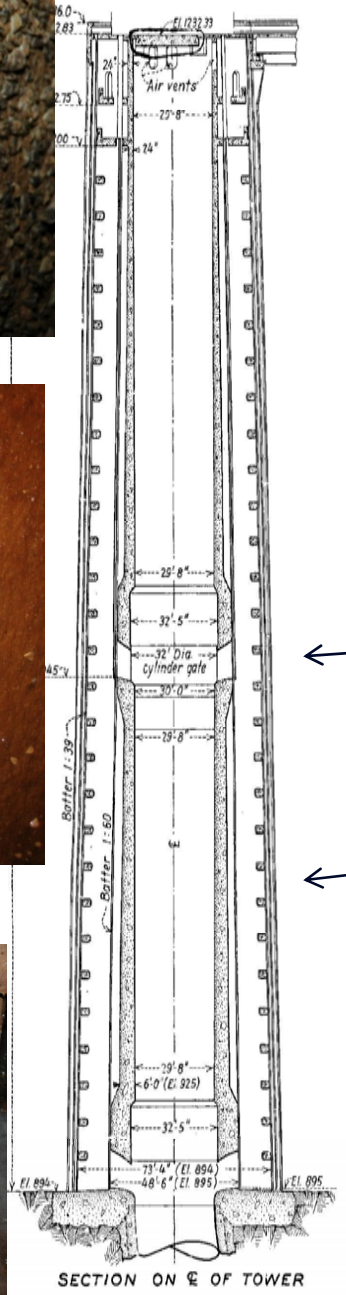
Quagga Mussel Infestation at Bureau of Reclamation Hoover Dam; What have we learned and what do we recommend

RNT CONSULTING INC

Structure of the presentation

- What we have observed at the dam
- Why and how to monitor mussels
- What control options are available
- Suggested path forward



SECTION ON ℄ OF TOWER

Elev 1045

Elev 970

Elev 894

Elevation 1045, (65’ below water)

Observations from inspection of external surfaces

- Mussels present in the intake towers at upper gate opening
- Decreasing settlement as depth increases
- Virtually no settlement at lower gate opening
- Inspection of the tower provided population vs depth of settlement profile

Observations from inspection of external surfaces

- Mussels are present in the lower penstock (under 200psi pressure)

Observations from inspection of external surfaces

Uncertainty about the ultimate size of the mussel population, if in doubt, expect the worse scenario

Penstock drains may be plugged by shell debris and live shells in the future

Observations from inspection of external surfaces

- Several size classes of mussels observed in the sample collected from the penstock, indicative of multiple spawning events
- Apparent new settlement present at the penstock, breeding is still on-going

Observations from inspection of external surfaces

- Mussels are present in the tailrace area, apparently in much lower numbers

Inside the Plant

Cooling Water

- All cooling water enters the plant either through;

penstock take-offs (four take offs /penstock)

Or through tailbay suction via eductors

Cooling Water

- There is no barrier to ingress of shells from penstock take offs

What have we observed in the plant

- Some evidence of mussel presence inside plant raw water systems
- Potential for fouling by primary settling and from incoming shells

What have we observed in the plant

- The smallest diameter of cooling water piping 2”
- Equipment most likely to get plugged by live mussels; oil coolers (5/16 inch diameter tubes) and supply leading to local airconditioners
- Equipment most susceptible to plugging by dead shells from upstream, generator coolers. Unlikely live mussels will settle in generator coolers as they are made of copper.

Generator Air Cooler

Inlet of generator air cooler

What do we recommend for Hoover Dam

Know thy enemy – monitor

Inspect and clean external structures as required

Implement control of incoming veligers and of mussel shell debris in critical areas of cooling water (generator cooling, turbine thrust bearing, turbine guide bearing, transformer coolers)

Develop rapid response plan should mussel infestation start to impact critical areas

Monitoring, why and how

- First year for Quagga mussels in the Colorado River system
- Great Lake experience useful but not necessarily accurate
- May see huge seasonal variations in population density, larval production, settling patterns
- Dam can’t make good decisions without better local data

Monitoring – why

- Outside of the plant, lake side
  - To determine when the breeding cycle starts, when settlement begins and ends at Hoover Dam
    - How many mussels will settle and grow in one year/cycle
  - How deep can mussels settle and grow

Monitoring – why

- Within the plant

  To determine the level of infestation and if required, efficacy of treatment using

  - side stream samplers
  - temperature sensors on critical coolers
  - ROV inspections of the penstocks

