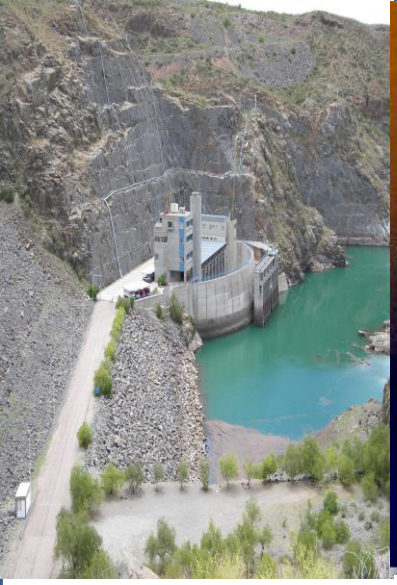
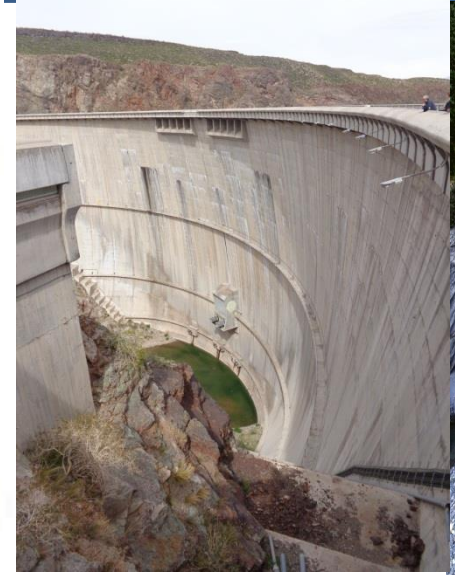






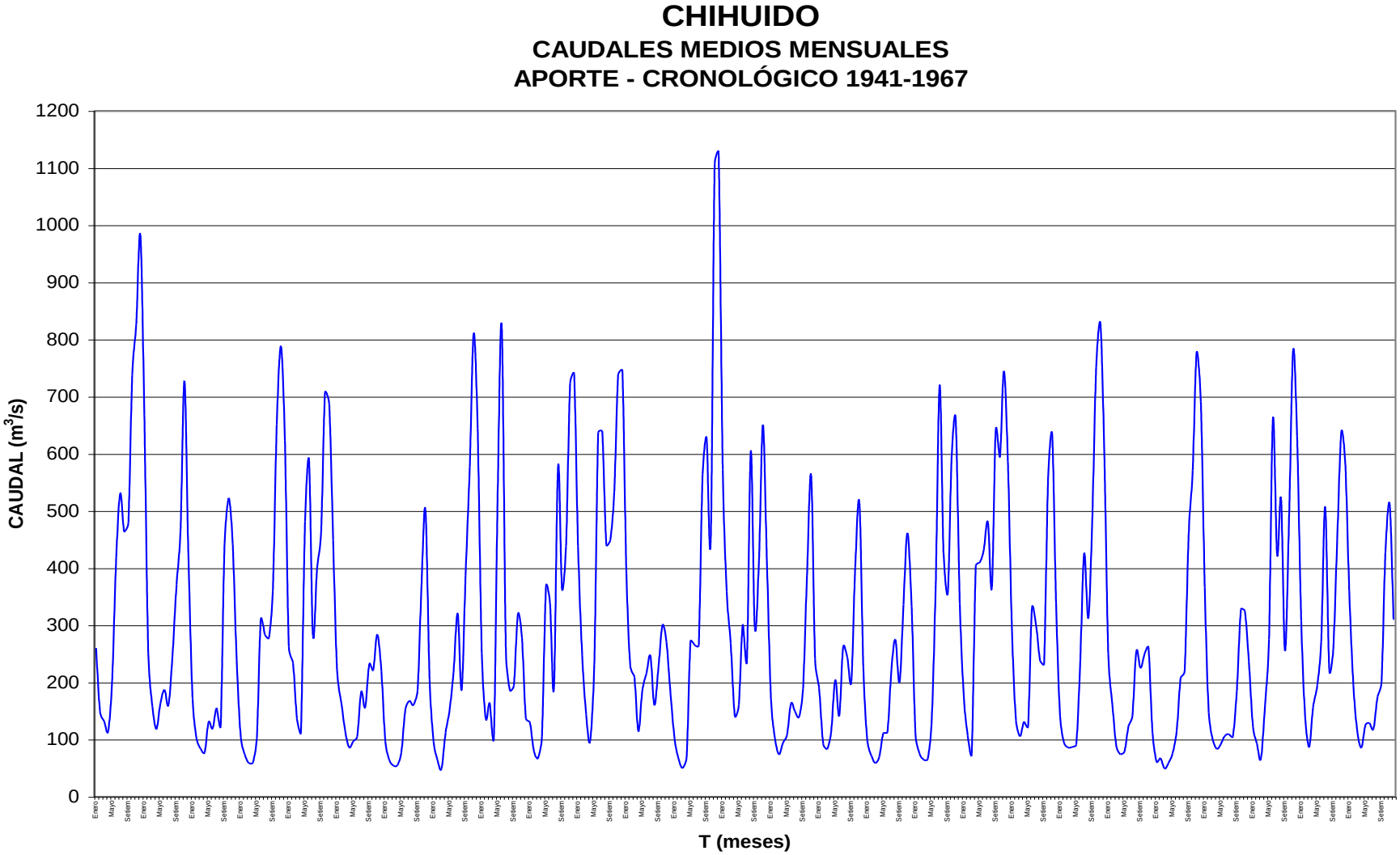

APROVECHAMIENTOS HIDRAULICOS

UNIDAD 2

JUAN CARLOS .C.CACCIAVILLANI

UNCUYO UNIVERSIDAD NACIONAL DE CUYO | FACULTAD DE INGENIERÍA

CURVA DE CAUDALES CRONOLOGICOS



JUAN CARLOS .C.CACCIAVILLANI

RANGO DE OPERACIÓN

El rango de operación está determinado por la especificación de los saltos netos en donde trabajará la máquina (saltos netos característicos) y las potencias máximas y mínimas de operación continua y temporaria para cada salto neto operativo.

