BUILDING A WORLD OF DIFFERENCE

May 6, 2011

WHEN HYDROPOWER MAKES SENSE FOR MUNICIPAL WATER SYSTEMS

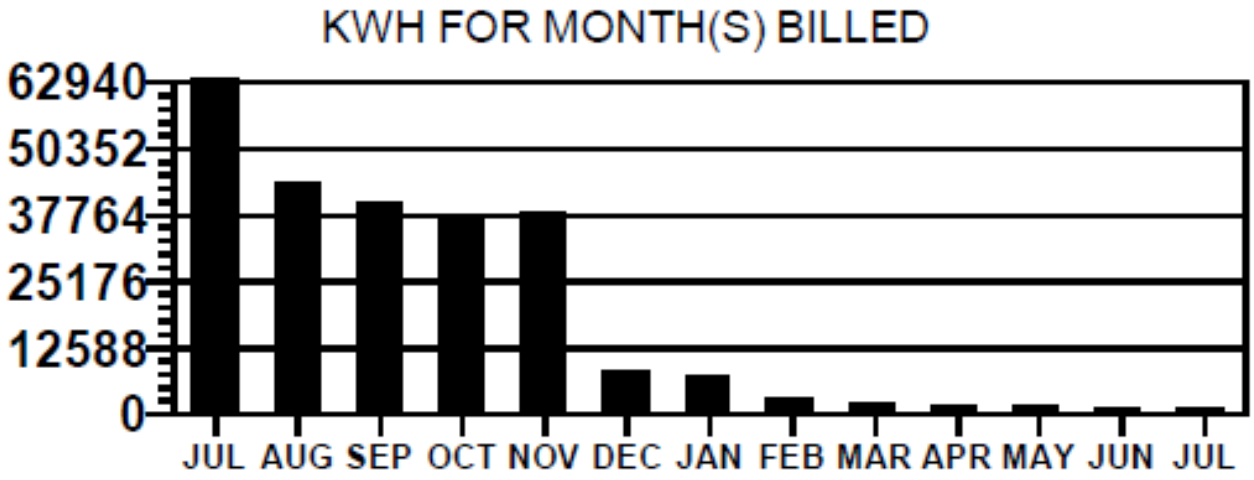
PNWS – AWWA – Boise, ID

Patrick Van Duser

BLACK & VEATCH
Building a world of difference.

WHY CONSIDER HYDRAULIC POWER RECOVERY IN YOUR SYSTEM

- Reduced energy costs
- Increased energy efficiency
- Public perception



- **Real power bill after energy recovery started in December.** Montrose, CO

SMALL HYDRO FOR MWS

Agenda

- MWS Hydropower Technology Overview
- Implementation, Permitting and Incentives
- Applications and Benefits
- Hydro Feasibility Study Examples:
  - TBWSP
  - City of Bend, OR

MWS HYDROPOWER OVERVIEW

HYDROPOWER SIZE CAN VARY GREATLY

TYPES OF HYDROPOWER

- Impoundment (Dam)
- Diversion (Run-of-River)
- Pumped Storage (Two reservoirs)
- Conduit (within an existing piping system)

FARADAY DIVERSION DAM, CLACKAMAS RIVER

WHAT IS MWS HYDRO?

- **Built within the existing system**
  - Harnesses unrealized hydraulic energy
  - "In-line" with existing pipeline or delivery system
- **Green energy source**
- **Considered small or micro-hydro**
  - Small hydro < 5 MW
  - Micro hydro < 250 kW

COMBIE NORTH POWERHOUSE UPGRADE, GRASS VALLEY, CA

"In line" hydropower also called "Conduit" hydropower.

HYDROPOWER BASICS
HEAD, FLOW, AND POWER

- **NET HEAD**
  - Static and Friction losses used to establish net head
  - Similar to pump system curve calculation
- **FLOW**
  - Several methods to establish and format flow data
  - Flow duration curve (flow plotted against time)
  - Percent flow occurrence curve (flow vs % exceedance)
- **POWER, ENERGY**
  - Head and flow determination
  - Power, KW=0.745*head(ft)*flow(**cfs**)*teff/8.81
  - Power, KW=0.745*head(ft)*flow(**gpm**)*teff/3960
  - Energy, KW-hr = Power*Period of operation*Availability%
  - Value of power = Energy*$/KW-hrs

MWS HYDROPOWER TECHNOLOGY & TERMINOLOGY

MUNICIPAL TERMS

- Pump
- Impeller
- Intake Pipe
- Motor
- Vane

HYDROPOWER TERMS

- Turbine
- Runner
- Penstock
- Generator
- Bucket

To communicate effectively we all must speak the same language.

HYDROPOWER PLANT SIZES

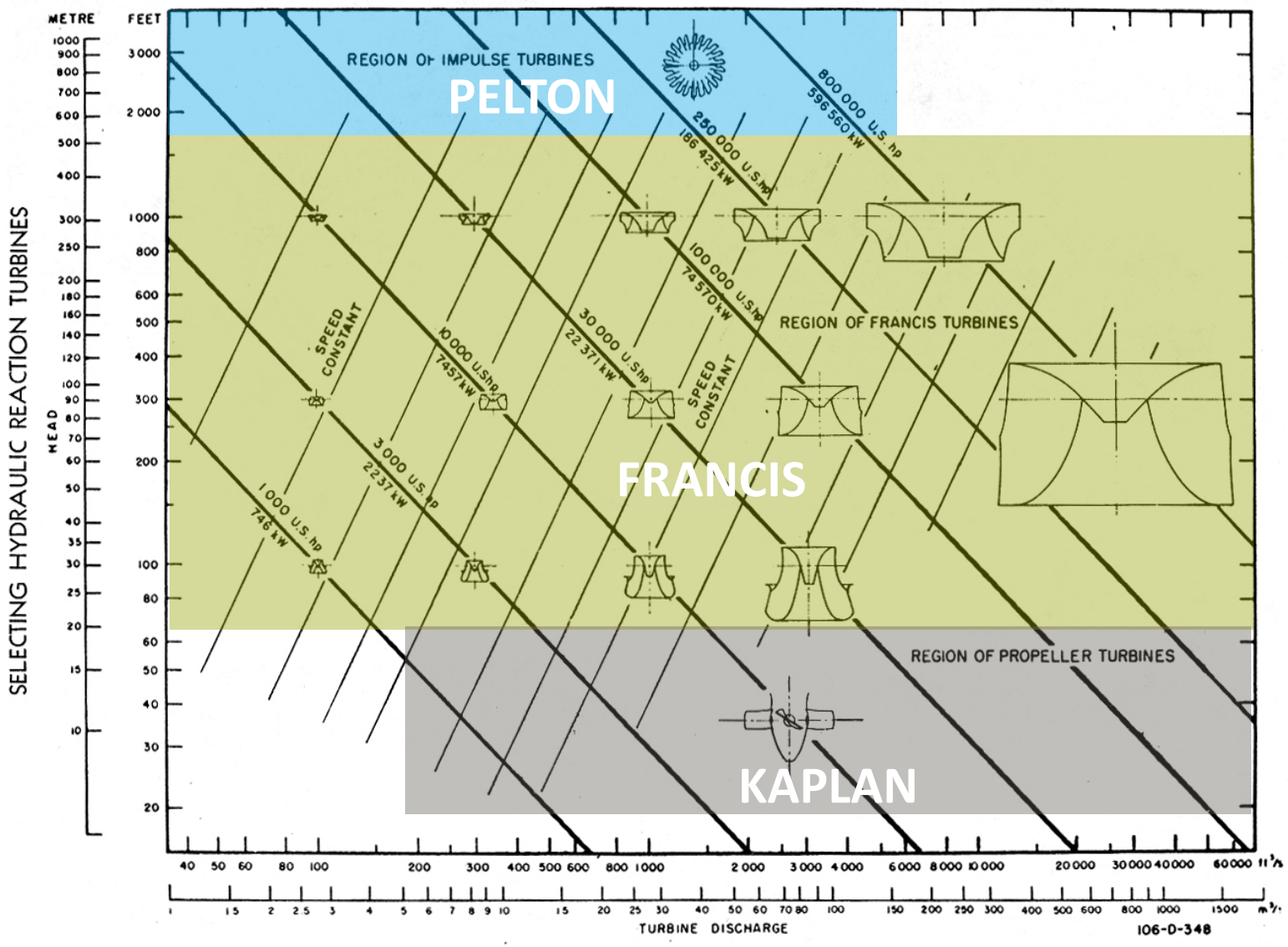
- **Large –** A capacity greater than 30 MW
- **Small –** A capacity of 250 kW to 30 MW
- **Micro –** A capacity of up to 250 kilowatts

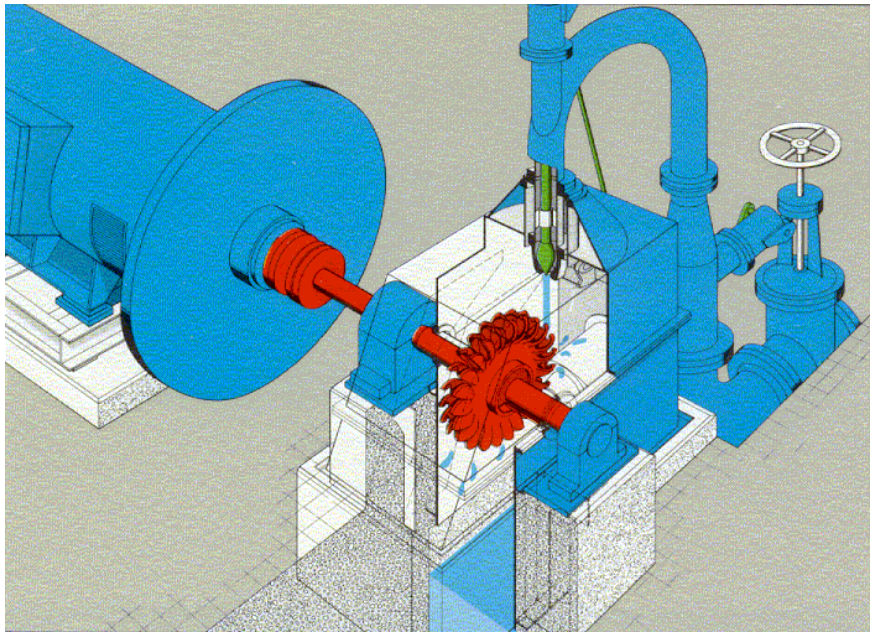
Although the definitions can vary from state to state when it comes to defining renewable energy.