Monitoring – How

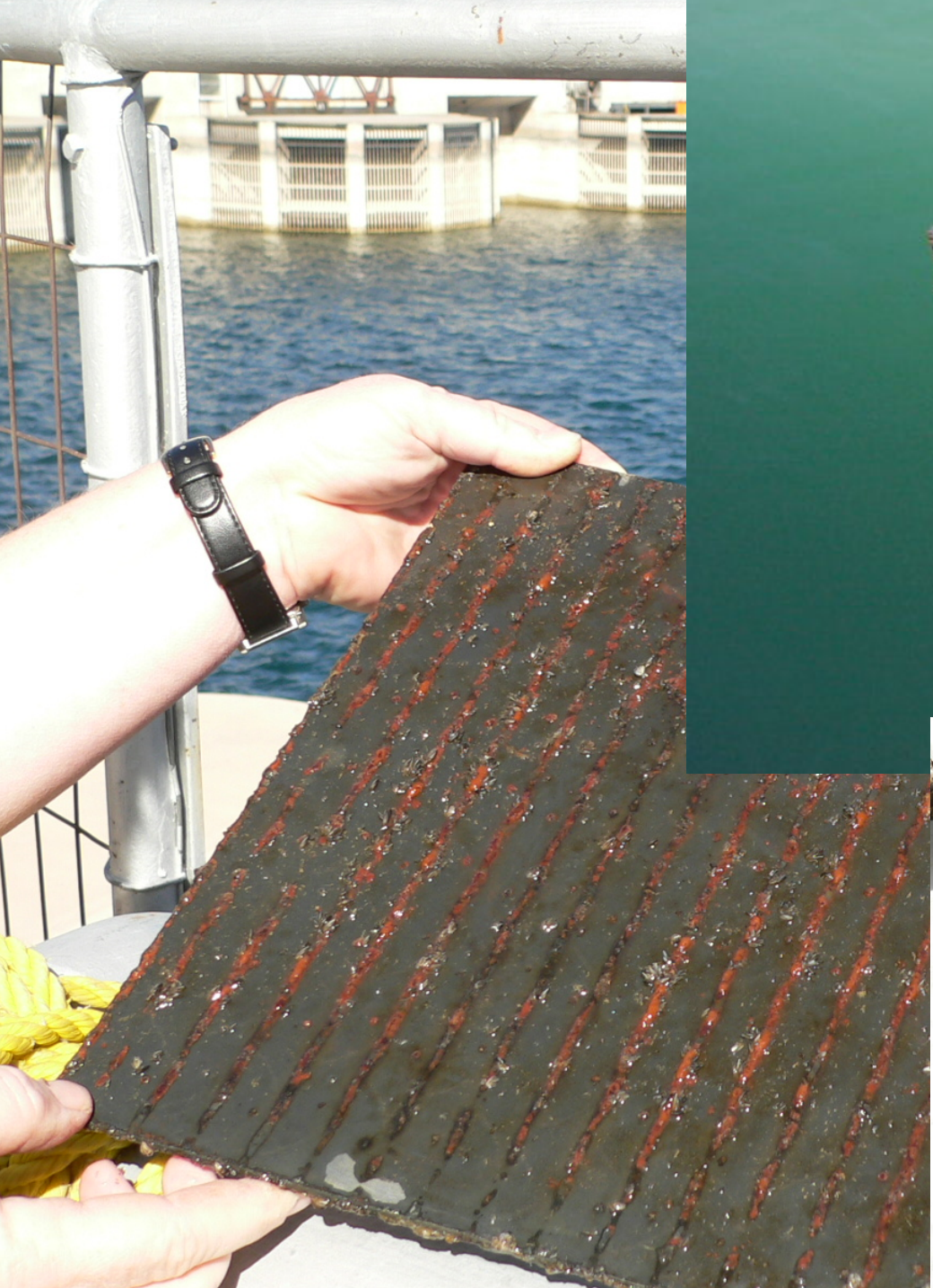
Plankton Tows


C. Ramcharan

Plankton tows

- Quick and easy way to establish presence or absence of veligers at the beginning and end of the breeding season. Take large samples, process by “density separation” using sugar solution method
- Can be used to do actual veliger counts in the incoming water, tedious and offers limited information for the plant

Settlement monitoring – probably the best return on investment



Recommendation

- Hoover dam use the same settlement substrate material as Parker and Davis
- Same dimensions
- At the same depth (10ft, 20….down to maximum depth)
- Examine the plates at the same time interval and in the same manner
- Multiple strings of sampling plates lakeside and in the tailbay

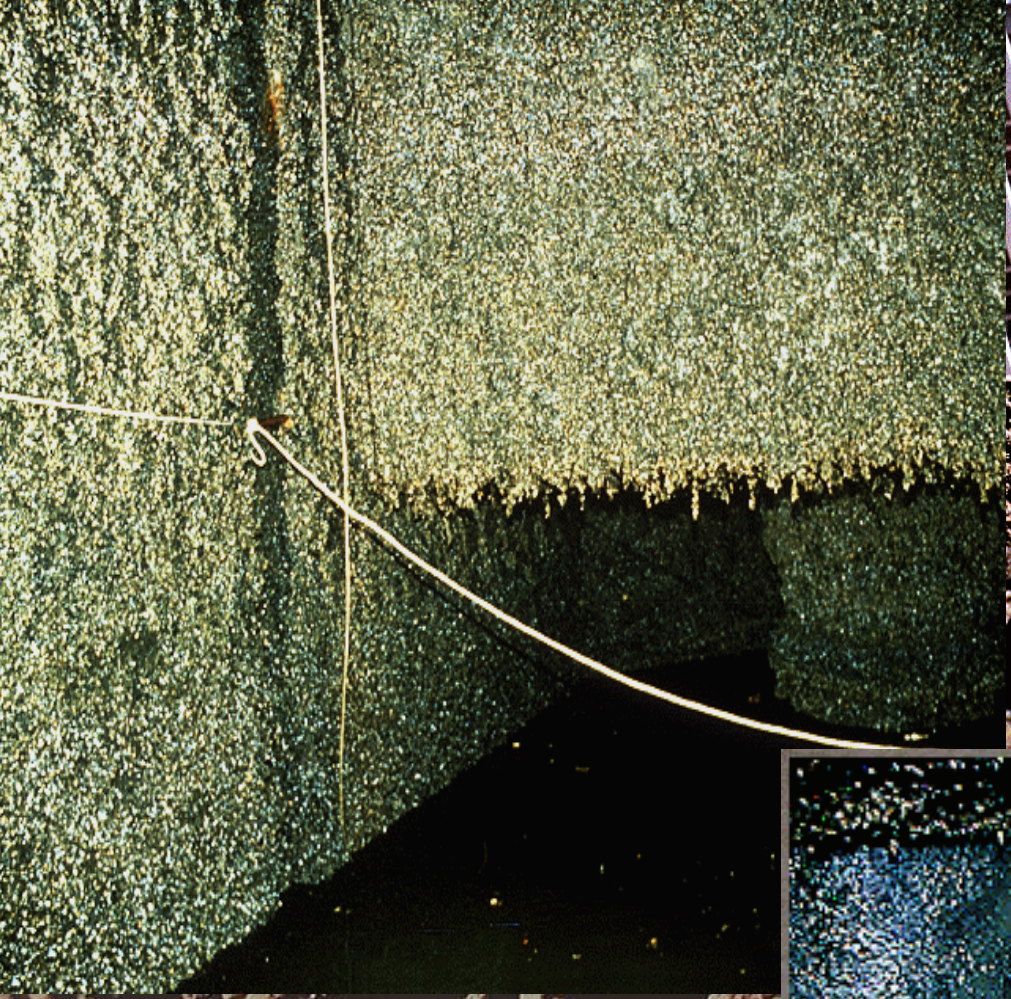
Side stream sampler - Within plant monitoring,

