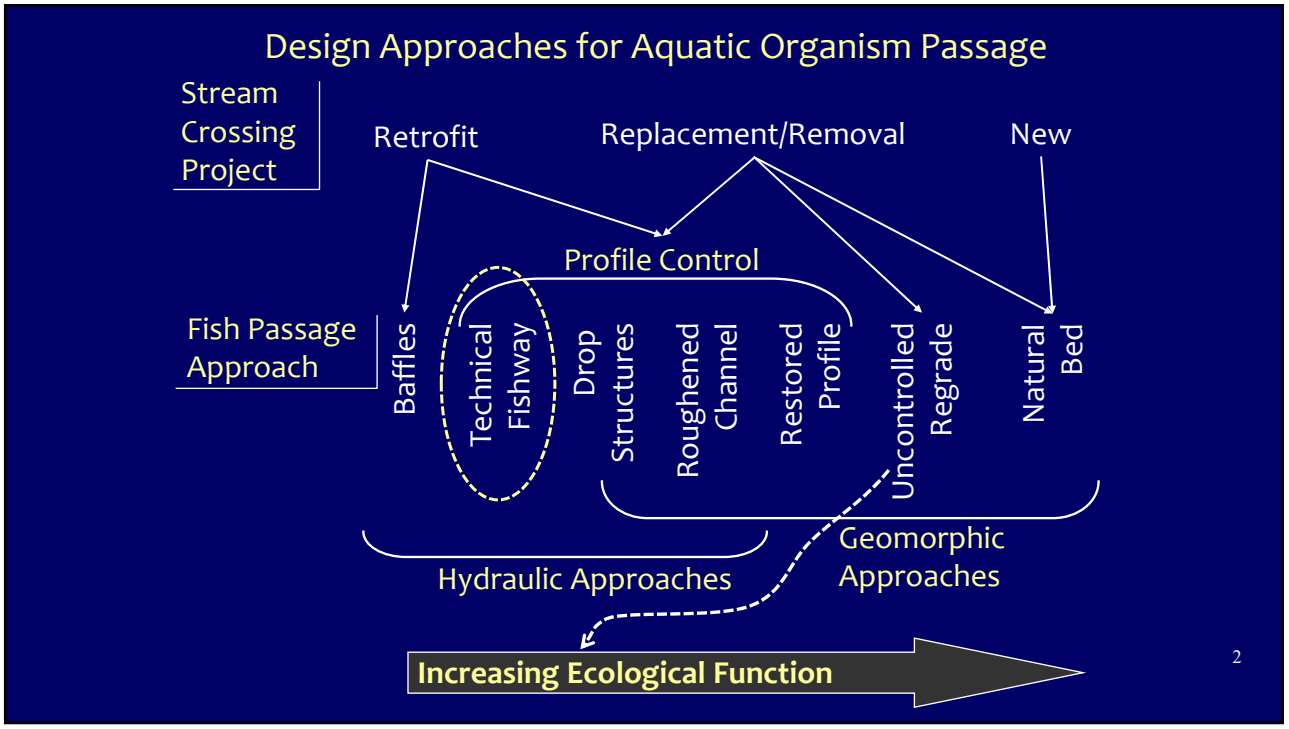
Traditional Hydraulic Designs for Fish Passage at Stream Crossings

Michael Love P.E.
Michael Love & Associates
Arcata, California
mlove@h2odesigns.com

