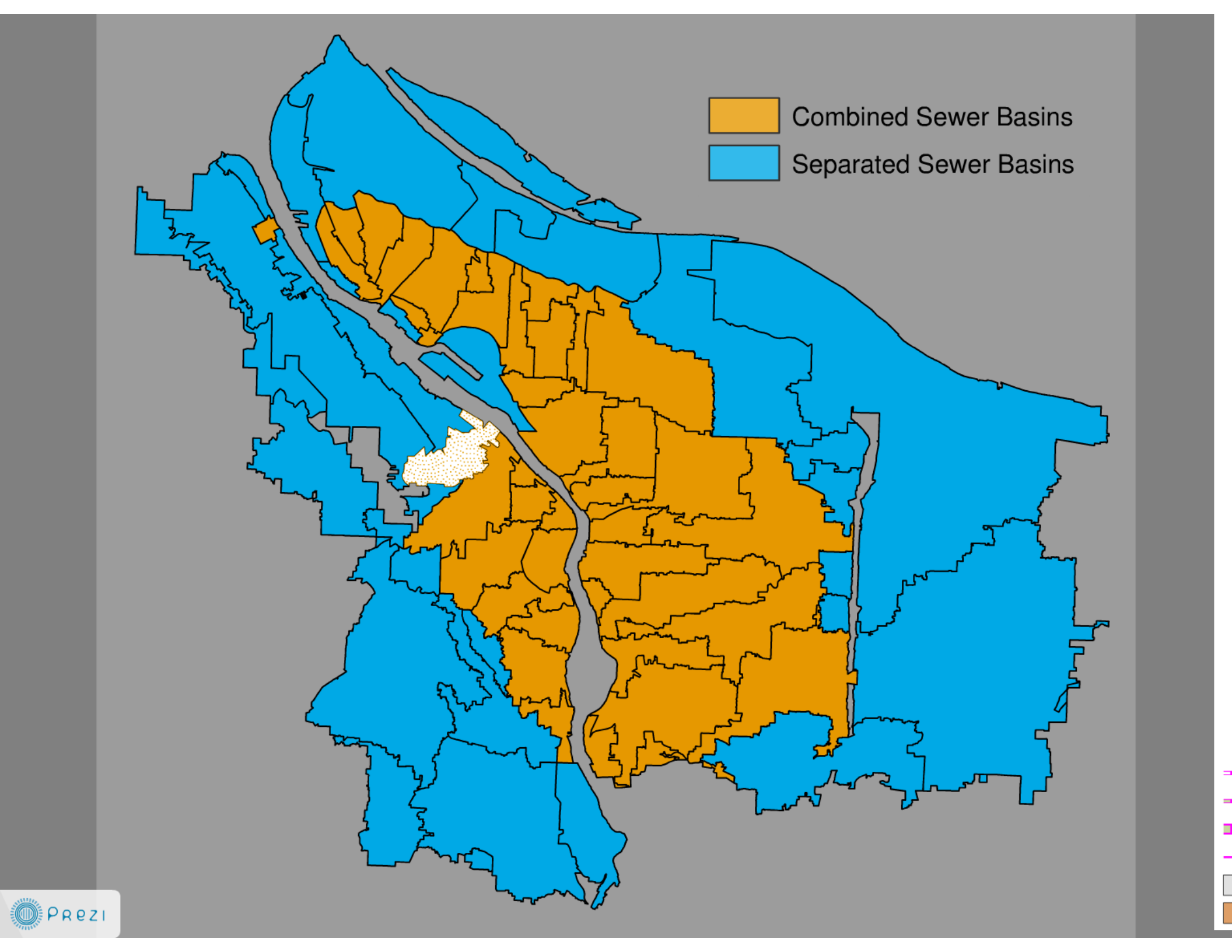




CSS of Portland, Oregon

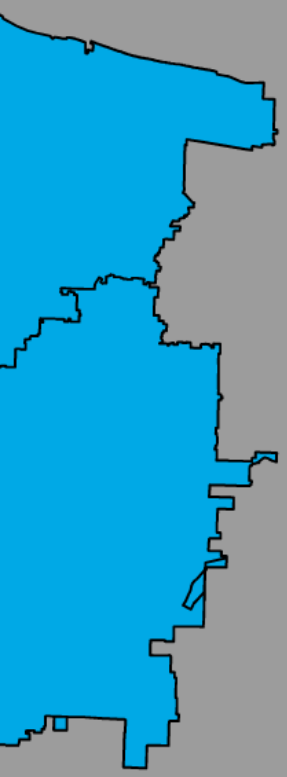


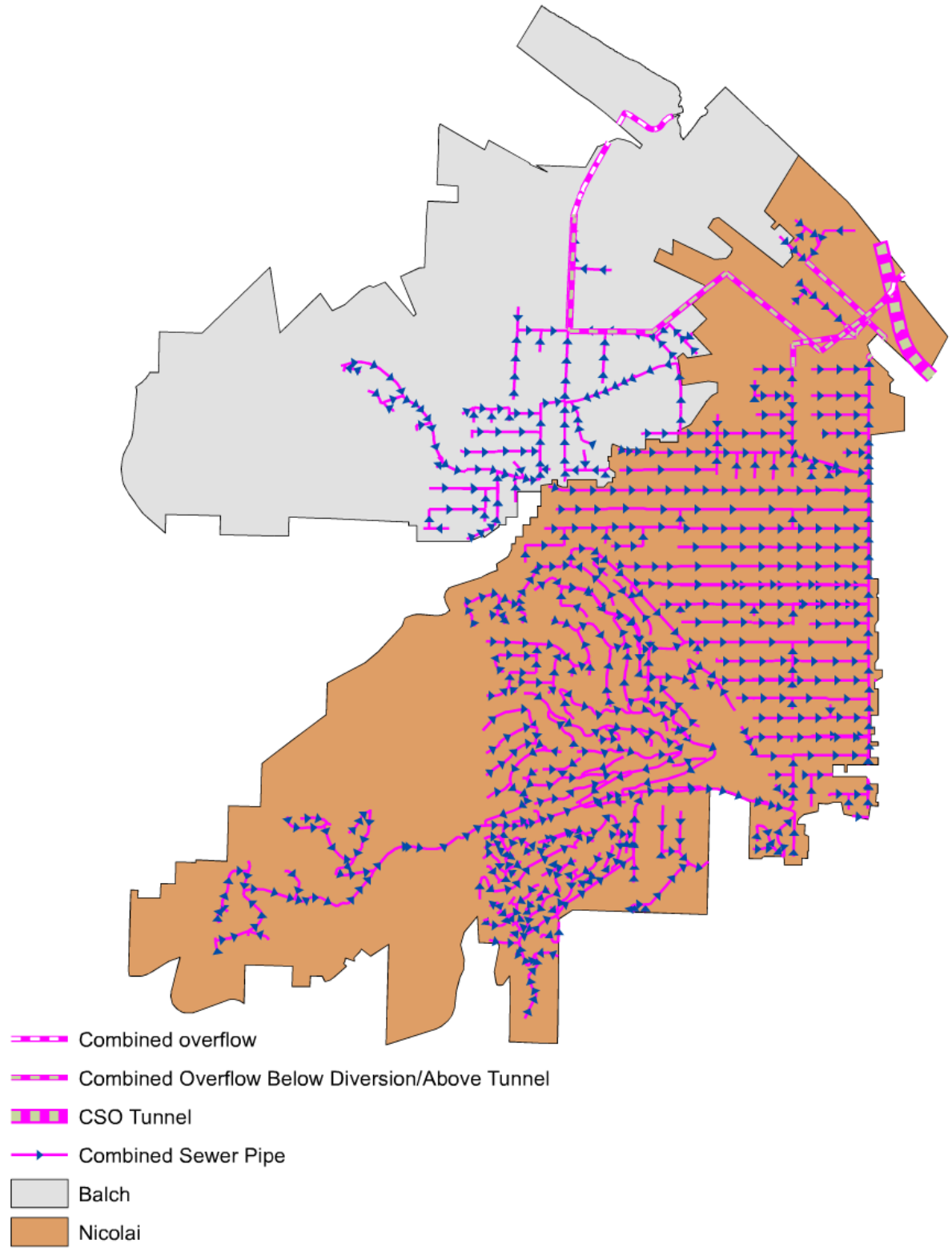



Combined Sewer Basins