Recommendation

- Install at least one sidestream sampler, two if possible as soon as practical
- One at the front of the system, one near the end would be ideal.
- Recommended flow-through 20L/min
- Settlement plates within the sampler should be the same material as outside settling plates

Mussel Control

- Develop rapid response plan to immediate threat
- Decide on long term strategy
- Implement



Control Options Myth

- **All facilities can use the same control options in the same way**
- **Engineering staff has all the knowledge require to design a perfect control system**
- **Technology vendors and Service providers do not have their own agenda**

So……Buyer beware

Fact – Every Facility is unique Evaluate before you decide on a strategy

- Strategy may be:
  - Do nothing, react only when disaster is imminent
  - Implement planned treatments at regular intervals
  - Prevent as many mussels as possible from entering the plant, alive or dead

Evaluation Criteria

- As a team decide what level of infestation is tolerable in the various parts of your cooling system
- If there is a danger of blockage by primary settlement or shell debris, what are the consequences of such a blockage (safety and economic)

- What will your customer/regulator/insurer/ fire marshall say about mussel presence in various systems and the risks they may pose?
- What will your regulator say about your treatment of choice? Can permits be obtained in time?
- What is your operational preference?

Proactive vs. Reactive

- **Proactive**

Does not allow growth of mussels in the system or on the surface protected

- **Reactive**

Does allow mussels to grow in the system or on the surface. Established populations have to be eliminated periodically

Options for External Structures*

*Structures That Are in Direct Contact With the External Environment; No Isolation Is Possible

Reactive Options for External Structures

Mechanical Cleaning

- de-water and use powerwash
- underwater, scrape and vacuum or powerwash

Proactive Options for External Structures

- **Antifouling Coatings** - for both steel and concrete
- Non-toxic, silicone based
- Toxic, copper based coatings
- Life-span 5-7 years before topcoat needs to be refreshed

Options for Internal Piping Systems

Reactive Options for Internal Piping Systems

- Thermal Wash - 32°C for 48 hours (90° F)
  40°C for 1 hour (104° F)
- Mechanical Cleaning such as
  - scrape large diameter pipes
  - use expanding air bubbles ?? or remote vehicle tools on difficult areas
- Flushing with weak acids
- Oxygen Deprivation

Reactive Options for Internal Piping Systems

- Periodic (once or twice/year) application of

  - Non-oxidizing chemicals
  - Oxidizing chemical

Non-oxidizing Chemical

Proprietary Chemicals Some of Which Have to Be De-toxified on Discharge.

Length of Treatment Depends on Ambient Temperature. Varies From Several Hours to Several Days.

Oxidizing Chemical Treatment

- chlorine
- bromine
- chlorine dioxide
- chloramines
- ozone
- potassium permanganate

Oxidizing Chemical Treatment

- None are proprietary chemicals
- Length of treatment tends to be temperature dependent. Up to two weeks of treatment may be required.