1

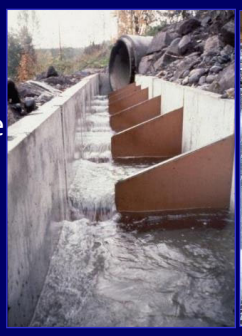
1



2

Technical Fishways

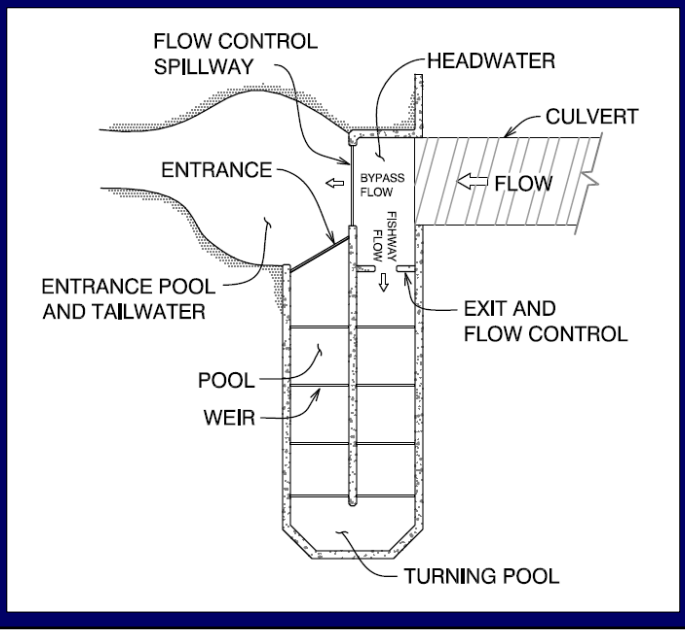
- Rigid permanent bed control (typically concrete or sheetpile)
- Passage typically optimized for target species
- Can be constructed steeper than most geomorphic based profile controls
- Minimum footprint
- Narrow flow range for passage
- High construction, operation, maintenance cost



3

3

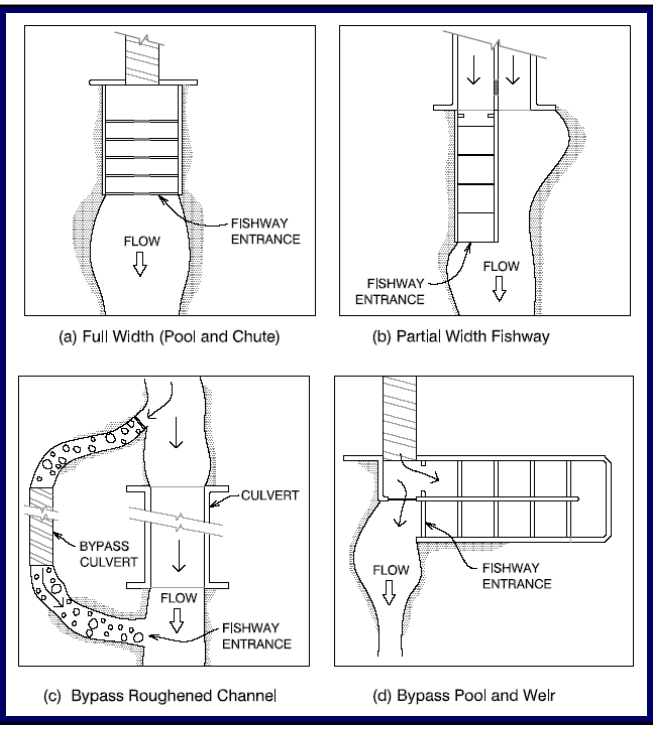
Fishway Nomenclature



4

4

Fishway Layouts



5

5

Roughened Chute Fishways
Denil and Alaskan Steeppass

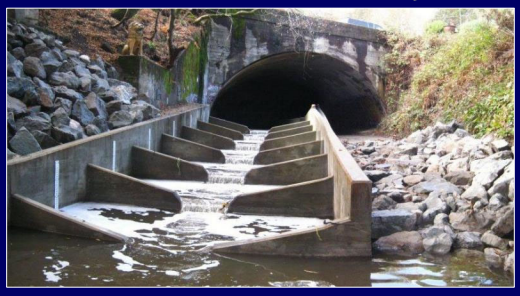
- Uses roughness to control velocities
- Placed at steep slopes
- Passes adult salmonids and alewives (but not weaker swimming fish)
- Tend to clog quickly with debris
- Operates over narrow flow-range
- Convey small portion of total flow (poor fish attraction in some cases)

CDFW/NMFS do not allow these types of fishways for permanent installations and are actively removing them

6

6

Technical Fishways for Stream Crossings



Partial Width Pool-and-Chute Fishway

Bypass Pool-and-Weir Fishway

Full Width "Vortex" Pool-and-Chute Fishway

Bypass "Serpentine" Pool-and-Weir

7

Fishway Types: Pool & Weir

Sloping Weir Crest (V-weir) Creates Good Passage Conditions along Edge

$$Q_{v-weir} = \frac{8}{15} C_d \sqrt{2g} \tan\left(\frac{\theta}{2}\right) H_{v-weir}^{2.5}$$

