Case Study: Pool 34 Embankment

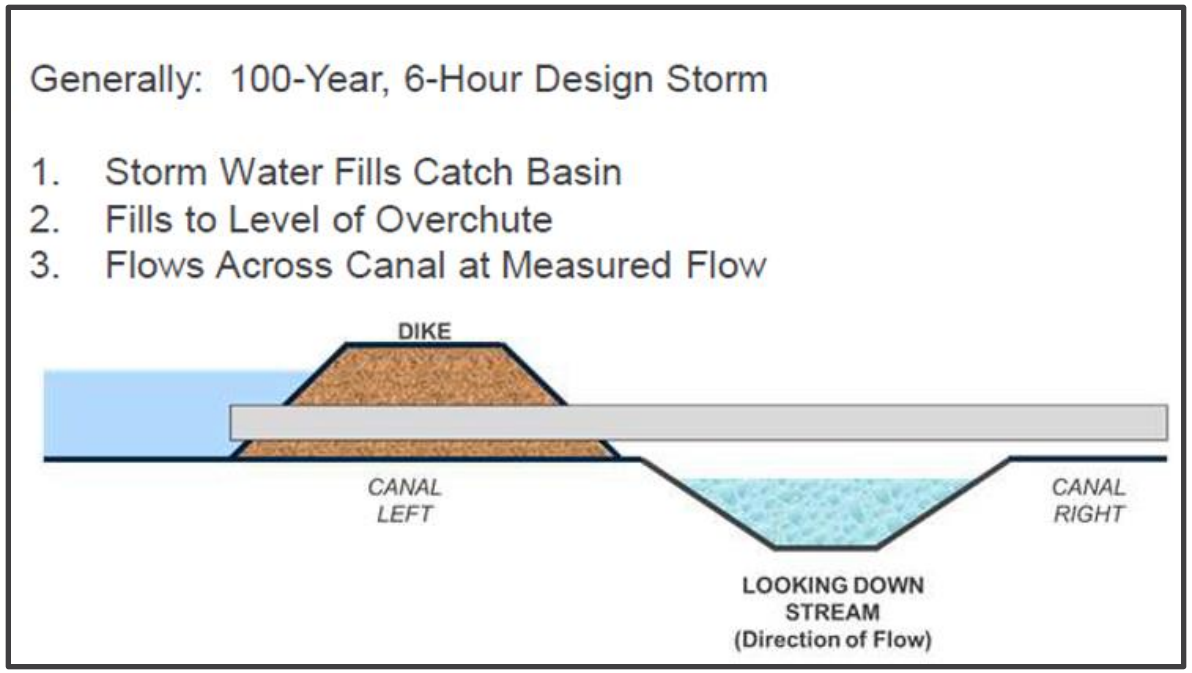
Ryan Johnson, Engineering Services Manager

