



# Çevre Mühendisliğinde Bilgisayar Destekli Simulasyon ve Modelleme

Proses Simulasyonu ve Hidrodinamik Modelleme Uygulamaları

Prof. Dr. Şevket ÇOKGÖR - Prof. Dr. Güçlü İNSEL - Dr. Öğr. Üyesi Murat AKSEL

19 Ocak 2019



# ÇEVRE MÜHENDİSLİĞİNDE BİLGİSAYAR DESTEKLİ SİMÜLASYON VE MODELLEME: SUNUŞ

**Prof. Dr. Şevket ÇOKGÖR**

Istanbul Teknik Üniversitesi, İnşaat Mühendisliği Bölümü

# Niçin Modelleme?

Analitik Deterministik Çözüm, (!)

Navier-Stokes Denklemi

$$\rho \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} \right) = \rho g_x - \frac{\partial p}{\partial x} + \mu \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2} \right)$$
$$\rho \left( \frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial v}{\partial z} \right) = \rho g_y - \frac{\partial p}{\partial y} + \mu \left( \frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2} \right)$$
$$\rho \left( \frac{\partial w}{\partial t} + u \frac{\partial w}{\partial x} + v \frac{\partial w}{\partial y} + w \frac{\partial w}{\partial z} \right) = \rho g_z - \frac{\partial p}{\partial z} + \mu \left( \frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2} \right)$$

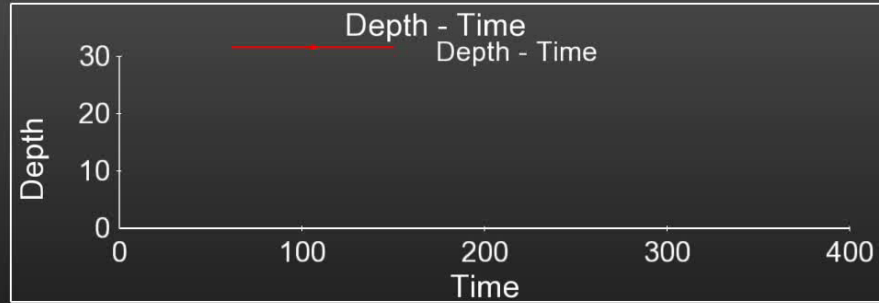
# Modelleme

- Fiziksel (Laboratuvar)
- (Kızkayası Barajı - Dolusavak)



# Sayısal Model

Time = 0.000000



FLOW-3D

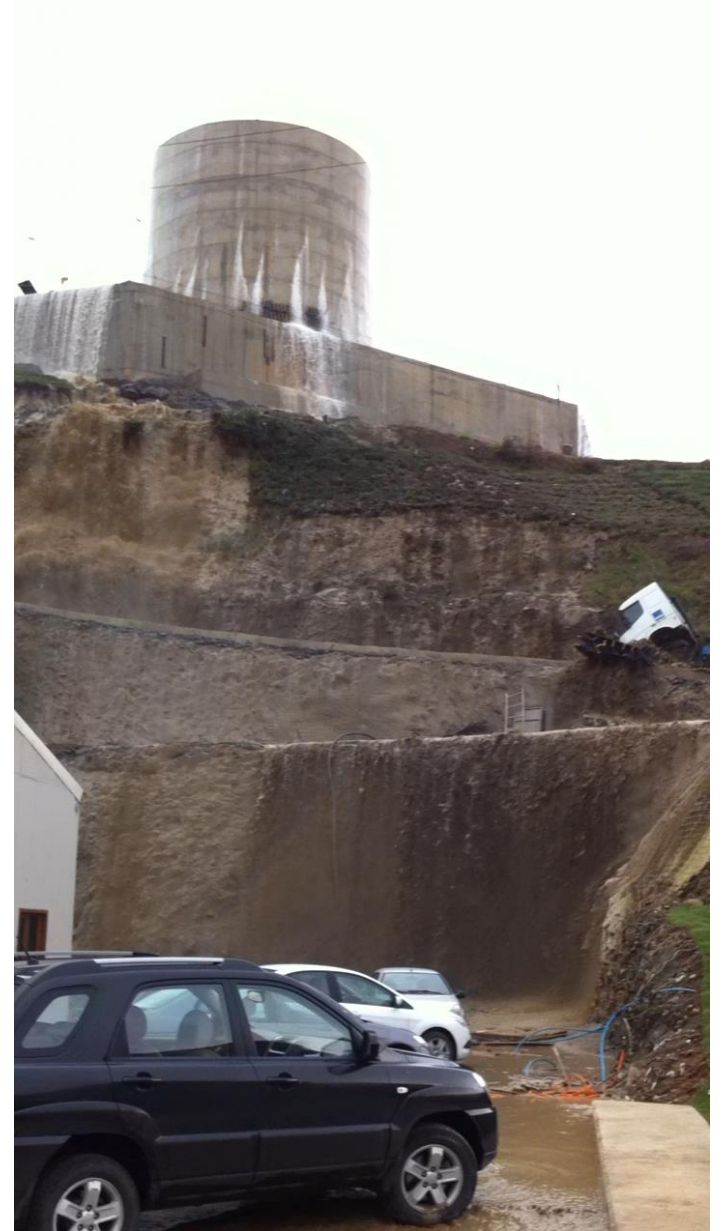
Flow Depth

7.204e+001  
5.403e+001  
3.602e+001  
1.801e+001  
0.000e+000

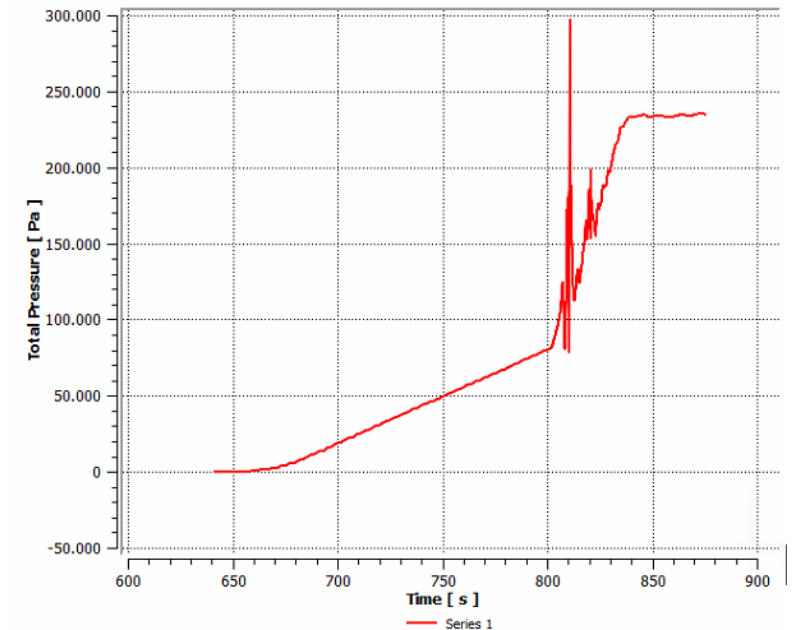
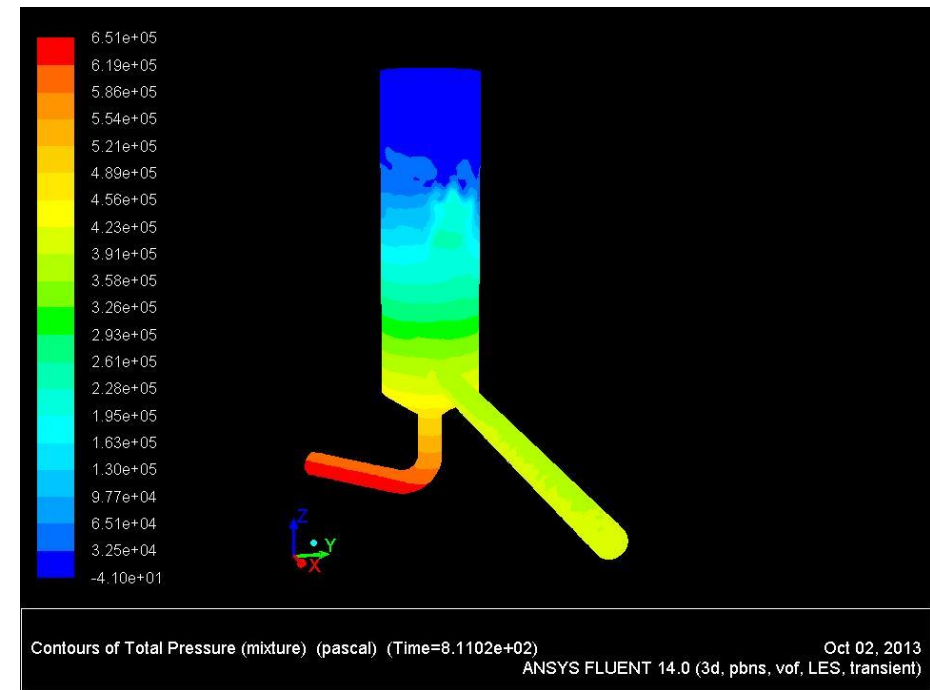
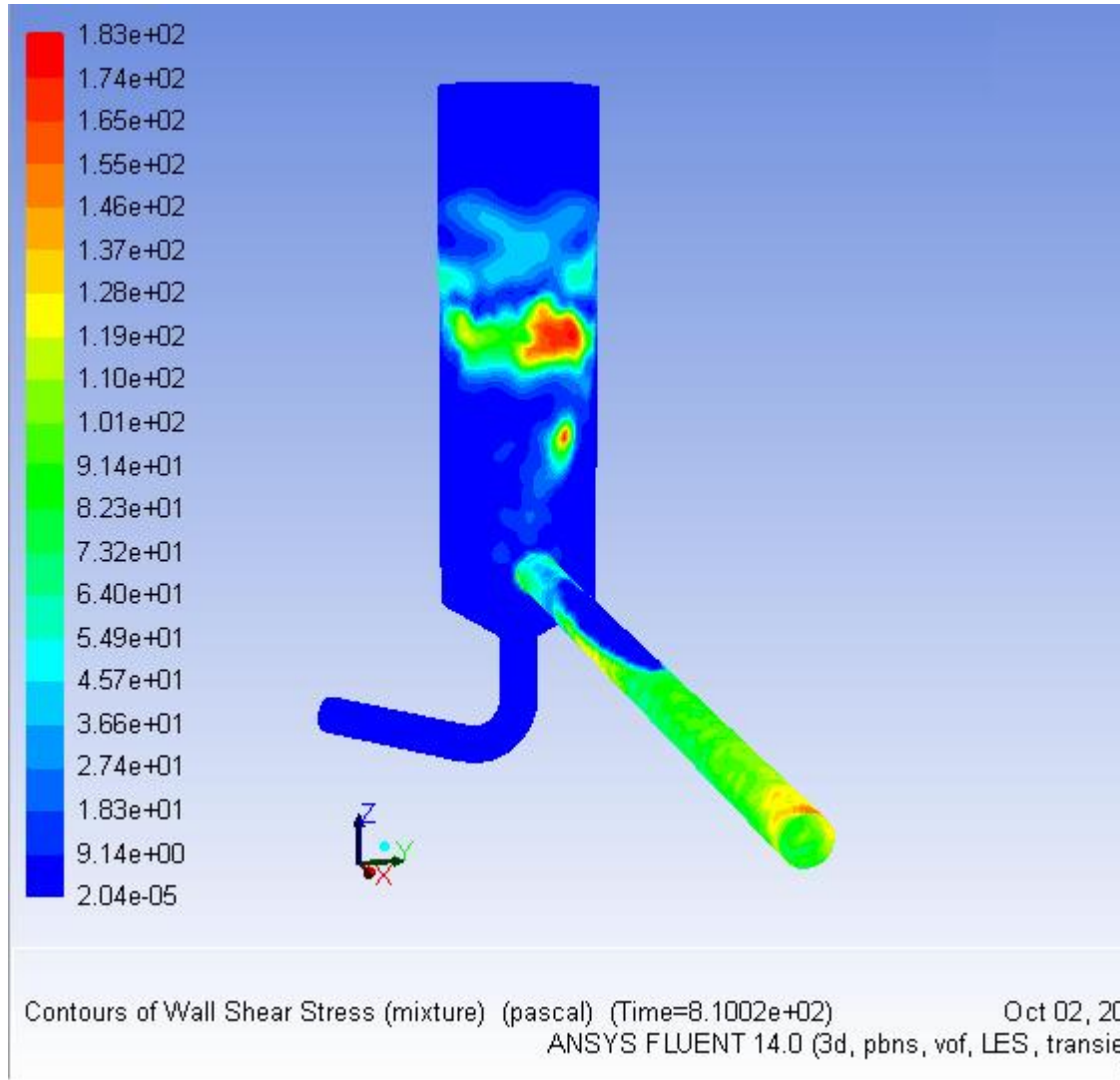


# Denge Bacası (İncirli HES)

- Dođadaki Hasar



# Sayısal Model



# Kıyı Mühendisliđi

- Model yapılmadan tasarım







# ÇEVRE MÜHENDİSLİĞİNDE BİLGİSAYAR DESTEKLİ SİMÜLASYON VE MODELLEME: PROSES SİMÜLASYONU

**Prof. Dr. H. Güçlü İNSEL**

**İstanbul Teknik Üniversitesi, Çevre Mühendisliği Bölümü**

**Çevre Mühendisleri Odası, Beyoğlu, 19 Ocak 2019**

# Proses simülatörlerini kim neden kullanır?

- Ana kullanım hedefleri

- Mühendis – tasarım, sistem geliştirme
- Mühendis – tesis optimizasyonu (what if?)
- İşletmeci – eğitim
- Araştırmacı – değerlendirme, proses geliştirme
- Öğrenci – öğrenme

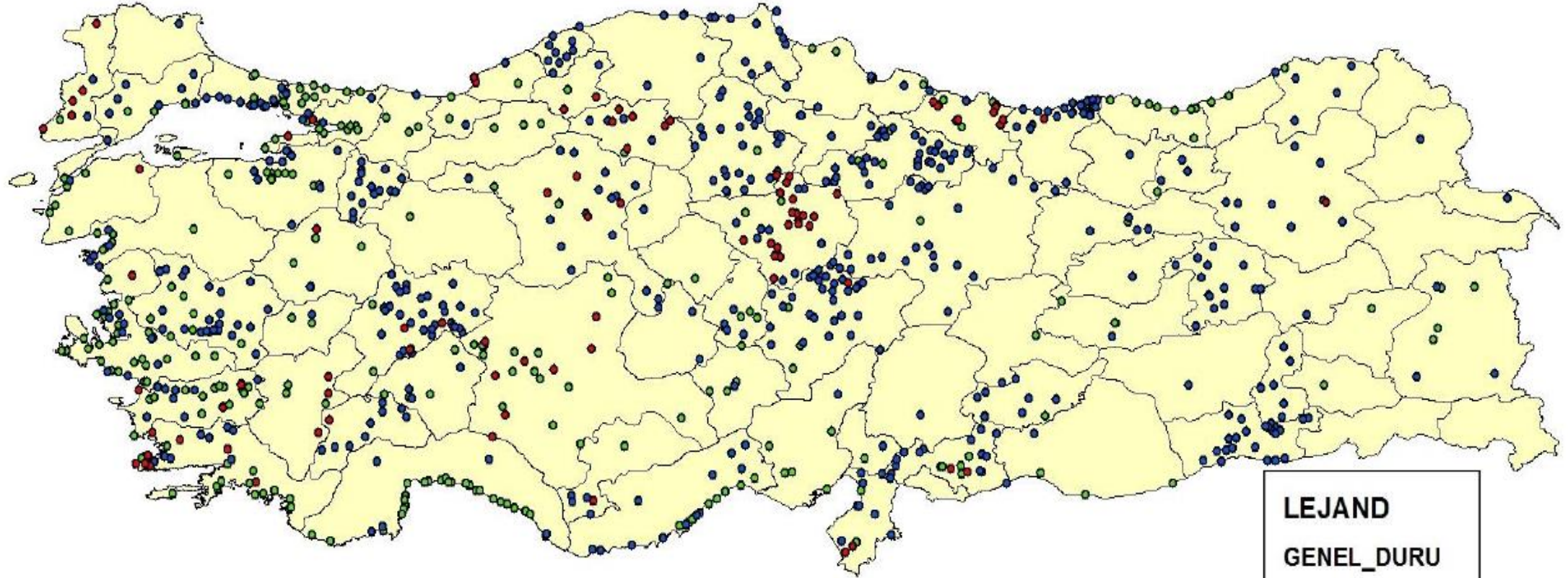
- Tesis karmaşıklığı

- Nütrient (N,P) giderimi
- Geri dönüş akımları
- Yeni teknoloji prosesler (Anammox, Biyofilm, GAÇ...)

# Atıksu Arıtma Hedefleri

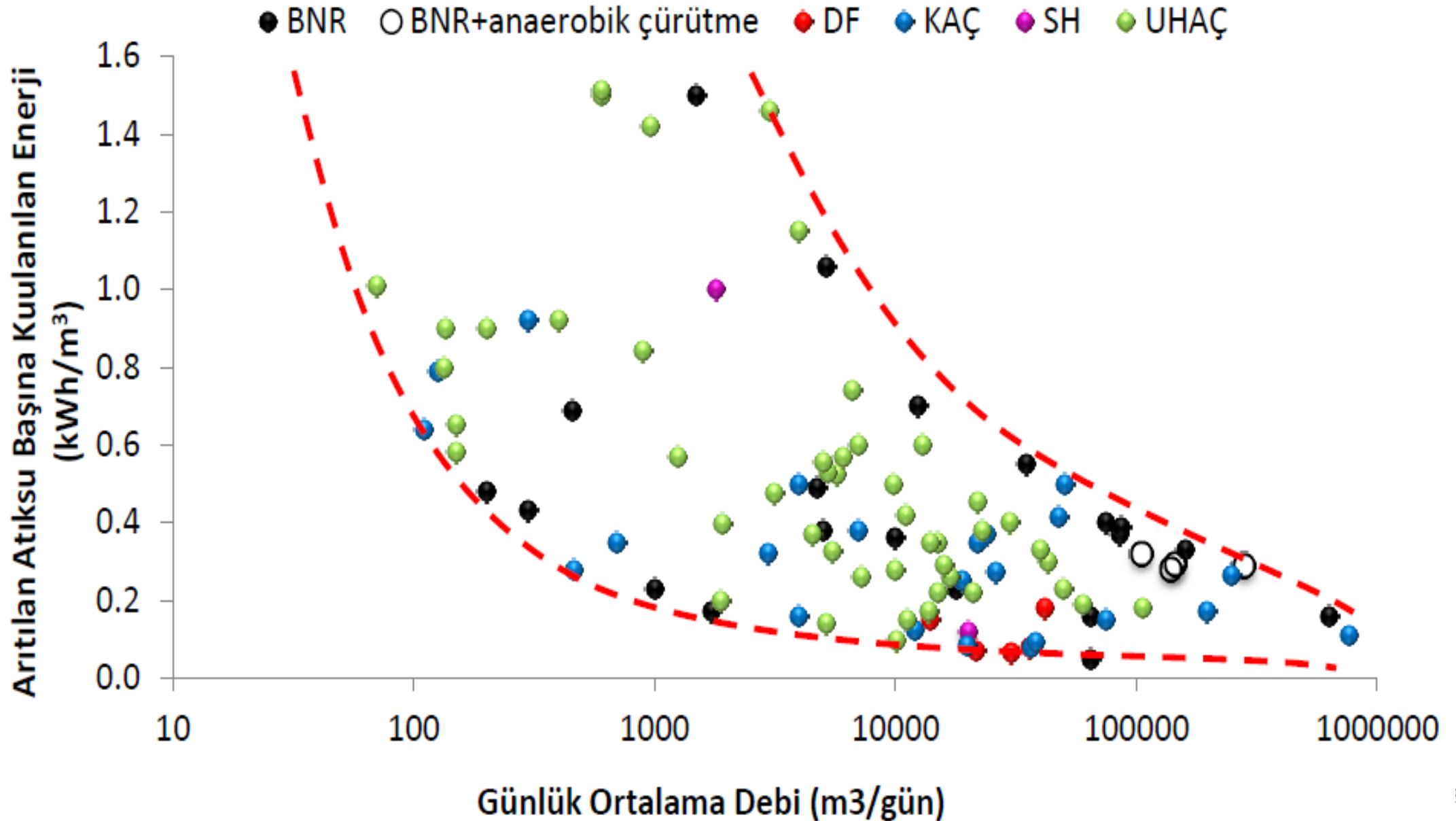
- Organik Madde Giderimi
- Enerji Amaçlı Kullanımı (Organik Karbon)
- Azot giderimi (Deşarj Limiti?)
- Fosfor giderimi ve geri kazanımı
- Kimyasal madde geri kazanımı (gübre, değerli organikler)
- GHG minimizasyonu

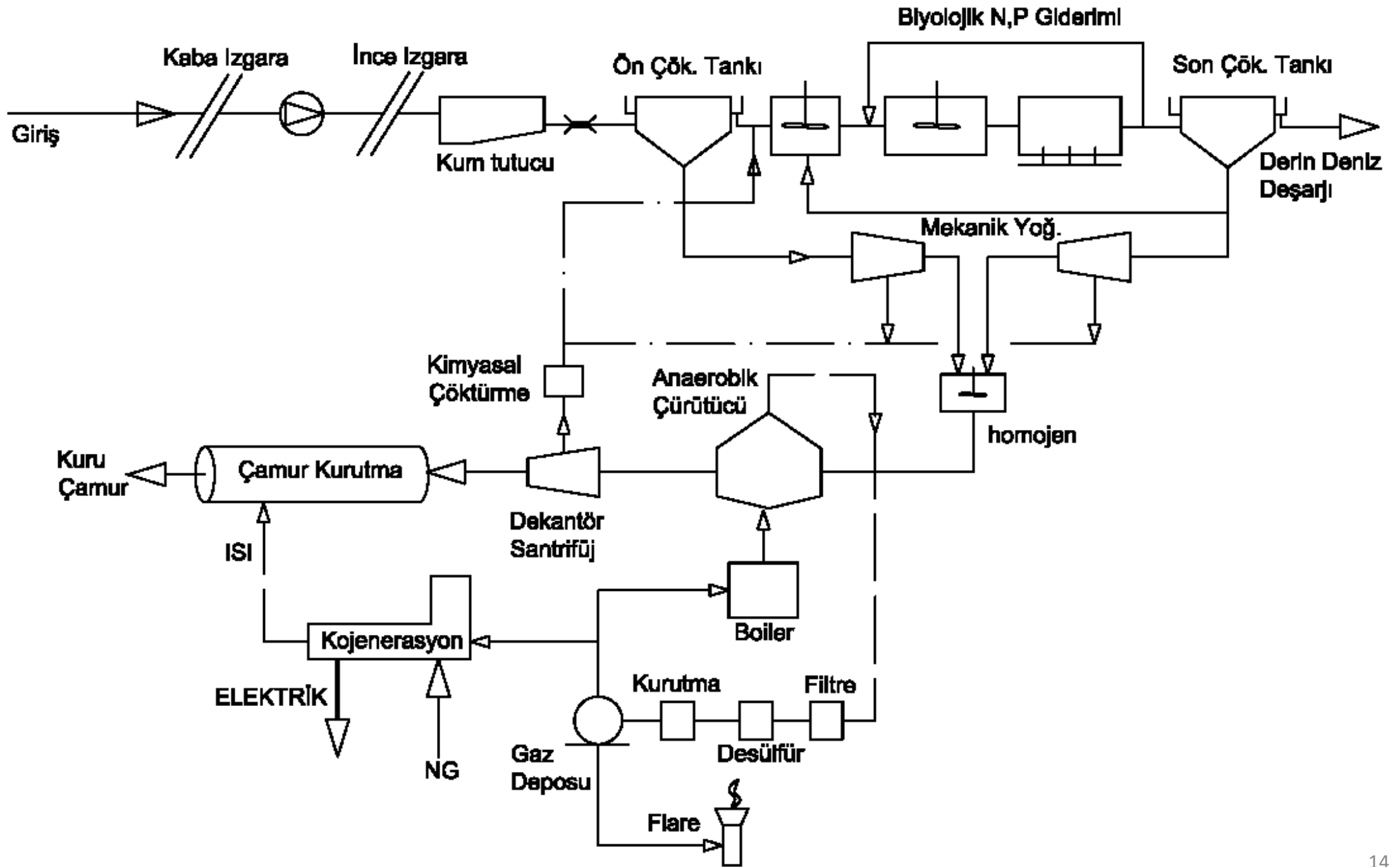
# Atıksu Arıtma Tesisleri



LEJAND	
GENEL_DURU	
●	ILAVE
●	MEVCUT
●	PLANLANAN

# Enerji Tüketimi







**Pompa İstasyonu**



**Blowerler**



**Aktif Çamur Havuzu**



**Anaerobik Çamur  
Çürütme**

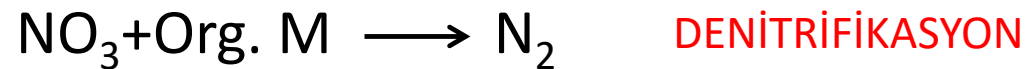
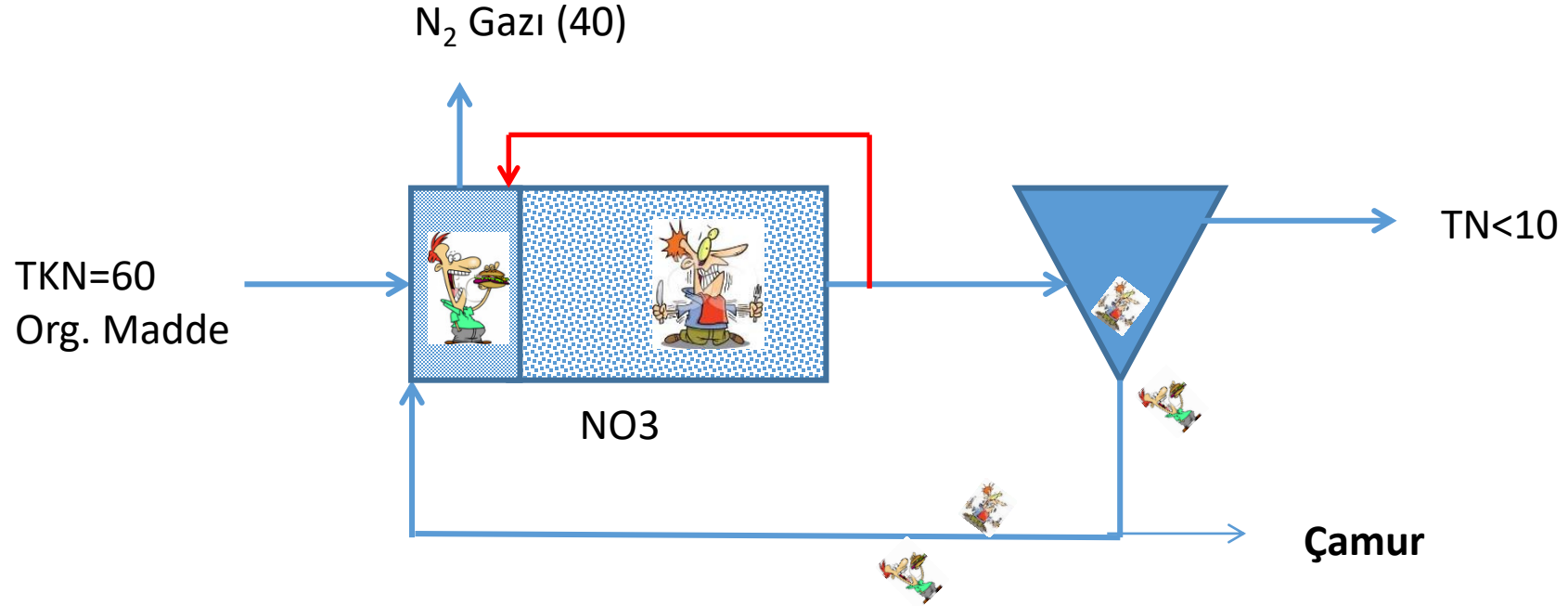


**Susuzlaştırma**



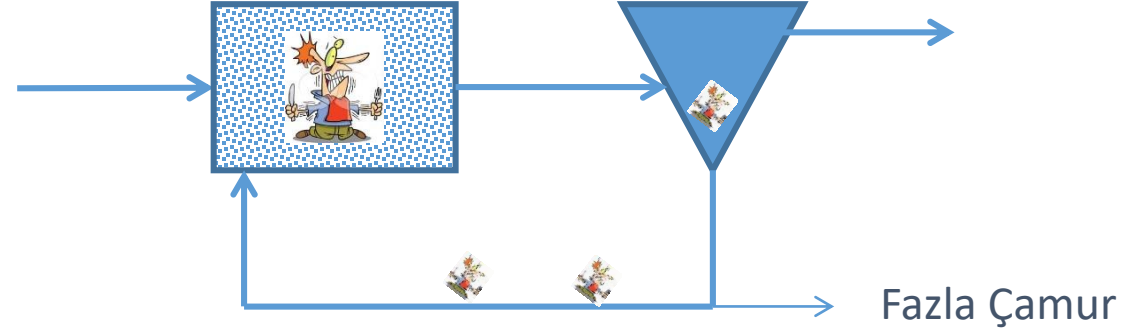
**Kurutma**

# Biyolojik Prosesler





# Nitrifikasyon Prosesi



$\hat{\mu}_A$  :Çoğalma Hızı: /gün (+)

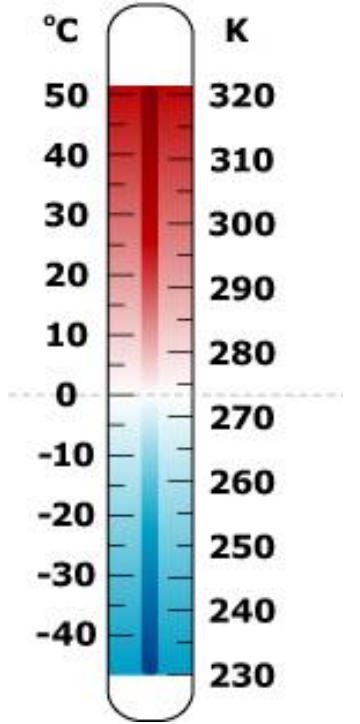
$b_A$  :Ölüm Hızı: /gün (-)

---

$\hat{\mu}_A - b_A$  :Net Çoğalma Hızı: /gün

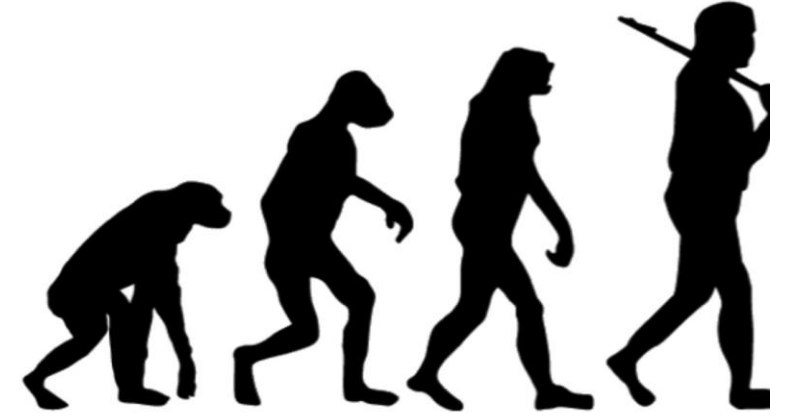
$\frac{1}{\hat{\mu}_A - b_A}$  :Çoğalmanın sağlanması için gerekli zaman : GÜN

**ÇAMUR YAŞI**



# MODELLEMENİN BAŞLANGICI

GARRET ve SAWYER, 1952



$$W = 0.5 B - 0.55 S$$

**W = Oluşan Çamur Miktarı**

**B = Giderilen  $BOI_5$  Miktarı**

**S = Havalandırılan UAKM kütlesi**



SCORE; 005970

HIGH SCORE; 012020

SPEED



FUEL



ROCKETS



BOMBS



# ilk Modeller (1980...)

Three components

Two fundamental processes

		Continuity				
Component	→	$i$	1	2	3	Process Rate, $\rho_j$ [ML <sup>-3</sup> T <sup>-1</sup> ]
$j$	Process	↓	$X_B$	$S_S$	$S_O$	
1	Growth		1	$-\frac{1}{Y}$	$-\frac{1-Y}{Y}$	$\frac{\hat{\mu}S_S}{K_S + S_S} X_B$
2	Decay		-1		-1	$bX_B$
Observed Conversion Rates		ML <sup>-3</sup> T <sup>-1</sup>	$r_i = \sum_j r_{ij} = \sum_j \nu_{ij} \rho_j$			Kinetic Parameters: Maximum specific growth rate: $\hat{\mu}$ Half-velocity constant: $K_S$ Specific decay rate: $b$
Stoichiometric Parameters: True growth yield: $Y$			Biomass [M(COD) L <sup>-3</sup> ]	Substrate [M(COD) L <sup>-3</sup> ]	Oxygen (negative COD) [M(-COD) L <sup>-3</sup> ]	

X – Particulate  
S – Soluble

# Aktif Çamur Modellerinin Gelişimi

<b>YIL</b>	<b>MODEL TİPİ</b>	<b>Biyokütle</b>	<b>Değişken</b>	<b>Parametre</b>
<b>1960</b>	<b>Empirical</b>	<b>1</b>	<b>4</b>	<b>4</b>
<b>1970</b>	<b>Structured models, electron balance</b>	<b>2</b>	<b>10</b>	<b>10</b>
<b>1980</b>	<b>Dynamic N-DN</b>	<b>2</b>	<b>13</b>	<b>19</b>
<b>1990</b>	<b>Bio-P</b>	<b>3</b>	<b>20</b>	<b>40</b>
<b>2000</b>	<b>Anaerobic digestion</b>	<b>7</b>	<b>30</b>	<b>60</b>
	<b>+ pH</b>		<b>30</b>	
	<b>Biofilms (spatial heterogeneity)</b>			
	<b>Two step N-DN</b>	<b>5-10</b>	<b>30</b>	<b>50</b>
<b>2010</b>	<b>Whole-plant (AS, AD)</b>	<b>10</b>	<b>40</b>	<b>200</b>
	<b>AS, AD, AMX</b>	<b>11</b>	<b>50</b>	<b>250</b>
	<b>Two populations (meso-thermo, r-k, etc.)</b>			
	<b>GHG (4-5 step N-DN)</b>			

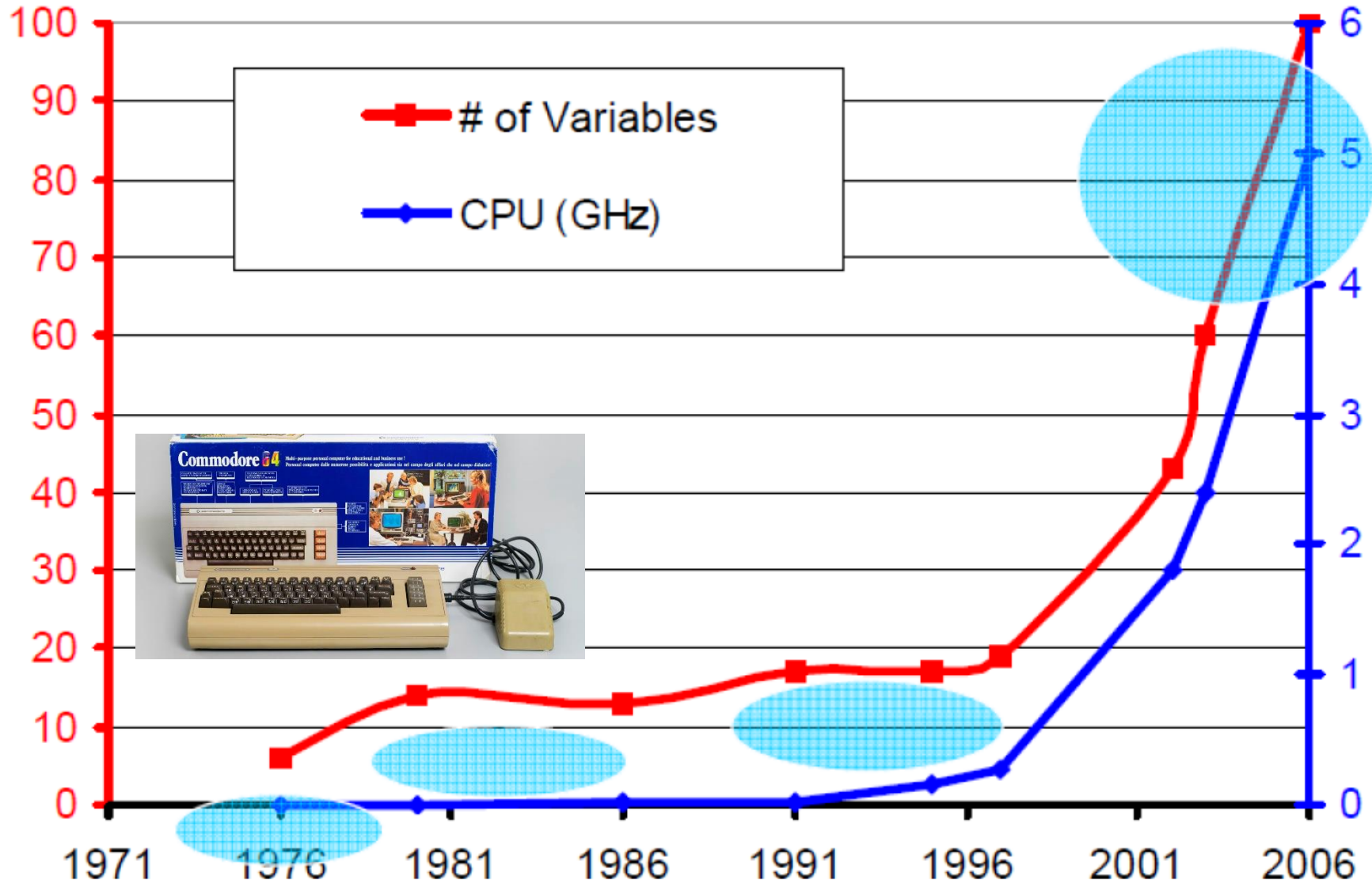
# Model Matris Gösterimi (ASM1) : C+N

j	Component i	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Process Rate $\rho_j$ , $ML^{-3}T^{-1}$
	Process	$S_i$	$S_S$	$X_i$	$X_S$	$X_H$	$X_A$	$X_P$	$S_O$	$S_{NO}$	$S_{NH}$	$S_{ND}$	$X_{ND}$	$S_{SMP}$	$S_{ALK}$	
1	Aerobic growth of heterotrophs		$-\frac{1}{Y_H}$			1			$-\frac{1-Y_H}{Y_H}$		$-i_{XB}$				$-\frac{i_{XB}}{14}$	$\hat{\mu}_H \left( \frac{S_S}{K_S + S_S} \right) \left( \frac{S_O}{K_{OH} + S_O} \right) X_H$
2	Anoxic growth of heterotrophs		$-\frac{1}{Y_H}$			1			$-\frac{1-Y_H}{2.86Y_H}$		$-i_{XB}$				$\frac{1-Y_H}{14 \cdot 2.86Y_H} - \frac{i_{XB}}{14}$	$\eta_g \hat{\mu}_H \left( \frac{S_S}{K_S + S_S} \right) \left( \frac{K_{OH}}{K_{OH} + S_O} \right) \left( \frac{S_{NO}}{K_{NO} + S_{NO}} \right) X_H$
3	Aerobic growth of autotrophs						1		$-\frac{4.57-Y_A}{Y_A}$	$\frac{1}{Y_A}$	$-i_{XB} - \frac{1}{Y_A}$				$-\frac{i_{XB}}{14} - \frac{1}{Y_A}$	$\hat{\mu}_A \left( \frac{S_{NH}}{K_{NH} + S_{NH}} \right) \left( \frac{S_O}{K_{OA} + S_O} \right) X_A$
4	Aerobic decay of heterotrophs					-1		$f_{EX}$	$-(1-f_{EX}-f_{ES})$				$i_{XB}-f_{EX}i_{XP}$	$f_{ES}$		$b_H \left( \frac{S_O}{K_{OH} + S_O} \right) X_H$
5	Aerobic decay of autotrophs						-1	$f_{EX}$	$-(1-f_{EX}-f_{ES})$				$i_{XB}-f_{EX}i_{XP}$	$f_{ES}$		$b_A \left( \frac{S_O}{K_{OA} + S_O} \right) X_A$
6	Anoxic decay of heterotrophs					-1		$f_{EX}$	$-\frac{1-f_{EX}-f_{ES}}{2.86}$					$f_{ES}$		$\eta_D b_H \left( \frac{K_{OH}}{K_{OH} + S_O} \right) \left( \frac{S_{NO}}{K_{NO} + S_{NO}} \right) X_H$
7	Anoxic decay of autotrophs						-1	$f_{EX}$	$-\frac{1-f_{EX}-f_{ES}}{2.86}$					$f_{ES}$		$\eta_D b_A \left( \frac{K_{OA}}{K_{OA} + S_O} \right) \left( \frac{S_{NO}}{K_{NO} + S_{NO}} \right) X_A$
8	Ammonification of soluble organic nitrogen										1	-1			$\frac{1}{14}$	$k_a S_{ND} X_H$
9	Hydrolysis of entrapped organics		1		-1											$k_h \frac{X_S}{K_X + \frac{X_S}{X_H}} \left[ \left( \frac{S_O}{K_{OH} + S_O} \right) + \eta_h \left( \frac{K_{OH}}{K_{OH} + S_O} \right) \left( \frac{S_{NO}}{K_{NO} + S_{NO}} \right) \right] X_H$
10	Hydrolysis of entrapped organic nitrogen											1	-1			$\rho_T \left( \frac{X_{ND}}{X_S} \right)$

Kinetic Parameters :  $\mu_H, K_S, b_H, \mu_A, K_{NH}, b_A, K_{NO}, k_h, k_x, K_{NH}, K_{ALK}, K_{OA}, K_{OH}, k_a$

Stoichiometric Parameters :  $Y_H, Y_A, \eta_g, \eta_D, \eta_h, i_{XB}, i_{XP}, f_{EX}, f_{ES}$