Where:

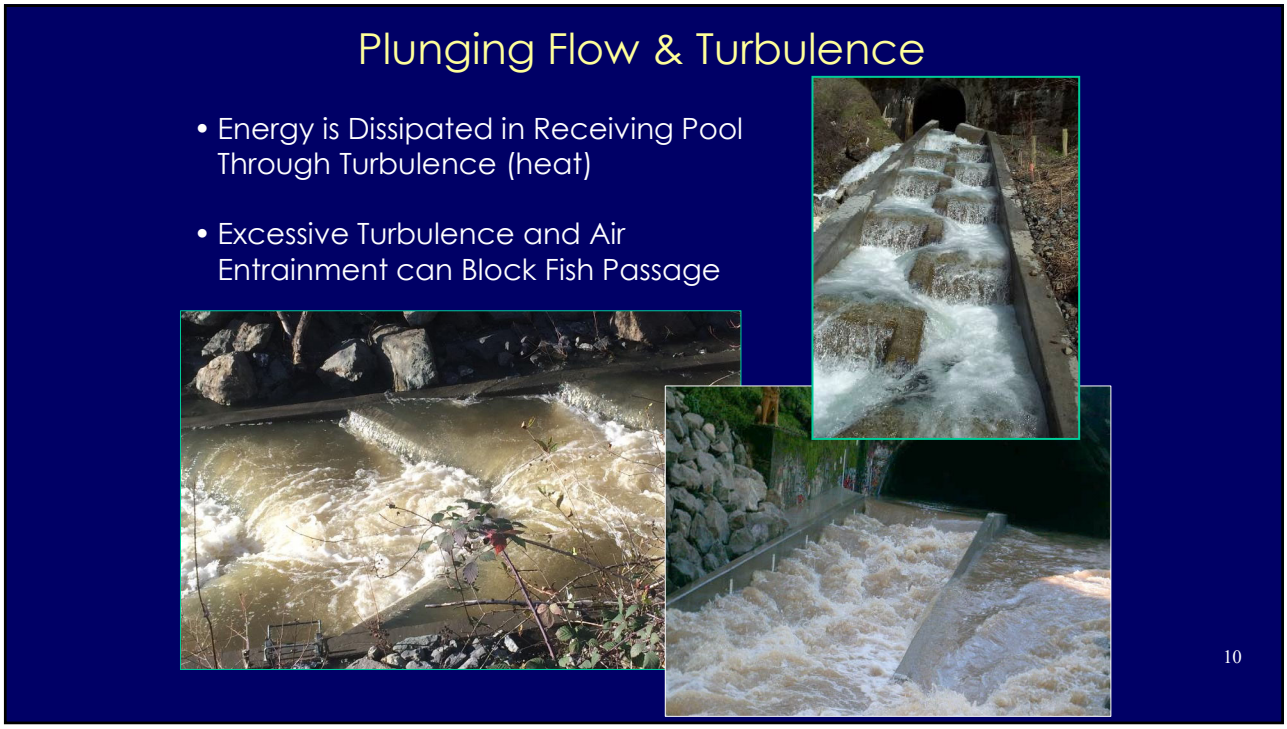
$$C_d = 0.6072 - 0.000874\theta + 6.1 \times 10^{-6}\theta^2$$

8

8


Fishways using “zero” stream length
Little Park Cr
Photos: Kozmo Bates
9

9


Plunging Flow & Turbulence
• Energy is Dissipated in Receiving Pool Through Turbulence (heat)
• Excessive Turbulence and Air Entrainment can Block Fish Passage
10

10

Example of Energy Dissipation Factor (EDF) in Pool and Weir Fishway

$$EDF = \frac{\gamma Q h}{V}$$

Calculate EDF in a fishway pool:

Q = 7.5 cfs
H = 1.0 ft
Pool; L=6', w=5', d=4'

