Constitution and Facilities of Long Railway Tunnel at Great Depth in Japan

Minoru SHIMOKAWACHI

; Sectional Group on Long Mountain-Tunnel

in JTA (Japan Tunnelling Association)

;Council, OYO Corporation.

Speed of Train → Higher

Curve- Radius →Larger / Vertical Gradient →Smaller

Tunnel → Longer / Deeper

1． Influence to Running Train due to High Speed.

(1) Aerial Resistance.

(2) Alteration of Aerial Pressure and Flow.

2． Operation and Maintenance in Long Tunnel.

(1) Drainage , Ventilation , Cooling.

(2) Maintenance of Railway and Tunnel.

3． Prevention from Disaster （Fire and Others）

Table- A Typical Tunnels for Railway in High Speed.

No.	Line	Tunnel	Length(km)	Constitution
1	Alp Transit	Gotthard Base	57.1	ST*2
2	Tsugaru St.	Seikan	53.9	DT
		(Part under sea;		+ Service T + Pilot T)
3	Channel	Euro	50.5	ST*2
				+ Service T
4	Alp Transit	Zimmerberg Basis	19.7	DT
	(Bahn 2000	Zurich-Tahlwil	8.4	DT)
5	TGV	(Standard		DT)
6	Shinkansen	(Standard		DT
	6-1	Dai- Shimizu	22.2	
	6-2	Iwate- Ichinohe	25.8	
	6-3	Sanbonkihara	4.3	)

Note 1) ST: Tunnel of Single- track.

2) DT: Tunnel of Double- track.

3) Alp Transit and Bahn 2000 will hold in common between Zurich and Tahlwil of Zimmerberg Basis.

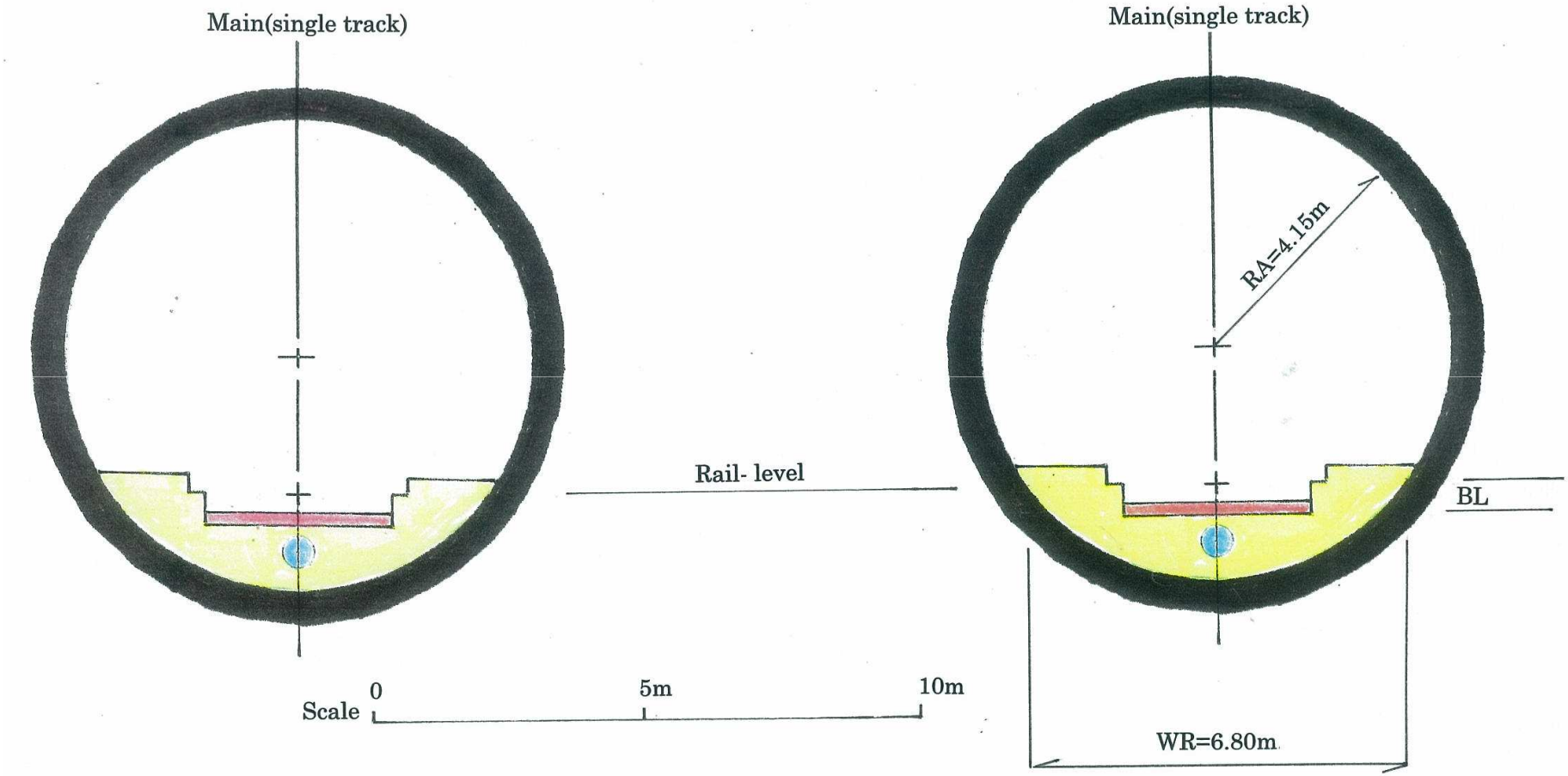


Fig. P-1. Inner Cross-section of Gotthard Base Tunnel.

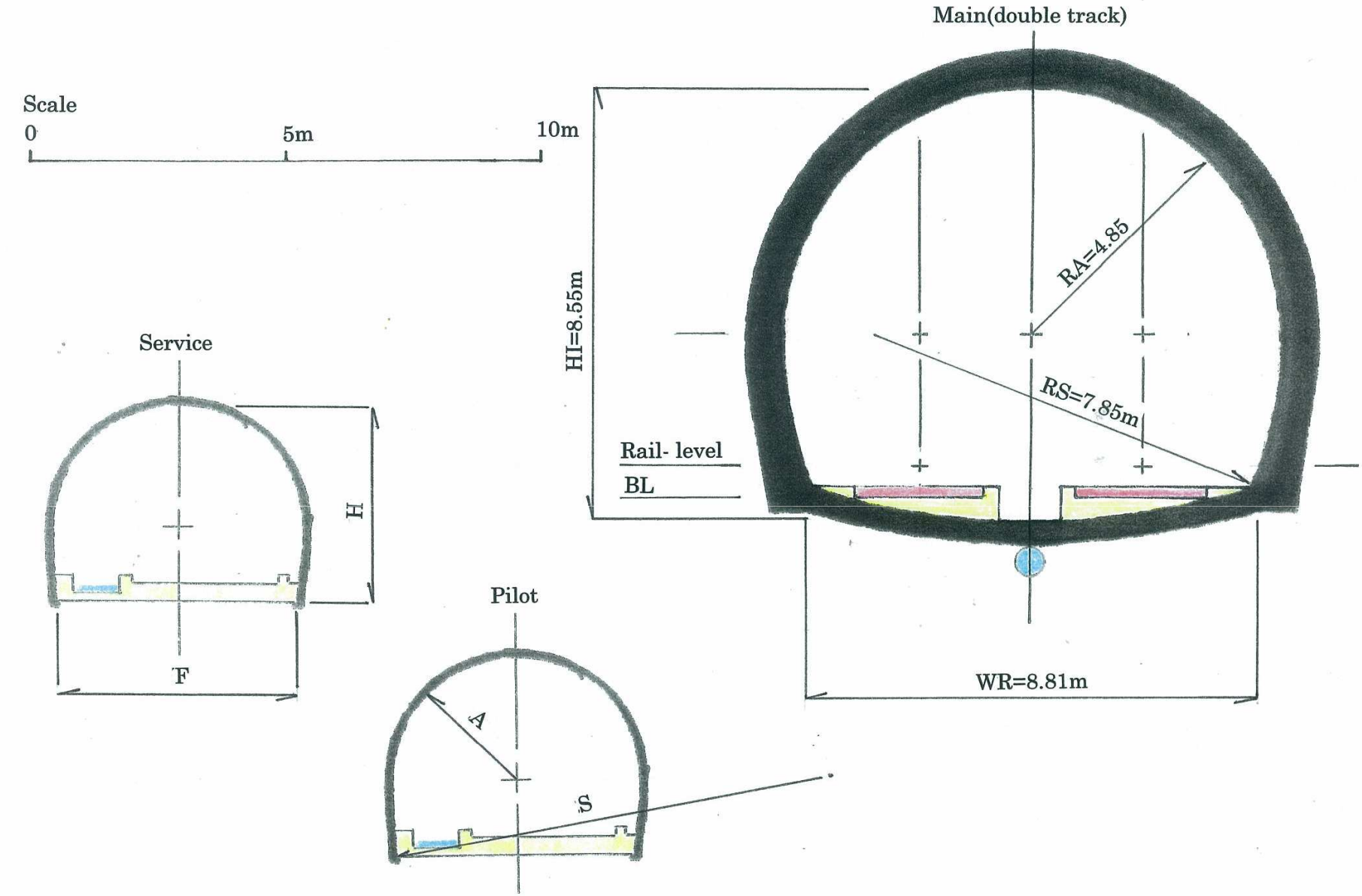


Fig. P-2. Inner Cross-section of the part under sea in Seikan Tunnel.

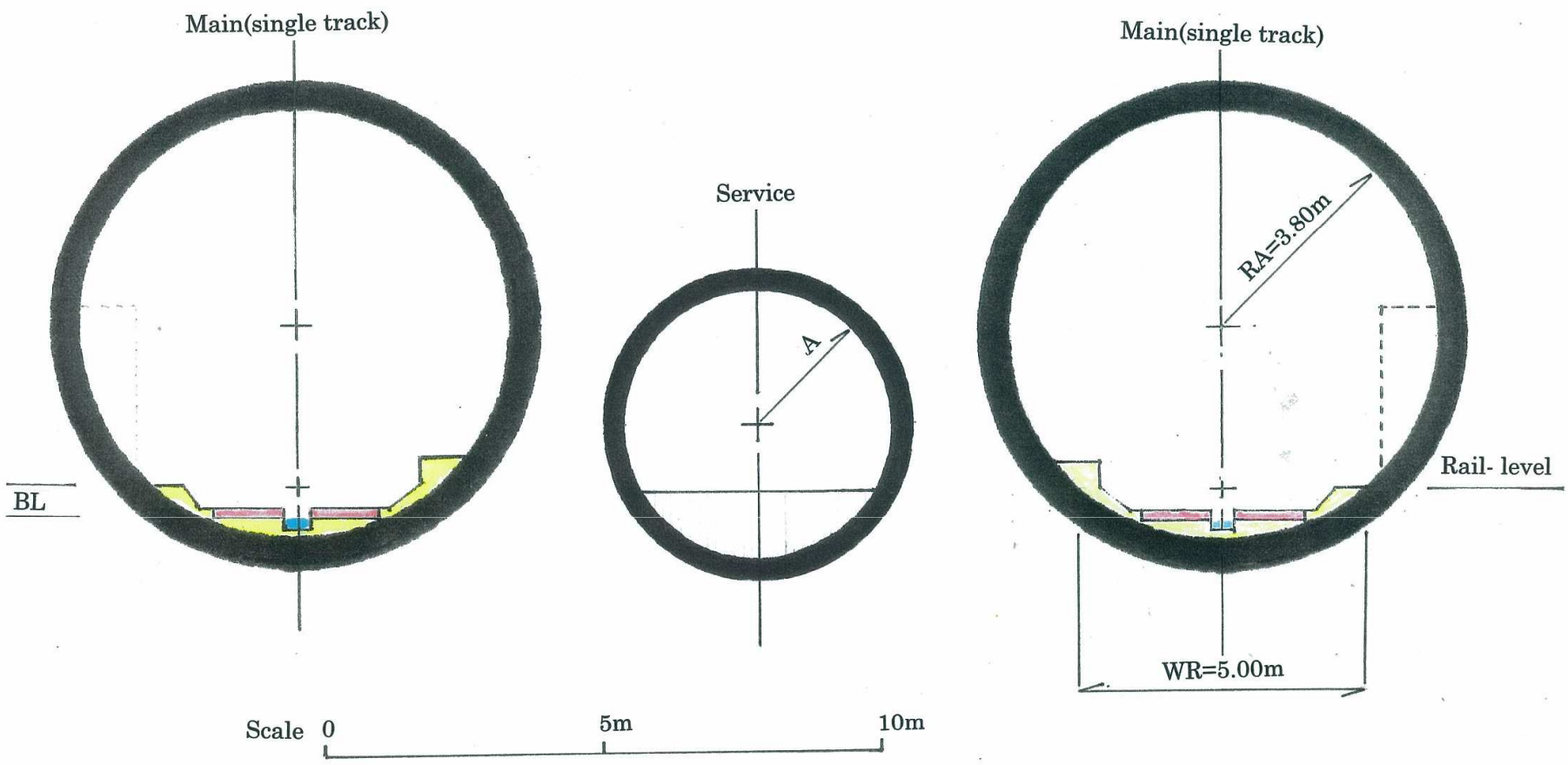


Fig. P-3. Inner Cross-section of EURO Tunnel.

