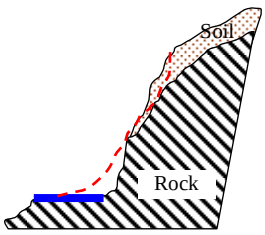
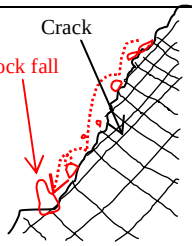
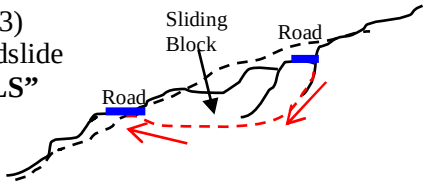
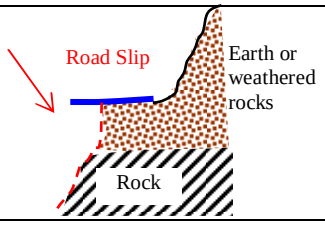
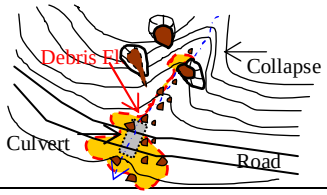
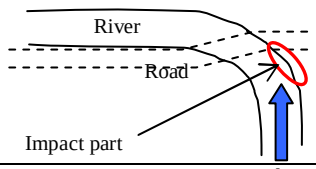
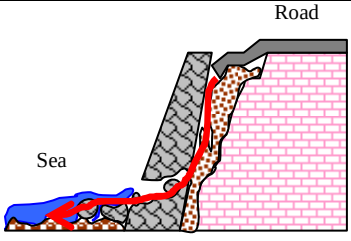
Appendix-2

Classification of Slope Disaster Types

A2.1 General

Table A2.1 Characteristics of Each Disaster Type

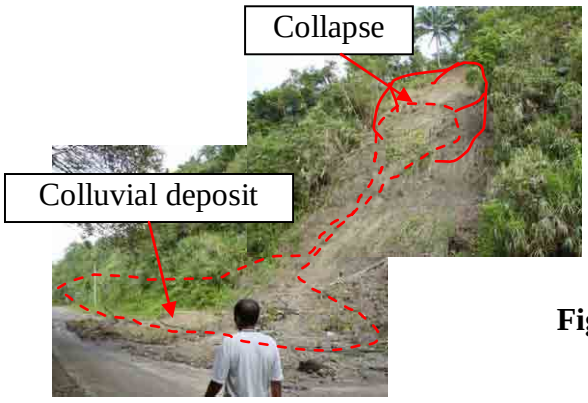
Disaster Type	Schematic Illustration	Characteristics
(1) Soil Slope Collapse **"SC"**		- Collapse (falling) of the soil on a mountainside slope - Mostly triggered by rainfall infiltration and saturation - Mostly occurring in knick line of the slope - Prone to occur at the boundary between impervious rock and the earth cover
(2) Rock Slope Collapse **"RC"**		- Free fall, falling of rocks/rock mass from the slope - Slope failure occurs due to gravity and is influenced by the distribution of cracks - Prone to occur in slopes with fractured rocks
(3) Landslide **"LS"**		- Upheaval or subsidence of part of the road or slope due to the sliding of the ground - Mostly activated by rainfall infiltration and earthquake - Prone to occur on slopes of earth and highly weathered rocks - Potential landslide slopes are generally gentle
(4) Road Slip **"RS"**		- Collapse/slide/erosion/settlement mainly on the road body and some parts of the valley-side slope - Mostly triggered by runoff of heavy rain - Prone to occur on valley-type slopes - Prone to occur on areas of earth and highly weathered rocks. - Insufficient embankment and retaining wall foundation.
(5) Debris Flow **"DF"**		- Occurs on catchment area with steep slope and affects/damages the road - Mostly caused by heavy rainfall - Flows are composed of boulders, gravel, sand, silt and clay mixed with substantial amount of water
(6) River Erosion **"RE"**		- Erosion/scouring of the river-side slopes of the road - Prone to occur in area impacted by river flow - Mostly caused by flooding - Prone to occur on earth and highly weathered rock slopes
(7) Coastal Erosion **"CE"**		- Settlement/collapse of a road along a seaside slope - Mostly triggered by tidal action - Prone to occur on steep earth slopes directly affected by waves - Sometimes occurs in areas with insufficient embankment and revetments, such as those without foot protection

A2.1 Examples and Characteristics of Each Disaster Type

A2.1.1 Soil Slope Collapse

(1) Examples of Soil Slope Collapse

Examples of Soil Slope Collapse along the national highways are shown in Figures A2.1 – Figure A2.3.



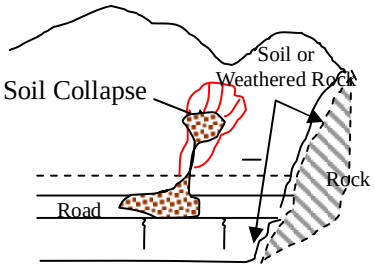


Figure A2.1 Soil Slope Collapse (SC) along Mahaplag-Sogod Road (Km 1006+500)

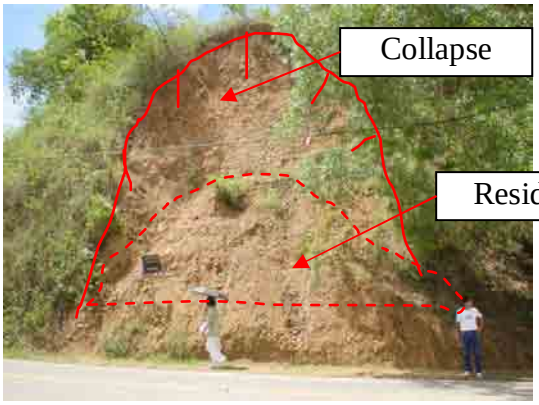
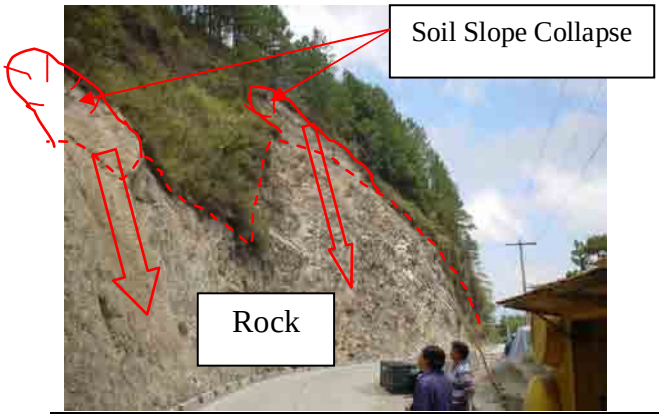


Figure A2.2 Soil Slope Collapse (SC) along Cebu-Balamban Road (Km 1007+100)



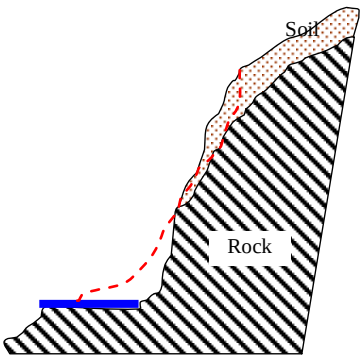


Figure A2.3 Soil Slope Collapse (SC) along Baguio-Bontoc Road (Km 281+780)

(1) Characteristics of Soil Slope Collapse

The characteristics of Soil Slope Collapse are as follows:

- Part of the mountain-side slope suddenly falls on the road. (see Figure A2.1);
- Mostly triggered by rainfall infiltration;
- Collapsed materials are earth and highly weathered rocks;
- Size/volume of collapsed materials is generally more than 200m^3;
- Prone to occur at the boundary between impervious rock and the earth cover. (see Figure A2.3); and
- Prone to occur on steep earth slopes around knick line (see Figure A2.4).

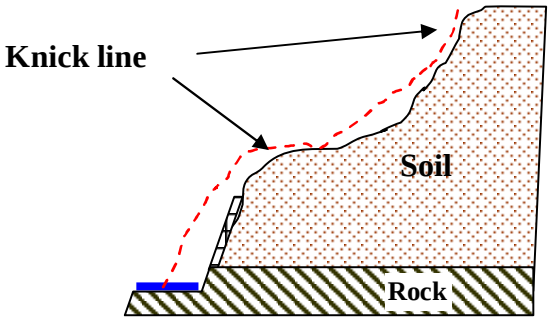


Figure A2.4 Schematic Illustration of Soil Slope Collapse

Knick: The junction where a gently inclined pediment and the adjacent mountain slope meet at a sharp angle.