SALTOS NETOS CARACTERÍSTICOS

De acuerdo a la Norma IEC, el salto neto se define como la diferencia entre el nivel del embalse y el nivel de restitución menos todas las pérdidas de carga incluidas desde la obra de toma hasta la entrada a la cámara espiral de la turbina y la energía cinética a la salida del tubo difusor.

$H_n = N_e - N_r - Dh_{conducto} - Dh_{salida\ tubo}$

Por lo tanto para la determinación de un salto deben determinarse con precisión los niveles de embalse y de restitución y definir con precisión los conductos de admisión para la determinación de las perdidas de carga.

SALTOS NETOS: NIVELES DE EMBALSE

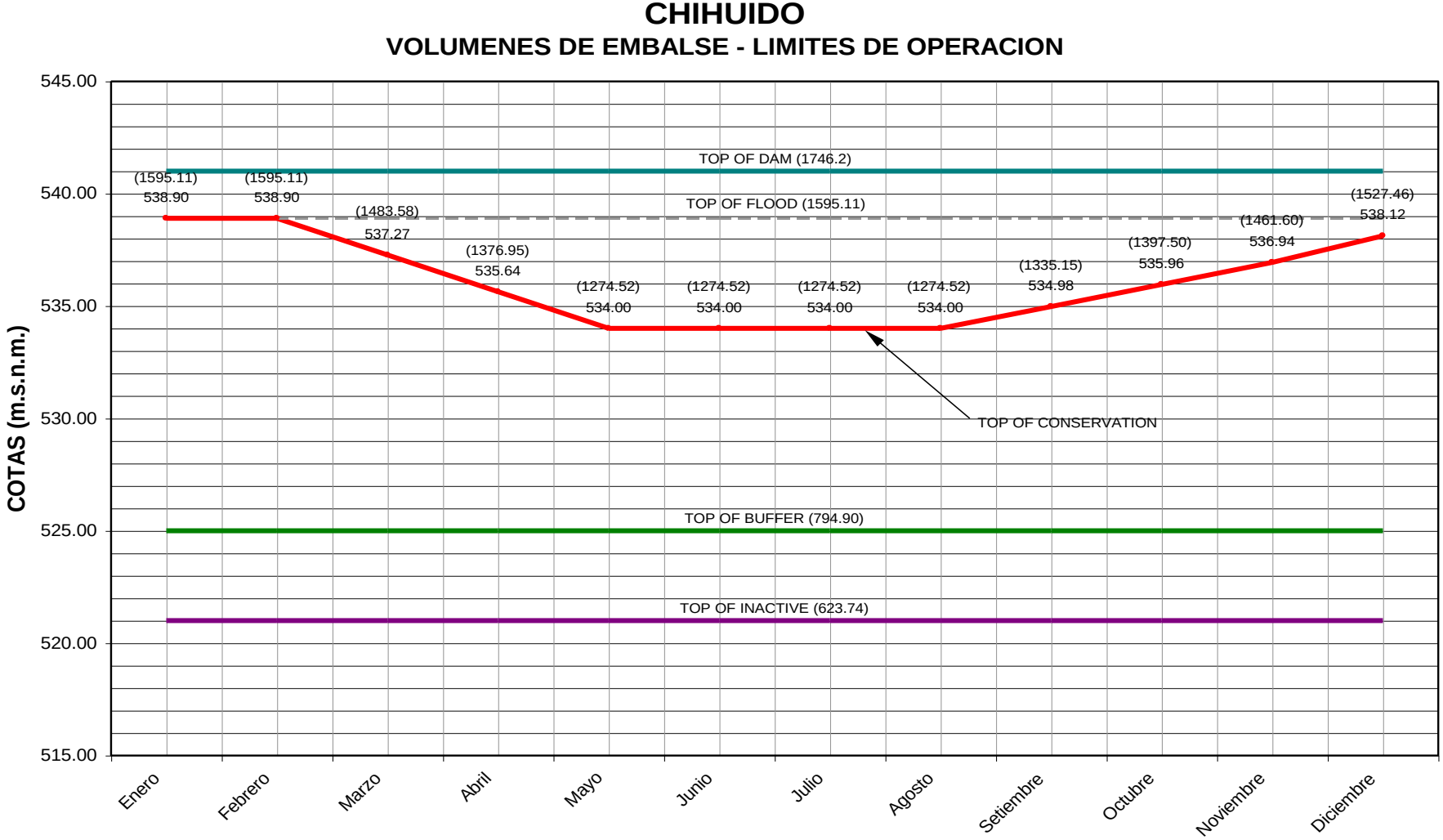
Nivel de embalse máximo maximorum: Corresponde al nivel máximo que es alcanzado ante la crecida deca-milenaria.

Nivel de embalse máximo normal: Corresponde al nivel máximo que el reservorio puede alcanzar en operación normal