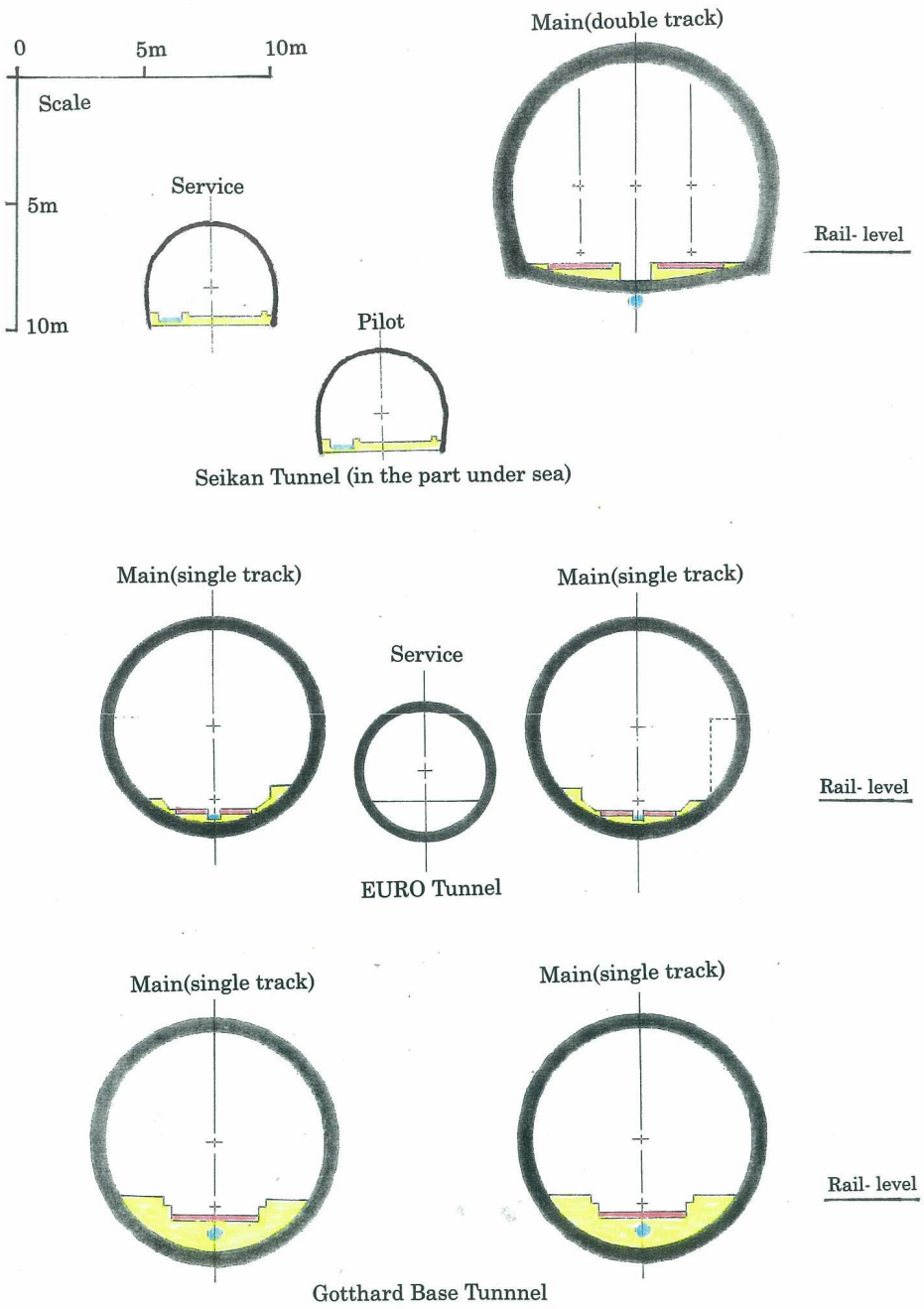


Fig. P-4. Inner Cross-section of Super Long Tunnels (>50km).

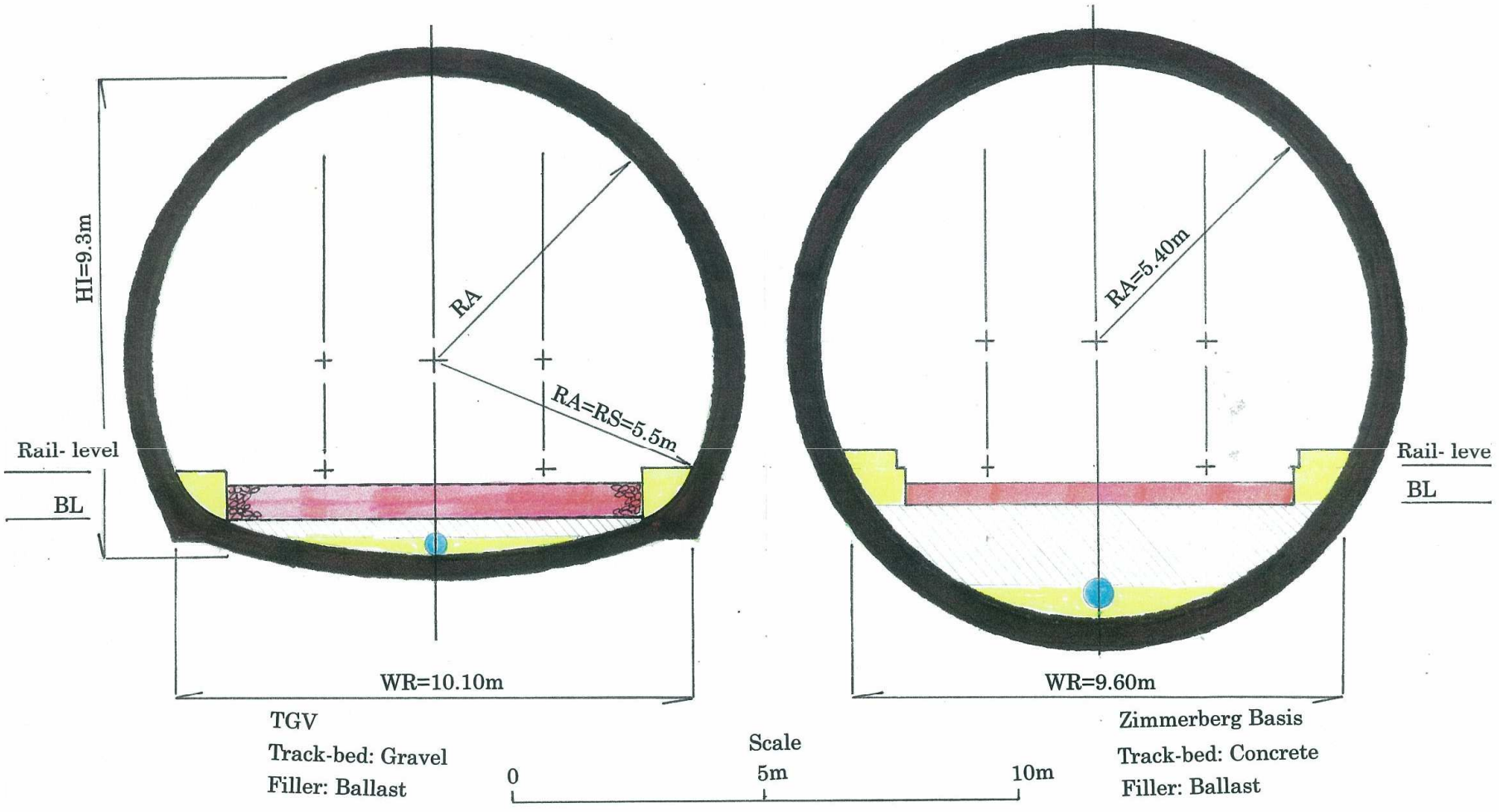


Fig. P-5. Typical Cross-section of Double Track Tunnels in Europe.

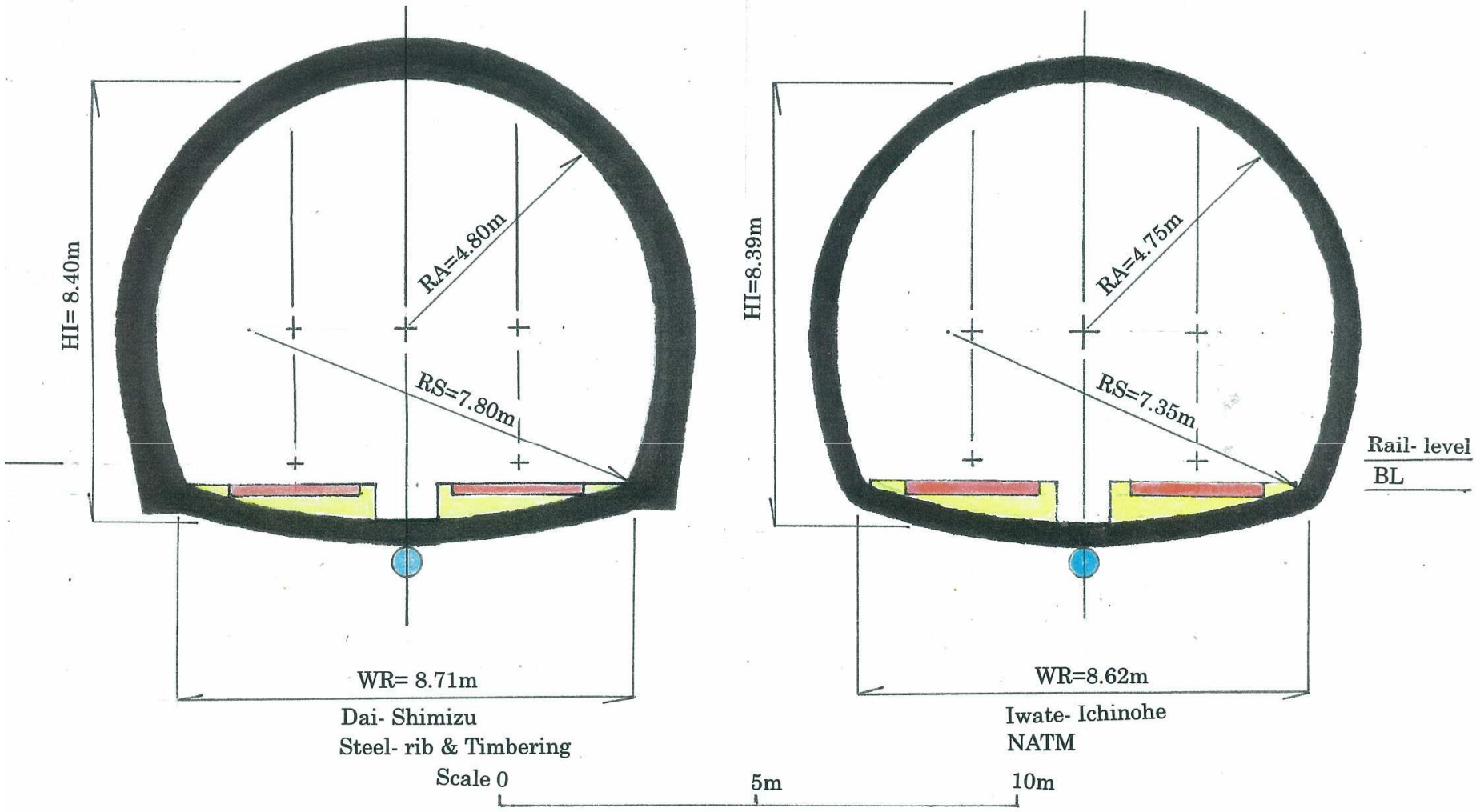


Fig. P-6. Typical Cross-section of Tunnels in Shinkansen. (constructed with conventional method; DB/ HC)