Separated Sewer Basins

wer Basins

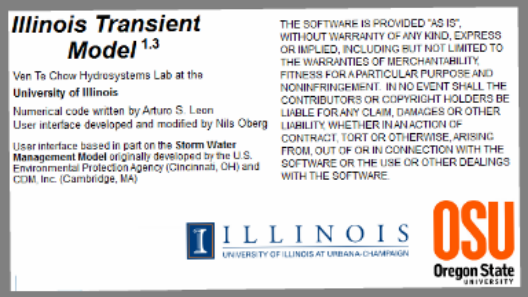
wer Basins

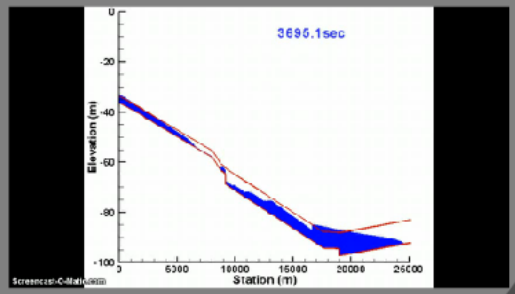


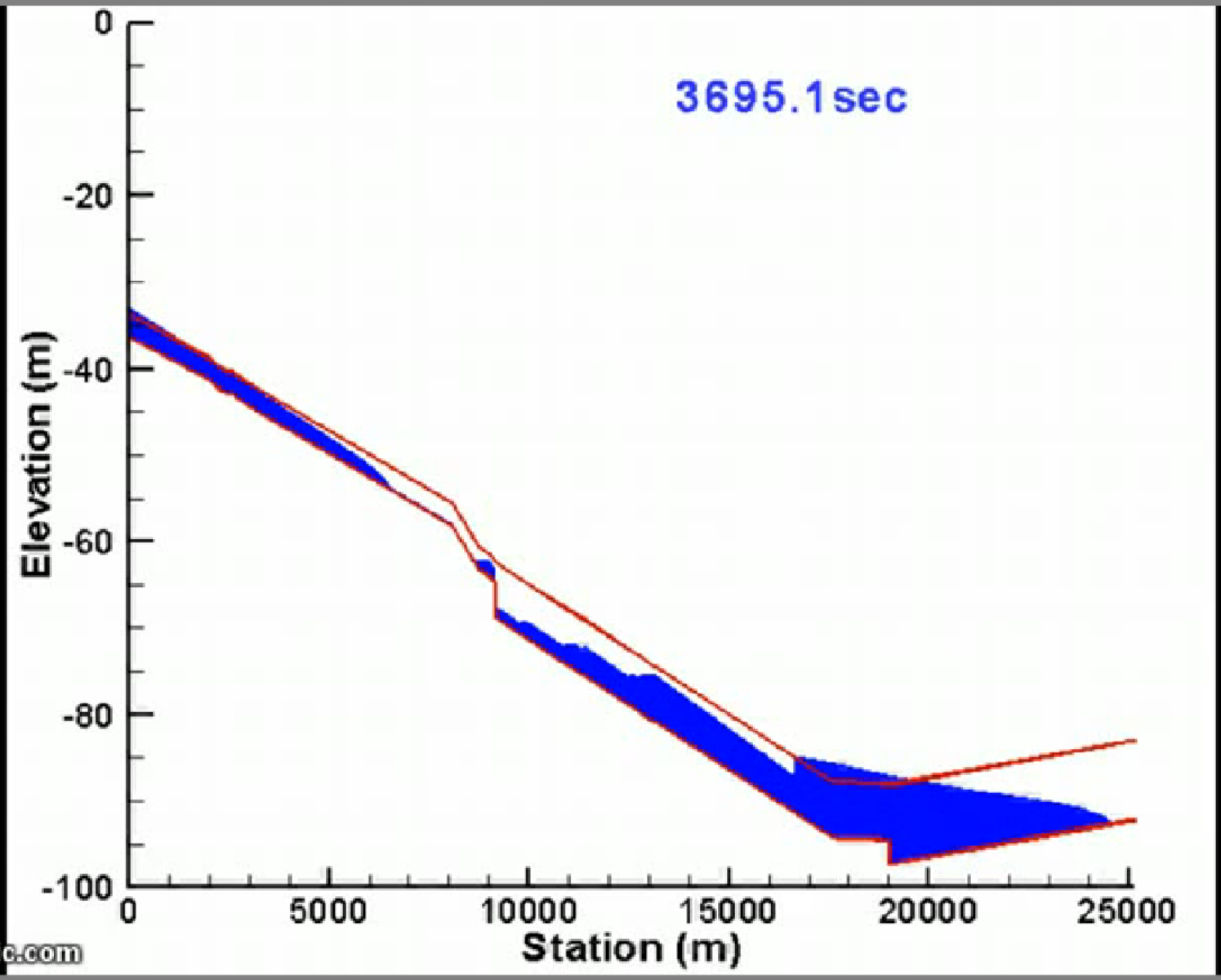