Emerging Options

- Bacterial product, zebra mussel specific chemical….being tested on Quagga now

- Biobullets

Proactive Options for Internal Piping Systems

- **Sand/media filtration** - has to remove all particles greater than 40 micron

- **Mechanical filtration** - has to remove all particles greater than 40 micron

Example of 40 micron self cleaning filters

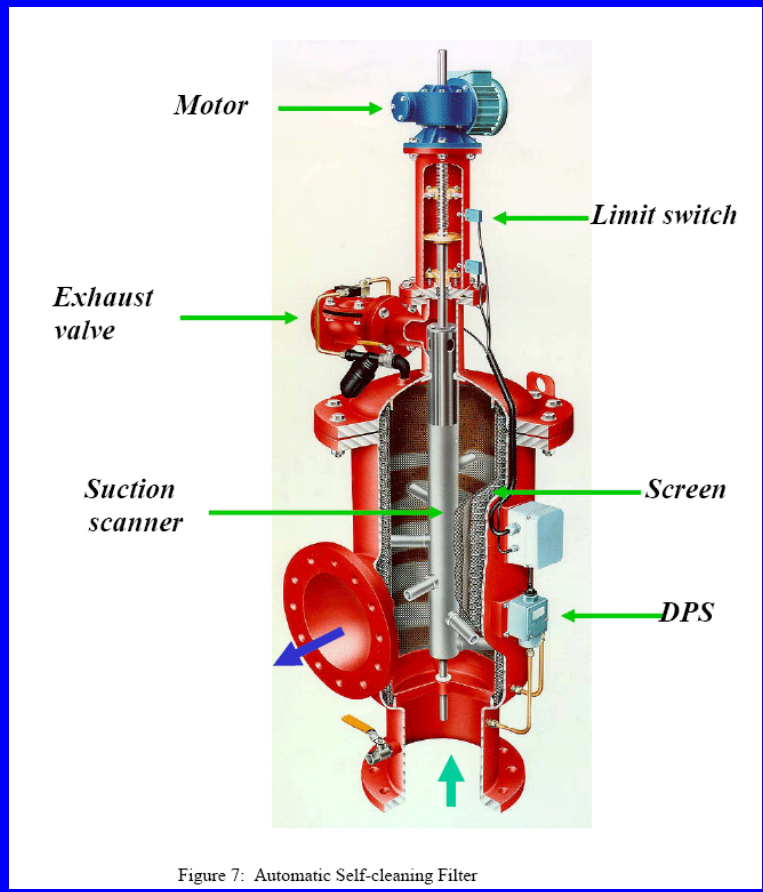
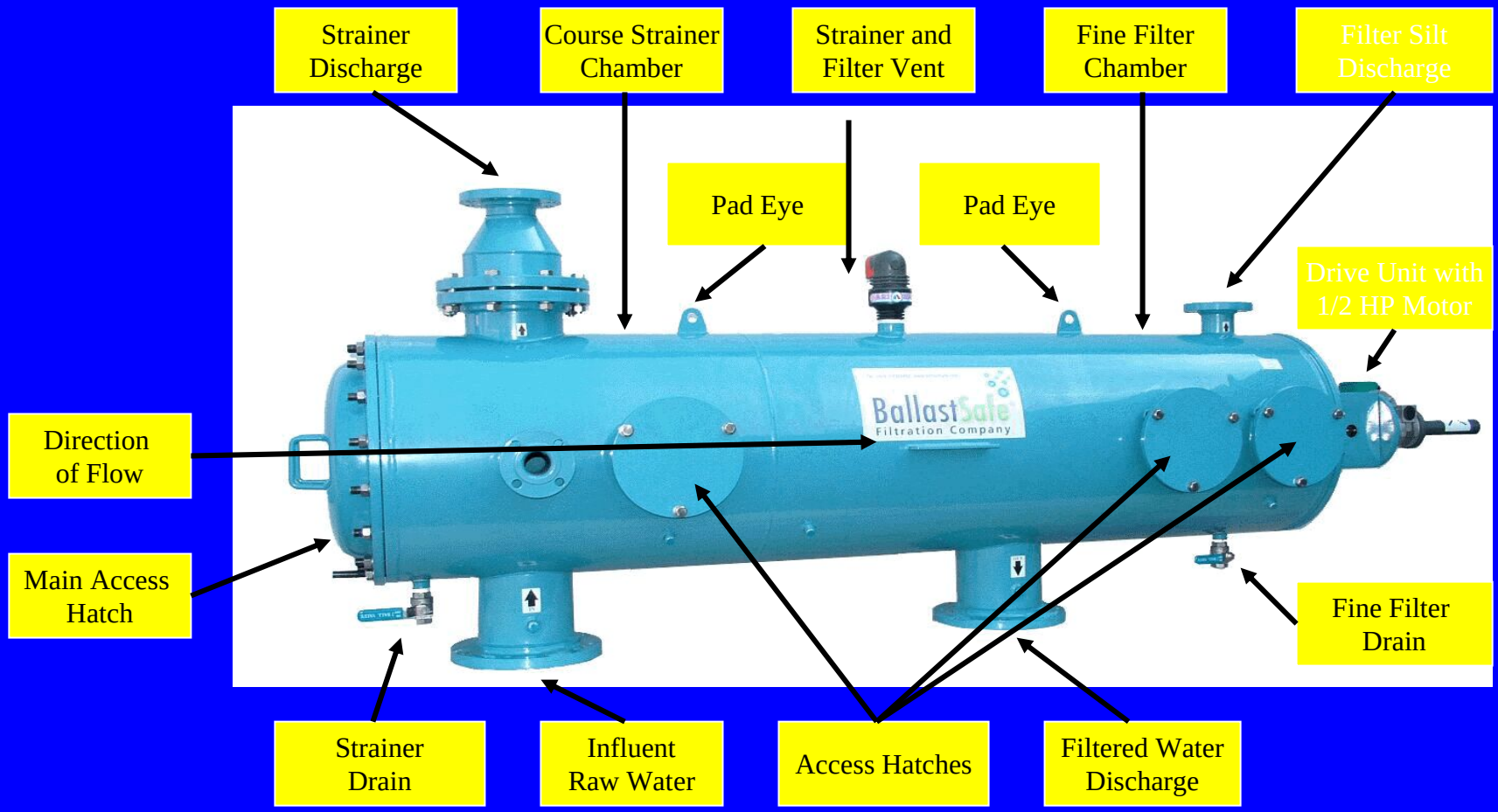


Figure 7: Automatic Self-cleaning Filter


Strainer Discharge
Course Strainer Chamber
Strainer and Filter Vent
Fine Filter Chamber
Filter Silt Discharge
Pad Eye
Pad Eye
Drive Unit with 1/2 HP Motor
Direction of Flow
Main Access Hatch
Fine Filter Drain
Strainer Drain
Influent Raw Water
Access Hatches
Filtered Water Discharge
BallastSafe
Filtration Company