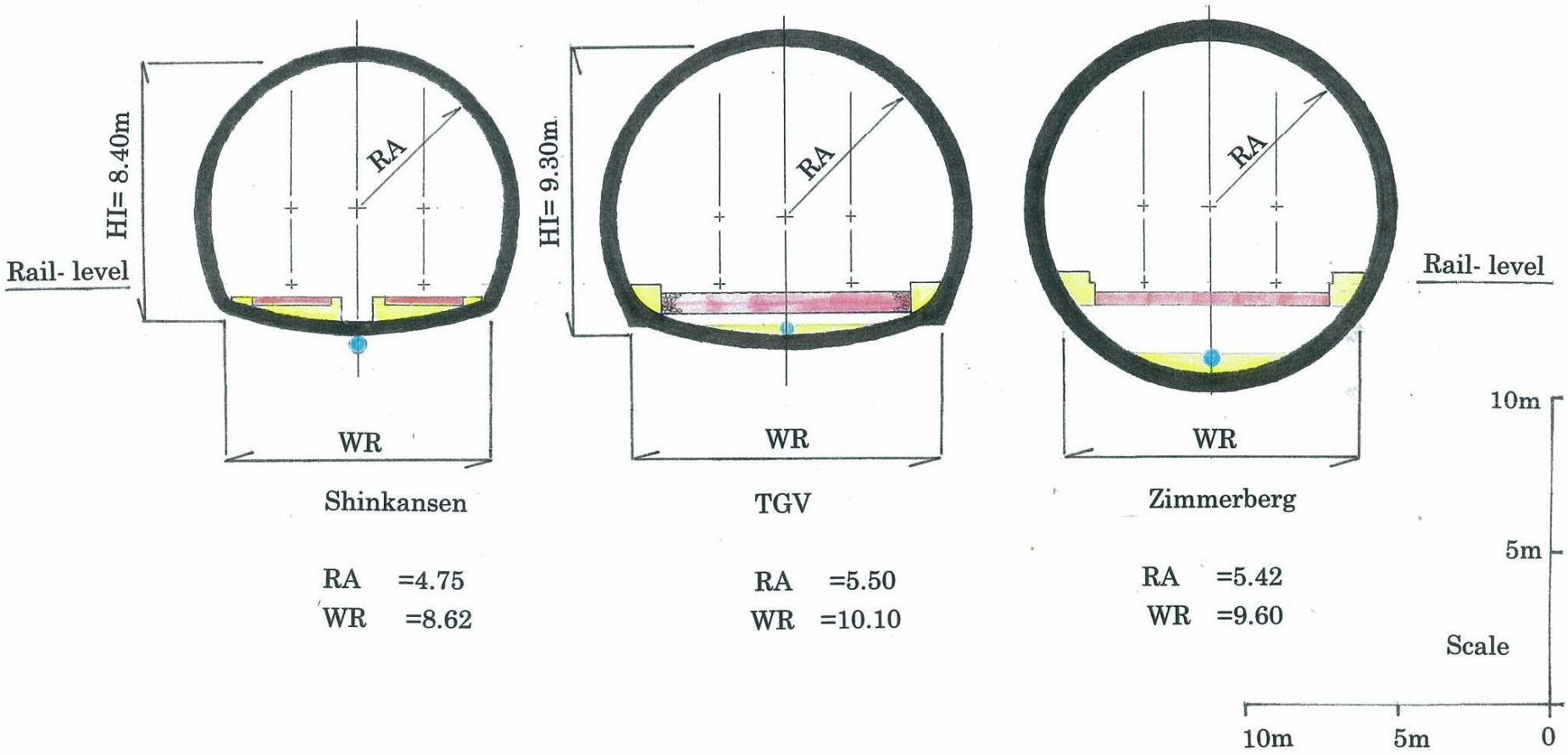
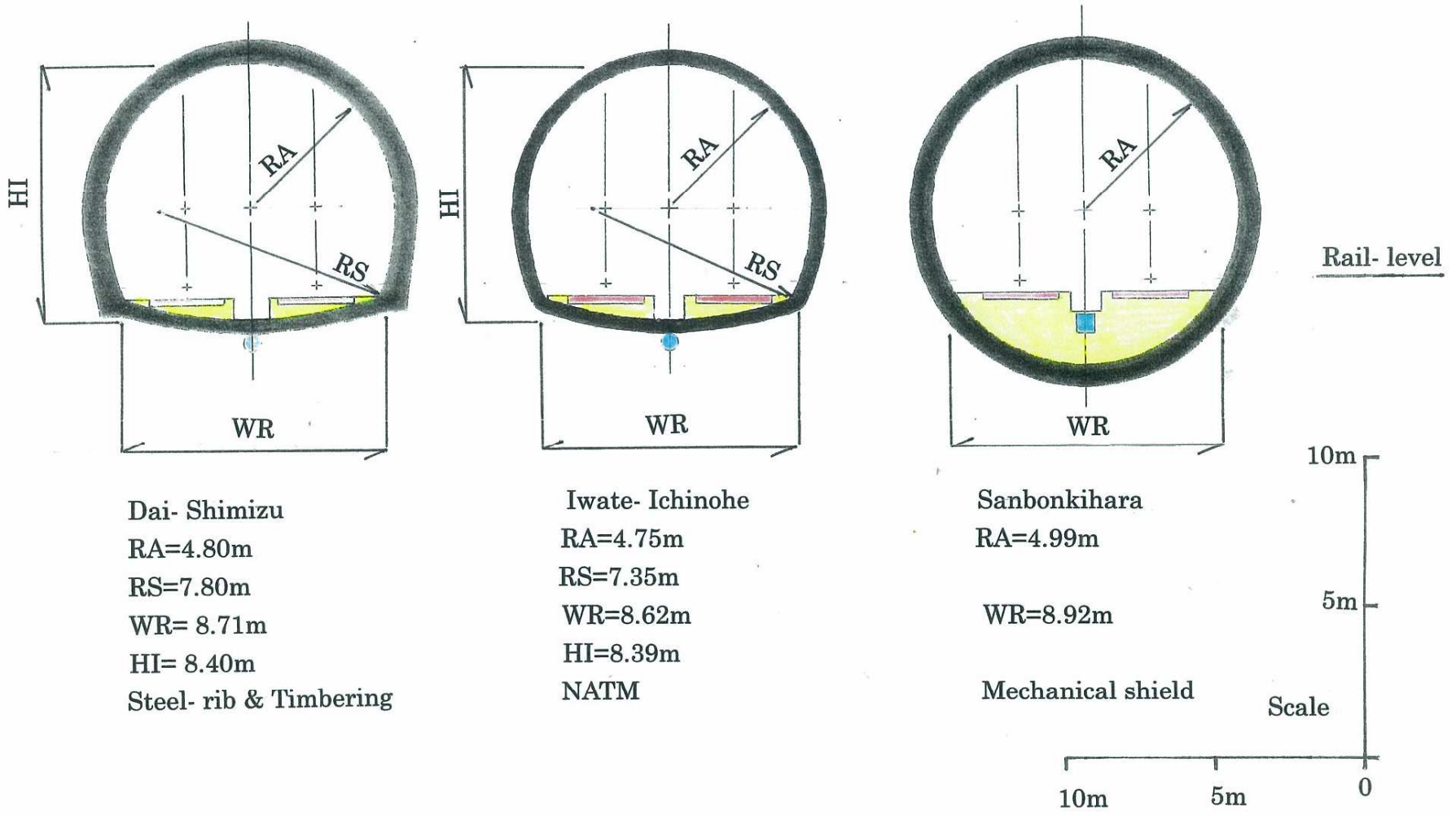


Fig. P-7. Inner Cross-section of Tunnels(double track) in High speed Railway.

e- B Standard of Inner Cross- Section of Typical Tunnels.

Shape	Radius	Width	Height	Area(Tunnel/ Effective)	Tunnelling
Circular	4.15	6.80		54.1/ 47.7	TBM/ DB
Horse- shoe					DB/ HC
Sea- part;	4.85	8.81	8.55	69.6/ 66.4	
Land- part;	4.80	8.71	8.50	67.7/ 64.7	
(Service T;	2.33	(4.45)	3.93	15.8	)
Circular	3.80	5.00		45.4/ 44.4(42.4)	TBM
(Service T;	2.40			18.1	)
Circular	5.42	9.60		92.3/ 74.0	TBM
Horse- shoe	5.50	10.10	9.30	83.6/ 73.2	DB/ HC
Horse- shoe	4.80	8.71	8.40	67.2/ 64.4	DB
Horse- shoe	4.75	8.62	8.39	66.1/ 62.6	DB/ HC
Circular	4.99	8.92		78.2/ 65.0	SM



Dai- Shimizu
RA=4.80m
RS=7.80m
WR= 8.71m
HI= 8.40m
Steel- rib & Timbering

Iwate- Ichinohe
RA=4.75m
RS=7.35m
WR=8.62m
HI=8.39m
NATM

Sanbonkihara
RA=4.99m
WR=8.92m
Mechanical shield

Fig. P-8. Various Cross-section of tunnels in Shinkansen.

System to Construct Long Tunnel

alternation or choice

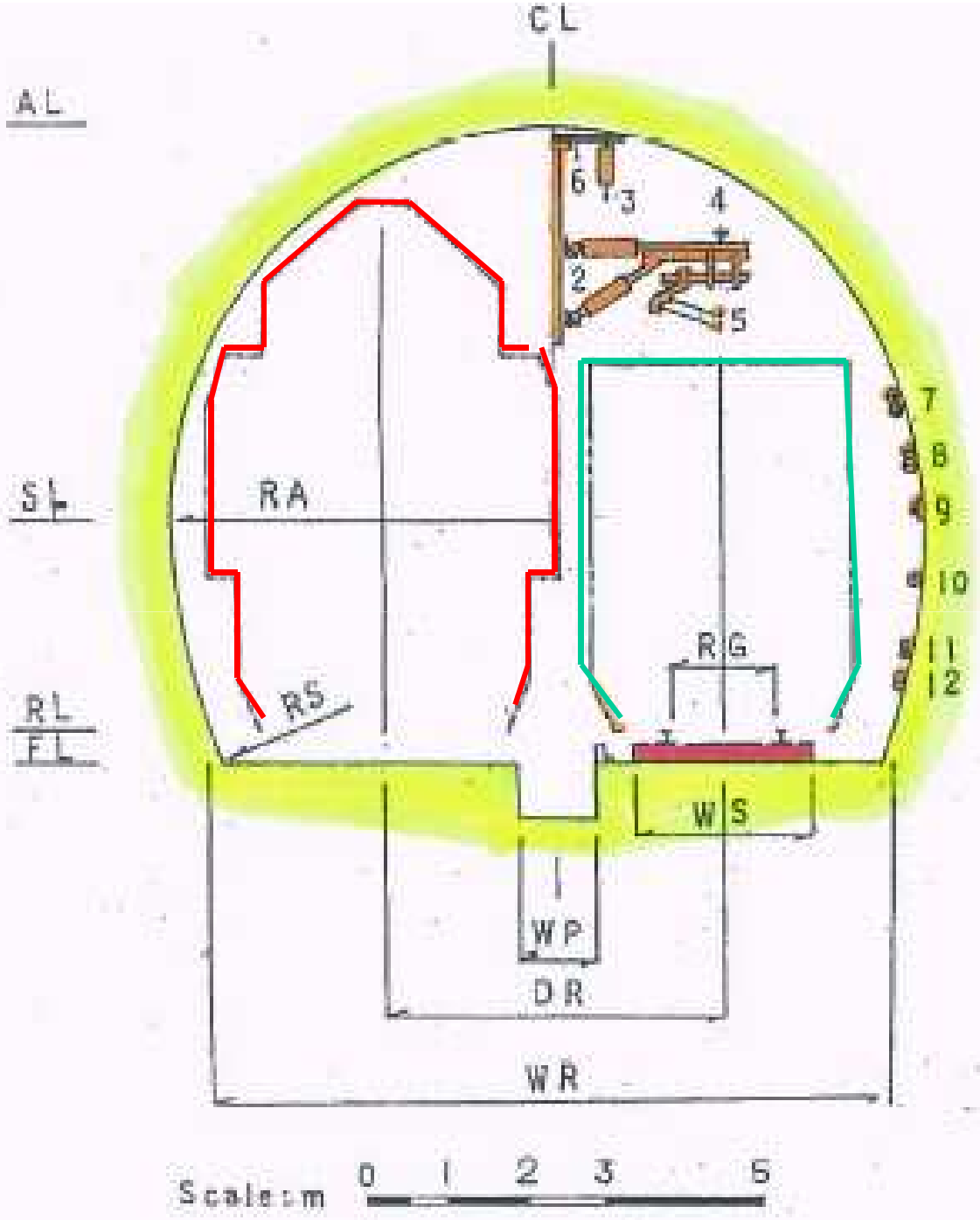
1. Geology.
2. Cross- Section.
3. Access- Shafts to Constructing Sections.

   Division of Long Tunnel into some

   Constructing Sections, not long.
4. Usage of Access- Shafts

   for Operation, Maintenance and Emergency.

.



