

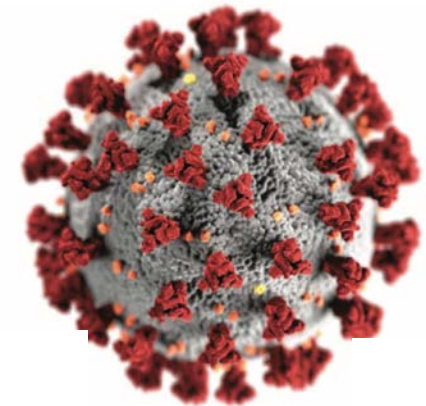
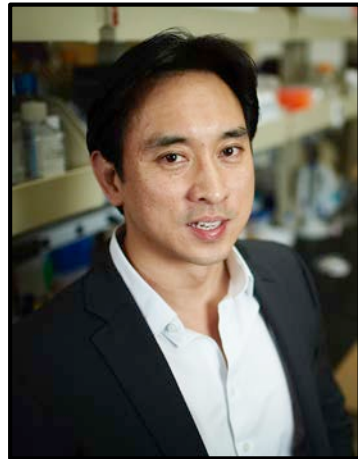
# Poops Don't Lie: Wastewater Surveillance of SARS-CoV-2 in Southern Nevada

**Daniel Gerrity and Katerina Papp**

Water Quality R&D, Southern Nevada Water Authority

**Edwin Oh, Van Vo, Richard Tillet, and Hayley Baker**

Institute of Personalized Medicine, University of Nevada Las Vegas





# 2010 Super Bowl



31



17

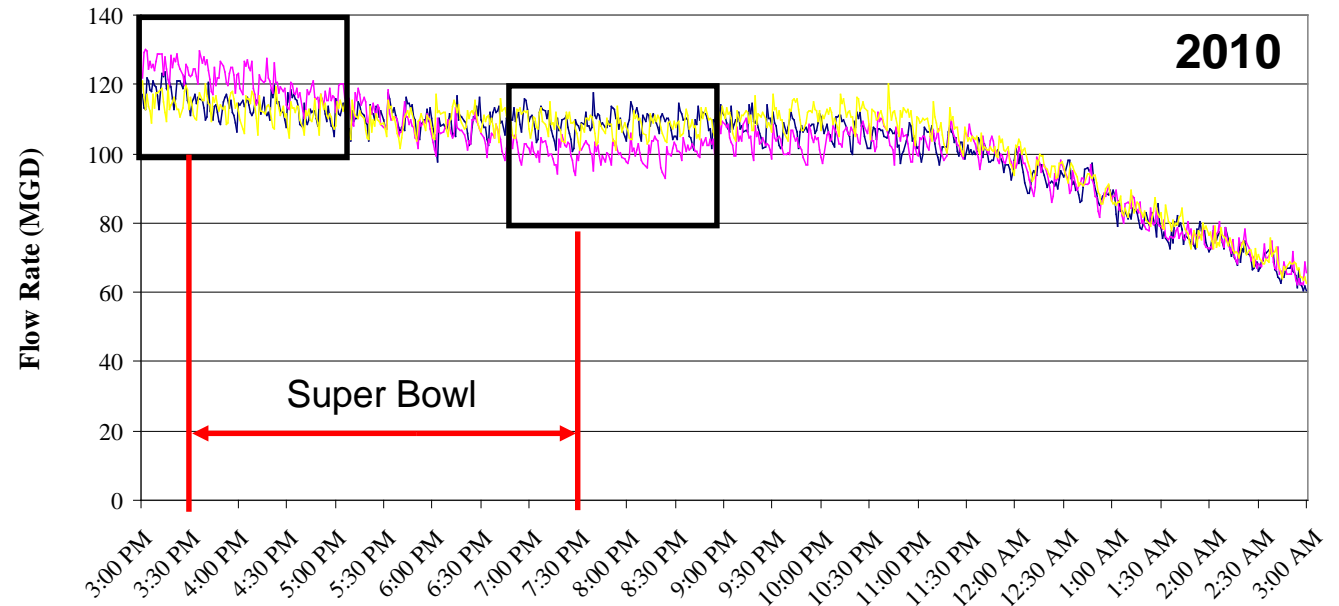
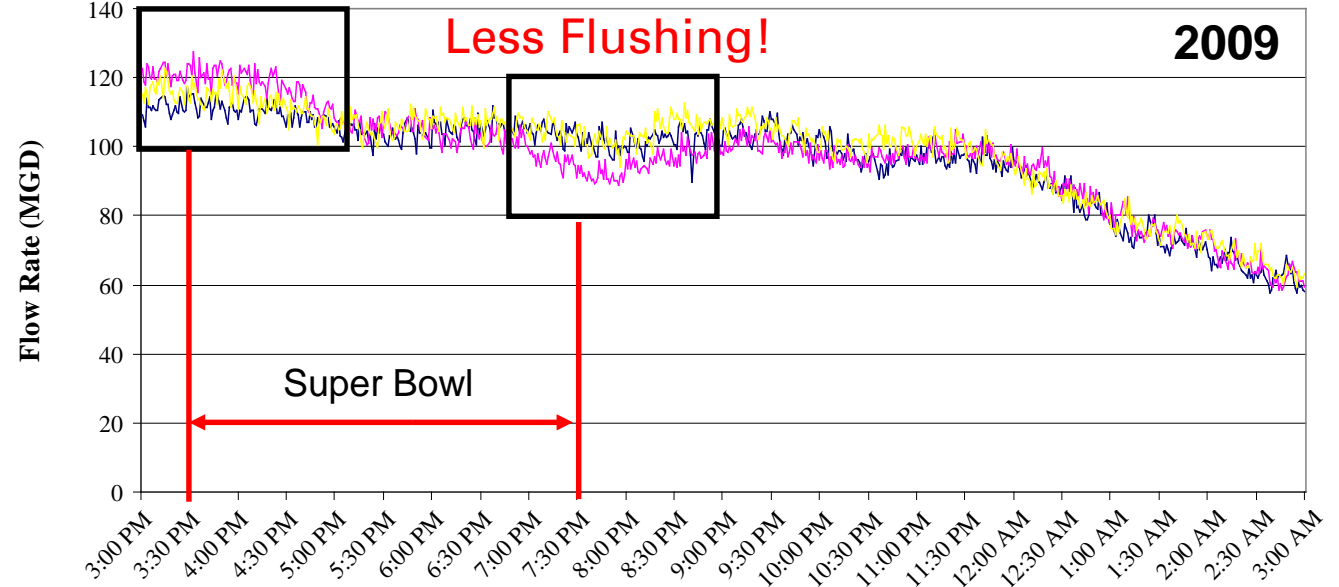
Location: Miami, Florida



Location: Las Vegas, Nevada  
+300,000 tourists

- Baseline before Super Bowl
- Super Bowl
- Baseline after Super Bowl

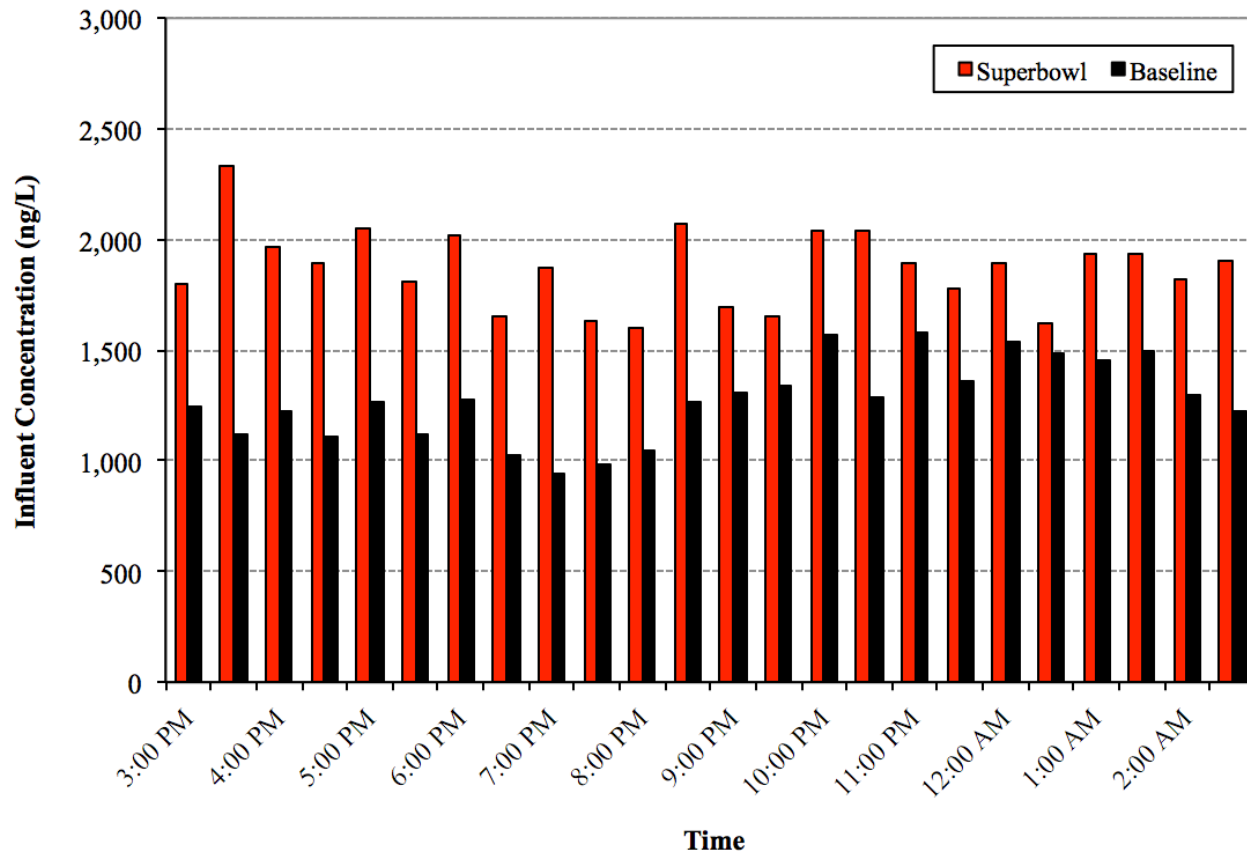
More Flushing!