Knick line: A line formed by the angle of a *knick* in a slope, especially in a desert region where there is an abrupt transition from a pediment surface to the mountain slope.

Knick point: Any interruption or break of slope; especially a point of abrupt change or inflection in the longitudinal profile of a stream or of its valley, resulting from rejuvenation, glacial erosion, or the outcropping of a resistant bed (Glossary of Geology, 3rd edition, American Geological Institute, AGI).

A2.2.2 Rock Slope Collapse

(1) Examples of Rock Slope Collapse

Examples of Rock Slope Collapse along the study roads are shown in Figures A2.5 – A2.7.

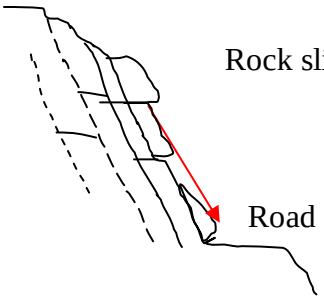


Figure A2.5 Rock Slope Collapse (RC) along Kennon Road

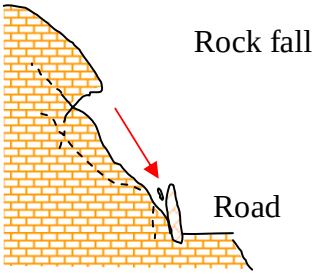


Figure A2.6 Rock Slope Collapse (RC) along Wright-Taft Road (km 846+050)

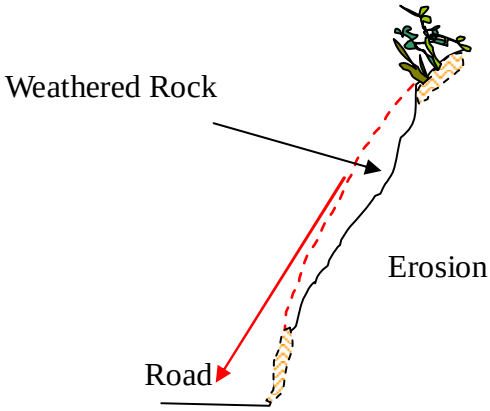


Figure A2.7 Rock Slope Collapse (RC) along Cebu-Balamban Road (km 1027)

(1) Characteristics of Rock Slope Collapse

The characteristics of Rock Slope Collapse are as follows:

- Free fall or rolling of rocks from the slope;
- Falls occur due to gravity and are influenced by the distribution of cracks;
- Prone to occur on slopes of fractured rocks;
- Occurs on steep slopes and cliffs;
- Size/volume of fallen materials is generally less than 5 m^3

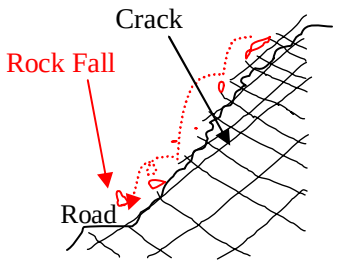


Figure A2.8 Schematic Illustration of Rock Slope Collapse (RC)

- Rocks fall to the road from an overhanging slope (See Figure A2.8);
- Fall occurs due to gravity and is influenced by distribution of cracks;
- Materials are usually weathered rock;
- Size/volume of fall material is generally more than 2-3 m^3;
- Failure mode is mostly planer slide (see Figure A2.5);
- Materials are mostly fractured rocks;
- Mostly occurs on steep slopes of mountainsides; and

A2.2.3 Landslides

(1) Examples of Landslides

Examples of landslides along the study roads are shown in Figures A2.9- A2.11 below.

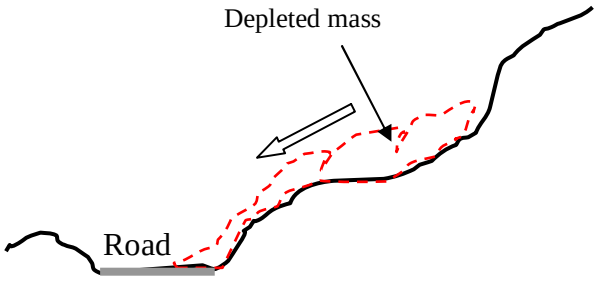


Figure A2.9 Landslide (LS) along Banaue-Lagawe Road (km 334+157)

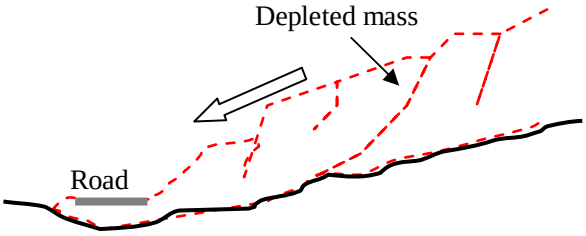


Figure A2.10 Landslide (LS) along Banaue-Lagawe Road (km 301+200)

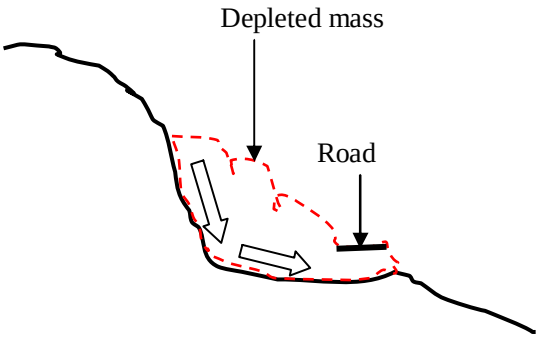


Figure A2.11 Landslide (LS) along Mahaplag-Sogod Road (km 1015)

(2) Definitions by the International Association of Engineering Geology (IAEG) 1990

Number	Name	Definition
1	Crown	Practically undisplaced material adjacent to highest parts of main scarp
2	Main Scarp	Steep surface on undisturbed ground at upper edge of landslide caused by movement of displaced materials (13, stippled area) away from undisturbed ground; it is the visible part of surface rupture (10)
3	Top	Highest point of contact between displaced materials (13) and main scarp (2)
4	Head	Upper parts of the landslide along contact between displaced materials and main scarp
5	Minor Scarp	Steep surface on displaced materials of the landslide produced by differential movements within the displaced materials
6	Main Body	Part of displaced material of landslide that overlies surface of rupture between main scarp (2) and toe of surface of rupture (11)
7	Foot	Portion of landslide that has moved beyond toe of surface of rupture (11) and overlies original ground surface (20)
8	Tip	Point on toe (9) farthest from top (3) of landslide
9	Toe	Lower, usually curved margin of displaced materials of a landslide, most distant from main scarp (2)
10	Surface of rupture	Surface that forms (or that has formed) the lower boundary of displaced materials (13) below the original ground surface (20); mechanical idealization of surface of rupture is called slip surface
11	Toe of surface of rupture	Intersection (usually buried) between lower part of surface of rupture (10) of a landslide and original ground surface
12	Surface of separation	Part of original ground surface (20) now overlain by foot (7) of landslide
13	Displaced material	Materials displaced from its original position on slope by movement in the landslide; forms both depleted mass (17) and accumulation (18)
14	Zone of depletion	Area of landslide within which displaced materials lie above original ground surface (20)
15	Zone of accumulation	Area of landslide within which displaced materials lie above original ground surface (20)
16	Depletion	Volume bounded by main scarp (2), depleted mass (17), and original ground surface (20)
17	Depleted mass	Volume of displaced materials that overlies above surface of rupture (10) but overlies original ground surface (20)
18	Accumulation	Volume of displaced materials (13) that lies above original ground surface (20)
19	Flank	Undisplaced material adjacent to slides of surface of rapture; compass directions are preferable in describing flanks, but if left and right are used, they refer to flanks as viewed from crown
20	Original ground surface	Surface of slope that existed before landslide took place

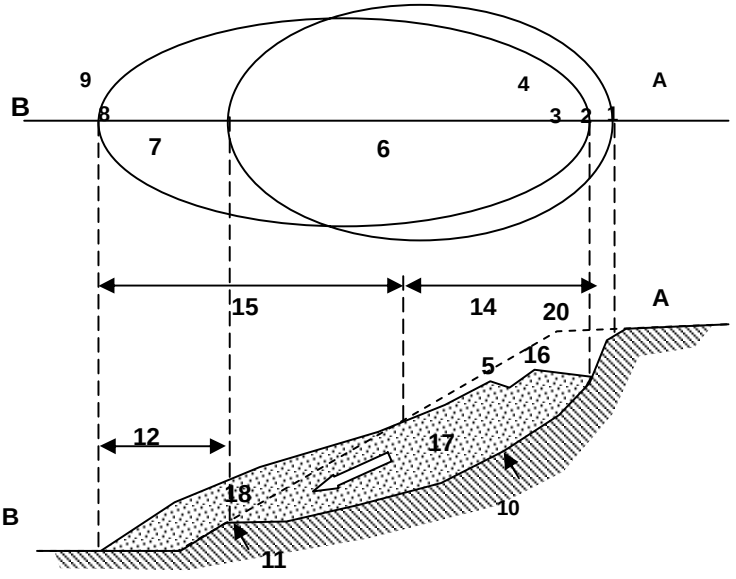


Figure A2. 12 Landslide Definitions (IAEG Commission on Landslides 1990)

(3) Characteristics of Landslides

The characteristics of Landslides are given below. Figure A2.13 shows the international perception of the landslide model by VARNES.