# MATEMATİK MODEL GELİŞİMİ VE İŞLEMCI HIZI







# Barbie ...

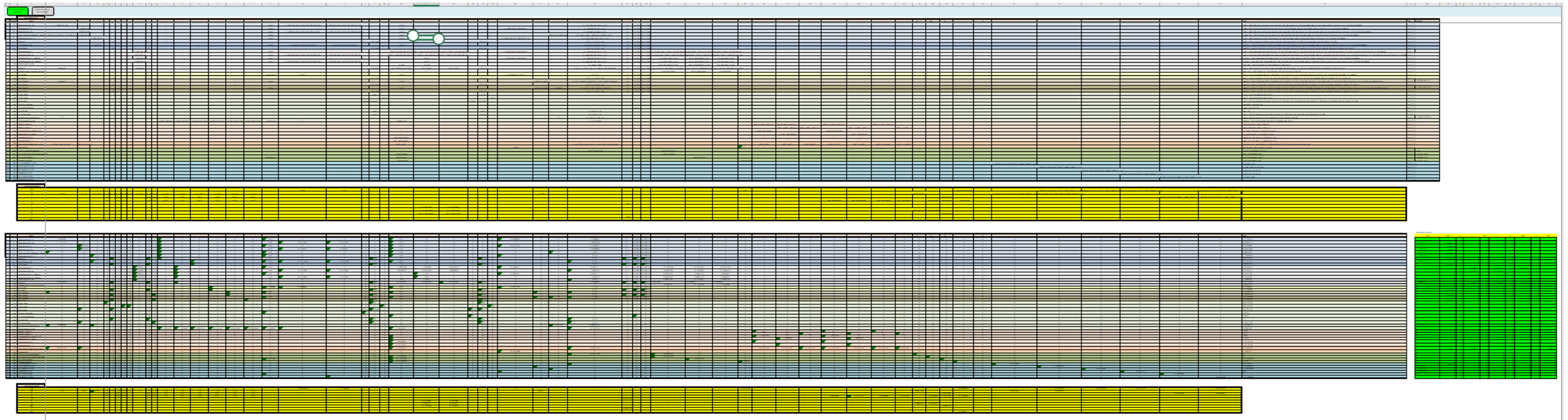


1989



25 2019

# Güncel Modeller (Whole Plant Models)

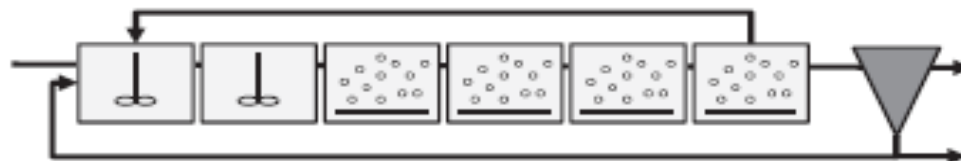
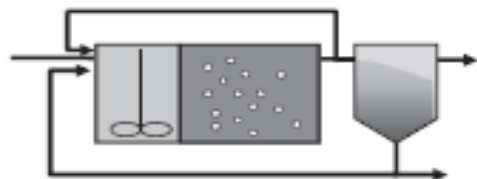


Plant scheme

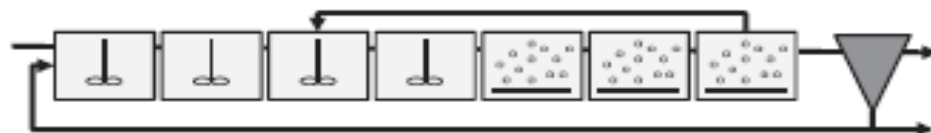
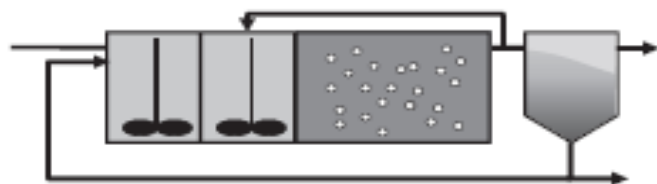
Real system

Model flow scheme

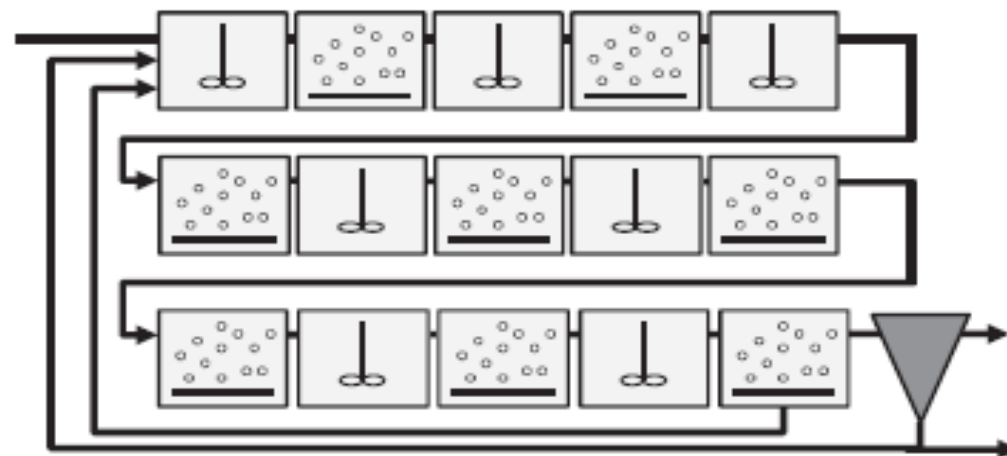
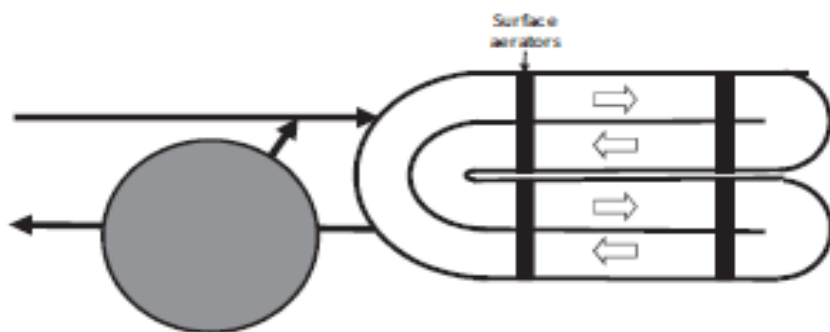
MLE



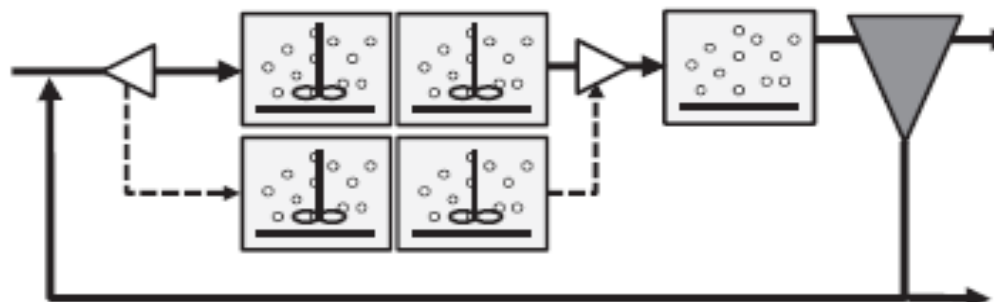
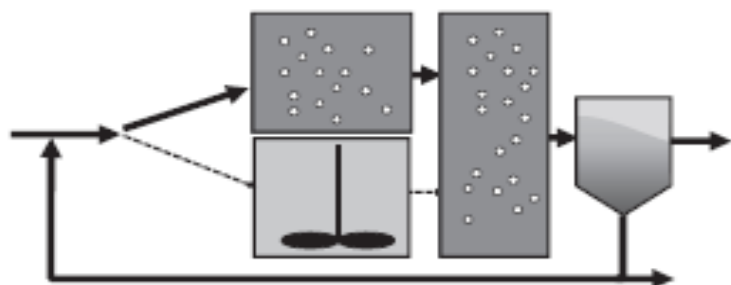
A<sub>2</sub>O



Oxidation ditch

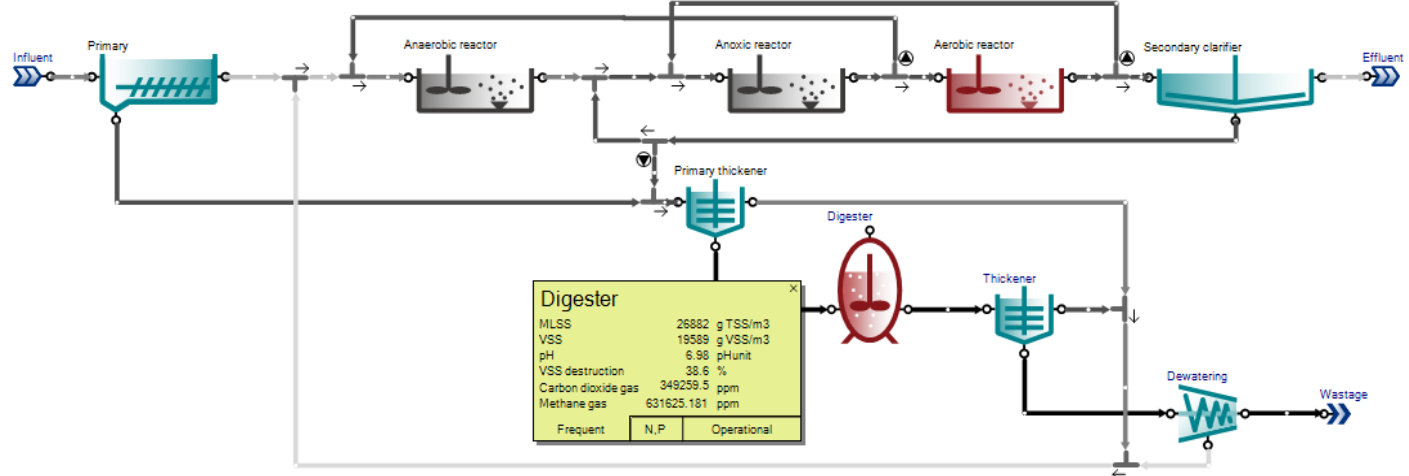


Alternating  
influent





- Add table
- Add timechart
- Add XY chart
- Add barchart
- Add piechart
- Add Sankey



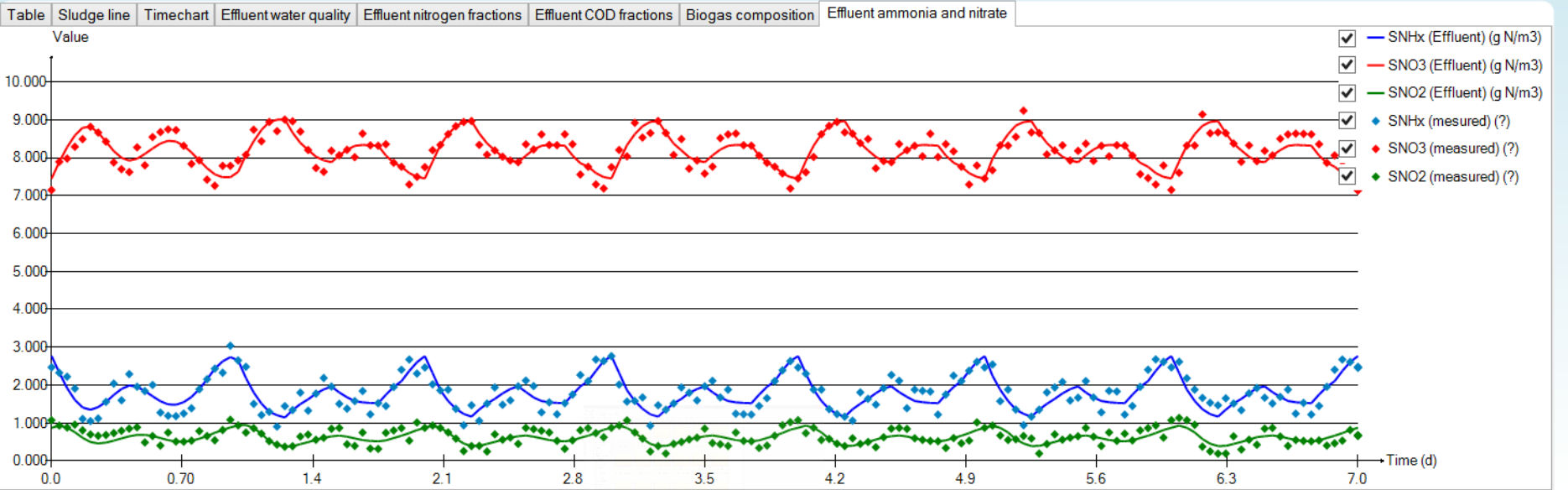
Effluent	
Flow	16079 m3/d
TSS	10.0 g TSS/m3
VSS	7.6 g VSS/m3
Total COD	33.7 g COD/m3
Total BOD5	10.2 g COD/m3
pH	7.16 pHunt
Frequent	N P

Digester	
MLSS	26882 g TSS/m3
VSS	19589 g VSS/m3
pH	6.98 pHunt
VSS destruction	33.6 %
Carbon dioxide gas	349259.5 ppm
Methane gas	631625.181 ppm
Frequent	N,P Operational

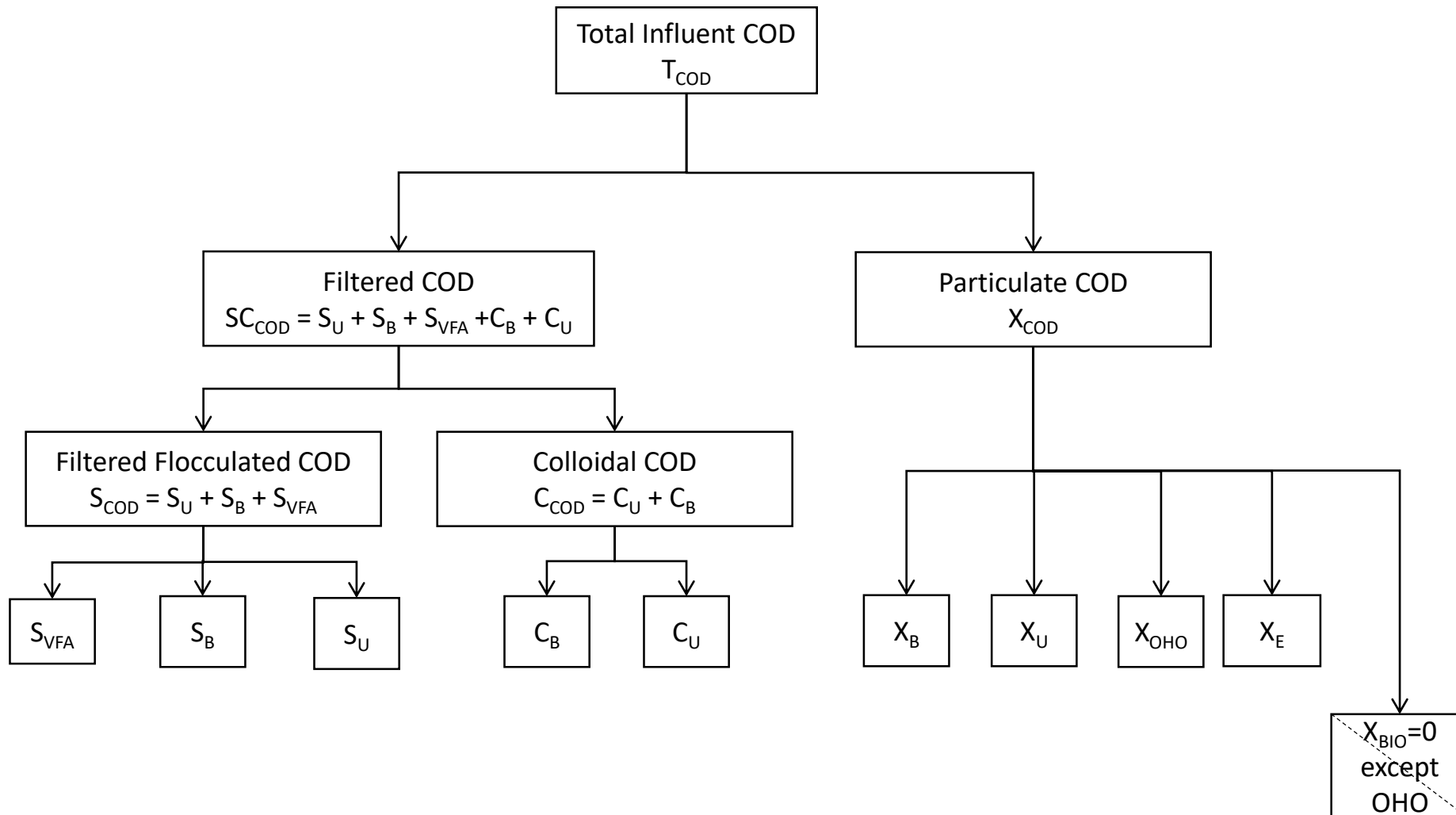
Variables

Sumo > Plant > Effluent > Frequently used variables

- Flow
- Total chemical oxygen demand
- Total 5 day biochemical oxygen demand
- Total suspended solids
- Volatile suspended solids
- pH
- Total nitrogen
- Ammonia (NH4+NH3)
- Nitrate and nitrite
- Nitrite
- Nitrate
- Total phosphorus
- Orthophosphate



# Giriş Organik Madde Fraksiyonları



S = soluble  
C = colloidal  
X = particulate  
VFA = volatile fatty acid  
B = biodegradable  
U = unbiodegradable  
OHO = ordinary heterotrophs  
E = endogenous decay products  
BIO = biomass

# Sumo influent tool

Key measurements	Value	Unit
Flow	24000.0	MGD or m <sup>3</sup> /d
TSS	215.0	mg/L
VSS	180.0	mg/L
TDS	800.0	mg/L
TKN	34.4	mgN/L
TP	4.3	mgP/L
Total Sulfur	20.0	mgS/L
Alkalinity	350.0	mgCaCO <sub>3</sub> /L
pH	7.2	-

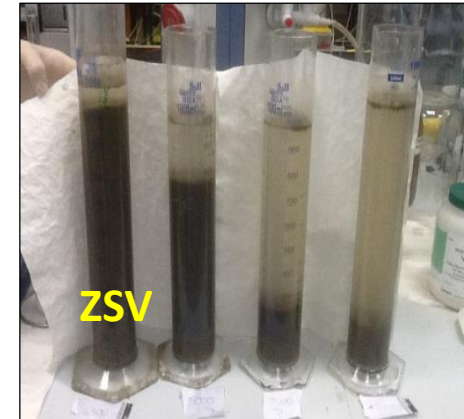
Key indicators for sanity check	Value	Unit	Usual value in US
VSS/TSS ratio	0.84	-	0.85
Particulate COD/VSS	1.50	mg COD/mg VSS	1.60
Dissolved salts	585.0	mg/L	
Alkalinity in molar units	7.0	meq/L	3 - 8

COD - BOD	Value	Unit
Influent COD	420.0	mgCOD/L
Influent filtered COD	150.0	mgCOD/L
Influent filtered flocculated COD	80.0	mgCOD/L
<i>Effluent</i> filtered COD (inert)	20.0	mgCOD/L
Influent cBOD <sub>5</sub>	190.0	mgBOD/L

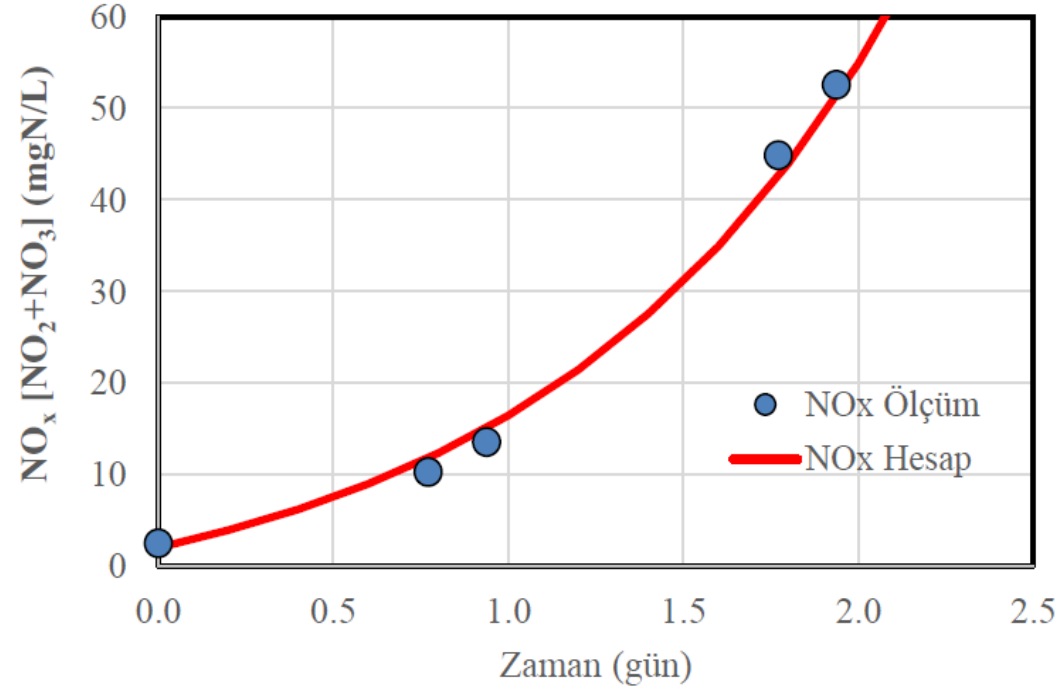
Particulate COD	270.00	mg COD/L	
Filtered COD fraction	0.36	-	0.40
Filtered flocculated COD fraction	0.19	-	0.20
Unbiodegradable fraction of filtered COD	0.05	-	0.05
COD/BOD ratio	2.21	-	2.20

[←](#)
[▶](#)
[Help](#)
[Data](#)
[Check fractions](#)
[Sumo forms](#)
[Balances](#)
[Diurnal flow](#)
[Calculations](#)
⊕

# Farklılıklar: Deneysel Karakterizasyon



## Nitrifikasyon Deneyi

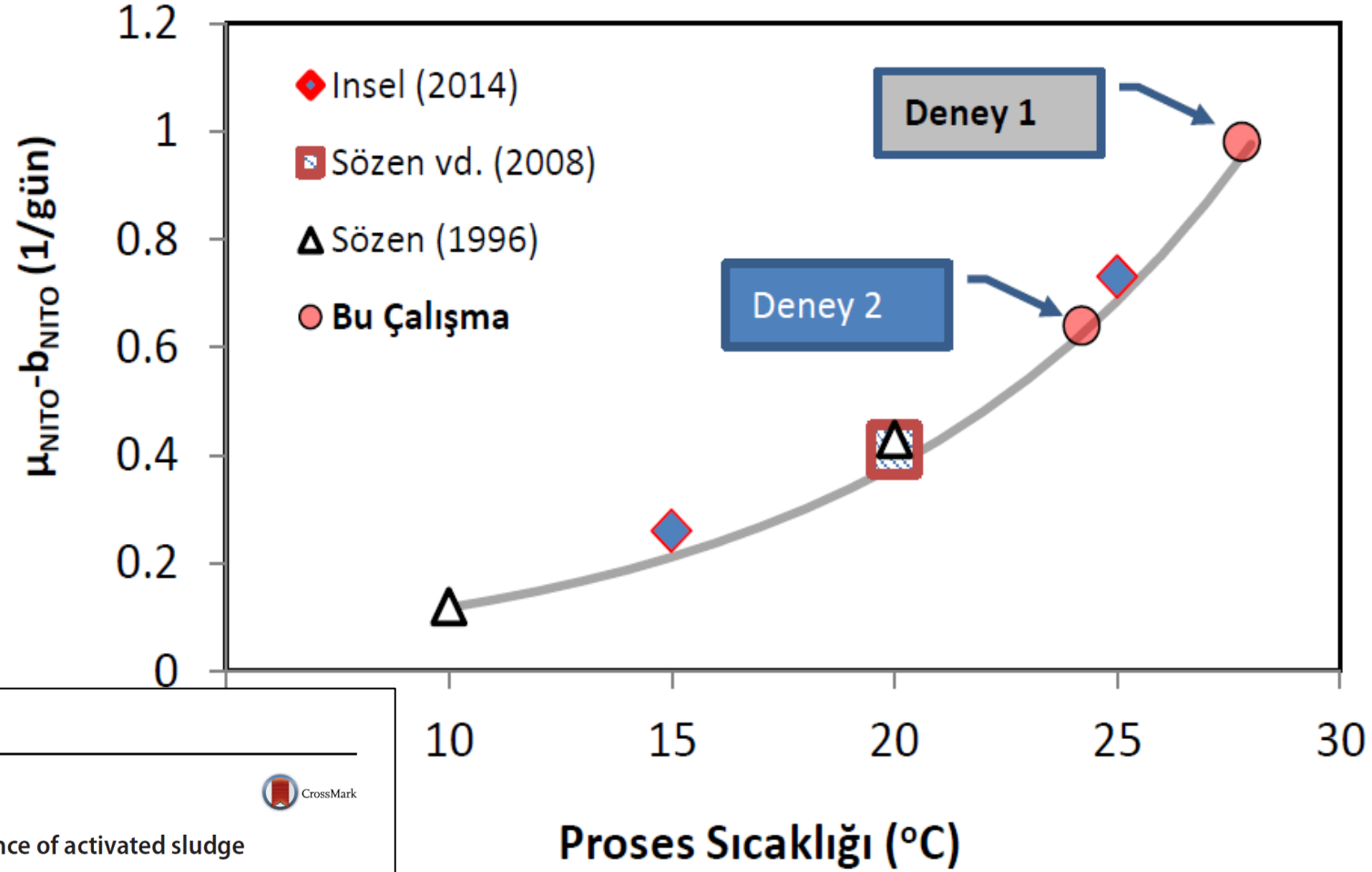


- Aerobik Çamur Yaşı
- Nitrifikasyon
- Çamur Yaşı Kontrolü
- Hava İhtiyacı (N)





# Nitrifikasyon Bakterileri Çoğalma Hızı



Bioprocess and Biosystems Engineering  
<https://doi.org/10.1007/s00449-018-2042-9>

RESEARCH PAPER



Enhancement of nutrient removal performance of activated sludge with a novel hybrid biofilm process

G. Güneş<sup>1</sup> · E. Hallaç<sup>2</sup> · M. Özgan<sup>2</sup> · A. Ertürk<sup>2</sup> · D. Okutman Taş<sup>2</sup> · E. Çokgor<sup>2</sup> · D. Güven<sup>3</sup> · I. Takacs<sup>4</sup> · A. Erdinçler<sup>5</sup> · G. Insel<sup>2</sup>

Received: 18 May 2018 / Accepted: 9 November 2018  
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

# Nitrifikasyon için Aerobik Çamur Yaşı (Kayser, 1993)

ATV-DVWK-A 131E

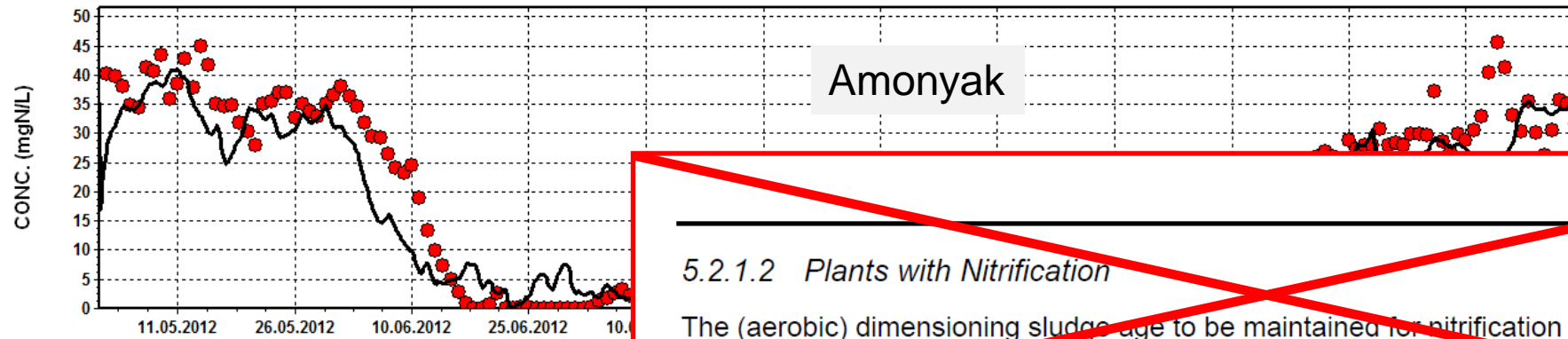
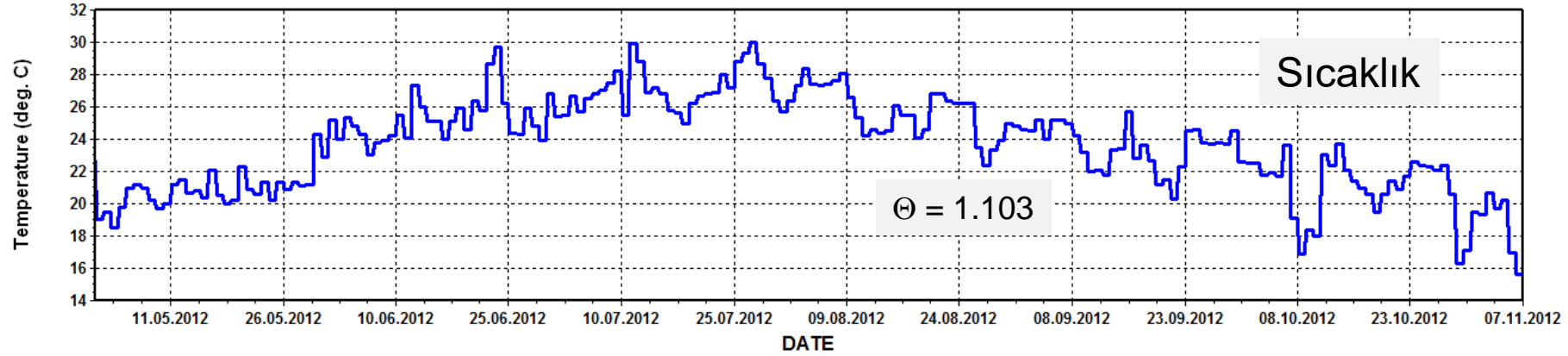
## 5.2.1.2 Plants with Nitrification

The (aerobic) dimensioning sludge age to be maintained for nitrification is:

$$t_{SS,aerob,dim} = SF \cdot 3.4 \cdot 1.103^{(15-T)} \quad [d] \quad (5-1)$$

- $b_A$  : Ototrofların ölüm hızı [1/gün]
- $f_{T,A}$  : Ototrofik çoğalma için sıcaklık düzeltme faktörü,  $1.103^{T-15}$
- $f_{T,bA}$  : Ototrofik çoğalma için sıcaklık düzeltme faktörü,  $1.029^{T-15}$
- $f$  : Emniyet faktörü: [1.45]
- $K_{NH}$  : Ototrofların yarı doygunluk konsantrasyonu [gN/m<sup>3</sup>]
- $S$  : Salınım faktörü [-]
- $S_{NHmax}$  : Çıkışta maksimum izin verilebilir amonyak kons. [10 gN/m<sup>3</sup>]
- $\hat{\mu}_A$  : Maksimum ototrofik çoğalma hızı [1/gün]

# Sıcaklığa bağlı çıkış NH<sub>4</sub>-N simülasyonu (2012)



ATV-DVWK-A 131E

## 5.2.1.2 Plants with Nitrification

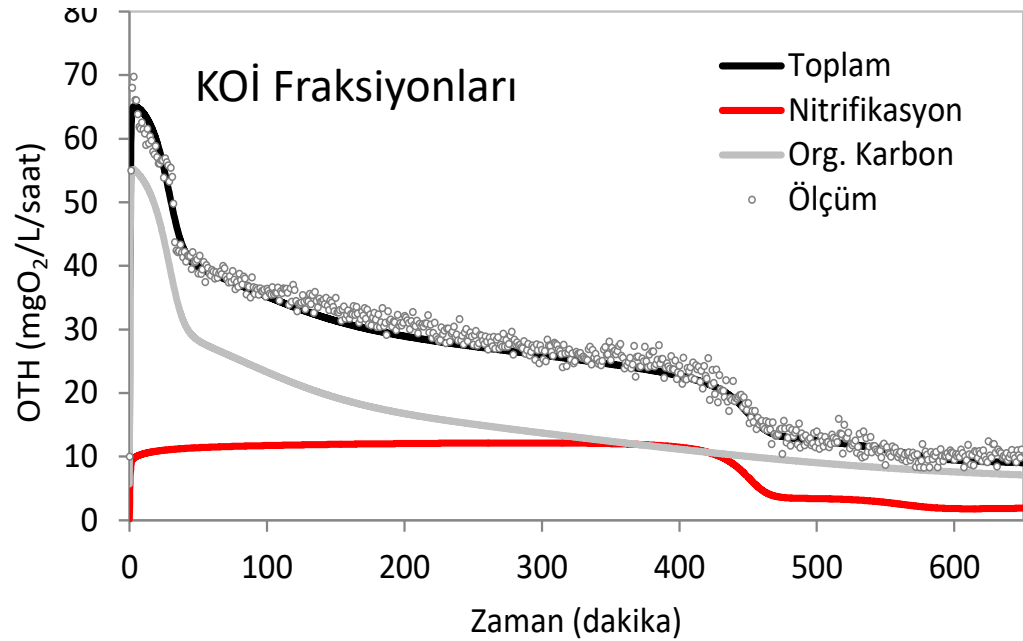
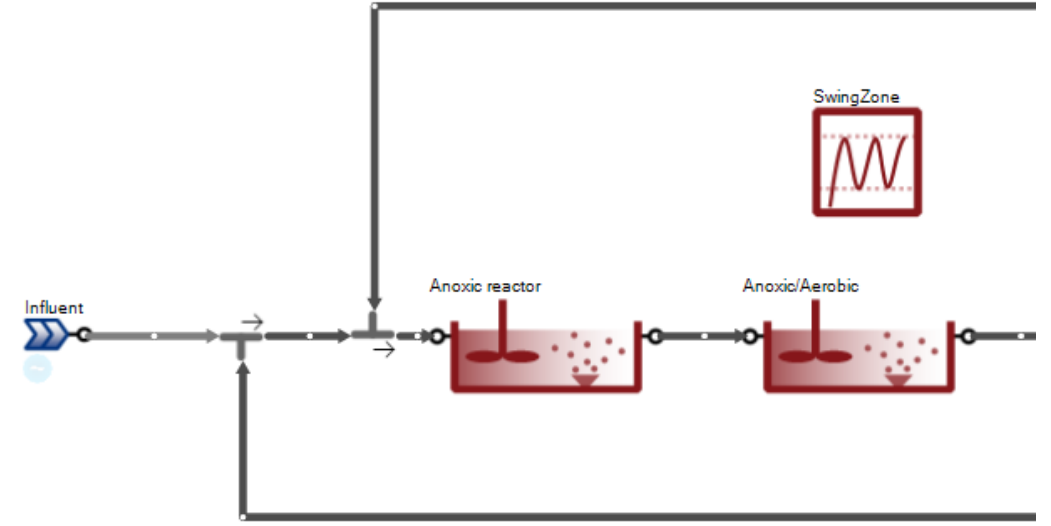
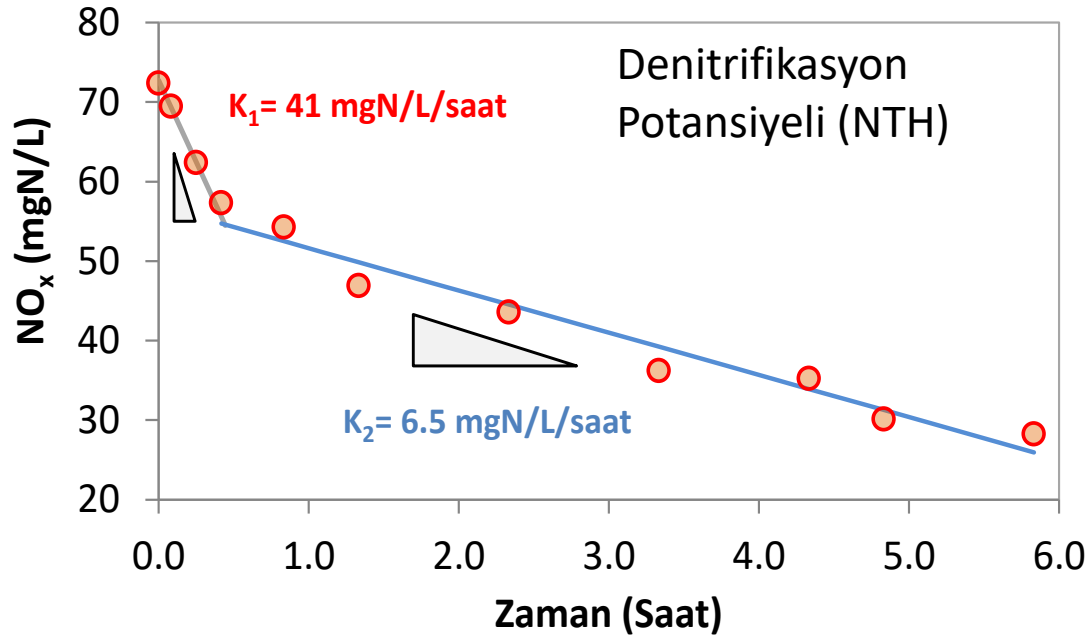
The (aerobic) dimensioning sludge age to be maintained for nitrification is:

$$t_{\text{sc,aerob,dim}} = SF \cdot 3.4 \cdot 1.103^{(15-T)} \quad [\text{d}]$$

(5-1)

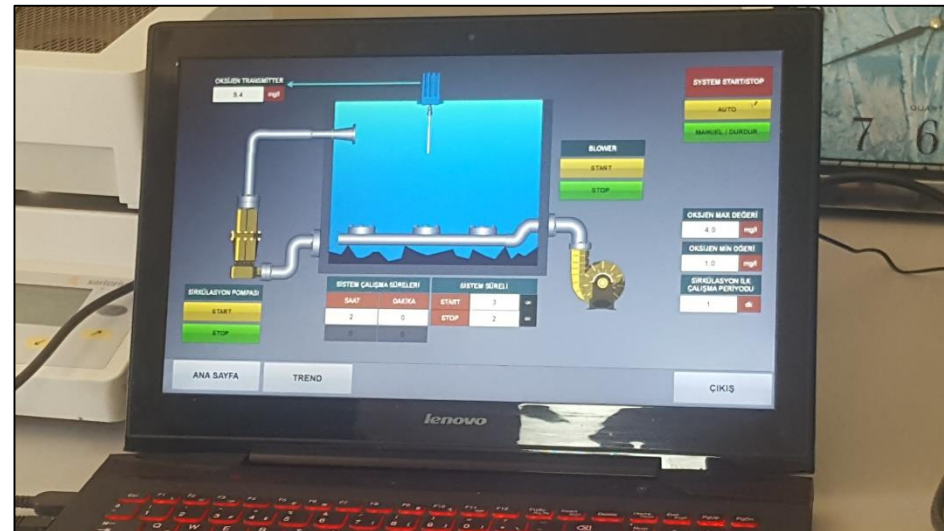
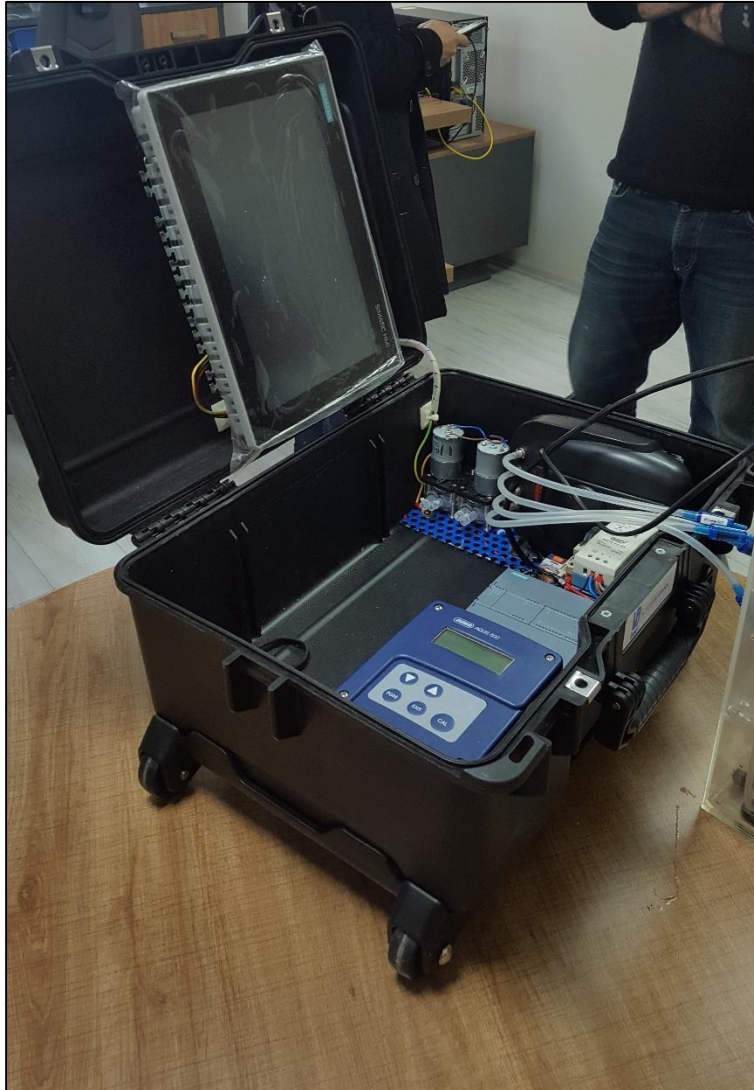
$$\hat{\mu}_A(15) = 0.32 \text{ /gün}$$

$$b_A(15) = 0.09 \text{ /gün}$$

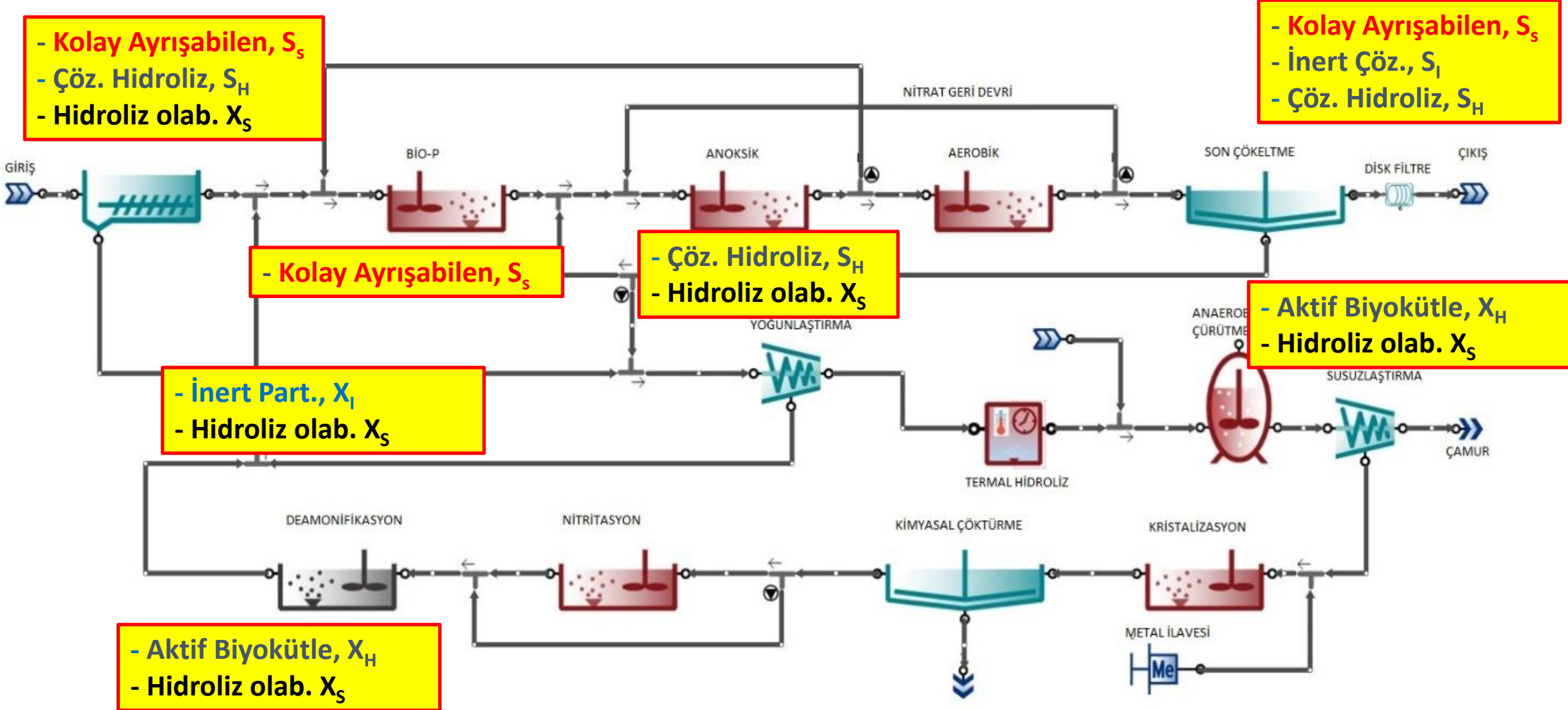


- Anoksik Hacim Oranı
- İçsel Geri Devir Debisi
- Aktif Çamur Konfigürasyon
- Hava İhtiyacı (C)