# 2010 Super Bowl – Illicit Drug Use in Vegas

## Cocaine Metabolite

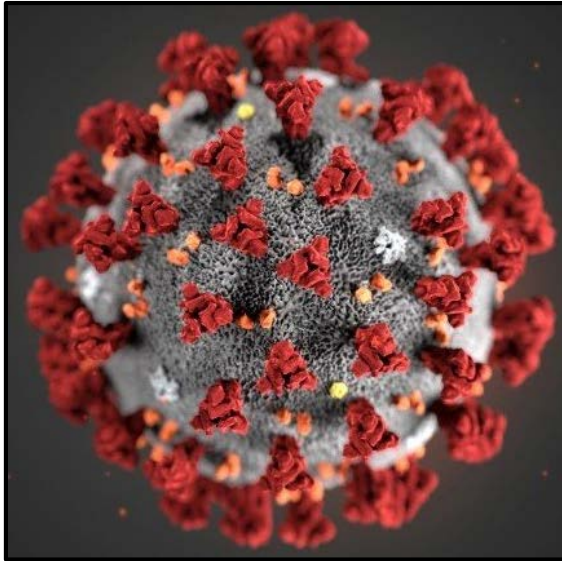


### Average Concentration:

- Baseline Weekend = 1,275 ng/L (parts-per-trillion)
- Super Bowl Weekend = 1,870 ng/L
- 50% higher during the Super Bowl

**We'll come back to this later!**

# SARS-CoV-2 and COVID

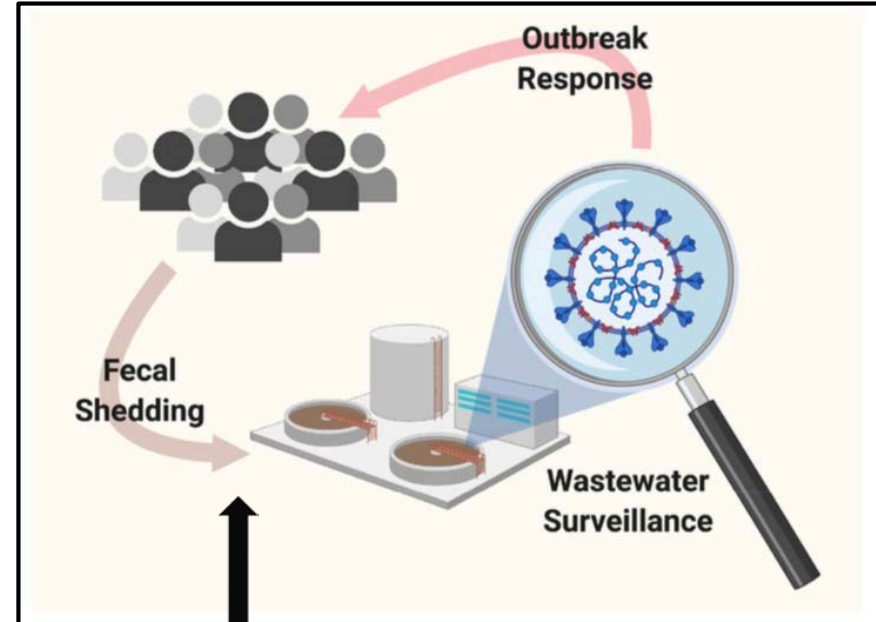
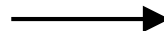
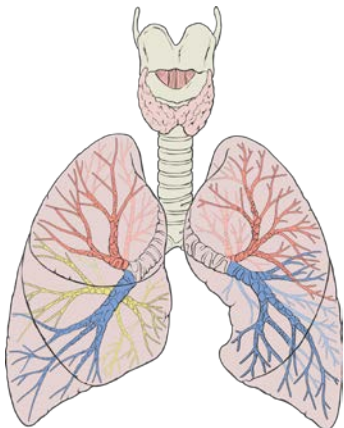
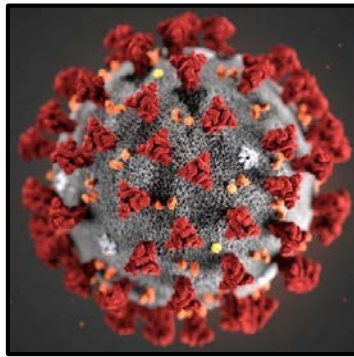






# What's the Connection to Wastewater?

**Severe Acute Respiratory  
Syndrome Coronavirus 2  
(SARS-CoV-2)**





# Wastewater Surveillance for SARS-CoV-2

## How Wastewater Became a COVID Crystal Ball

By Matt Stieb



Analytical chemist Katelyn Foppe holds a tube with a wastewater sample in the lab of Biobot Analytics. Photo: M. Scott Brauer/Redux

## Gorilla at the San Diego Zoo gets monoclonal antibody therapy after being infected with Covid-19

By Marika Gerken, CNN

Updated 5:21 PM ET, Tue January 26, 2021



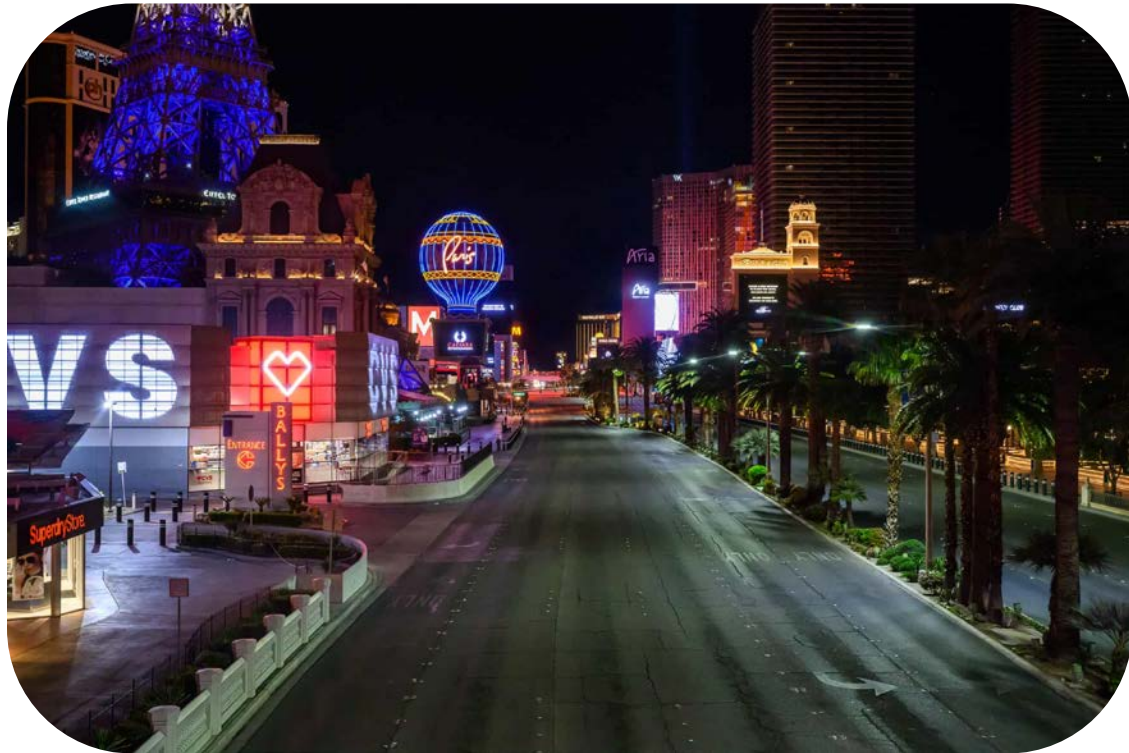
Winston received antibody treatment due to his old age and underlying health conditions.

- 48-year-old Silverback Gorilla (and several others) at San Diego Zoo tested positive for COVID-19
- Infections confirmed through **fecal samples**



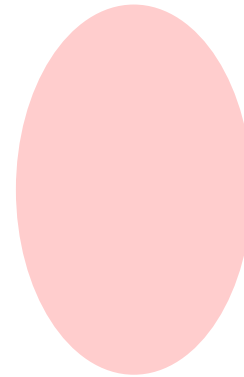
# Vegas Goes Dark

## Stay-At-Home Directive



Source: The Guardian

## Wastewater Flow Data



Peak flow  
decreased and  
shifted later in  
the day





# Wastewater Surveillance of SARS-COV-2



## SNWA Study:

- Sampling every Monday morning; results by Tuesday afternoon
- One site since March 2020; one site since April 2020
- Now 7+ samples per week (since August 2020)
- Short-term monitoring of a **homeless shelter**