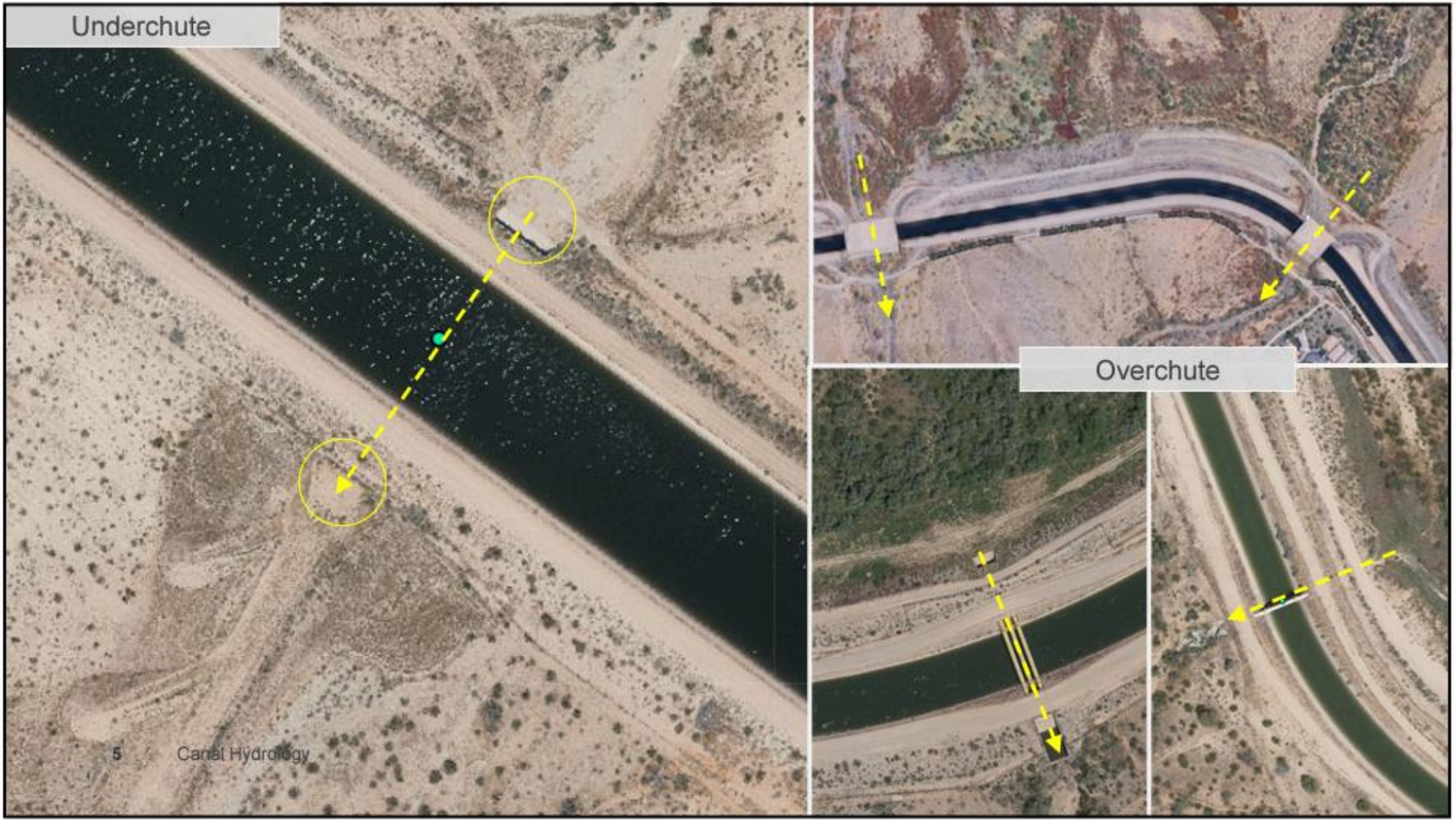
Canal Design for Hydrology

- CAP canal bi-sects the State's natural hydrology
- Bureau of Reclamation's general design Storm
  - 100-year, 6-hour storm (major drainage ways and dike bank height)
  - 50-year, 6-hour storm (minor drainage ways)
- Storm water:
  - Contained and flows over/under CAP canal

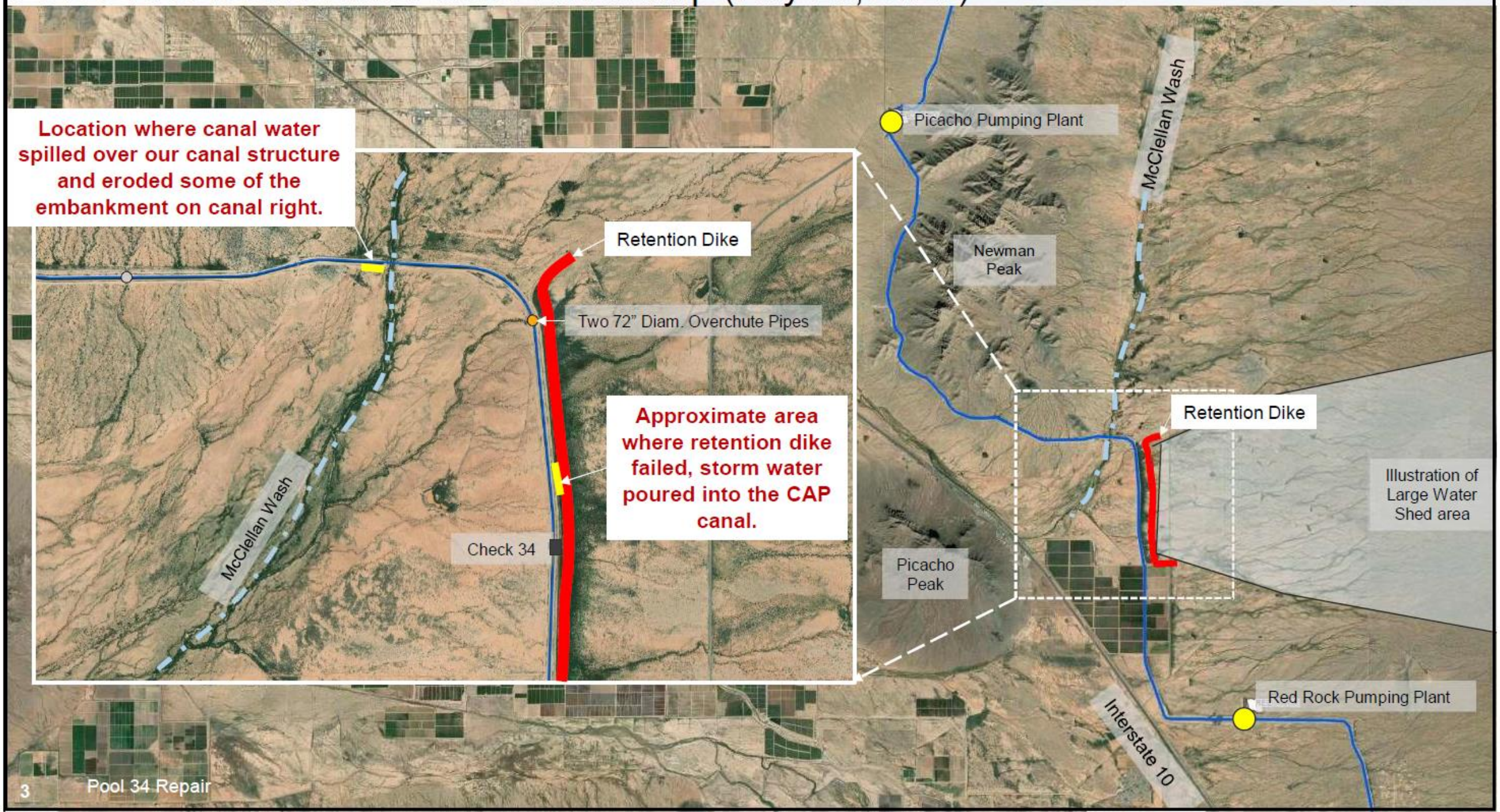
Canal Was Designed for Hydrology

- CAP owns and maintains 165 miles of earthen dike:
  - Primarily utilized native soils (not zoned embankments)
  - Contain storm and control peak flows
- Cross drainage
  - 149 overchutes – canal in “cut”
  - 102 underchutes – canal in “fill”
  - Safely convey impounded storm water