# RespirO<sub>2</sub>- metre

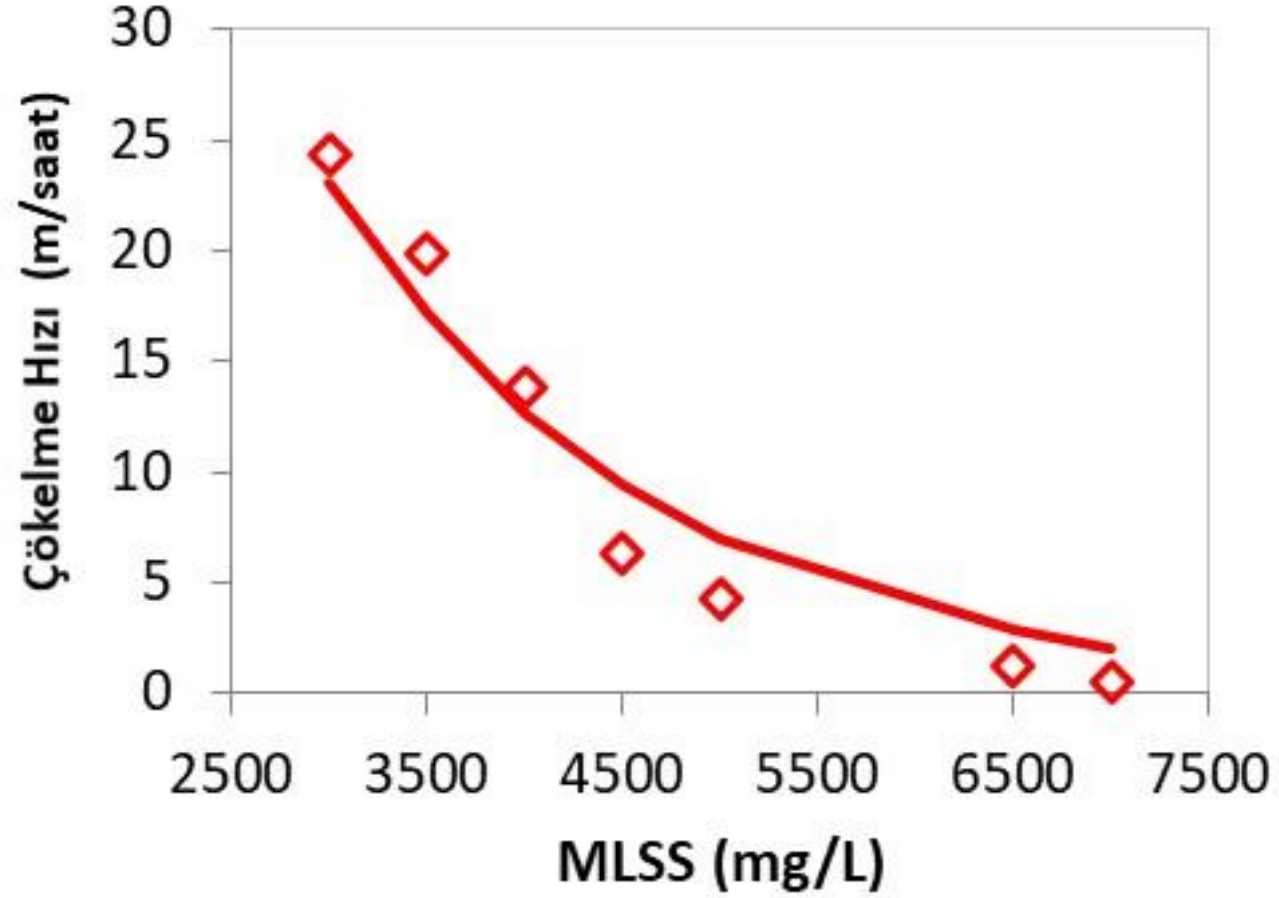


# Proses Üzerindeki Etkileri

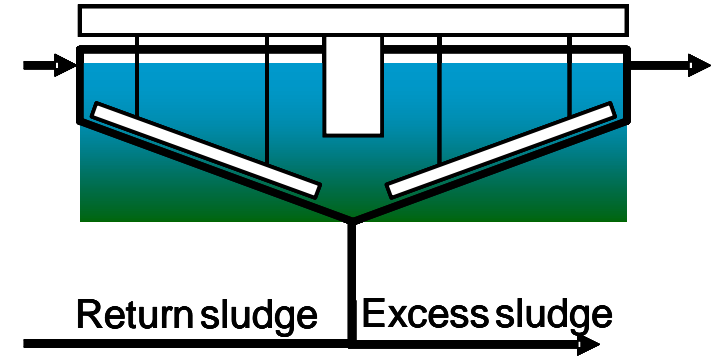
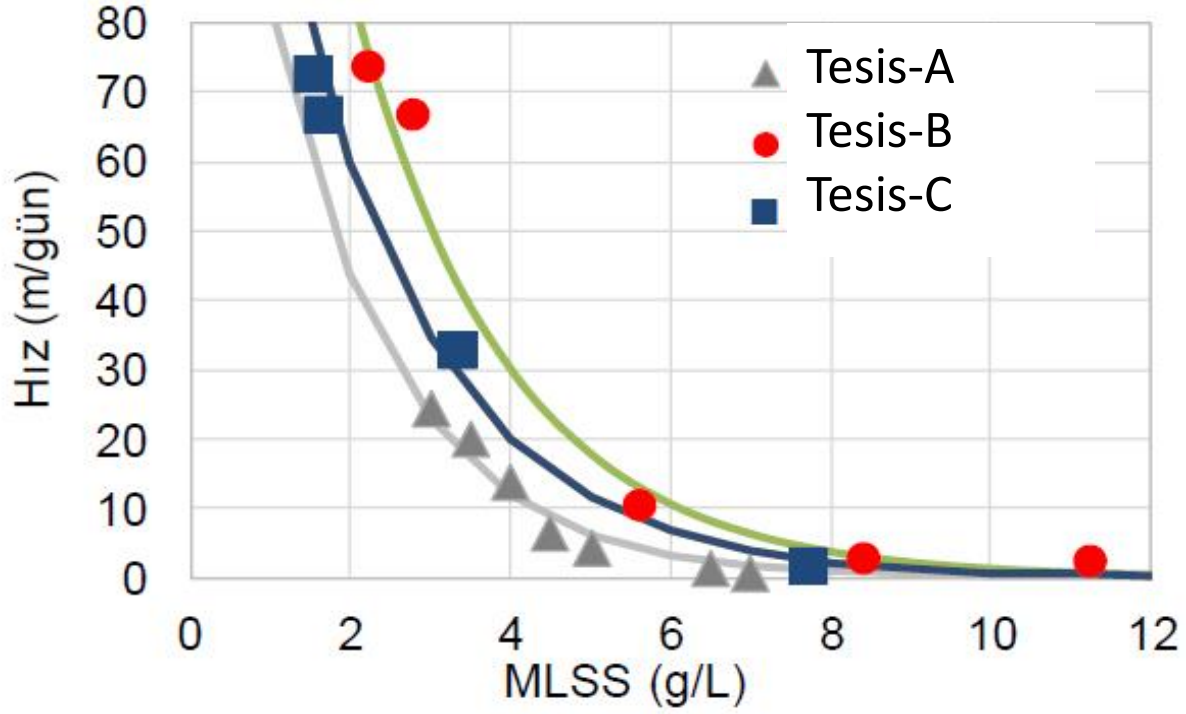


# Çamur Çökeltme Hızı (Son Çökeltme)

Denitrifikasyon  
Potansiyeli (NTH)

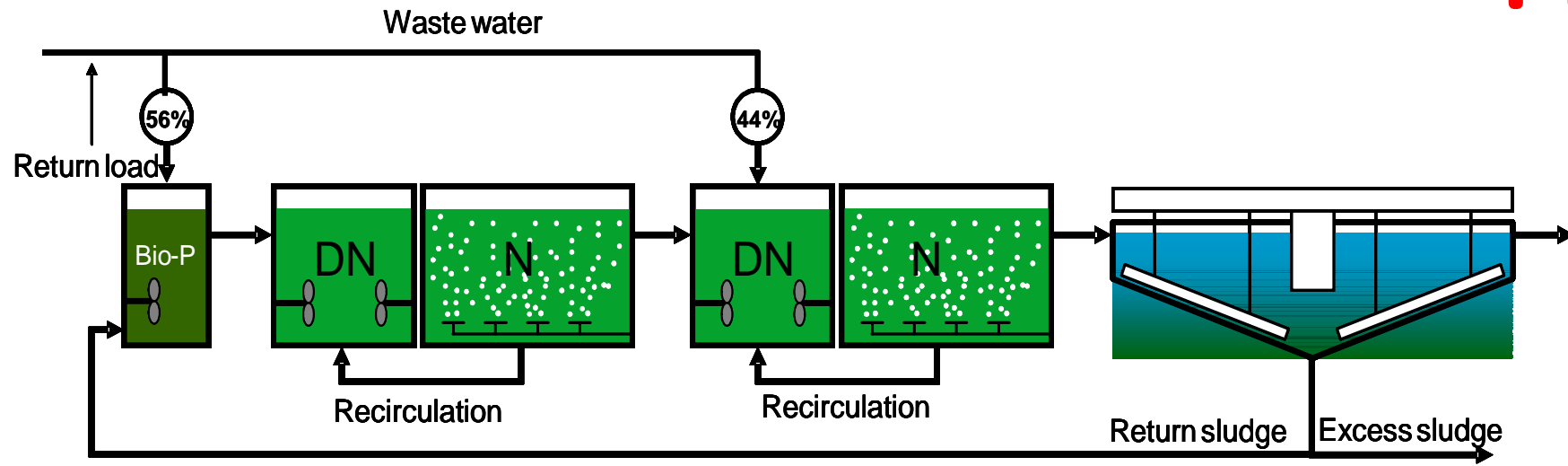


SVI?



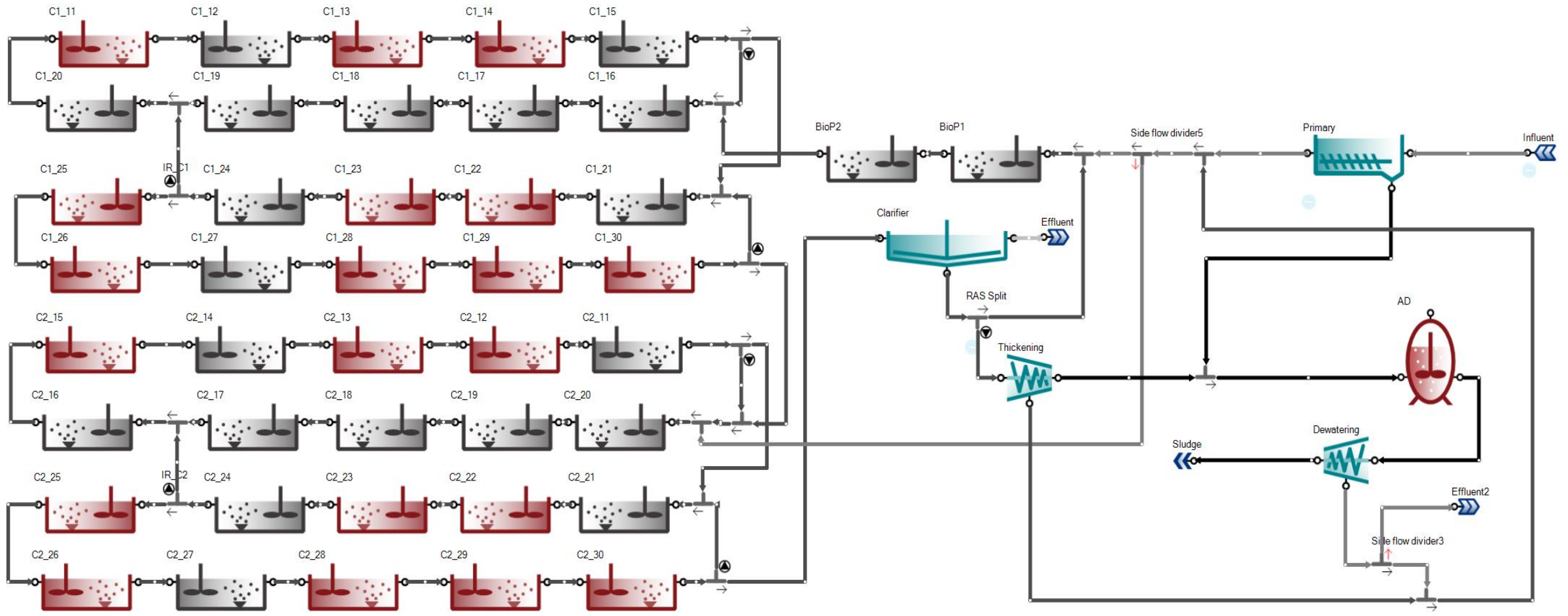


???



- Step Feed
- A<sup>2</sup>O
- Simultaneous Nite/Denite





# CFD: havalandırmanın karıştırma üzerine etkisi

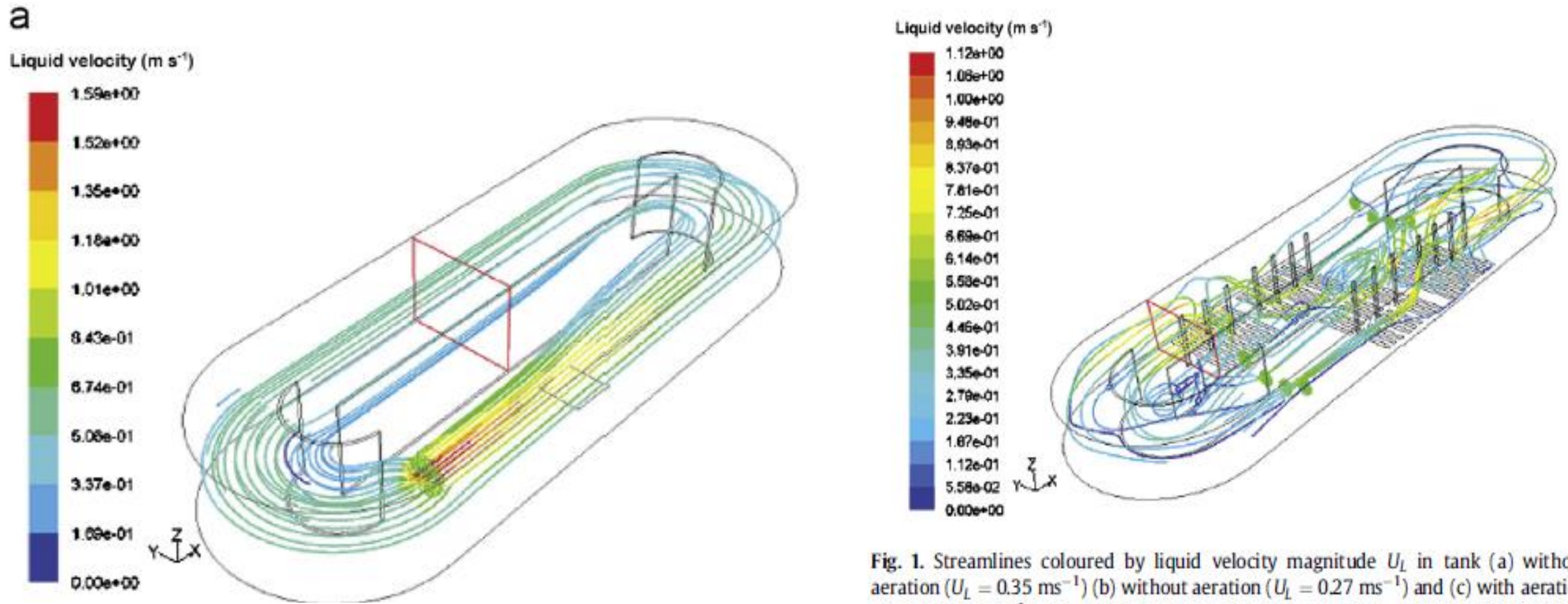
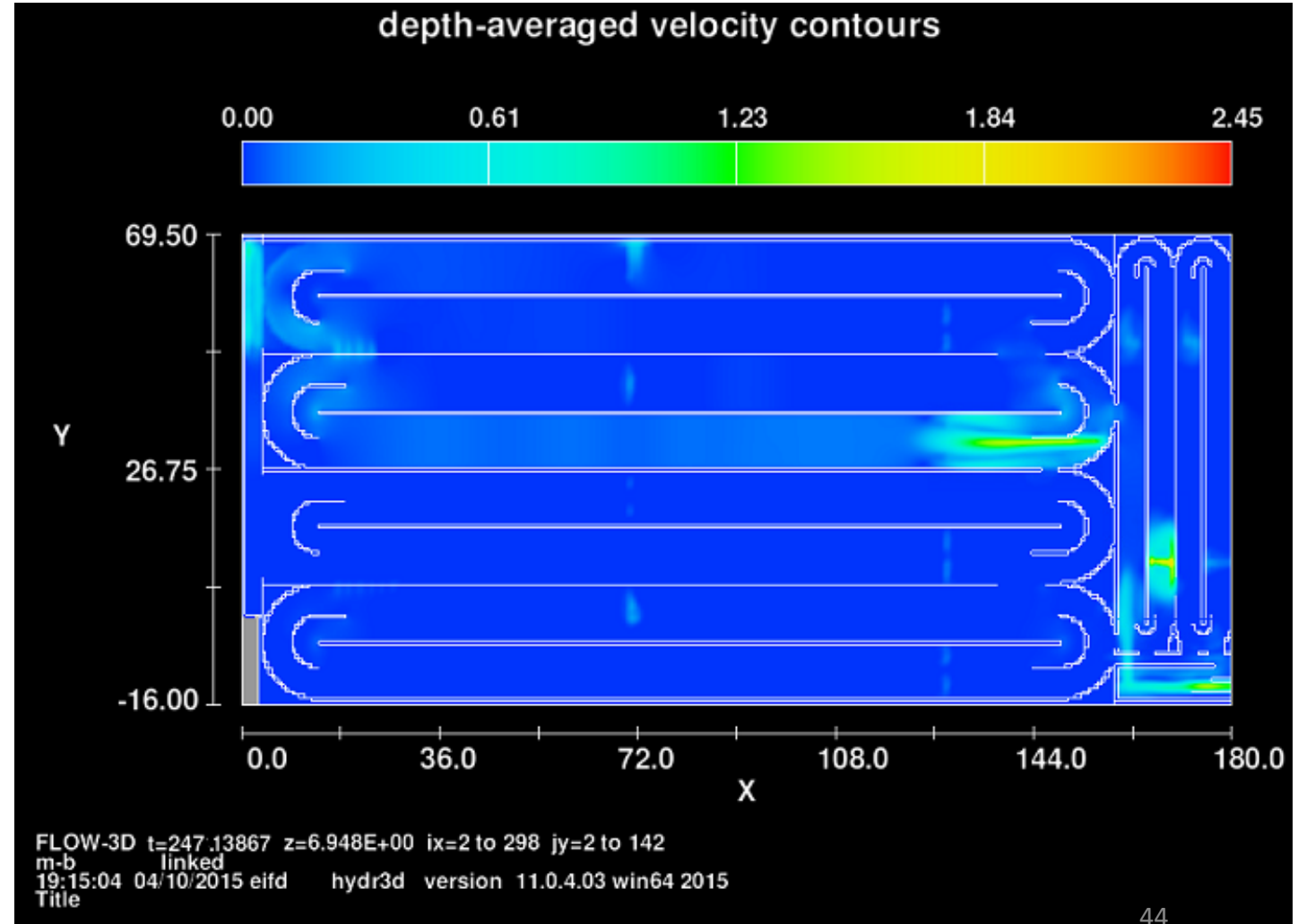
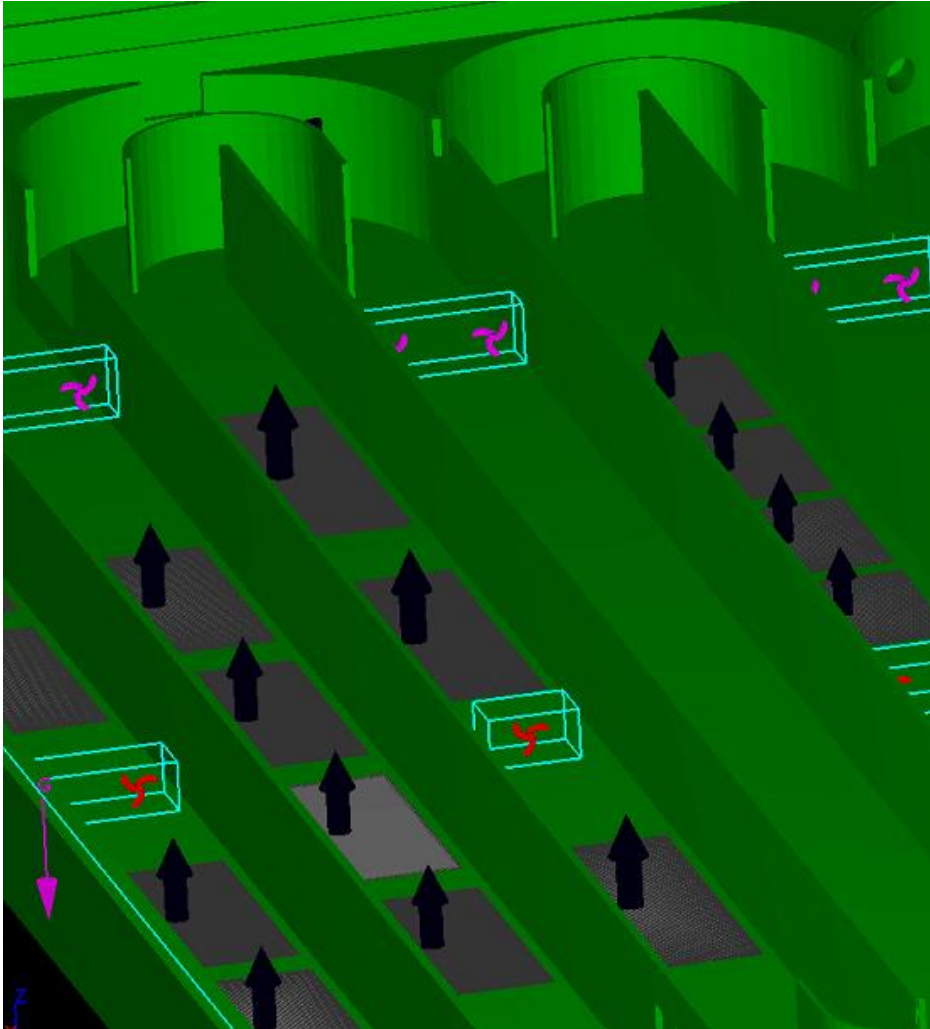


Fig. 1. Streamlines coloured by liquid velocity magnitude  $U_L$  in tank (a) without aeration ( $U_L = 0.35 \text{ ms}^{-1}$ ) (b) without aeration ( $U_L = 0.27 \text{ ms}^{-1}$ ) and (c) with aeration ( $U_L = 0.23 \text{ ms}^{-1}$ ). Reprinted from [Fayolle et al. \(2007\)](#). Copyright (2007) with permission from Elsevier.

# Karışım Bölgeleri ve Havalandırma Verimi



## Air volume fraction in %

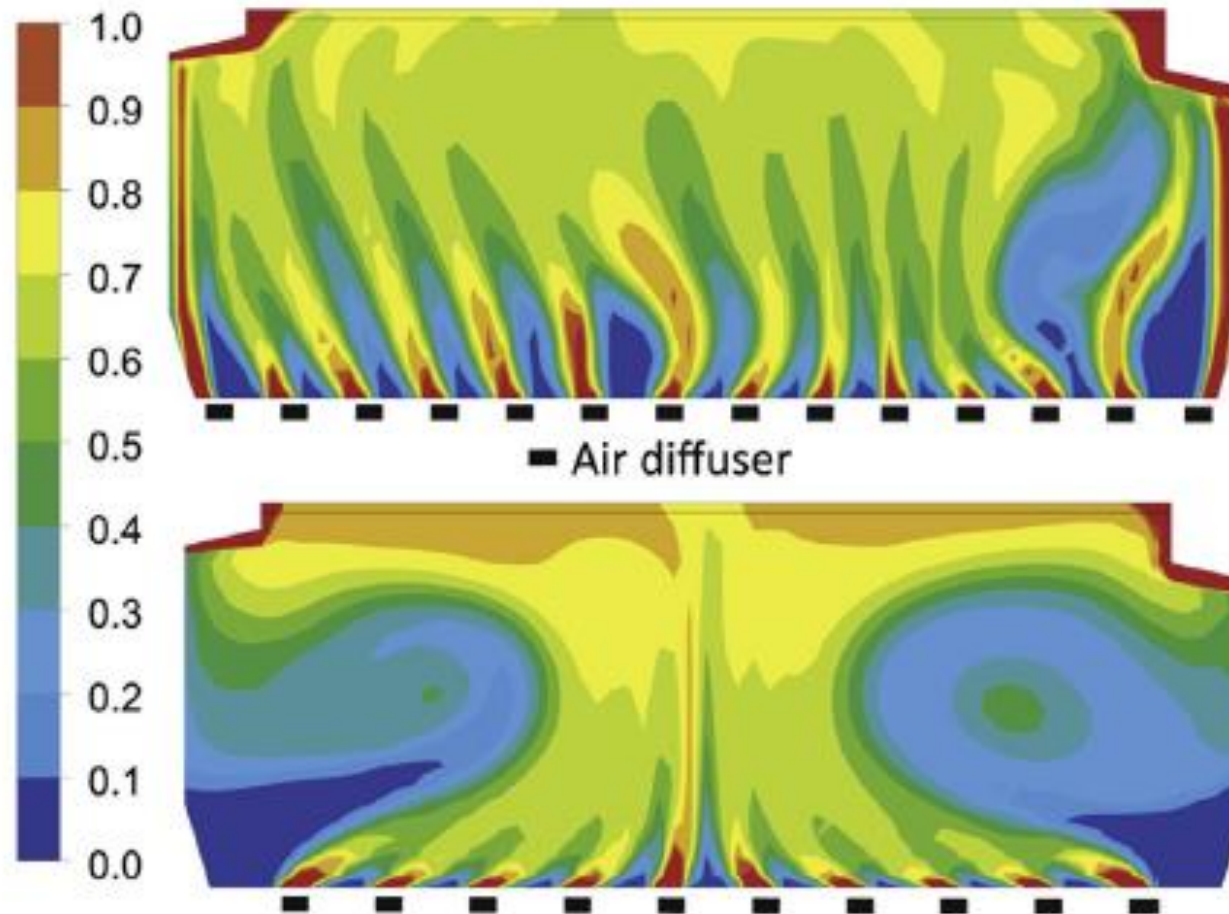
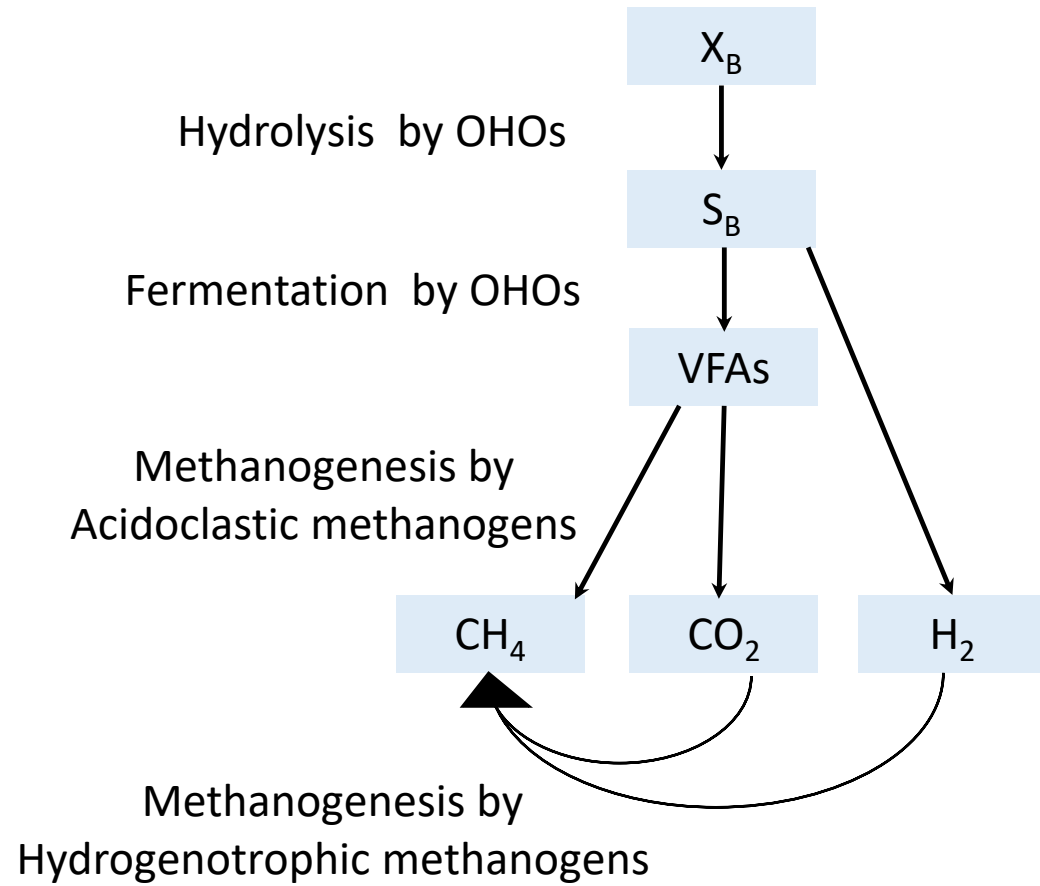
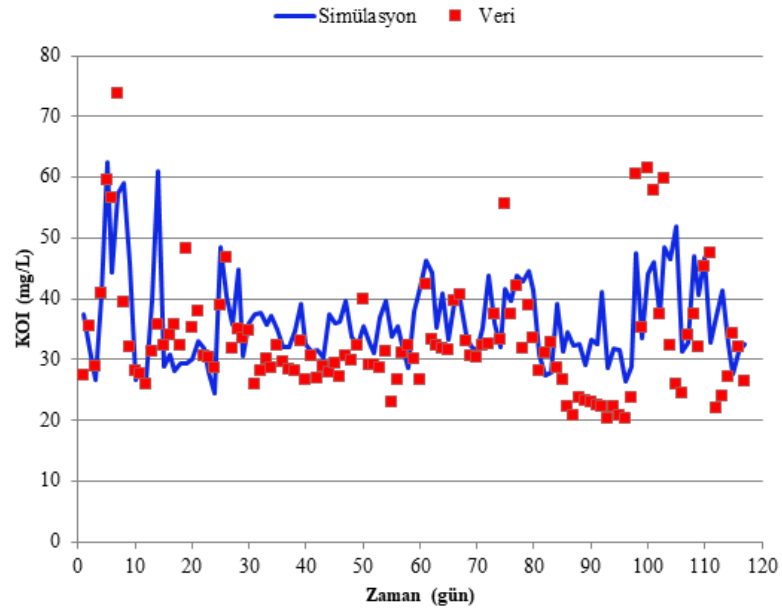


Fig. 2. Snapshot of air volume fractions at two cross sections with different diffuser patterns. Reprinted from Gresch et al. (2011). Copyright (2011) with permission from Elsevier.

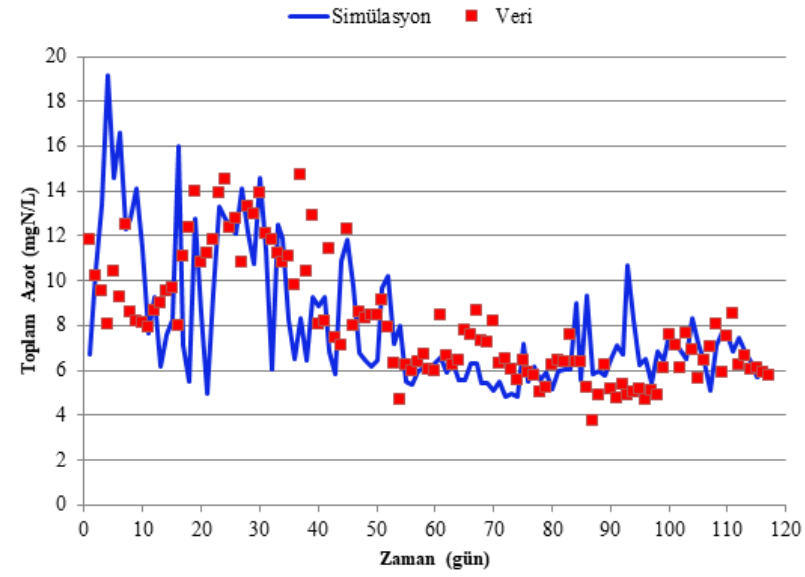
# Anaerobik Çürütme



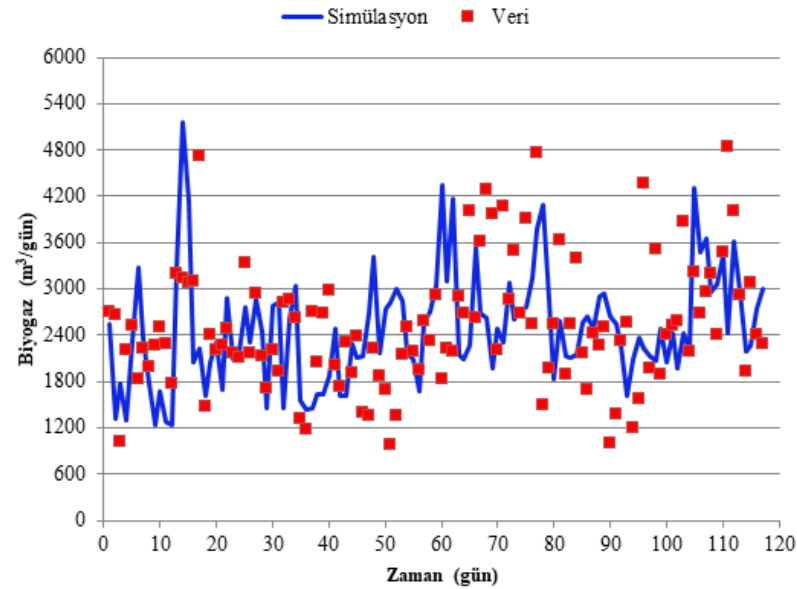




Çıkış Organik Madde



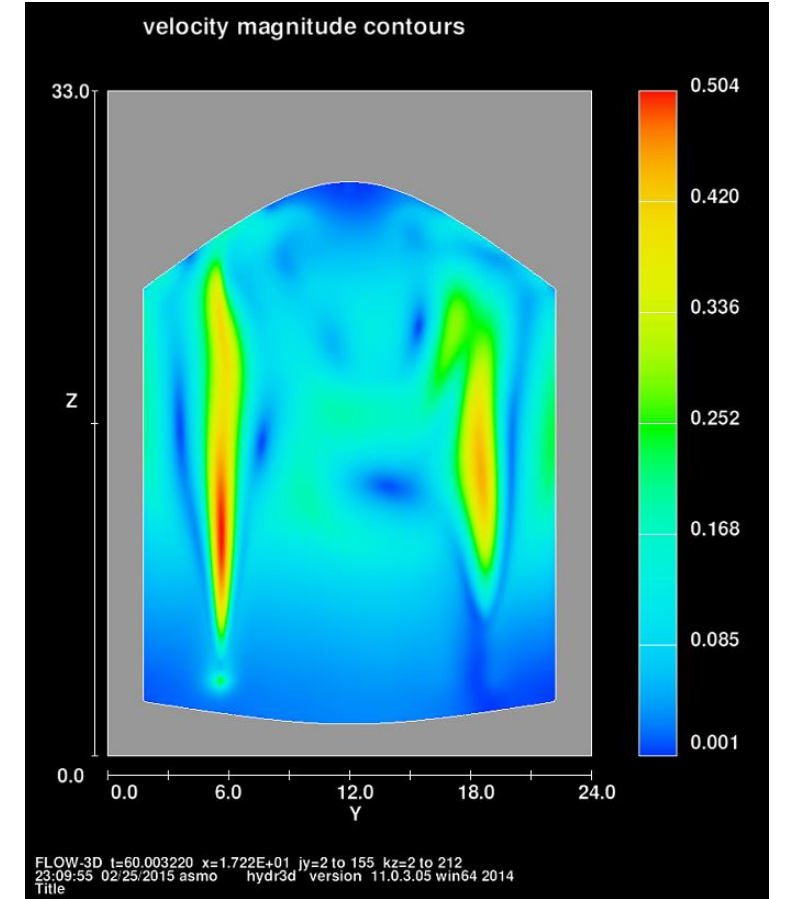
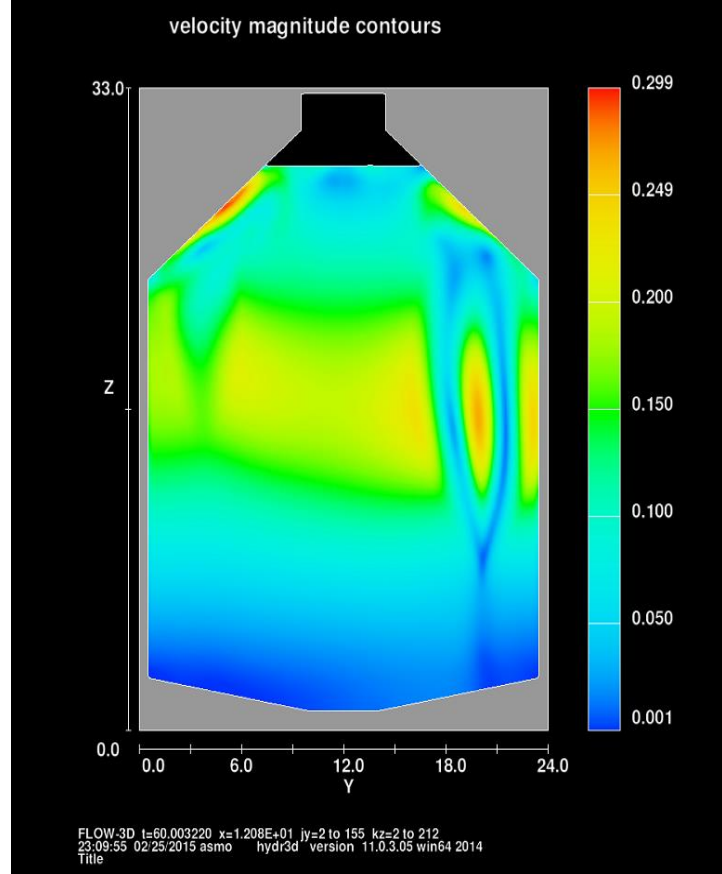
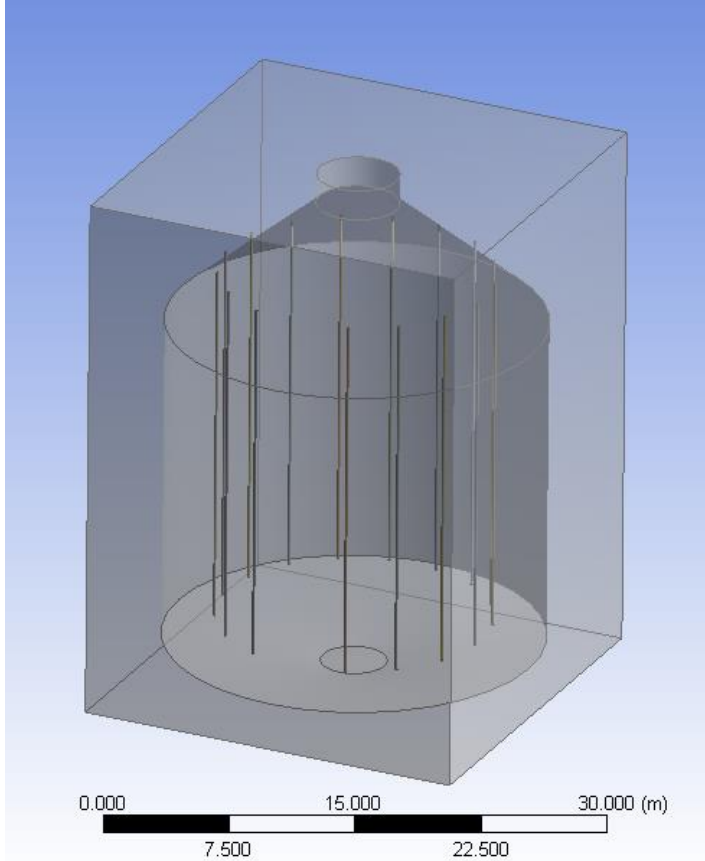
Çıkış Toplam Azot



Biyogaz  
Debisi/Digester



# Anaerobik Çamur Çürütme

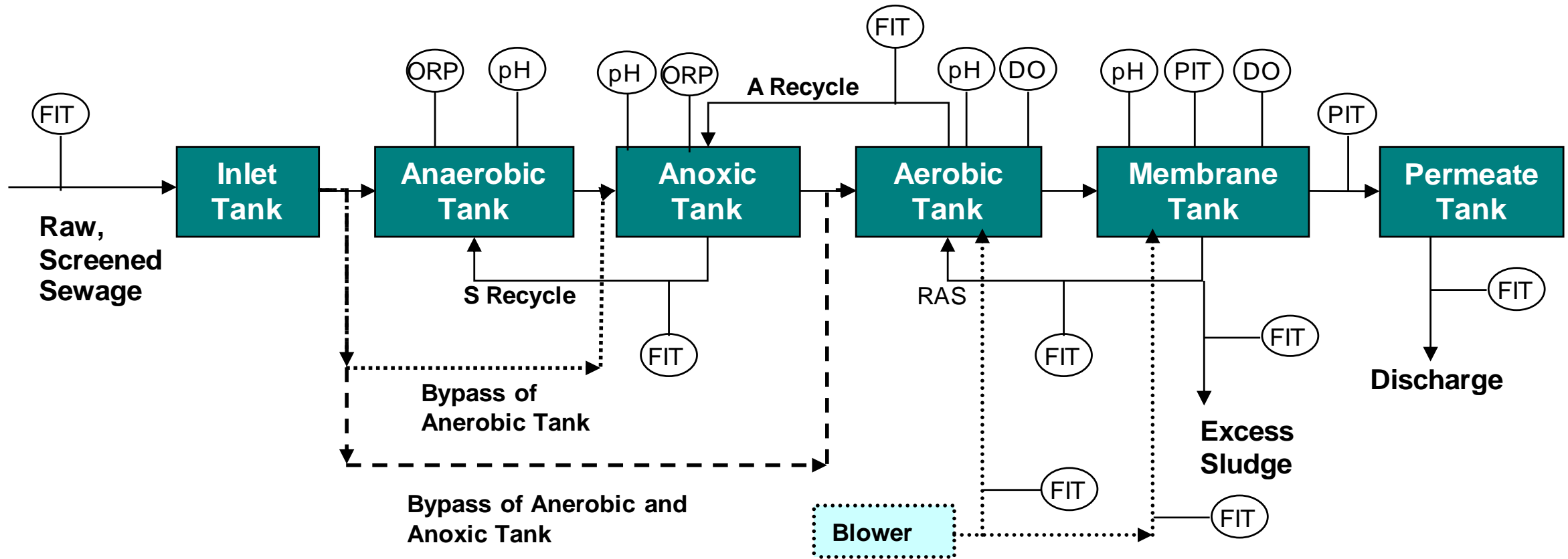


Aksel M., Insel G., Keskinler B. (2015) ÇEVRE MÜHENDİSLİĞİNDE HESAPLAMALI AKIŞKANLAR DİNAMIĞI UYGULAMALARI, 11 ULUSAL ÇEVRE MÜHENDİSLİĞİ KONGRESİ 15-17.10.2015, Uludağ Üniversitesi Mete Cengiz Kongre ve Kültür Merkezi, Bursa.