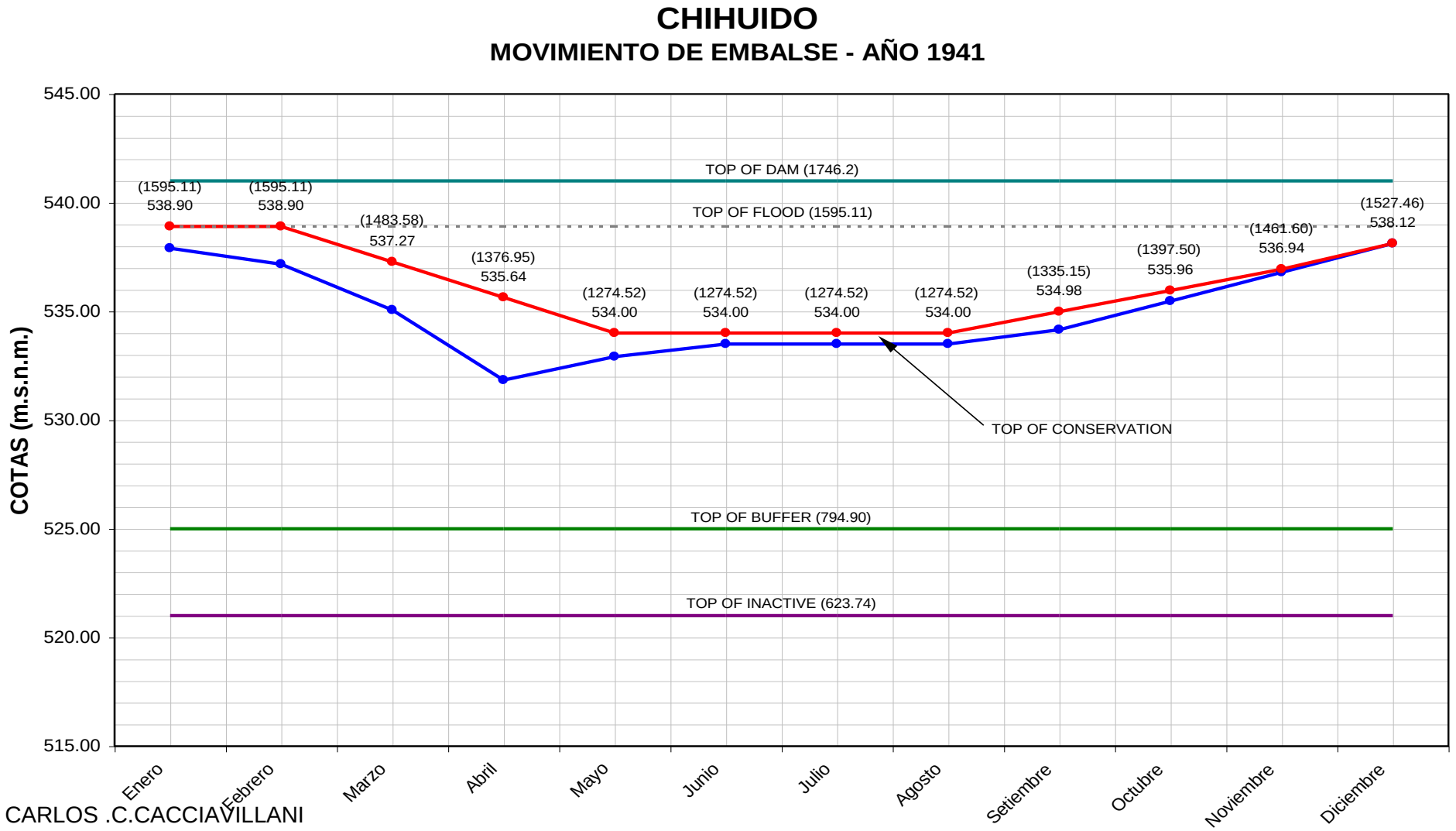
Nivel de embalse mínimo normal: Corresponde al nivel resultante de la máxima depleción operativa que contemplan las ganancias de energía firme.

Nivel mínimo extraordinario: Corresponde a un nivel de trabajo entre el nivel de embalse mínimo normal y el mínimo para operación de las unidades.

SALTOS NETOS: NIVELES DE EMBALSE



SALTOS NETOS: NIVELES DE EMBALSE



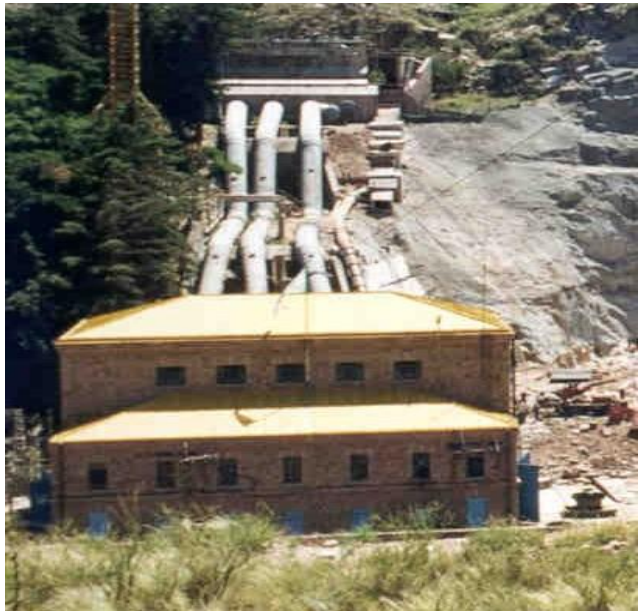
PERDIDAS DE CARGA

Pérdidas de carga localizadas

Pérdidas localizadas en:

- ✓ Curvas
- ✓ Codos
- ✓ Obra de toma
- ✓ Bifurcadores
- ✓ Válvulas
- ✓ Transiciones.

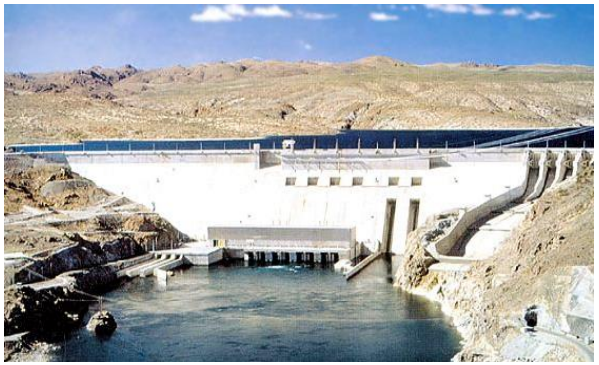
Es importante la adecuación de los coeficientes a los resultados de prototipo.