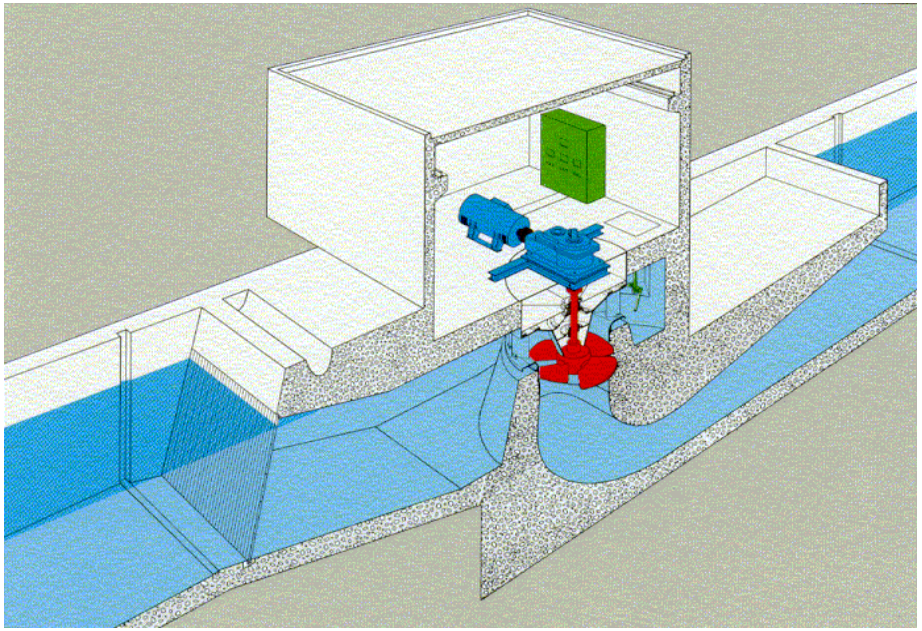
3 TRADITIONAL TYPES OF TURBINES AVAILABLE

- **Pelton**
  - For high head applications
  - 250’ to 2500’
  - Impulse type turbine
- **Francis**
  - For intermediate head applications
  - 50’ to 500’
  - Reaction type turbine
- **Propeller / Kaplan**
  - For low head applications
  - 15’ to 130’
  - Reaction type turbine

APPLICATION DIAGRAM

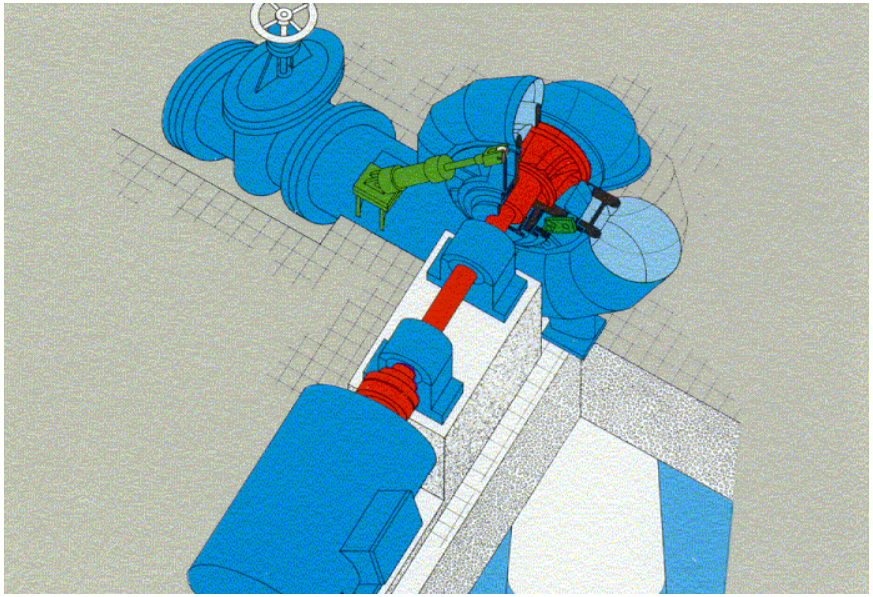






Pelton

(Horizontal)



Kaplan

(Vertical w/ gear reducer)

(One of many variations)

Francis

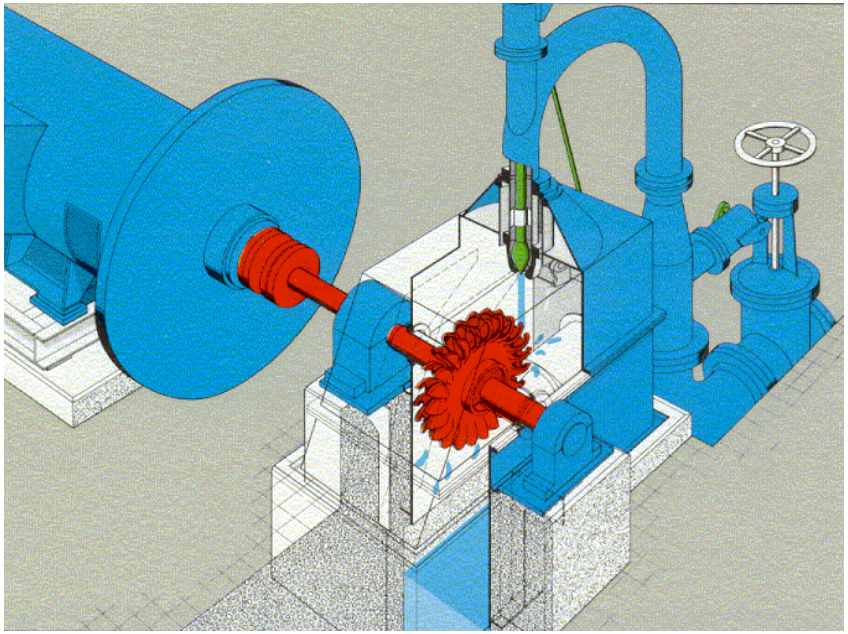
(Horizontal arrangement)