# Örnek Çalışma Yüksek Sıcaklıklarda MBR İşletmesi



# Proses Akim Diyagramı

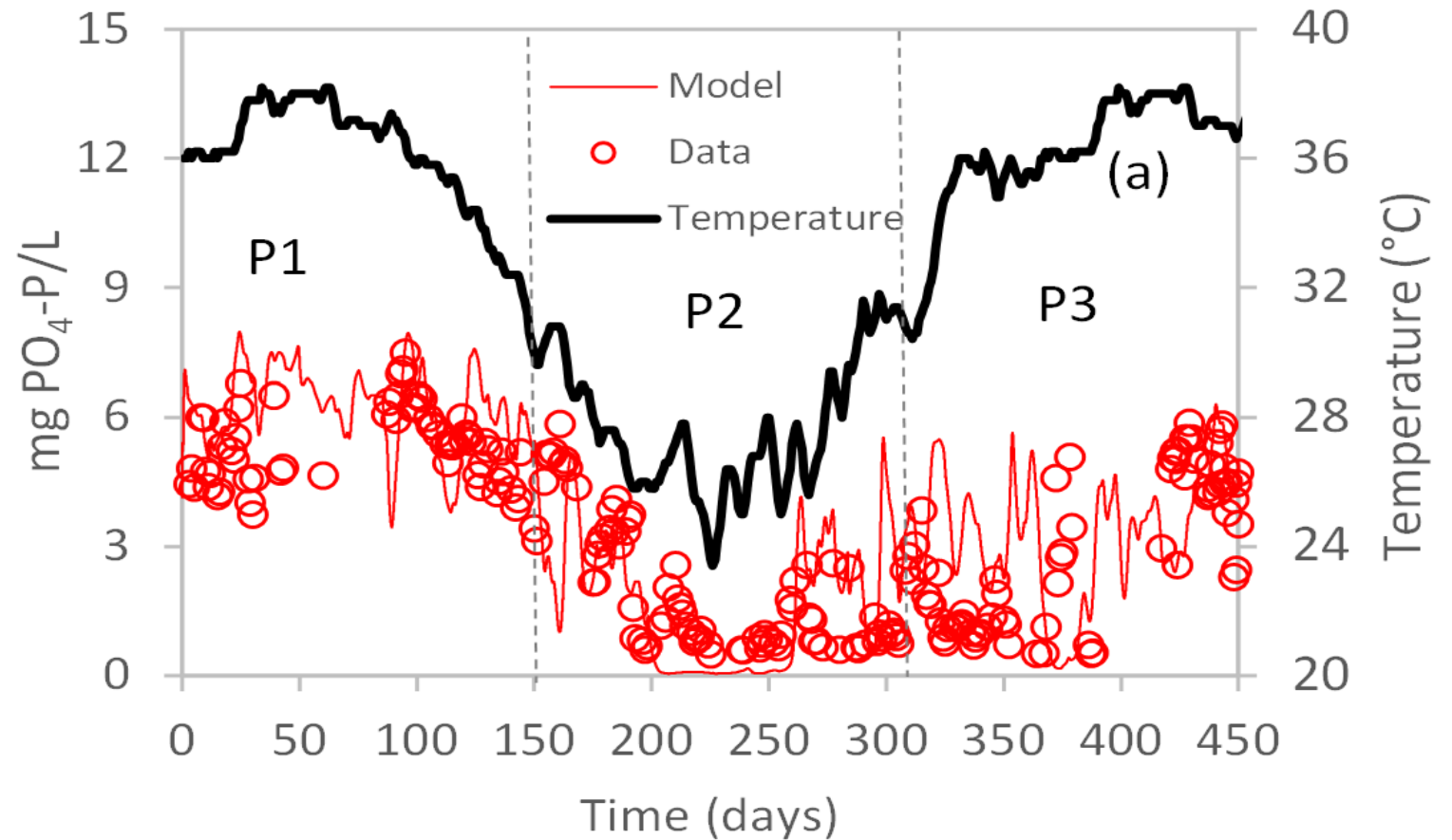


# Plant and MBR Unit



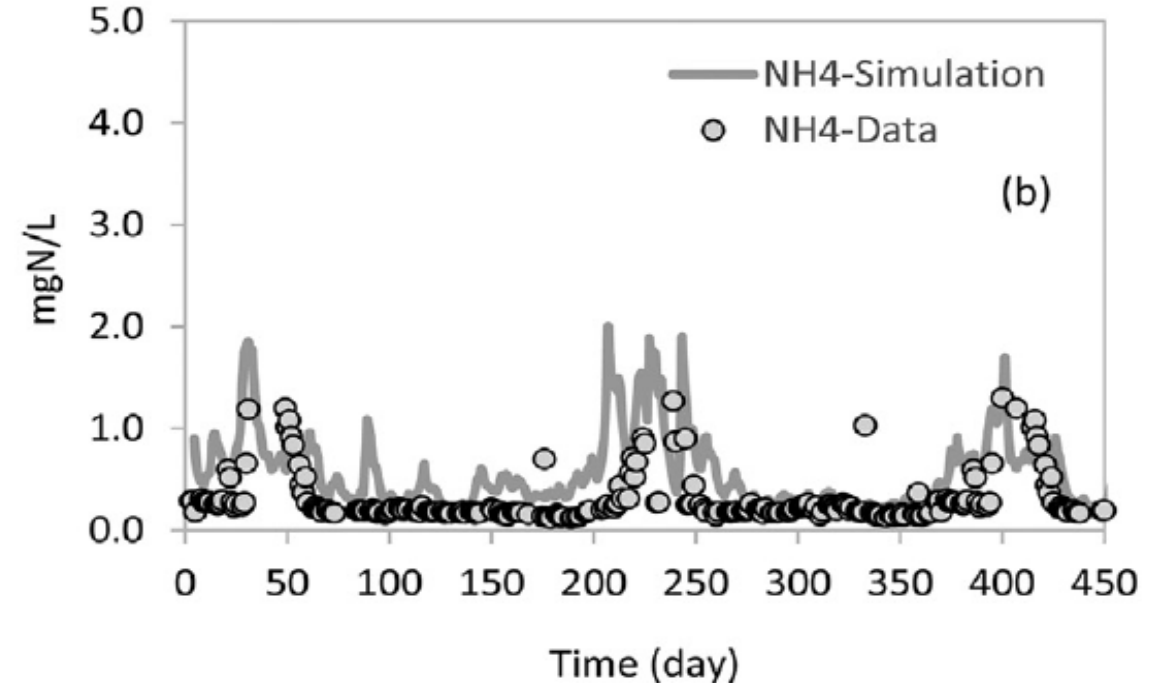
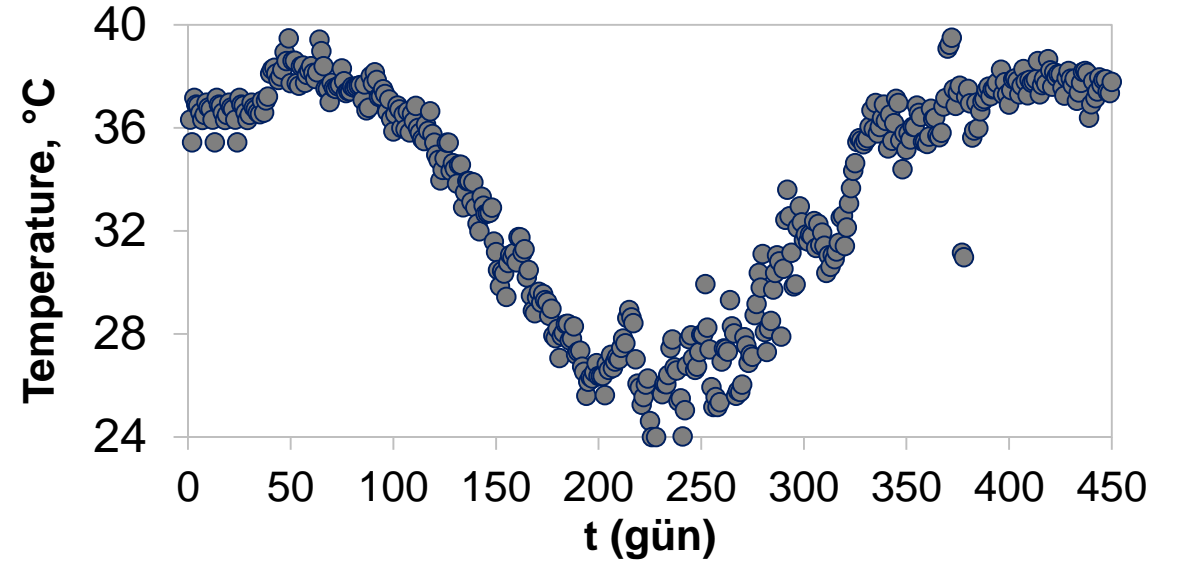
# Fosfor Giderimi

Parameter	Unit	Value
COD	mgO <sub>2</sub> /L	780
VFA	mgO <sub>2</sub> /L	105
TSS	mg/L	400
TKN	mgN/L	65
TP	mgP/L	10
PO <sub>4</sub>	mgP/L	7



# Çıkış Azot

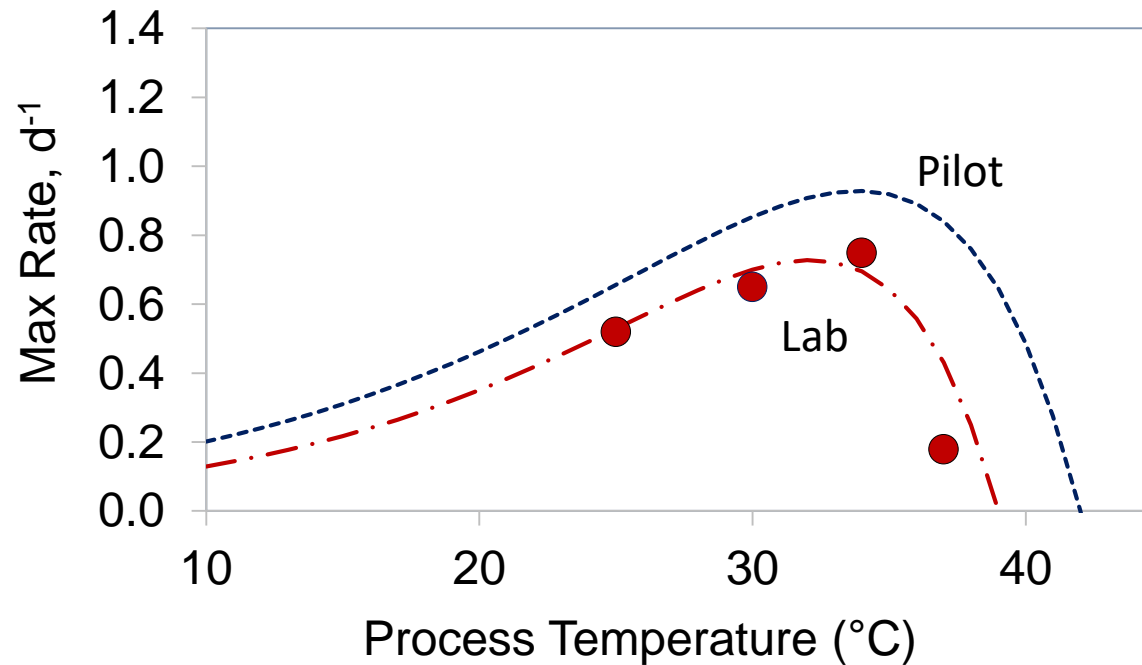
- 100% Azot Giderimi
- Sıcaklığın Azot Giderimine etkisi



# Reaksiyon İnhibisyonu

Genişletilmiş Arrhenius denklemi (Basin and Prosser, 2000)

$$r_T = r_{20} \cdot \theta_1^{T-20} \left[ 1 - \theta_2^{T-T_{max}} \right]$$

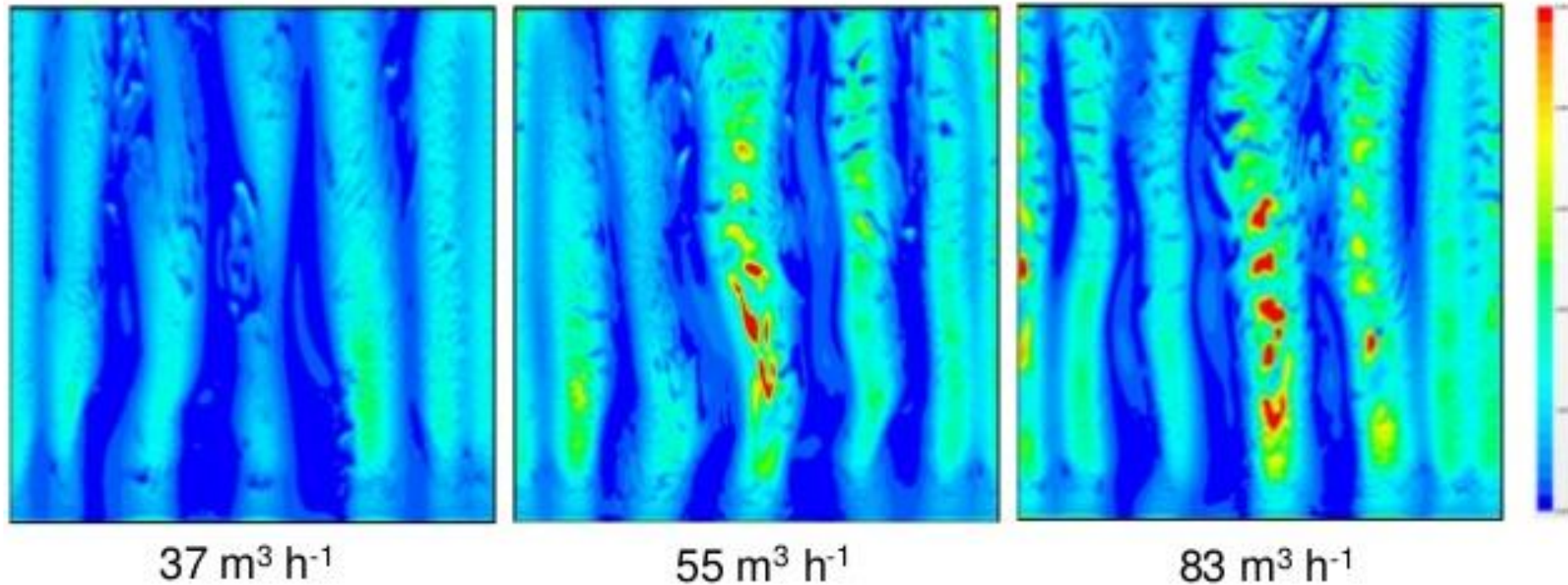


# MBR Modülü HAD Analizi

## CFD Results – HS MBR (IV)

Wall shear stress:

Air flow rate ( $\text{m}^3 \text{h}^{-1}$ )	CFD (Pa)
37	0.71
55	0.88
83	1.17

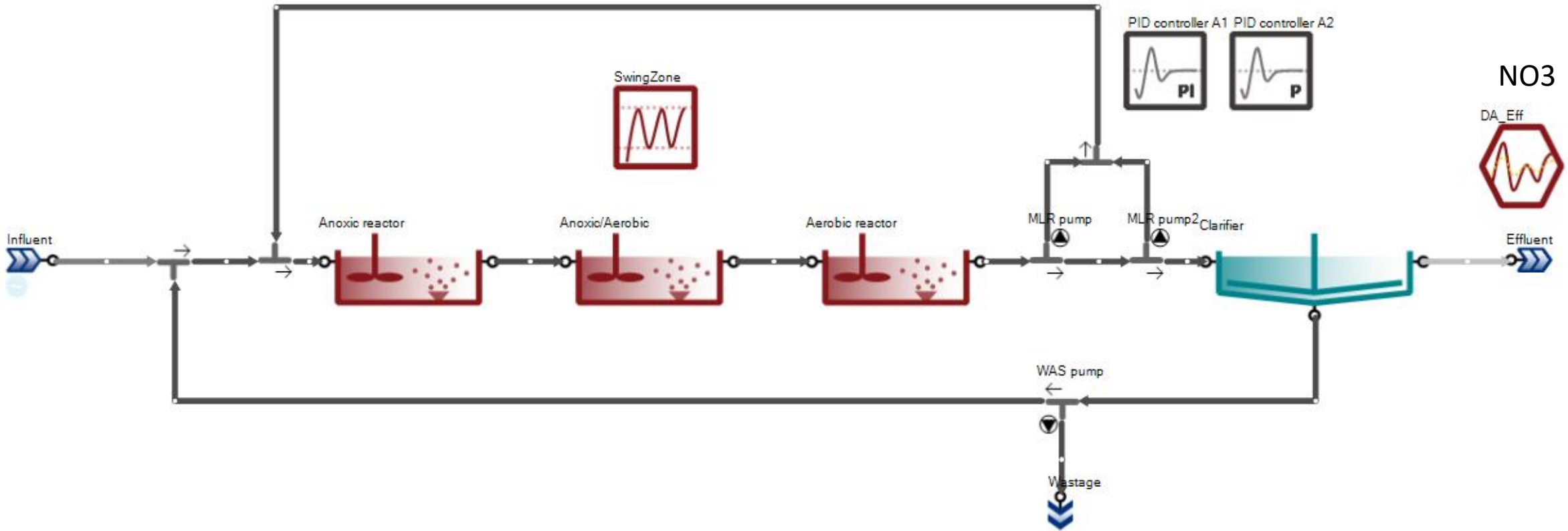




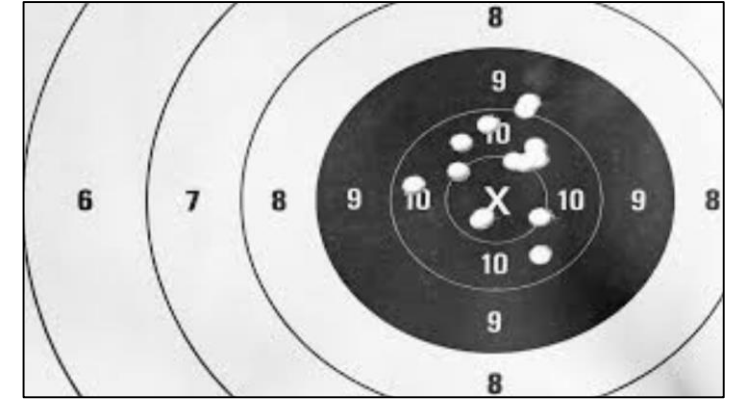
# PROSES KONTROL

- Nasıl enstrümantasyona ihtiyaç var?
- Problemleri nereye yerleştirelim?
- Amonyum, Nitrat ve Oksijen Problemleri: Nereye bağlayalım?
- Blower kontrolün parametrelerini nasıl girelim (PI, PID)
- Amonyak Ölçüme Bağlı Oksijen Kontrolü Uygun bir alternatif mi?
- Anoksik Hacim Kontrolü Gerekli mi?
- İçsel Geri Devir Pompası Kontrolü için kapasite ne olsun, VFD gerekli mi?
- Kimyasal Madde İlavesi Kontrolü İçin en uygun koşul nedir?

# Kontrol Sistemi Tasarımı



# SONUÇLAR



- Genel amaçlı proses simülatörleri tüm tesis bazında çözüm
- Tasarım alternatifleri ve İşletme senaryolarının risk olmadan denenmesi
- Yerel koşullara uygun giriş koşulları ve model parametreler belirlenmeli
- Proses Kontrolü için Simülasyon Programları ile Stabilite Analizi
- Hesaplamalı akışkanlar dinamiği (HAD) yapılan kabuller için önemli
- Dinamik koşullar tasarımda ciddi değişiklikler gerektirebilir.

A photograph of a bald man with glasses, wearing a black t-shirt, playing an acoustic guitar on a stage. He is seated and looking down at his instrument. The stage is lit with blue light. In the background, there is a drum set and a conga. A microphone is positioned in front of him. On the left, a white bass drum has the text 'amin' and 'Water' on it. The word 'TEŞEKKÜRLER' is written in large yellow letters at the bottom of the image.

TEŞEKKÜRLER



# ÇEVRE MÜHENDİSLİĞİNDE BİLGİSAYAR DESTEKLİ SİMÜLASYON VE MODELLEME: HESAPLAMALI AKIŞKANLAR DİNAMİĞİ

(Computational Fluid Dynamics - CFD)

**Dr. Murat AKSEL**

**İstanbul Aydın Üniversitesi, İnşaat Mühendisliği Bölümü**

# HİDRODİNAMİK MODELLEME

Hidrodinamik Modelleme, özellikle hareket halindeki akışkanın davranışının matematiksel yöntemle bilgisayar kullanılarak araştırılmasıdır.

Akışkan farklı kuvvetlerin birlikte veya tekil olarak etkisi sebebiyle hareket edebilir. Örnek olarak gel-git, yerçekimi, rüzgar, dalga, basınç farkı, enerji veya kütle ilavesi vb. olarak ifade edilebilir.

Akışkanın hidrodinamik davranışına etki eden faktör ne kadar fazla ise davranışın çözümlenmesi de o denli zorlaşır.

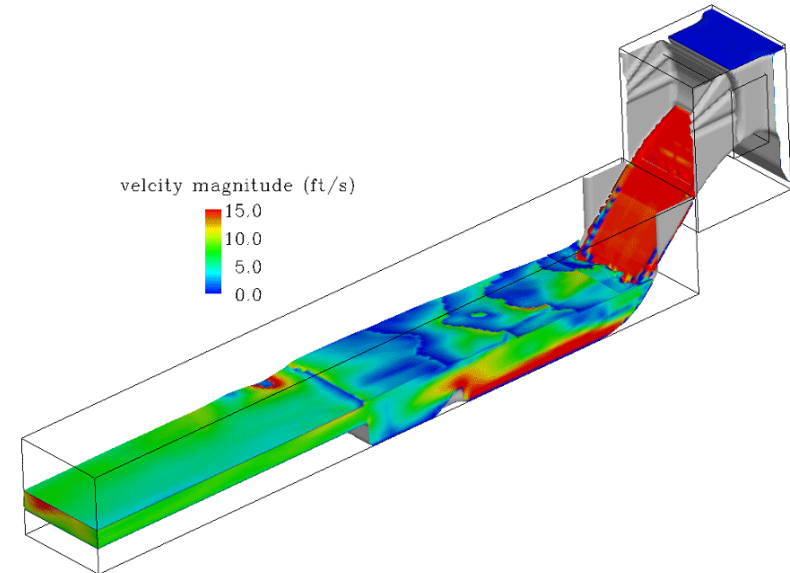
Örneğim bir boru içindeki suyun hareketinin hesaplanması görece kolayken bir dere ağzının akıntı, dalga, yoğunluk akıntısı, sediment hareketine bağlı morfolojik değişimler vb. etkileri altındaki akışkanın davranışının ifadesi son derece komplekstir.

# HESAPLAMALI AKIŞKANLAR DİNAMIĞI

Hesaplamalı akışkanlar dinamiği, uzun süreler isteyen akışkanlar mekaniği problemlerini bilgisayar ortamında çeşitli algoritmalar ve yöntemler oluşturularak çözümlenmesidir.

Sonlu farklar, sonlu elemanlar, sonlu hacimler gibi metotlar kullanılarak yapılan çözümler ile karmaşık ve uzun soluklu problemlerin bilgisayar performansına bağlı olarak hızlı ve etkili olarak çözülmesi sağlanır.

Son yıllarda bilgisayar teknolojilerinde yaşanan hızlı gelişim, modelleme programlarının da gelişmesine katkıda bulunmuştur.



# Hidrodimanik Modelleme Programları

Open  FOAM • OpenFOAM



• FLUENT

FLUENT®

• CFX



• Flow3D



• Delft3D

  
Water Modelling System  
Copyright by Mantes

• MOHID

• Flowvision



• Phoenics

• AQUAVEO

• EpaNET

Ücretlerine, kullanım alanlarına, gereksinimlerine göre pek çok farklı modelleme yazılımı mevcuttur.

Paket programlar dışında programlama dilleri kullanılarak da kendi problemlerimize çözümler üretebiliriz.



# HESAPLAMALI AKIŐKANLAR DİNAMIĐİ

Hesaplmalı akıőkanlar dinamiĐi yöntemi,

- Hidrolik
- Uzay
- Savunma
- Havacılık
- Kıyı ve Liman Tasarımı
- Enerji
- Çevre

Sektörlerinde özellikle yurtdıőı çalıőmalarda yıllardır kullanılmaktadır.

# MODELLEME UYGULAMALARI

1 Boyutlu

Boru Hidroliđi – EPANET

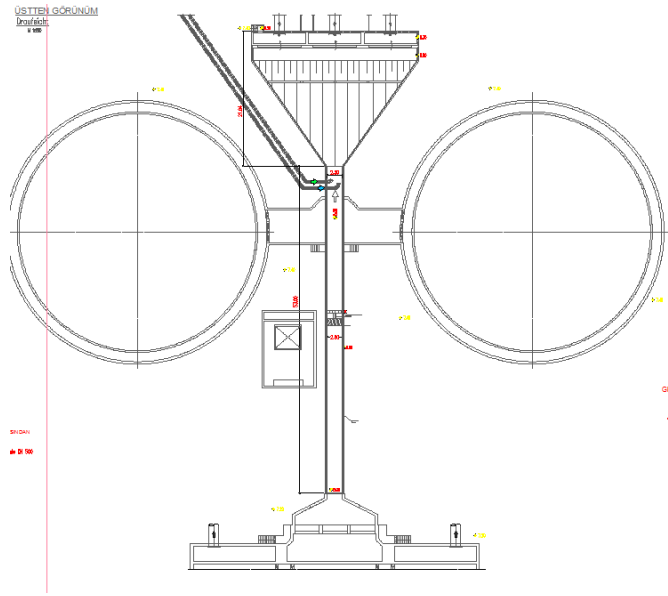
2 Boyutlu

Dalga Transformasyonu, Dere Ađzı Modellemesi, Sediment Tařınımı, Termal Seyrelme, Dere Modellemesi ...

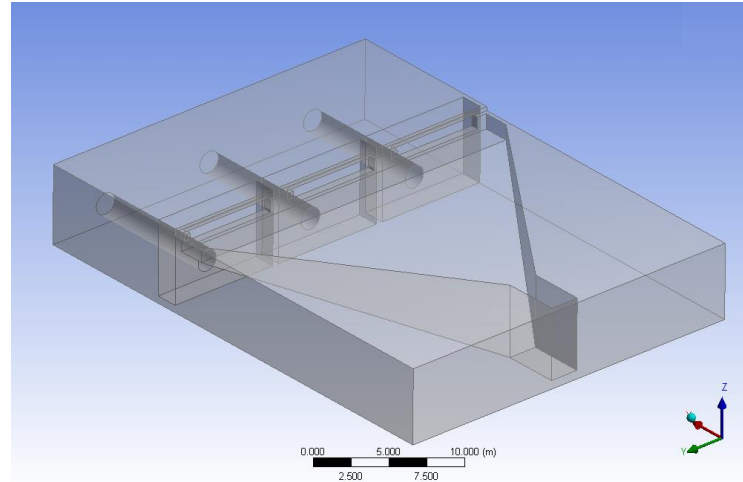
3 Boyutlu

# ARITMA TESİSİ UYGULAMALARI

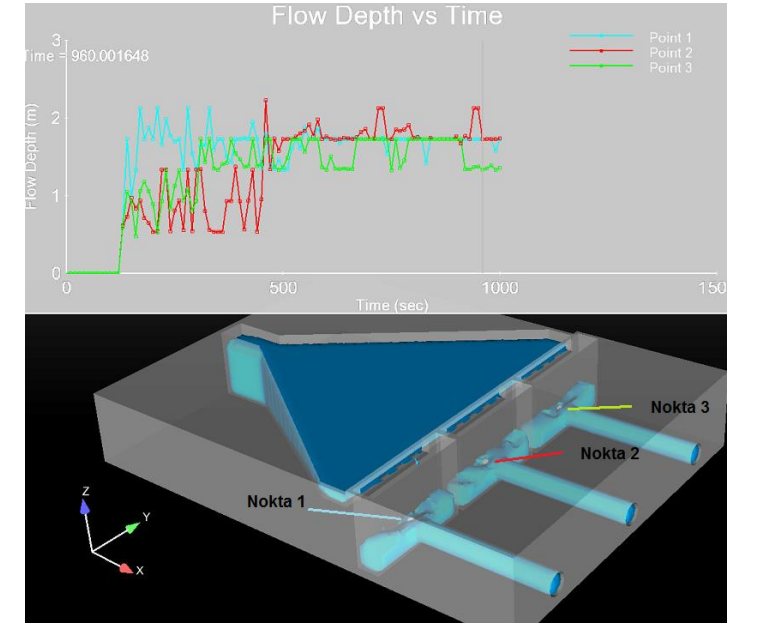
## Dağıtım Yapısı



Şekil 1. Ön Çökeltme Havuzları ve Dağıtım Yapısı



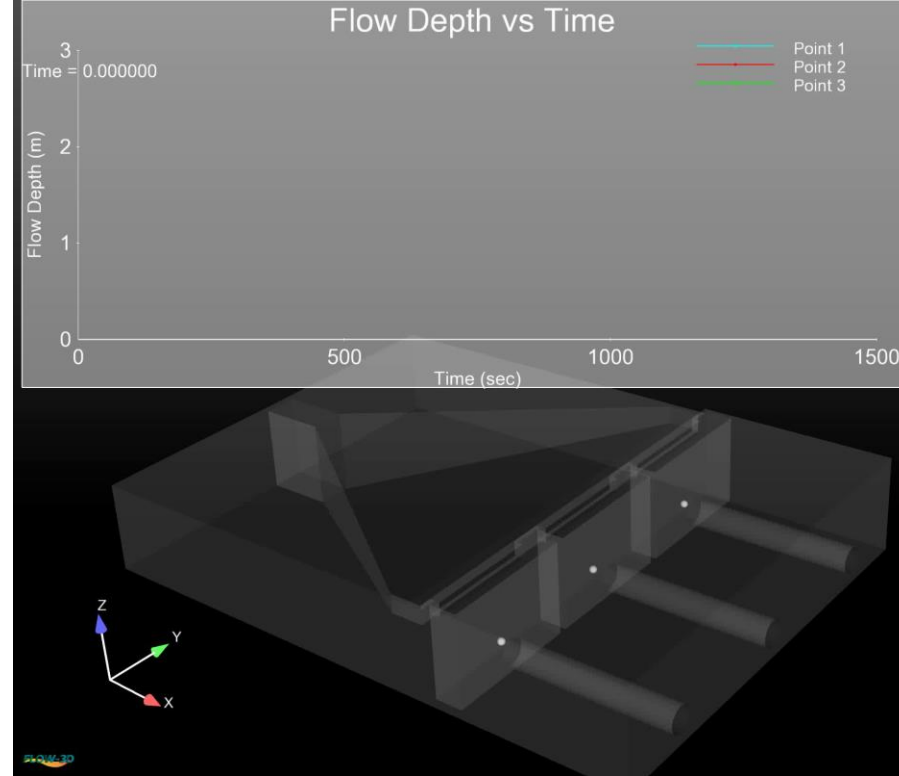
Şekil 2. Atıksu Dağıtım Yapısının 3D Modeli



Şekil 3. Dağıtım Yapısı Çıkışında Boruların Önündeki Su Seviyesi

# ARITMA TESİSİ UYGULAMALARI

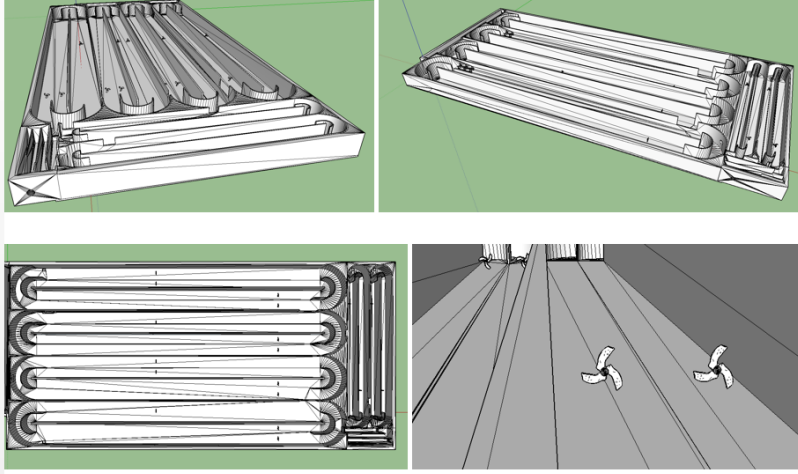
## Dağıtım Yapısı



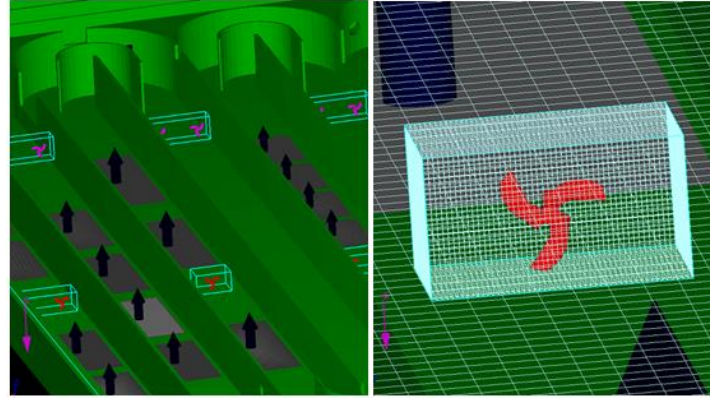
**Görüntü 1.** Dağıtım Yapısı – Akım Modellemesi

# ARITMA TESİSİ UYGULAMALARI

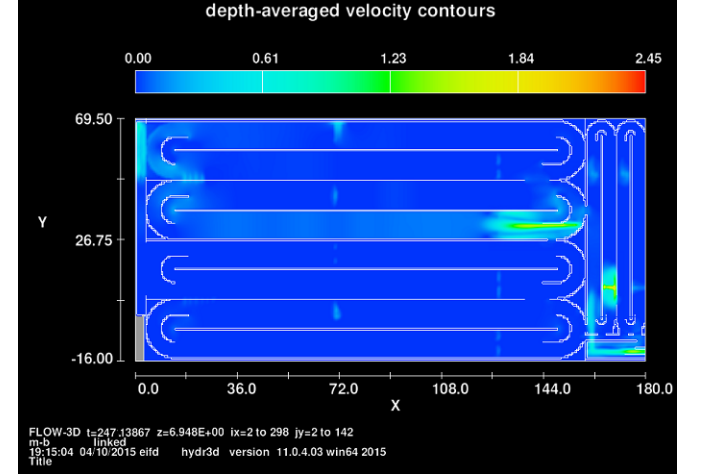
## Havalandırma Havuzu



**Şekil 4.** Havalandırma Havuzu ve Biyofosfor Havuzu 3D Model Çizimi



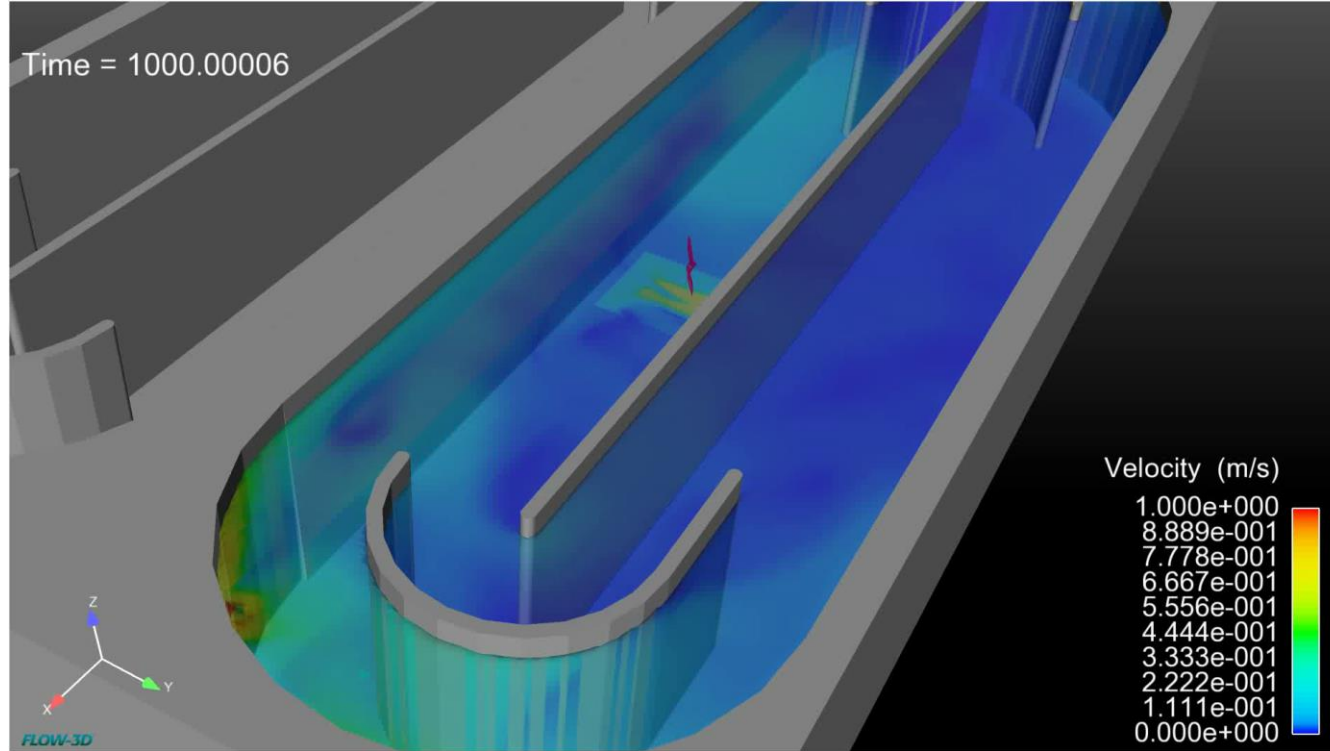
**Şekil 5.** Ağ Yapısı ve Modelleme Elemanları