Illinois Transient Model

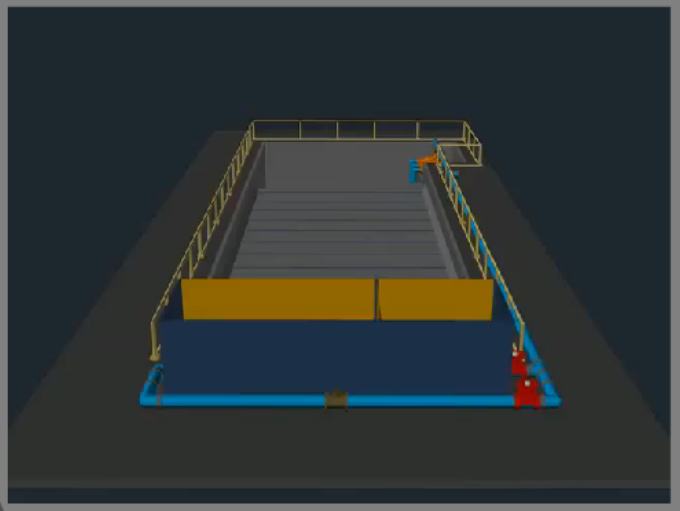
- Open source, state-of-the-art model
- Applied to various CSS in the U.S. (e.g; Chicago, Dallas) and around the world (e.g; New Zealand, Mexico)

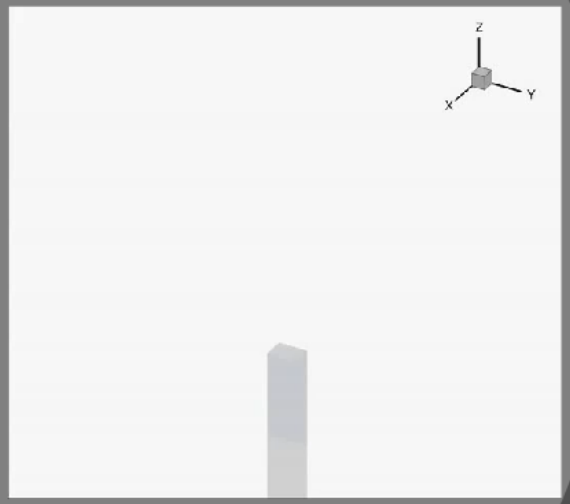





3695.1sec
0
-20
-40
-60
-80
-100
Elevation (m)
0
5000
10000
15000
20000
25000
Station (m)
Screencast-O-Matic.com