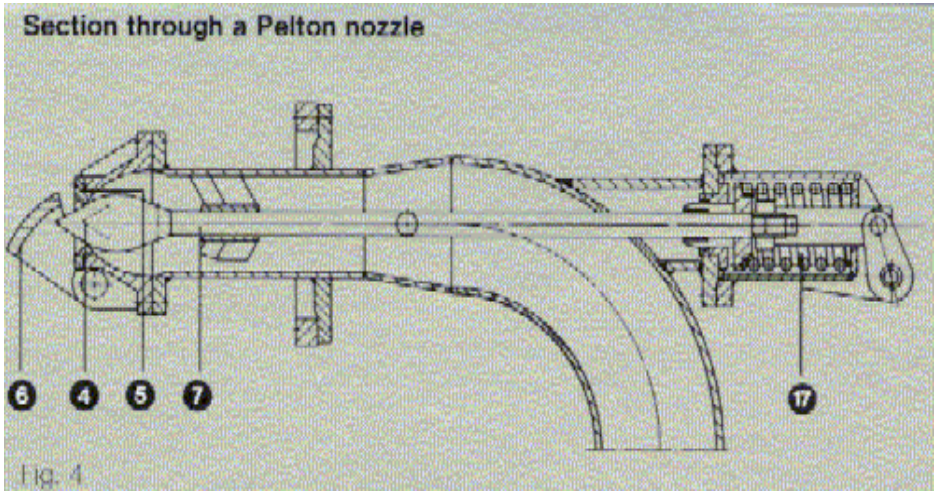
PELTON TURBINES

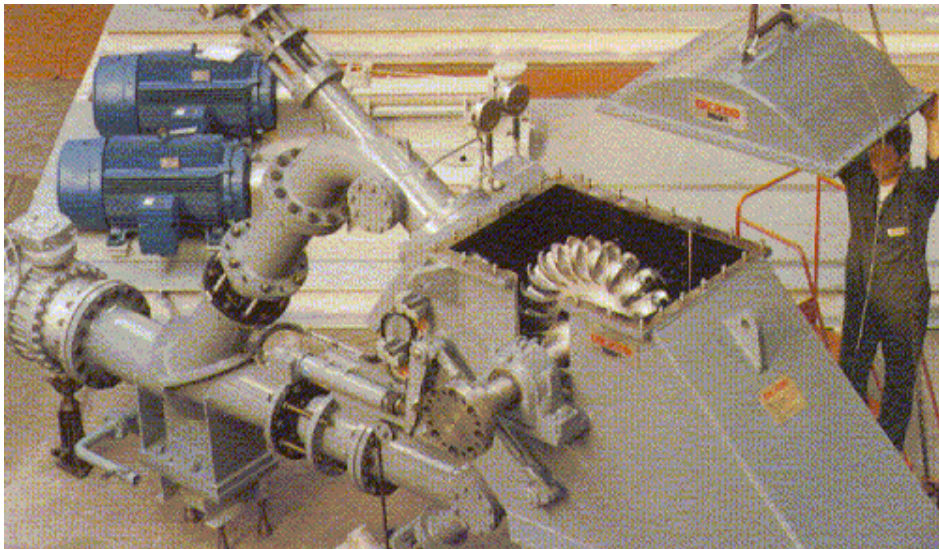
- Impulse type turbine
- Used for high head applications
- Possible to have 1 to 6 nozzles (jets)
- Pelton units can cover a very wide range of flows for 20% to 100% at high efficiencies
- Effective in controlling the effects of water hammer problems as a result of load rejection
- Fewer components subject to wear, unit is easy to inspect
- High unit outputs for minimal space

Disadvantage: Runner must operate in air. Makes operation with a pressurized discharge challenging.

PELTON TURBINE (Horizontal Arrangement)







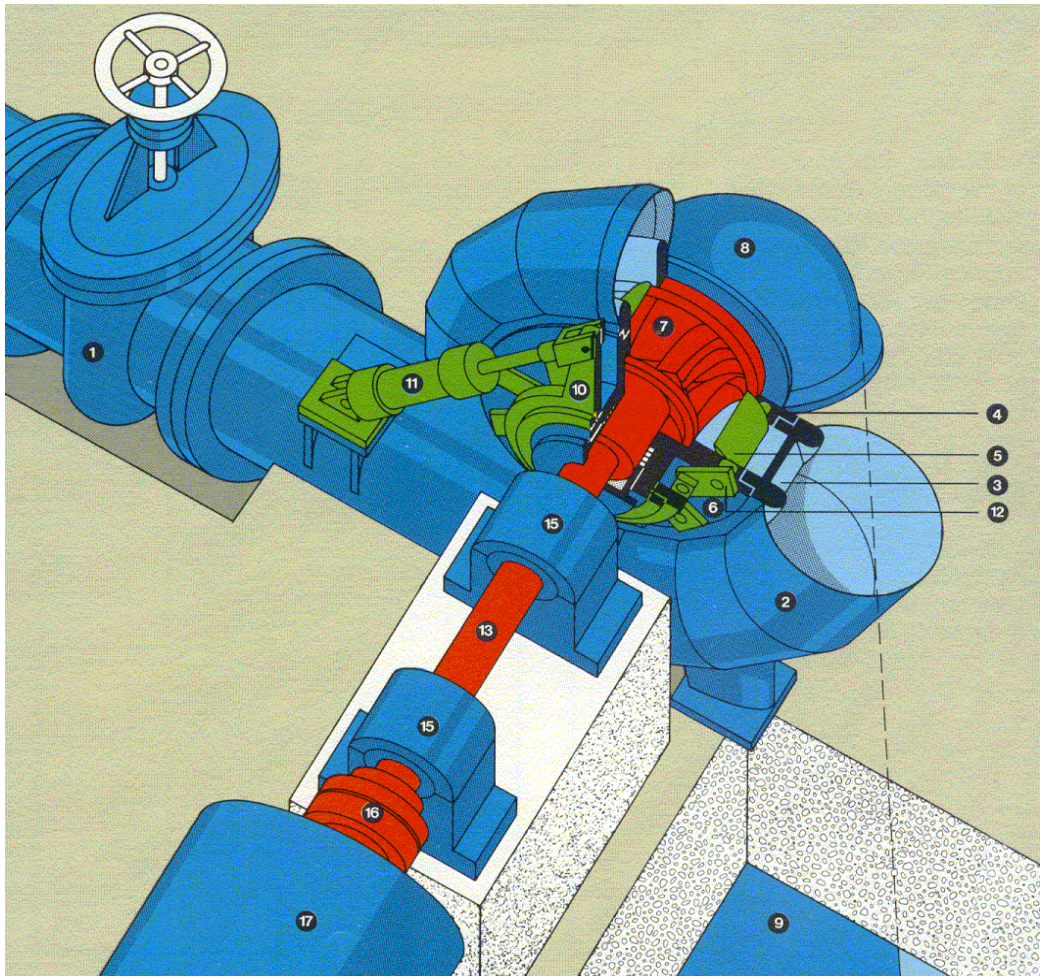
FRANCIS TURBINES

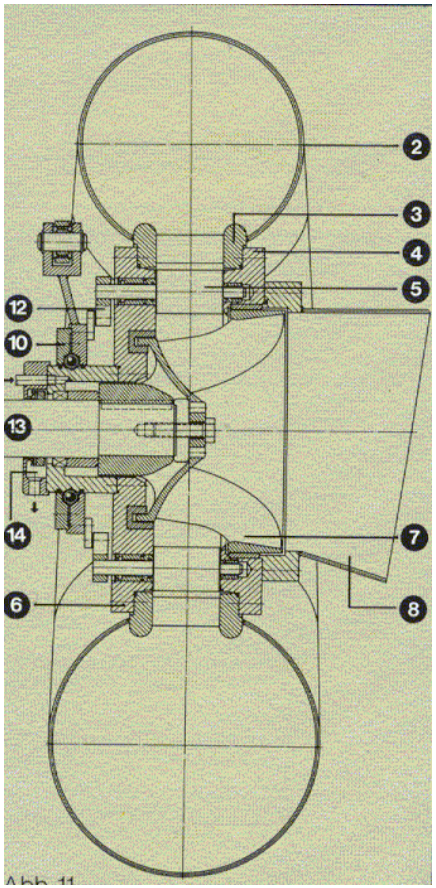
- Reaction type turbine
- Used for intermediate head applications
- Most common type of unit installed as it covers the majority of the sites available in the hydro, water and waste water industries
- Operates in the head range between 65% to 125% of the best efficiency on the unit
- Operates between 40% to 100% of the unit's maximum flow at best efficiency head

Typical unit for MWS installations. Efficiency is improved by wicket gates.

FRANCIS TURBINES

Principal Component Parts





1. Shut off valve
2. Spiral case
3. Stay ring
4. Curb ring
5. Guide vane
6. Head cover
7. Runner
8. Draft tube elbow
9. Draft tube
10. Operating ring
11. Servomotor
12. Lever
13. Turbine shaft
14. Shaft seal
15. Bearing
16. Flexible coupling
17. Generator z

Most common use for municipal systems is a centrifugal pump spinning in reverse.

TRADITIONAL HORIZONTAL FRANCIS TURBINES.

TECHNOLOGY FOR MUNICIPAL HYDRAULIC POWER RECOVERY TRADITIONAL

- Horizontal turbine with inlet flow control wicket gates
- Synchronous generator
- Orientation similar to end suction centrifugal pump
- In lower power production situations an end suction pump in reverse rotation may be used typically without wicket gates

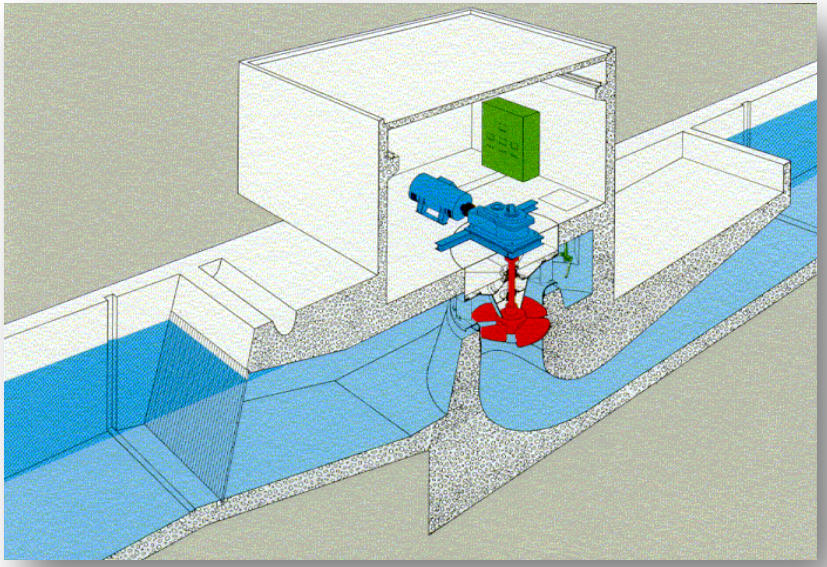
Conduit hydropower looks very similar to traditional pumping systems.