Underchute
Overchute

Pool 34 Protective Dike Failure Event Map (July 25, 2021)



July 25th Photos – Active Flooding, Water Behind Dike, Breaches in Dike

Earthen Dike Failure

Pool 34 Repairs

2021 Repair Contract

- Earthen dike and O&M Road
- Remove damaged concrete liner
- Clean debris from canal

September 2021 Board Meeting

- Not to exceed $4.5 million
- $3.4 million final cost

2022 Repair Contract

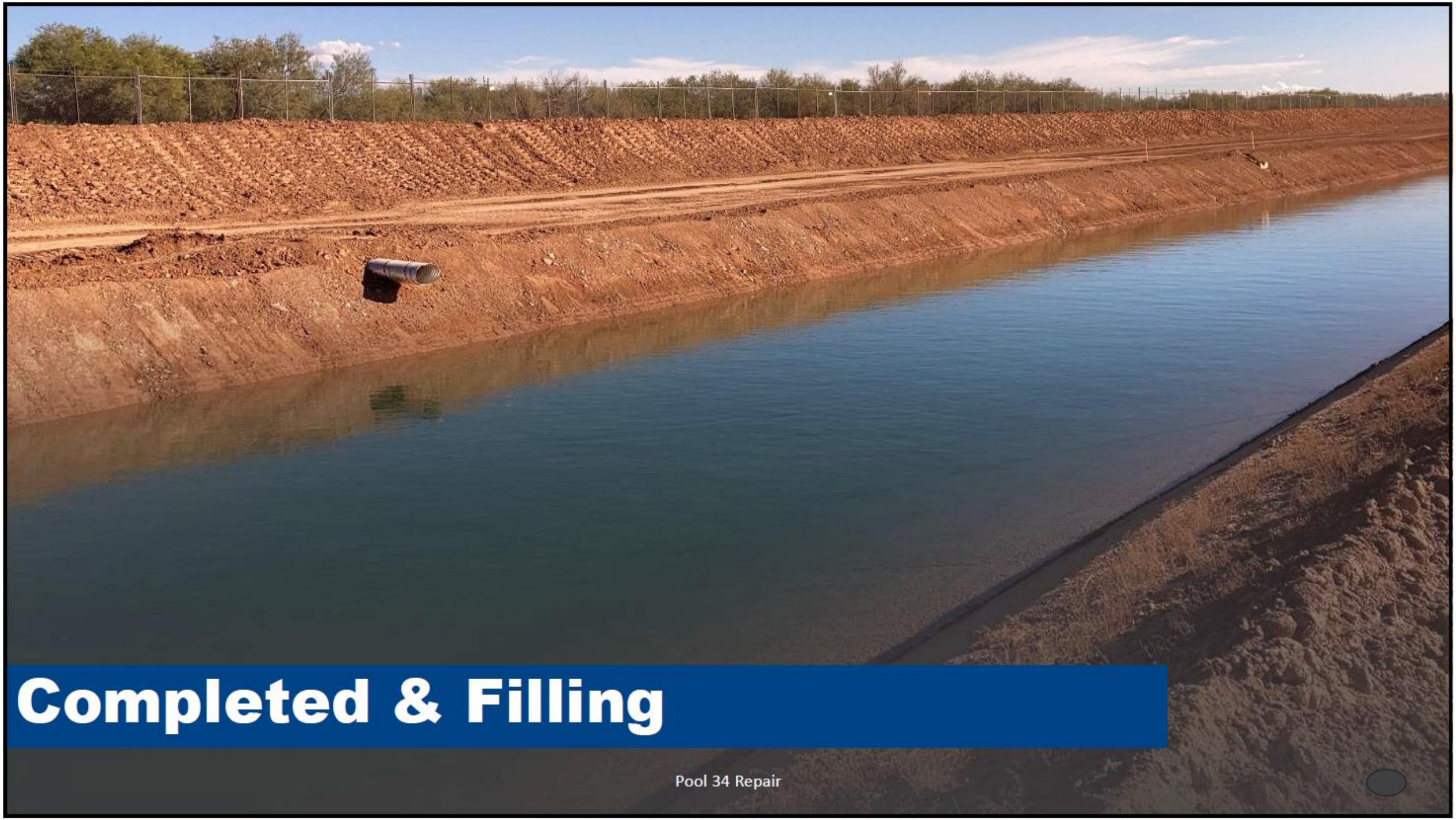
- Concrete liner replacement
- Over 4,100 ft

August 2022 Board Meeting

- Not to exceed $8.5 million
- $7.1 million final cost

Final total cost:
$10.5 million
(NTE $13 million)