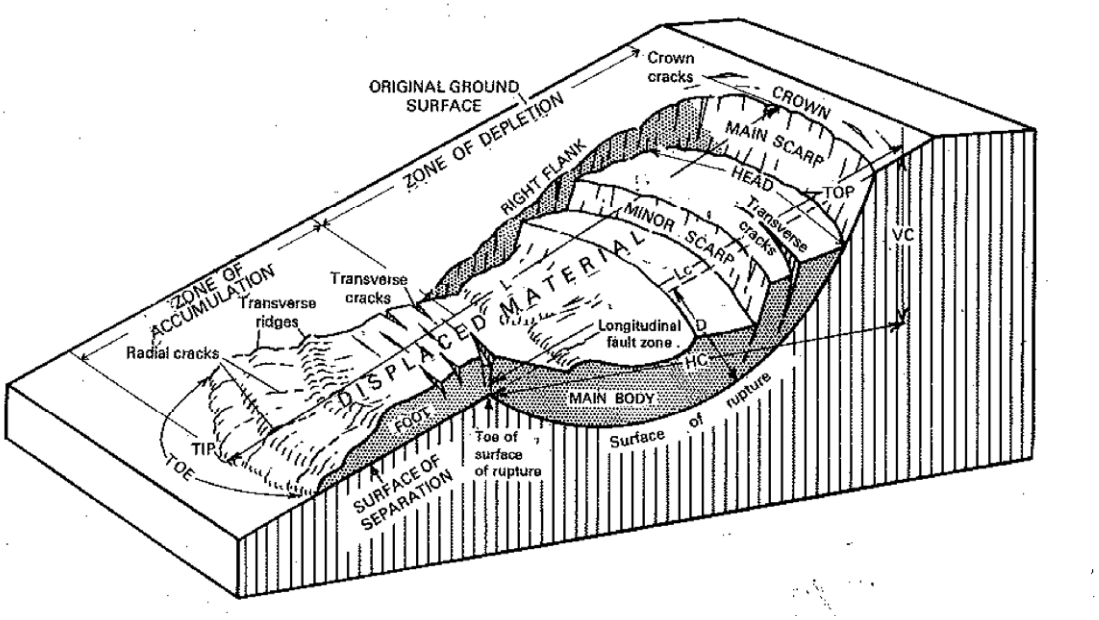


Figure A2.13 Block Diagram of Idealized Complex Earth Slide – Earth Flows (Varnes 1978, Figure 2.1t)

- A part of the road upheaves an inch or more. (See Figure 2.5.15 and 16)
- Mostly triggered by rainfall infiltration, earthquake and sometimes by cutting the toe of the slope along the road.
- Materials are earth and highly weathered rocks.
- Landslide slope is generally gentle and deformed.
- Size/volume of displaced materials is generally more than 5,000 m^3.

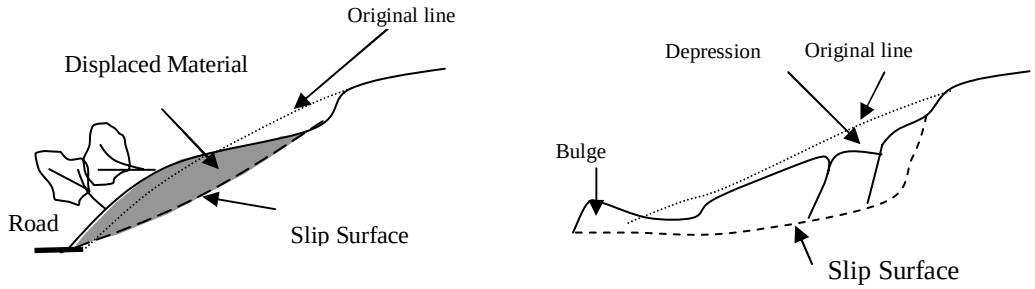


Figure A2.14 Schematic Illustration of a Landslide

A2.2.4 Road Slips

(1) Example of Road Slips

Examples of Road Slips are shown in Figures A2.15 - A2.16 below.

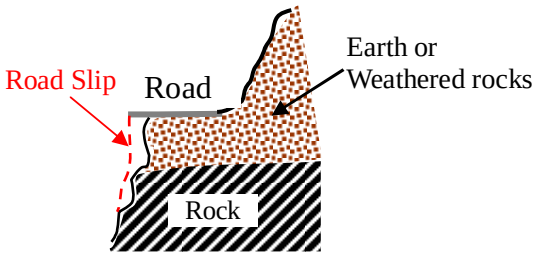


Figure A2.15 Road Slip (RS)
Slip of roadway and valley side slope along Wright-Taft Road (km 858+250)

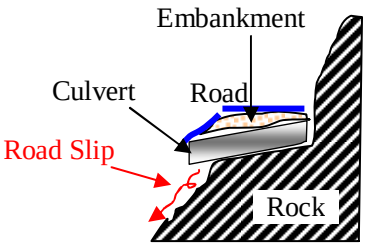
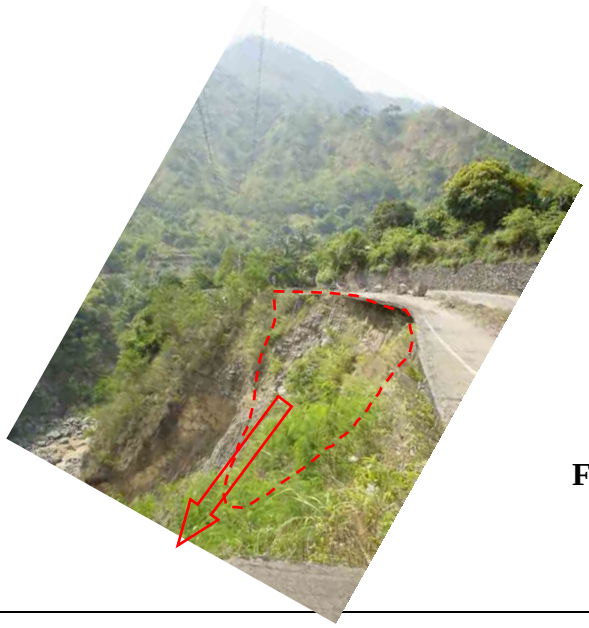


Figure A2.16 Road Slip (RS)
Slip of roadway and valley side slope along Wright-Taft Road (km 844+060)



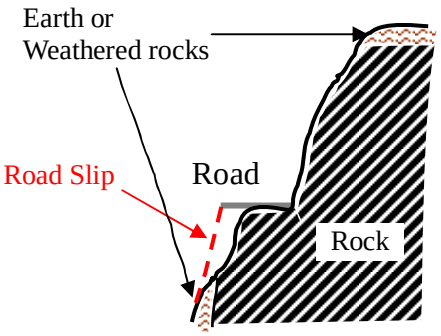


Figure A2.17 Road Slip (RS)
Slip of roadway and valley side slope along Kennon Road

(2) Characteristics of Road Slips

The characteristics of Road Slips are as follows:

(a) They are one of the most common disasters on national highways;

(b) Collapse/Slide/Erosion/Settlement mainly of roadway and some part of the valley side slope;

(c) Mostly triggered by runoff of heavy rain;

(d) Prone to occur in steep valley-type slopes;

(e) Prone to occur in earth and highly weathered rocks, insufficiently compacted embankment and retaining wall foundations;

(f) When the slide and the collapse of the road have occurred as part of a landslide, the disaster is not considered a Road Slip (RS), but a Landslide (LS);

(g) Collapsed materials may include the roadway and/or some valley side slope materials (See Figures A2.15 and A2.17);and

(h) Road Slips sometimes occur around culverts (See Figure A2.16).

A2.2.5 Debris Flow

(1) Example of Debris Flow

Example of Debris Flow in the study road is shown in Figure A2.18.