**Şekil 6.** Havuzlardaki Hız Kontürleri - Derinlik Ortalamalı ( t=240 sn)

# ARITMA TESİSİ UYGULAMALARI

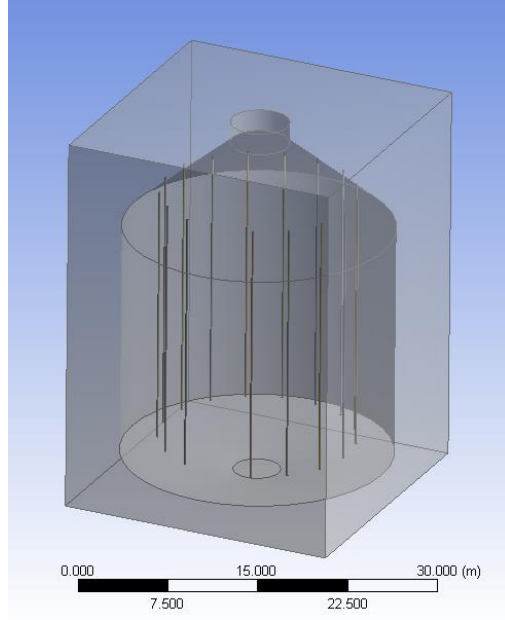
## Havalandırma Havuzu



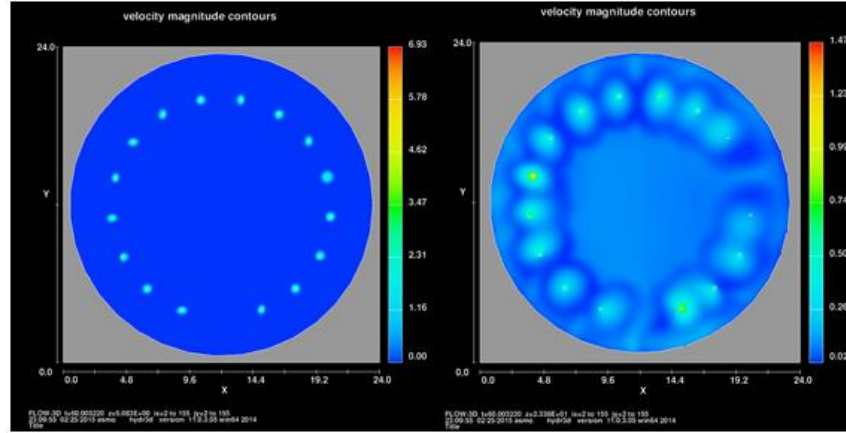
Görüntü 2. Havalandırma Havuzu

# ARITMA TESİSİ UYGULAMALARI

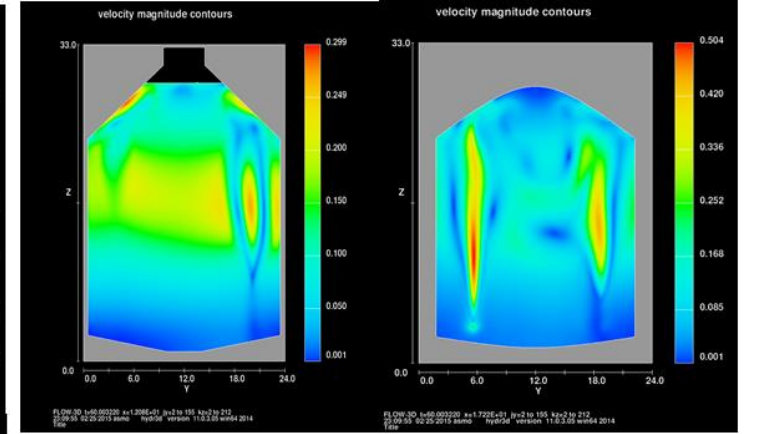
## Çamur Çürütücü



Şekil 7. Çamur Çürütücü Ünitesinin 3D Modeli



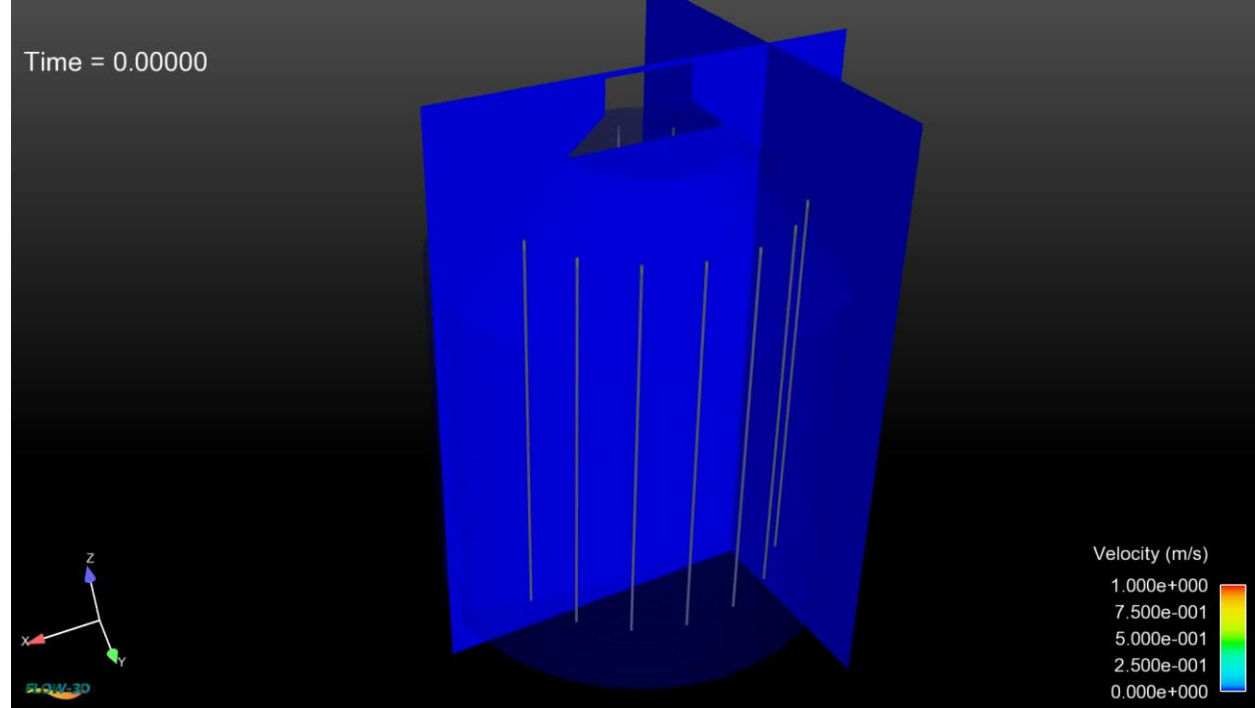
Şekil 8. Plan Kesitleri (Hız Dağılımı)



Şekil 9. Boy Kesitler (Hız Dağılımı)

# ARITMA TESİSİ UYGULAMALARI

## Çamur Çürütücü

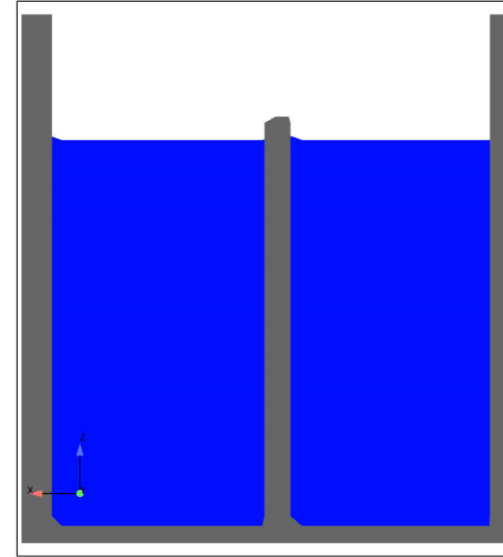
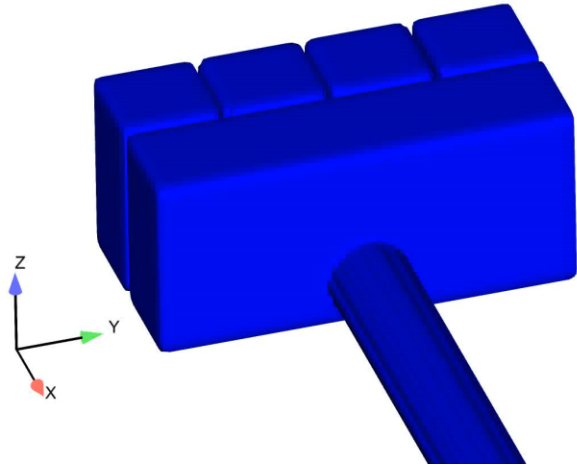
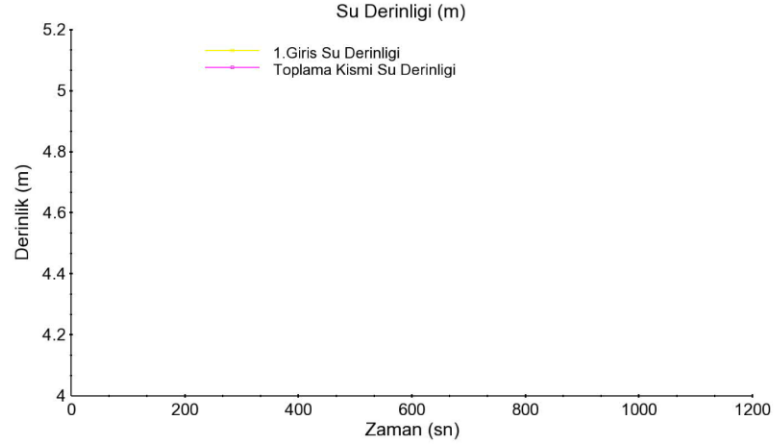


**Görüntü 3.** Çamur Çürütücü Hız Dağılımı



# ARITMA TESİSİ UYGULAMALARI

## Dağıtım Yapısı



Akim Hızı (m/s)

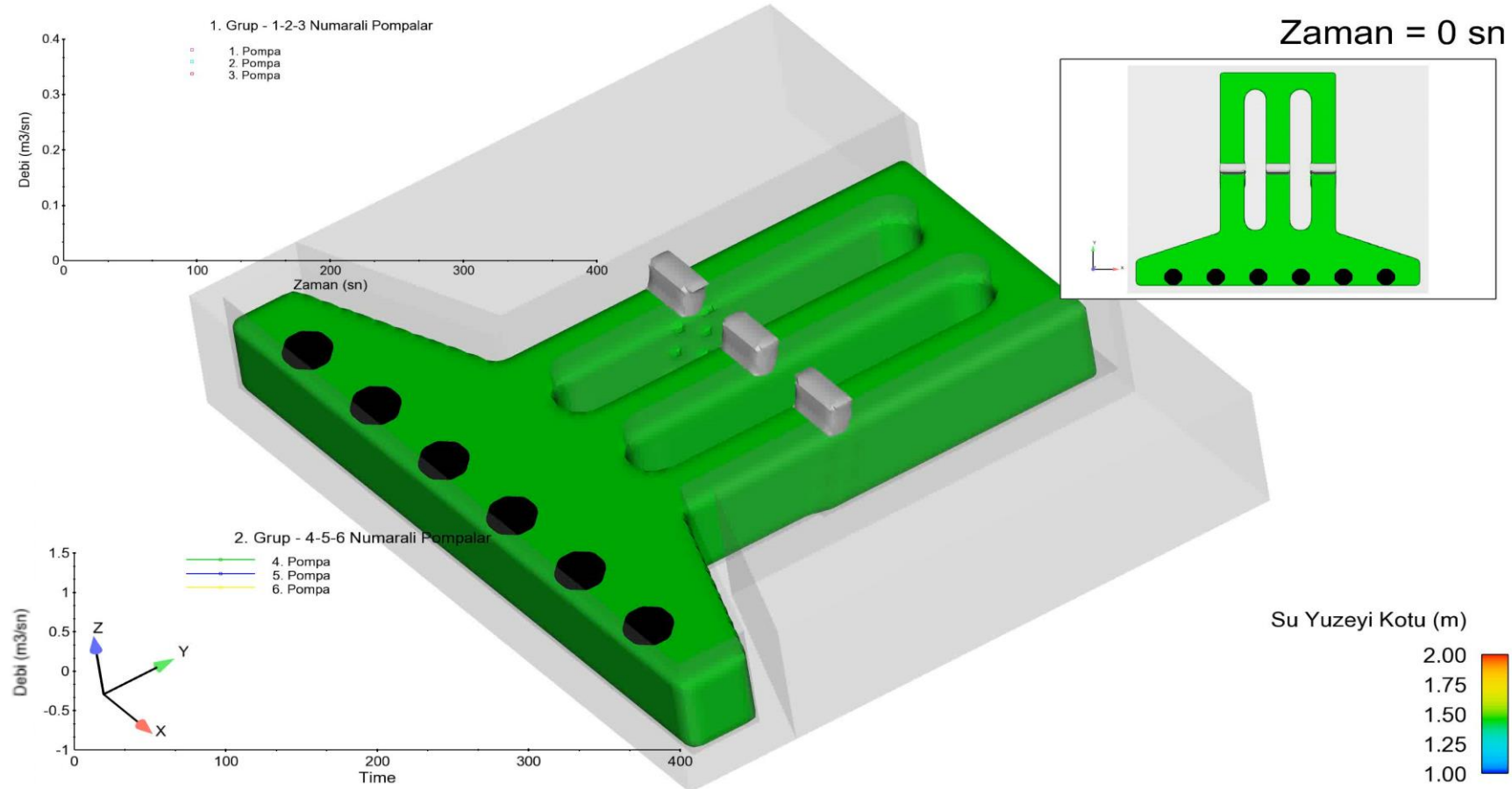


Zaman = 0 sn

Görüntü 4. Dağıtım Yapısı

# ARITMA TESİSİ UYGULAMALARI

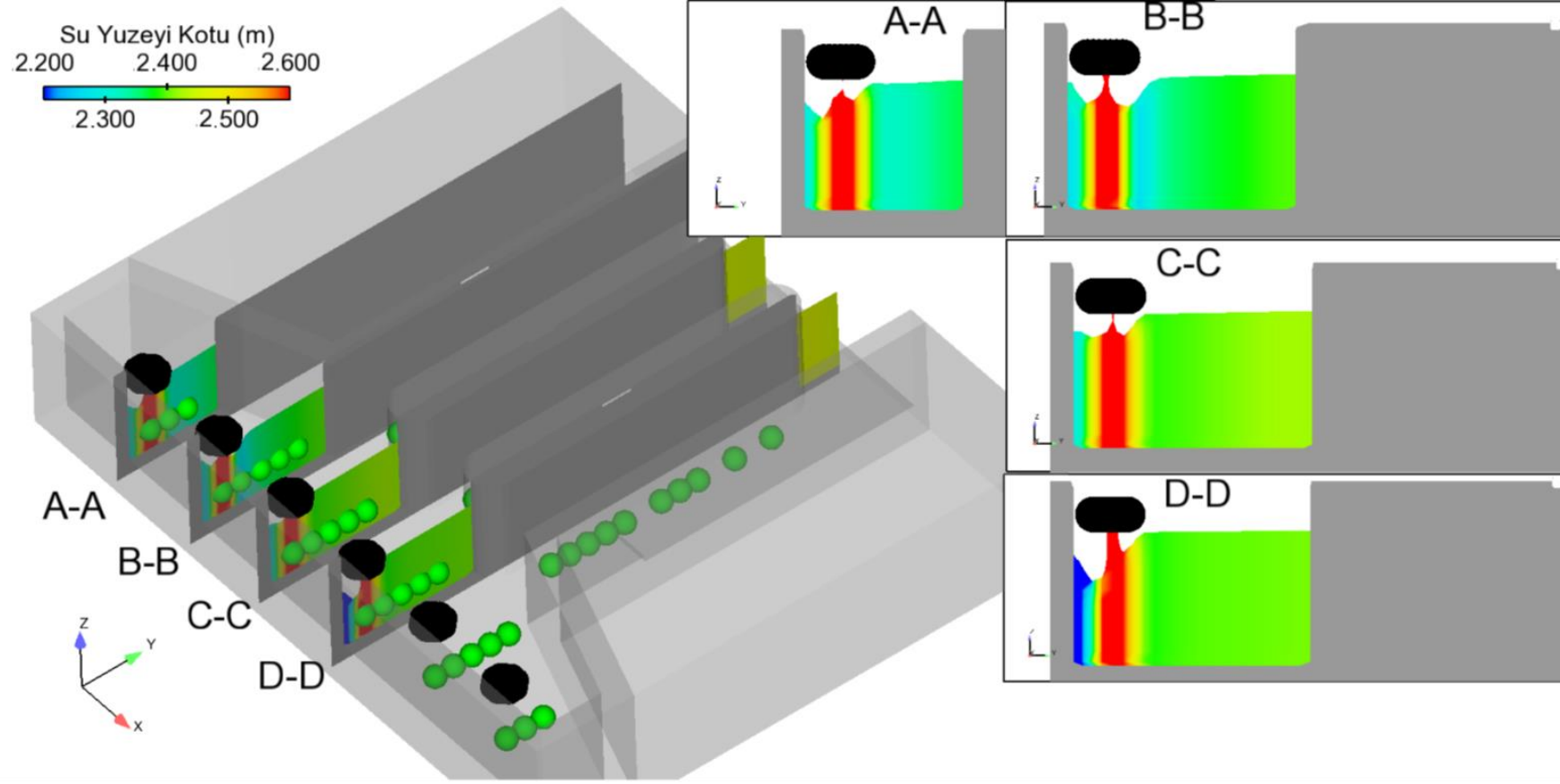
## Dağıtım Yapısı



Görüntü 5. Terfi + Izgara Kanalı

# ARITMA TESİSİ UYGULAMALARI

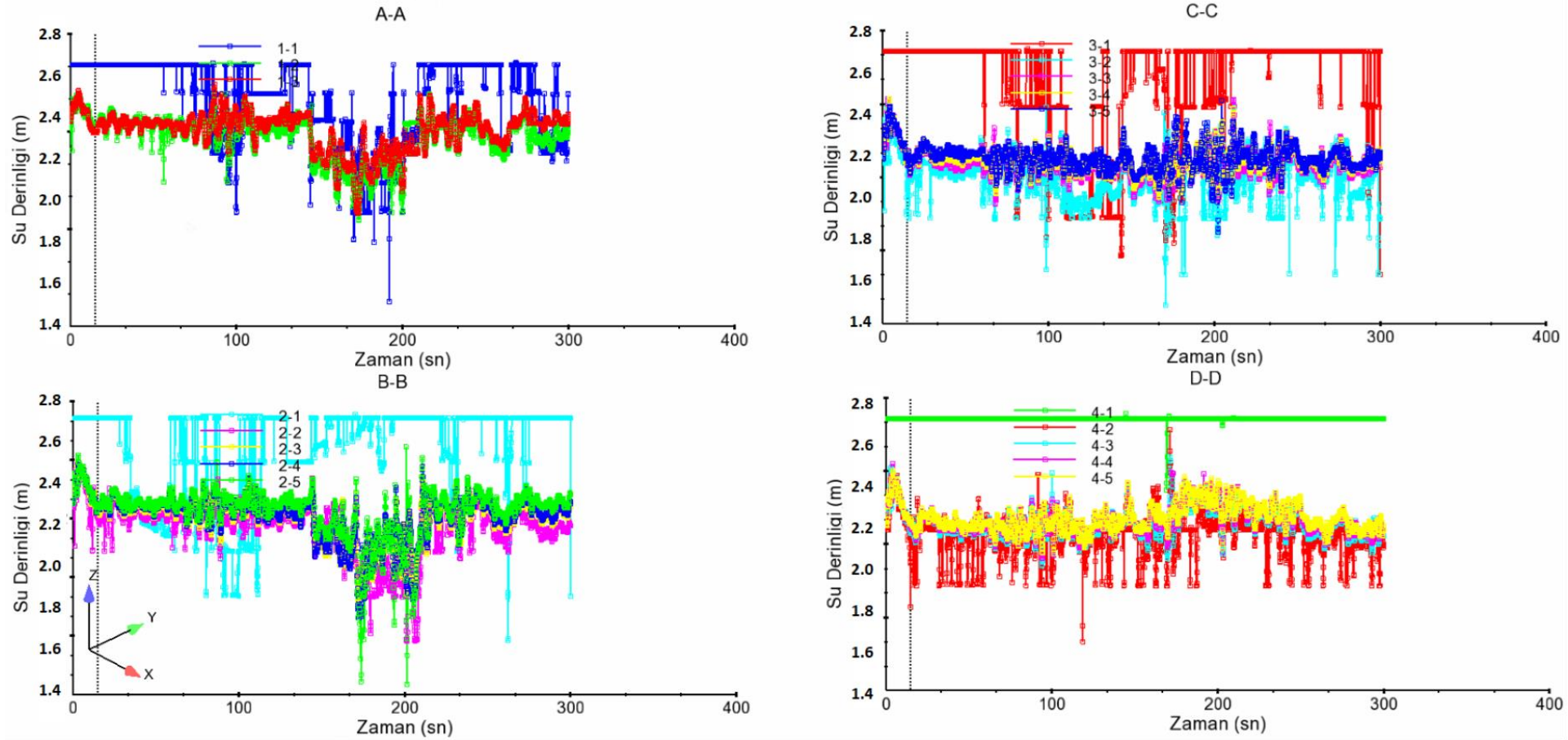
## Dağıtım Yapısı



Şekil 10. İzleme Noktaları

# ARITMA TESİSİ UYGULAMALARI

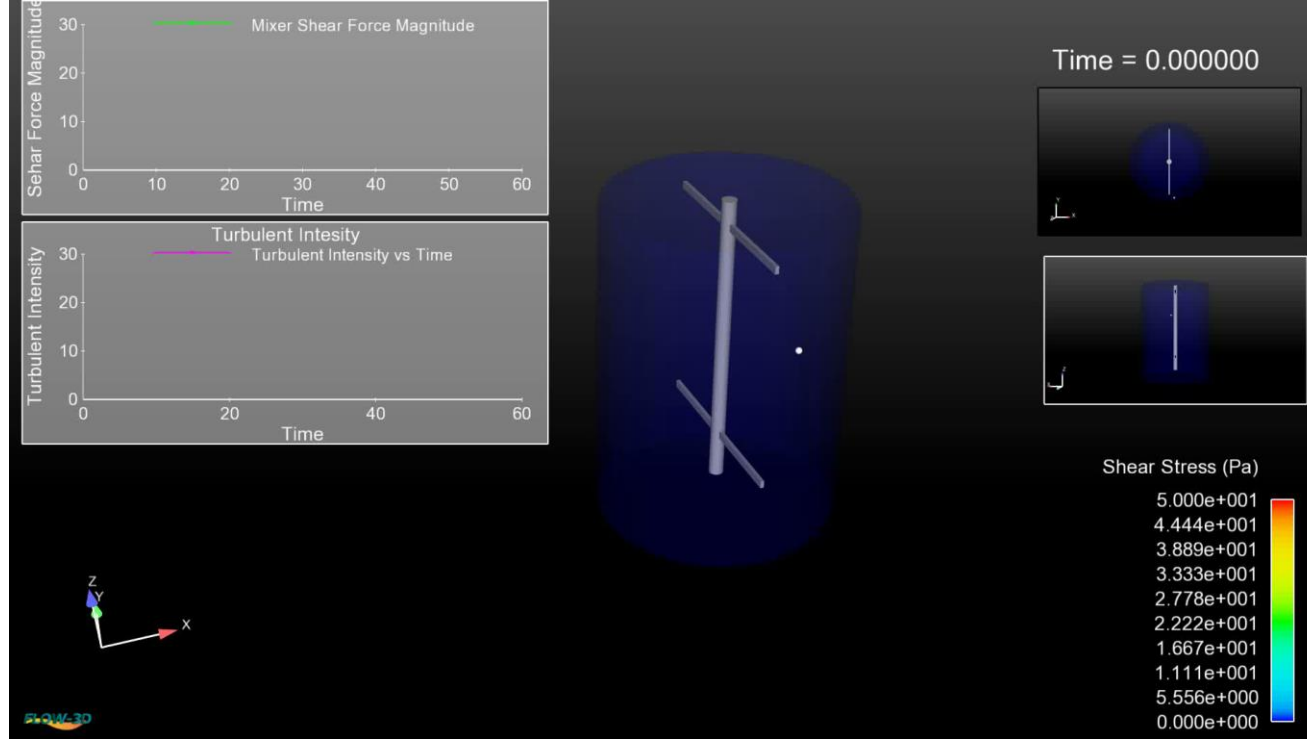
## Dağıtım Yapısı



Şekil 11. İzleme Noktalarındaki Su Derinliği (sn - m)

# ARITMA TESİSİ UYGULAMALARI

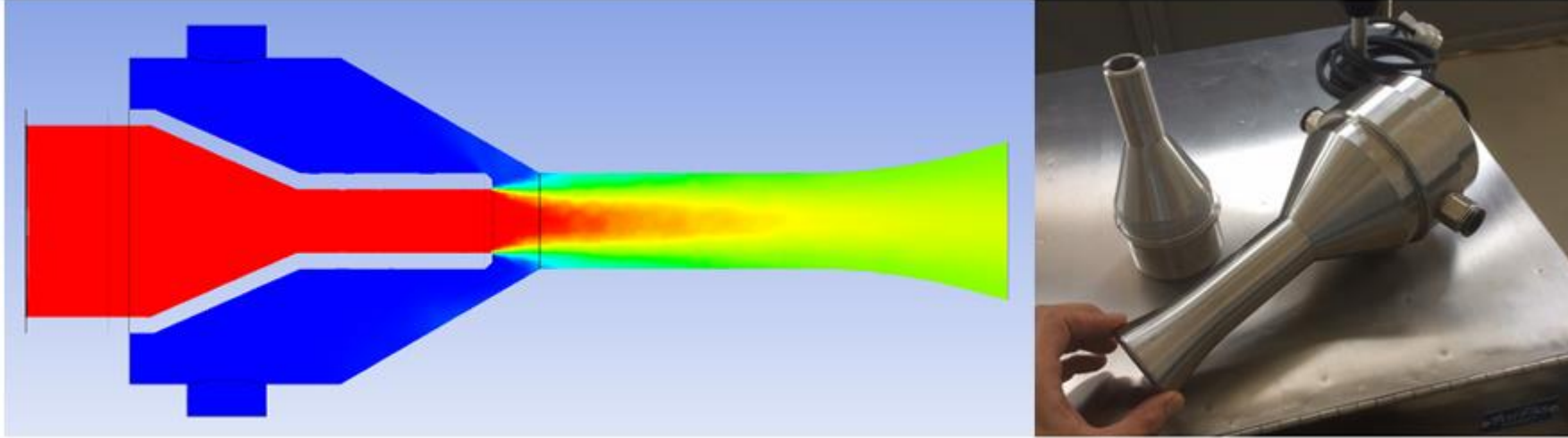
## 3. Diğer Çalışmalar – Karıştırıcı Performansı



Görüntü 6. Karıştırıcı Modellemesi

# ARITMA TESİSİ UYGULAMALARI

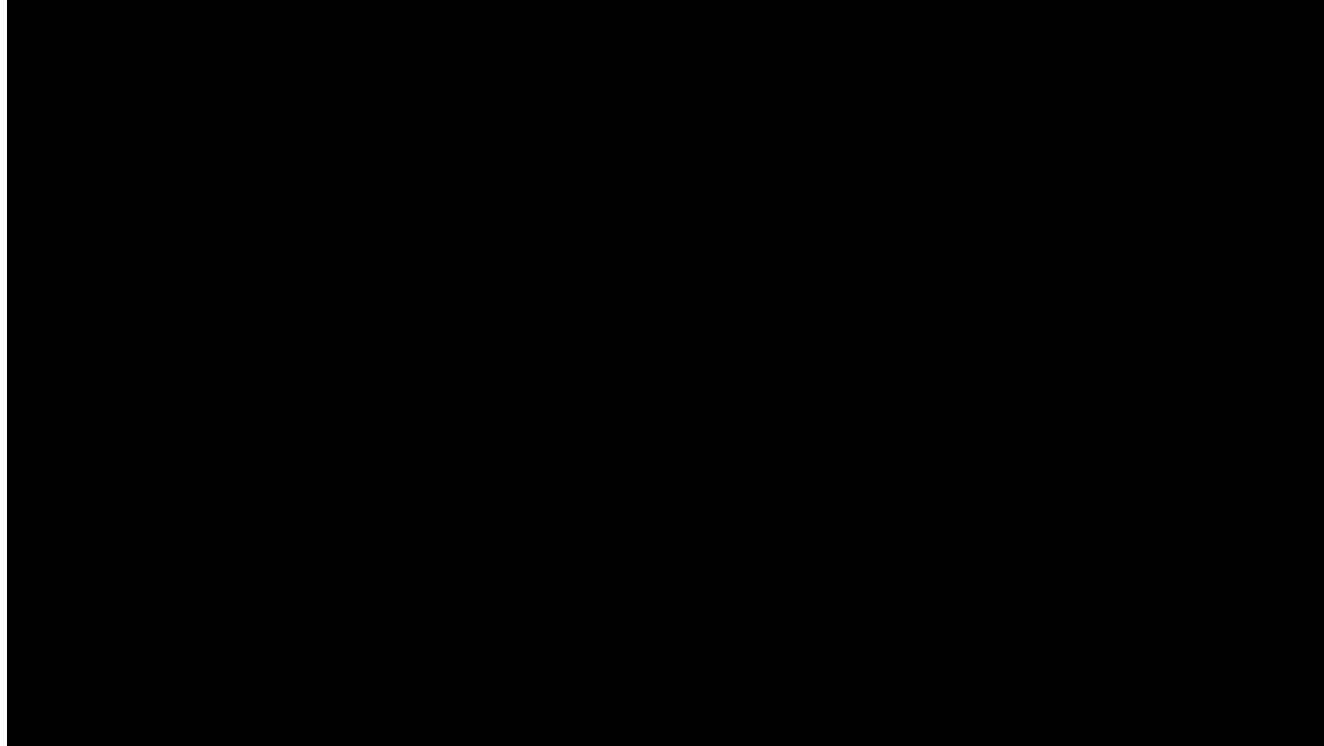
## 4. Diğer Çalışmalar – MBR Hidrojektör Nozülü Geliştirilmesi