PERDIDAS DE CARGA

Pérdidas de carga generalizadas

Pérdidas generalizadas por fricción
(Manning _ Darcy -Weissbach)
Rugosidad relativa - Reynolds



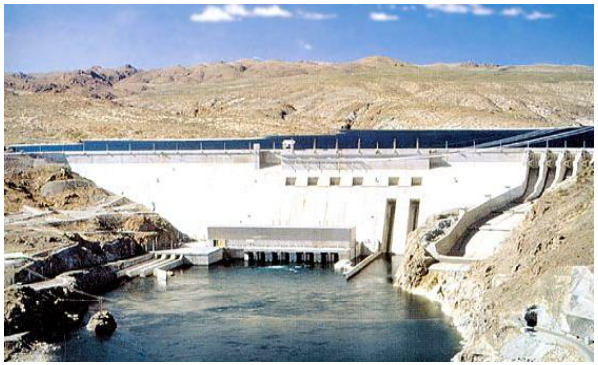
Ecuación de pérdidas de carga para una o mas máquinas en funcionamiento:

$$DH = k * Q^2$$

PERDIDAS DE CARGA

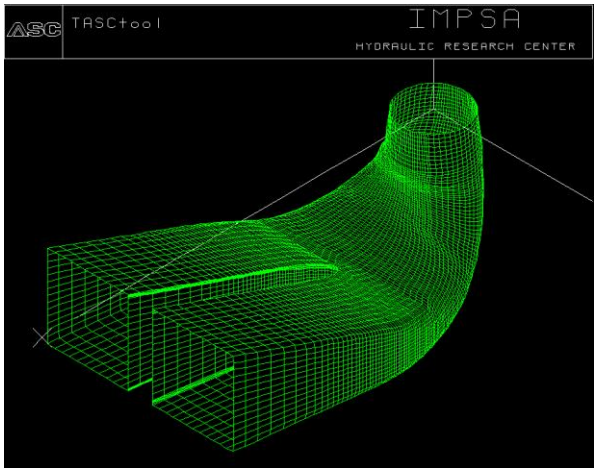
Pérdidas de carga a la salida del tubo de aspiración :

$$DH = v^2 / (2*g)$$

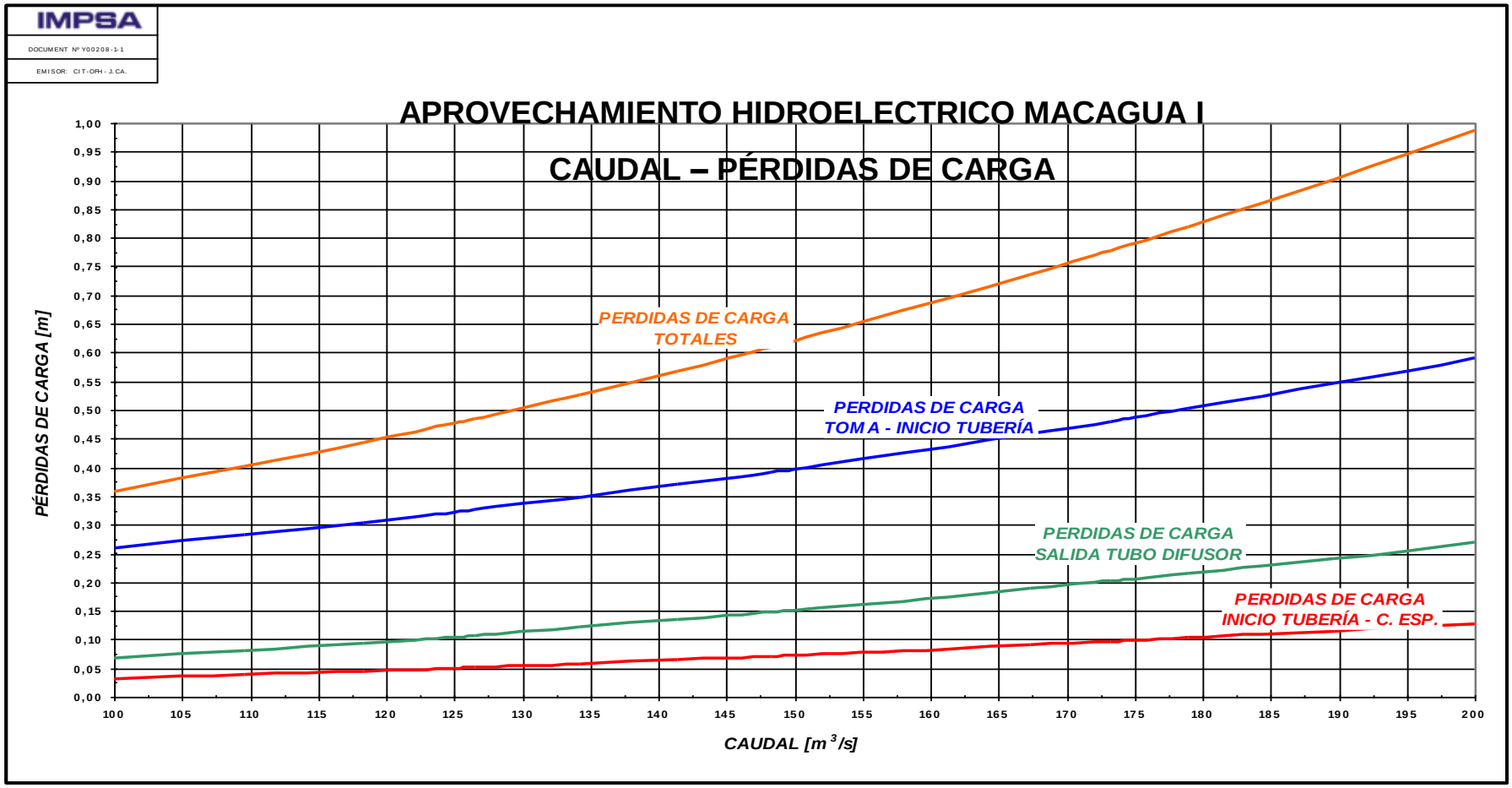


Ejemplo:

.....El diseño del tubo de aspiración contemplará una velocidad media de salida en su extremo de aguas abajo, que no excederá de 2,5 m/s para el caudal nominal.....