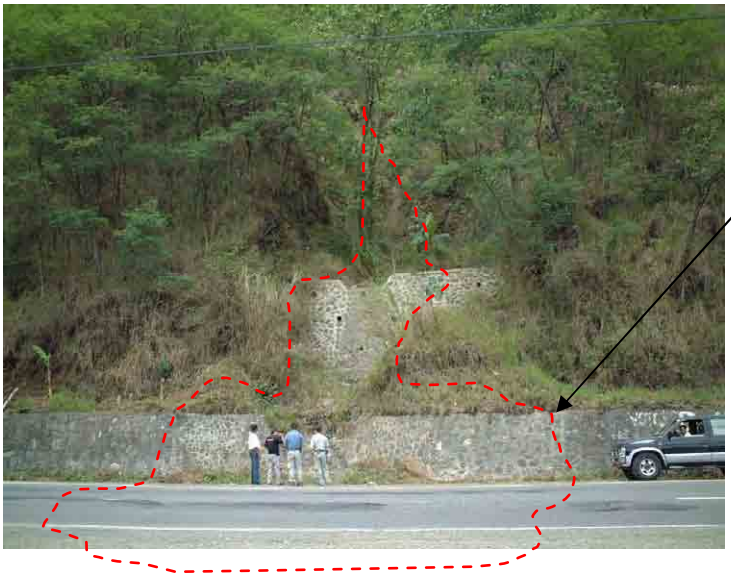


Figure A2.18 Debris Flow (DF) in Alitao, Nueva Vizcaya

(2) Characteristics of Debris Flow

The characteristics of Debris Flow are as follows:

- They occur in drainage areas with steep slopes and affect or damage the road (See Figure A2.19);
- Mostly caused by heavy rainfall; and
- Flow is composed of boulders, gravel, sand, silts and clay mixed with a substantial amount of water.

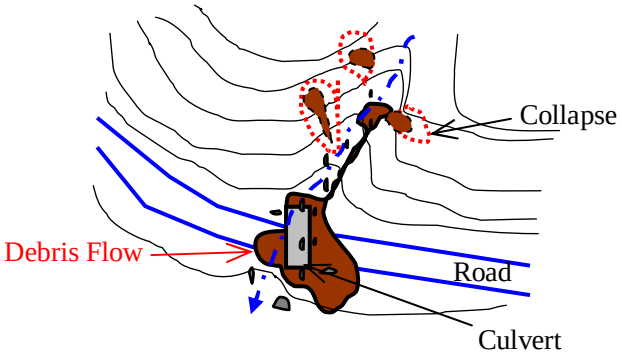


Figure A2.19 Schematic Illustration of Debris Flow

A2.2.6 River Erosion

The characteristics of River Erosion are as follows:

- Erosion/scouring of the riverside slopes of the road;
- Mostly caused by flooding;
- Prone to occur on earth and highly weathered rock slopes;
- Prone to occur on the area impacted by river flow resulting in bank scouring or erosion (See Figure A2.20); and
- Damaged structure and accumulated debris on a riverbed along the road indicate a section at risk of overflow (See Figure A2.21).

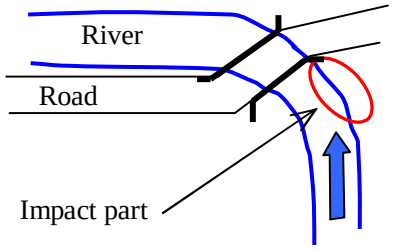


Figure A2.20 Schematic Illustration of River Erosion (Plan)

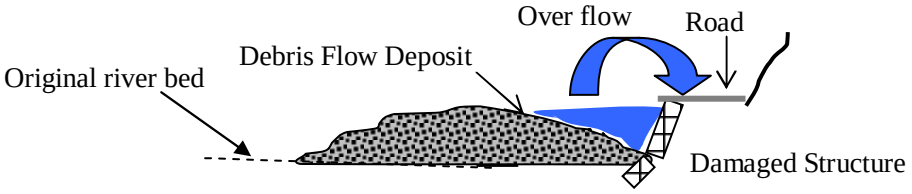


Figure A2.21 Schematic Illustration of River Erosion (Section)

A2.2.7 Coastal Erosion

(1) Example of Coastal Erosion

Examples of coastal erosion along the study roads are shown in Figures A2.24 - A2.26.

Erosion of a foundation of grouted riprap
↓
Outflow of fill material from behind

Figure A2.22 CE on Ginalitan-Alegria Road (km 77 + 700)

Collapse of Grouted Riprap
↓
Outflow of fill material from behind

Figure A2.23 CE on Ginatilan-Alegria Road (km 172 + 050)

Outflow of fill material from behind
↓
Settlement of roadway

Figure A2.24 CE on Ginatilan-Alegria Road (km 177 + 910)

(2) Characteristics of Coastal Erosion

The characteristics of Coastal Erosion are as follows:

- Settlement/ Collapse of a roadway on a seaside slope (See Figure A2.25);
- Breakage of grouted riprap due to erosion of its foundation (See Figure A2.25);
- Settlement of a roadway or slope shoulder of a seaside slope due to outflow of the fill material of the grouted riprap caused by the collapse of the grouted riprap (See Figure A2.25);
- Mostly triggered by tidal action;
- Materials are earth and highly weathered rocks;
- Sometimes occur on insufficiently compacted embankments and revetments such as those without foot protection.

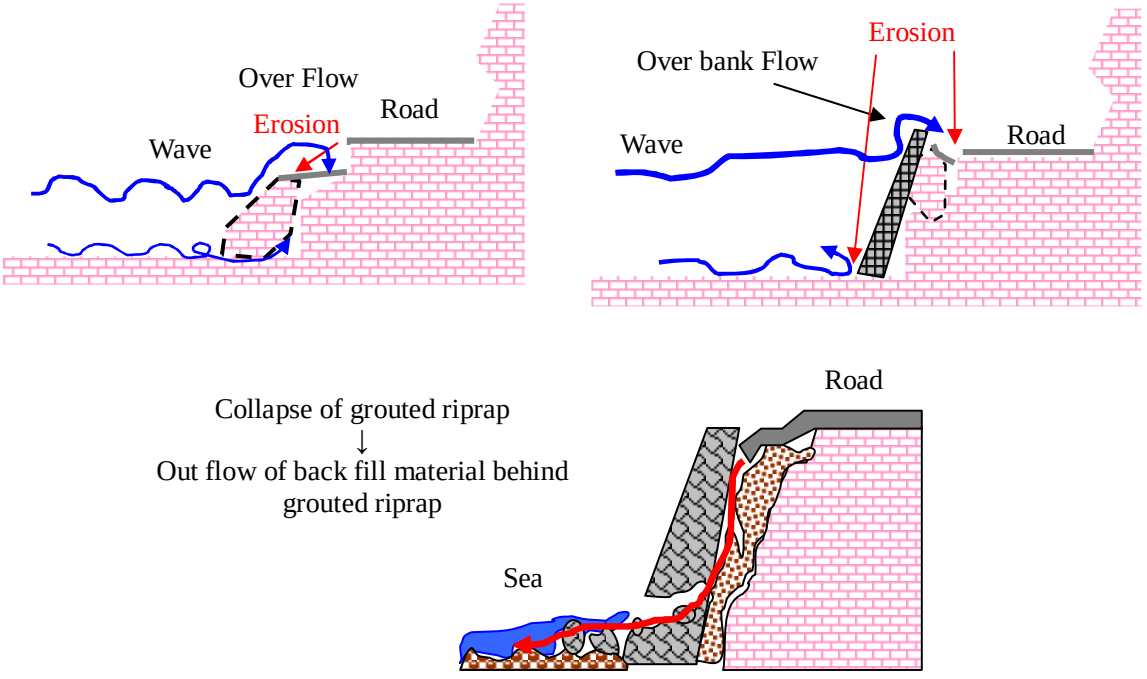
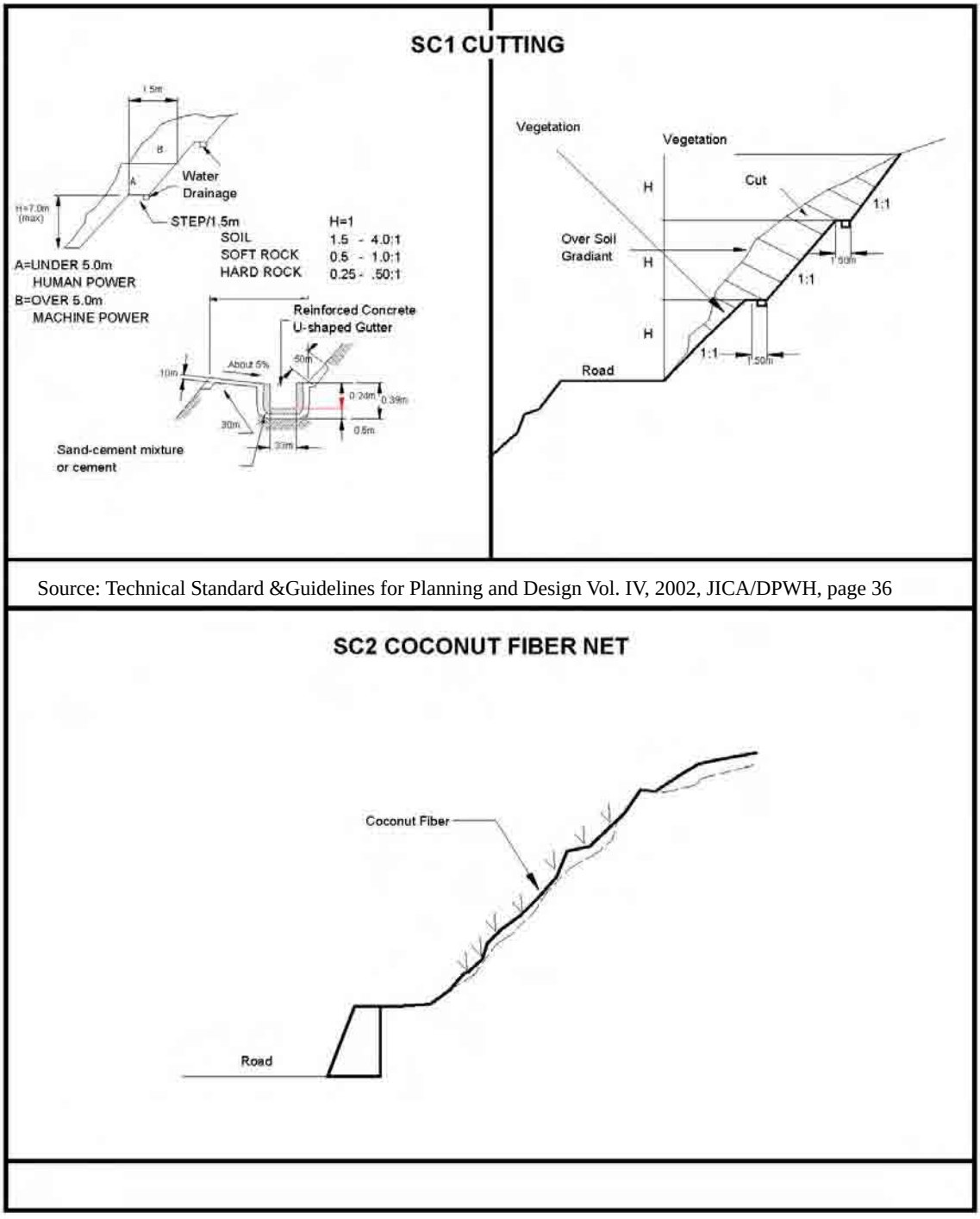