Legend

CL: Center line of cross-section

AL: Top of inner section

SL: Spring line

RL: Rail-level

FL: Formation-level

PL: Pedestal-level of side wall

RA: Radius of arch(upper half)

RS: Radius of side wall

WR: Inner width in rail-level

— · · — : Limitation of vehicle

— · —— : Limitation of architecture

Shinkansen(Very high speed Railway)

Rail-gauge: RG=1435 mm

Electrical motivity

Double track

AL−SL=4.800

SL−RL=2.600

RL−FL=0.400

RA=4.800, RS=7.900

WR=8.708

DR=Distance between both track center=4.300

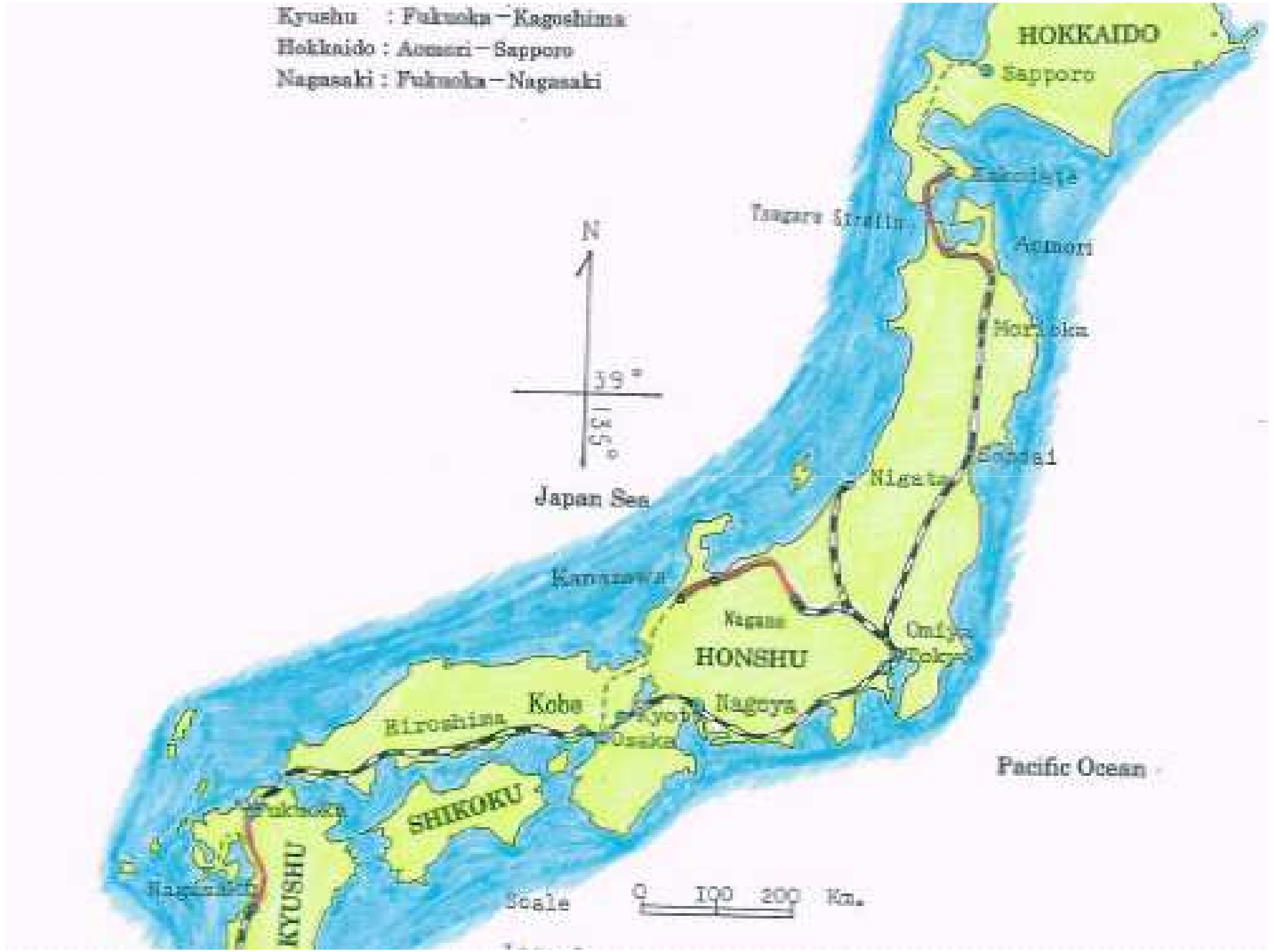

Kyushu : Fukuoka – Kagoshima
Hokkaido : Aomori – Sapporo
Nagasaki : Fukuoka – Nagasaki
HOKKAIDO
Sapporo
Hakodate
Tsugaru Strait
Aomori
Morioka
N
39°
Sendai
Niigata
Japan Sea
Kanazawa
Nagano
HONSHU
Tokyo
Nagoya
Kobe
Hiroshima
Kyoto
Osaka
Pacific Ocean
Shikoku
SHIKOKU
KYUSHU
Nagasaki
Scale
0 100 200 Km.

Table- 2. Long tunnels used for railway in Japan. (longer than 10km)

No.	Name	Line (kind)	Length	Depth	Track	Constructing term
1	Seikan	Tsugaru-Straits (O,S)	53.850	500	D	1971-1987
2	Hakkoda	Tohoku (S)	26.455	540	D	1998-
3	Iwate	Tohoku (S)	25.810	200	D	1991-2000
4	Iiyama	Hokuriku (S)	22.225	325	D	1998-
5	DaiShimizu	Johetsu (S)	22.221	1,300	D	1971-1980
6	SinKanmon	Sanyo (S)	18.713	460	D	1970-1974
7	Rokko	Sanyo (S)	16.220	440	D	1967-1971
8	Haruna	Johetsu (S)	15.350	170	D	1972-1981
9	Gorigamine	Hokuriku (S)	15.175	620	D	1991-1995
10	Nakayama	Johetsu (S)	14.857	410	D	1972-1982
11	Hokuriku	Hokuriku (O)	13.870	490	D	1957-1962
12	SinShimizu	Johetsu (O)	13.500	1,200	S	1963-1967
13	Aki	Sanyo (S)	13.030	530	D	1970-1974
14	Tsukushi	Kyushu(S)	11.865	515	D	2002-
15	KitaKyushu	Sanyo (S)	11.747	270	D	1970-1974
16	Fukushima	Tohoku (S)	11.705	230	D	1972-1976
17	Kubiki	Hokuriku (O)	11.353	230	D	1966-1969

Table- 1. Fire- accidents in tunnel.

Time(year/month)	Tunnel	Length(km)	Use	Country	Nr. of death
1972/11	Hokuriku	13.9	Railway	Japan	28
1979/07	Nihonzaka	2.0	Road	Japan	7
1993/03	Mont Branc	11.6	Road	France	41
1995/05	Tauern	6.4	Road	Austria	2
1996/11	Euro	49.6	Railway	UK-Fr.	0
2000/11	Kitzsteinhorn	3.3	Cable-tram	Austria	155
2001/10	St.Gotthard	16.9	Road	Swiss	11

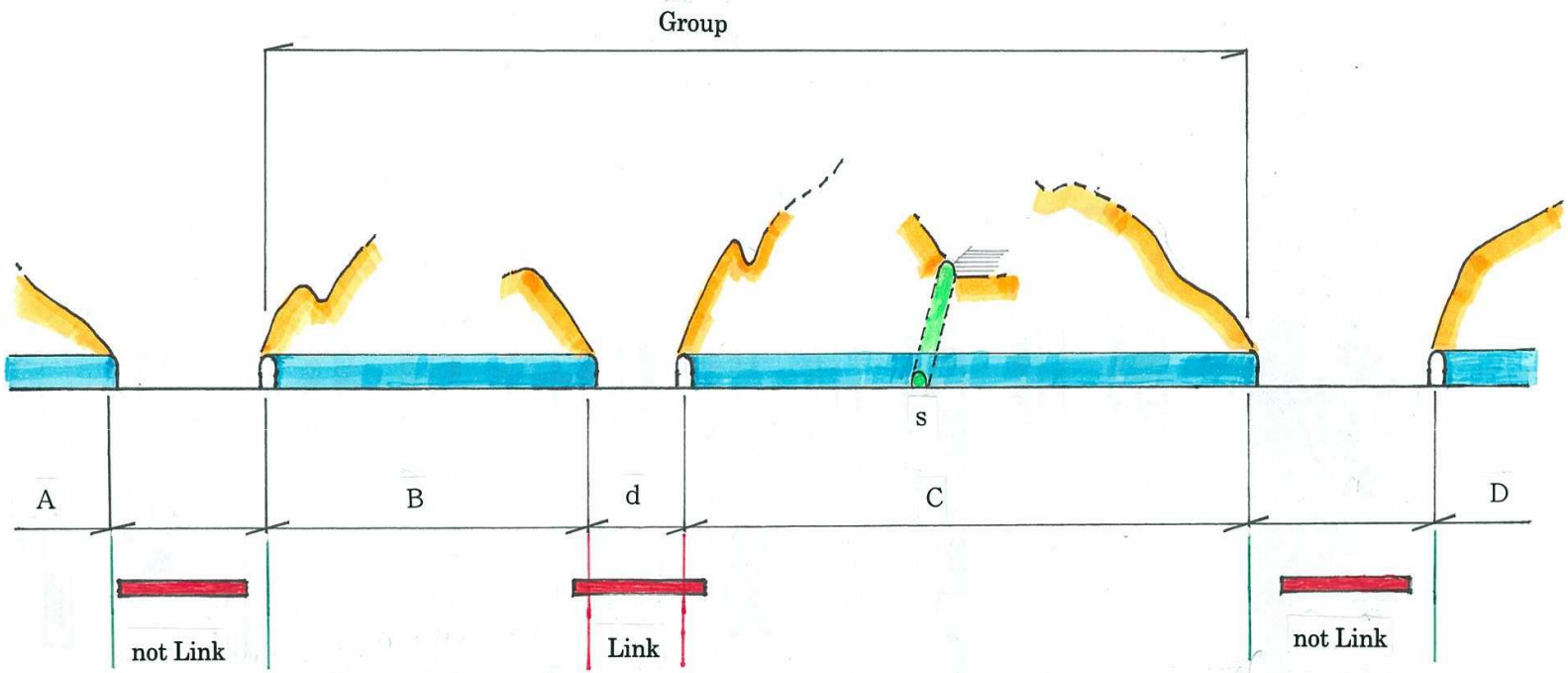
Note 1; not included fire- accidents in subway (metro).

2; summarized by only some proclamations.

Most Effective Method for passengers suffer minimum Disaster

If train is fired by any Accident in Tunnel,

1. Train Running to the out of Tunnel,
2. To stop at Adequate Position out of Tunnel, there
3. Passengers to evacuate or be rescued for Refuge from the train.



Regend

A, B, C, D : Tunnel

d : distance of open portion

: length of a train

s : evacuation- shaft

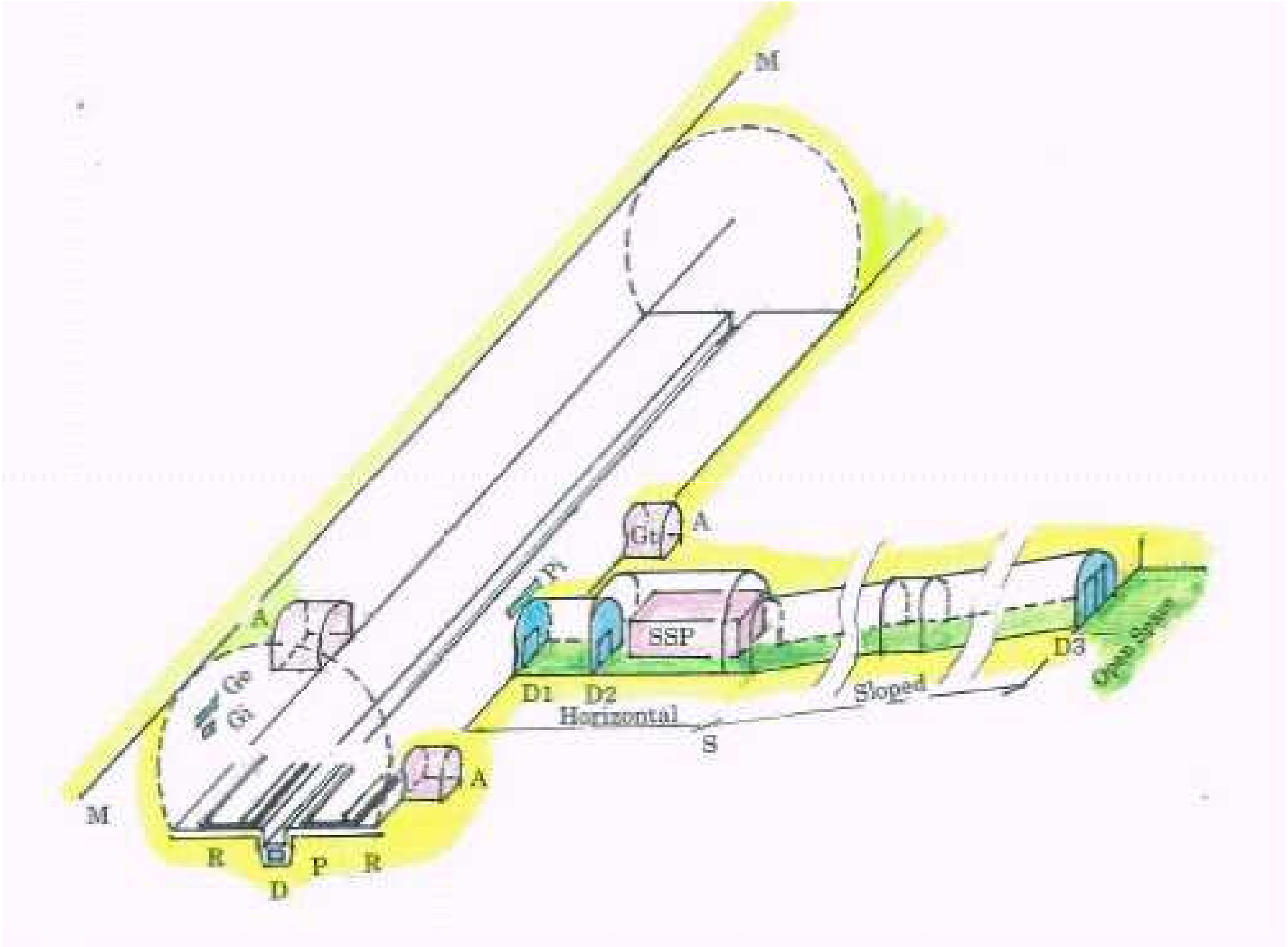
Fig. –P8. Conception of Link and Group of Tunnels.