Mesh Requirements

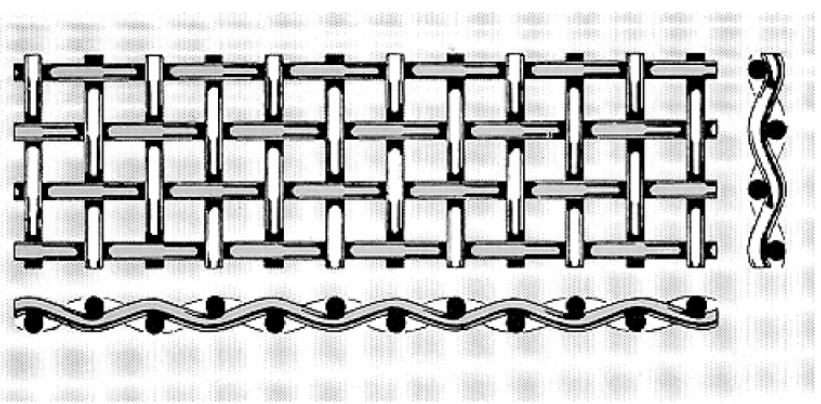


Figure 2: Square Weave

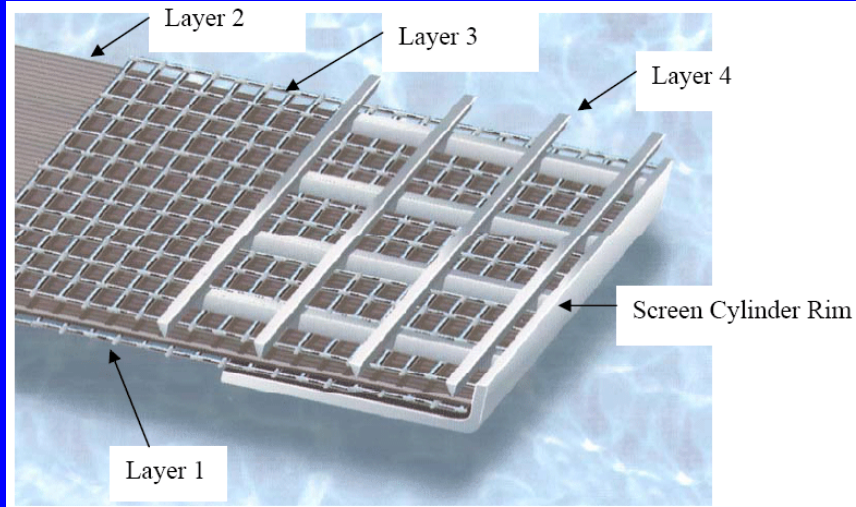
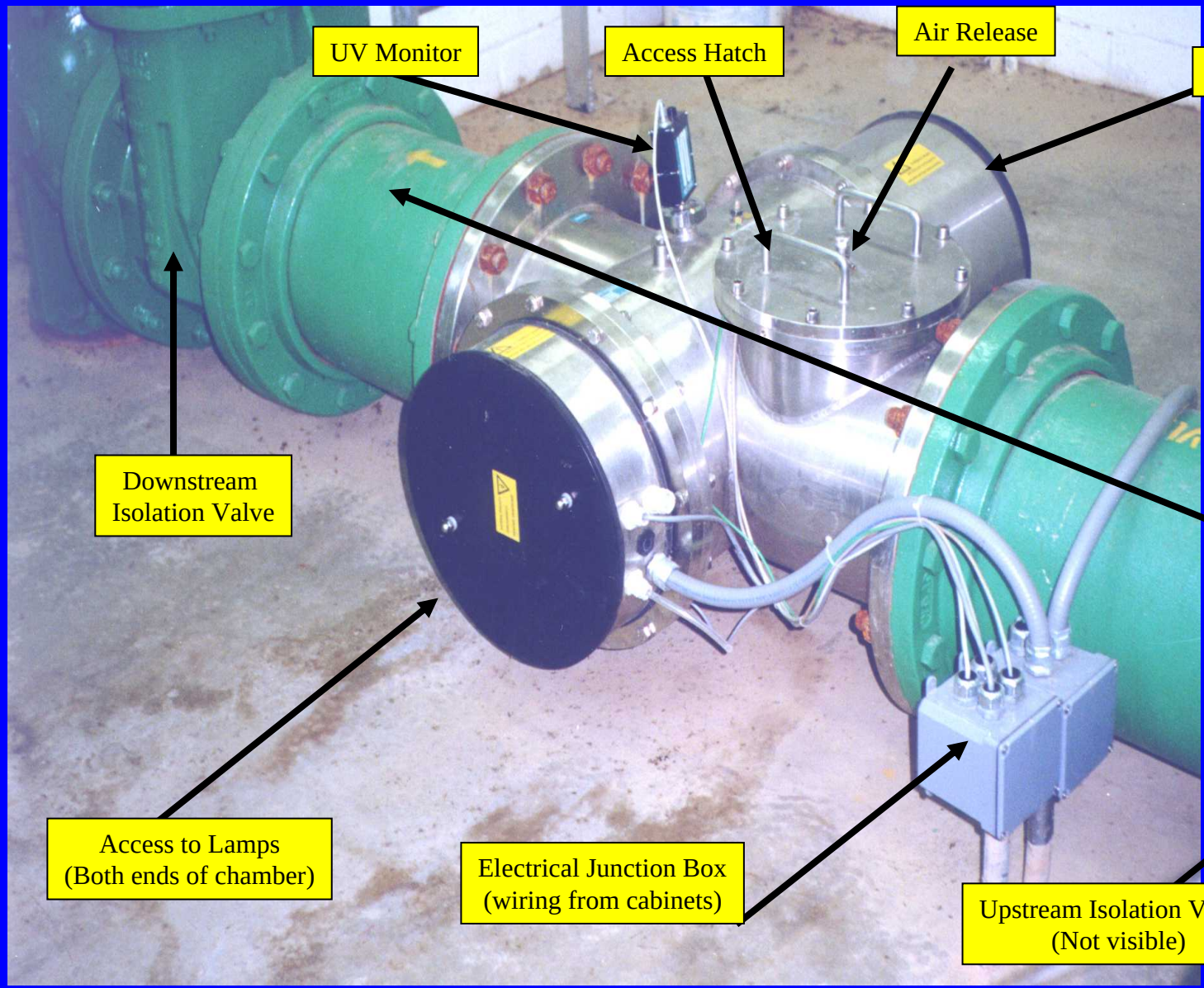