Figure A2.25 Schematic Illustration of Coastal Erosion

Appendix-3

Countermeasure Options for Each Disaster Type



Source: Technical Standard &Guidelines for Planning and Design Vol. IV, 2002, JICA/DPWH, page 36

Figure A3.1 Standard Countermeasure Options for Soil Slope Collapse (1)

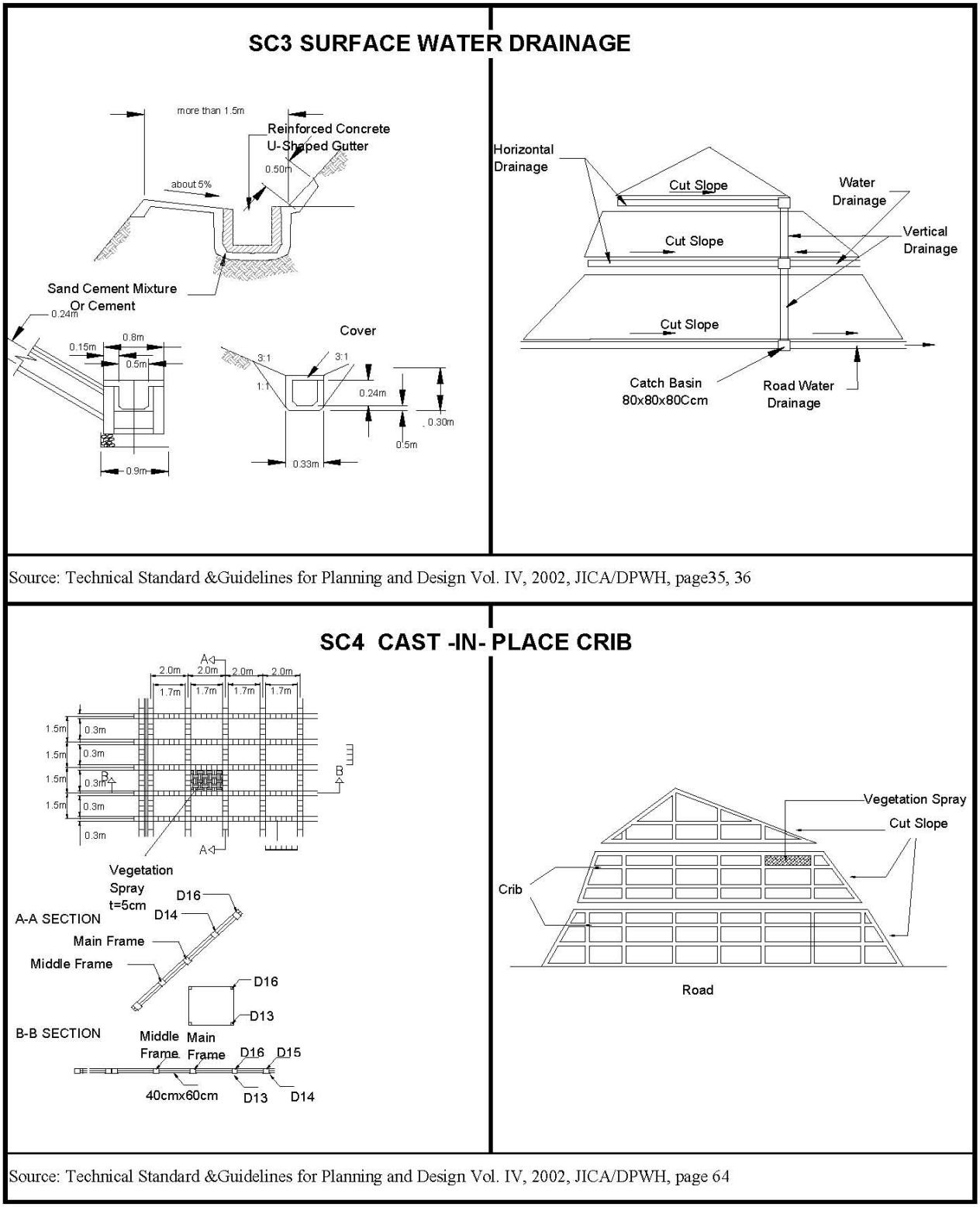
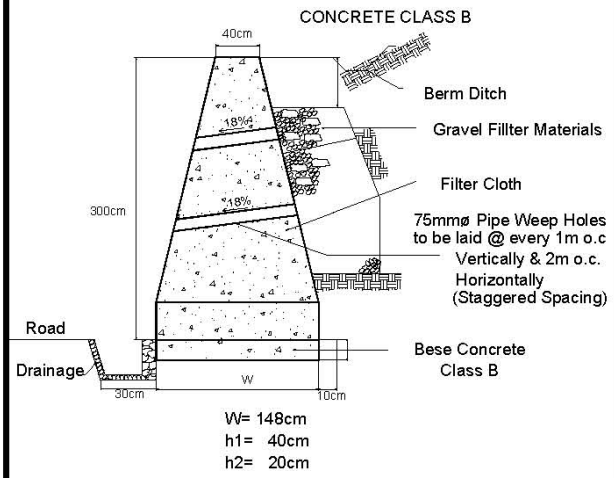
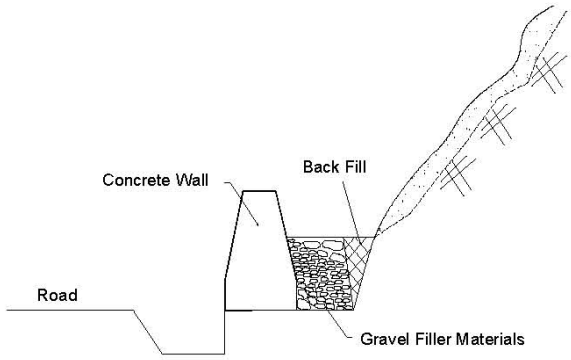


Figure A3.2 Standard Countermeasure Options for Soil Slope Collapse (2)