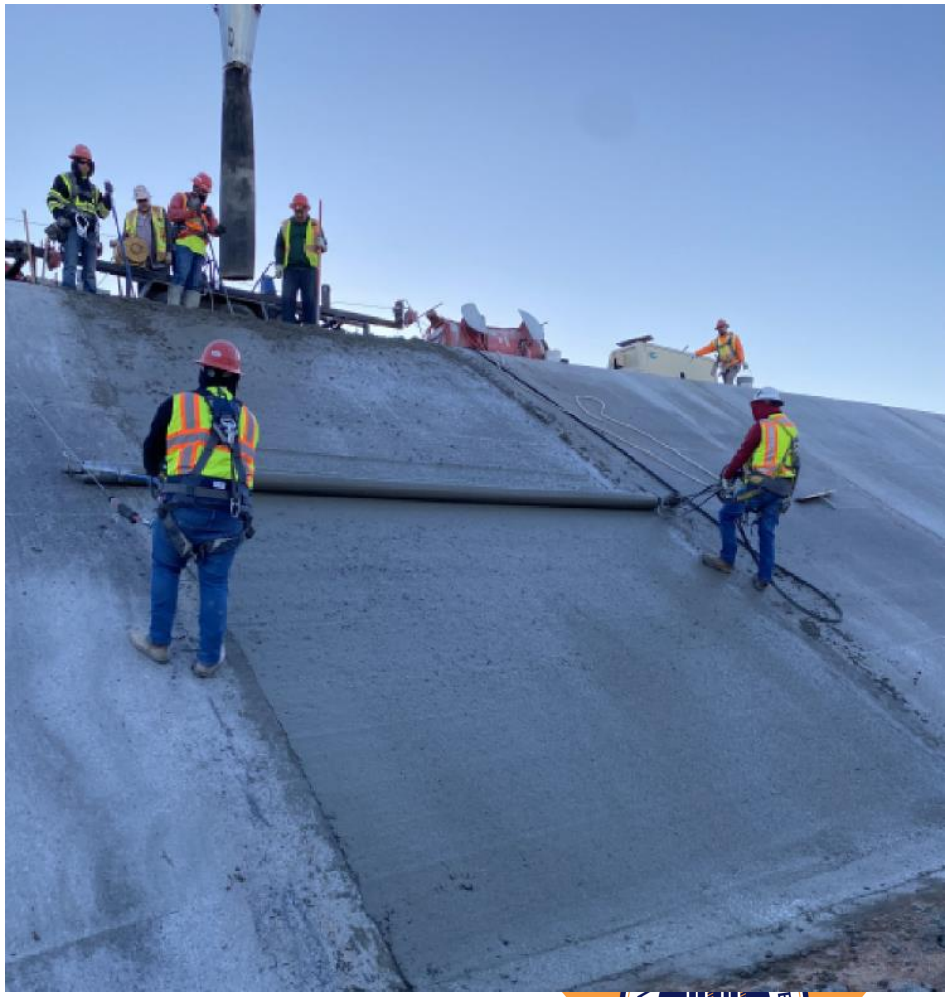
Damaged Canal Liner & Debris Removal



Completed & Filling

Pool 34 Repairs - 2022

Pool 34 Repairs - 2022



Pool 34 Repairs - 2022

Addressing Service Area Canal Risk

Changes in watershed or design storm & climate impact to design hydrology

- Changing upstream hydrology from development
  - Development containing stormwater
  - Hardscape – less infiltration, more runoff
- Potential for more intense or extreme storm events
  - Picacho area: 2018 and 2021 storm events

Addressing Service Area Canal Risk

Formation of Aqueduct Resiliency Committee

- Management Council sponsor: OP&E Director *(Brian Buzard)*
- Committee Chair: Engineering Services Manager *(Ryan Johnson)*
  - Maintenance Control Mnaager *(Robert Hitchcock)*
  - Reliability Engineering Supervisor *(Brandon Vigil)*
  - Civil-Mechanical Engineering Supervisor *(Sami Korpelainen)*
  - Engineers across maintenance and engineering & GIS Administrators

Addressing Service Area Canal Risk

Aqueduct Resiliency Committee Focus Areas

- Evaluates risk (probability x consequence)
  - Fill section, downstream population, hydrology
- Technical studies, analysis, and relevant data
  - External consultants – industry experts
- Recommends: project execution, maintenance procedures, elevated monitoring
- Utilization of GIS for geo-referenced data visualization