CAUDAL - PÉRDIDAS DE CARGA



PERDIDAS DE CARGA

PROYECT: CALIRAYA

TABLE Nº1: WATERWAY HEAD LOSSES FOR ONE UNIT WITH HIGH ROUGHNESS

PIPE SINGULARITY		SECTION TYPE [-]	DIAMETER [m]	LENGHT HORIZ. PROJECTION [m]	TANGENT ALPHA	ALPHA ANGLE [radians]	ALPHA ANGLE [degrees]	HORIZONTAL LENGHT [m]	TOTAL LENGHT [m]	BENDING RADIUS [m]	DELTA [degrees]	AREA [m²]	MATERIAL TYPE	DISCHARGE [m³/s]	SPEED V [m/s]	ABSOLUTE ROUGHNESS [mm]	LOSS COEFFICIENT K	V²/2g [m]	HEAD LOSS Dh [m]	TYPE OF LOSS
KINETIC ENERGY	INTAKE STRUCTURE	RECTANGULAR	[illegible]	[illegible]			[illegible]	0	—	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
SLOTS [illegible]	INTAKE STRUCTURE	RECTANGULAR	[illegible]	[illegible]			[illegible]	0	0	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
TRASH RACKS FLOW	INTAKE STRUCTURE	RECTANGULAR	[illegible]	[illegible]			[illegible]	0	0	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
INTAKE	INTAKE STRUCTURE	RECTANGULAR	—	[illegible]				[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
TRANSITION INTAKE - TUNNEL	INTAKE STRUCTURE	RECTANGULAR	[illegible]	[illegible]				[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	F.L.
CONCRETE PIPE 1-2	CONCRET TUNNEL	CIRCLE	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
ELBOW Nº2	CONCRET TUNNEL	CIRCLE	[illegible]	—	—	—	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
CONCRETE PIPE 2-3	CONCRET TUNNEL	CIRCLE	[illegible]	[illegible]	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
ELBOW Nº3	CONCRET TUNNEL	CIRCLE	[illegible]	—	—	—	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
CONCRETE PIPE 3-4	CONCRET TUNNEL	CIRCLE	[illegible]	[illegible]	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
ELBOW Nº4	CONCRET TUNNEL	CIRCLE	[illegible]	—	—	—	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
CONCRETE PIPE 4-5	CONCRET TUNNEL	CIRCLE	[illegible]	[illegible]	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
ELBOW Nº5	CONCRET TUNNEL	CIRCLE	[illegible]	—	—	—	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
CONCRETE PIPE 5-6	CONCRET TUNNEL	CIRCLE	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
STEEL PIPE 6 - SURGE TANK	EXISTING PENSTOCK	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
PIPE SURGE TANK - ANCHOR A2	EXISTING PENSTOCK	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
BUTTERFLY VALVE (*)	EXISTING PENSTOCK	CIRCLE	[illegible]	—	—	—	—	—	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
ELBOW Nº6 (Anchor A2)	EXISTING PENSTOCK	CIRCLE	[illegible]	—	—	—	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
ANCHOR A2 - ANCHOR A4	EXISTING PENSTOCK	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
ELBOW Nº7 (Anchor A4)	EXISTING PENSTOCK	CIRCLE	[illegible]	—	—	—	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
ANCHOR A4 - ANCHOR [illegible]	EXISTING PENSTOCK	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
ELBOW Nº8 (Anchor [illegible])	EXISTING PENSTOCK	CIRCLE	[illegible]	—	—	—	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
STEEL PIPE [illegible]	PENSTOCK REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
STEEL PIPE [illegible]	PENSTOCK REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
STEEL PIPE [illegible]	PENSTOCK REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
ELBOW Nº9	PENSTOCK REPLACEMENT	CIRCLE	[illegible]	—	—	—	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
STEEL PIPE [illegible] - MANIFOLD	PENSTOCK REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
CONICAL TRANSITION [illegible]	MANIFOLD REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
STEEL PIPE ([illegible])	MANIFOLD REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
CONICAL TRANSITION [illegible]	MANIFOLD REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
STEEL PIPE ([illegible])	MANIFOLD REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
CONICAL TRANSITION [illegible]	MANIFOLD REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
ELBOW Nº10	MANIFOLD REPLACEMENT	CIRCLE	[illegible]	—	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
STEEL PIPE ([illegible])	MANIFOLD REPLACEMENT	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
STEEL PIPE	POWERHOUSE ENTRANCE	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
BUTTERFLY VALVE (*)	POWERHOUSE ENTRANCE	CIRCLE	[illegible]	—	—	—	—	—	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.
BUTTERFLY VALVE - SPIRAL CASE	POWERHOUSE ENTRANCE	CIRCLE	[illegible]	—	—	—	—	[illegible]	[illegible]	—	—	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	F.L.
KINETIC ENERGY	POWERHOUSE OUTLET	RECTANGULAR	[illegible]	[illegible]								[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	L.L.

Partial Dh: [illegible]

Partial Dh: [illegible]

Final Dh: [illegible]

(*) EXISTING VALVES - HEAD LOSSES COEFFICIENT ESTIMATED

(**) F.L.=FRICTION LOSSES; L.L.=LOCAL LOSSES

Total lenght: [illegible]

TOTAL LOSSES | DH= | [illegible]

SALTOS NETOS – NIVELES DE RESTITUCION

Nivel de restitución máximo maximorum :

Es el nivel correspondiente al caudal de crecida deca-milenaria

Nivel de restitución máximo normal:

Es el nivel correspondiente al caudal total turbinado correspondiente a la totalidad de las unidades operando con el distribuidor en la máxima apertura.