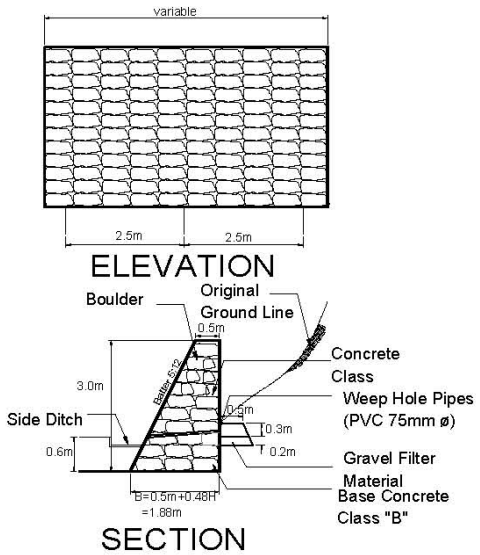
SC5 CONCRETE RETAINING WALL

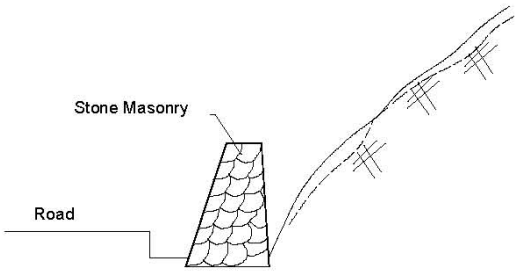




Source: Technical Standard &Guidelines for Planning and Design Vol. IV, 2002, JICA/DPWH, page 57

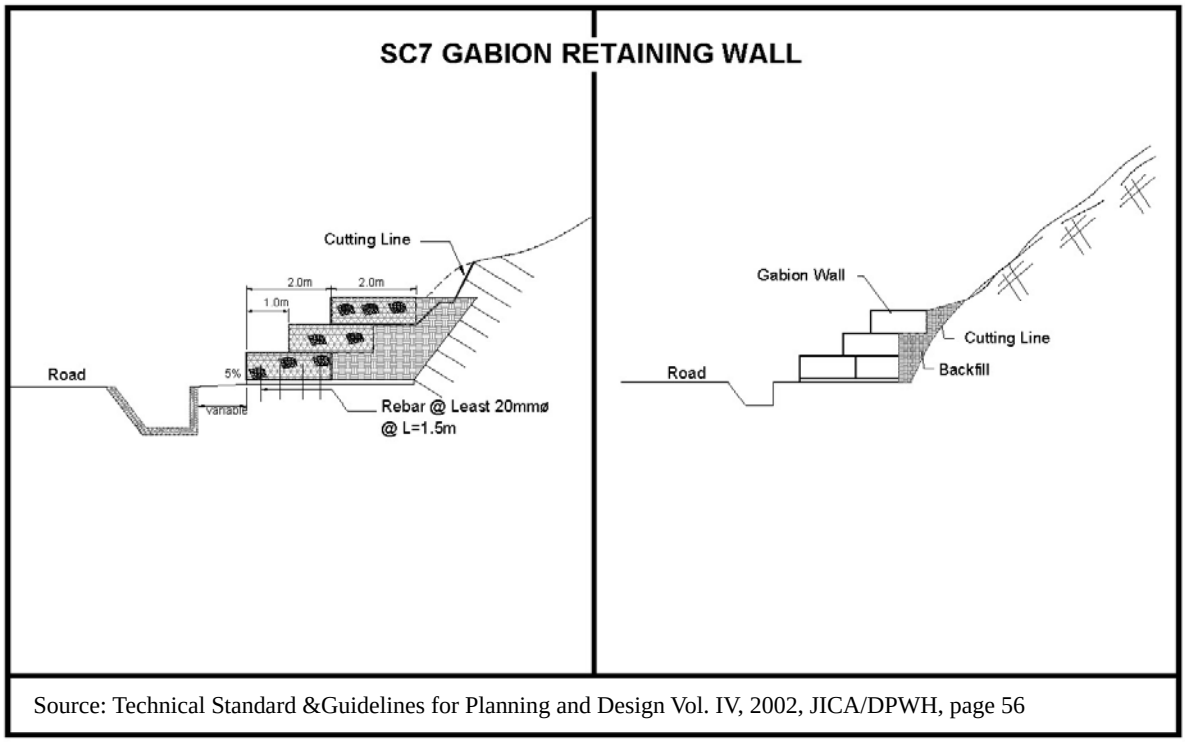
SC6 STONE MASONRY RETAINING WALL





Source: Technical Standard &Guidelines for Planning and Design Vol. IV, 2002, JICA/DPWH, page 59

Figure A3.3 Standard Countermeasure Options for Soil Slope Collapse (3)



Source: Technical Standard &Guidelines for Planning and Design Vol. IV, 2002, JICA/DPWH, page 56

Figure A3.4 Standard Countermeasure Options for Soil Slope Collapse (4)

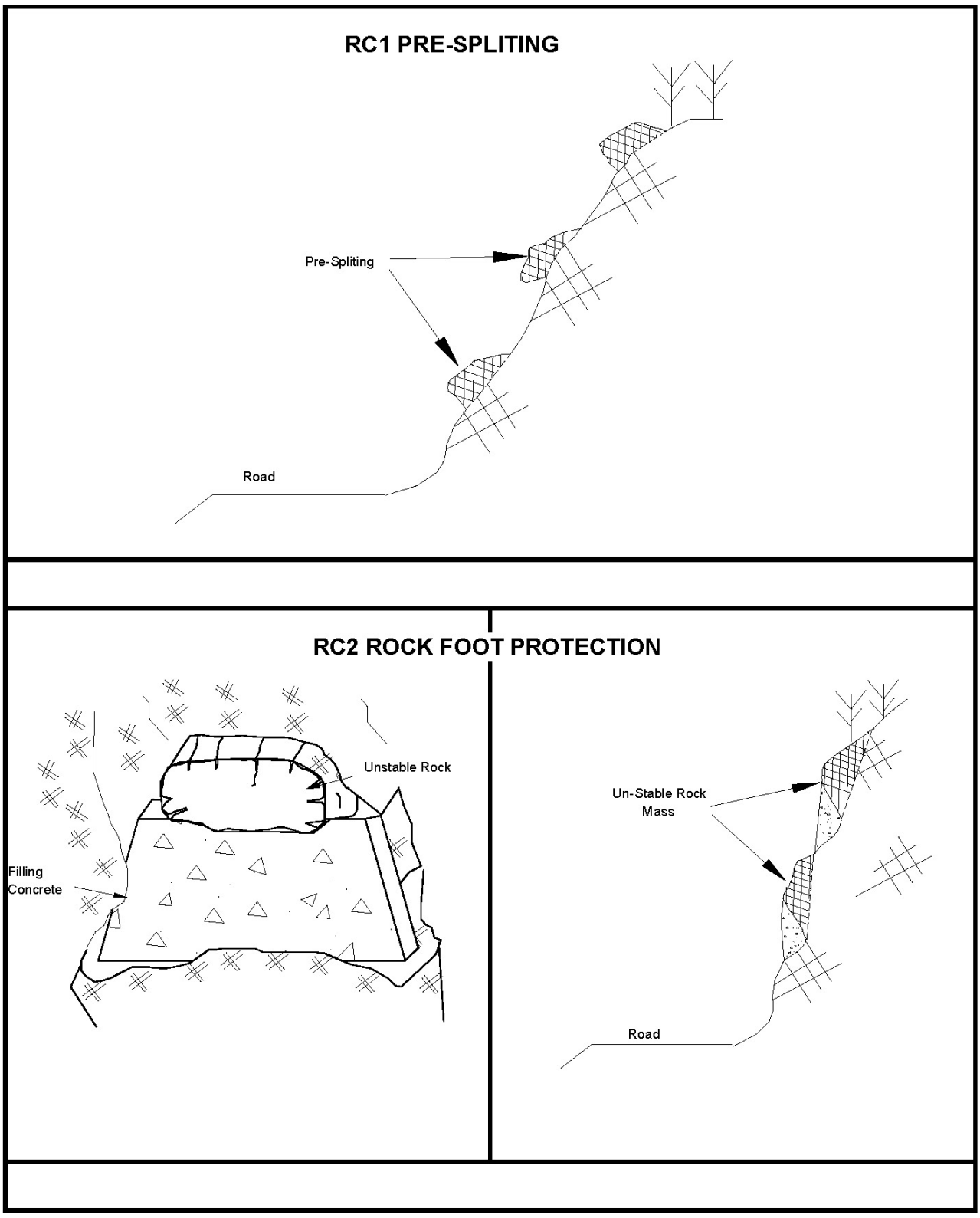


Figure A3.5 Standard Countermeasure Options for Rock Slope Collapse (1)