Figure 4: Patented Four-layer Screen

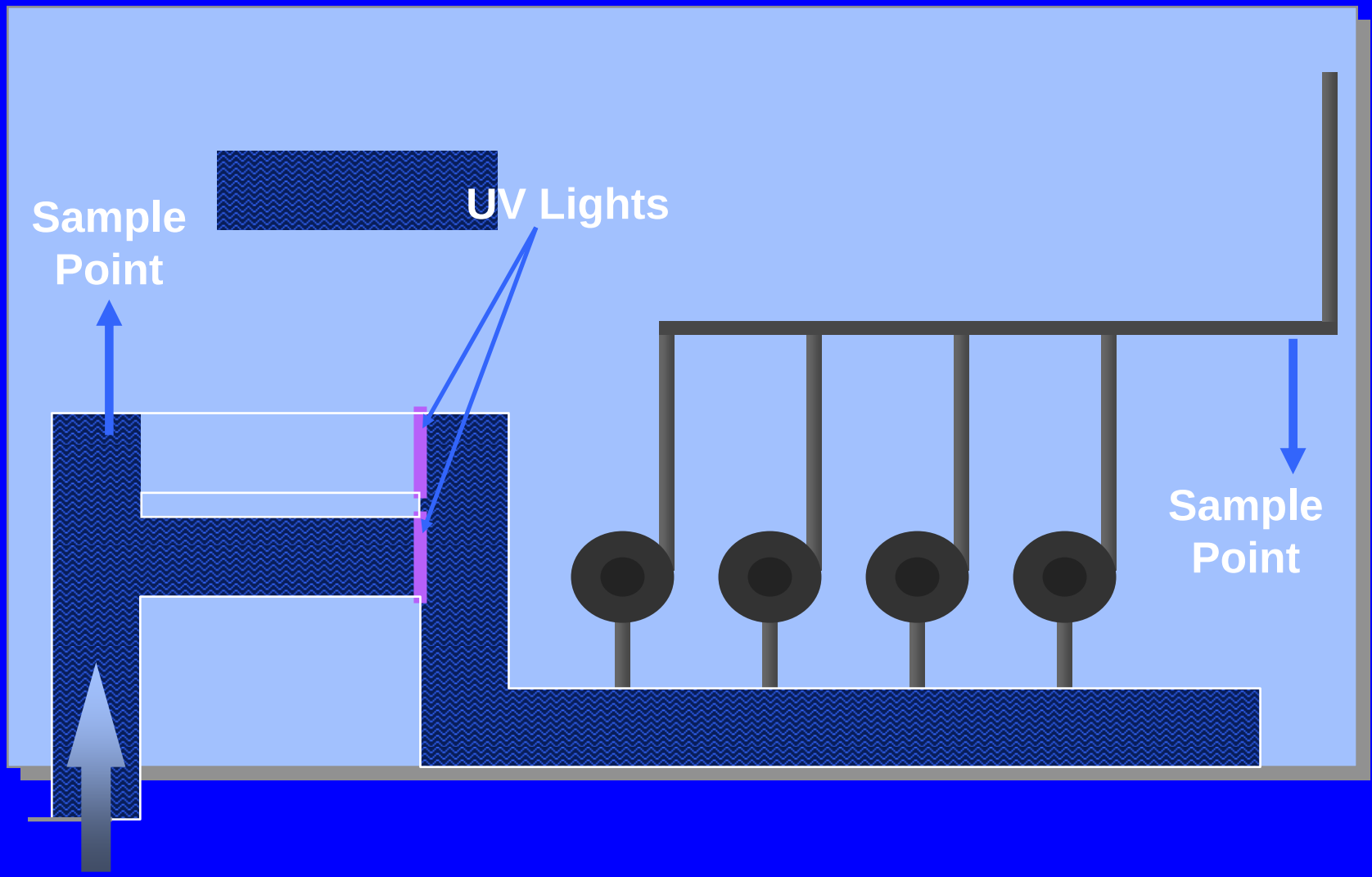
Proactive Options for Internal Piping Systems

- UV systems
- Closed Loop Cooling
- Oxidizing chemicals
- Non-Oxidizing chemicals