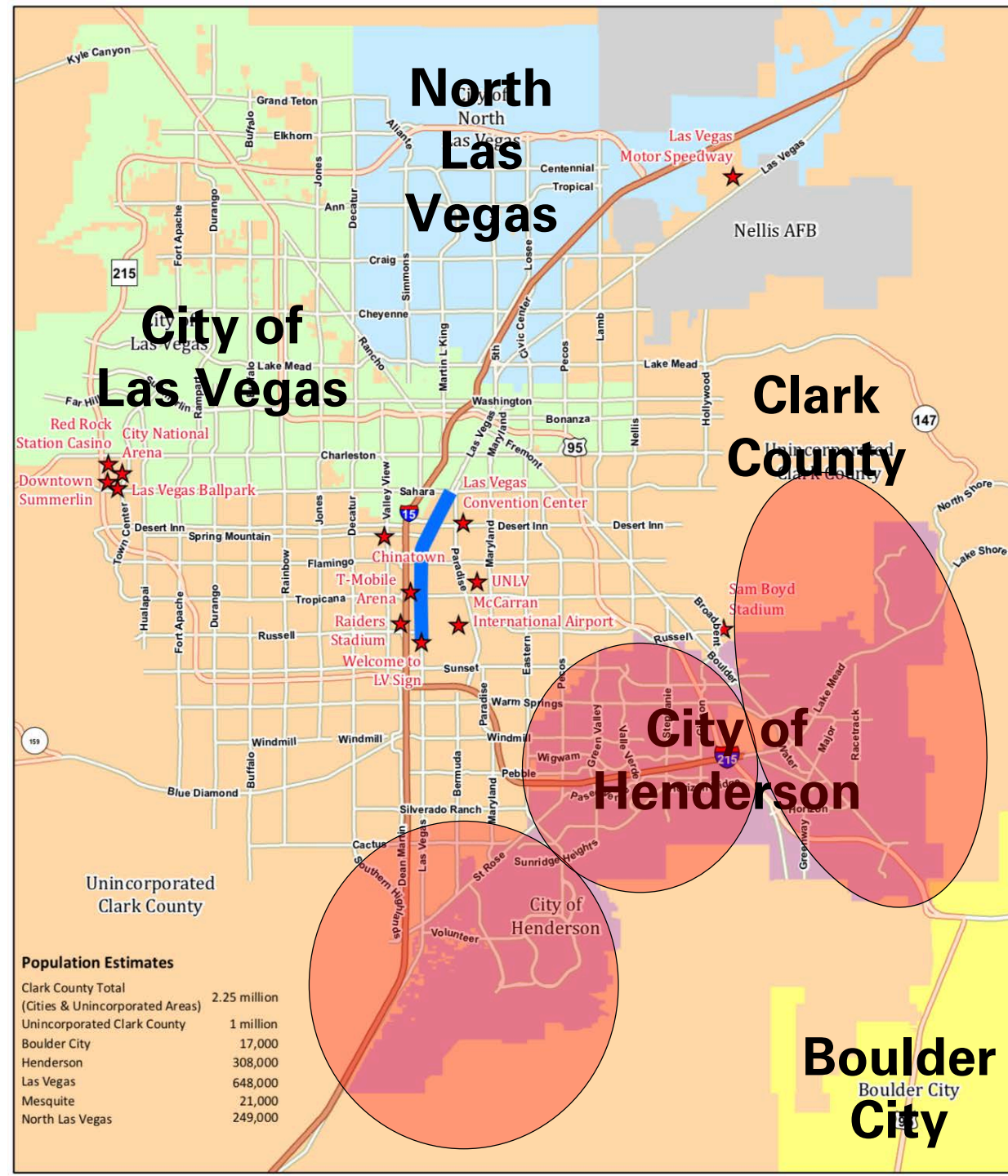




# Sampling Resolution

## Las Vegas Strip

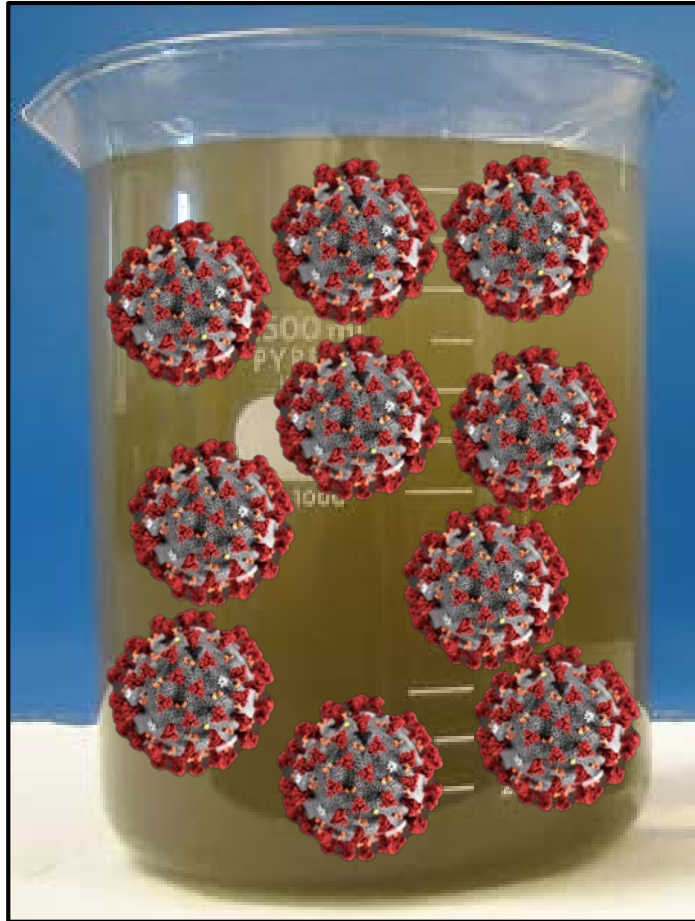
Flow (mgd)	Population	Sample Type
100	872k	Grab Primary Effluent
42	757k	Composite Influent
20	255k	Composite Influent
15	134k	Grab Influent
6	115k	Grab Influent
5	86k	Composite Influent
0.8	16k	Grab Influent