Şekil 12. Hidrojektör Nozülü CFD Analizi

# TERMAL SEYRELME UYGULAMALARI

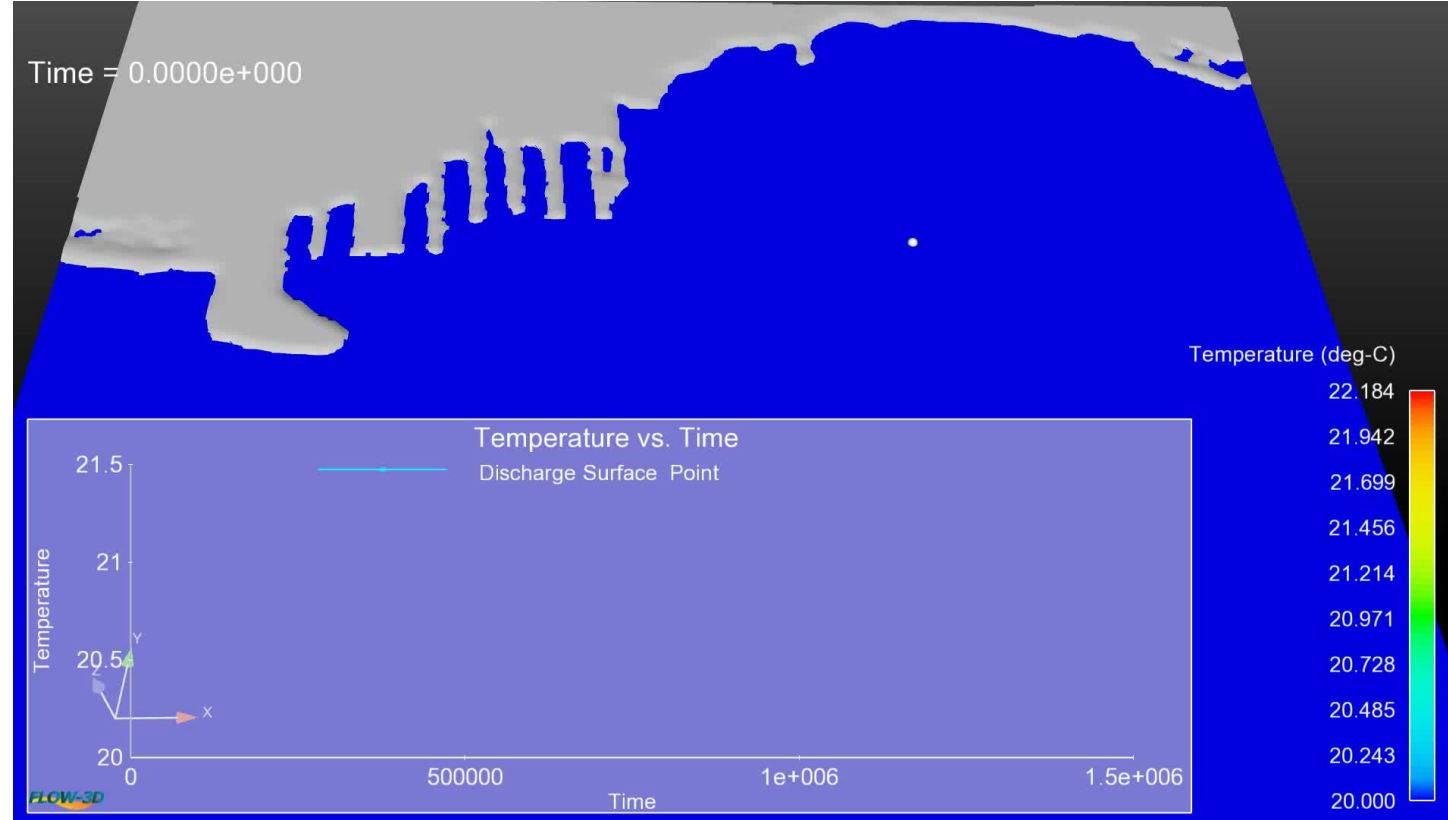
Termal Deřarj Modellemesi - 1



**Görüntü 7.** Termal Deřarj Seyrelme Analizi - Dere

# TERMAL SEYRELME UYGULAMALARI

## Termal Deşarj Modellemesi - 2

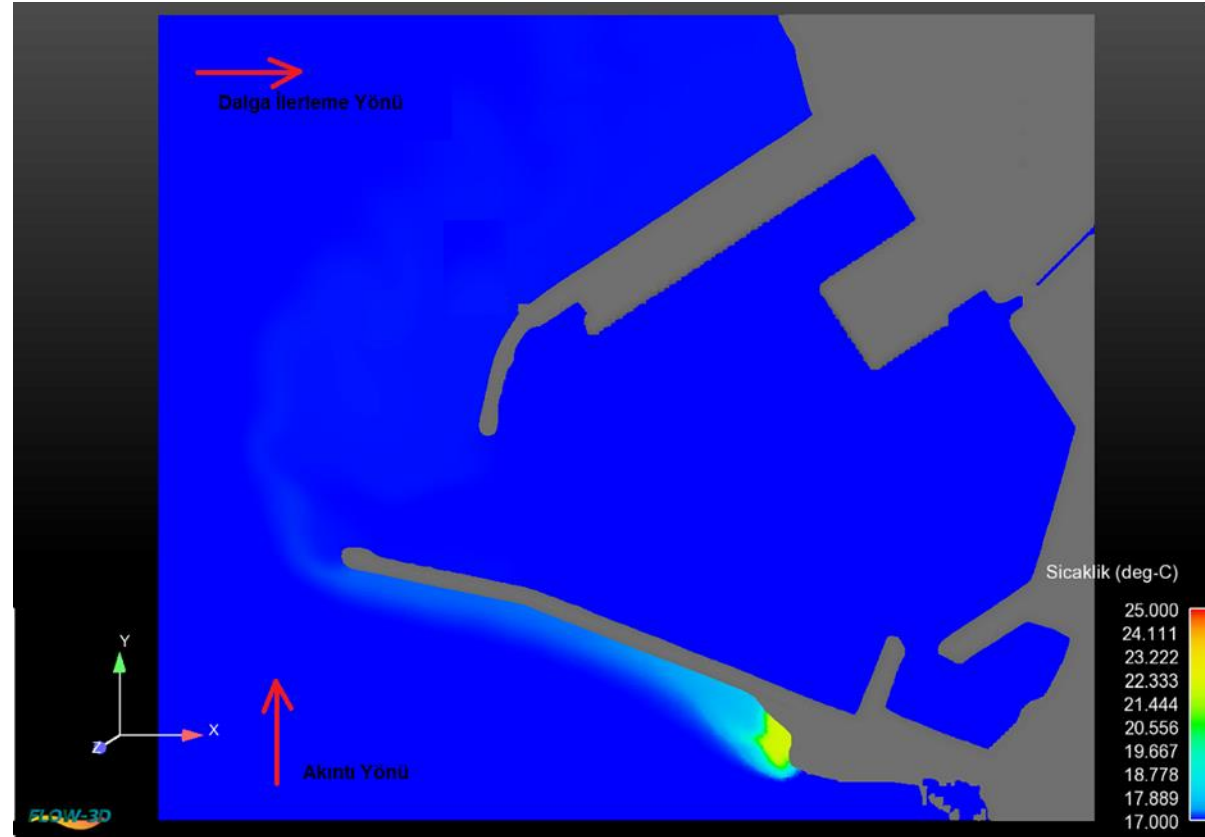


**Görüntü 8.** Termal Deşarj Seyrelme Analizi - Deniz



# TERMAL SEYRELME UYGULAMALARI

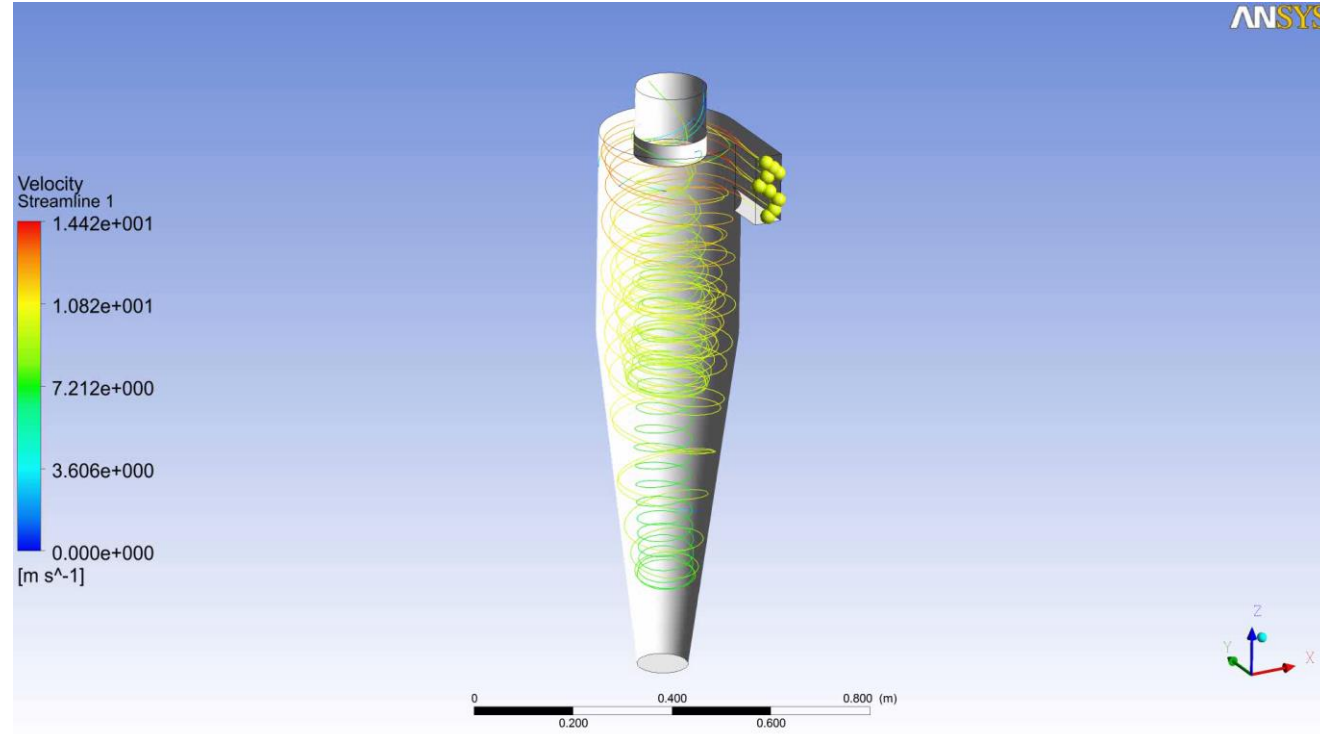
## Termal Deşarj Modellemesi - 3



Şekil 12. Termal Deşarj Seyrelme Analizi - Deniz

# HAVA KİRLİLİĞİ KONTROL EKİPMANI

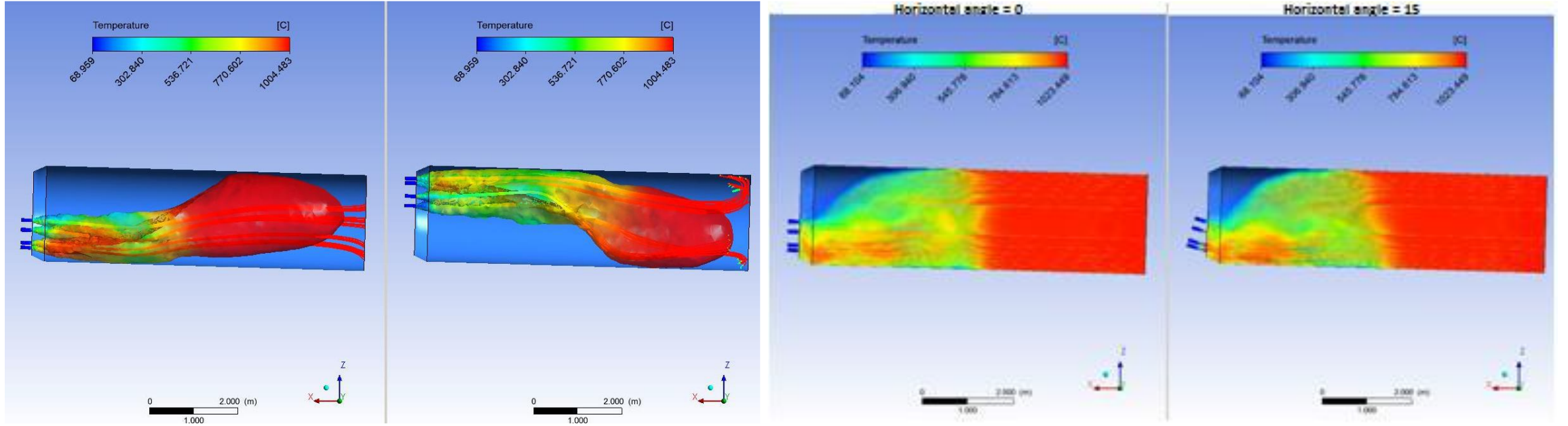
## Siklon Modellemesi



Görüntü 9. Siklon Modellemesi

# YANMA MODELLEMESİ

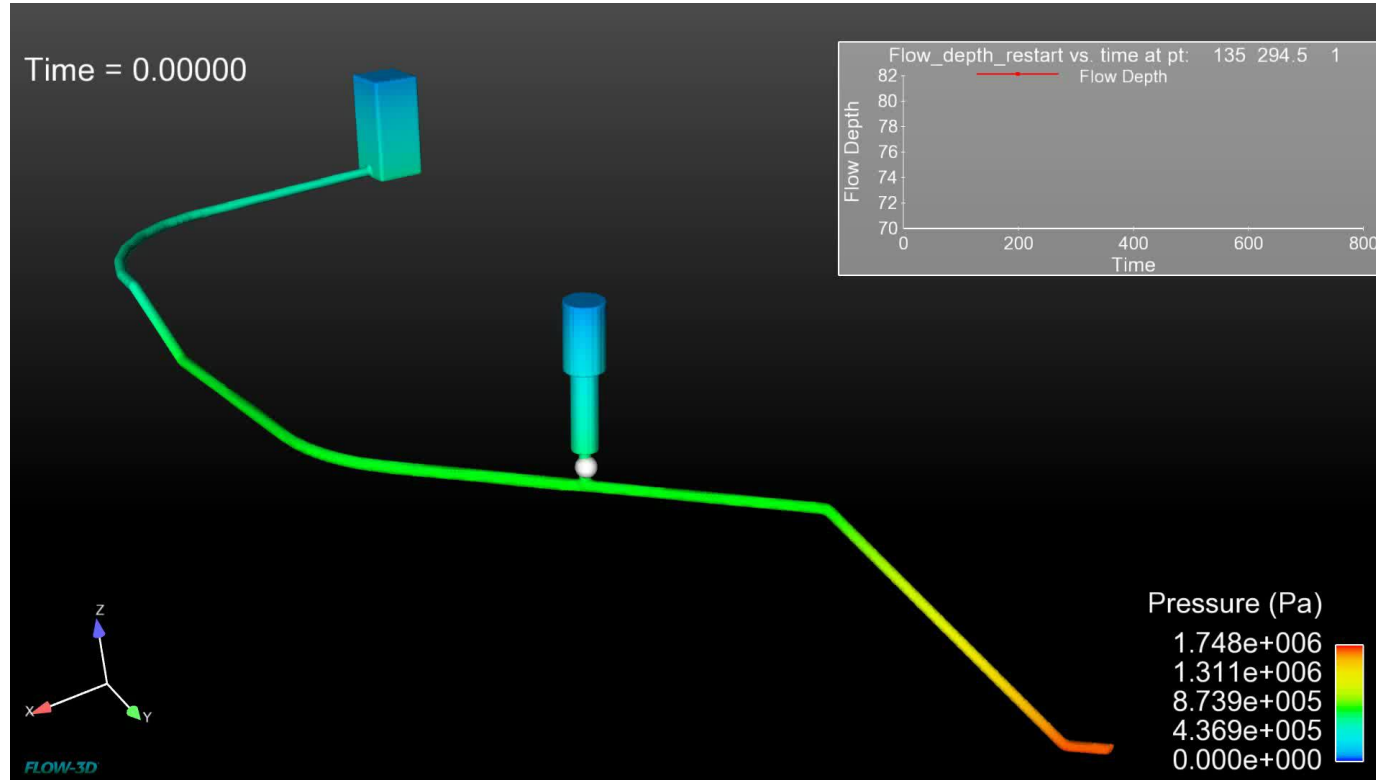
## Döner Fırın Modellemesi



Şekil 13. Döner Fırın Yanma Modellemesi

# BARAJ ÜNİTELERİ

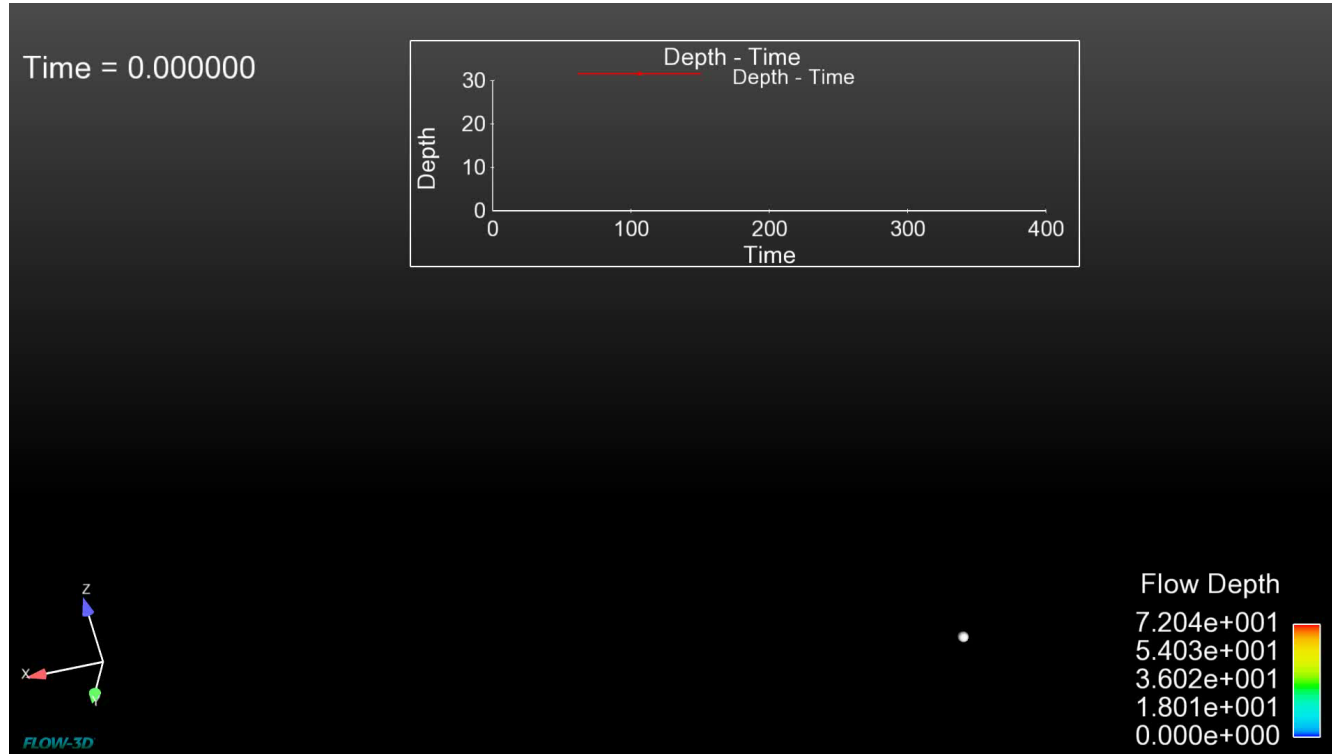
## Denge Bacası Modellemesi



Görüntü 10. Denge Bacası Modellemesi

# BARAJ ÜNİTELERİ

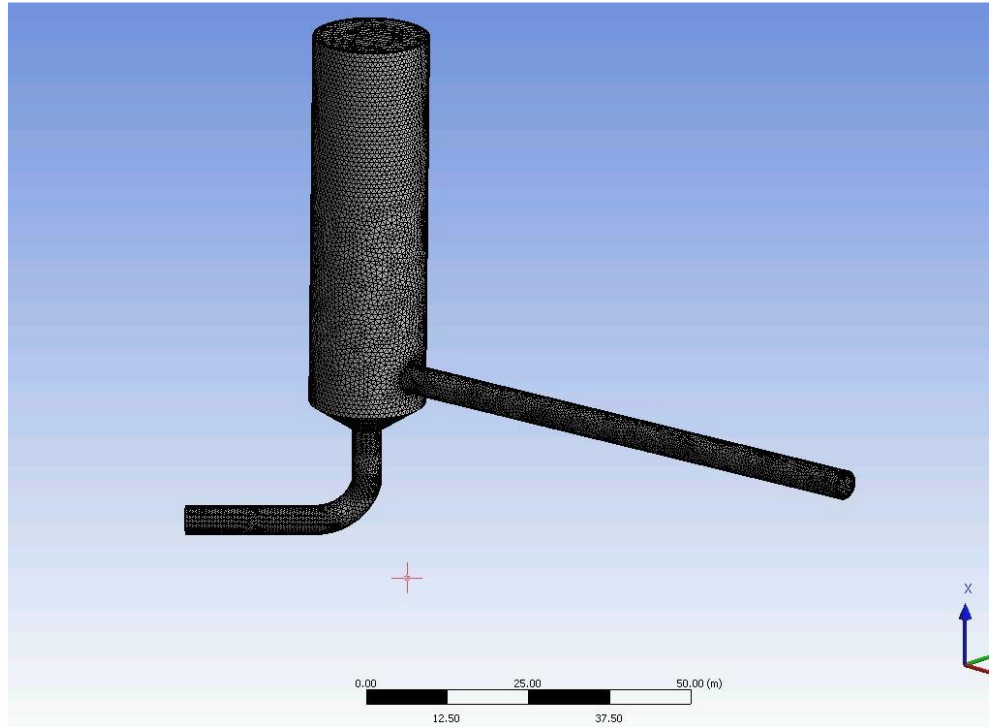
## Dolu Savak ve Sıçrama Havuzu Modellemesi



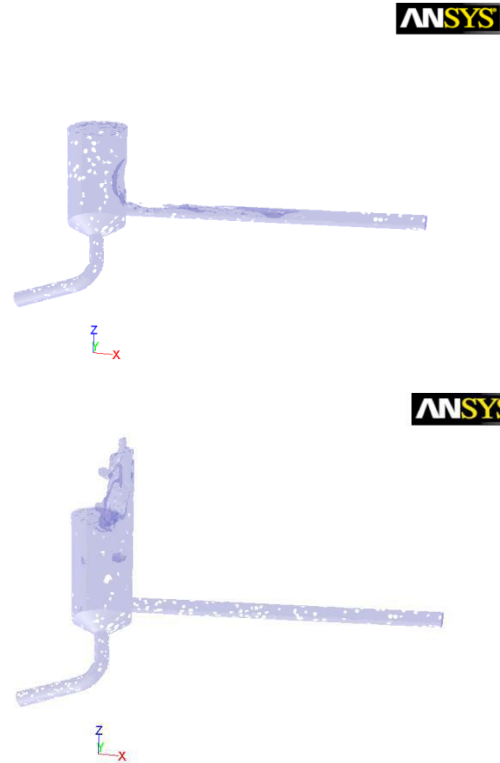
Görüntü 10. Dolu Savak ve Sıçrama Havuzu Modellemesi

# BARAJ ÜNİTELERİ

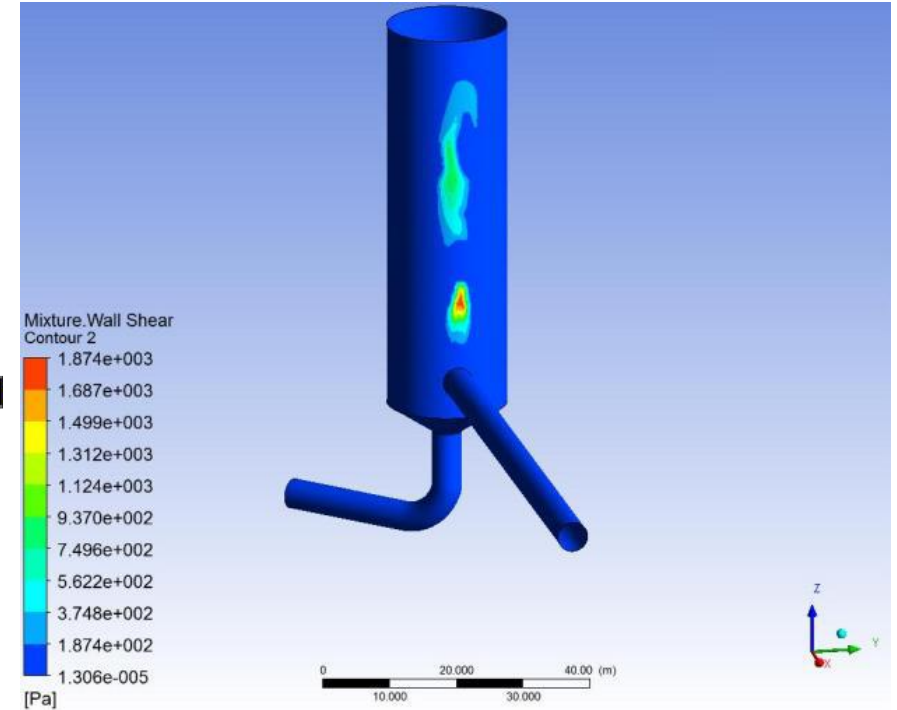
## Denge Bacası Dinamik Performans Analizi



Mesh (Time=1.3705e+03)



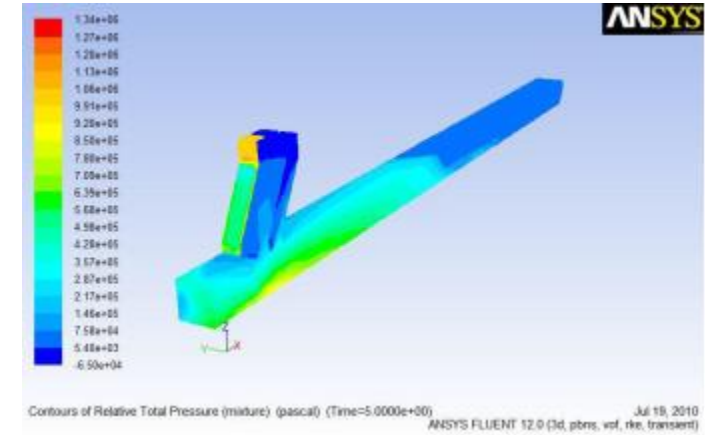
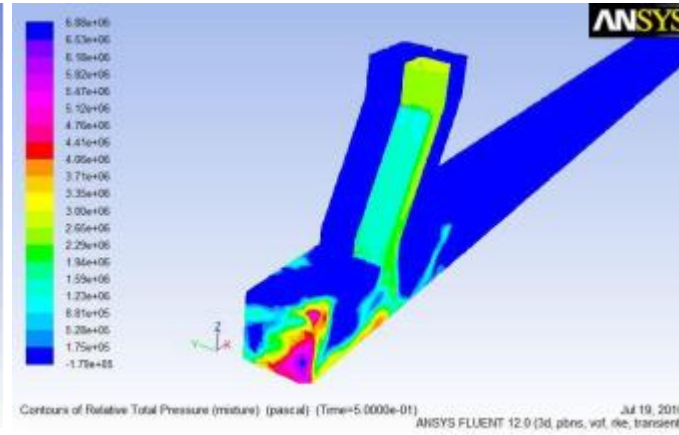
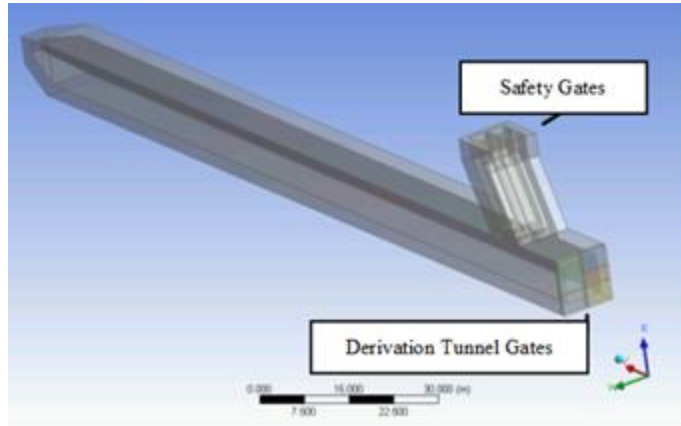
May 04, 2011  
ANSYS FLUENT 12.0 (3d, pbn, vof, rke, transient)



Şekil 14. Denge Bacası

# BARAJ ÜNİTELERİ

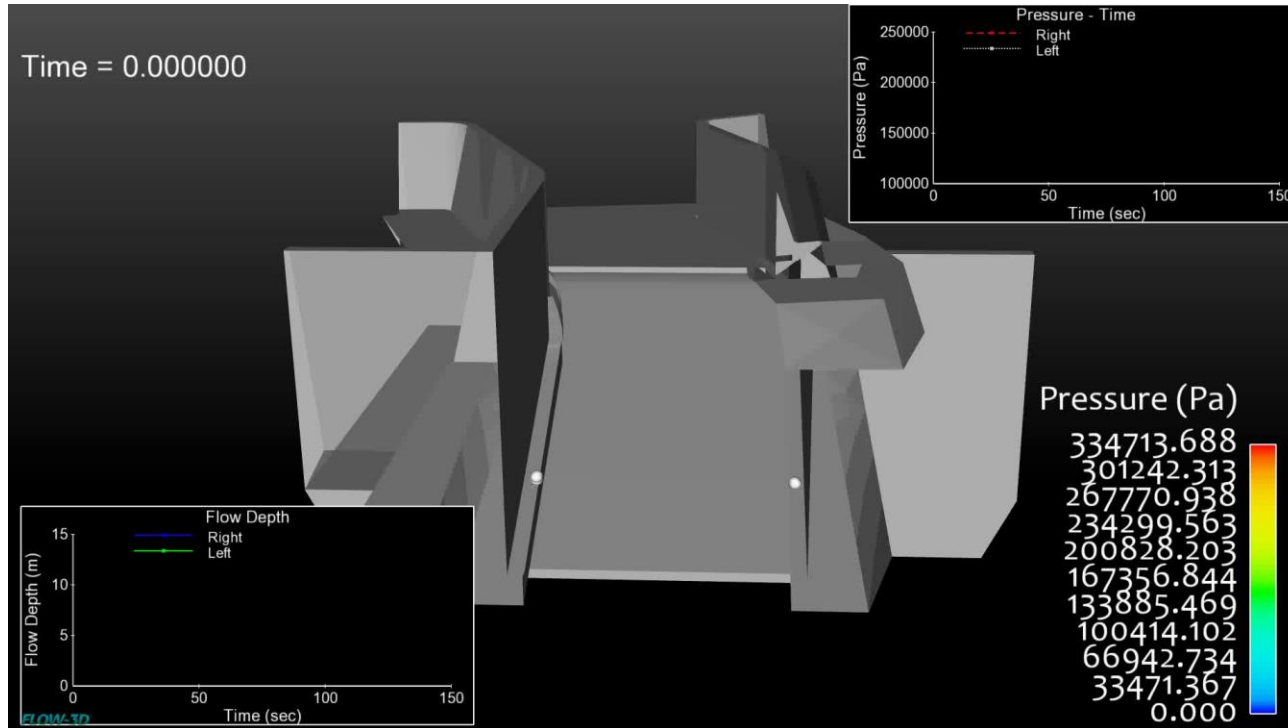
## Dip Savak Kontrolsüz Boşalma Modellemesi



Şekil 15. Dip Savak Tüneli

# BARAJ ÜNİTELERİ

## Kuyruksuyu Çıkışı Modellemesi

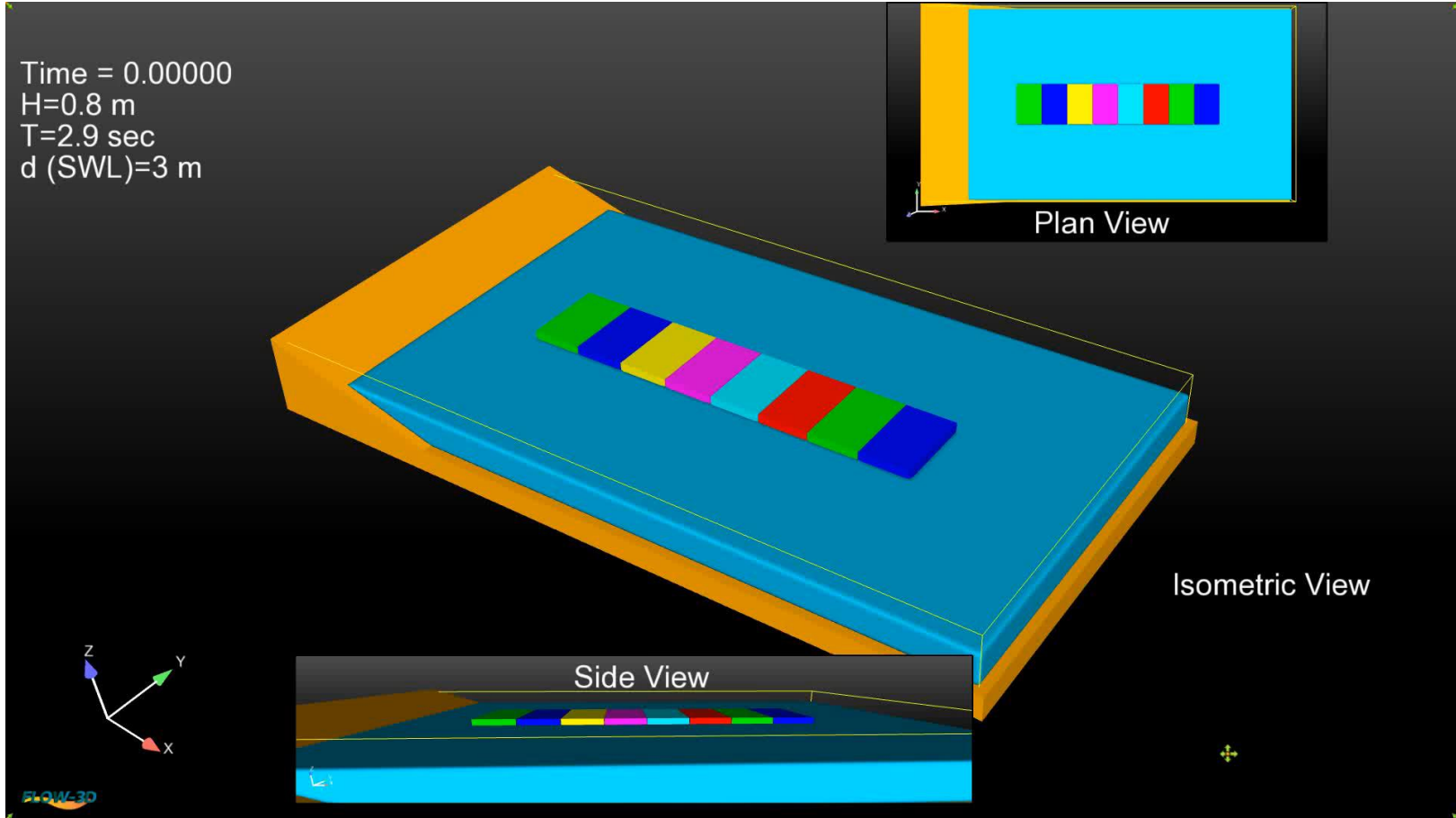


Görüntü 10. Kuyruksuyu Çıkışı



# KIYI YAPILARI

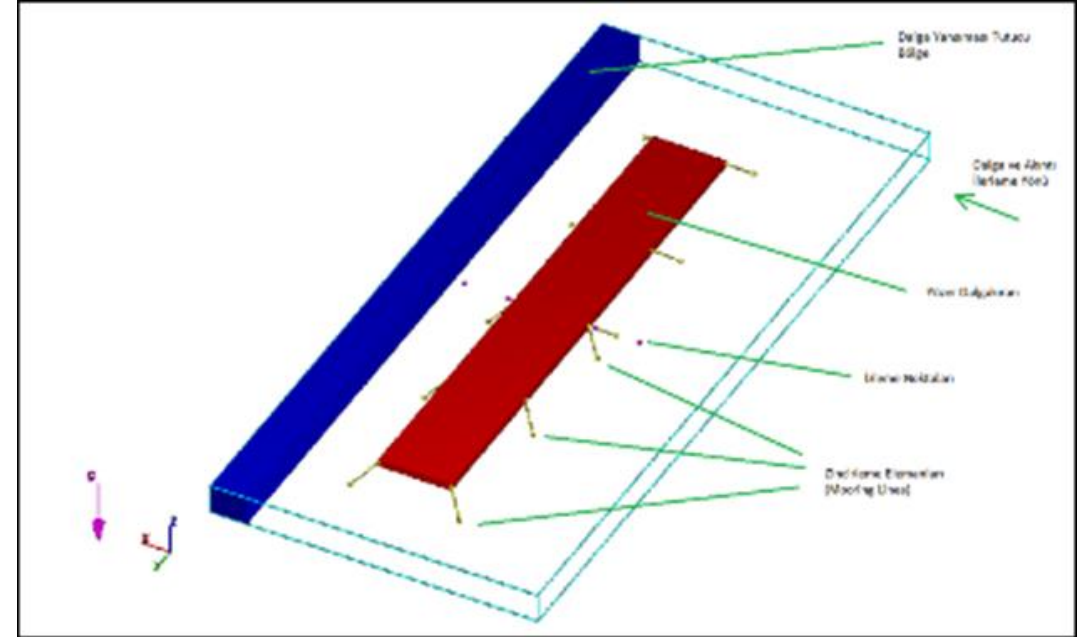
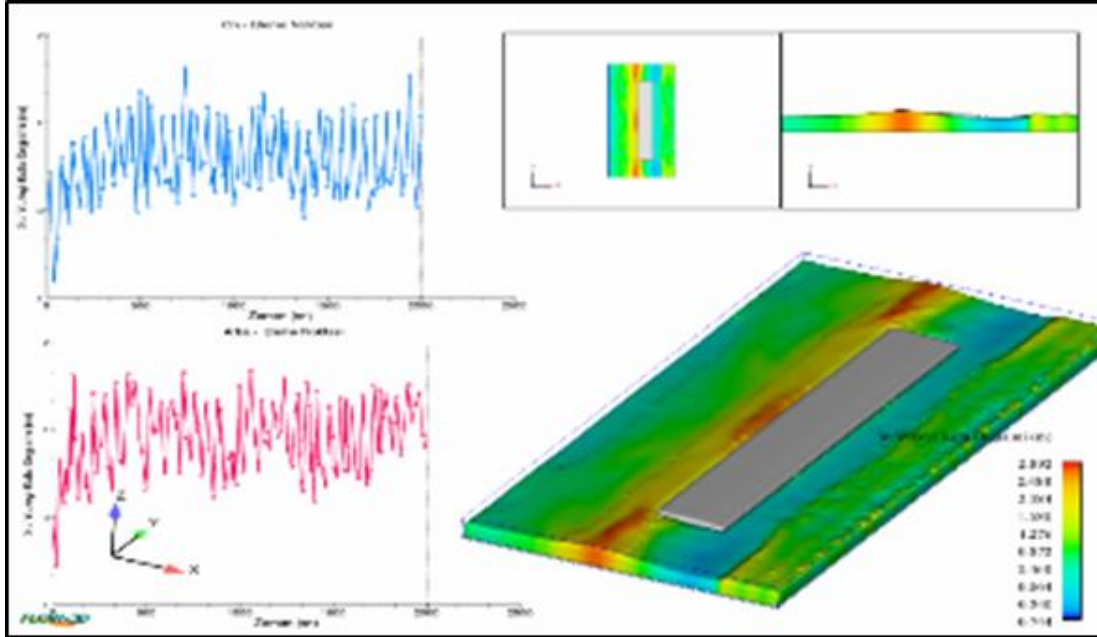
## Yüzer İskele