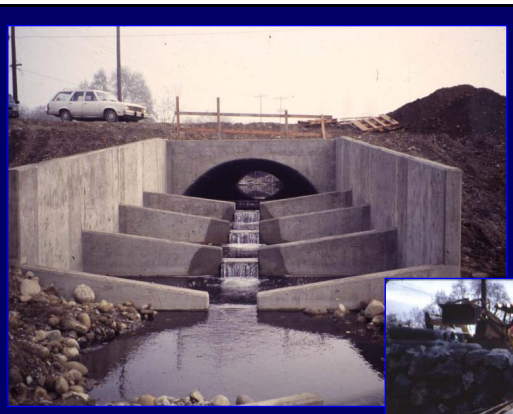
EDF = $\frac{62.4\ lb/ft^3 \times 7.5\ ft^3/s \times 1.0\ ft}{6\ ft \times 5\ ft \times 4\ ft}$

= 3.9 ft-lb/sec/ft^3
< 4.0 ft-lb/sec/ft^3

Adult Resident Trout
Max EDF = 3 ft-lb/sec/ft3

11

11



Hybrid Fishway Type: Pool & Chute Fishway

Plunging at Low Flow

Streaming & Plunging at High Passage Flow

Photos: Kozmo Bates

12

12

Hybrid Fishway Type: Pool & Chute Fishway

Big Sulphur Creek Retrofit

Pool and Chute Fishways:

- Can be built at slopes up to 10%
- At this slope, avoid overall drop greater than approximately 7 feet
- Lower slopes, may increase overall drop

13

13

Vortex Pool & Chute Fishway

Plunging at Low Passage Flow

Fishway Slope = 7%
8" Drops
Overall Fall = 7 feet

Maintains Plunging along Shoulders & Dry Shoulder for "Passage Corridor"

Streaming down Center at High Passage Flow

14

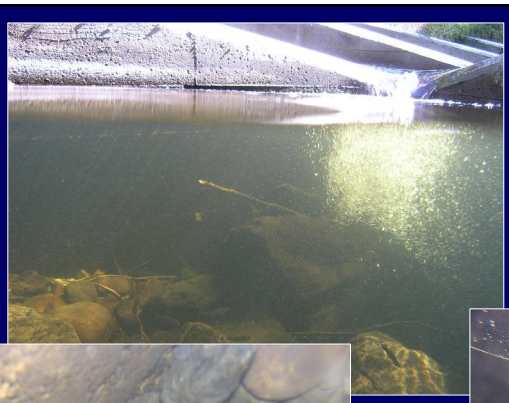
Pool & Chute Fishway Limitations

- Applicable to low head dams and some culvert retrofits
  - At fishway slope of 10%, observed undesirable hydraulics with total drop across fishway greater than 6 to 7 feet.
  - At slopes of 7% to 8% and drops up to 12 feet, undesirable hydraulics not observed
- Must be relatively straight due to streaming flow (no switchbacks)
- Fishway velocities at downstream end are High. Can cause downstream channel scour.

Alameda Creek Flood Control Channel

15

15



Substrate in Fishways

- Some coarse substrate good
- Dissipates energy
- Creates velocity shadows for fish
- Excess substrate can fill fishway pools, making for poor passage

Photos: Zack Larson

16

16

Inspection and Maintenance of Technical Fishways

- Develop an Inspection and Maintenance Plan
- Plan inspections after every large flow event and annually to ensure timely clearing of debris/sediment
- Maintenance may include repairs to damaged concrete and steel
- A biological monitoring may be needed at project start-up to ensure project objectives are satisfied