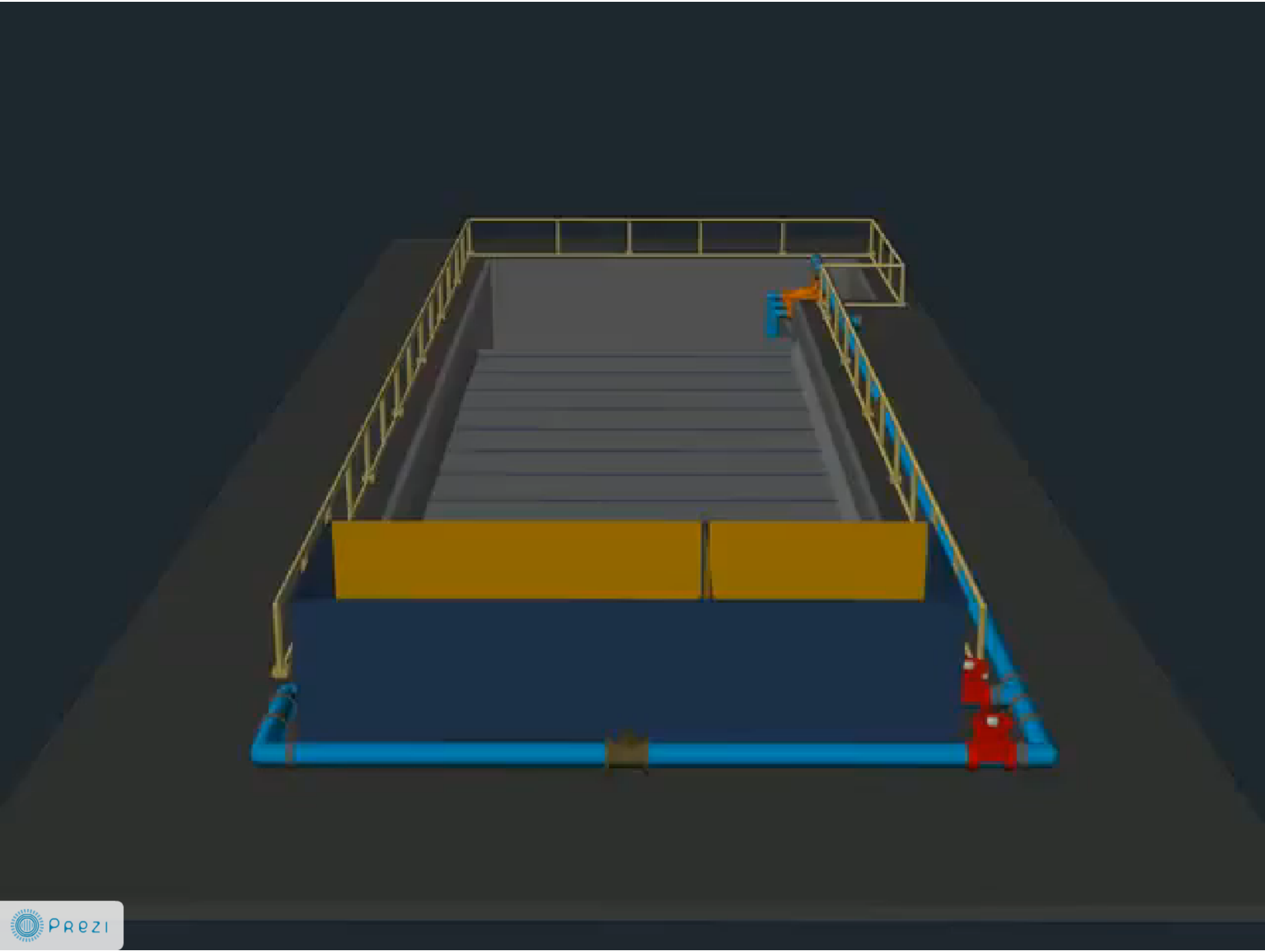
Preliminary Results

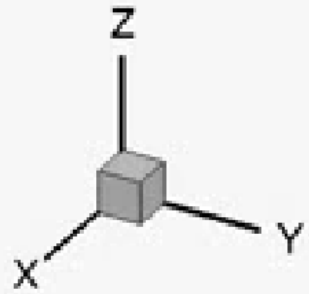




Parti

CSS of Portl





References

- EPA (2004). "Impacts and control of csos and ssos." Report to Congress EPA 833-R-04-001, United States Environmental Projection Agency, Office of Water (4203), Washingron, D.C. 20460.
- Wright, S. J., Vasconcelos, J. G., Creech, C. T., and Lewis, J. W. (2008). "Flow regime transition mechanisms in rapidly filling stormwater storage tunnels." Environ Fluid Mech, 8(5).
- Guo, Q. and Song, C. S. S. (1991). "Hydrodynamics under transient conditions." J. Hydraul. Eng, 266 117(8), 1042–1055.
- Guo, Q. and Song, C. S. (1988). "Hydraulic transient analysis of tarp phase II o'hare system." Project Report 276, University of Minnesota, St. Anthony Falls Hydraulic Laboratory.
- Bellos, C. V. and Sakkas, J. G. (1967). "1-d dam-break flood-wave propagation on dry bed." J. Hydraul. Eng, 113(12), 1510–1524.
- Vasconcelos, J. G. and Wright, S. J. (2006). "Mechanisms for air pocket entrapment in stormwater storage tunnels." World Environmental and Water Resources Congress, ASCE.
- Wright, S. J., Lewis, J.W., and Vasconcelos, J. G. (2011). "Geysering in rapidly filling storm-water tunnels." J. Hydraul. Eng, 137(1), 112–115.
- Milwaukee Metropolitan Sewer District's Deep Tunnel System, Created by Suite Imagery LLC.
- Dan Troolinm, University of Minnesota, PIV (Particle Image Velocimetry) Principle, http://www.aem.umn.edu/people/students/troolin/tutorial_piv_principle.html, accessed 2/22/2013
- Earthzine, Winning Students, Runner-Up Announced in NASA University Research Centers Virtual Poster Session, http://www.earthzine.org/nasa-urc-fall-2012-vpss/, accessed 2/22/2013

Researc

Thank you!

Many thanks for your attention!

Contact:
Arturo Leon, Ph.D., P.E.
Assistant Professor,
School of Civil and Construction Engineering
Oregon State University
arturo.leon@oregonstate.edu
Research webpage: http://web.engr.oregonstate.edu/~leon/

Towards Predicting the Occurrence of Geysers and CSOs in Combined Sewer Systems

Recent developments and future perspectives

Arturo Leon[1], Assistant Professor
YunJi Choi[1], PhD Student
[1]Oregon State University
2/27/2013