FOCUS LIMITED RESOURCES ON HIGHEST PRIORITY

On-going team, address system-wide risk to canal

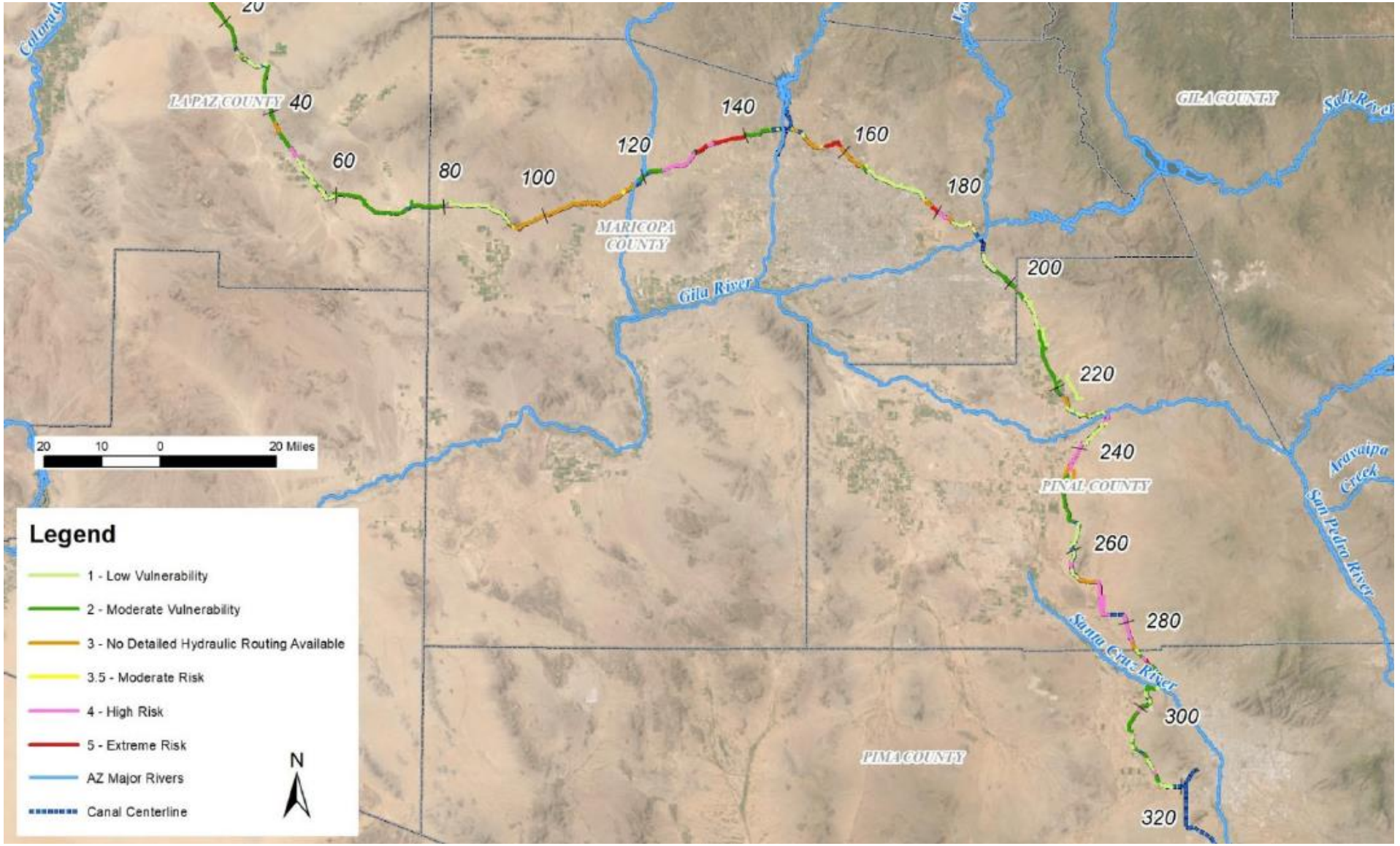
2022 Committee Action Plan

- GIS Visualization
- Build off the 2010 Canal-Wide Data Collection Study
  - Execute External Hydrology Contract
  - Local & Specific Expertise
  - Focus on Identified Higher Risk Hydrology Areas / Structures
- Identify System Improvements