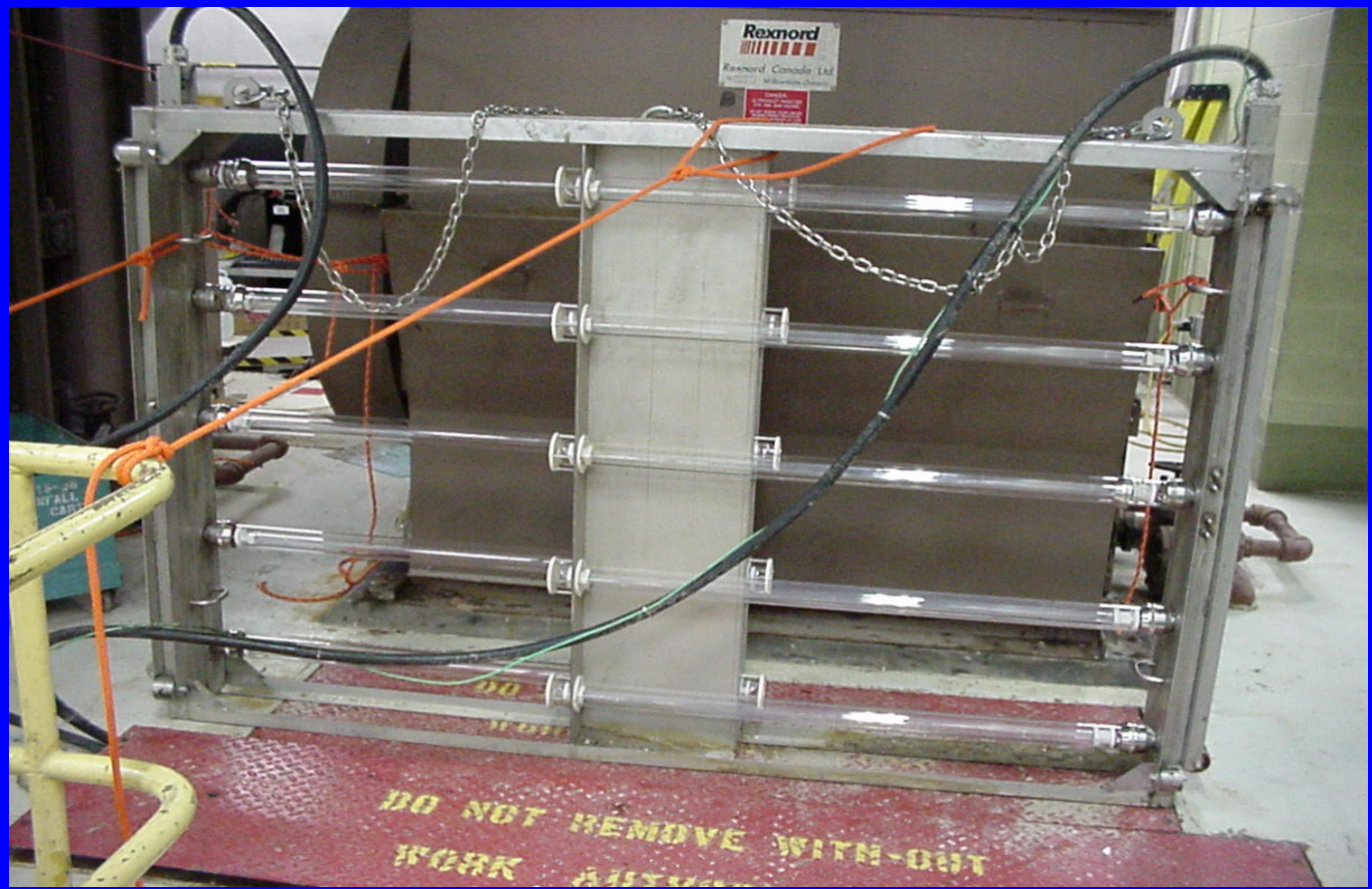
In pipe Uv Installation



Open channel UV Installation



UV Light Bank



Closed Loop Cooling

- Choose cooling heat sink (air or water)
- Does not necessarily address all challenges
- Space considerations
- Piping layout changes and constructability

Proactive Use of **Oxidizing** Chemicals for Protection of Internal Piping Systems

- Low levels of the chemical are added continuously or semi-continuously throughout the mussel breeding season to prevent settling by creating a hostile environment.

Observations on Cooling Water System design at Hoover

- Use of eductors taking water from tailbay is unique
- Multiple intakes of raw water into plant.
- Units are all interconnected
- Some favorable materials of construction (copper and brass)
- Some head loss from original lake level

Initial Suggestions for Control

- Rapid Response Option (if settlement and shell transport increases dramatically and suddenly):
  - Install portable chlorine skids to protect critical areas
  - Use thermal treatment where possible
  - Use weak acids to dissolve shells and corrosion products
  - Mechanical cleaning as system performance deteriorates.

Control and Mitigation Ideas

- Use Lower Intake Only
  - Will minimize entry of veligers into station
  - Settlement and growth in penstock will be reduced or possibly eliminated.
  - Falling lake level may negate this option.
  - Reduced generating capacity due to one intake only

Control and Mitigation Ideas

Use Self Cleaning Strainers with 1/8th screen to keep out shells

- Install strainers on HPW lines
- Replace tailbay intake strainers

- Evaluate if eductors can provide enough suction from tailbay with new strainers
- Risk- allows veligers to settle in piping (could use UV or oxidizing chemicals)

Control and Mitigation Ideas

Use 40 micron self cleaning filters instead of strainers.

- Protects all downstream equipment
- Coarse pre-straining may still be required

- Evaluate if eductors can provide enough discharge pressure (35 psi for backwash)

Control and Mitigation Ideas

Use Partial Closed Loop + Filters

- Closed loop for transformer cooling
- Reduced HPW demand is redirected to CSW
- By pass tailbay suction
- Use 40 micron filters for HPW
- Protects all downstream equipment

- Generator air coolers may operate at higher temperature. Evaluate if this is acceptable.

Control and Mitigation Ideas

Chemical Injection

- Periodic or Continuous approach
- Requires approval of Regulator
- Multiple injection points required
- May require detoxification before discharge

- Risk – Shell material can still enter, strainers may still be required

Suggested Path Forward

- Implement monitoring immediately
- Team made up of stakeholders does a detailed engineering evaluation of cooling systems at risk vs. mitigation options
- Team agrees on the acceptable risks and selects mitigation options best suited to achieve control within the risk criteria