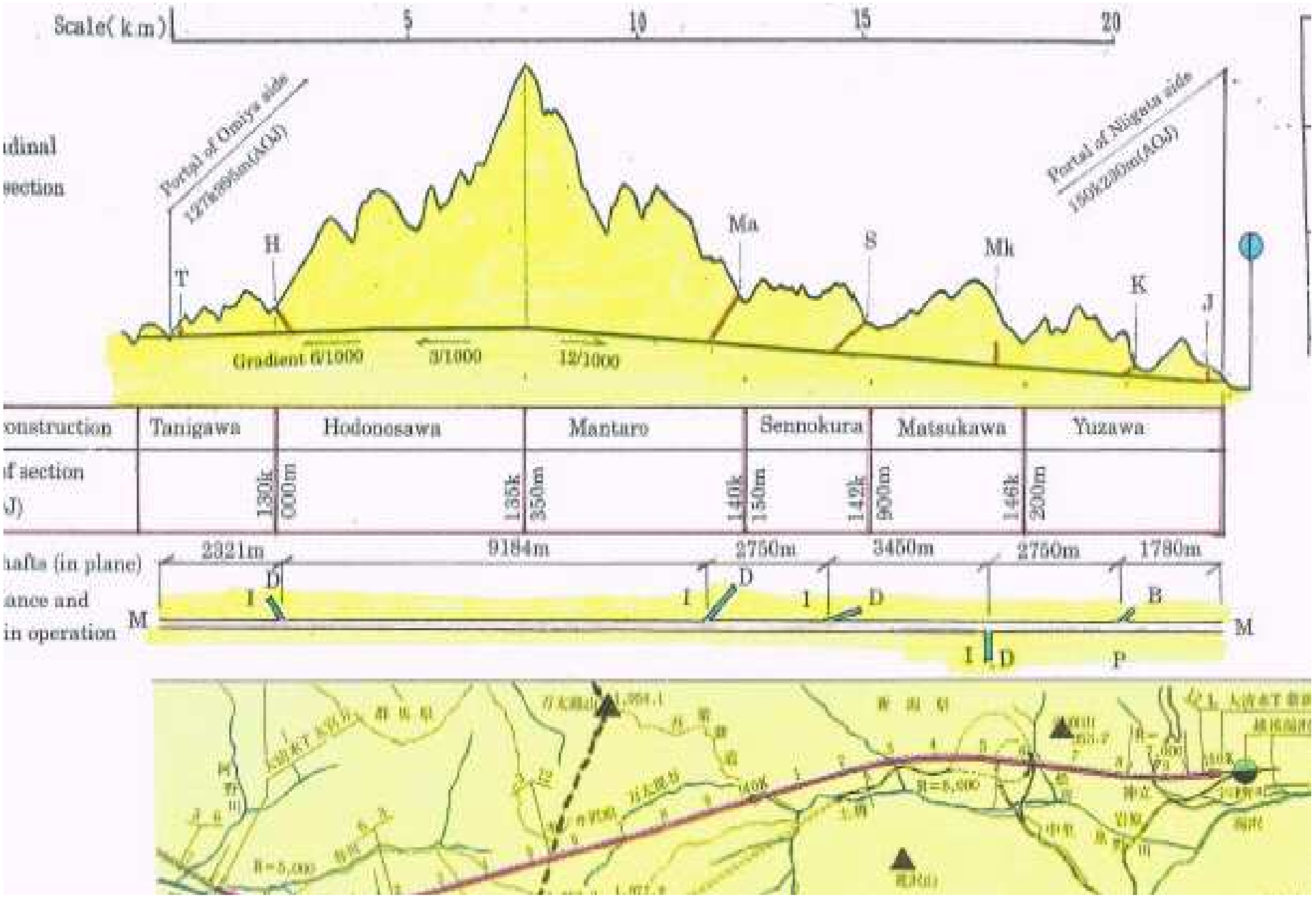
If train fired,
Countermeasure for

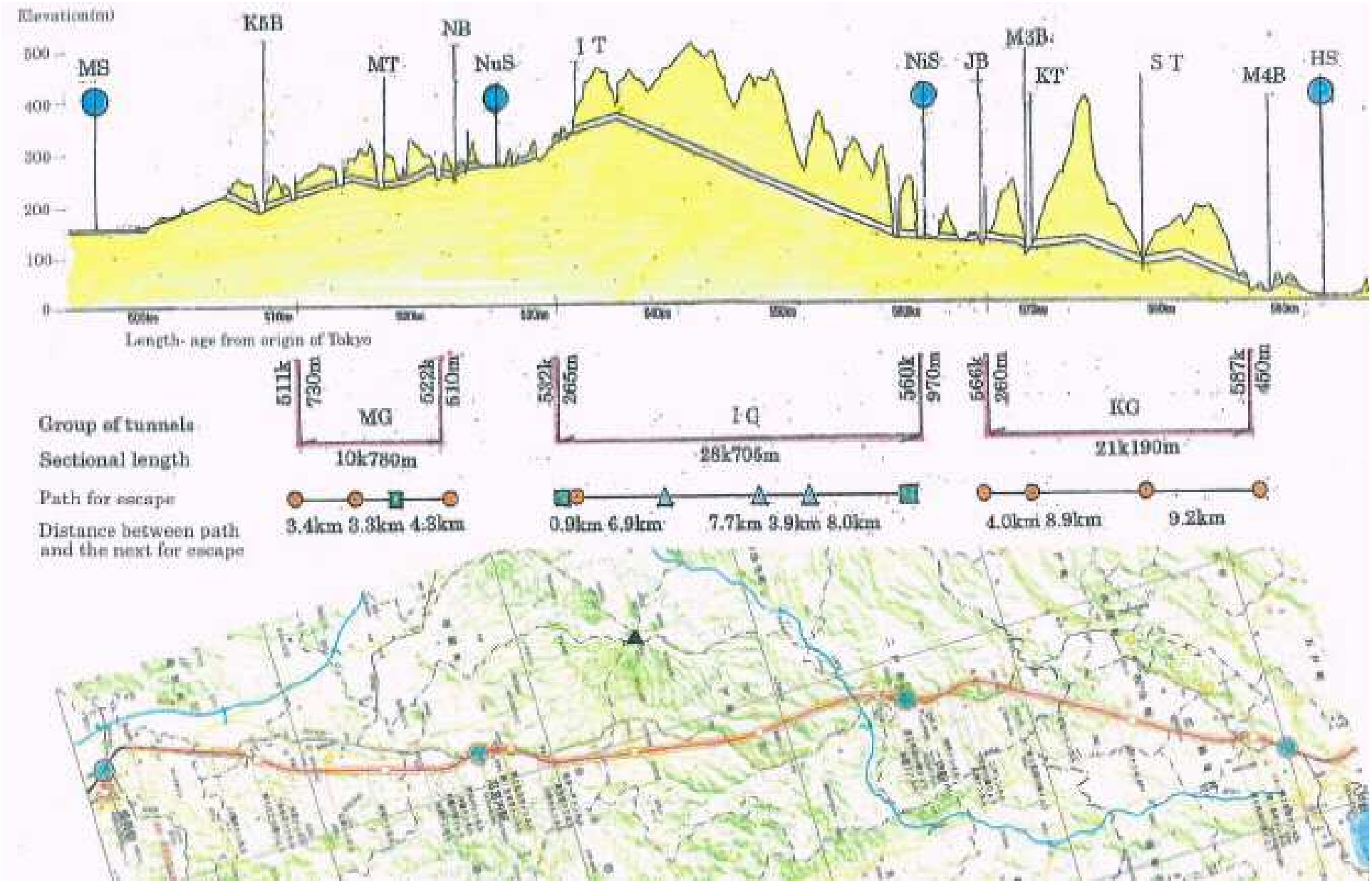
1. Fired Train to run out of the Tunnel.
2. Another Train not to go into the Tunnel.

   when the Train not to run by any accident in the tunnel,,
3. Passengers to evacuate from the tunnel, smoothly safely.

Information	; Correspondence between synthetic operation- head and train by means of wireless telephone, and inner of tunnel by means of telephone set along line.
Illumination	; Fluorescent lamps set on both inner sides of tunnel(1).
Feedings of electricity	; Trolley-wire and assistant suspender of heat- proof.
Transformer of electricity	; of type of oil-less in tunnel.
Cables for correspondence	; set at low position on side- wall, and by claspers of fire-proof.
Interceptor of electricity	; Sectional interceptor of remote- control in tunnel longer than 7km(2).
Switch to stop train	; set on central path, for other train not to be drag the disaster .
Conducting to refuge	; Board set indicating distance to refuge on side-wall. Lamps set indicating telephone set along line and juncture of shaft for evacuation.
Fire- extinguisher	; Handy-type set 20 in each adit for electrical facilities. Facility set to use water in central ditch at 100m interval in longitude of tunnel.


M
A
Gt
A
SSP
D1
D2
Horizontal
S
Sloped
D3
Open Space
M
A
R
P
R
D


Scale(k m)
5
10
15
20
udinal
section
Portal of Omiya side
127k289m(AOJ)
Portal of Niigata side
150k230m(AOJ)
T
H
Ma
S
Mk
K
J
Gradient 6/1000
3/1000
12/1000
onstruction
Tanigawa
Hodonosawa
Mantaro
Sennokura
Matsukawa
Yuzawa
f section
J)
130k 000m
135k 350m
140k 150m
142k 900m
146k 200m
shafts (in plane)
ance and
in operation
2321m
9184m
2750m
3450m
2750m
1780m
I
D
M
B
P


Elevation(m)
500
400
300
200
100
0
MS
K5B
MT
NB
NuS
I T
NiS
JB
M3B
KT
S T
M4B
HS
Length- age from origin of Tokyo
Group of tunnels
Sectional length
Path for escape
Distance between path and the next for escape
511k 730m
522k 610m
MG
10k780m
532k 265m
560k 970m
I·Q
28k705m
566k 260m
587k 450m
KG
21k190m
3.4km 3.3km 4.3km
0.9km 6.9km
7.7km 3.9km 8.0km
4.0km 8.9km
9.2km

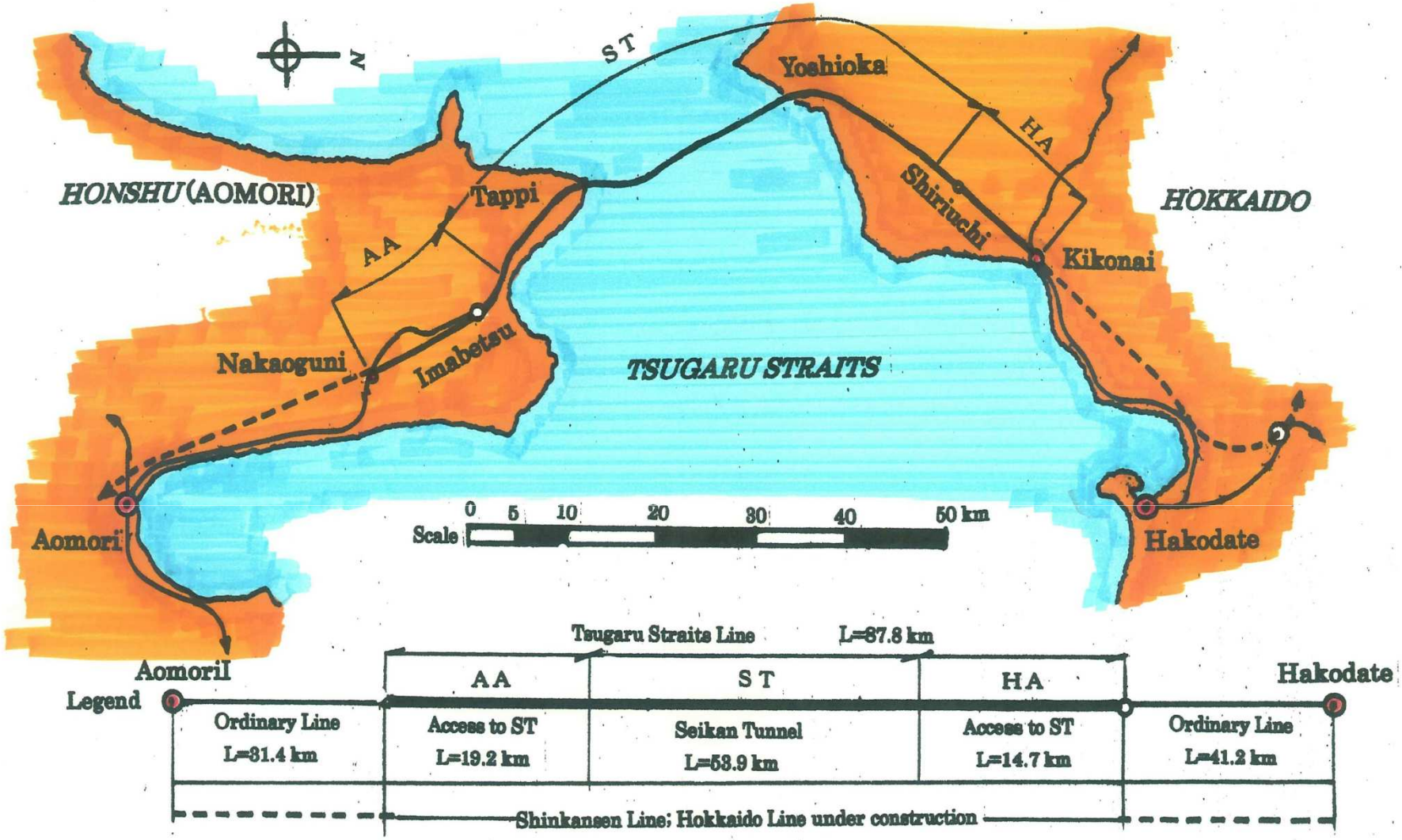


Fig. 6. Location of Tsugaru Straits Line and Seikan Tunnel.