# SARS-CoV-2 Concentrations and Variants

## SNWA



**Example:** 10 genome copies (gc) per liter of sewage

## UNLV



**Example:** 80% Wild Type  
10% Alpha (UK) Variant  
10% Epsilon (California) Variant

# Wastewater Surveillance Data for Southern Nevada

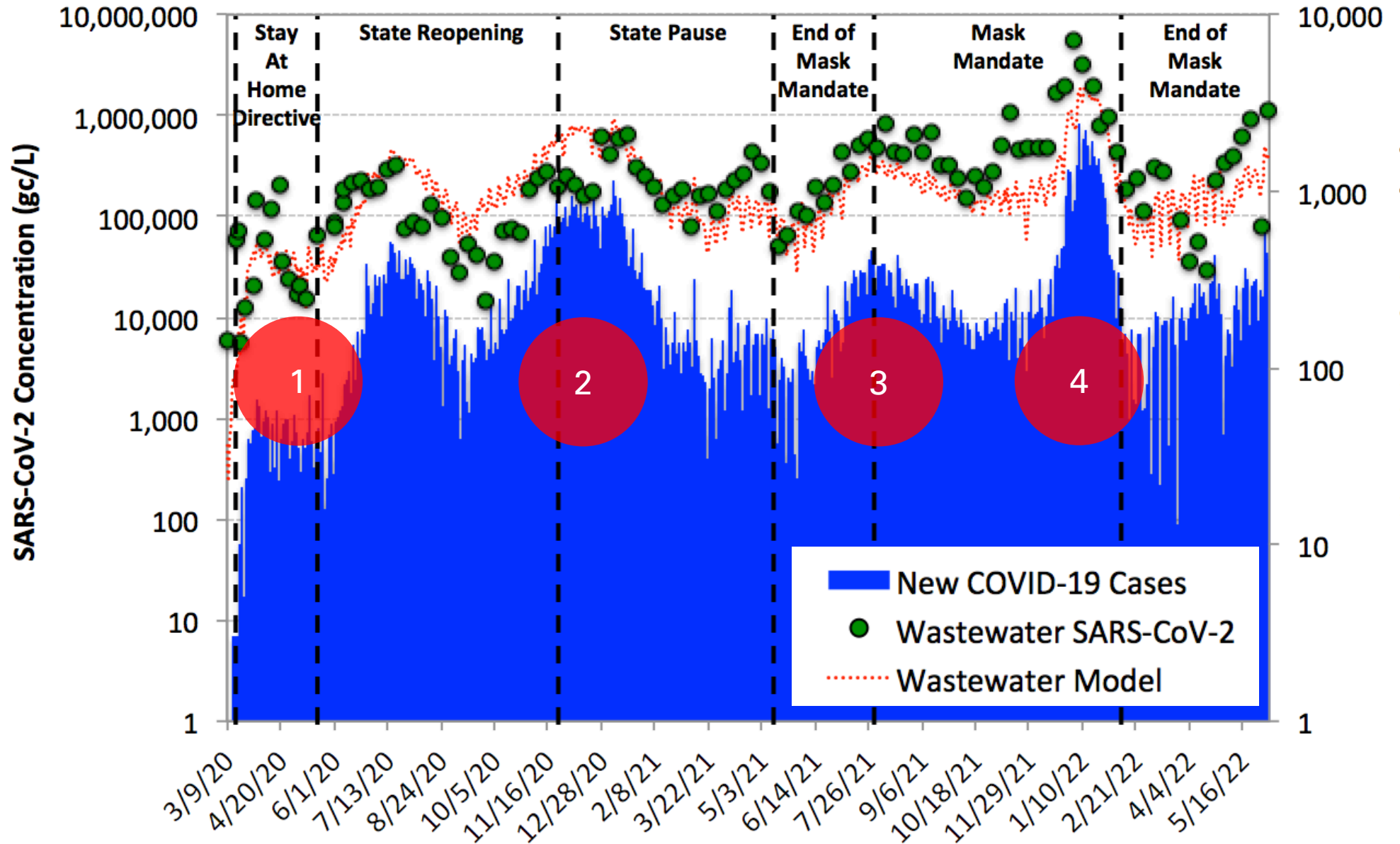




# Southern Nevada: March 2020 – June 2022

## Focal Points:

1. Early Pandemic
2. Winter Spike
3. Delta Wave
4. Omicron Surge




New COVID-19 Cases in Sewershed

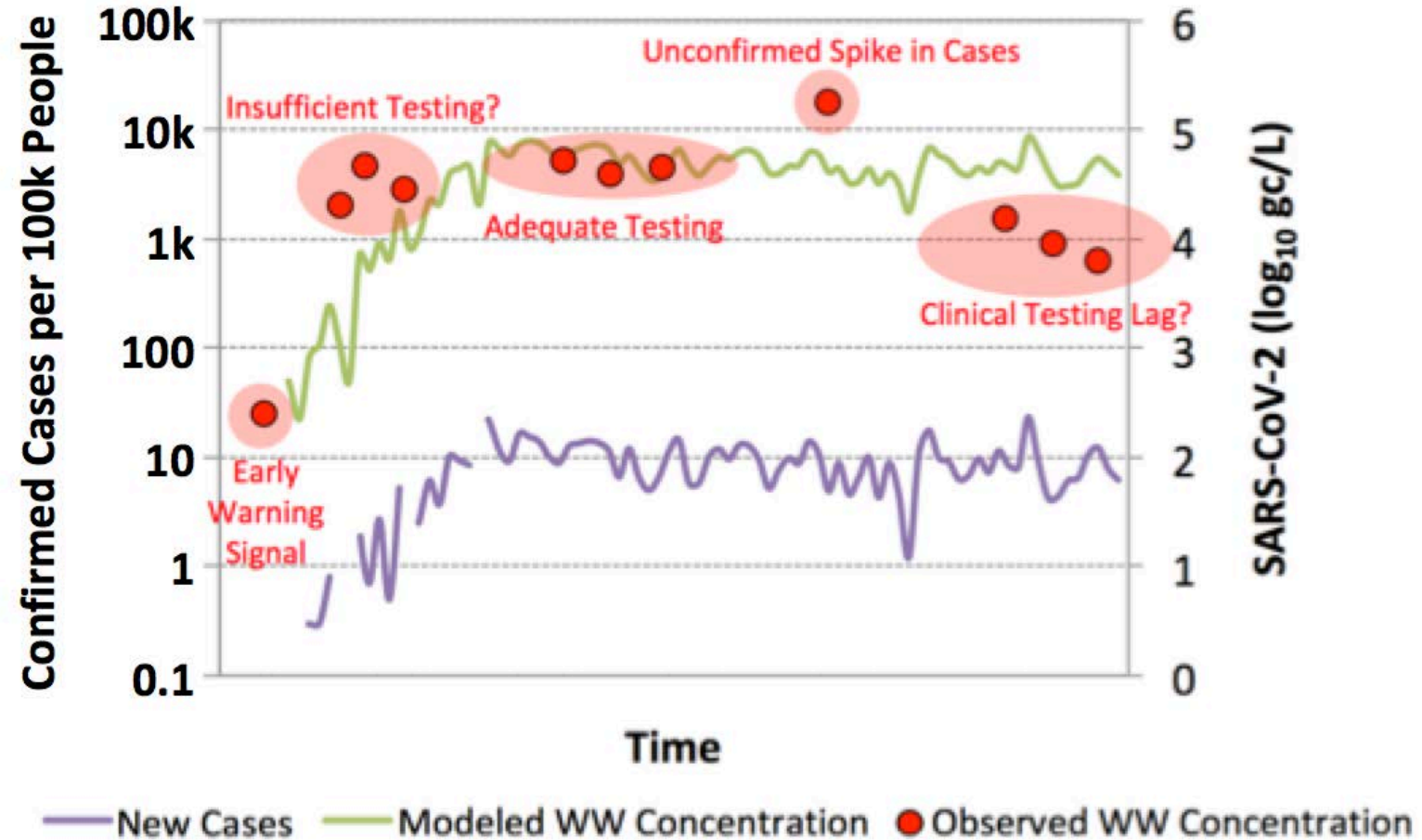


# Phase 1: Early Pandemic

## Goals:

1. Assess drinking water risk 
2. Develop and Finalize Methods
3. Make Sense of the Data:
  - Clinical Testing Data
  - Observed Wastewater Data
  - Modeled Wastewater Data

## Hypothetical Example

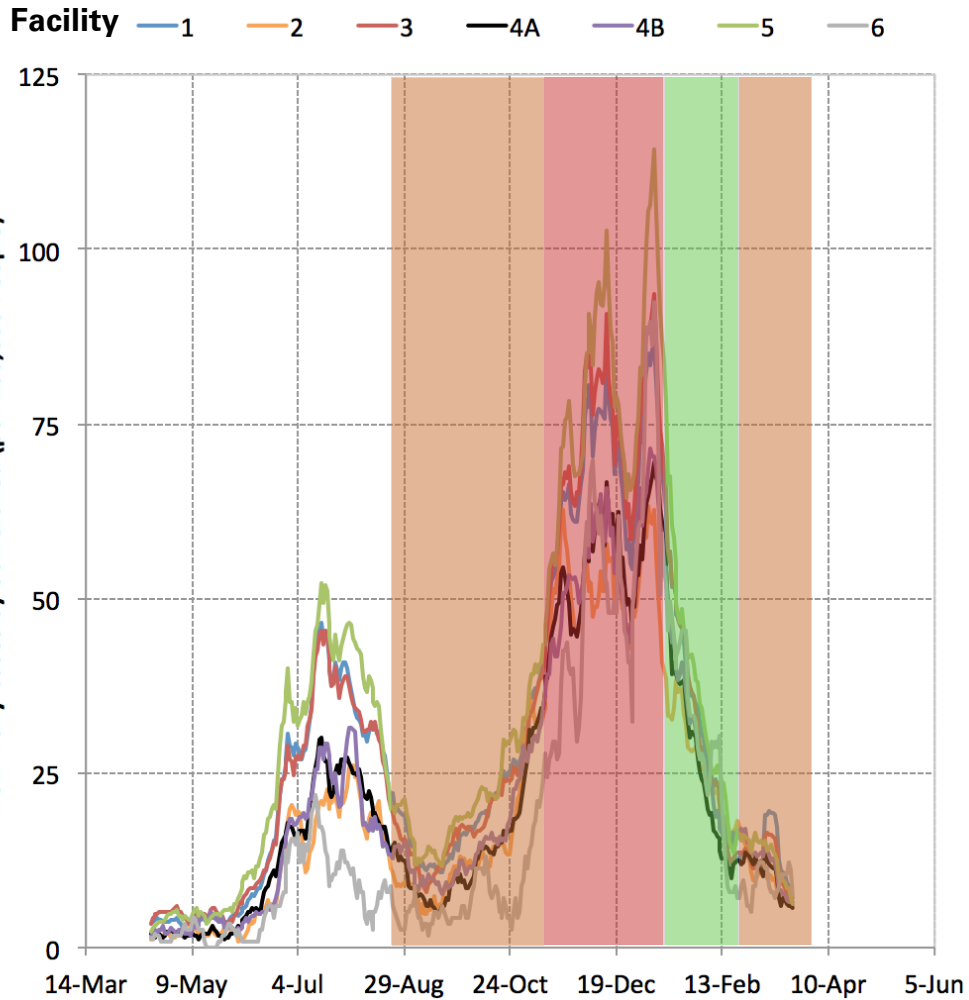




# Phase 2: Winter Spike

**Sewershed COVID-19 Cases**  
(per 100,000 people)

**Sewershed SARS-CoV-2 Concentrations**  
(log<sub>10</sub> gc/L)

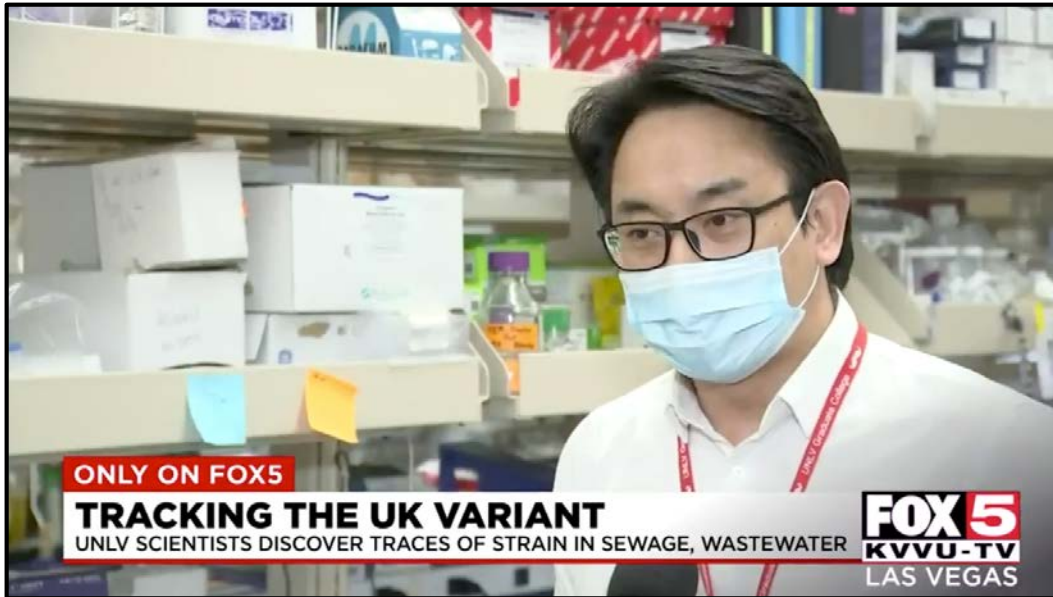


Date	Facility 1	Facility 2	Facility 3	Facility 4A	Facility 4B	Facility 5	Facility 6
Sample	Grab Prim.	Comp. Inf.	Comp. Inf.	Grab Inf.	Grab Inf.	Comp. Inf.	Grab Inf.
Mon. 8/24	5.0	4.4	5.3	No Sample	No Sample	No Sample	No Sample
Mon. 8/31	4.6	4.4	5.2	5.3	7.2	5.8	No Sample
Tue. 9/8	4.5	5.1	5.4	4.8	4.4	5.3	No Sample
Mon. 9/14	4.7	4.9	5.8	5.1	5.9	5.8	No Sample
Mon. 9/21	4.6	5.1	5.2	5.3	5.4	5.4	No Sample
Mon. 9/28	4.2	5.0	5.3	5.2	6.4	5.4	No Sample
Mon. 10/5	4.6	No Sample	5.8	No Sample	No Sample	No Sample	No Sample
Mon. 10/12	4.9	4.9	5.8	5.9	5.9	5.8	No Sample
Mon. 10/19	4.9	4.8	5.9	5.6	6.2	5.6	No Sample
Mon. 10/26	4.8	5.1	5.8	5.5	5.5	5.6	No Sample
Mon. 11/2	5.3	5.2	6.3	6.5	5.6	6.3	No Sample
Mon. 11/9	5.4	5.4	6.0	6.7	6.0	6.0	No Sample
Mon. 11/16	5.5	5.6	6.4	5.8	7.1	6.0	No Sample
Mon. 11/23	5.3	5.6	6.4	6.5	No Sample	6.2	No Sample
Mon. 11/30	5.4	5.4	6.2	5.9	6.5	6.0	No Sample
Mon. 12/7	5.3	5.5	6.3	6.5	7.0	6.3	No Sample
Mon. 12/14	5.2	5.6	6.2	6.5	6.7	6.4	5.9
Mon. 12/21	5.2	5.6	5.9	5.9	6.4	6.1	5.9
Mon. 12/28	5.8	5.9	6.6	6.4	6.9	6.4	8.7
Mon. 1/4	5.6	6.1	6.6	6.6	6.5	6.3	6.4
Mon. 1/11	5.8	5.8	6.5	6.2	6.4	6.5	6.0
Mon. 1/18	5.8	5.8	6.1	5.9	6.4	6.0	6.1
Mon. 1/25	5.5	5.9	6.1	6.2	6.2	5.9	6.5
Mon. 2/1	5.4	5.4	6.1	5.7	6.1	5.9	5.5
Mon. 2/8	5.3	5.4	6.0	6.1	6.0	5.3	6.2
Mon. 2/15	5.1	5.1	6.5	5.6	5.9	6.1	6.3
Mon. 2/22	5.2	5.4	5.6	6.0	6.0	5.7	5.4
Mon. 3/1	5.3	5.0	5.8	5.8	5.4	6.1	5.3
Mon. 3/8	4.9	4.9	5.5	5.5	5.4	5.6	5.5
Mon. 3/15	5.2	5.5	5.9	5.2	6.4	Non-Detect	6.4
Mon. 3/22	5.2	5.2	5.9	5.5	5.8	Inconclusive*	6.8
Mon. 3/29	5.1	5.0	5.8	6.0	5.1	5.6	5.0