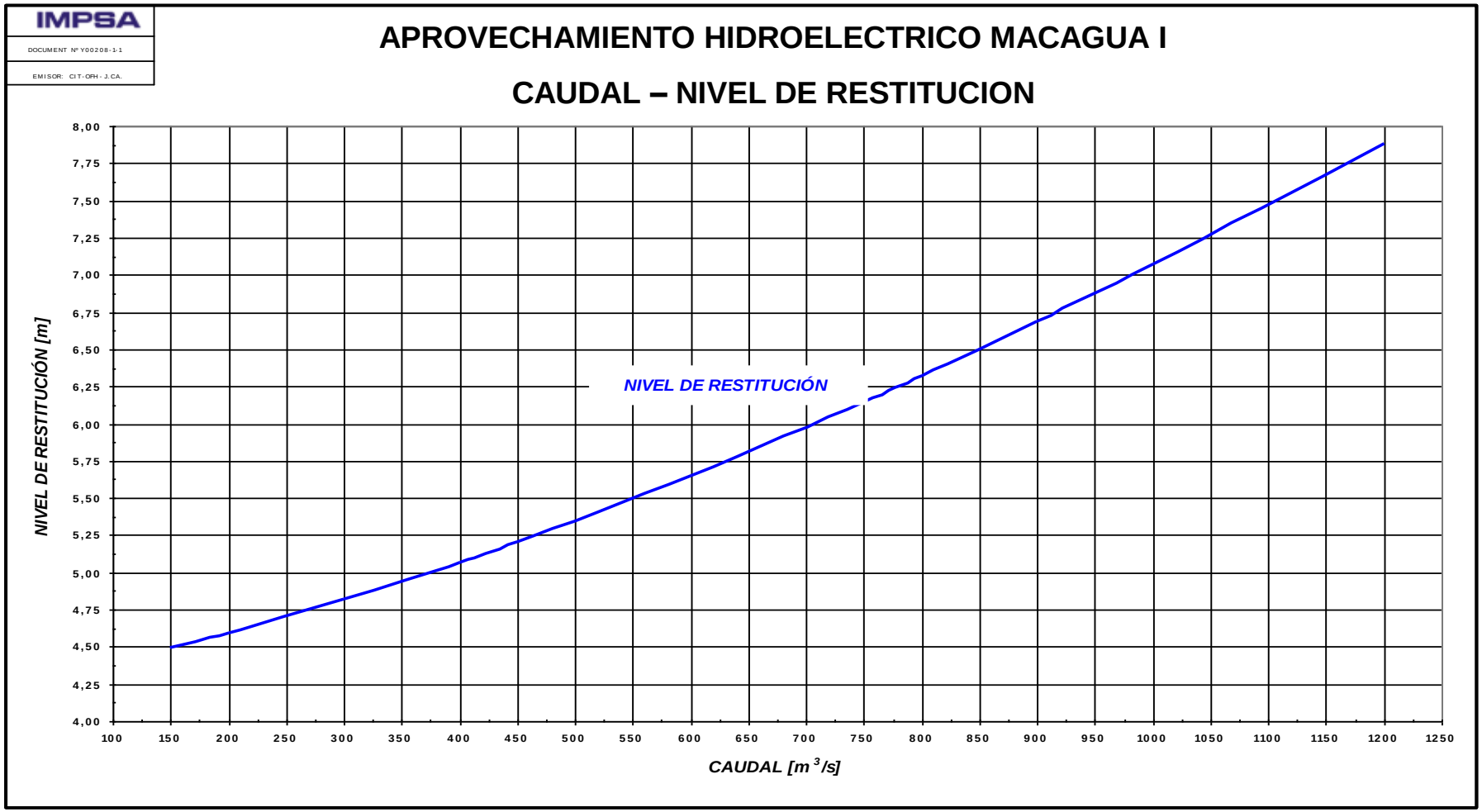
Nivel de restitución normal:

Es el nivel correspondiente al caudal turbinado correspondiente a una unidad operando a la potencia máxima de modo de atender las condiciones mas criticas de cavitación.

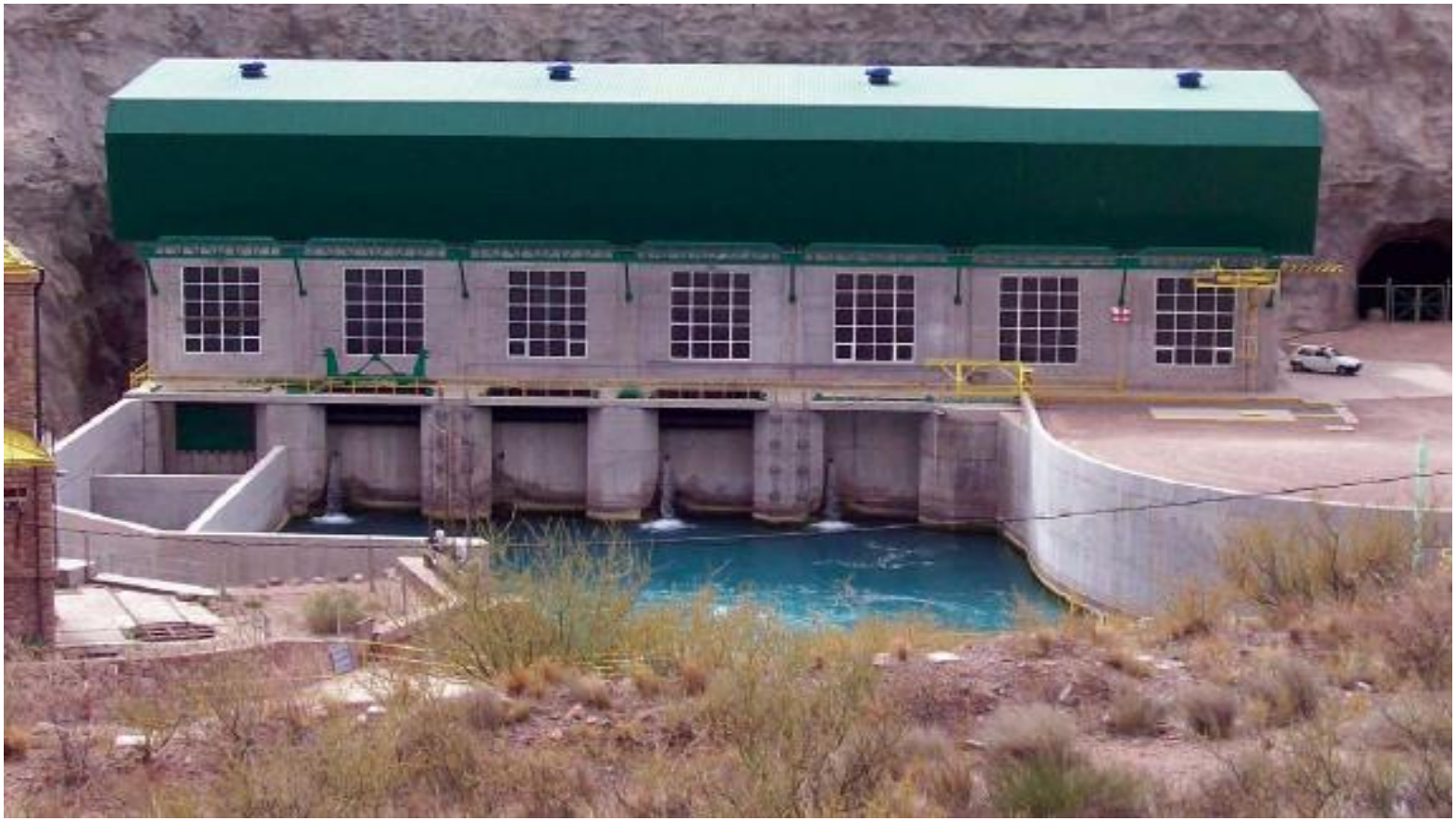
Nivel de restitución mínimo normal:

Es el nivel correspondiente a la operación de una unidad cuando la misma esta funcionando a carga parcial.

CAUDAL – NIVEL DE RESTITUCIÓN



NIVEL DE RESTITUCIÓN



SALTOS NETOS CARACTERÍSTICOS

Salto neto máximo :
Es el salto resultante de la combinación entre el nivel de embalse máximo normal y el nivel de restitución mínimo.

Salto neto de proyecto :
Es el salto correspondiente al punto de rendimiento máximo.

Salto neto mínimo :
Es el salto resultante de la combinación entre el nivel de reservorio mínimo normal y el nivel de restitución máximo normal.

Salto neto nominal:
Es el menor salto en la cual la turbina deberá suministrar la potencia correspondiente a la potencia efectiva del generador con el distribuidor totalmente abierto. Hay diferentes criterios para dimensionar este salto. Por lo general esta definición en embalses regulados da un salto bajo por lo que es preferible definirlo a partir de un estudio energético económico. Este salto es de fundamental importancia para la definición de la turbina.

CAMPO OPERATIVO

POTENCIA MÁXIMAS Y MÍNIMAS OPERACIONALES

POTENCIA HIDRÁULICA :

$$Potencia\,Hidraulica = \frac{Q*Hn*Rho*g*\eta_{hidraulica}}{1000} \quad [\mathrm{Kw}]$$

Q = Caudal [m³/s]

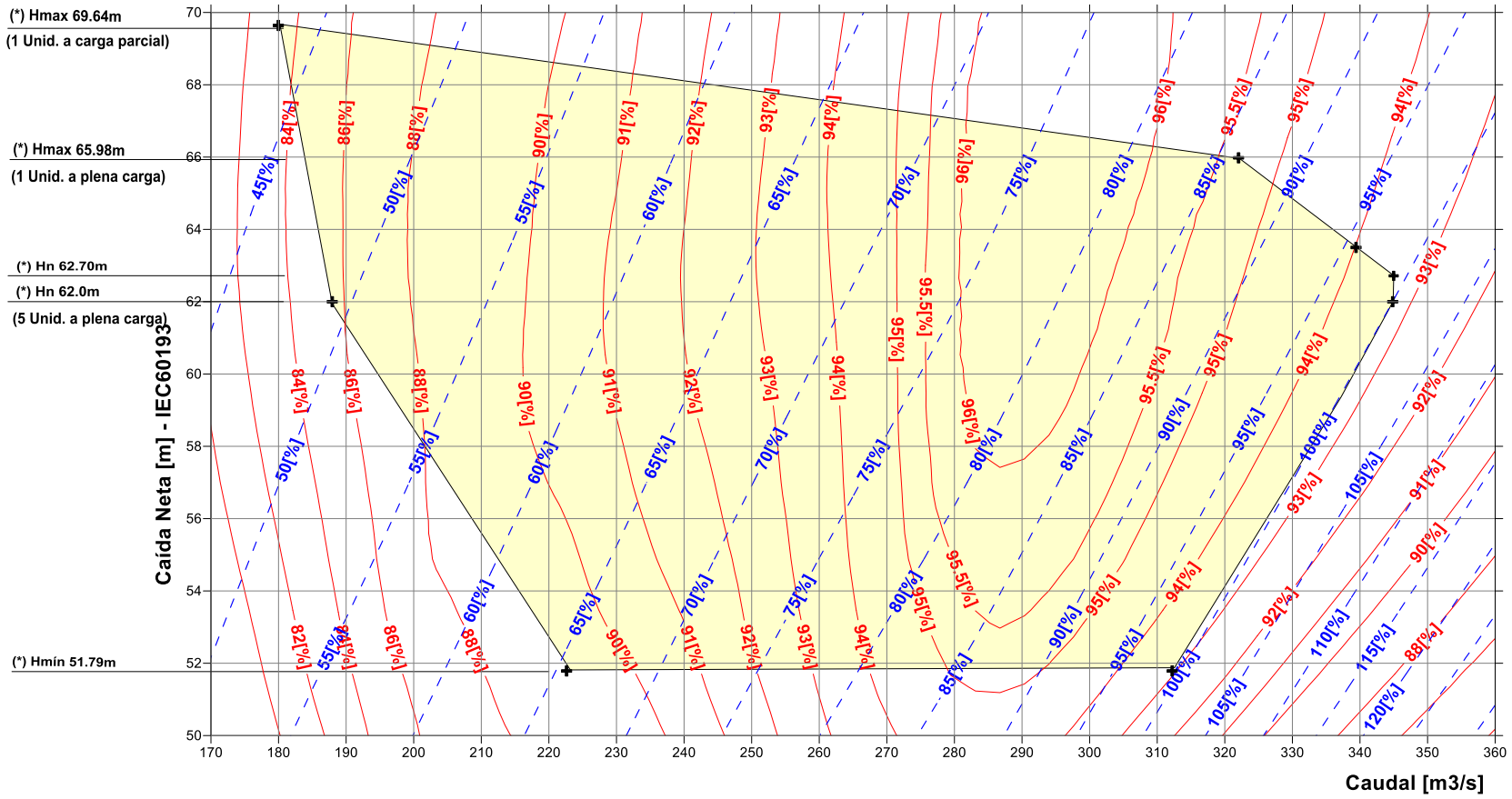
Hn = Salto Neto [m]