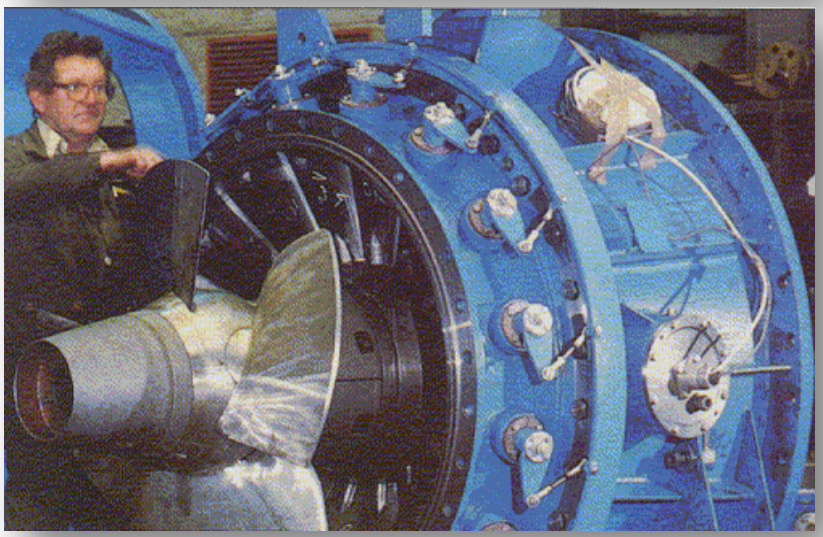
KAPLAN TURBINE

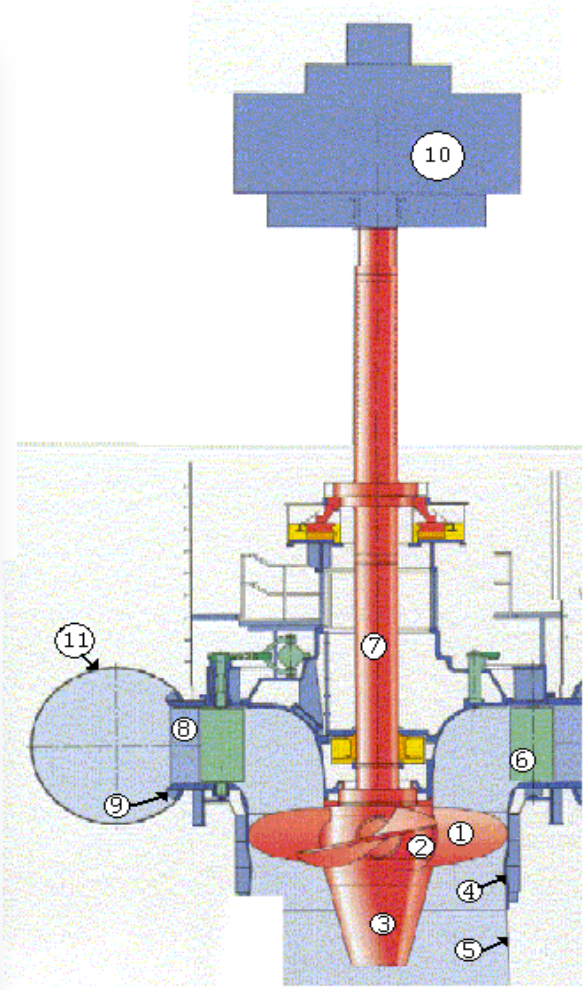
- Reaction type turbine
- Used for low head applications
- A Kaplan turbine is an adaptation of a propeller turbine. The Kaplan turbine has moveable blades where as the propeller blades do not move. Both types of units have wicket gates, similar to Francis units.
- Kaplan turbines include what are called Pit Turbines, S Turbines, and Bulb Turbines.
- Provide excellent efficiency over a wide head and flow range. Flows may be from 15% to 100% and heads from 65% to 125% of the best efficiency head.

Disadvantage: Large units that need high flows to be cost effective. Usually run of river installations.