Görüntü 11. Yüzer İskele

# KIYI YAPILARI

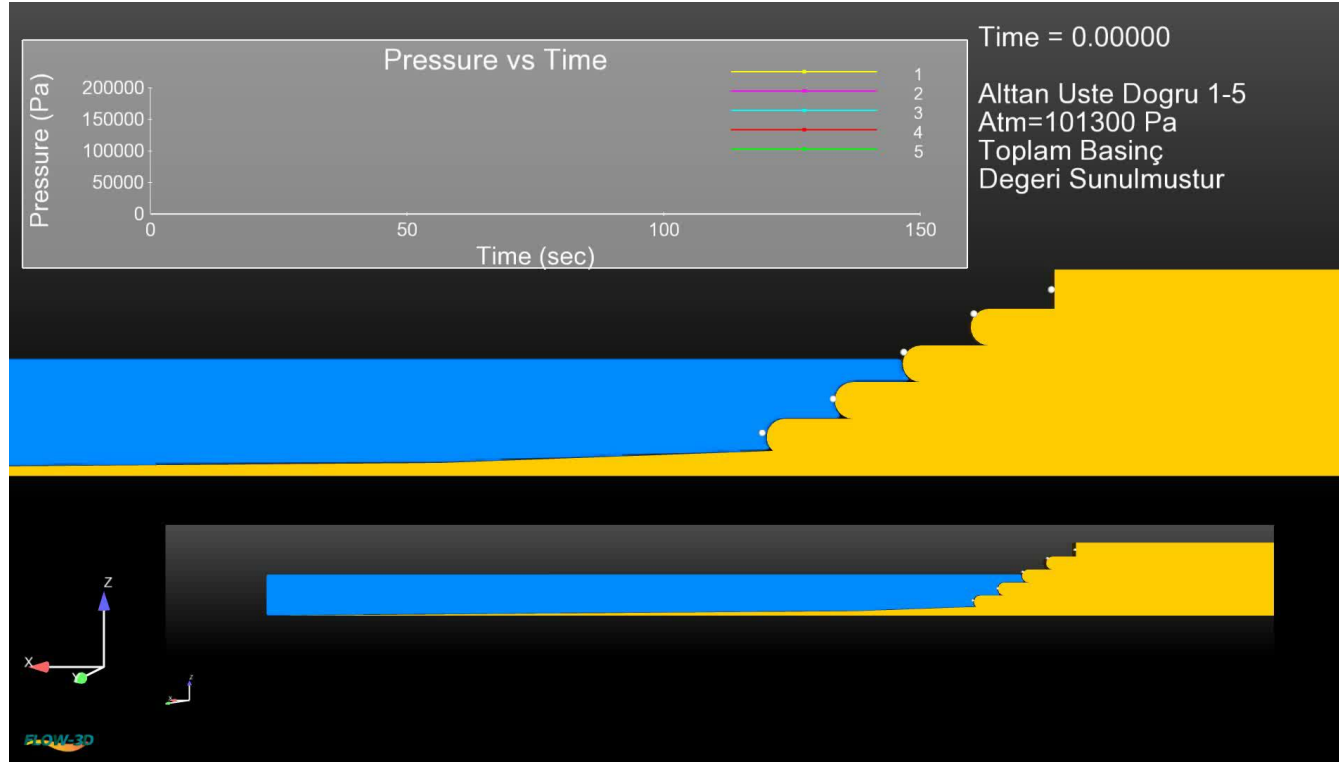
## Yüzer İskele



Görüntü 11. Yüzer İskele

# KIYI YAPILARI

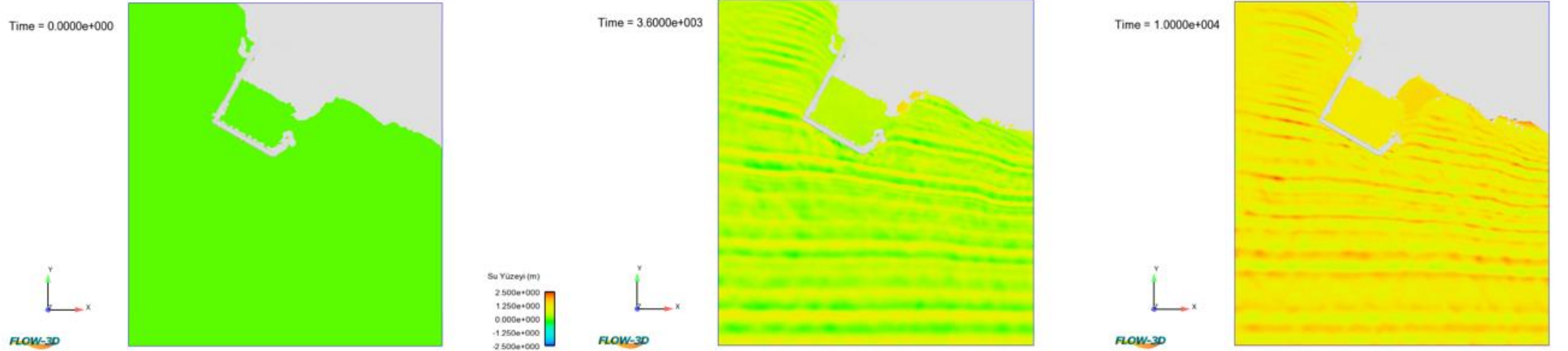
## Kıyı Dolgusu



Görüntü 12. Dolgu Mukavemeti

# KIYI YAPILARI

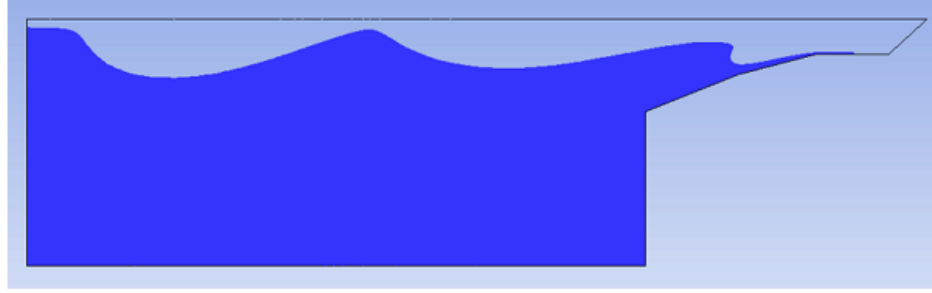
Fırtına



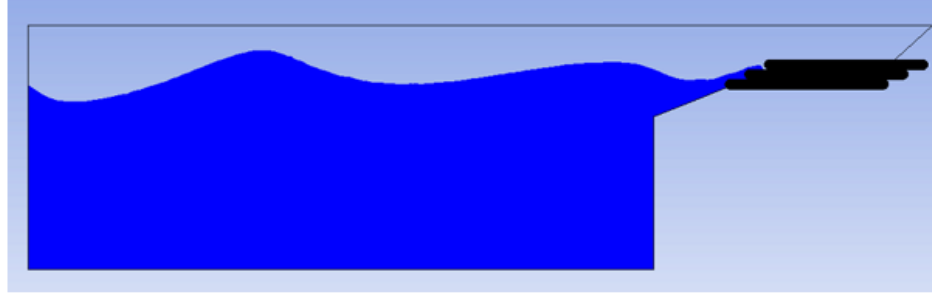
Şekil 15. Dalga Tırmanması

# KIYI YAPILARI

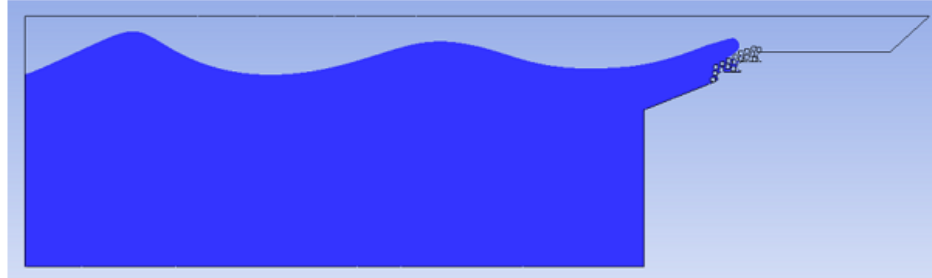
Fırtına



Şekil 4. Korumasız Durum Dalga Tırmanması



Şekil 5. Korumasız Durum Dalga Tırmanması

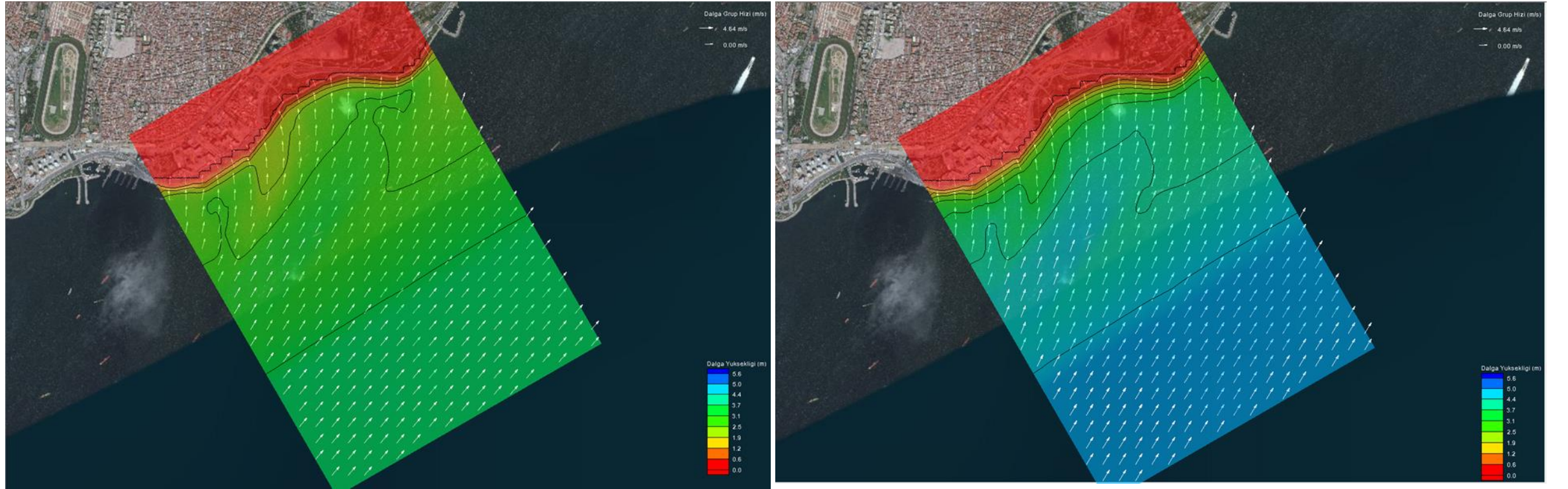


Şekil 6. Geotube ve Koruma Tabakası Yerleştirilmesi Durumunda Dalga Tırmanması

**Şekil 15.** Dalga Tırmanması

# KIYI YAPILARI

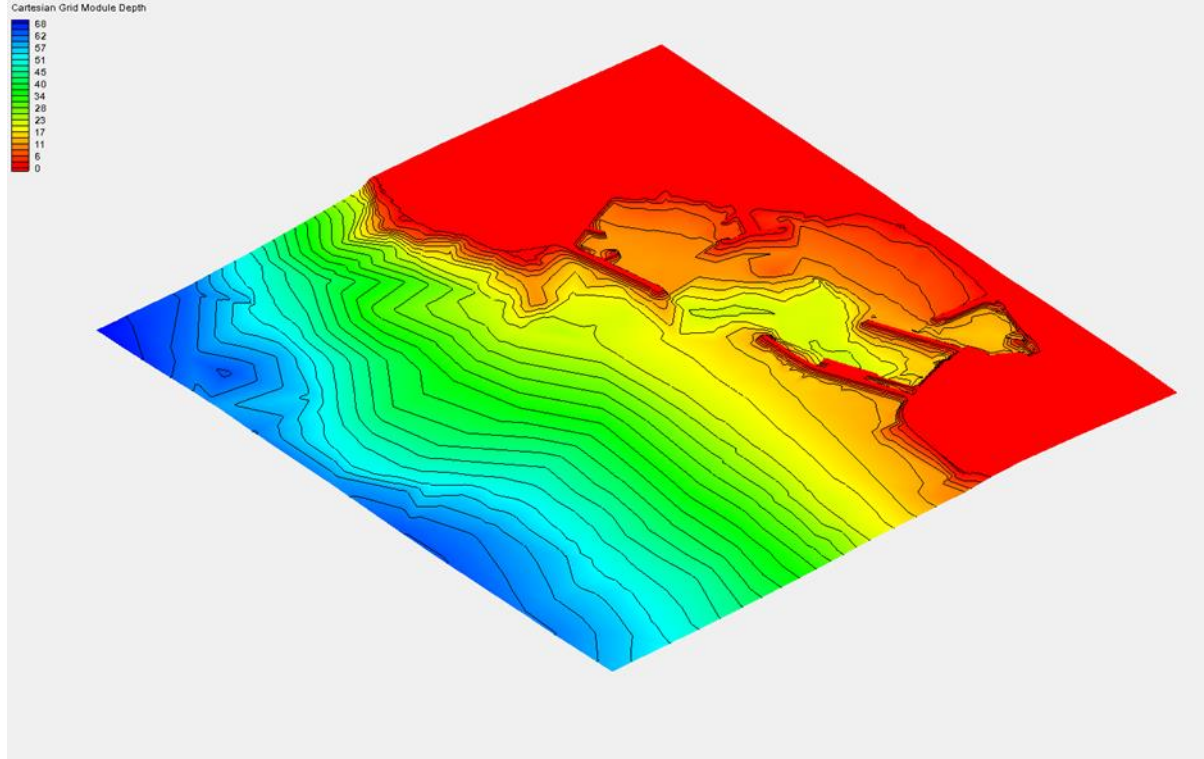
## Dalga Transformasyonu



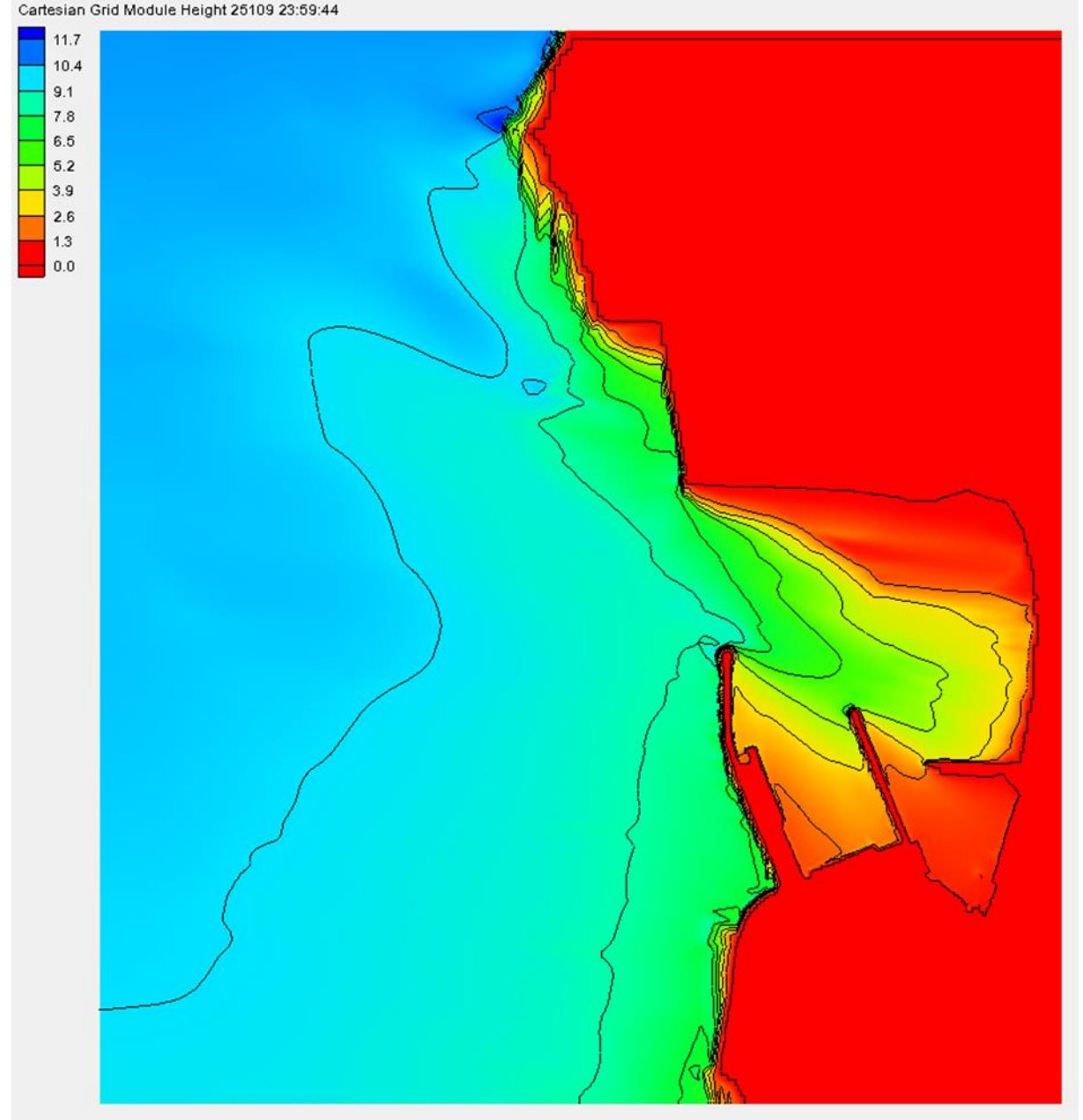
Şekil 16. Dalga Transformasyonu

# KIYI YAPILARI

## Dalga Transformasyonu

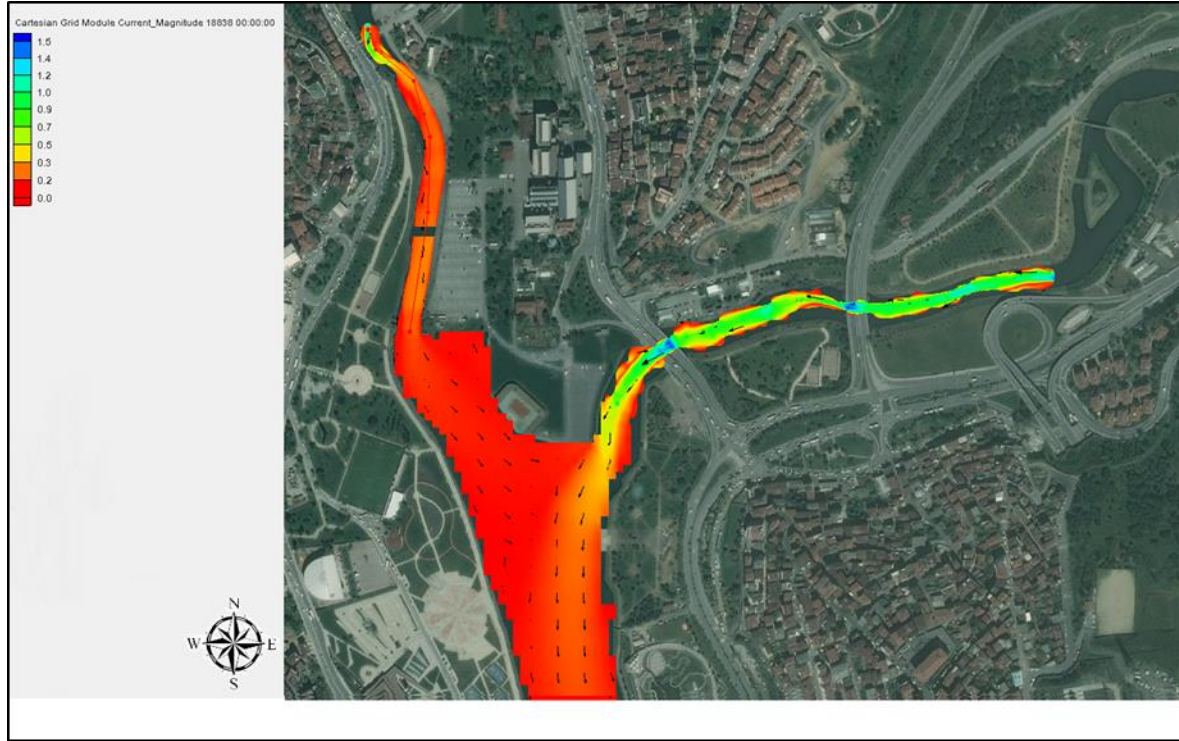


Şekil 17. Dalga Transformasyonu



# KIYI MODELLEMESİ

Haliç

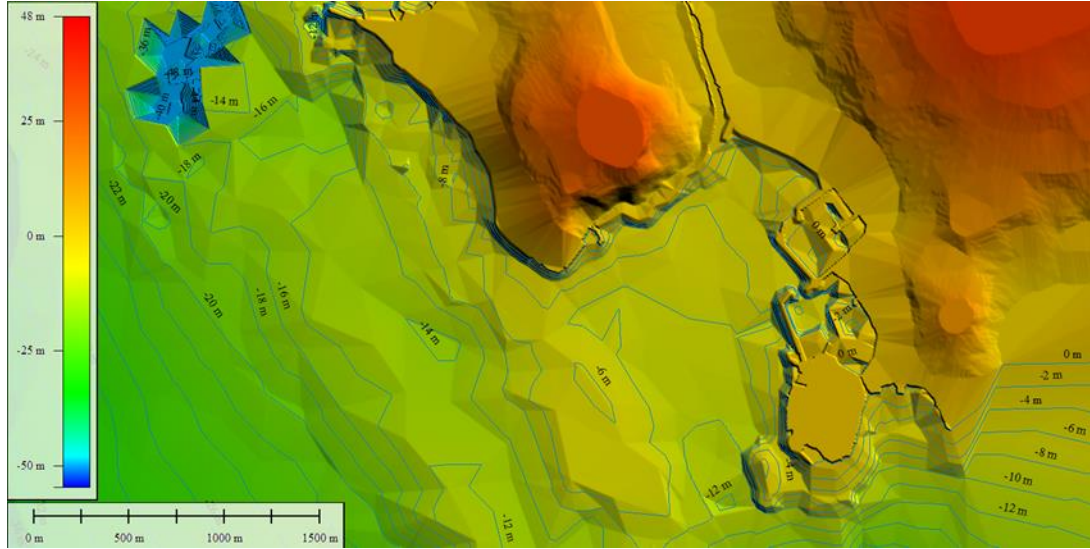


Şekil 18. Haliç Birleşimi Modeli (Kağıthane – Alibeyköy)

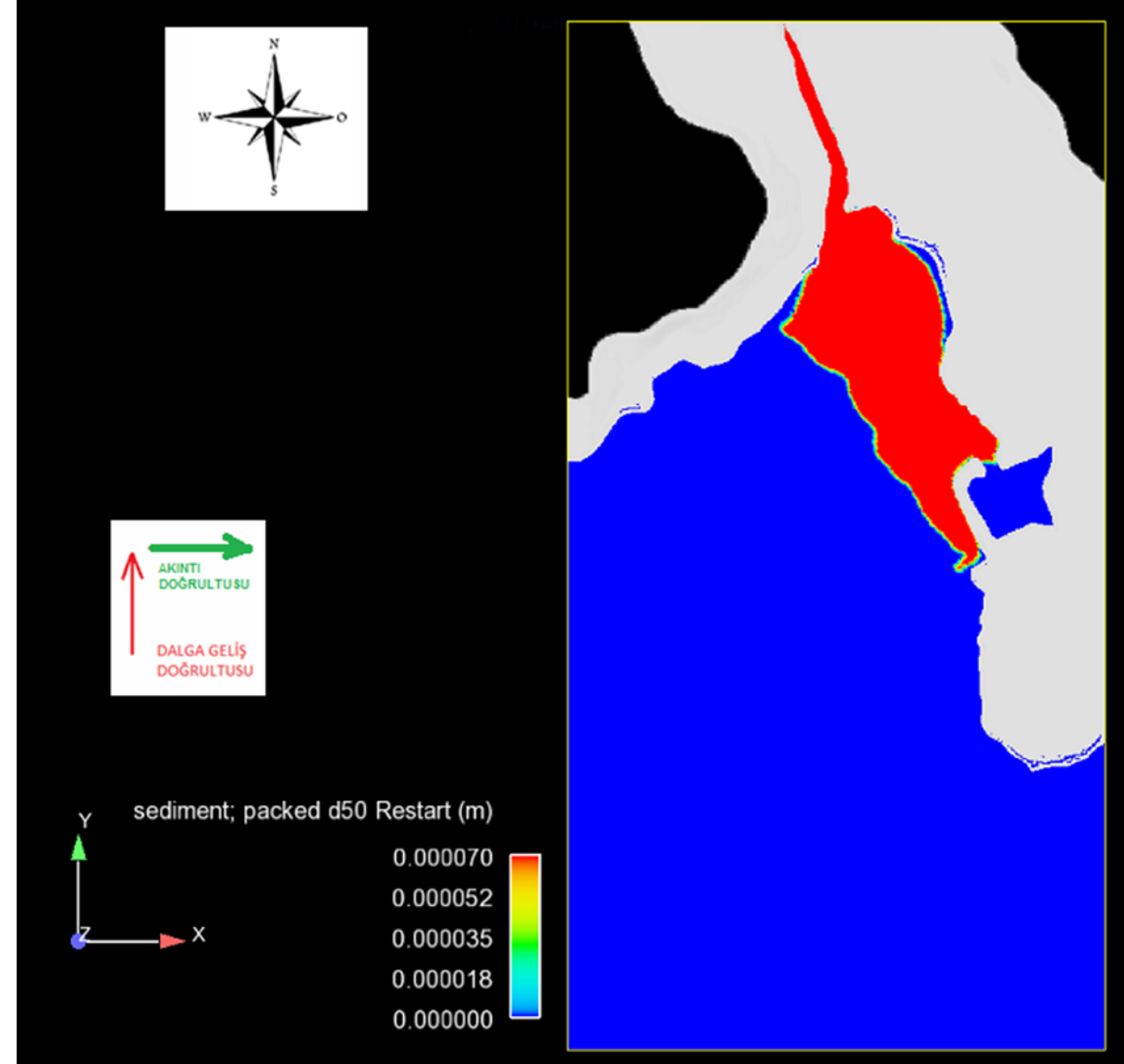


# KIYI MODELLEMESİ

Kurbağalıdere

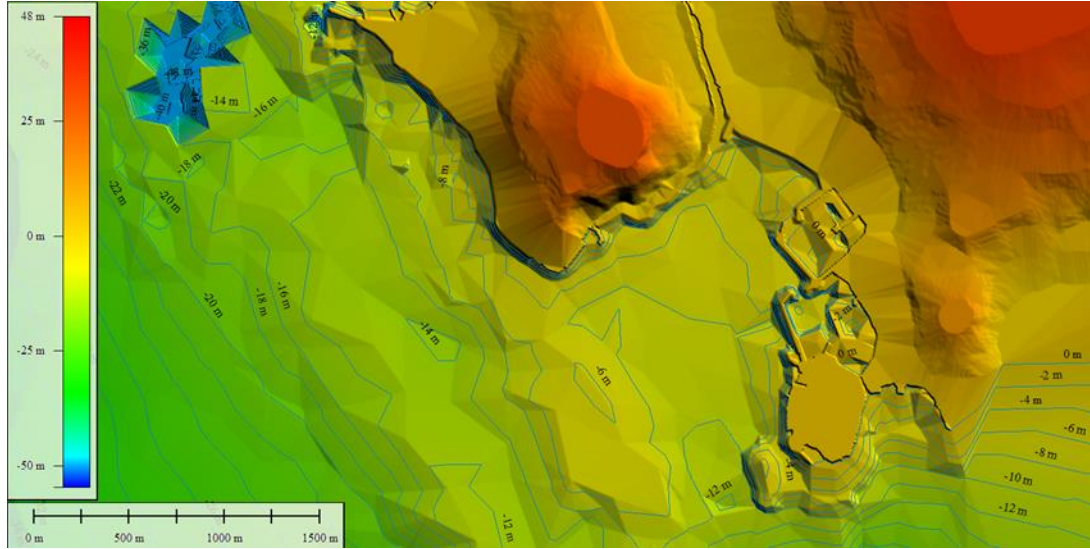


Şekil 19.Dere Ağızı

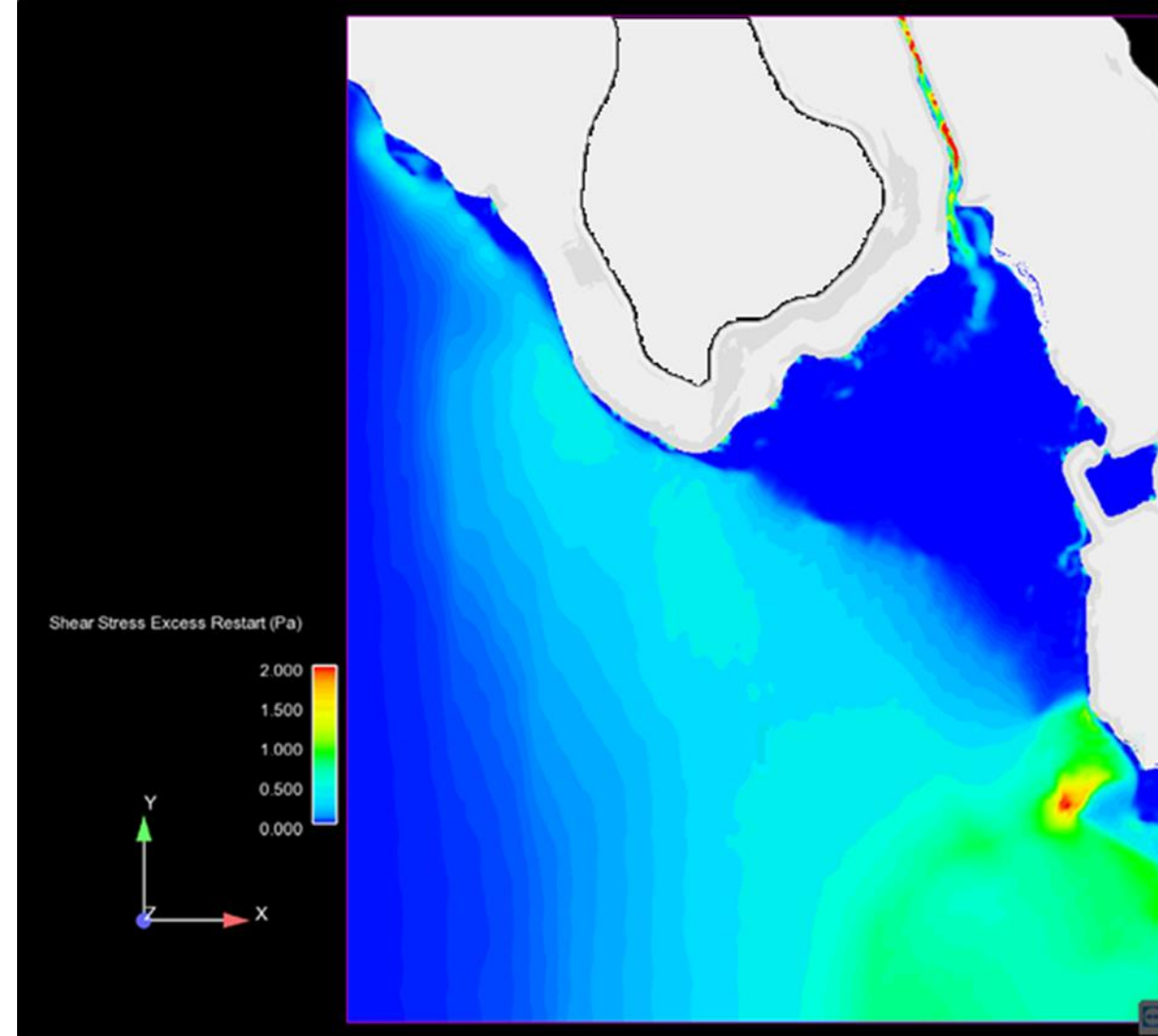


# KIYI MODELLEMESİ

Kurbağalıdere

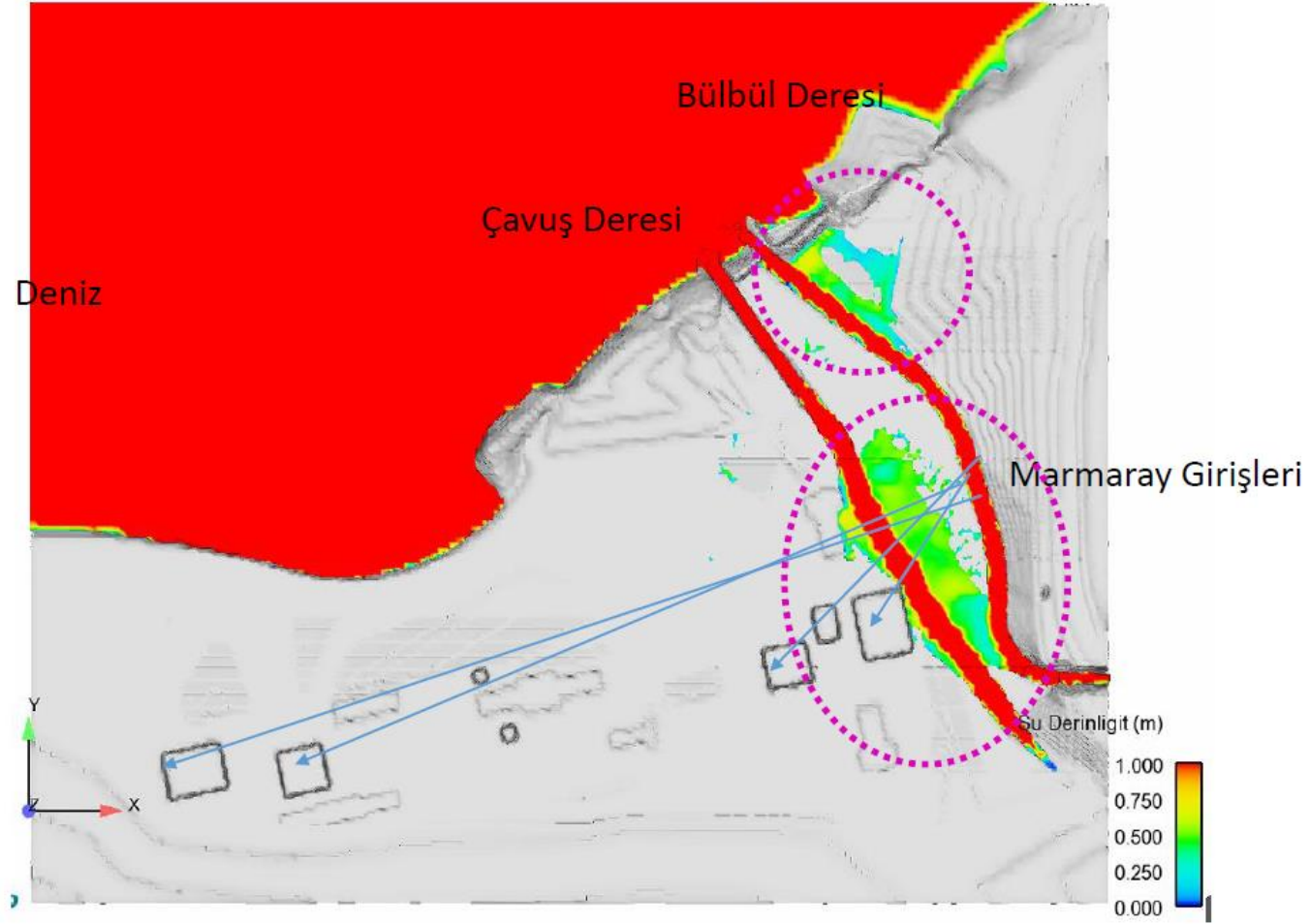


Şekil 20.Dere Ağızı



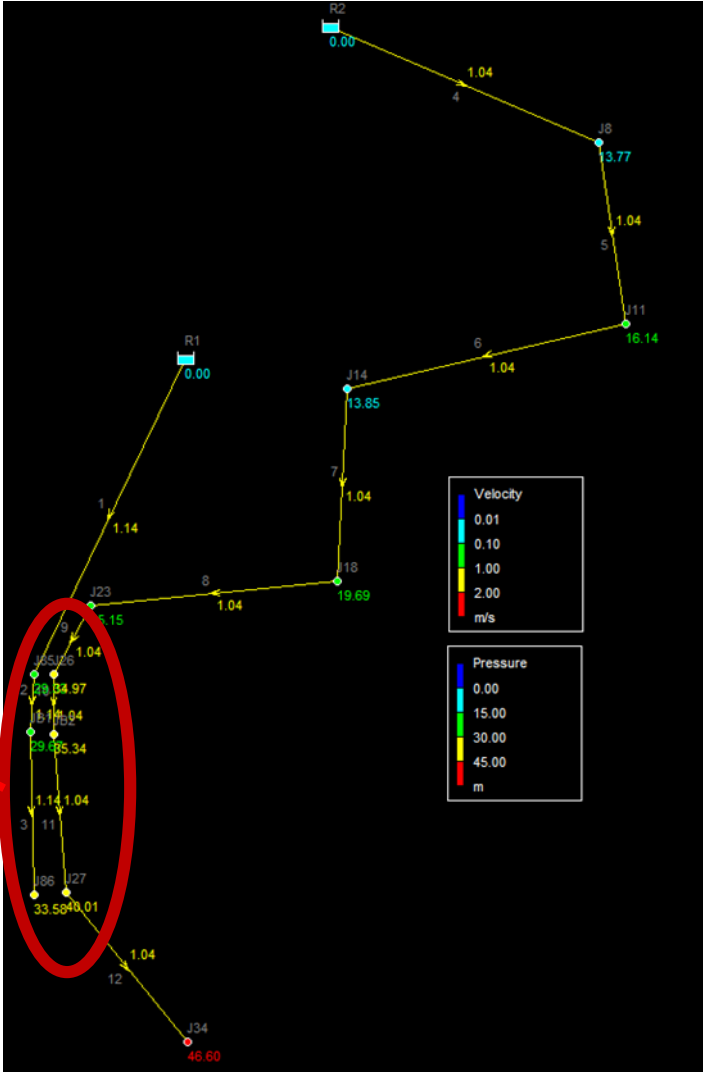
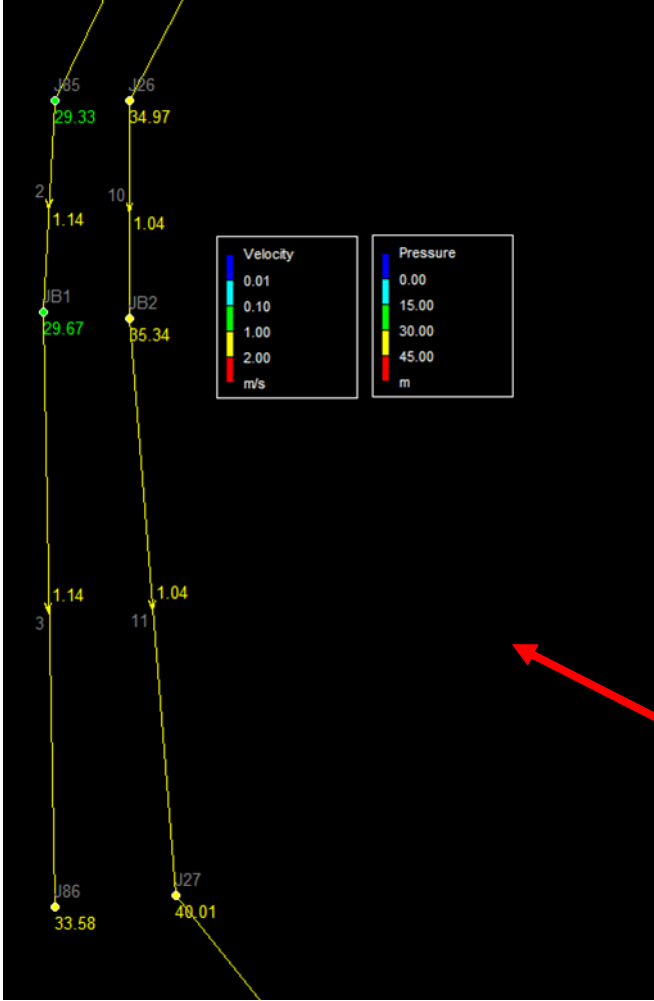
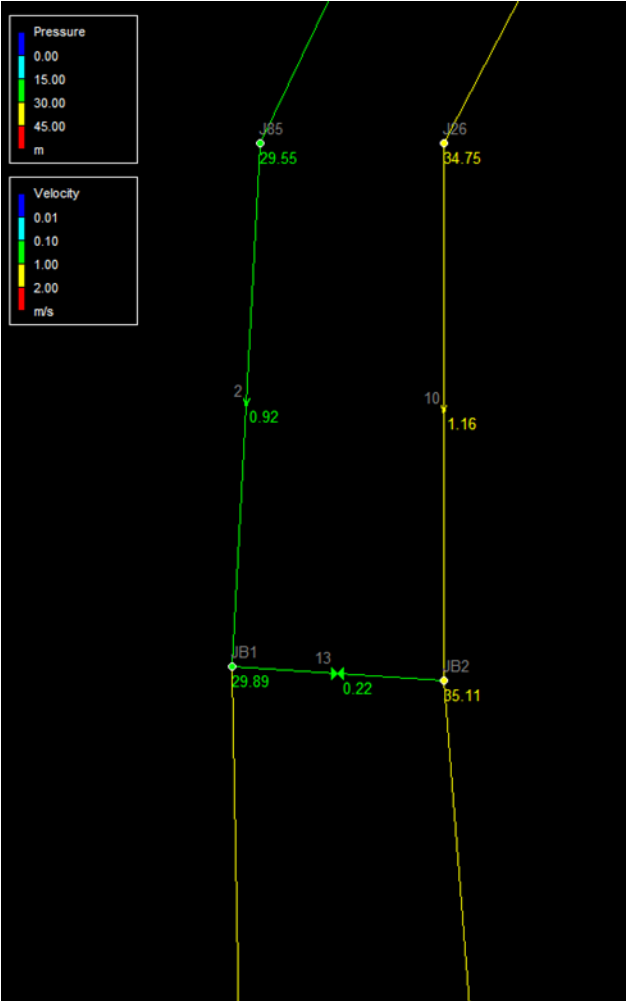
# TAŞKIN MODELLEMESİ

ÜSKÜDAR

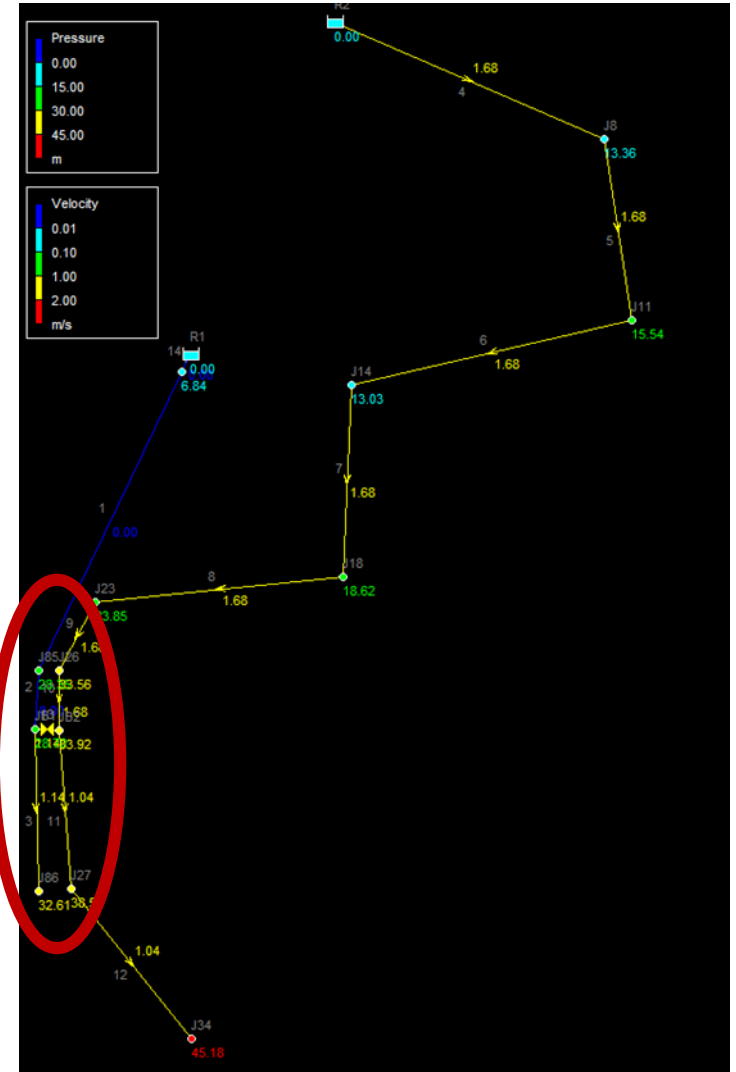
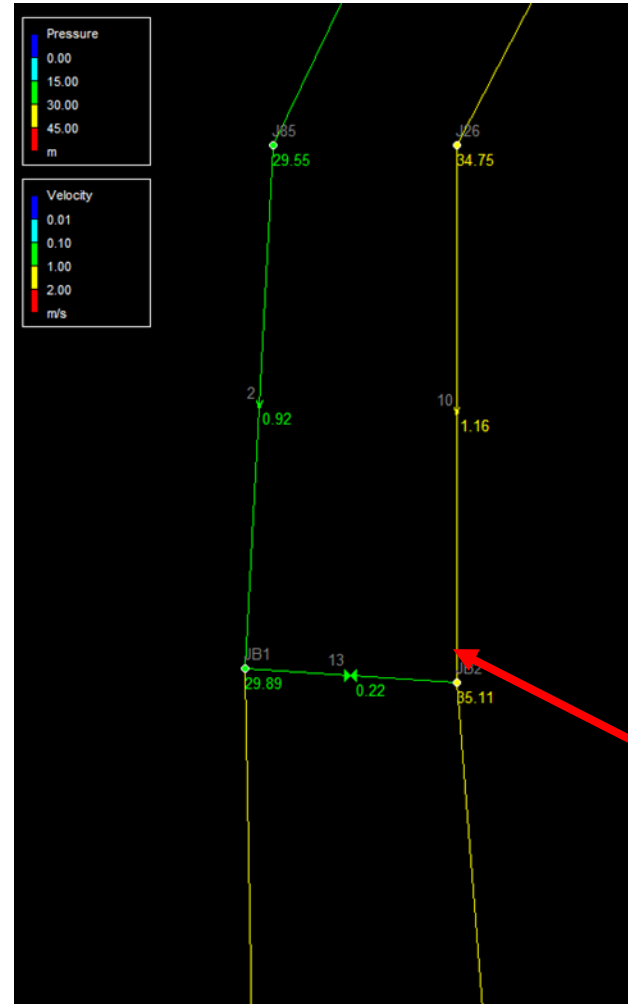
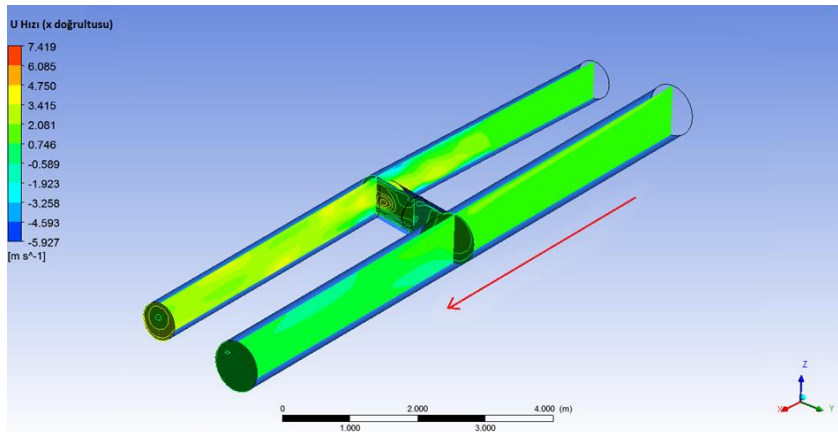
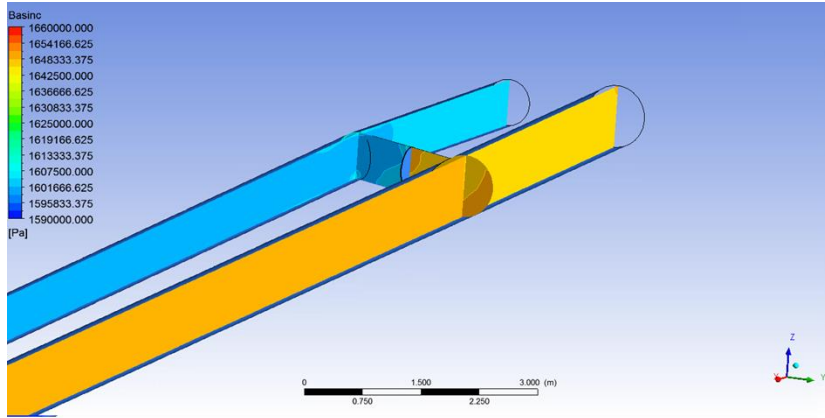