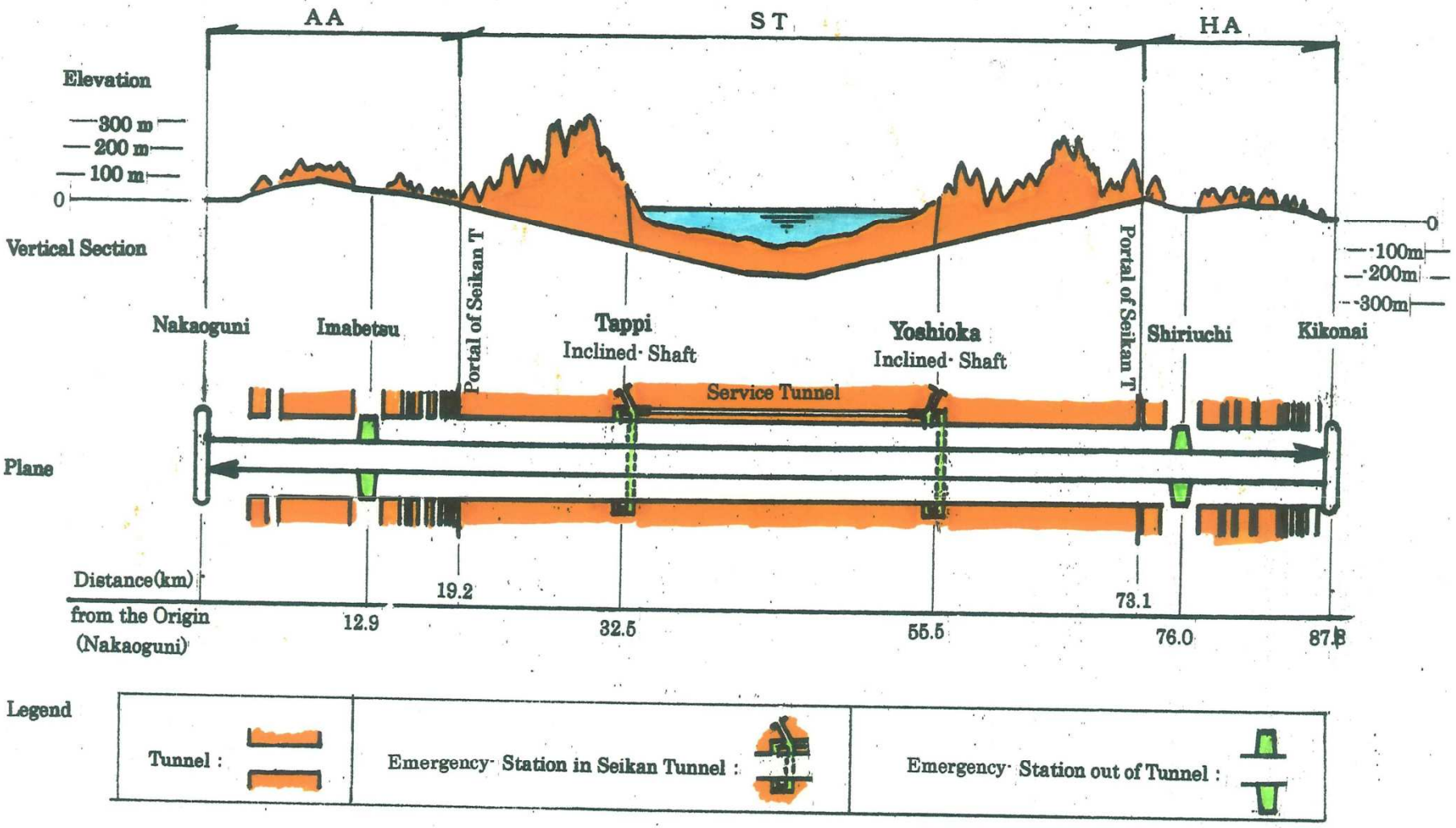


Fig. 7. Arrangement of Tunnels and Emergency· Station in Tsugaru Straits Line.

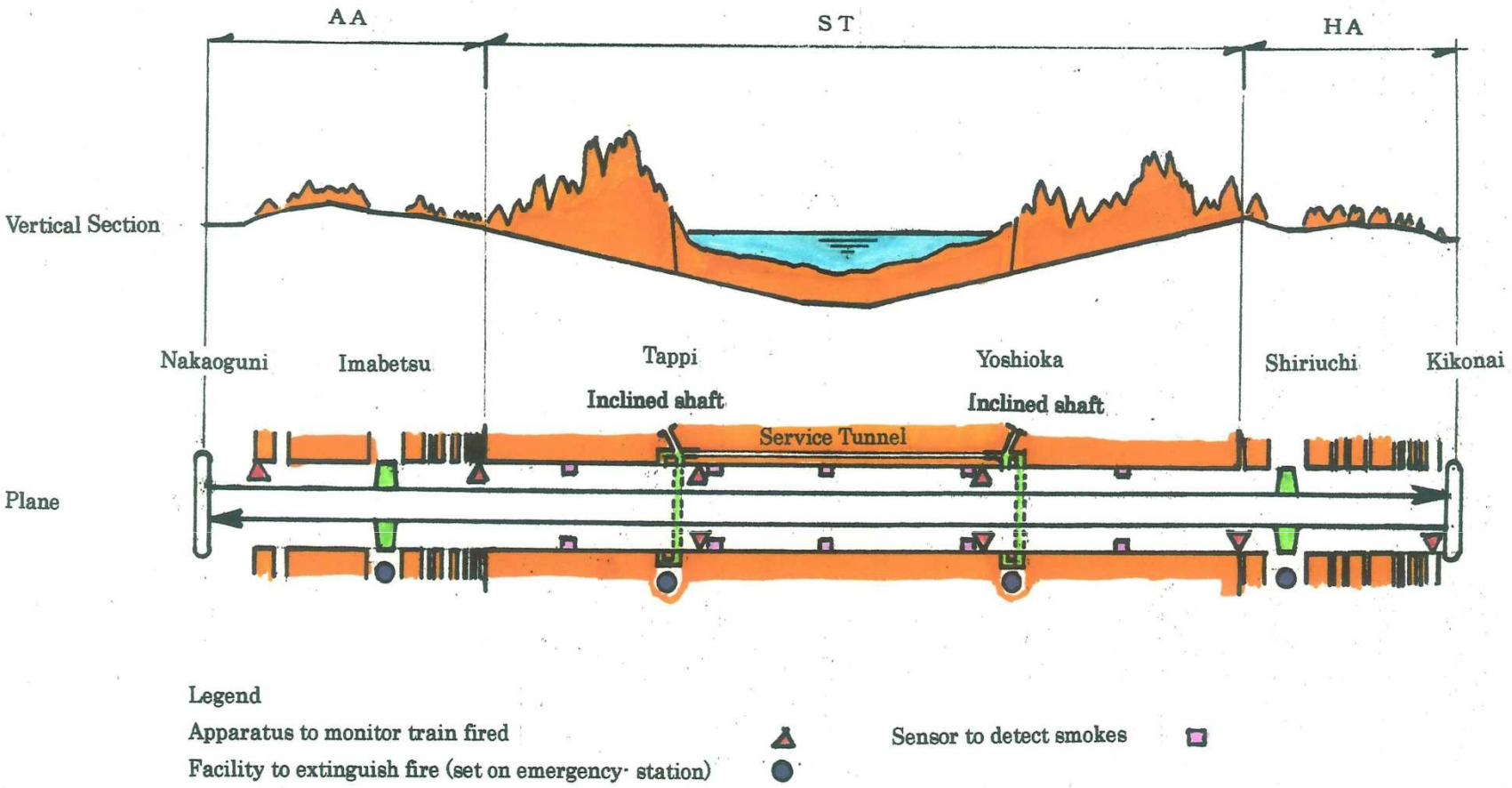


Fig. 8. System to prevent fire· disaster in Tsugaru Straits Line.