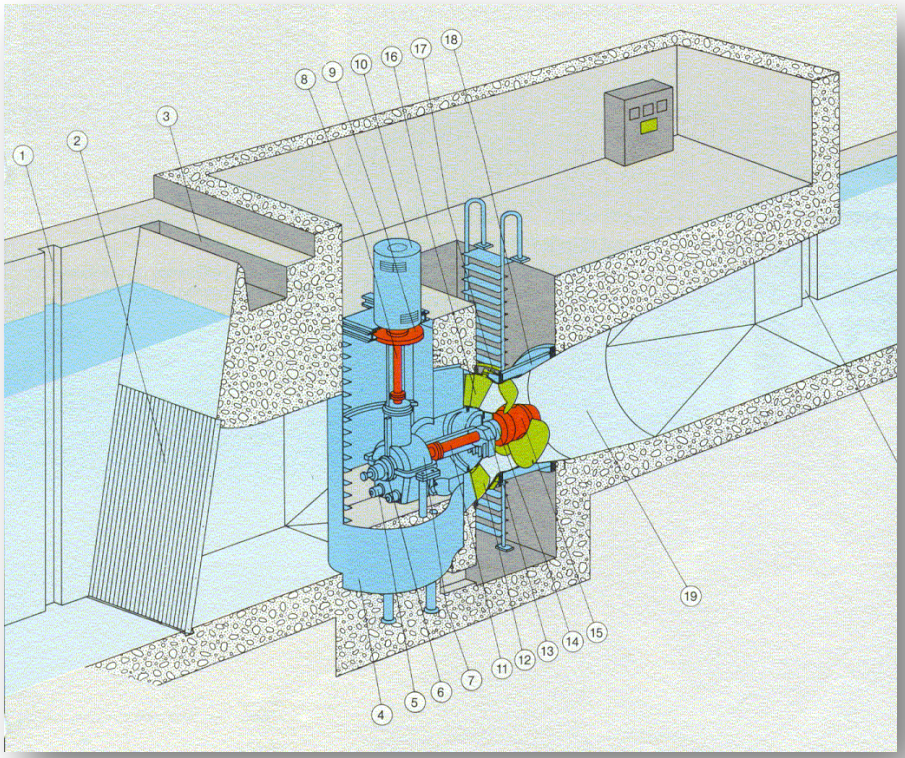
TRADITIONAL KAPLAN ARRANGEMENT



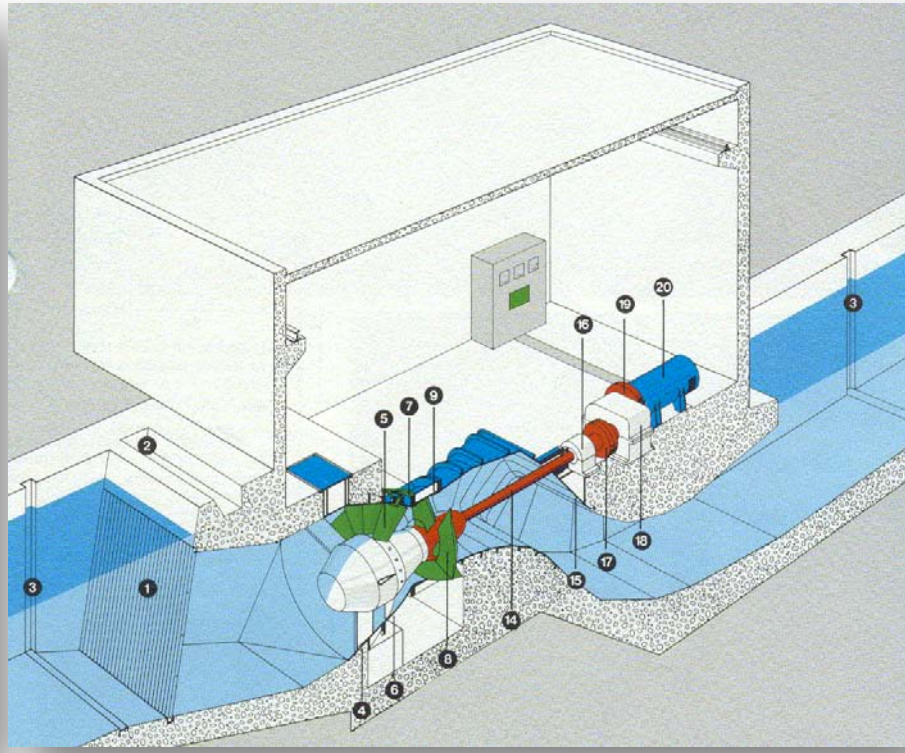




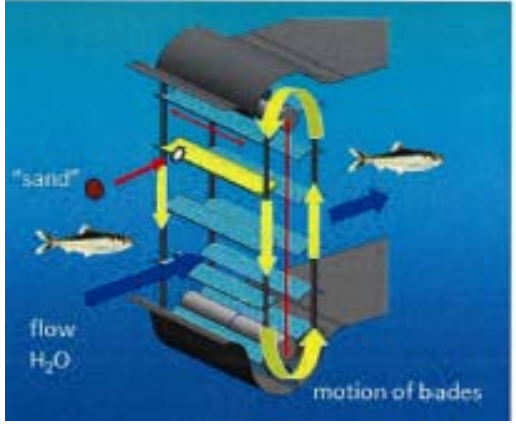
ALTERNATIVE KAPLAN ARRANGEMENTS PIT TURBINE – “COMPACT” BELT DRIVE



PIT KAPLAN ARRANGEMENT



S-BULB KAPLAN ARRANGEMENT



NATEL ENERGY SLH GRAPHIC

RITZ-ATRO HYDRODYNAMIC SCREW

NOVATECH-LOWATT TURBINES INC. VLH TURBINE

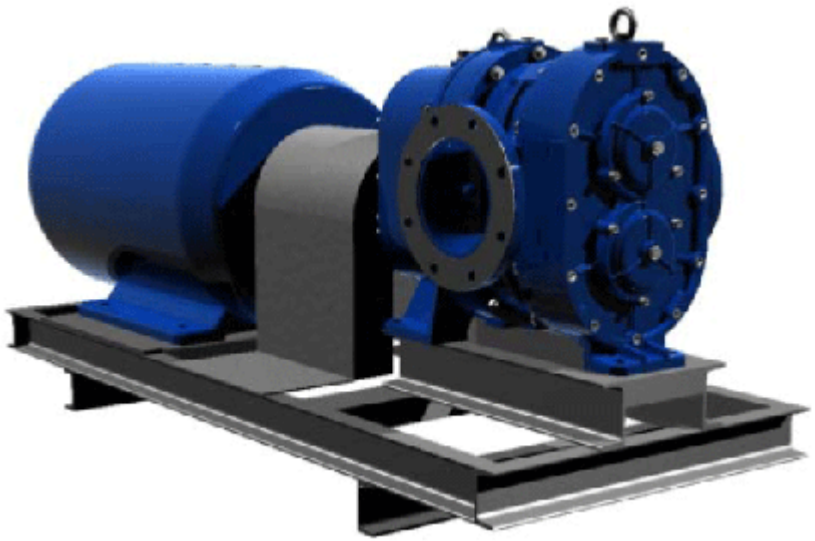
TECHNOLOGY FOR MWS HYDRAULIC POWER RECOVERY INNOVATIVE TECHNOLOGIES

- Hydrodynamic screw (Archimedes screw in reverse)
- VLH "gate" turbine
- Schneider Linear Hydroengine (SLH)
- Siphon turbine
- All low head < 20 ft (6 m)

Appropriate technology depends on specific site conditions.

NEW TECHNOLOGY
POWER RECOVERY AND PRESSURE CONTROL

- Introduced to market in 2010
- Still under testing.



ROTARY LOBE ENERGY RECOVERY UNIT

- Pressure reduction helical rotary lobe
- Uses “off the shelf” components
- Utilizes AFD and induction motor to generate power
- AFD converts power and adjusts unit speed
- Capable of pressure control

Applicable for pressure reduction stations within distribution systems or between zones.

OLD TECHNOLOGY IN NEW APPLICATIONS

- Unregulated centrifugal pumping units
- No wickets gates = simplified operation
- Standard production items means lower unit cost
- Slight loss in efficiency
- Best for fixed flow rates
- Suitable for residual discharge pressure (forcemain applications)

CORNELL PUMP COMPANY
UNREGULATED MICRO TURBINE

OTHER ARRANGEMENTS AVAILABLE

MWS HYDROPOWER IMPLEMENTATION PERMITTING AND INCENTIVES

MWS HYDRO EVALUATION PROCESS

Power

- Determine Hydraulic Power Available
- Identify Power User

Tools

- Identify Acceptable Technology
- Determine Optimum Equipment Size
- Evaluate Permitting Requirements

$

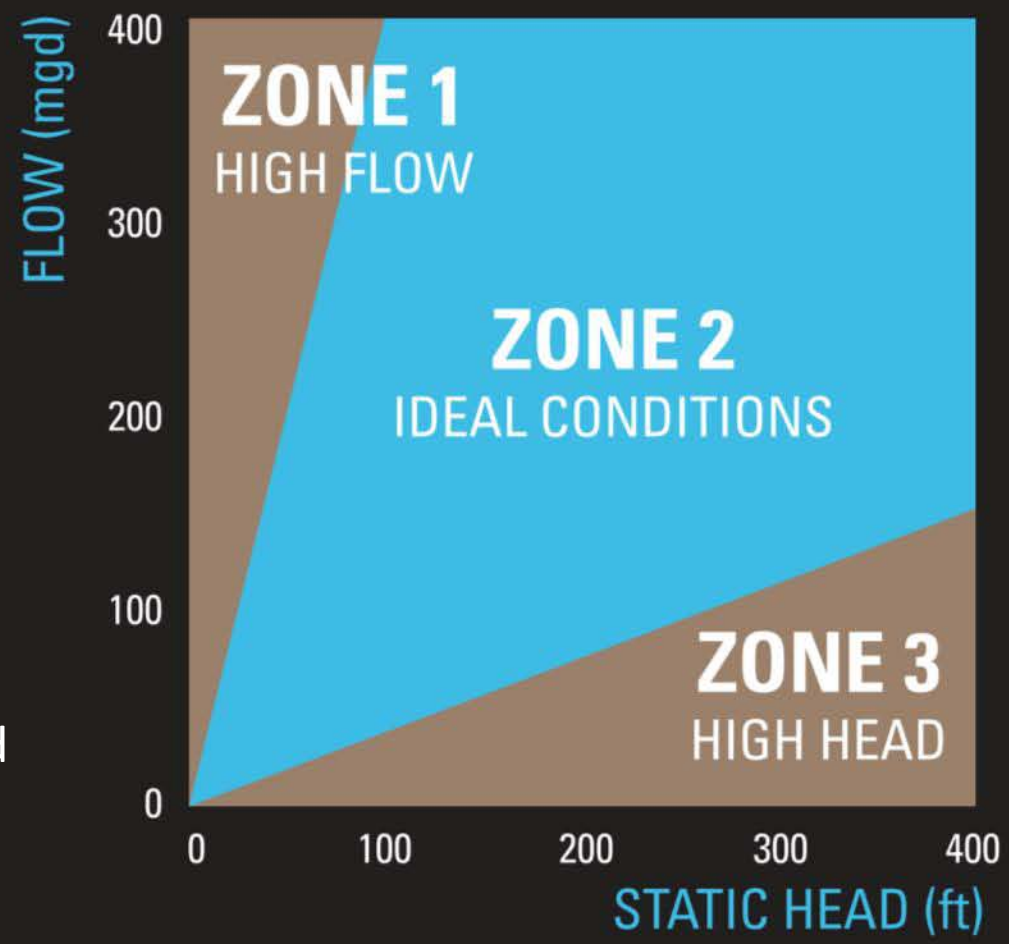
- Determine Cost Of Power or PPA
- Estimate Capital Investment
- Determine Rate of Return/Payback

MWS HYDRO EVALUATION

- Criteria Different for Every Owner
- Payback Must Be Acceptable to Continue
- Timing Must Be Acceptable
- Not Every Project Is Viable

HEAD AND FLOW RELATIONSHIP

Head and flow alone do not guarantee generation capability. Project specific constraints must be evaluated on a case-by-case basis.



IDEAL CONDITIONS

- **Zone 2 head & flow conditions**
  - > 1 MGD
  - > 30 psi or > 70 ft static head
- **Zones 1 and 3 may be possible in certain circumstances**

POTENTIAL ISSUES FOR WATER AGENCIES

- **Energy Market vs Water Market**
- **Federal Energy Regulatory Commission (FERC)**
- **Equipment Terms & Conditions**
- **Equipment lead time**
- **Interconnection of Generator to power demands**
- **Power Purchase Agreement**
  - Selling price less than retail buying price

MWS HYDRO FINANCING OPTIONS

FEDERAL INCENTIVES

- **Qualified Energy Conservation Bonds (QECBs)**
  - Interest free, bondholder receives federal tax credits in lieu of traditional bond payments
  - Allocated through State Energy Office
- **US Department of Treasury Renewable Energy Grants**
  - Not available for federal, state, local governments or non-profits
  - Applications only made after construction has commenced
  - Grant covers up to 30% of eligible costs

EXAMPLE PROJECT APPROACH

FOCUS OF DISCUSSION	
Phase 1	**Feasibility Study**
Phase 2	Project Implementation
Phase 3	Design
Phase 4	Construction
Phase 5	Start Up/Commissioning

MWS HYDRO BENEFITS AND APPLICATIONS

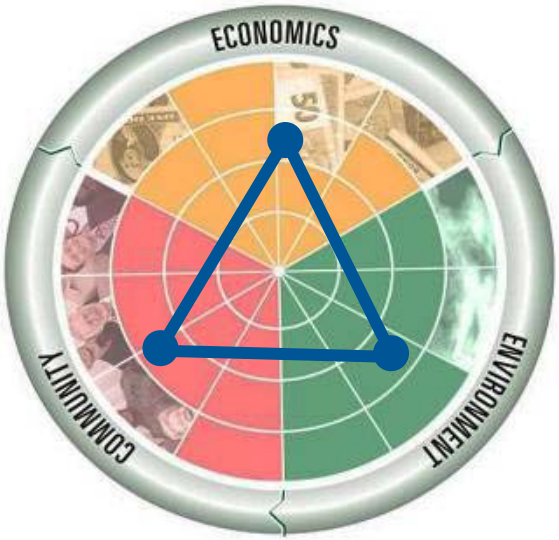
BENEFITS OF MWS HYDRO

- **Offsets power consumption for water utility**
  - Extra power may be able to be sold
- **Sustainable**
  - Considered a renewable energy source
  - May qualify for Renewable Energy Credits (REC)
- **Needs Reliable and predictable head and flow**
  - Reliable base-load power supply
  - Helps balance other renewable energy assets