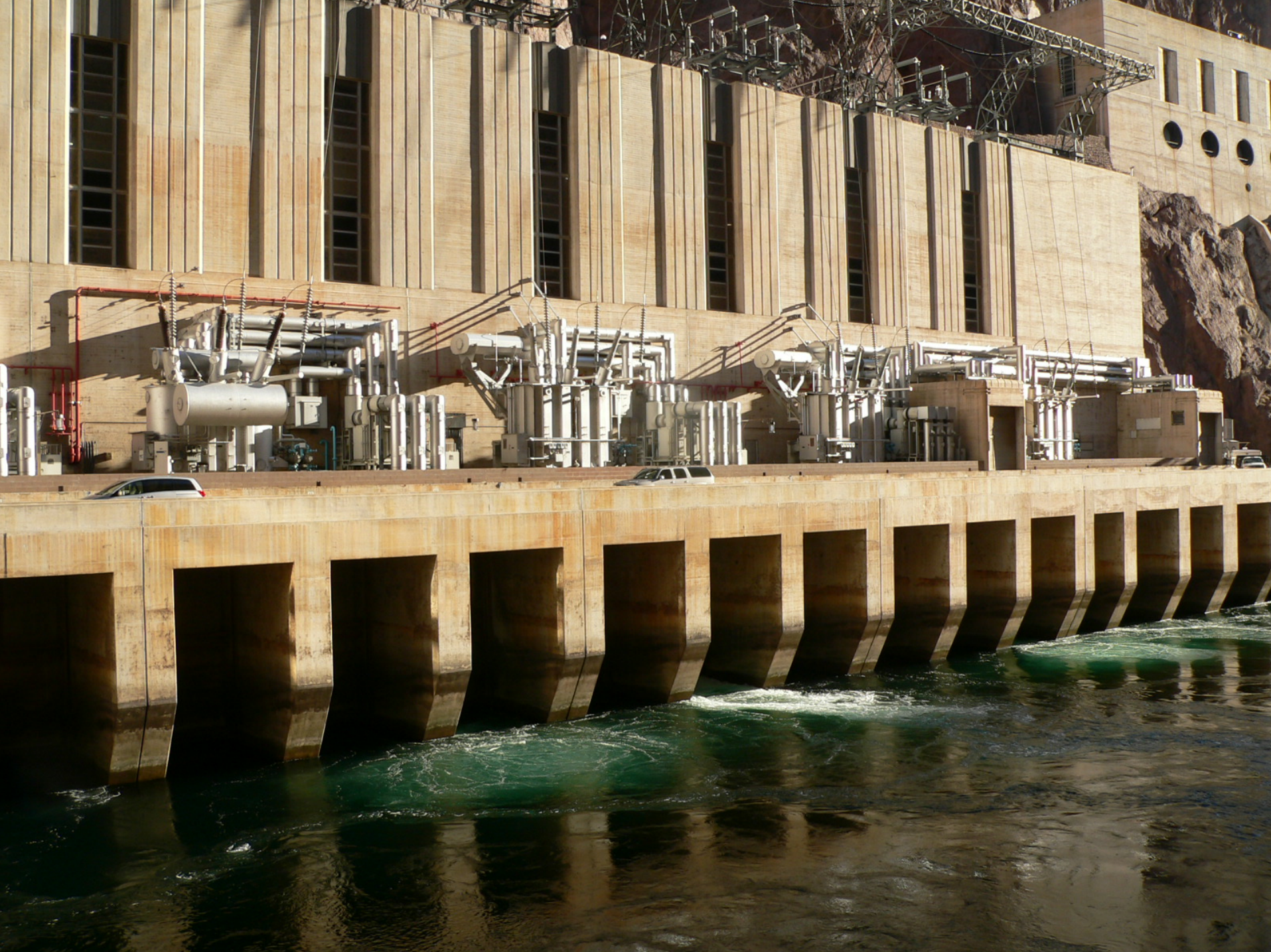
Suggested Path Forward

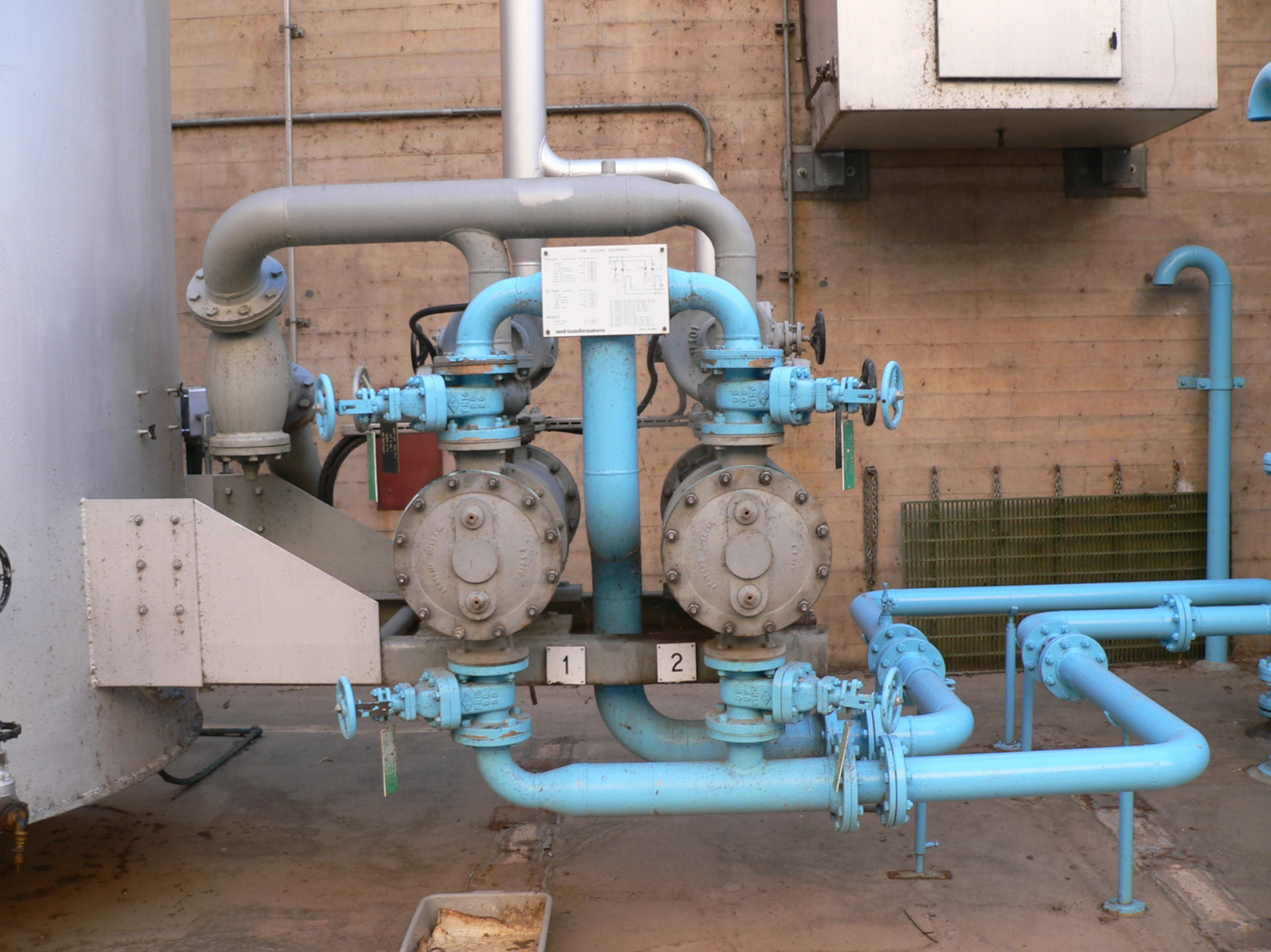
- One person takes ownership of the monitoring program and possibly of the implementation of the control strategies
- Team should re-evaluate chosen path on periodic basis, monitoring data and plant performance data should provide the basis for the re-evaluation

Summary

- **Current Situation –**
  - **Still learning characteristics of the mussel in this environment.**
- **Monitor and measure to: detect presence, understand the mussel breeding and growth cycle, determine risk areas in plant and develop response.**
- **Engineering evaluation of possible control options to establish feasibility vs operational preference vs risk**
- **The actual choice of treatment will be based on a combination of regulatory, economic and operational considerations**

- **There is no silver bullet !**
- **The mussels are adaptive and continue to surprise…..No one has a crystal ball!**
- **Site specific integration of control strategies and continuous vigilance is required.**

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Elev 1045, (65’ below water)

Elev 970, (140’below water)

Elev 894, (217’ below water)