Rho = Densidad [kg/m³]

g= Gravedad [m / s²]

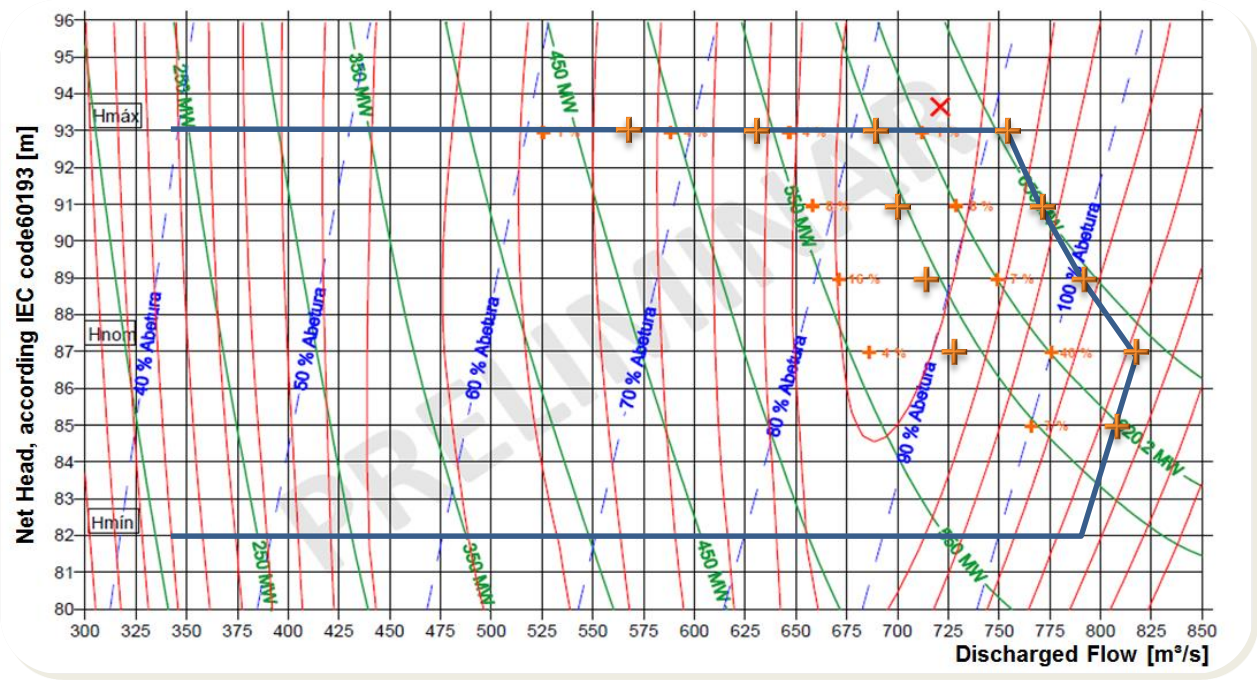
η = Eficiencia Hidráulica [-]

CAMPO OPERATIVO –DIAGRAMA DE COLINA



CONDICIÓN DE OPERACIÓN

Uno de los parámetros de especial atención al momento de definir y diseñar una máquina es la valoración que se tiene de la energía generada por el aprovechamiento que generalmente viene definida por los valores ponderados de eficiencia requeridos.



Cuando no se disponen de valores ponderados entonces un análisis energético conjugado con variables económicas de despacho eléctrico permite determinarlos.

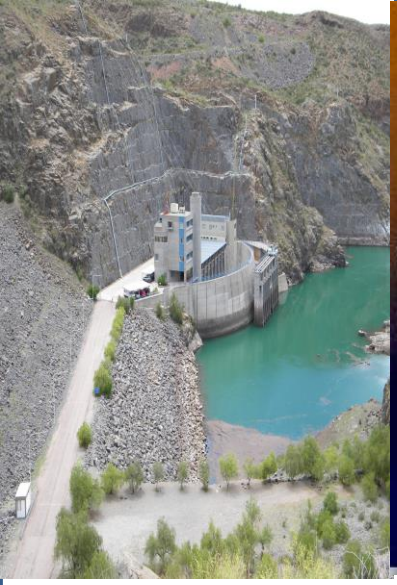
PUNTOS PONDERADOS - CRITERIOS DE ADJUDICACIÓN

Head (m)	Rated Output [%]	A 100%	B 90%	C 80%	Best efficiency point
Rated Head	Output [kW]				▲
172.7 [m]	Efficiency [%]				▲
	Discharge [m3/sec]		▲	▲	▲
	Wicket Gate opening [%]	100	▲	▲	▲

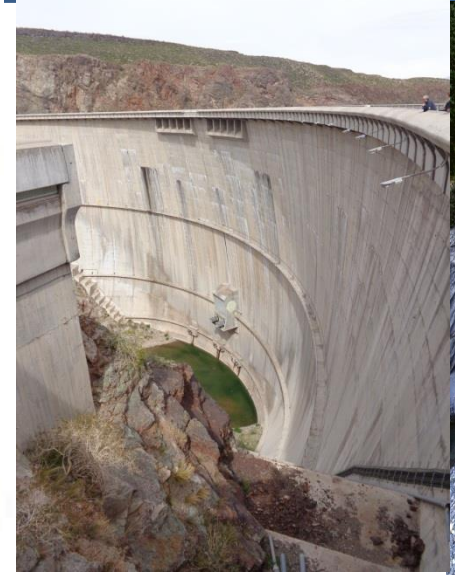
…….“The columns with this mark “▲” should be accurate, but only for reference of review and acceptance inspection. The effective value of guaranteed efficiencies shall be indicated in four figures rounding to the second digital of decimal fraction.

The total efficiency of Turbine & Generator shall be used for bid comparison, and the comparison and assessment regulation according to point....

GWAE (Guaranteed Weighted Average Efficiency): (3A+3B+4C) / 10 = …….%








APROVECHAMIENTOS HIDRAULICOS

UNIDAD 2

JUAN CARLOS .C.CACCIAVILLANI