FRENCH MEADOWS SECOND POWERHOUSE, AUBURN, CALIFORNIA

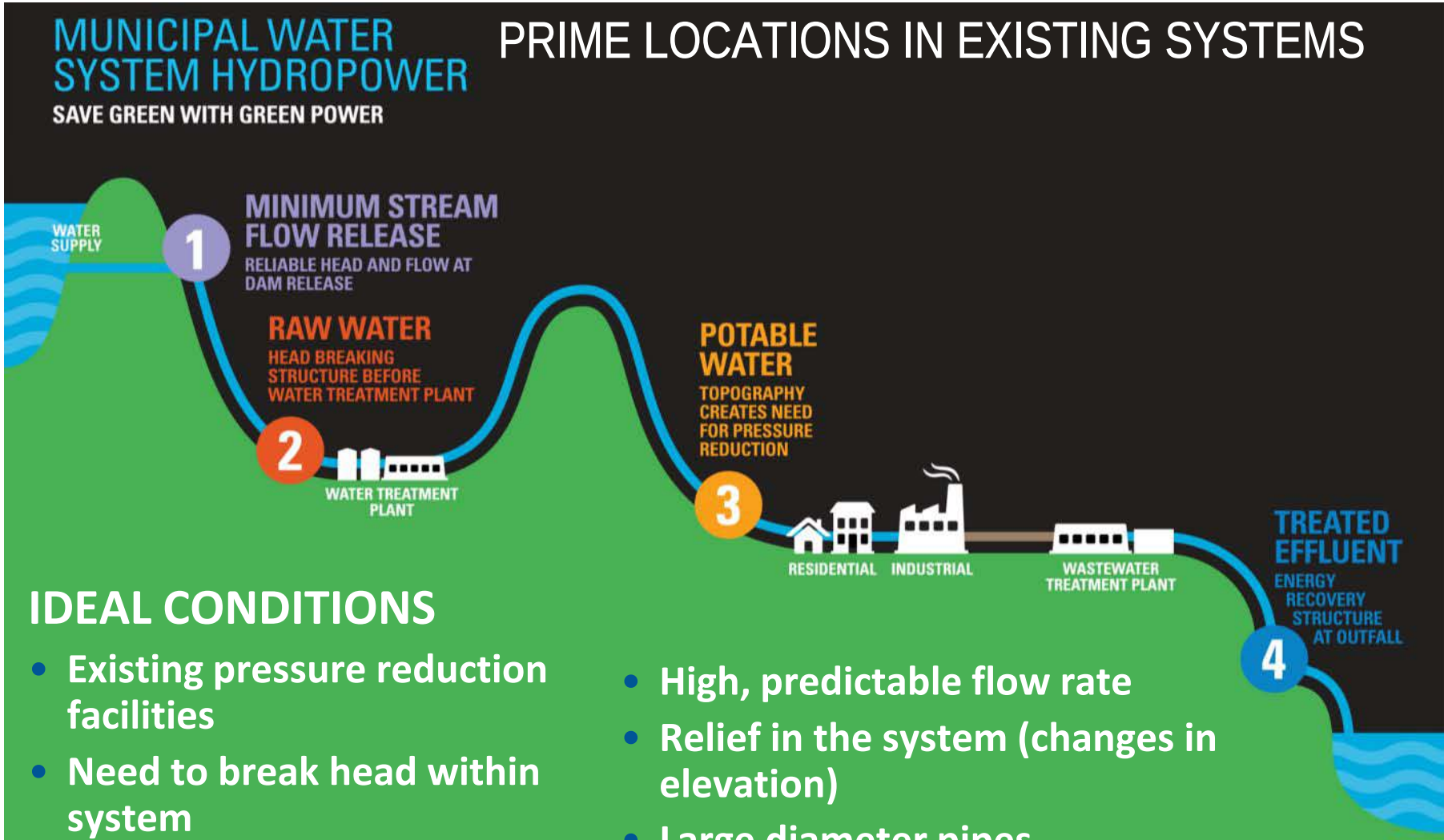
BENEFITS OF MWS HYDRO

- **Limited community impact**
  - Typically within existing utility property
  - Small site footprint
- **Limited ecological impact since water is already in treatment system**
- **Favorable financials**
  - Small initial capital expense
  - Favorable ROI
  - Low operations & maintenance costs
  - ***Federal and state financial incentives may be available***



TRIPLE BOTTOM LINE

PRIME LOCATIONS IN EXISTING SYSTEMS

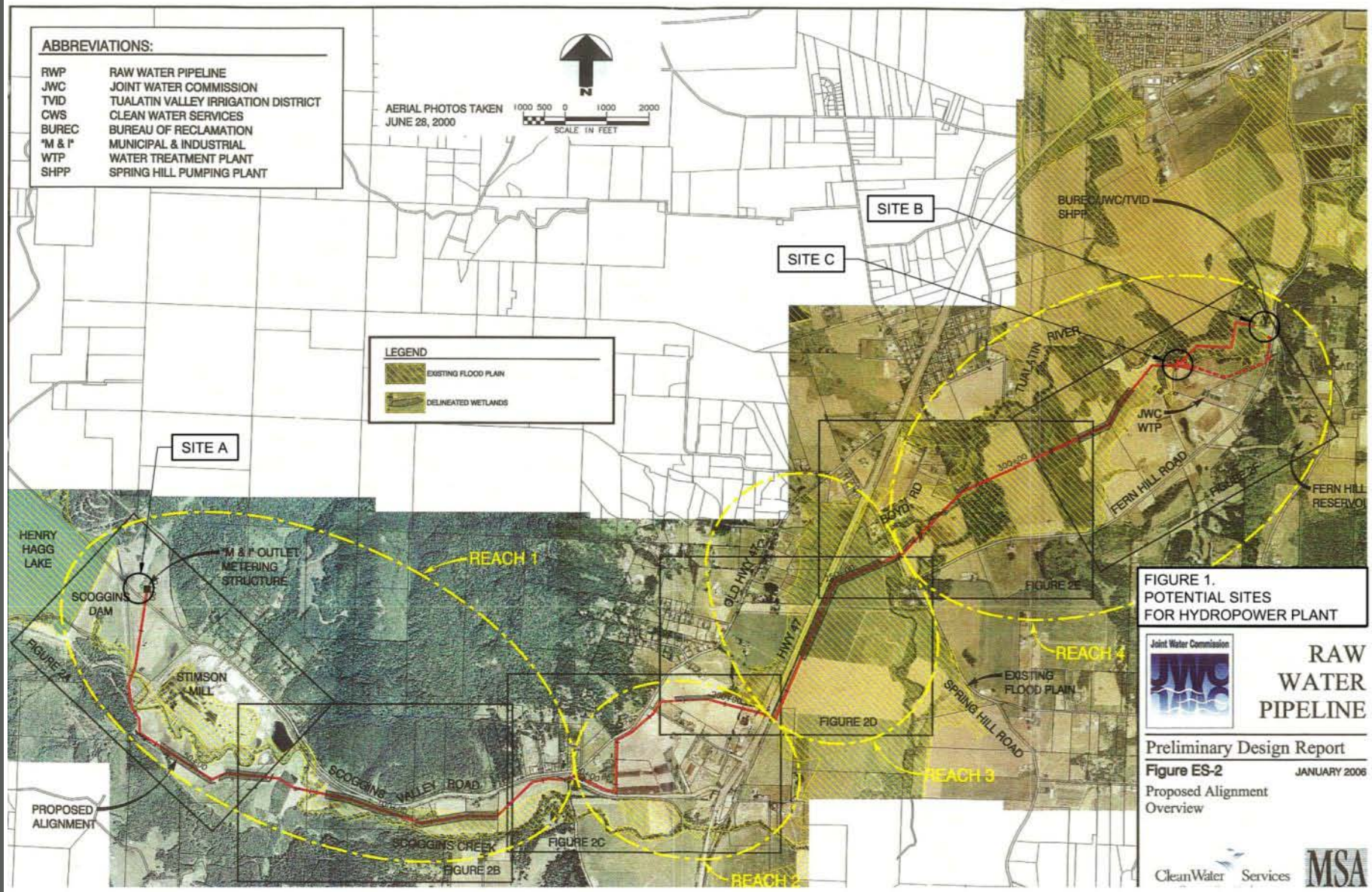


IDEAL CONDITIONS

- Existing pressure reduction facilities
- Need to break head within system
- High, predictable flow rate
- Relief in the system (changes in elevation)
- Large diameter pipes