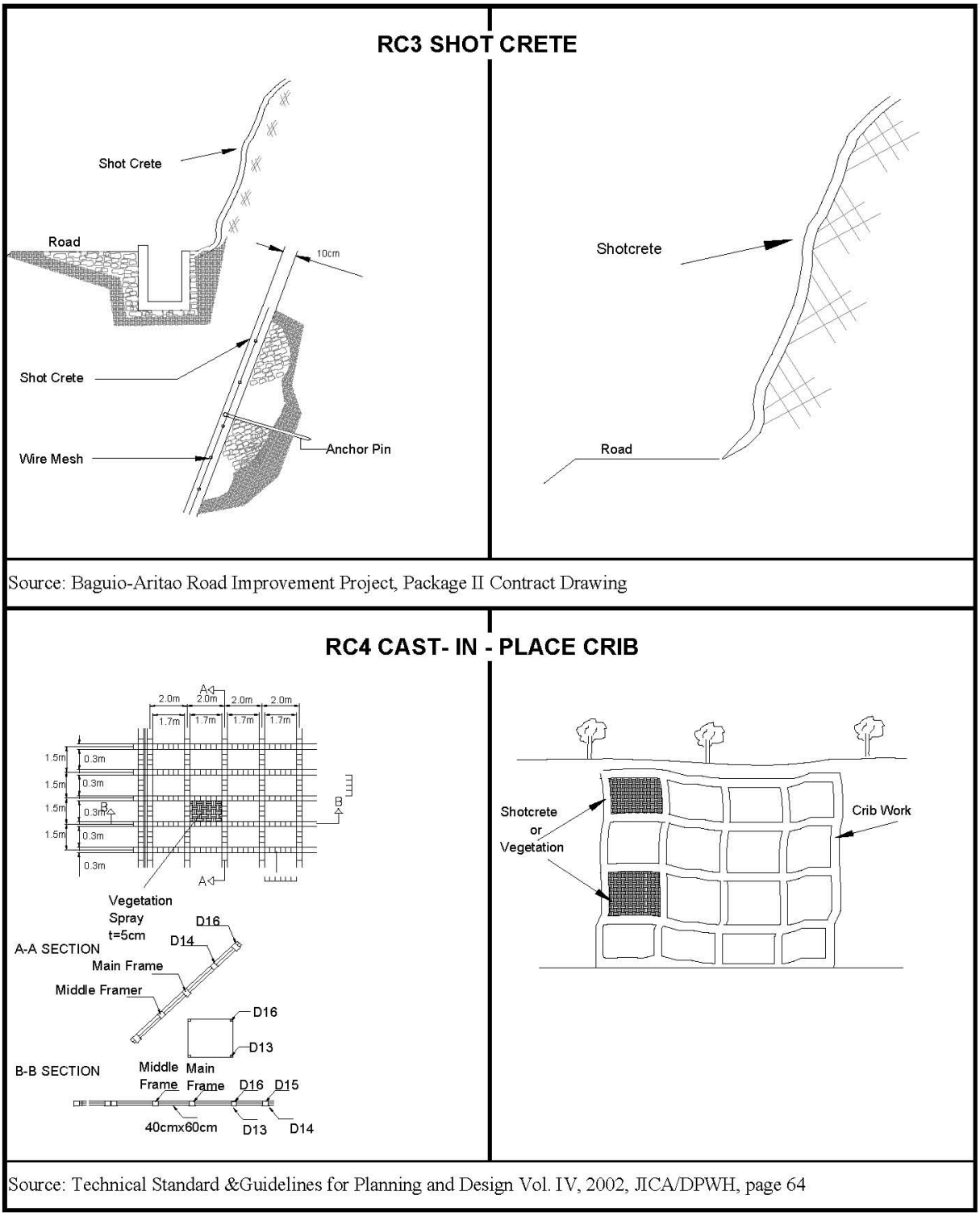
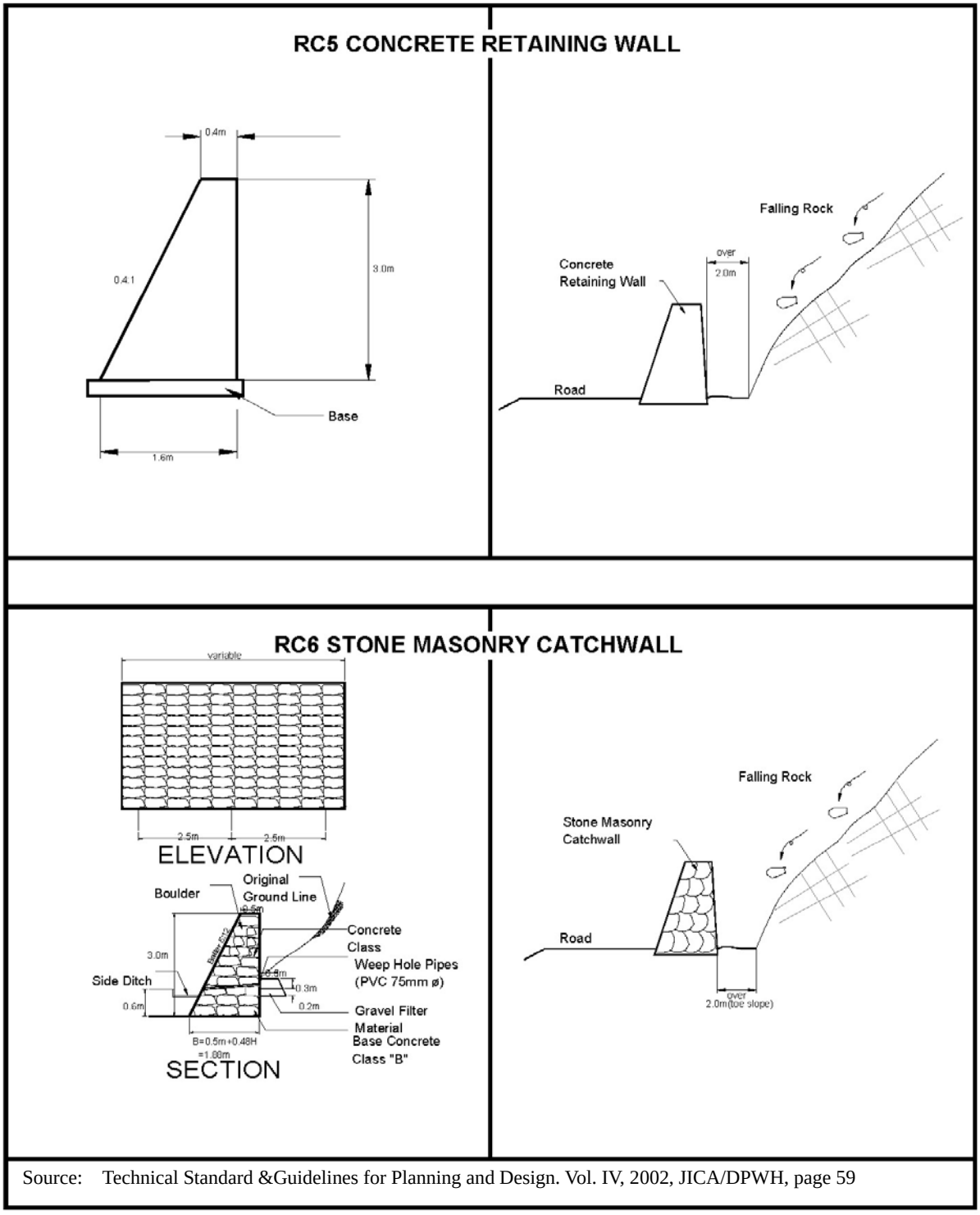
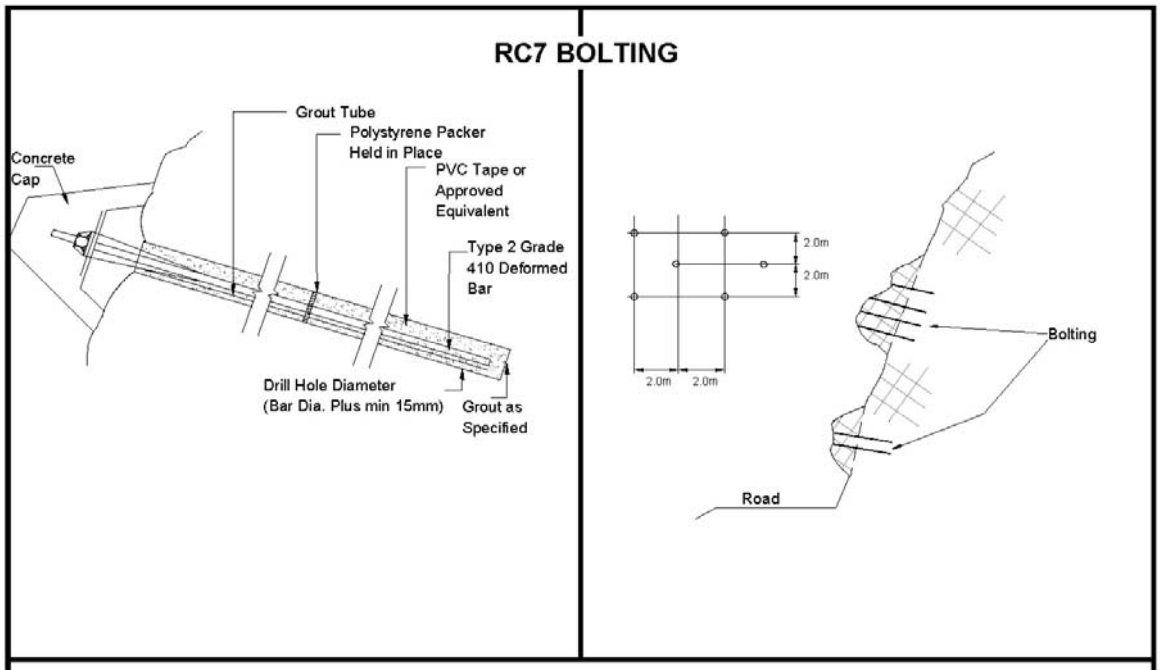