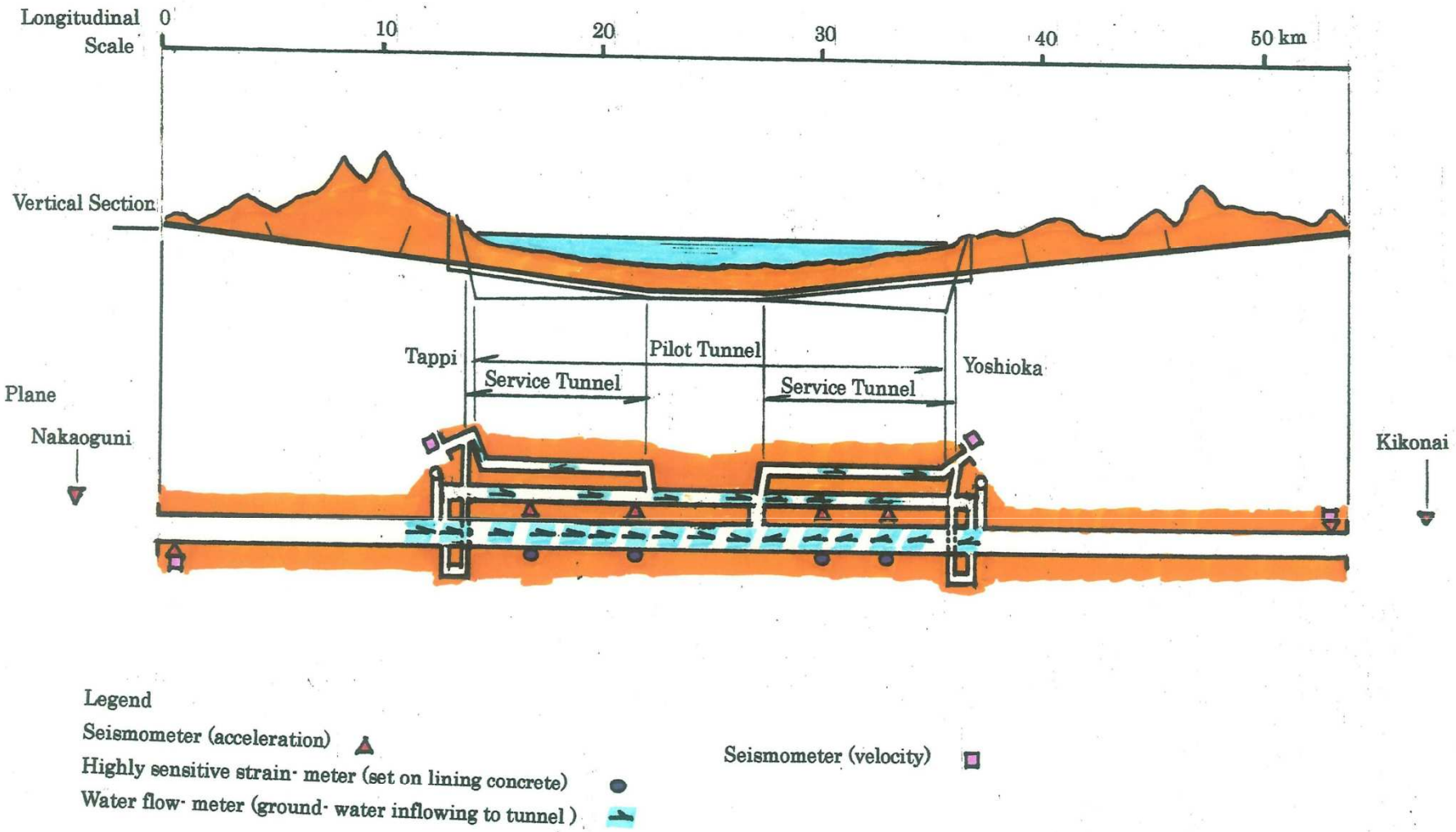
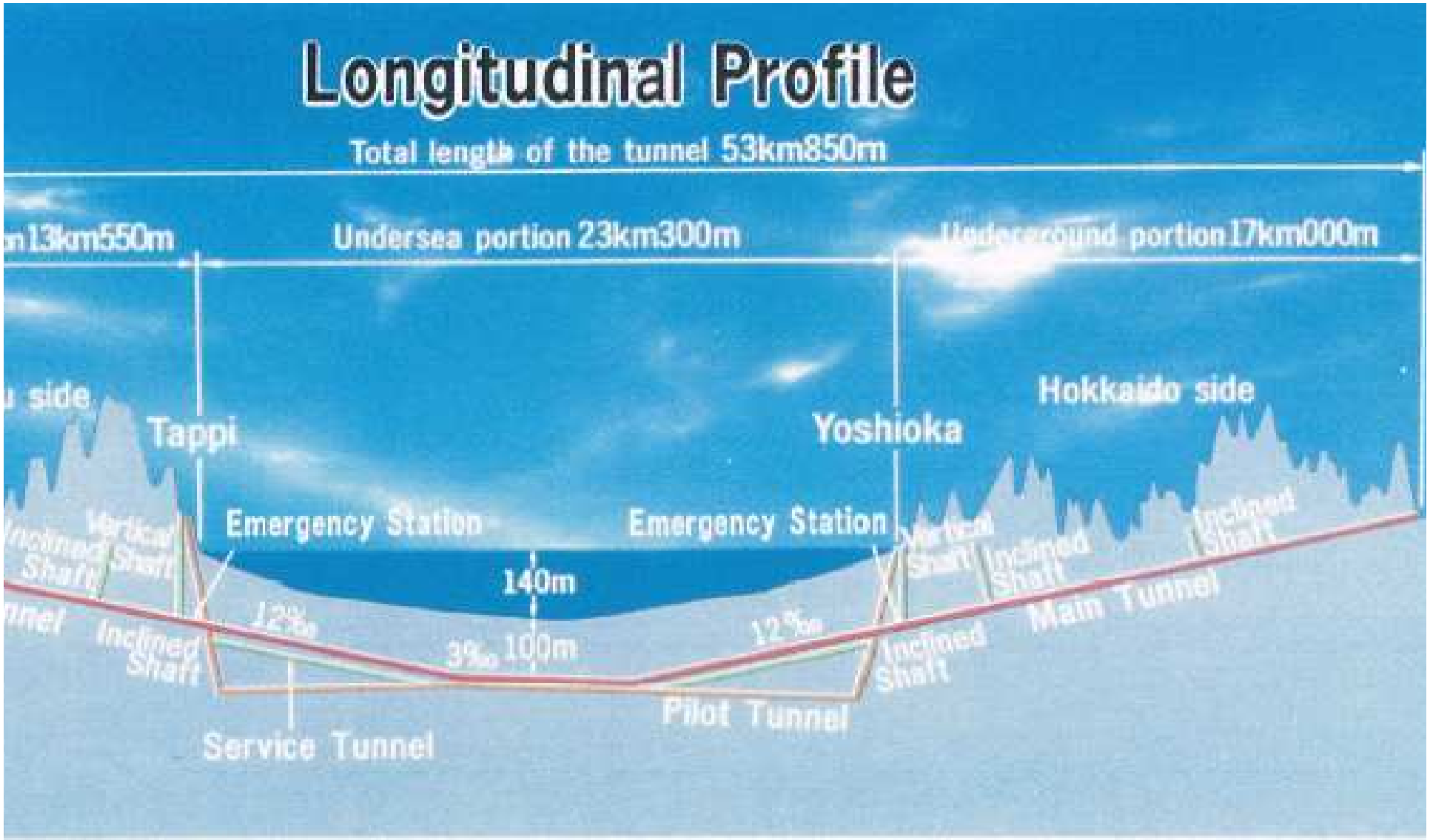
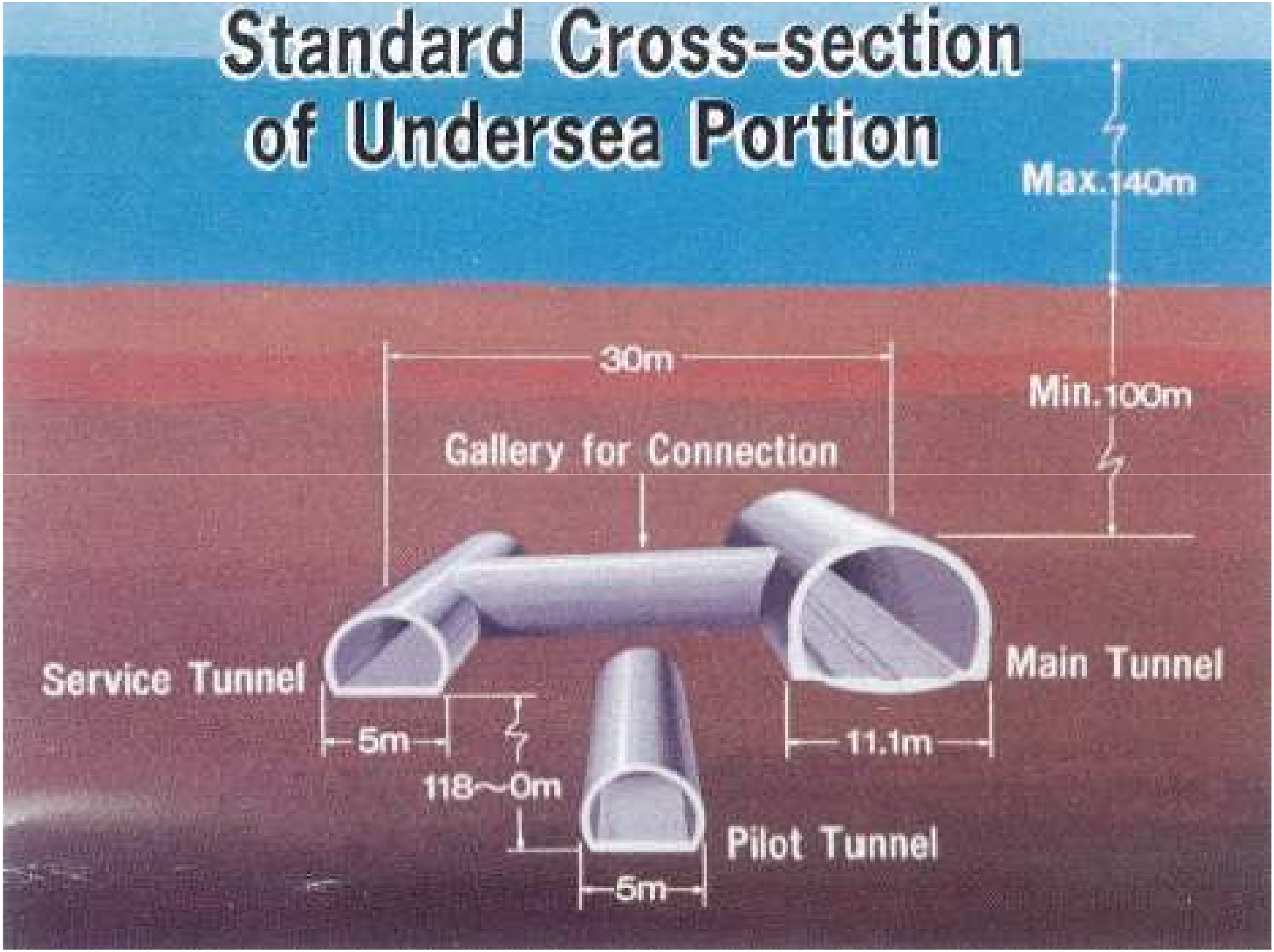


Fig. 9. System to measure Earthquake and Seismic- damage.


Plan
Honshu portal
0km000m
Inclined Shaft
Vertical Shaft
Inclined Shaft
Inclined Shaft
Vertical Shaft
Inclined Shaft
Inclined Shaft
Hokkaido portal
53km850m
10km
20km
30km
40km
50km
Aomori side
Hakodate side
100m
150m
200m
250m


Longitudinal Profile
Total length of the tunnel 53km850m
13km550m
Undersea portion 23km300m
Underground portion 17km000m
side
Tappi
Yoshioka
Hokkaido side
Emergency Station
Emergency Station
Vertical Shaft
Inclined Shaft
140m
12‰
3‰ 100m
12‰
Inclined Shaft
Inclined Shaft
Main Tunnel
Pilot Tunnel
Service Tunnel


Standard Cross-section
of Undersea Portion
Max.140m
30m
Min.100m
Gallery for Connection
Service Tunnel
Main Tunnel
5m
11.1m
118~0m
Pilot Tunnel
5m

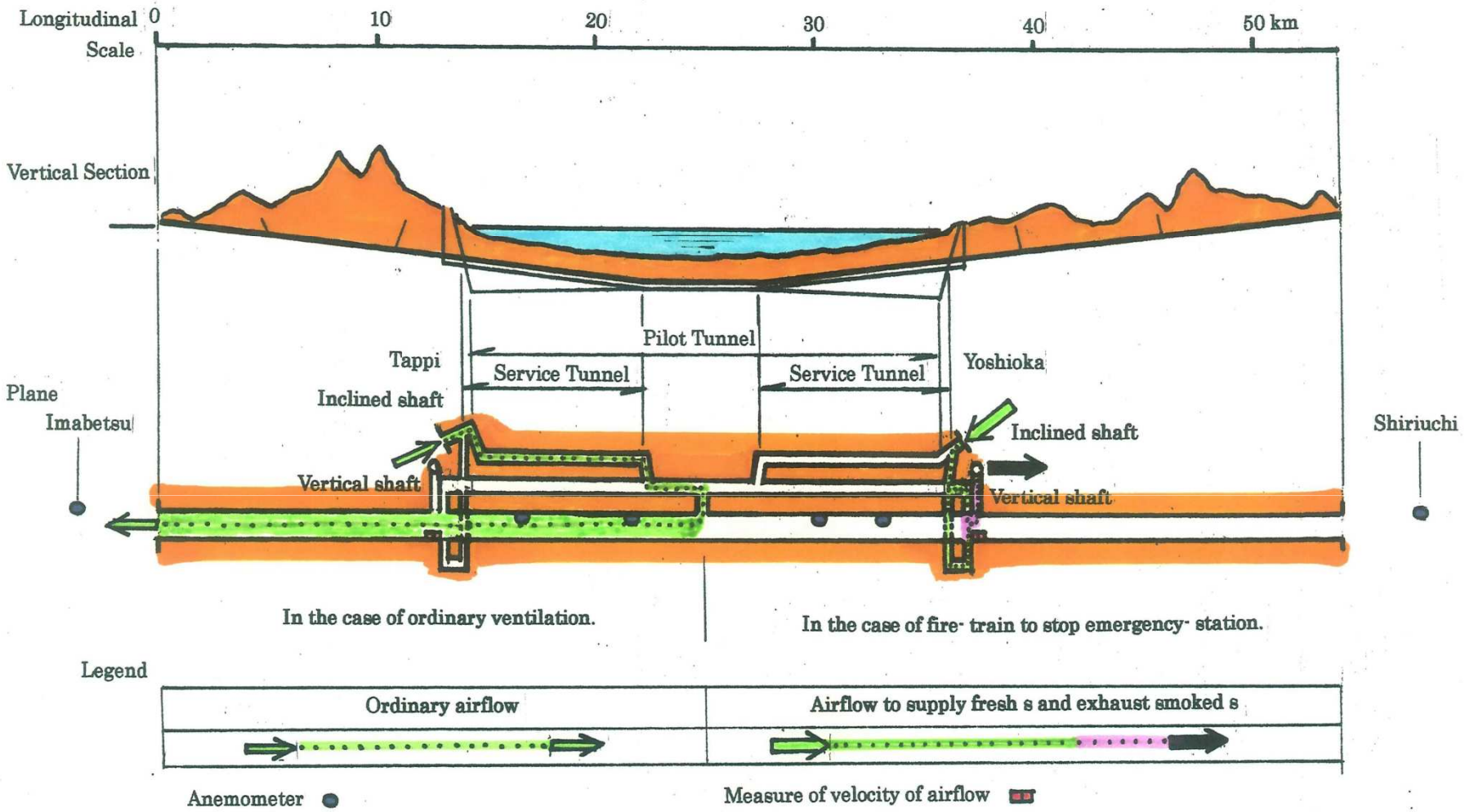
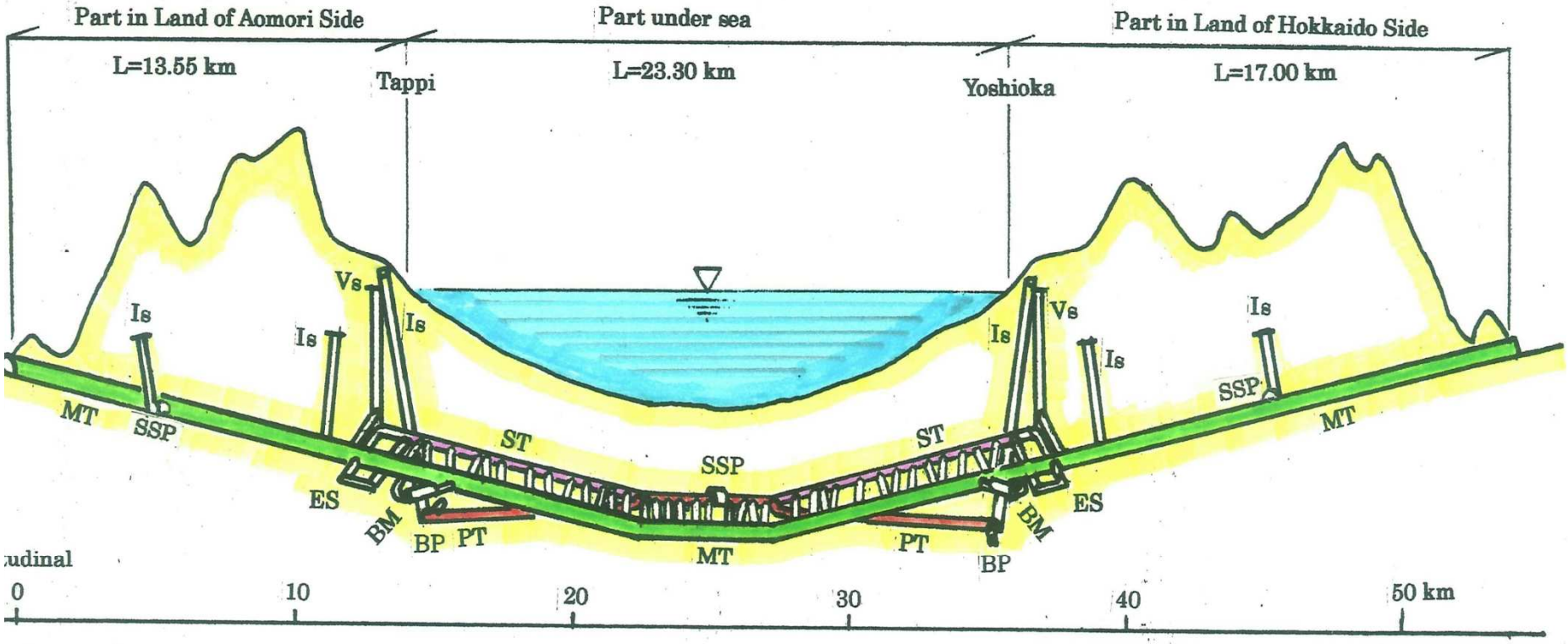
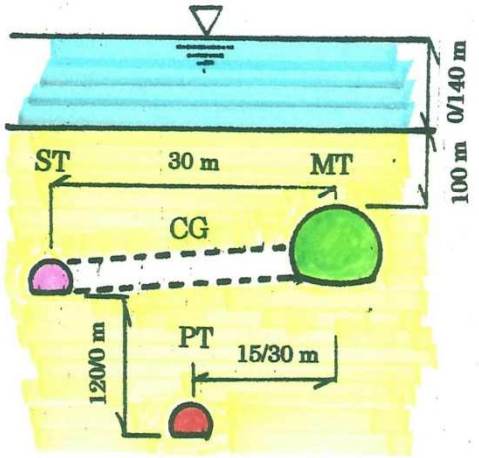