Şekil 21. Çavuşdere ve Bülbüldere

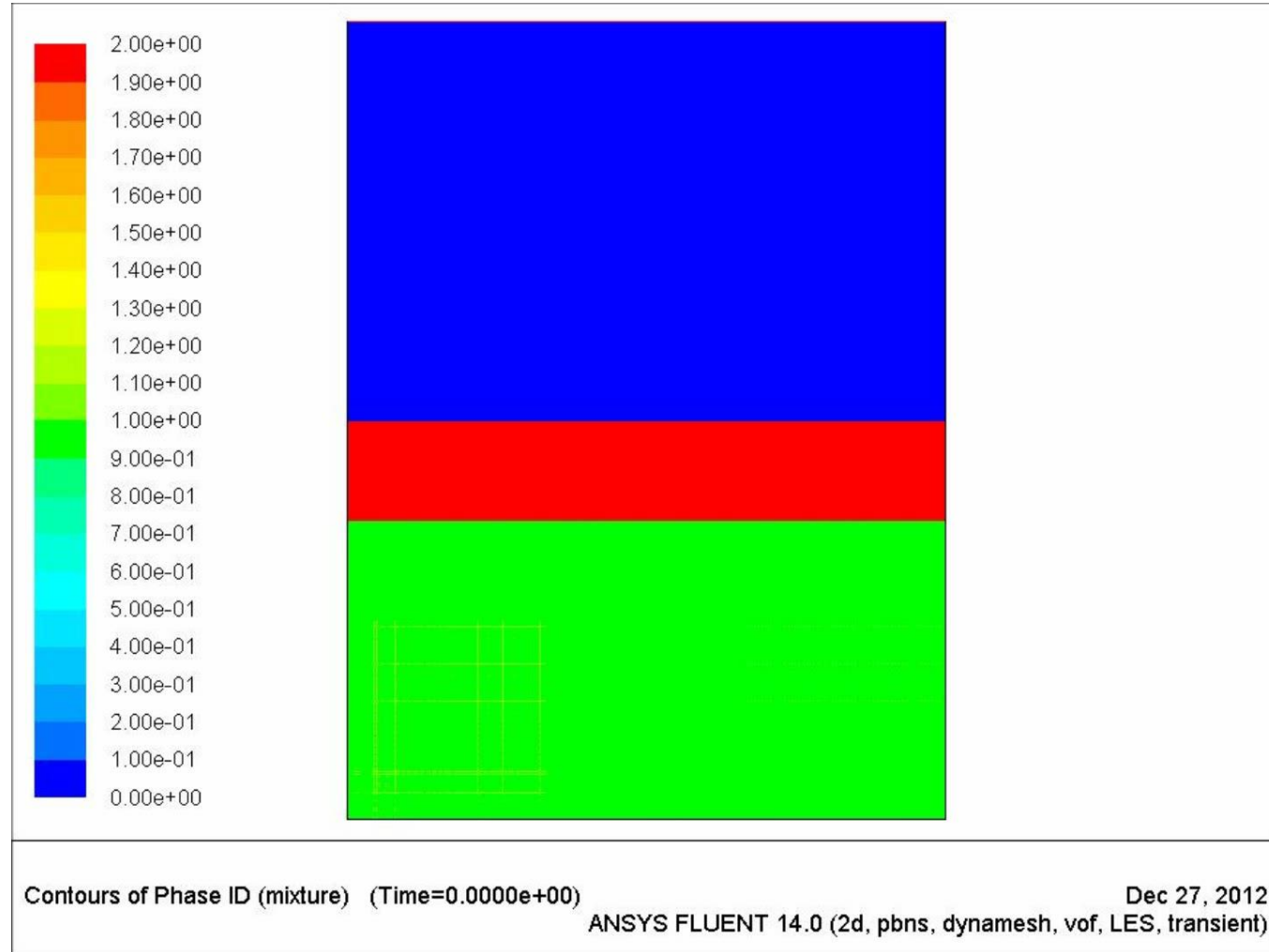
# BORU MODELLEMESİ



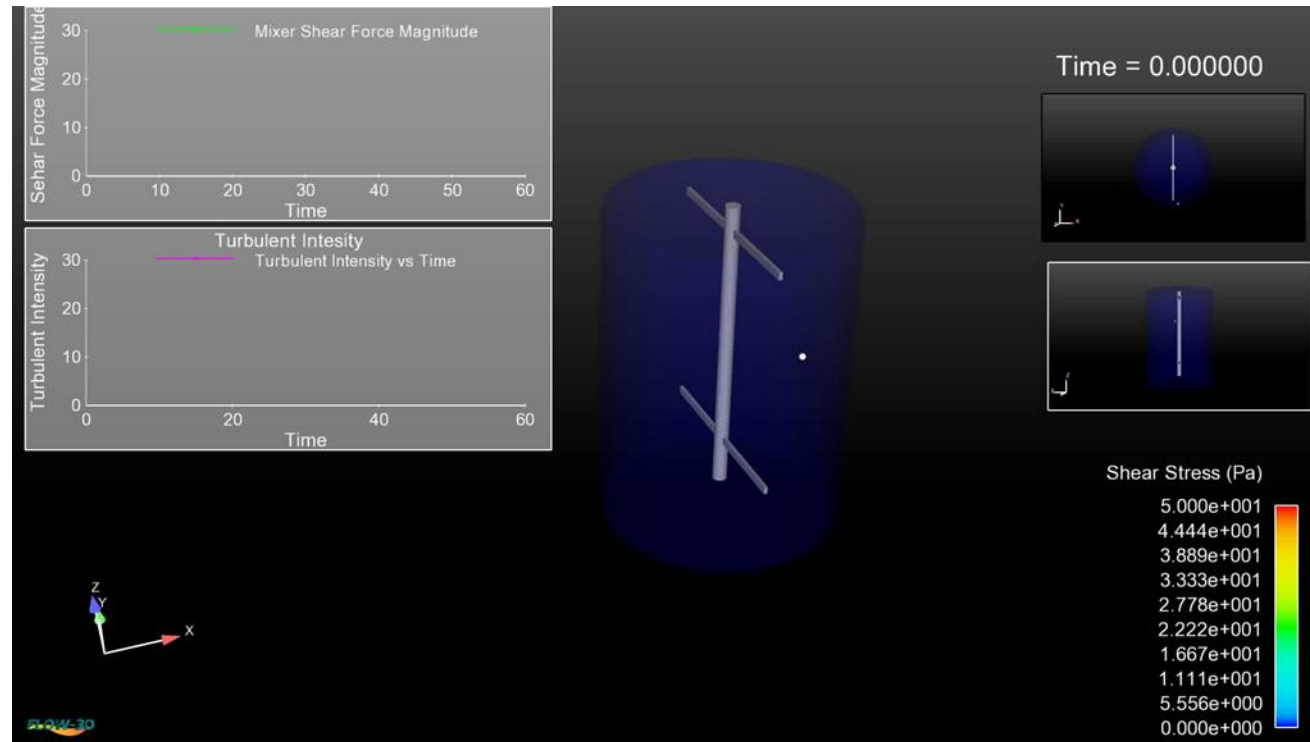
# BORU MODELLEMESİ



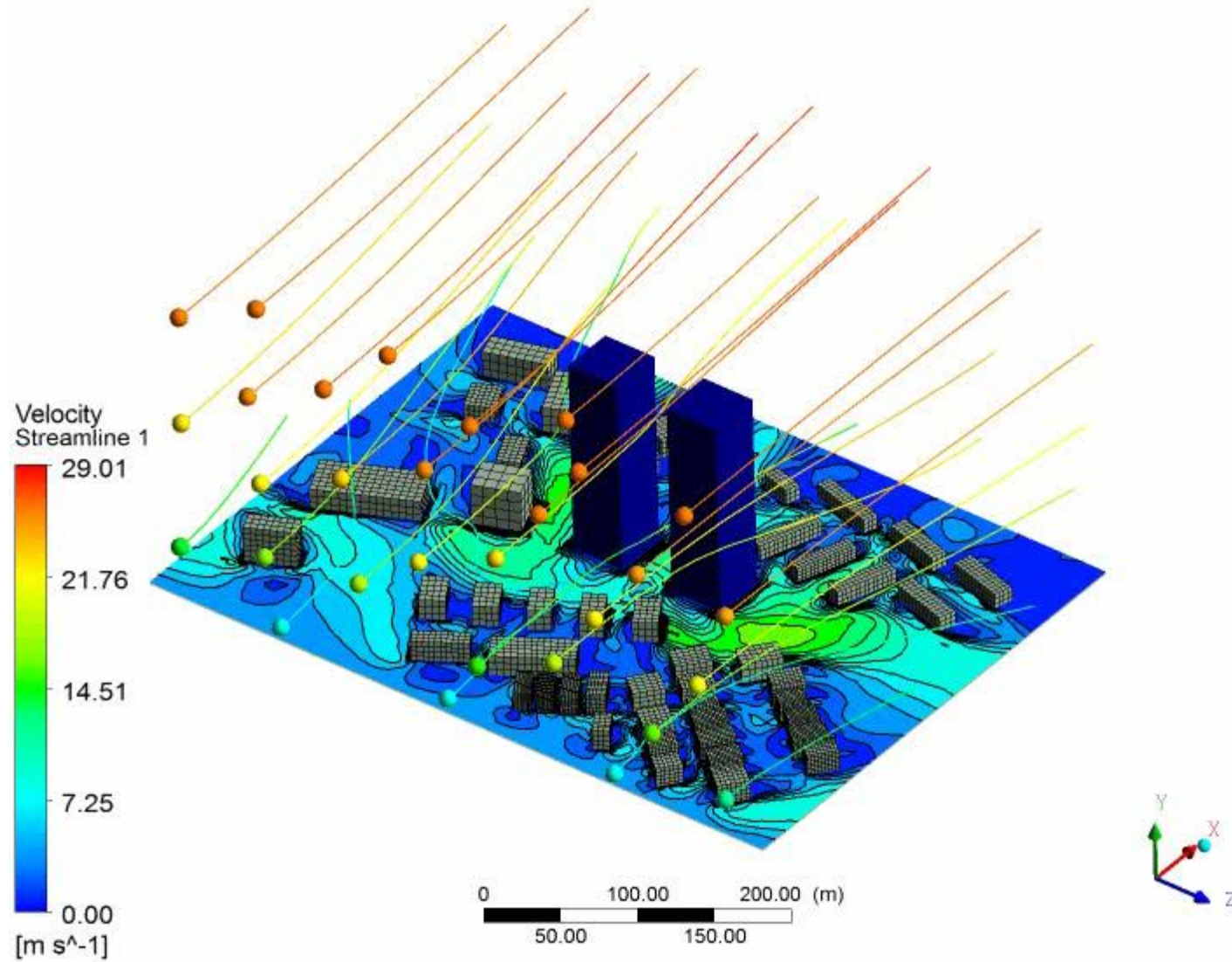
# ÇALKALANMA ANALİZİ



# KARIŞTIRICI ANALİZİ

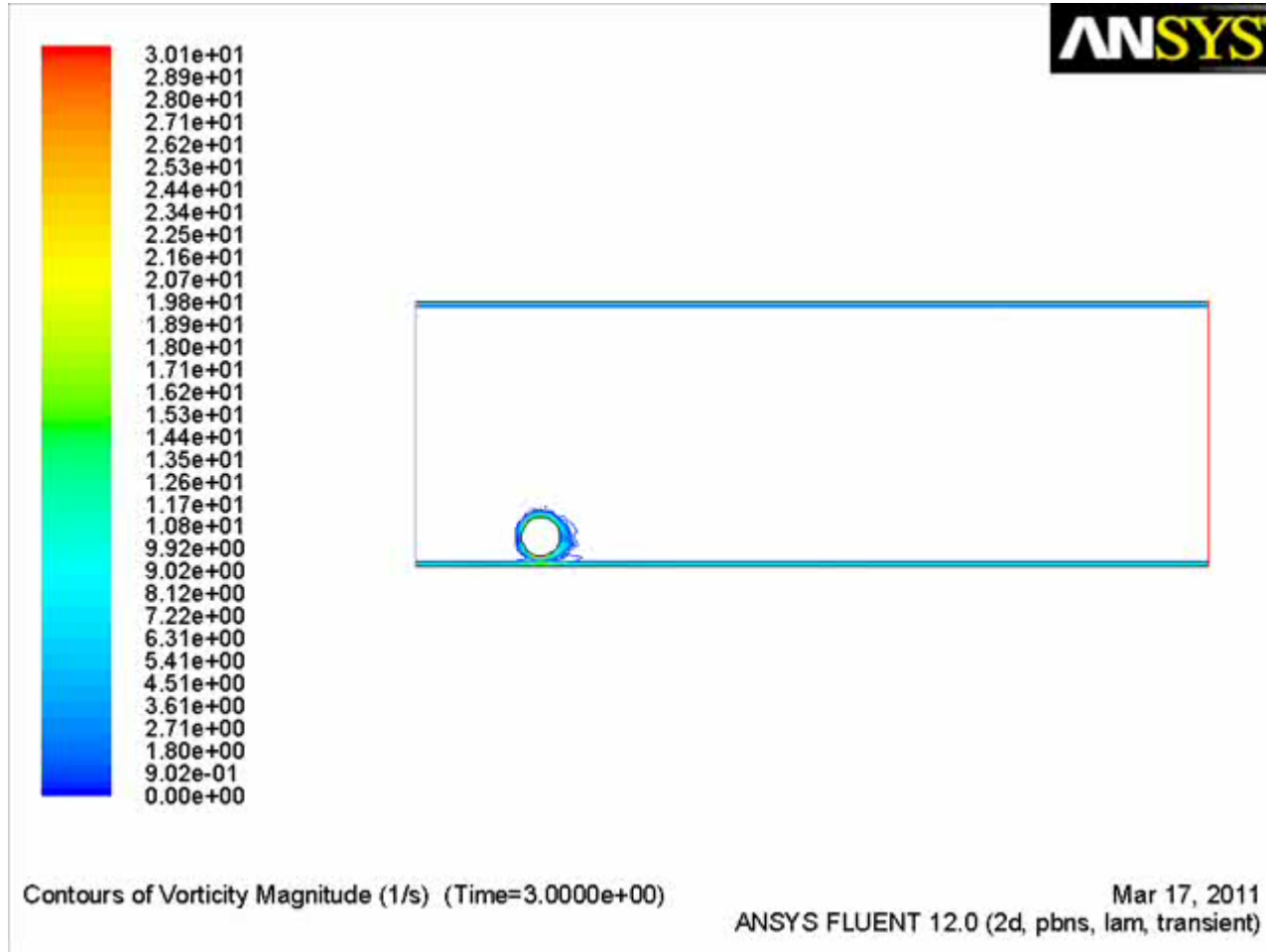


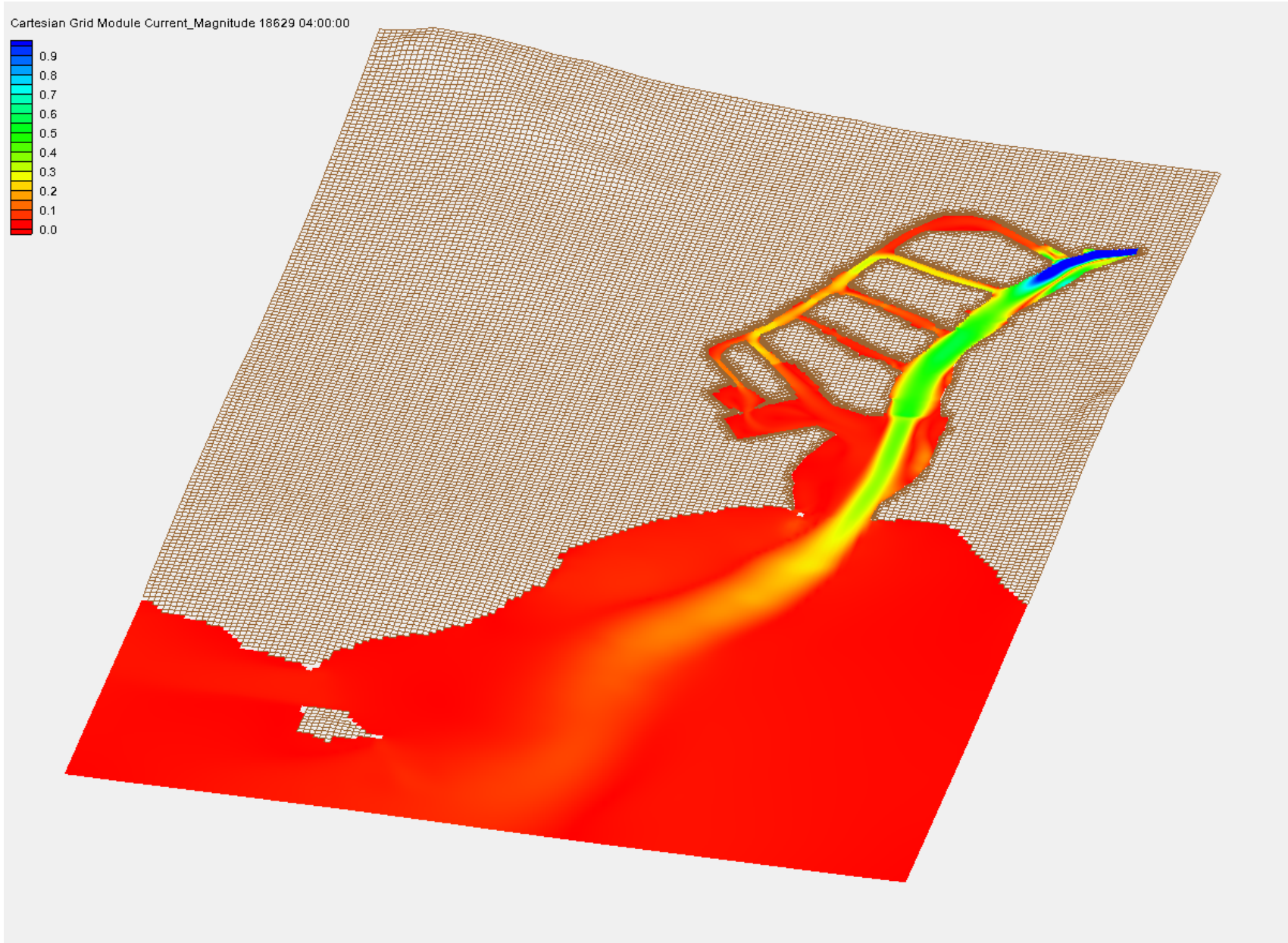
# RÜZGAR ANALİZİ





# VIV ANALIZI

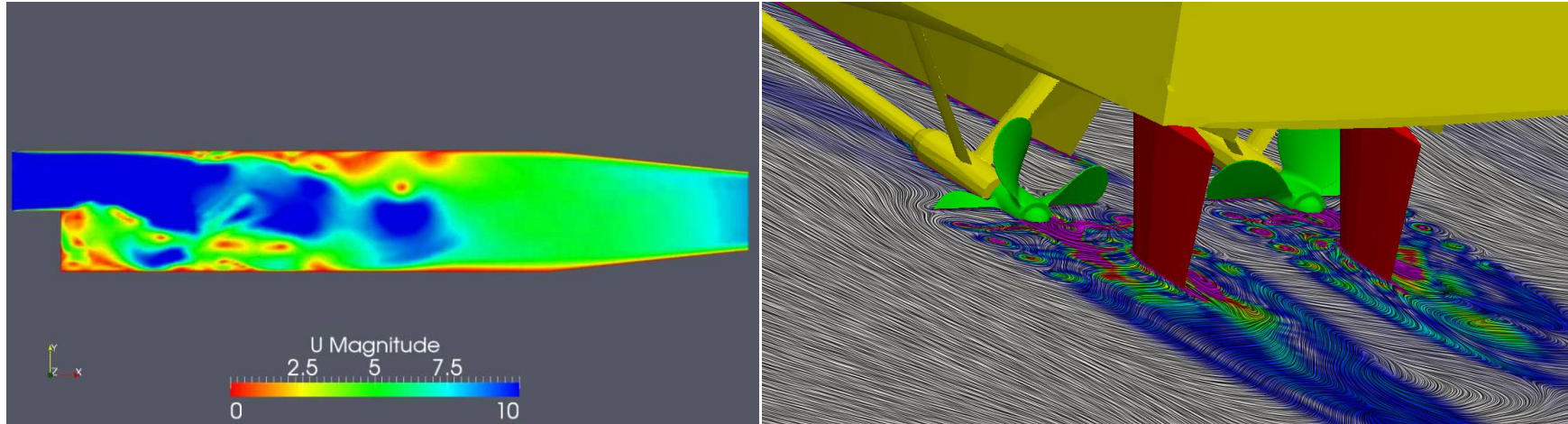


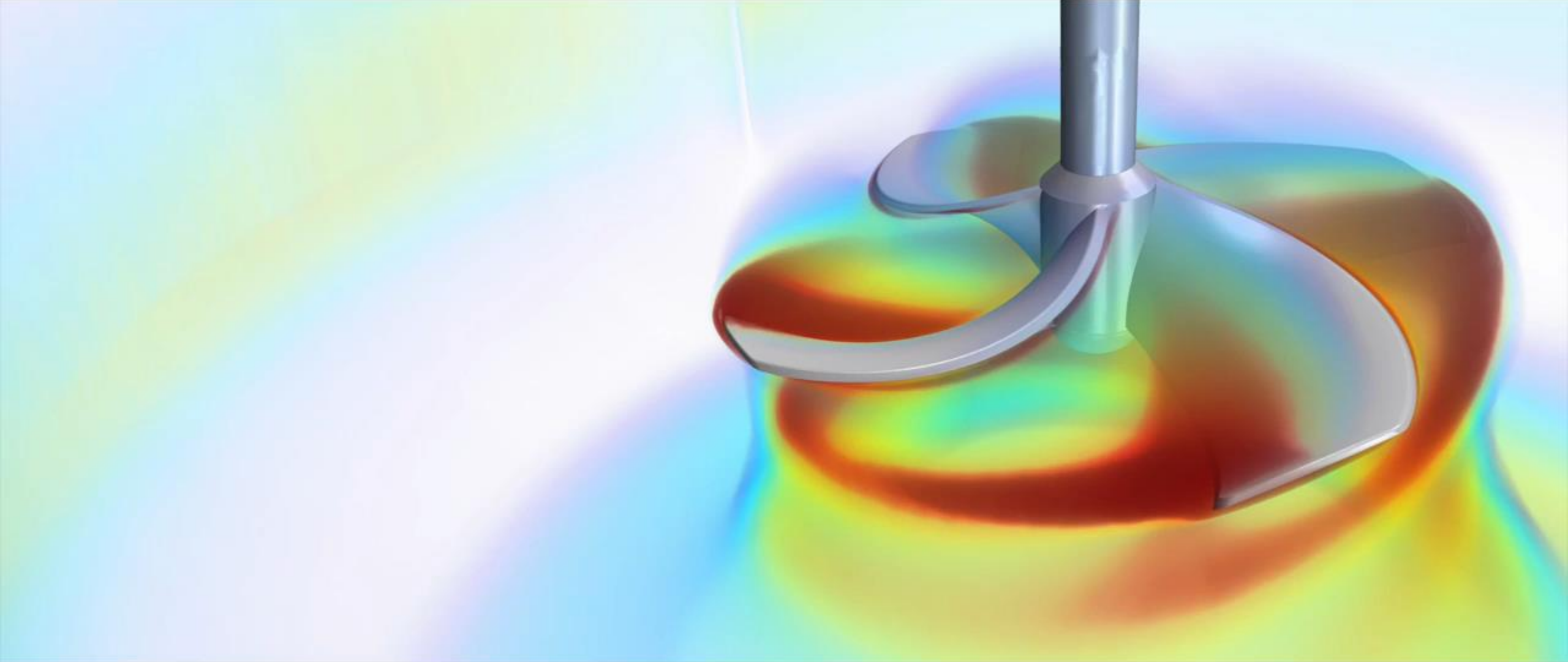


PLANLANANLAR

# OpenFOAM Nedir?

OpenFOAM açık kaynak kodlu tamamen ücretsiz bir hesaplamalı akışkanlar dinamiği (HAD) hesaplamalarını ve similasyonlarını yapabileceğimiz bir yazılımdır.





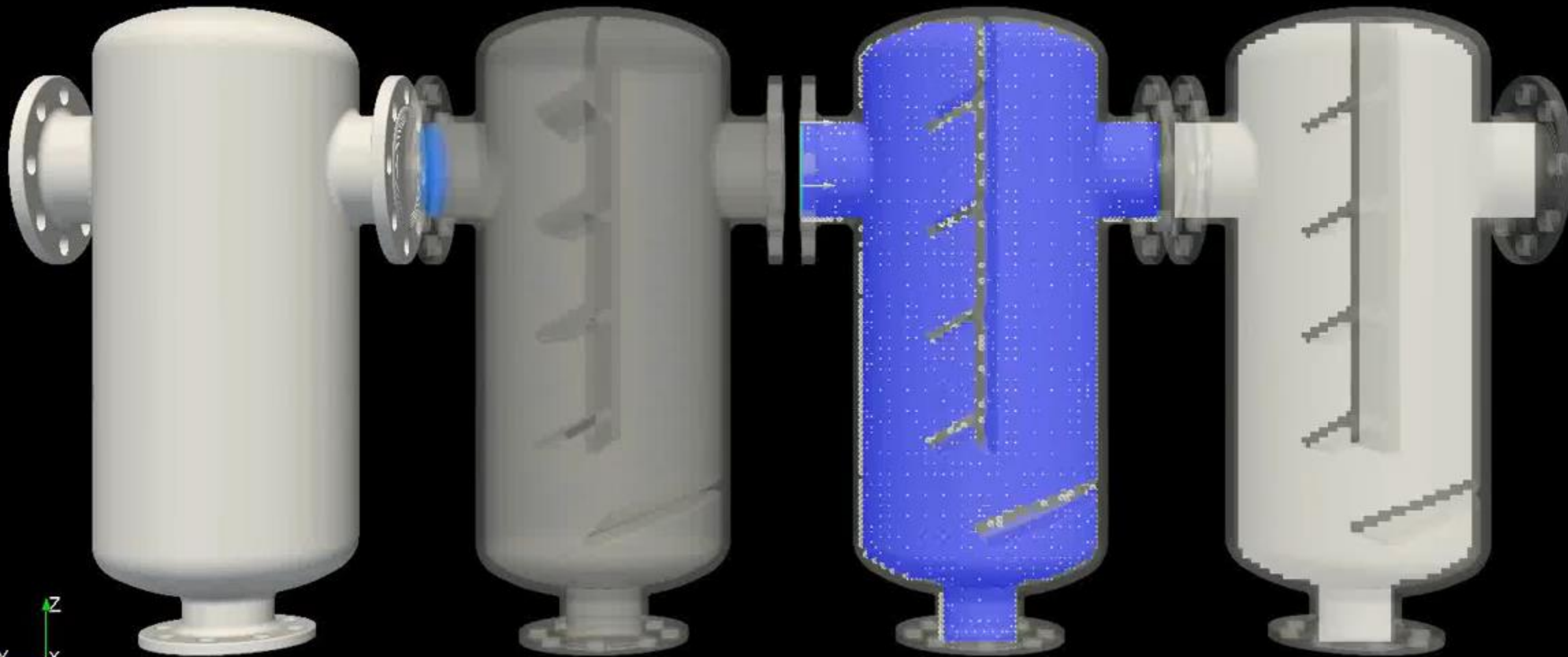
# CFD analysis of a water steam separation drum

*design geometry*

*isosurface water*

*velocity profile*

*static pressure profile*



Time: 0 sec

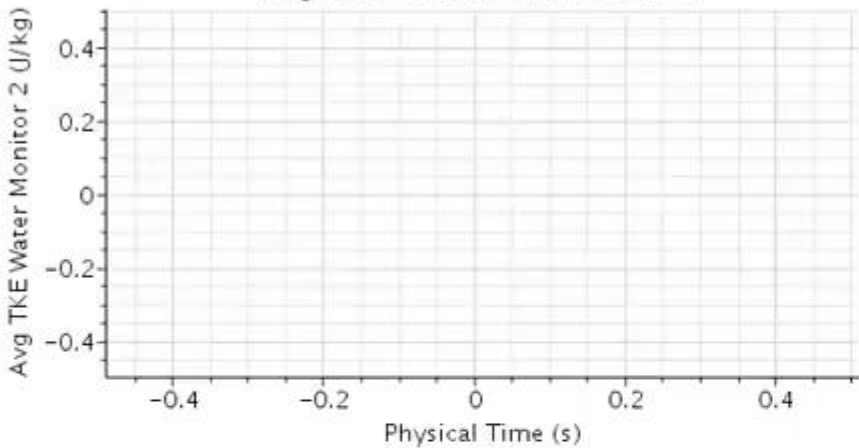
water fraction at inlet: 10%  
volumetric flow: ~ 86 m<sup>3</sup>/hr  
separation efficiency: > 99,9%

simulation done by: Clemens Lischka (M. Sc.), 2016  
contact: [lischka.engineering@gmail.com](mailto:lischka.engineering@gmail.com)  
this video is purely for educational uses

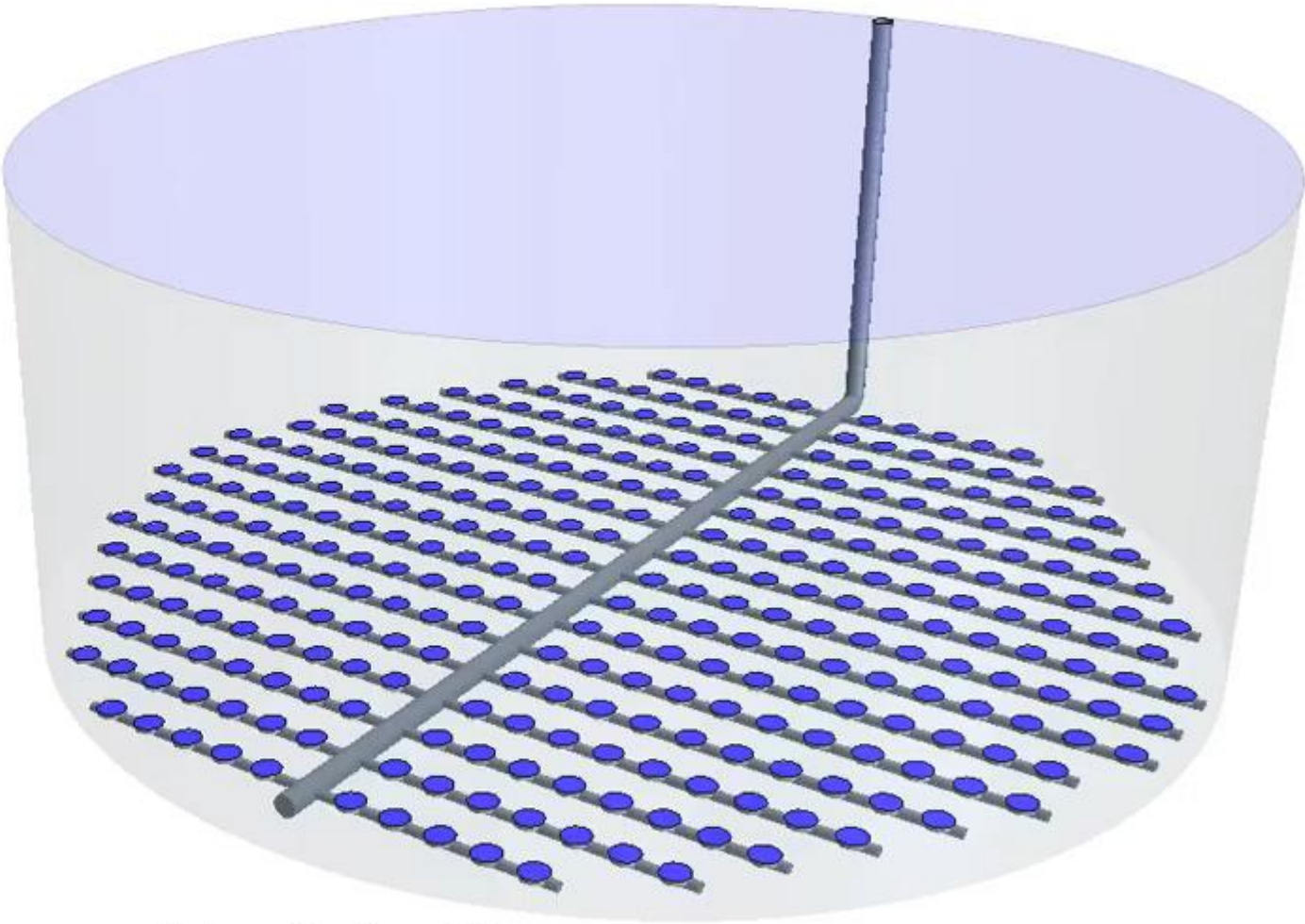
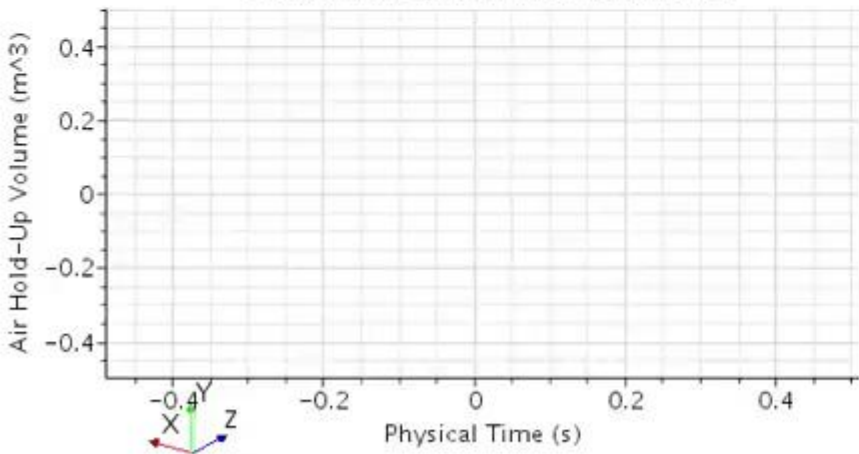
Solution Time 0.01 (s)

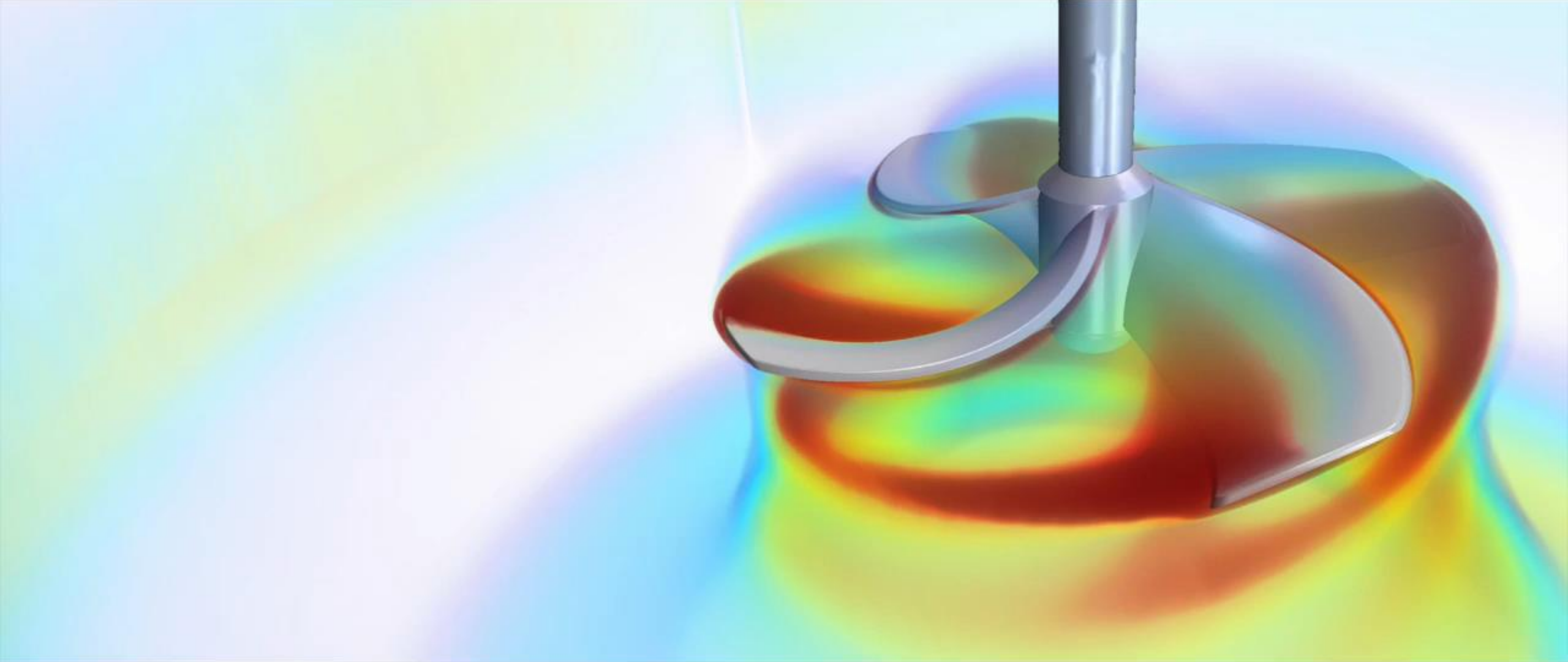
# THINK Fluid Dynamix

Avg TKE Water Monitor 2 Plot



Volume Integral 1 Monitor 2 Plot





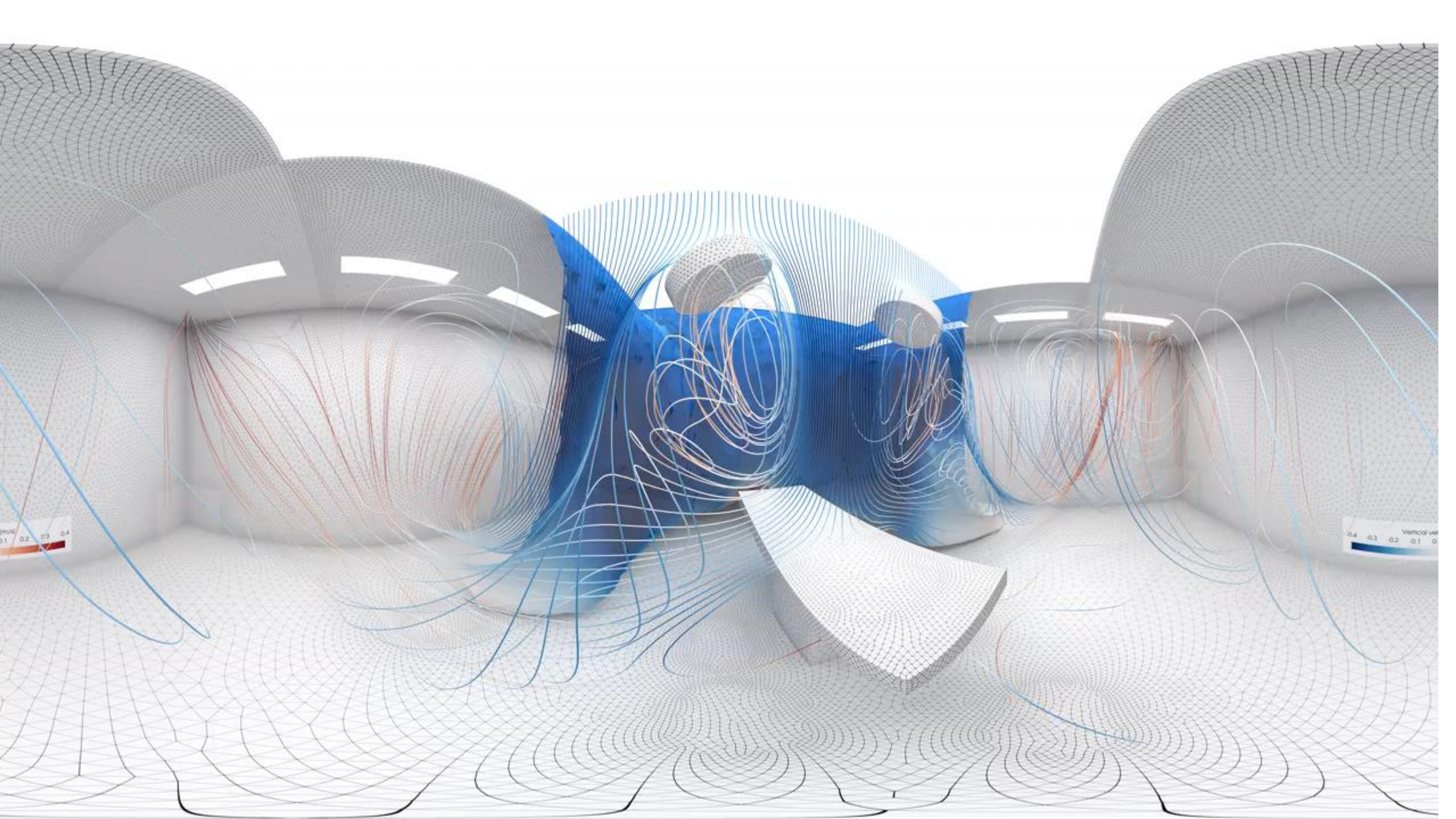


# Sanal Gerçeklik (VR) Nedir?

Teknik olarak sanal gerçeklik terimi bireylerin orda olma hissini yaşadığı üç boyutlu bilgisayar teknolojileri ile oluşturulmuş ortama verilen isimdir.







# Artırılmış Gerçeklik (AR) Nedir?



**Artırılmış gerçeklik (AR) video,** grafik verileri gibi bilgisayar tarafından üretilip duyuşal girdi ile artırılıp canlandırılan elemanların fiziksel, gerçek dünya ortamıyla birleřtirilmesiyle oluşturulan yeni bir algı ortamının canlı doğrudan ya da dolaylı bir görünümüdür.

# Augmented Reality using High-Fidelity Models

## Wind Tunnel

A. Badías, I. Alfaro, D. González, F. Chinesta and E. Cueto

✉ [abadias@unizar.es](mailto:abadias@unizar.es)



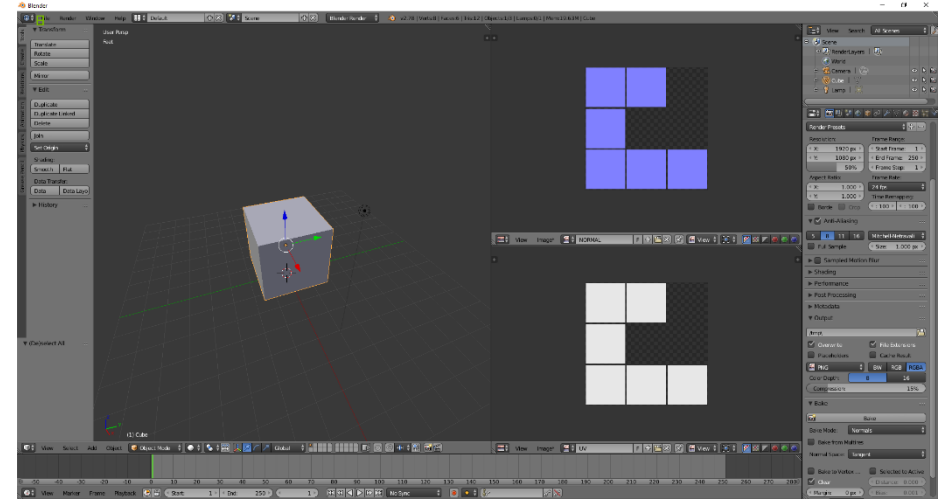
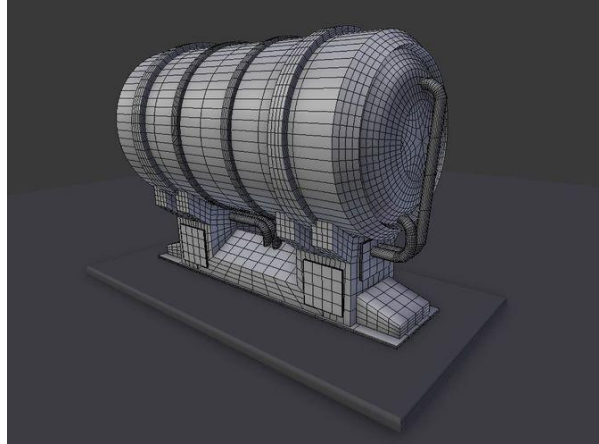
Instituto Universitario de Investigación  
en Ingeniería de Aragón  
Universidad Zaragoza



Universidad  
Zaragoza

# Blender 3D

Blender 3D yazılımını da OpenFOAM gibi tamamen ücretsiz ve açık kaynak kodlu bir yazılımdır. Bütün dünyada 3D modelleme konusunda kendini kanıtlamış ve sektörde yerini almıştır.



# Blender ve Openfoam Birlikteliđi

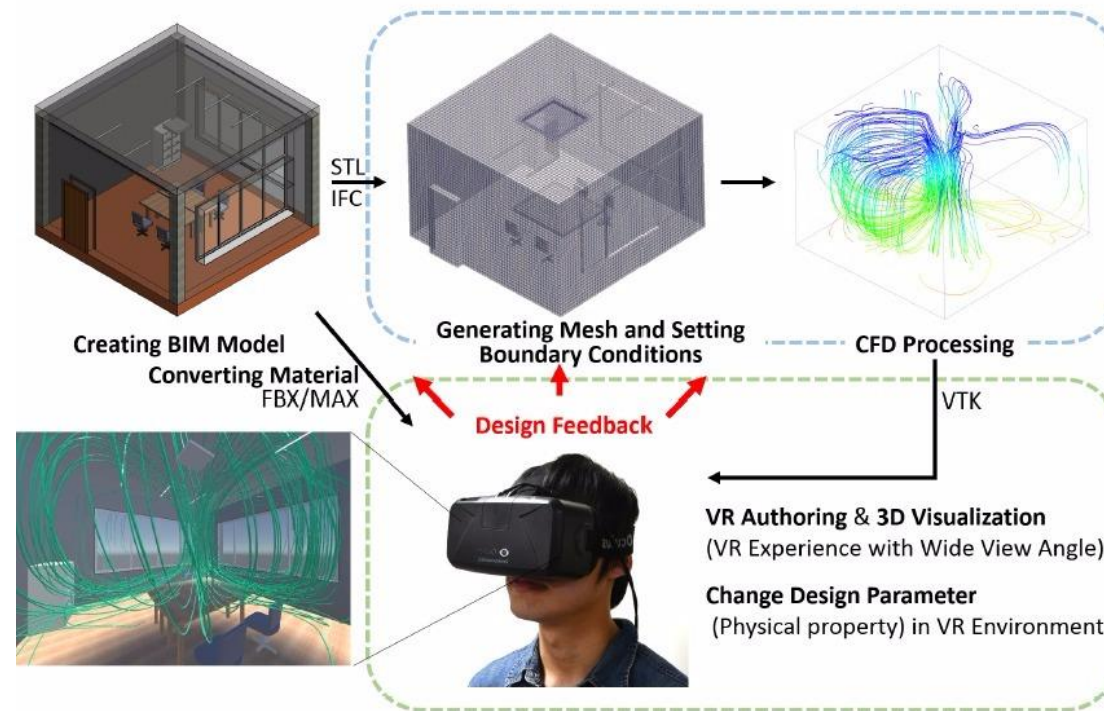
Openfoam arayüzü olmayan kendi bünyesinde karmaşık modeller çizilmesi oldukça güç kullanıcı dostu olmayan bir yapıya sahiptir.

Blender ise son kullanıcıya daha çok hitap eder. Kullanıcı dostu bir arayüze sahiptir.

Karmaşık modelleri kolaylıkla çizmemize olanak sağlar.

Buradaki amacımız bu iki açık kaynak kodlu yazılımı düzenleyip kendi yazılımlarımızla destekleyerek sağlıklı entegresini sağlamak olacaktır. Bu sayede CFD simülasyonlarını kolay bir şekilde kullanıcı dostu blender arayüzü ile yapmamızı sağlamaktır.

# Blender, OpenFOAM, VR/AR Birlikteliği



*Figure 1. Overview of the system process flow.*



# Blender, OpenFOAM, VR/AR Birlikteliği

<https://www.youtube.com/watch?v=cczJBcAEfrE>

<https://www.youtube.com/watch?v=tAcRX7S7DDQ>

<https://play.google.com/store/apps/details?id=com.PMCLLC.CityCFDVR&hl=en>