Canal-Wide Hydrology Study

Study Purpose

Identify areas vulnerable to damage from storm water runoff

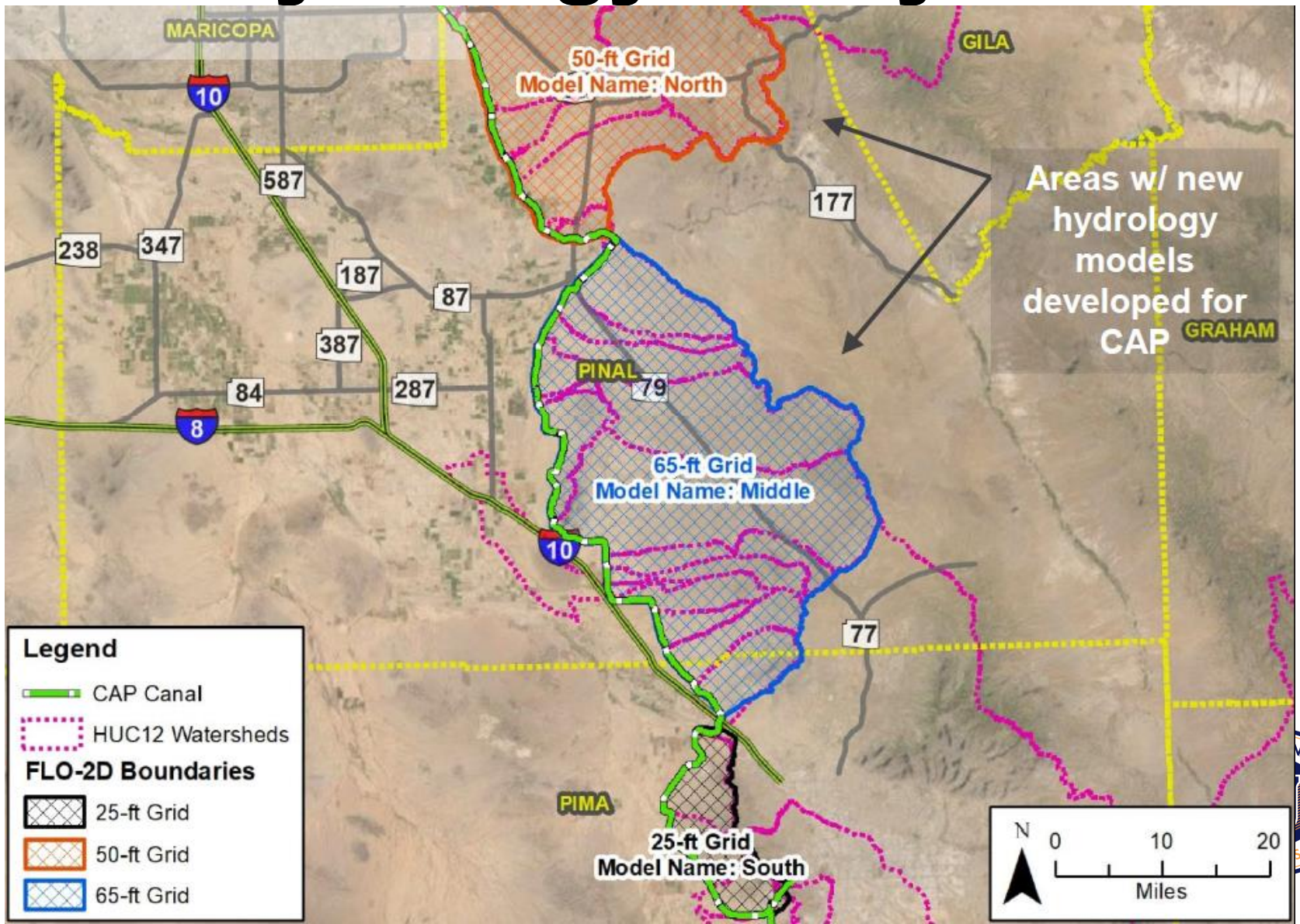


Pool 34

Canal-Wide Hydrology Study

Use new, modern hydrology models

Developed new models for much of the canal; areas without new studies by others



Canal-Wide Hydrology Study

Utilize the latest rainfall statistics

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.216 (0.178-0.266)	0.281 (0.233-0.348)	0.380 (0.311-0.468)	0.455 (0.370-0.559)	0.555 (0.446-0.680)	0.632 (0.501-0.770)	0.710 (0.554-0.862)	0.790 (0.606-0.957)	0.895 (0.671-1.09)	0.977 (0.716-1.19)
10-min	0.328 (0.271-0.408)	0.428 (0.355-0.529)	0.578 (0.473-0.712)	0.694 (0.564-0.850)	0.846 (0.678-1.03)	0.963 (0.763-1.17)	1.08 (0.843-1.31)	1.20 (0.922-1.46)	1.36 (1.02-1.65)	1.49 (1.09-1.81)
15-min	0.407 (0.336-0.503)	0.531 (0.440-0.656)	0.717 (0.587-0.883)	0.860 (0.699-1.05)	1.05 (0.841-1.28)	1.19 (0.946-1.45)	1.34 (1.05-1.63)	1.49 (1.14-1.81)	1.69 (1.26-2.05)	1.84 (1.35-2.24)
30-min	0.548 (0.452-0.677)	0.715 (0.592-0.884)	0.965 (0.790-1.19)	1.16 (0.942-1.42)	1.41 (1.13-1.73)	1.61 (1.27-1.96)	1.81 (1.41-2.19)	2.01 (1.54-2.43)	2.28 (1.70-2.76)	2.48 (1.82-3.02)
60-min	0.678 (0.560-0.838)	0.885 (0.733-1.09)	1.19 (0.978-1.47)	1.43 (1.17-1.76)	1.75 (1.40-2.14)	1.99 (1.58-2.42)	2.24 (1.74-2.71)	2.48 (1.91-3.01)	2.82 (2.11-3.42)	3.07 (2.25-3.74)
2-hr	0.789 (0.661-0.956)	1.02 (0.852-1.24)	1.35 (1.13-1.64)	1.61 (1.33-1.95)	1.96 (1.60-2.36)	2.23 (1.79-2.67)	2.50 (1.98-2.99)	2.78 (2.16-3.32)	3.15 (2.40-3.76)	3.44 (2.57-4.13)
3-hr	0.833 (0.696-1.02)	1.06 (0.894-1.30)	1.40 (1.17-1.70)	1.66 (1.37-2.01)	2.02 (1.65-2.43)	2.30 (1.86-2.77)	2.60 (2.06-3.12)	2.92 (2.27-3.49)	3.35 (2.53-4.01)	3.70 (2.73-4.43)
6-hr	0.984 (0.846-1.17)	1.24 (1.07-1.48)	1.59 (1.36-1.88)	1.86 (1.57-2.19)	2.23 (1.86-2.62)	2.53 (2.08-2.95)	2.83 (2.30-3.30)	3.14 (2.50-3.67)	3.57 (2.77-4.17)	3.90 (2.96-4.56)
12-hr	1.12 (0.970-1.32)	1.41 (1.22-1.66)	1.78 (1.53-2.08)	2.07 (1.77-2.42)	2.46 (2.08-2.87)	2.77 (2.31-3.21)	3.08 (2.53-3.57)	3.39 (2.76-3.94)	3.81 (3.02-4.44)	4.13 (3.22-4.85)
24-hr	1.28 (1.11-1.49)	1.62 (1.41-1.89)	2.09 (1.81-2.44)	2.47 (2.13-2.86)	3.00 (2.56-3.46)	3.41 (2.89-3.94)	3.85 (3.23-4.45)	4.30 (3.57-4.98)	4.93 (4.02-5.73)	5.44 (4.37-6.35)
2-day	1.37 (1.18-1.59)	1.75 (1.51-2.03)	2.28 (1.96-2.64)	2.71 (2.32-3.13)	3.31 (2.82-3.82)	3.78 (3.19-4.37)	4.28 (3.58-4.96)	4.80 (3.97-5.57)	5.53 (4.50-6.45)	6.11 (4.90-7.17)
3-day	1.45 (1.26-1.69)	1.86 (1.61-2.16)	2.45 (2.11-2.83)	2.92 (2.52-3.38)	3.59 (3.07-4.15)	4.13 (3.50-4.77)	4.71 (3.95-5.44)	5.31 (4.42-6.16)	6.17 (5.05-7.17)	6.86 (5.55-8.02)
4-day	1.54 (1.34-1.79)	1.97 (1.72-2.29)	2.62 (2.27-3.02)	3.14 (2.71-3.62)	3.88 (3.33-4.47)	4.48 (3.81-5.17)	5.13 (4.33-5.93)	5.82 (4.86-6.74)	6.80 (5.61-7.90)	7.61 (6.20-8.87)
7-day	1.74 (1.50-2.03)	2.23 (1.92-2.59)	2.95 (2.55-3.43)	3.55 (3.05-4.11)	4.39 (3.75-5.08)	5.08 (4.30-5.87)	5.81 (4.88-6.73)	6.60 (5.49-7.67)	7.72 (6.33-9.00)	8.64 (7.00-10.1)
10-day	1.89 (1.64-2.19)	2.43 (2.11-2.81)	3.22 (2.78-3.71)	3.85 (3.32-4.44)	4.76 (4.07-5.47)	5.49 (4.66-6.31)	6.27 (5.29-7.22)	7.09 (5.93-8.19)	8.27 (6.82-9.58)	9.22 (7.50-10.7)
20-day	2.34 (2.04-2.66)	3.01 (2.63-3.45)	3.98 (3.47-4.56)	4.72 (4.10-5.40)	5.73 (4.95-6.56)	6.51 (5.60-7.45)	7.32 (6.25-8.39)	8.14 (6.91-9.36)	9.27 (7.79-10.7)	10.1 (8.44-11.8)
30-day	2.75 (2.38-3.17)	3.54 (3.07-4.08)	4.67 (4.04-5.38)	5.54 (4.78-6.37)	6.72 (5.76-7.71)	7.63 (6.51-8.75)	8.56 (7.28-9.84)	9.52 (8.04-10.9)	10.8 (9.05-12.5)	11.8 (9.81-13.7)
45-day	3.22 (2.81-3.68)	4.15 (3.62-4.75)	5.48 (4.77-6.26)	6.48 (5.62-7.40)	7.80 (6.74-8.92)	8.81 (7.58-10.1)	9.84 (8.42-11.3)	10.9 (9.26-12.5)	12.3 (10.4-14.2)	13.4 (11.2-15.5)
60-day	3.57 (3.12-4.07)	4.62 (4.04-5.25)	6.08 (5.32-6.92)	7.16 (6.24-8.14)	8.58 (7.45-9.75)	9.64 (8.34-11.0)	10.7 (9.22-12.2)	11.8 (10.1-13.5)	13.2 (11.2-15.2)	14.3 (12.0-16.5)