# Phase 2: Winter Spike





# Phase 2: Early Variants of Concern

## Alpha Variant (UK or B.1.1.7)

- Identified as variant of concern in Late 2020
- First detection in Southern Nevada **wastewater** in **December 2020**
- First **confirmed case** in Southern Nevada in late **January 2021**
- ~1,000 confirmed cases in Clark County in total

## Epsilon Variant (California or B.1.427/B.1.429)

- Started spreading rapidly in CA in November 2020
- Dominated sewage from **homeless shelter** in early December 2020
- ~200 confirmed cases in Clark County in total

## Beta Variant (South Africa or B.1.351)

- Never detected in Southern Nevada wastewater
- 9 confirmed cases in Clark County in total





## Phase 2: Estimating Infections

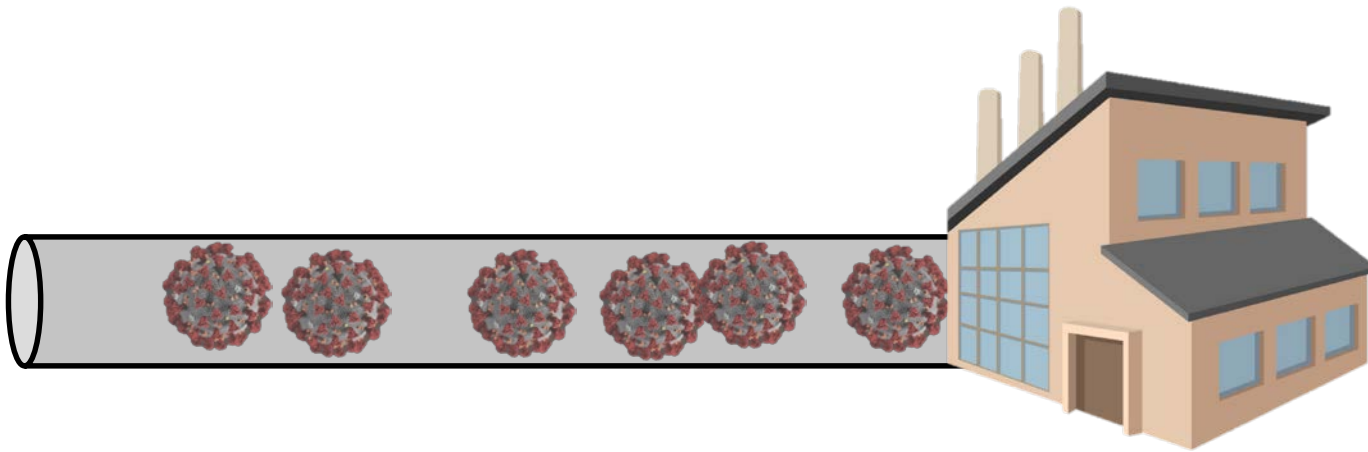
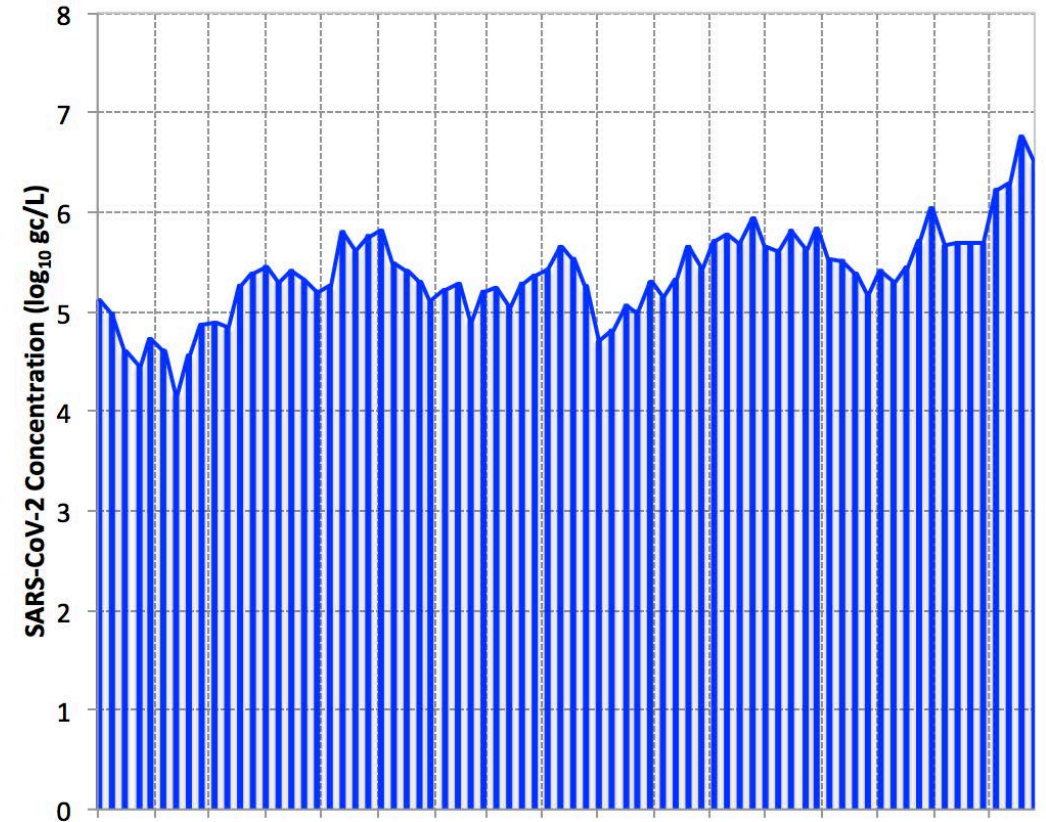
$$\text{INFECTIONS} = \frac{\text{TOTAL VIRAL LOAD}}{\text{VIRAL LOAD PER INFECTION}}$$





# Phase 2: Total Viral Load at Facility 1

Facility 1 Wastewater Concentration

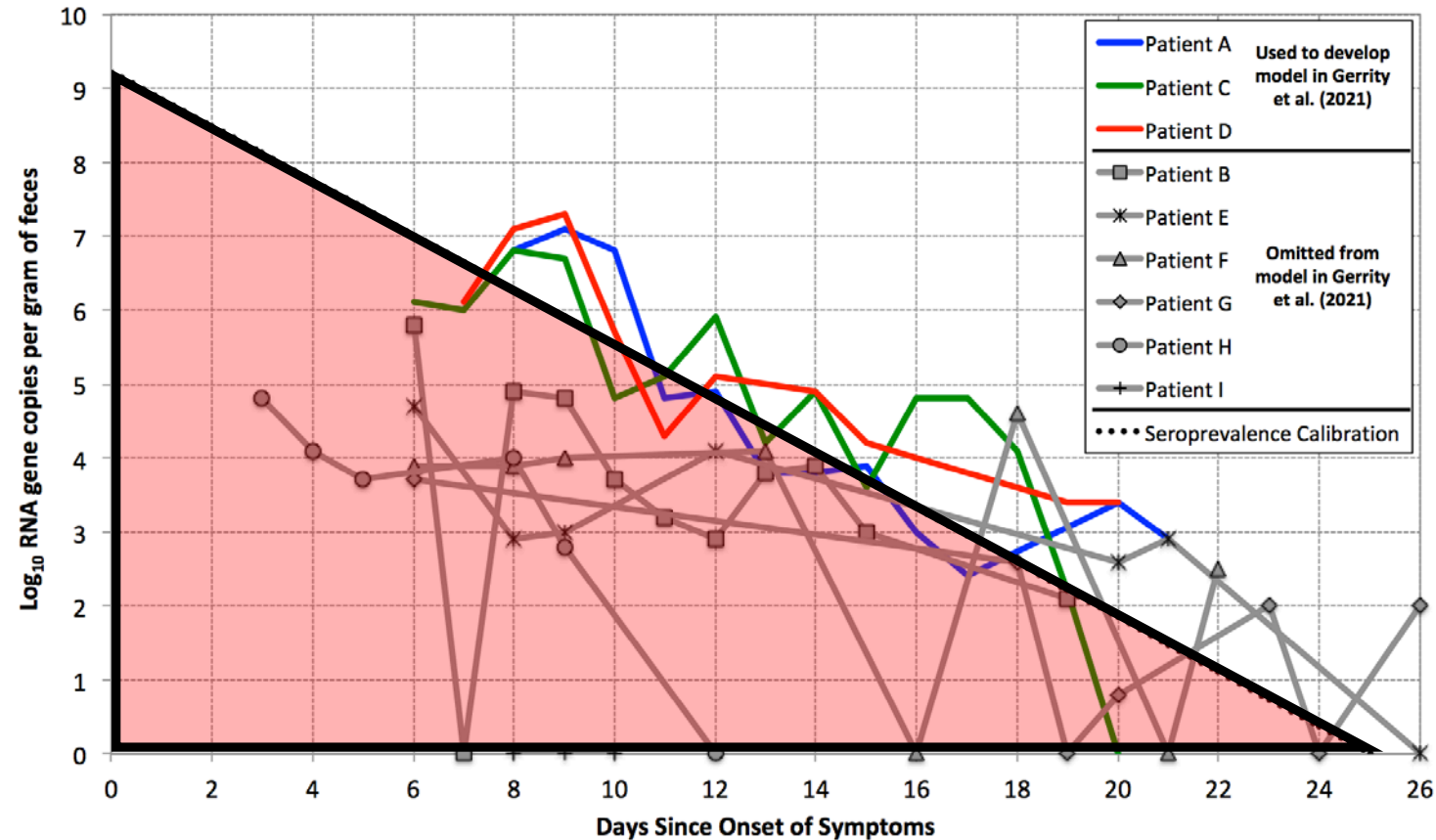
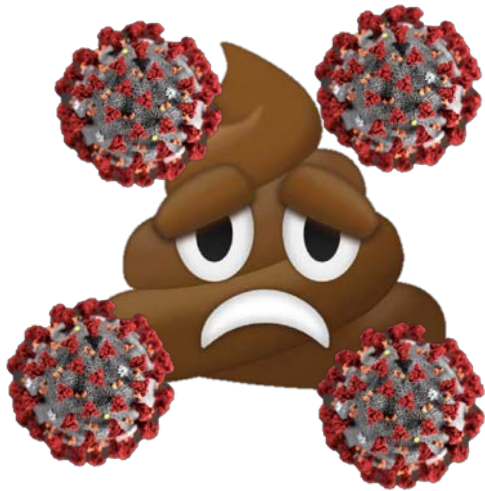