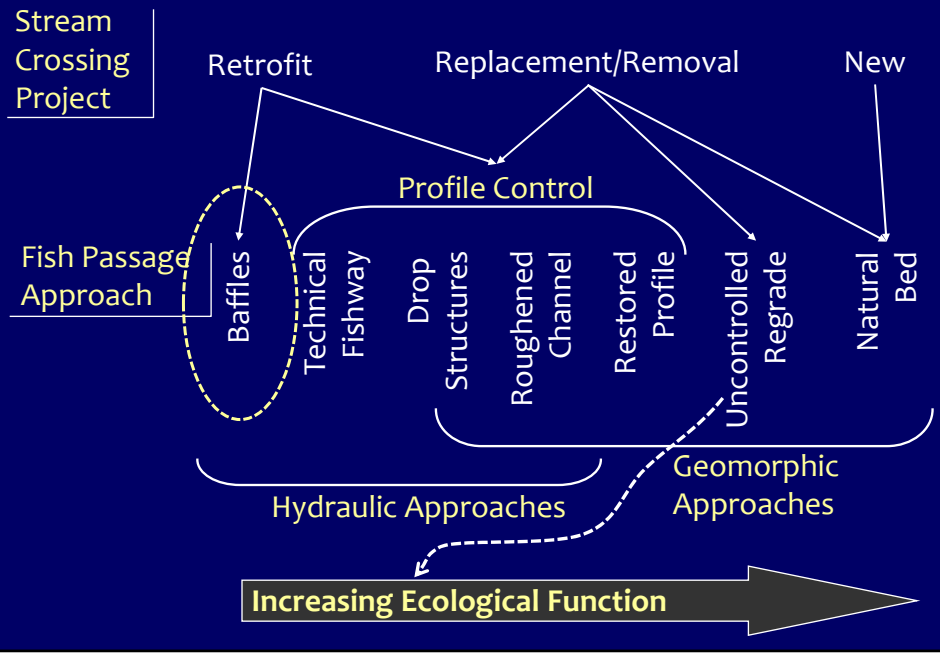
Big Sulphur Creek Fishway

Alameda Creek Flood Control Channel

17

17

Design Approaches for Aquatic Organism Passage



18

18

Hydraulic Retrofits of Culverts for Fish Passage using Baffles

Concrete Angled Baffle Retrofit

Slip-lined CMP with Corner Baffles

19

Baffles for Fish Passage

Culvert Retrofit Improves Fish Passage

- Increases Hydraulic Roughness
- Decreases Velocity
- Increases Depth

Invert Paving with Corner Baffles Added

20

20

Baffles for Fish Passage

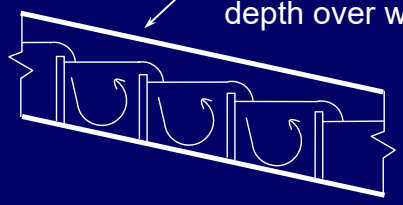
Two Hydraulic Regimes

- **Plunging Weir Flow (Low Flow)**
  - sharp crested weirs
  - turbulence dissipated in pool below baffle
  - excess turbulence generally not an issue
- **Streaming Flow (High Flow)**
  - hydraulic roughness
  - uniform turbulence

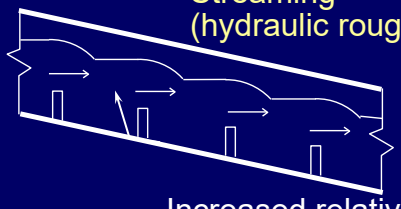
21

21

Plunging (weir flow)



Streaming
(hydraulic roughness)



Increased relative
depth over baffle

22

22

Turbulence in Streaming Flow

Moderate Flow – Transition from weir to roughness

- Energy is Dissipated in Receiving Water Column Through Turbulence (heat)
- Excessive Turbulence Creates can Block Fish Passage

23

23

Hydraulic Roughness & Turbulence

Corner Baffles

EDF in Baffled Culverts with Streaming Flows:

$$EDF = \frac{\gamma QS}{A}$$

S = Channel/Culvert Slope (ft/ft)
Q = Flow (cfs)
A = Wetted Area (sf)
γ = Unit Weight of Water (62.4 lb/cf)