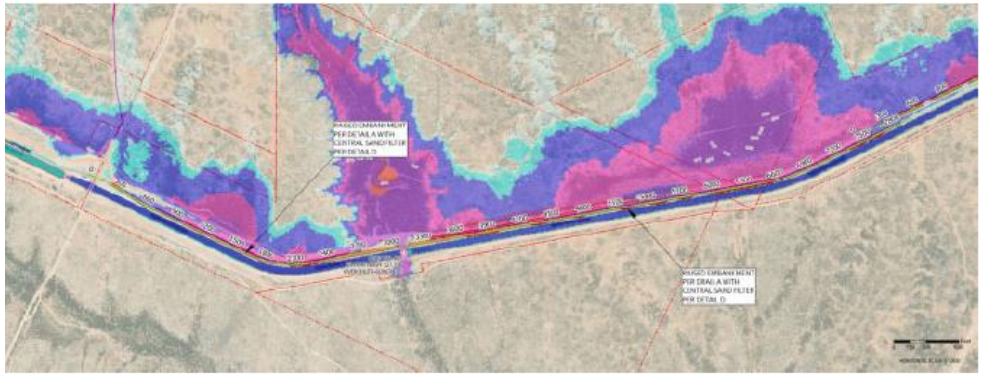
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

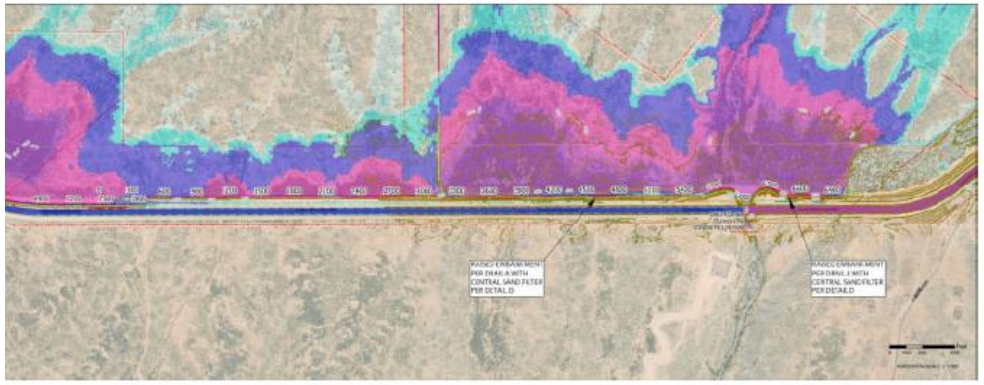
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