**Area under wastewater curve = total SARS-CoV-2 in wastewater (after accounting for flow rate)**

**≈ 83 quadrillion gene copies into Facility 1 (March 2020 – April 2021)**



# Phase 2: Fecal Shedding of SARS-CoV-2



**Calibrated to CDC seroprevalence data for Nevada:  $10^{9.2}$  gc/gram and 126 grams feces/day**

**Area under fecal shedding curve = total number of viruses shed over infection period**

**≈ 240 billion SARS-CoV-2 viruses per infection!**



## Phase 2: Infection Estimates (April 2021)

Estimated Infections (Wastewater)	% of Sewershed Population (Wastewater)	Reported Infections (Confirmed) <sup>c</sup>	% of Sewershed Population (Confirmed)	Ascertainment Ratio
342,558 <sup>a</sup>	39%	90,271	10%	3.8
256,809	34%	79,423	10%	3.2
93,428	37%	30,104	12%	3.1
6,420	7%	6,420	7%	1.0
79,440	59%	10,334	8%	7.7
61,579	54%	9,173	8%	6.7
3,441 <sup>b</sup>	21%	1,050	6%	3.3
N/A	N/A	N/A	N/A	N/A
<b>843,675</b>	<b>38%</b>	<b>226,775</b>	<b>10%</b>	<b>3.7</b>

### Potential Questions to Answer:

- Herd Immunity? → Infections + 'SARS-CoV-2 Naive' Vaccinations = Target
- Vaccine Prioritization? → Which subpopulations are most susceptible?
- Demographics? → Age and income impact prevalence and access to testing?



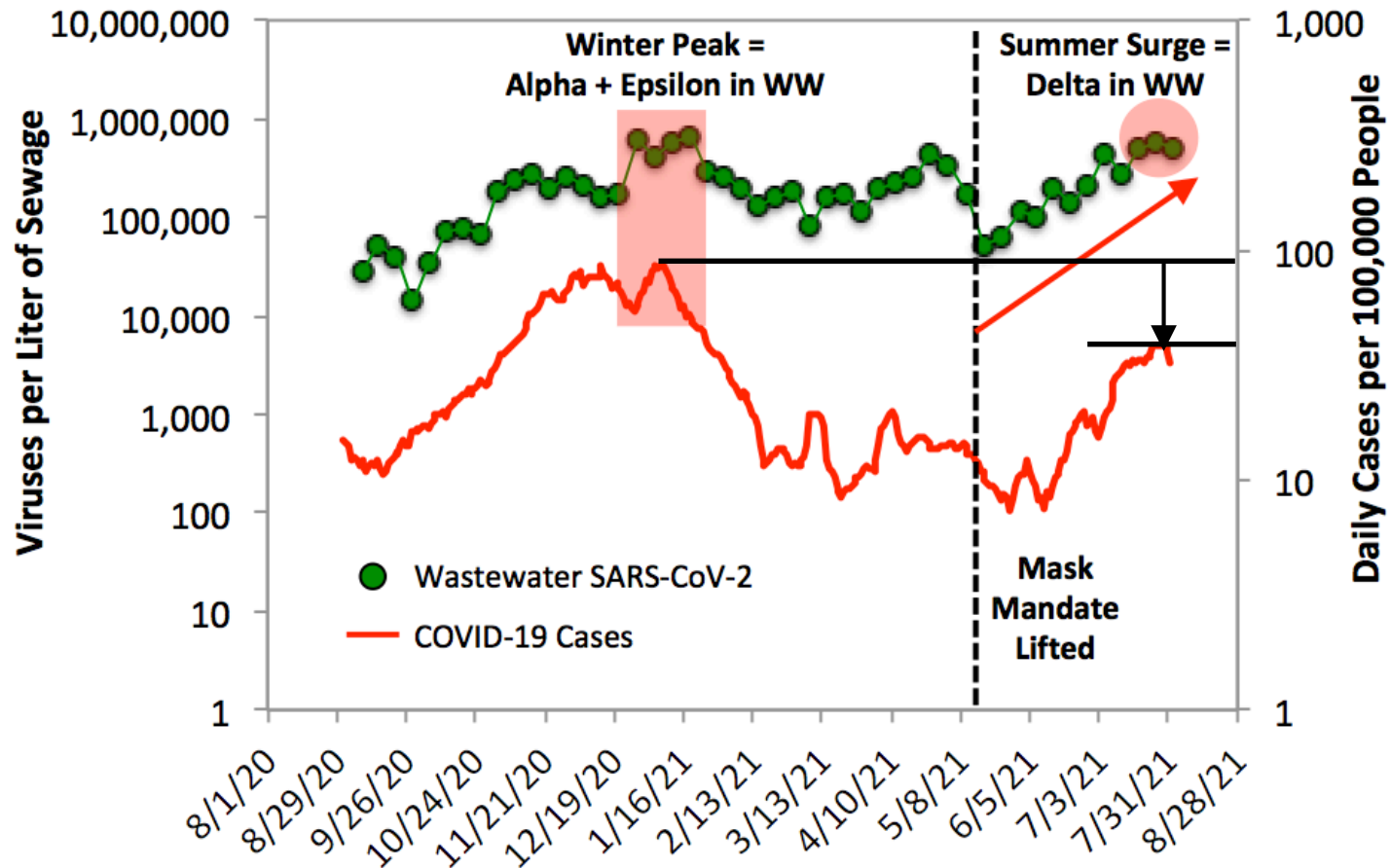
# Phase 3: Delta Wave

MATT SIMON

SCIENCE 08.27.2021 03:21 PM

## Why Florida's Covid Surge Is Screwing With the Water Supply (Hint: Oxygen)

More people in the hospital means more people need oxygen. But treatment plants also need the gas to purify water.



### Case vs. WW Discrepancy:

- Undertesting?
- Tourism impact?
- Change in fecal shedding?
- Combination?





# Phase 4: Omicron Surge

HOME > SPORTS

## Nearly 4% of NFL players tested positive for COVID-19 in 2 days and it could turn into a nightmare for the league

 **Barstool Sports** ✓  
2h · 🌐

The Washington Covid Football Team



BARSTOOLSPORTS.COM

Every Player On The Washington Football Team Now Has COVID

 **NBA Communications** ✓  
@NBAPR

The following was released by the NBA:



**GOLDEN STATE AT DENVER GAME POSTPONED**

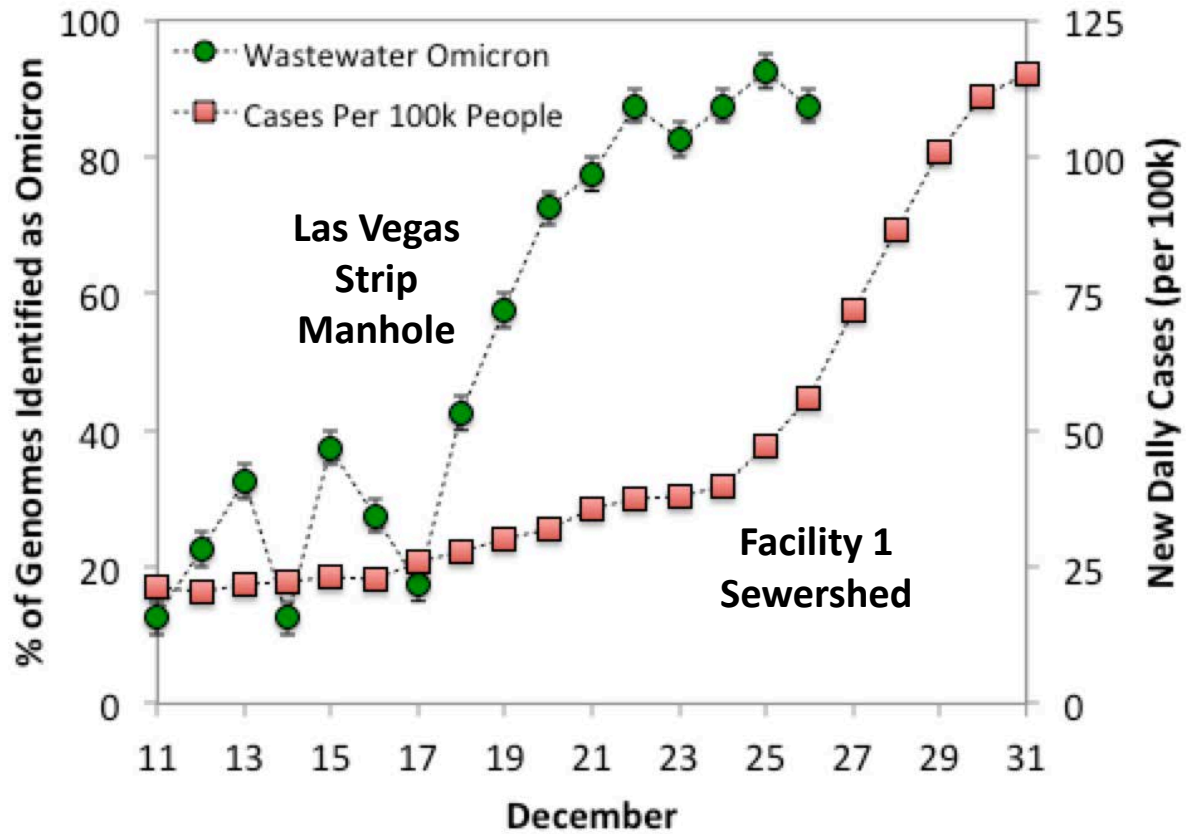
NEW YORK, Dec. 30, 2021 – The NBA announced today that the Golden State Warriors at Denver Nuggets game scheduled for tonight at Ball Arena has been postponed. The Nuggets do not have the league-required eight available players to proceed with the game against the Warriors.