Thresholds (rule-of-thumb for Baffles):
Adult Salmon: EDF > 5 ft-lb/s/ft^3

24

24

Baffles from Yesteryear

Ramp Baffles

Lack of Depth at Low Flows
Functional over Narrow Flow Range

Off-Set Baffles

Tend to Catch Debris!!!
Slot Velocities too Fast for Small Fish

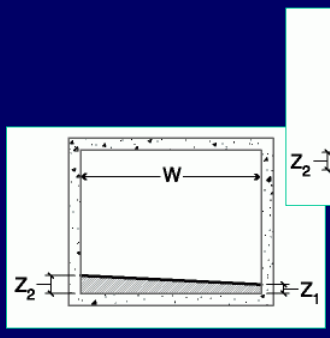
25

25

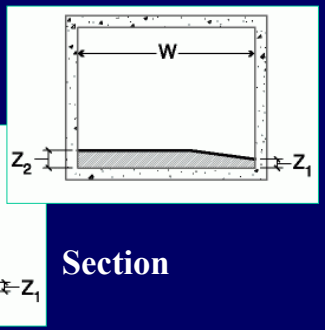
Angled Baffles for Flat-Bottom Culverts

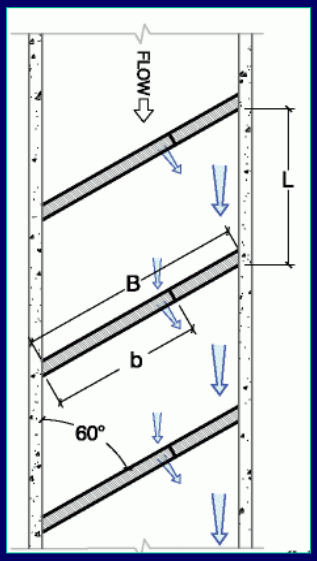
Angled Baffles

- Skew shunts flow and debris to one side
- Fish passage corridor on high side



Section





Plan

26

26

Angled Baffles for Flat-Bottom Culverts

Wooden Angle Baffle
(looking downstream)

Double Angle Baffles for Wide Culvert ("Vortex Baffle")
(looking upstream)

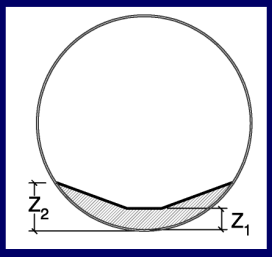
27

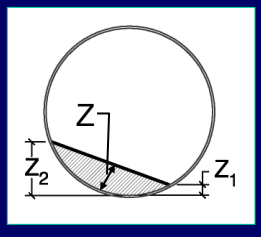
27

Corner & Weir Baffles

Weir Baffles

- For circular or pipe-arch culverts
- For larger culverts (W>8')
- Convey flow & debris in center
- Passage along sides





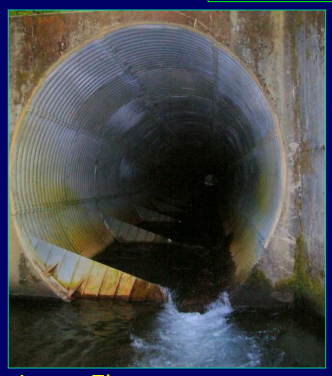
Corner Baffles

- For circular culverts
- Smaller culverts
- Convey flow & debris along low side
- Passage along high side

28

28

Outlet Transition



Low Flow

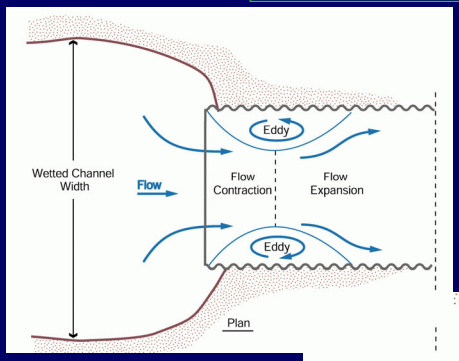
High Fish Passage Flow
(excessive hydraulic drop)

- Evaluate the Outlet Transition with FishXing
- Avoid Excessive Hydraulic Drop at Outlet
- Match Normal Depth to Tailwater

29

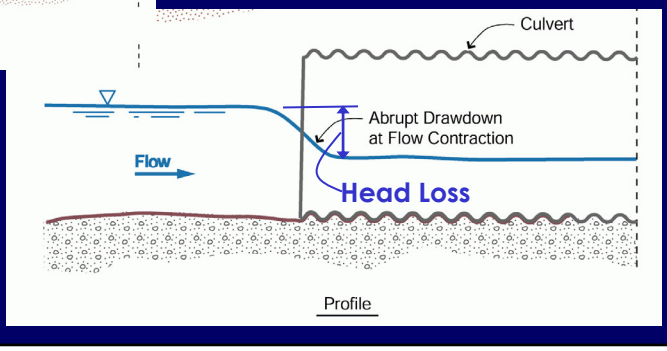
29

Inlet Transition



Max Inlet Head Loss for Fish Passage (Rule of Thumb)

- 0.5 feet for Adult Salmonids
- 0.2 feet for Juvenile Salmonids



30

30

Baffling Thoughts

- ONLY for Retrofits
- Requires Maintenance/Debris Cleaning
- Frequently Reduces Capacity
- Turbulence blocks fish
- Match normal depth to tailwater

For More on Design of Baffles:
Refer to the California Department of Fish and Wildlife Fish Passage Design Manual (Love & Bates, 2009)

31

31