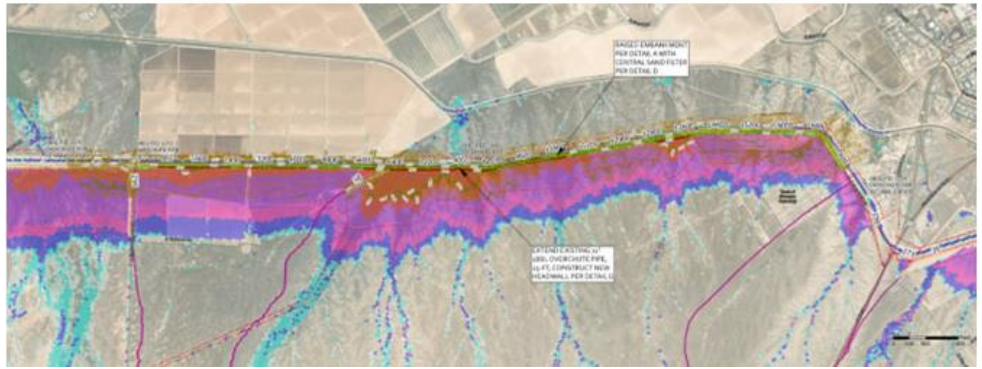
Please refer to NOAA Atlas 14 document for more information.

Elevated Risk of Canal Damage

- Highest risk areas identified
- Why vulnerable now?
  - Uniform design storm used
  - Climate change
  - Changes in embankment crest elevation over 30 years of operations / weather
  - 1960's vs 2020's technology used







Addressing Prioritized Risk

21 areas with elevated risk identified

Generally, showed overtopping of existing dike

CAP Priority	Problem ID	Milepost	Name	Downstream	2022 Evaluation	2010 Evaluation	Fill Percentage*	Estimated Max Fill**	Approximate Project Cost
5	1	127.80	Wittmann 235th Ave & Pinnacle Peak Rd	Desert	4	Further Analysis	80%	12 feet @ Wash Siphon @ MP 127.796	$ 6,000,000
5	2	129.75	Wittmann Iona Wash	Desert	4	Further Analysis	0%	Confirmed zero fill.	$ 3,300,000
5	3	131.94	Wittmann 211th Ave & Patton Rd	Urbanization	5	Okay	0%	Confirmed zero fill.	$ 3,200,000
5	4	134.17	Wittmann Wittmann Wash	Urbanization/Desert	4	Problem	2%	Short length of fill that starts 100' west of the eastbound 60 bridge and is between 6 and 10 feet deep. Not sure this is accurate with the bridge improvements.	$ 4,900,000
5	5	138.66	Wittmann East of US60	Urbanization/Desert	5	Problem	3%	12 feet @ 3 - 72" Overchute Pipes @ MP 140.084	$ 14,900,000
1	6	157.68	Skunk Creek	Urbanization	5	Problem	0%	Confirmed zero fill.	$ 400,000
1	7	157.68	Sonoran Wash	Urbanization	5	Okay	0%	Confirmed zero fill.	$ 1,400,000
3	8	179.0	Scottsdale Lost Dog Wash	Urbanization	5	Problem	0%	Confirmed zero fill.	$ 1,600,000
3	9	179.80	Scottsdale Wash B	Urbanization	5	Problem	35%	5 feet @ 3 -72" Overchutes Pipes @ MP 179.801	$ 1,300,000
4	10	181.67	Doubletree Ranch Rd at SRPMIC	Desert	4	No Revised Hydro	3%	4.5 feet @ MP 181.125	$ 2,300,000
2	11	187.23	East of SR87 Upstream of Salt River Siphon	Desert	4	No Revised Hydro	84%	20 feet @ 4 - 42" Pipe Culverts @ MP 187.231	$ 2,300,000
6	12	233.44	South of Gila River Siphon	Agricultural	4	Problem	0%	Confirmed zero fill.	$ 6,000,000
STUDY 2	13	240.65	North of Cactus Forest Rd	Agricultural	4	Problem	14-22%	3.5 feet @ MP 239.23	$ 25,300,000
STUDY 2	14	244.97	Coolidge Airport	Desert	3	Okay	21%	3.5 feet @ 2 - 4'x6' Box Culvert @ MP 244.967	$ 16,600,000
STUDY 1	15	262.59	Picacho - Phillips Rd	Desert	4	No Revised Hydro	67%	25 feet @ MP 262.35	$ 4,500,000
STUDY 1	16	266.5	West of McClellan Wash Siphon	Desert	3	No Revised Hydro	0%	4 feet @ 72" Overchute Pipe @ MP 265.848	$ 7,200,000
STUDY 1	17	273	Red Rock Downstream of Pecan Rd Dike	Agricultural	4	Problem	100%	7 feet @ 18" Overchute Pipe @ MP 273.455	$ 19,000,000
8	18	279.65	Downstream of Red Rock Pumping Plant	Desert	4	Problem	0%	Confirmed zero fill.	$ 20,000,000
9	19	287.92	Marana Owl Head Ranch Rd	Urbanization/Desert	5	Problem	0%	3 feet @ MP 287.207	$ 7,800,000
7	20	300.59	South of Marana Airport	Desert	4	No Revised Hydro	34%	6 feet @ MP 300	$ 4,300,000
STUDY 4	21	305.5	Downstream of Sandario Pumping Plant	Desert	4	Further Analysis	0%	Confirmed zero fill.	$ 2,100,000