###

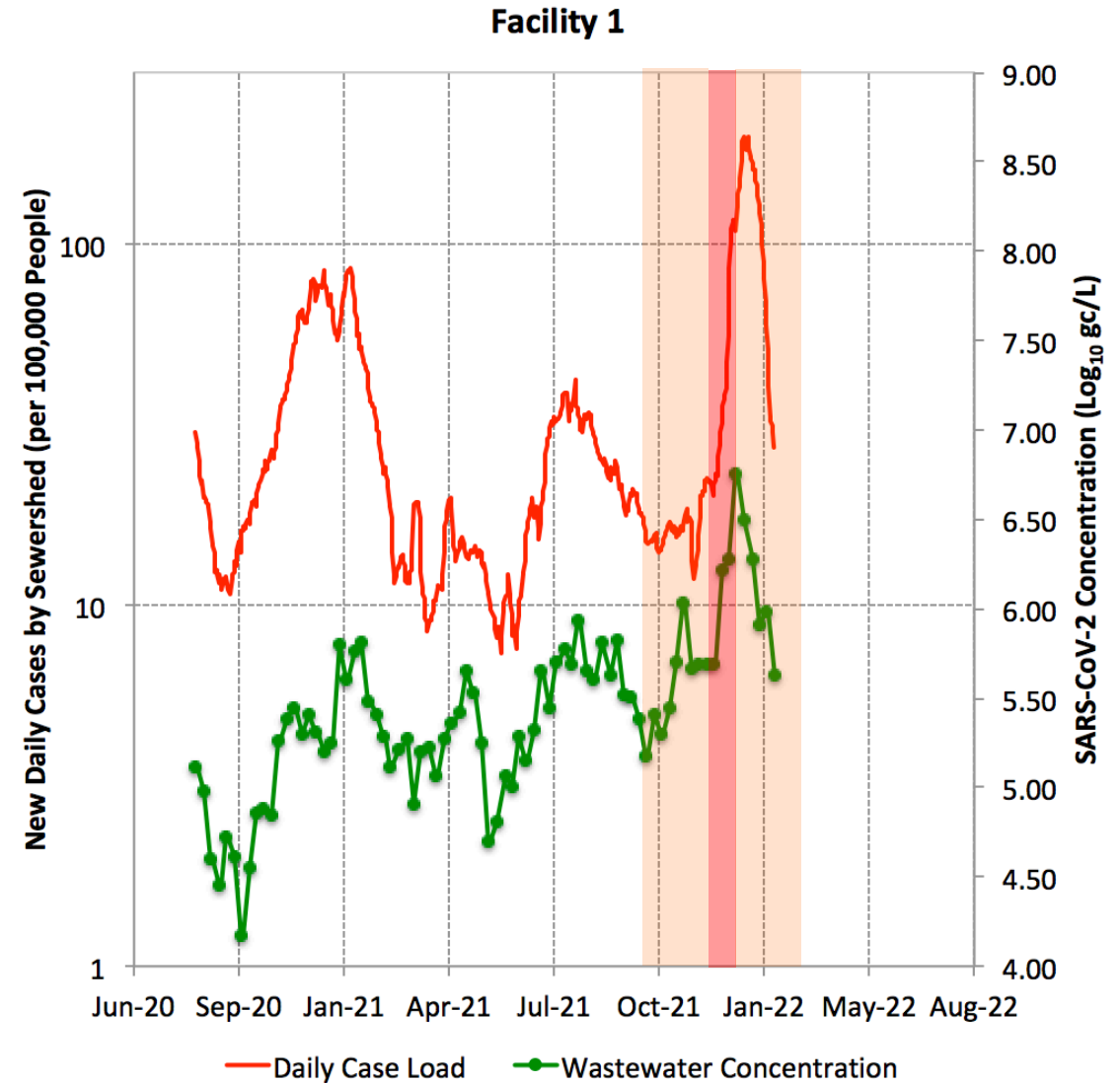
4 PM · Dec 30, 2021



# Phase 4: Omicron Surge

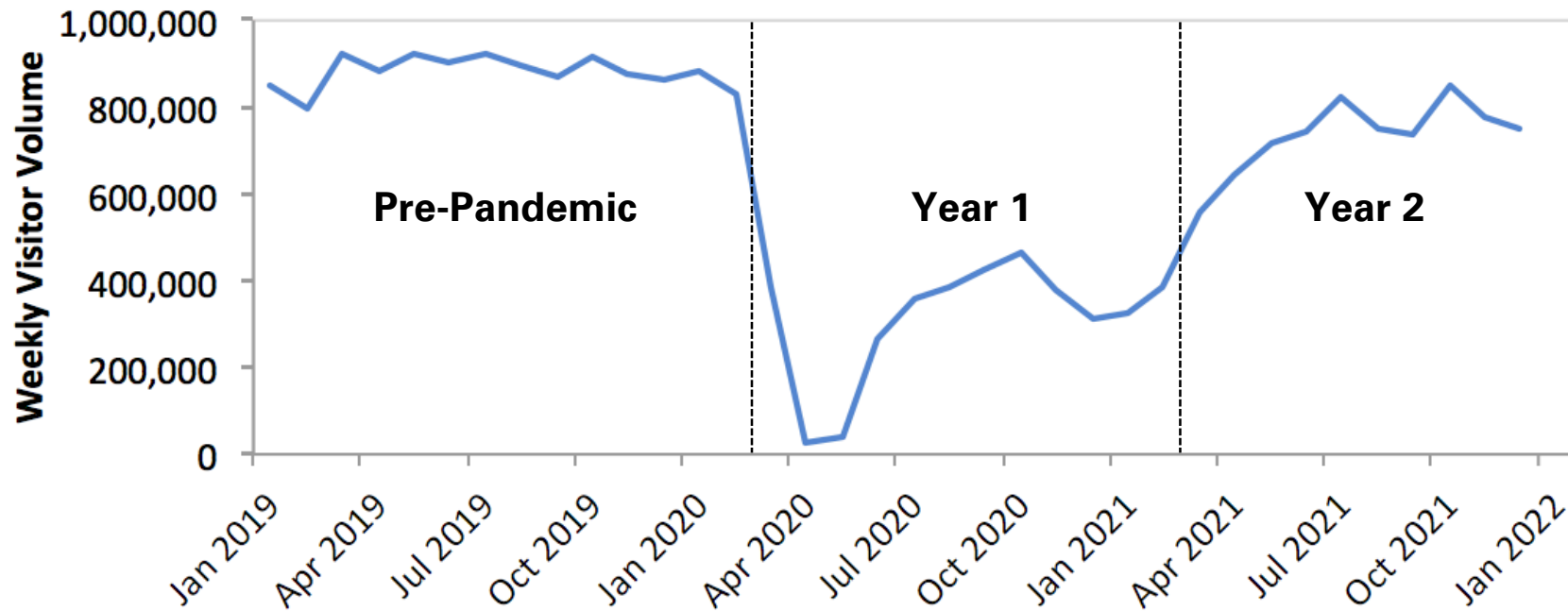


**Omicron displaced Delta in <2 weeks!**





# Phase 4: Impacts of Tourism



## Leveraging wastewater sequencing data:

- Facility 1 (Locals + Tourism) → Omicron = 38% on 12/13 and 80% on 12/20
- Other WWTPs (Locals) → Omicron = 4% on 12/13 and 48% on 12/20
- Developed a System of Equations
- Visitors may be contributing >60% of viral load to Facility 1 in Year 2

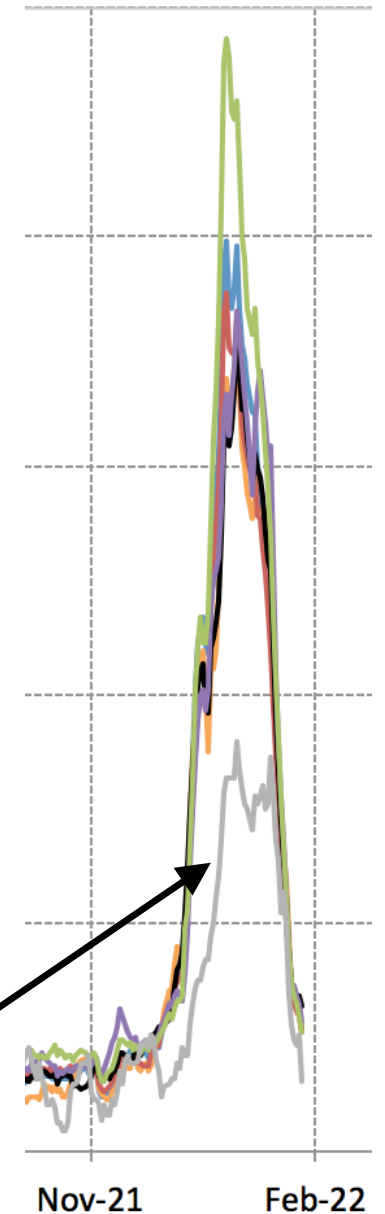


# Phase 4: Ascertainment Ratios

Ascertainment Ratios = X-Fold Infection Undercount					
Month	Clark County	City of Las Vegas	North Las Vegas	Clark County (No Tourism)	Boulder City
August	18	7	8	7	6
September	13	6	5	5	4
October	8	4	4	3	4
November	23	6	4	9	5
December	12	2	3	5	10
January	13	3	6	5	16
February	11	2	3	5	3
<b>Average</b>	<b>14</b>	<b>4</b>	<b>5</b>	<b>6</b>	<b>7</b>

**WW Estimate = 475,000 infections in January → 20% of population!**

**Boulder City**





# Concluding Thoughts



# Wastewater Surveillance for Policy Changes

## Nevada governor announces an immediate end to mask mandate



STEVE MARCUS

Nevada Gov. Steve Sisolak responds to question from a reporter during a visit to the Horizon Ridge Wellness Clinic on East Flamingo Road Thursday, Dec. 23, 2021. The visit was part of Protect Nevadas Future week of action, a statewide effort to vaccinate children ages 5 to 11 years against COVID-19 from Dec. 18 to 23.