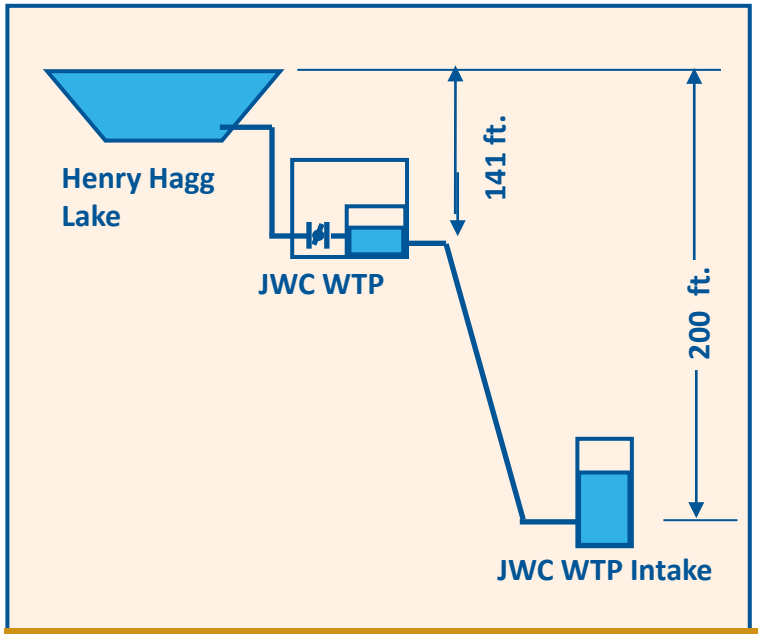
MWS FEASIBILITY STUDY EXAMPLE - TBWSP

TUALATIN BASIN WATER SUPPLY PROJECT



TBWSP – RAW WATER DELIVERY SYSTEM

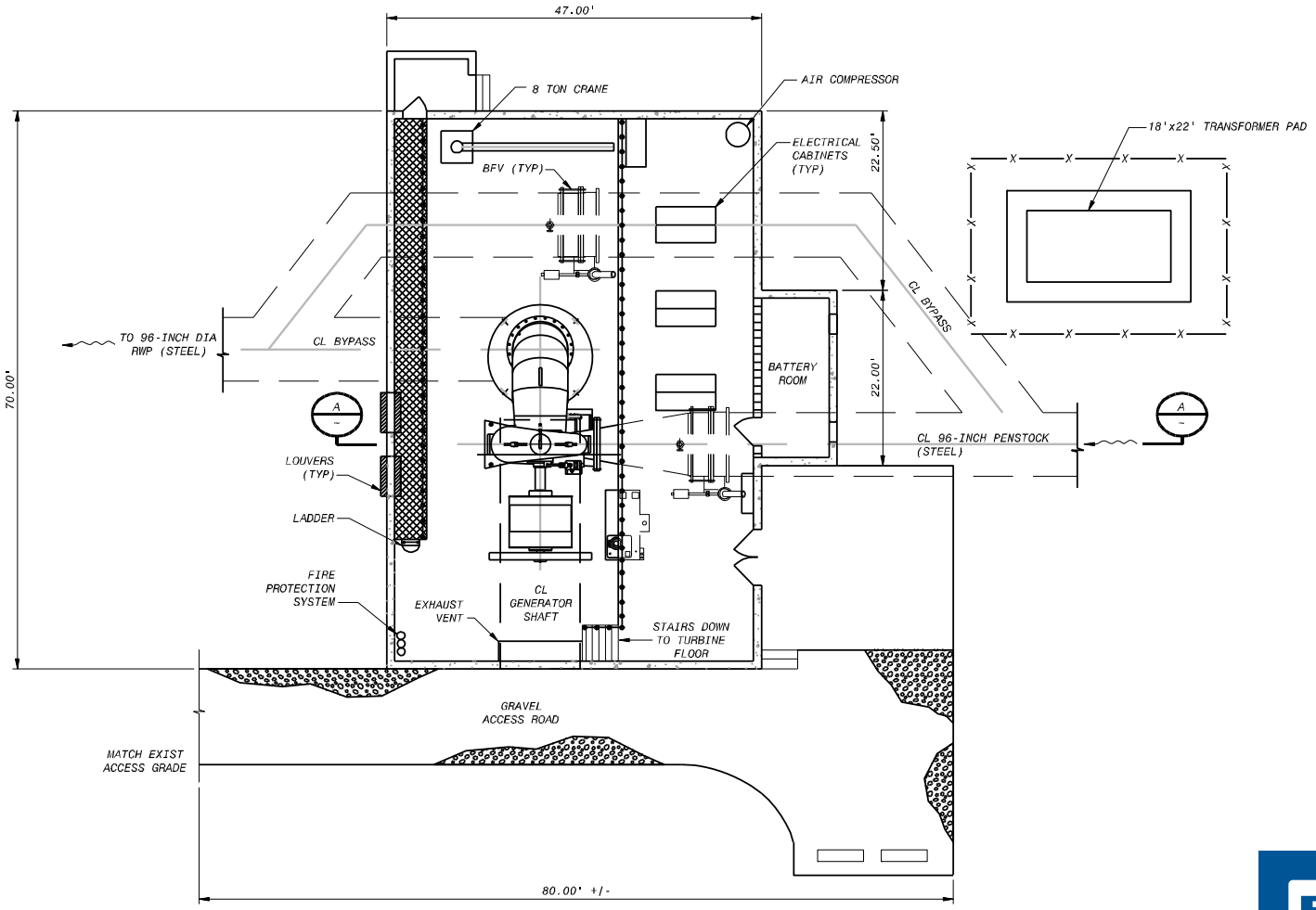
- **Study performed for Clean Water Services. JWC is teaming partner**
- **Source Water – Tualatin River Basin**
- **Proposed Dam Raise Project:**
  - 40-foot raise of Scoggins Dam
  - 35,000 LF of 96-inch pipeline from dam to JWC WTP
  - 300 cfs (194 MGD) maximum drawout
  - Reservoir Pool Elevations
    - Max 345.7’
    - Min 239’



TBWSP Hydraulic Profile

TBWSP – POWERHOUSE SITES

TBWSP – FRANCIS TURBINE LAYOUT



PLAN
1"=20'-0"

TUALATIN BASIN WATER SUPPLY PROJECT

- **3 flow scenarios were considered:**
  - 1 JWC + CWS flow in the 96-inch pipe (lowest flow)
  - 2 JWC + CWS and TVID flow in the pipe (requires agreement from the irrigation district)
  - 3 300 cfs in the pipe. (best case scenario for hydro. But this is a water project

- **3 turbine configurations were considered:**
  - A Single Francis Turbine Unit.
  - A Single Kaplan Turbine Unit.
  - Two Small Francis Turbine Units.

TUALATIN BASIN WATER SUPPLY PROJECT

Table 2. Scenario 2 - Draw-out per the May 2006 MWH Hydrologic Model Report with TVID flow in the RWP

(JWC and CWS and TVID in the RWP up to a maximum of 300 cfs in the RWP. In-stream flow out of the RWP and not guaranteed.)

Single Francis Unit Results

Month	Total Avg Flow cfs	RWP Flow cfs	Reservoir Elev. ft	Tailwater El. 200 ft	Avg.Static Head ft	Penstock loss ft	Total Dynamic Head, ft	turbine flow, Q_t cfs	Bypass flow, Q_{bp} cfs	Turbine Eff. %	Turbine output P KW	Generator Eff, %	Plant output KW	Time hrs	Energy MW hrs
June	111.0	111.0	341	200.0	141.0	3.92	137.08	0	111	79.25	0	0.874	0	720	0
July	376.0	300.0	330	200.0	129.5	28.62	100.88	300	0	89.70	2,296	0.951	2184	720	1,572
August	435.0	300.0	307	200.0	107.0	28.62	78.38	294	6	90.00	1,757	0.969	1701	720	1,225
September	353.0	300.0	279	200.0	79.0	28.62	50.38	0	300	32.77	0	0.874	0	720	0
October	163.0	163.0	254	200.0	53.5	8.45	45.05	0	163	29.96	0	0.874	0	720	0
November	24.0	24.0	247	200.0	46.5	0.18	46.32	0	24	30.68	0	0.874	0	720	0
												hours =		4320	
												energy MWHr =			**2,797**

Single Kaplan Unit - The spreadsheet for the Kaplan Unit is shown in the Appendix. The maximum mWH was **3528**.