Fig. 11. Ordinary Ventilation and Airflow of Fire- Accident in Seikan Tunnel.



Standard of Cross- section in Part under Sea



Legend

MT: Main Tunnel , PT: Pilot Tunnel , ST: Service Tunnel

CG: Gallery connected with ST/PT at 600 to 1000 m intervals of longitude in MT,

ES: Emergency- Station , BM: Base to maintain railway in Seikan Tunnel ,

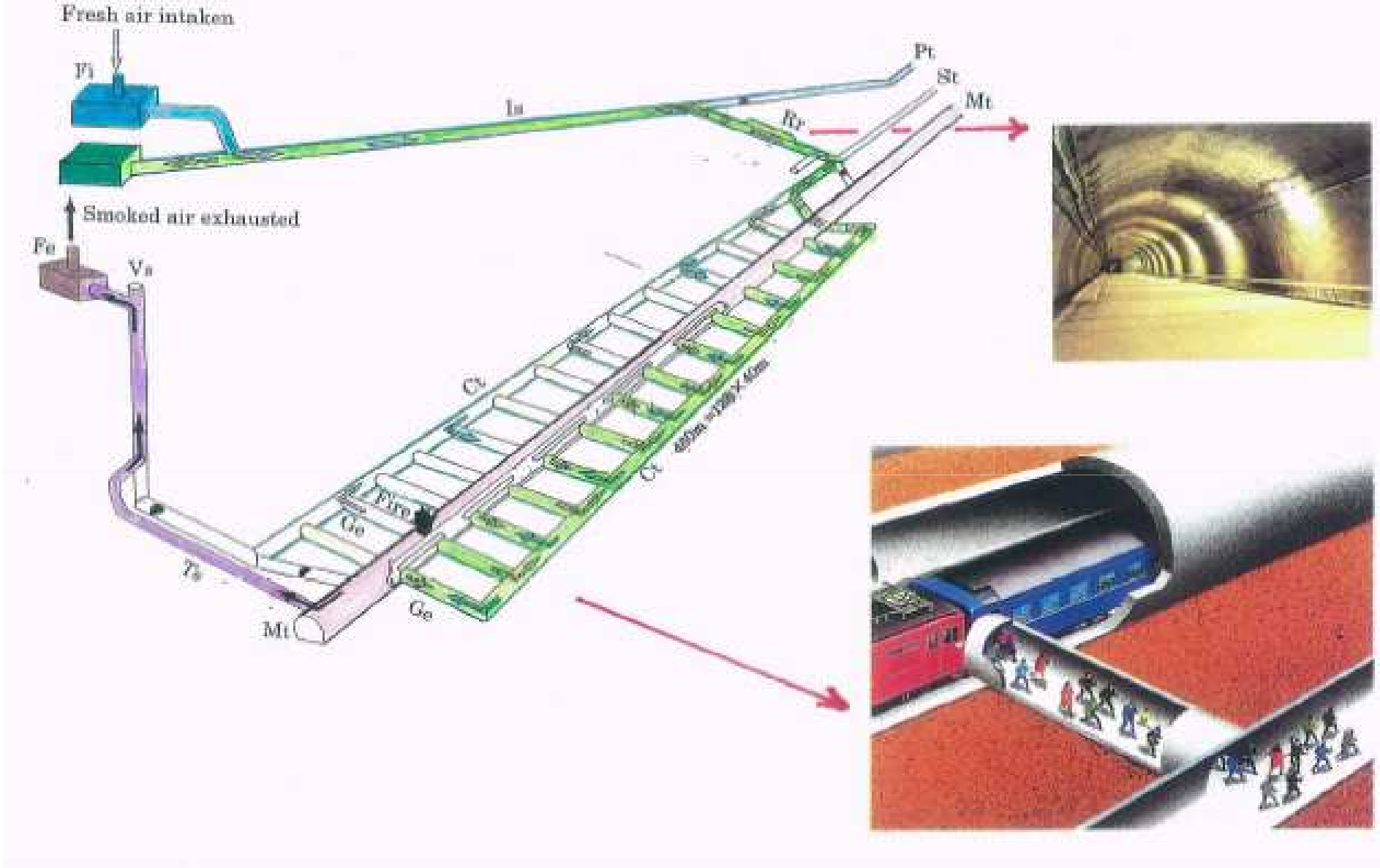
BP: Base to pump up inflow- water

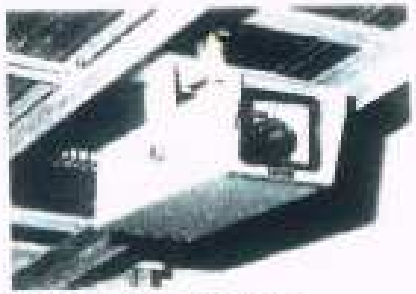
SSP; Substation of sectional electric transformer

Note: Longitudinal Profile (Outline in stereo- graph)

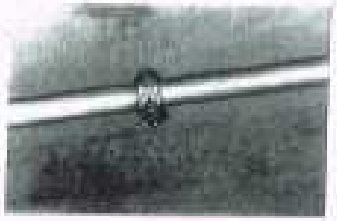
Fig. 10. Constitution and Arrangement of Facilities in Seikan Tunnel.

Evacuation and refuge	
Platform	; set 500m length on side- walls of main tunnel.
Connecting gallery	; connected to conductive path, set at 40m intervals.
Conductive path	; set parallel to main tunnel, to refuge- space.
Refuge- space	; for waiting or curing till to go out of tunnel.
Inclined shaft	; to go out of tunnel, with cable-tram and stairs.
Ventilation	
Ordinary ventilation	; mainly to remove heat accumulated due to train- operation in main tunnel, by means only intake-fan. Air flows intake, inclined shaft, pilot tunnel, main tunnel, and portal of main tunnel, in sequence.
Emergent ventilation	; to send fresh air and to exhaust smoked air at station for emergency, by means of both of intake- and exhaust- fan, controlled by air- gates set in inclined shaft and service tunnel. Air flows intake, inclined shaft, service tunnel, conductive path, connecting gallery, main tunnel, exhausting gallery, vertical shaft and exhaust, in sequence.
To extinguish fire	
Sprinklers	; set at upper and lower position on side- wall and center of railway, at 5m interval in longitude of main tunnel.
Hydrant	; set at connecting gallery, generals for attendants to


Fresh air intaken
Fi
Pt
St
Mt
Is
Ry
Smoked air exhausted
Fe
Ve
Cv
Ct
Fire
Ge
Te
Mt
Ge



■モニターカメラ



Illumination

Speaker

Sprinkler

Fire-extinguishing equipment

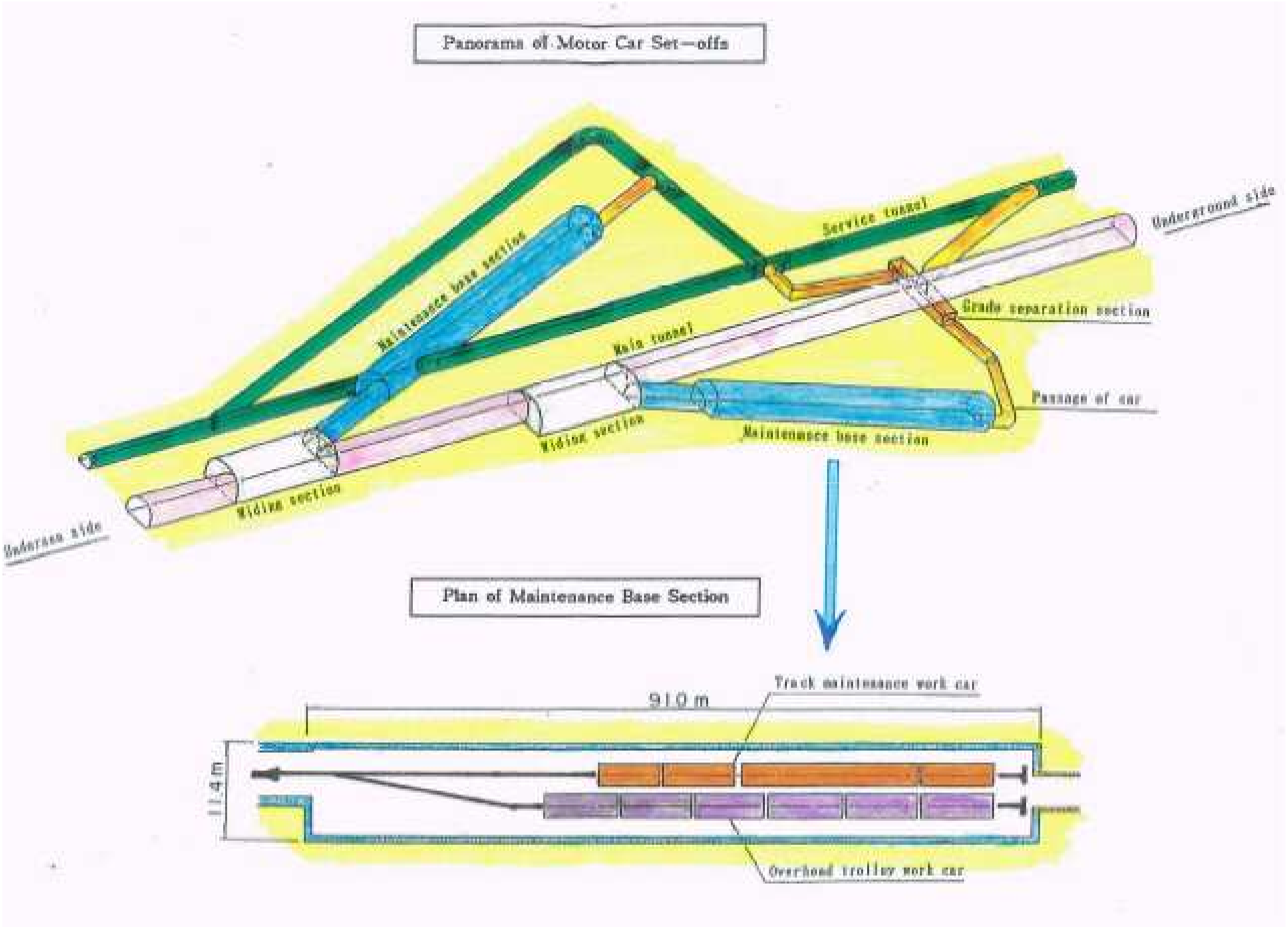
Path of escape

Path of escape

Fire hydrant

Platform

Sprinkler


Panorama of Motor Car Set-offs
Service tunnel
Underground side
Maintenance base section
Grade separation section
Main tunnel
Passage of car
Midium section
Midium section
Maintenance base section
Underseam side
Plan of Maintenance Base Section
Track maintenance work car
910 m
11.4 m
Overhead trolley work car

Tunnelers' indefatigable spirit has linked both banks of the Tsugaru Straits.

There was a great dream; there were strenuous effort.

Both human knowledge embodied in scientific technology and human energy, together, have now linked Hokkaido and Honshu with a tunnel running under the Tsugaru Straits.

The tunnel, our imagination's gateway, connects the longing predecessors with our own future.

Upon this stage for the 21st century is offered a new high- spirited drama.

March 1988.

From Tappi (Site in Honshu) to Hokkaido.

From Yoshioka (Site in Hokkaido) to Honshu