In making his announcement, Sisolak cited a decline in overall cases, hospitalizations and the amount of virus detected during wastewater testing. At the height of the omicron variant surge on Jan. 10, Nevada recorded 7,865 new cases; that number has declined to about 1,280 in recent days.



# Path Forward for Wastewater Surveillance

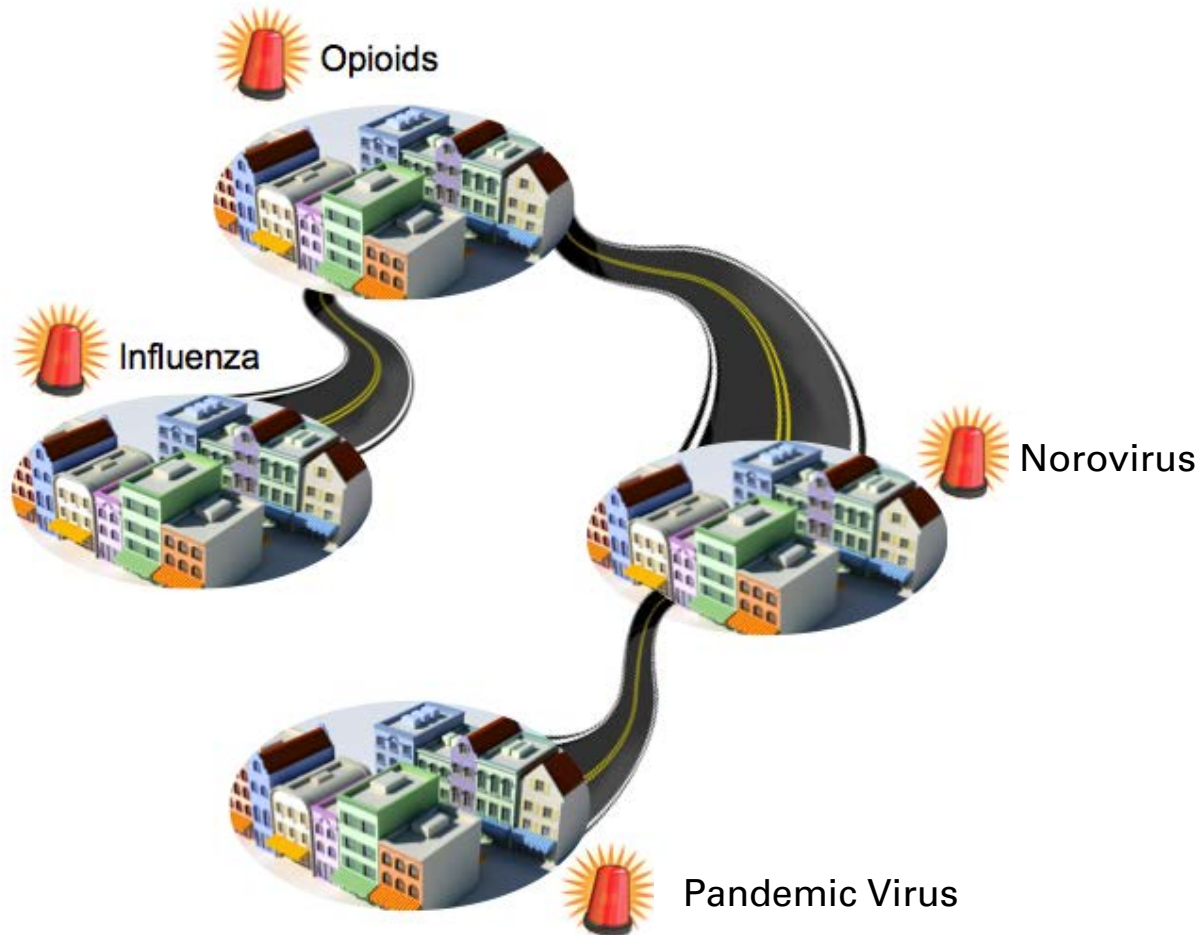
## Other Targets

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- Pharmaceuticals, illicit drugs, metabolites<sup>a</sup>
- Antimicrobial resistance
- Enteric viruses (norovirus, adenovirus)
- Influenza
- *Candida auris*<sup>b</sup>
- Monkeypox

<sup>a</sup>Initiated in May 2022 (39 compounds)

<sup>b</sup>Isolated from Facility 1 by Utah Public Health Laboratory (sequencing comparison pending)

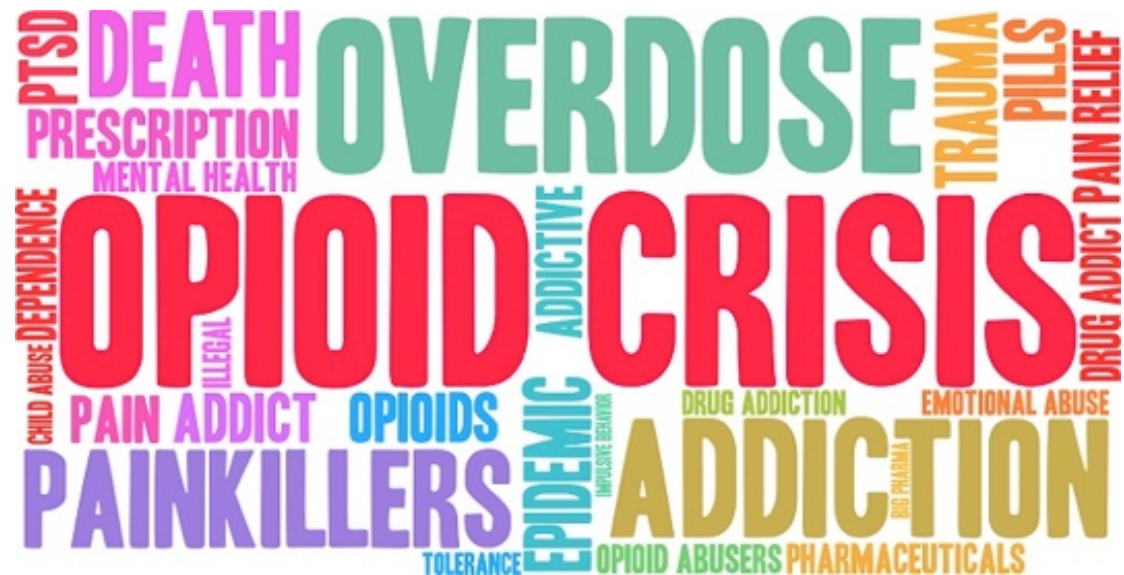




# Intersection of Crises – Drug Abuse

**Percent increase in Facility 1 wastewater concentrations from 2010 to 2022:**

- Heroin Metabolite = **264%**
- Cocaine = **56%**
- Metabolite 1 = **72%**
- Metabolite 2 = **147%**
  
- Methamphetamine = **274%**
- Metabolite = **217%**







# WW Surveillance – Trace Organics (ng/L)

## Consistently Elevated (Heroin Metabolite)

Acetylmorphine	Facility 1	Facility 2	Facility 3	Facility 4A	Facility 4B	Facility 5	Facility 6
Week 1	63	73	100	<50	<50	54	<50
Week 2	<50	<50	110	51	<50	<50	<50

## Intermittent Spikes (Cocaine Metabolite)

Benzoyllecgonine	Facility 1	Facility 2	Facility 3	Facility 4A	Facility 4B	Facility 5	Facility 6
Week 1	2,500	1,100	2,800	1,400	920	2,500	450
Week 2	2,400	1,500	2,600	2,000	3,000	2,400	1,700

## Sewershed Discrepancies → Demographics? (Methamphetamine)

Methamphetamine	Facility 1	Facility 2	Facility 3	Facility 4A	Facility 4B	Facility 5	Facility 6
Week 1	9,300	2,200	8,100	5,000	5,200	5,800	5,000
Week 2	6,900	980	8,300	4,900	4,900	5,900	4,300



# Acknowledgments

- Staff at the collaborating wastewater agencies: Clark County Water Reclamation District, City of Henderson, City of Las Vegas, City of North Las Vegas, Boulder City
- This work was partially supported by the **National Science Foundation** under Grant No. 1832713 and by the **Southern Nevada Health District** and the **U.S. Centers for Disease Control and Prevention** under Award C2200025/NH75OT000057
- **For additional information:**
  - SNWA Podcast: Poops Don't Lie – Tracking a Pandemic Using Wastewater<sup>a</sup>
  - SNWA Podcast: How the Pandemic Led to New Insights for Wastewater Surveillance<sup>b</sup>
  - WEF 'Sewer Signals' Podcast<sup>c</sup>
  - NV Empower Program<sup>d</sup>
  - SNWA: [Daniel.Gerrity@snwa.com](mailto:Daniel.Gerrity@snwa.com)
  - UNLV: [Edwin.Oh@unlv.edu](mailto:Edwin.Oh@unlv.edu)

<sup>a</sup><https://watersmarts.buzzsprout.com/1568941/8125328-poops-don-t-lie-tracking-a-pandemic-using-wastewater>

<sup>b</sup><https://watersmarts.buzzsprout.com/1568941/10506941-ah-ha-how-the-pandemic-led-to-new-insights-for-wastewater-surveillance>

<sup>c</sup>[https://nwbe.org/?page\\_id=465#episode-3](https://nwbe.org/?page_id=465#episode-3)