TUALATIN BASIN WATER SUPPLY PROJECT

Table 9. Present Worth Analysis – Alternative 3	
FRANCIS TURBINE AT RIVER INTAKE	
All Revenue Streams	$ 12,096,871
Capital and O&M Costs	$ 21,568,591
Gain / (Loss)	$ (9,471,721)
Reference Year Cost of Energy (2006$) (cents/kWh)	7.52
Break-even Cost of Energy (2006$) (cents/kWh)	13.41
Simple Payback Period, From Study Start Year (rounded to nearest integer) (years)	35
Values are 2016$, unless otherwise noted	

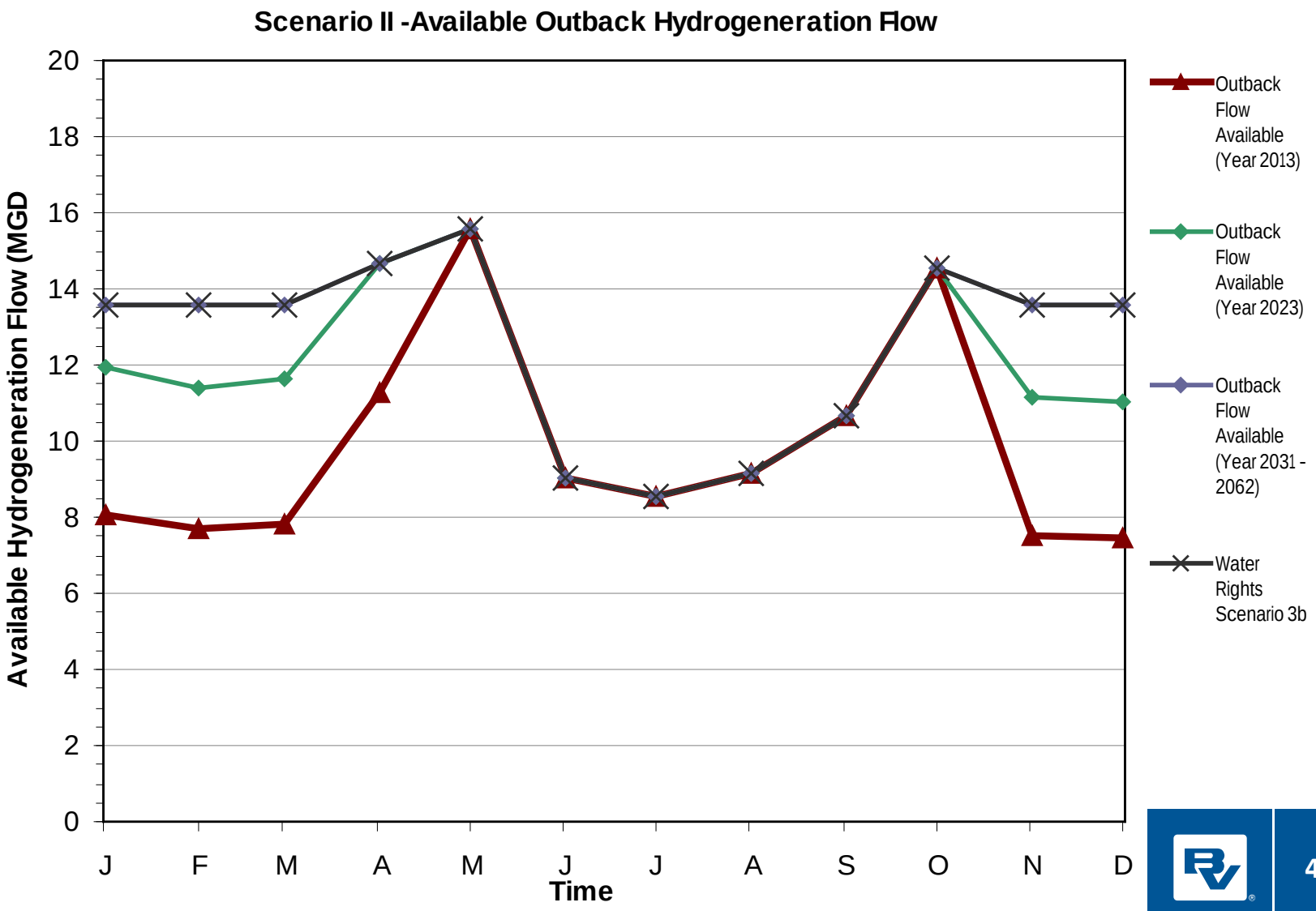
MWS FEASIBILITY STUDY EXAMPLE - CITY OF BEND, OREGON

CITY OF BEND WATER SUPPLY PROJECT

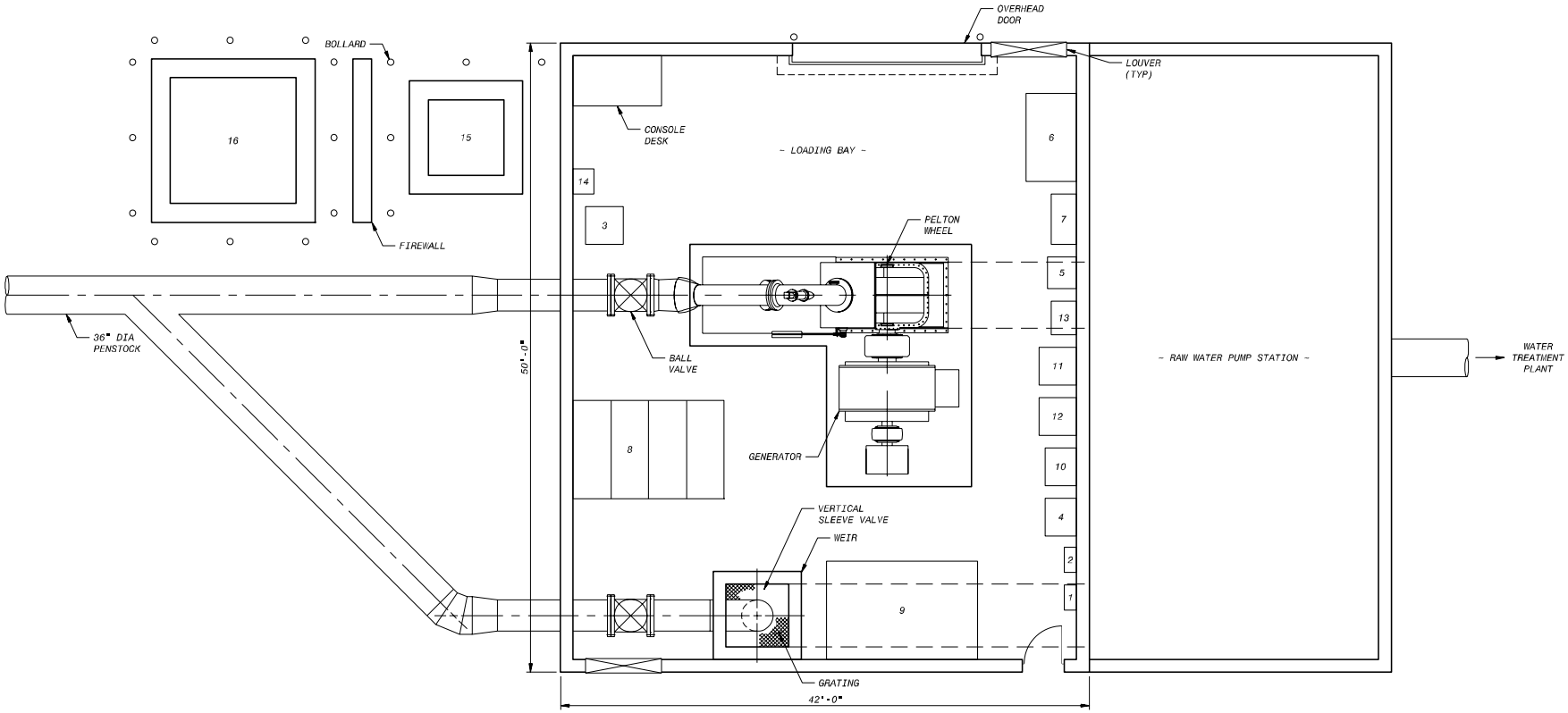
- **LT2SWTR driving new WTP**
- **Source Water – Bridge Creek – Elevation 4,000'**
- **Outback Site – Elevation 3,000'**
- **Proposed Project Elements:**
  - New Intake Screens
  - Replace RW Pipeline – 36" Steel
  - Membrane WTP at Outback
  - Hydro Powerhouse at Outback

BRIDGE CREEK INTAKE

CITY OF BEND WATER SUPPLY PROJECT



BEND – PELTON WHEEL POWERHOUSE



CITY OF BEND WATER SUPPLY PROJECT

- **Capital Costs – Powerhouse with Single 2MW Pelton Wheel**
  - Powerhouse - $5,770,000
  - Interconnection - $662,000
  - Contingencies - $2,250,000
  - Engineering - $867,000
  - Permitting - $818,000
  - **Total - $11,400,000**
- **O&M Costs**
  - Annual O&M Costs*
    - $35,200

** O&M Costs escalated to 2013 dollars*

TUMALO FALLS

CITY OF BEND WATER SUPPLY PROJECT

- Potential Tax Credits

TABLE 5. TAX CREDITS, GRANTS, AND INCENTIVES	
Business Energy Tax Credit*	50% construction cost up to $10 million/program
Federal Business Energy Investment Tax Credit*	$200/kW for 1st 2MW (up to $400,000)
Federal Renewable Energy Grants*	$200/kW for 1st 2MW (up to $400,000)
Energy Trust of Oregon	10% Capital Cost

CITY OF BEND WATER SUPPLY PROJECT

- Results - 50-year Present-Worth Analysis

OUTBACK TANK SITE

TABLE 9. PRESENT WORTH ANALYSIS

Facility	Turbine Size (kW)	Calculated Annual Power Generation	All Revenue Streams	Capital and O&M Costs	Gain / (Loss)	Simple Payback Period, From Study Start Year (years)
OUTBACK HYDROGENERATION FACILITY						
Scenario II	2,000	8,990,000 kW-Hr, (2013) 11,440,000 MW-Hr, (2063)	$63,611,000	$37,822,000	$25,789,000	27

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