Figure A3.6 Standard Countermeasure Options for Rock Slope Collapse (2)

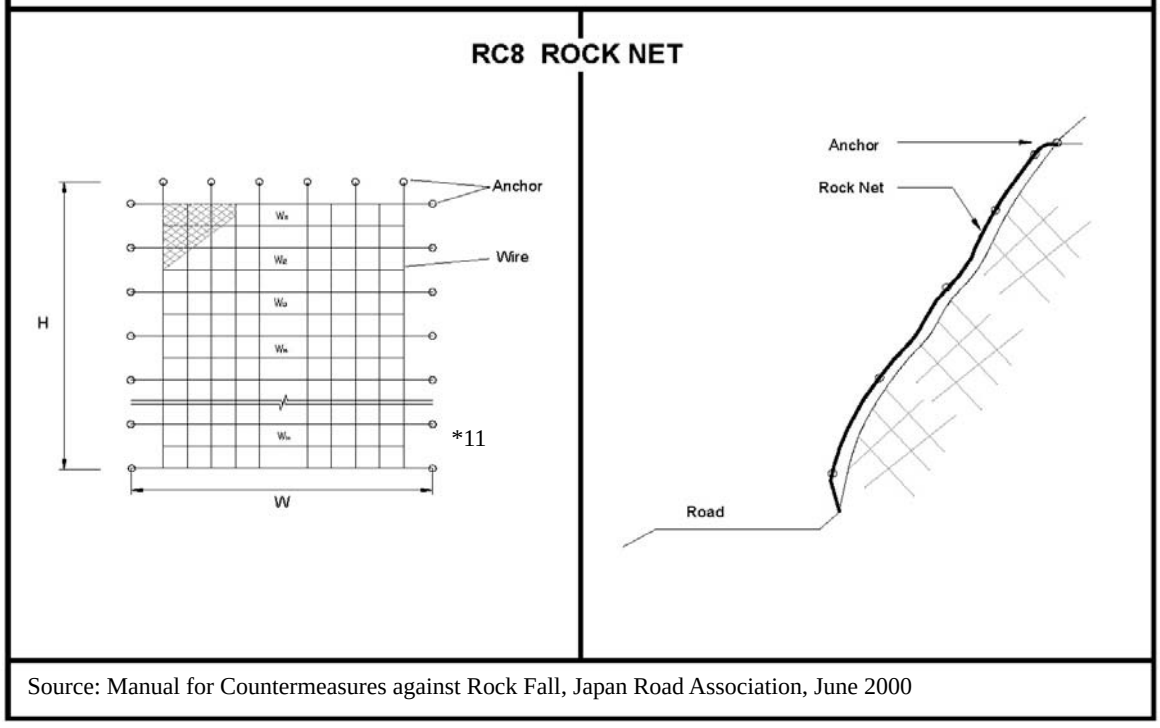


Source: Technical Standard &Guidelines for Planning and Design. Vol. IV, 2002, JICA/DPWH, page 59

Figure A3.7 Standard Countermeasure Options for Rock Slope Collapse (3)



Source: Baguio- Bontoc- Banaue Road Tender/Contract Drawings



Source: Manual for Countermeasures against Rock Fall, Japan Road Association, June 2000

Figure A3.8 Standard Countermeasure Options for Rock Slope Collapse (4)

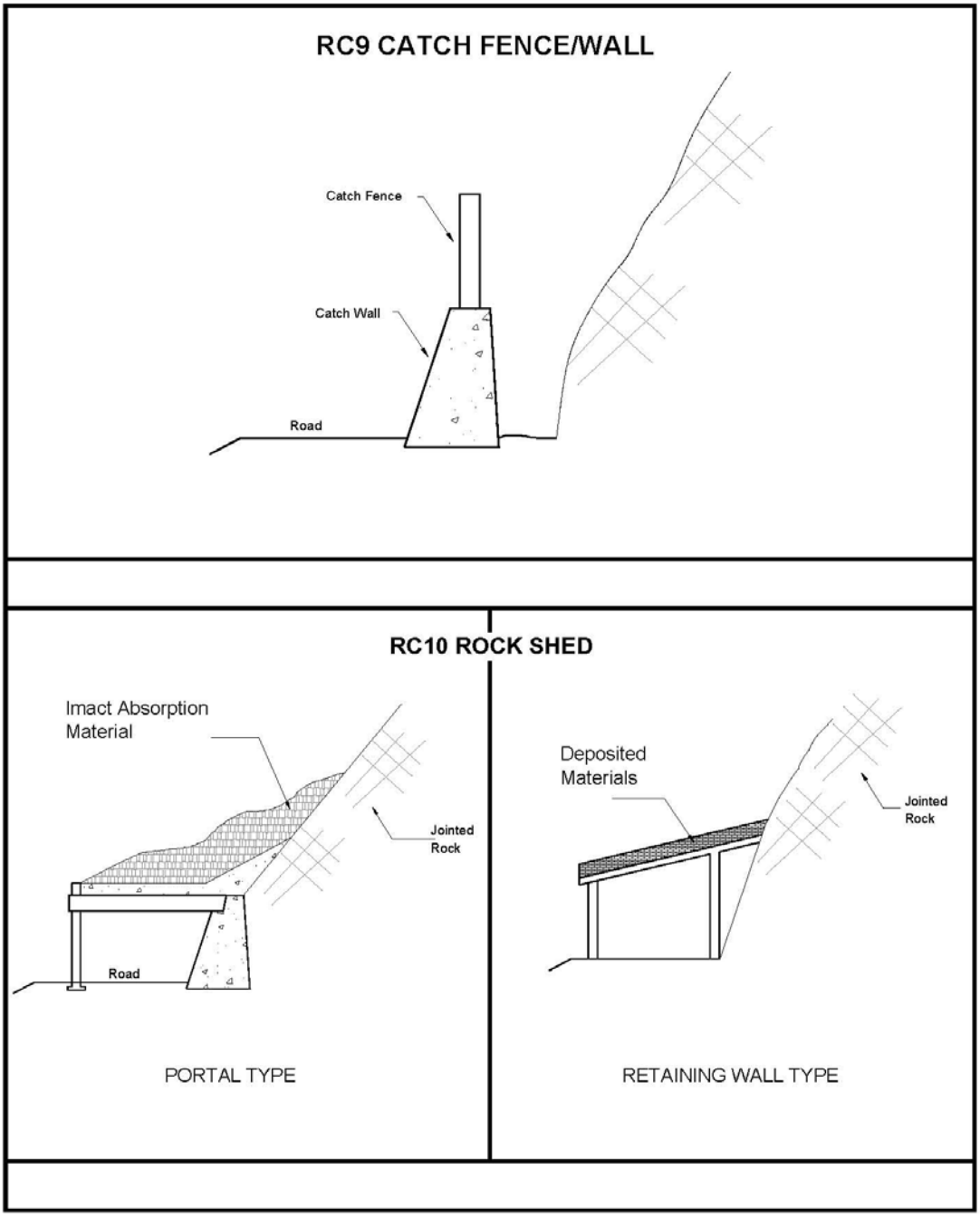


Figure A3.9 Standard Countermeasure Options for Rock Slope Collapse (5)

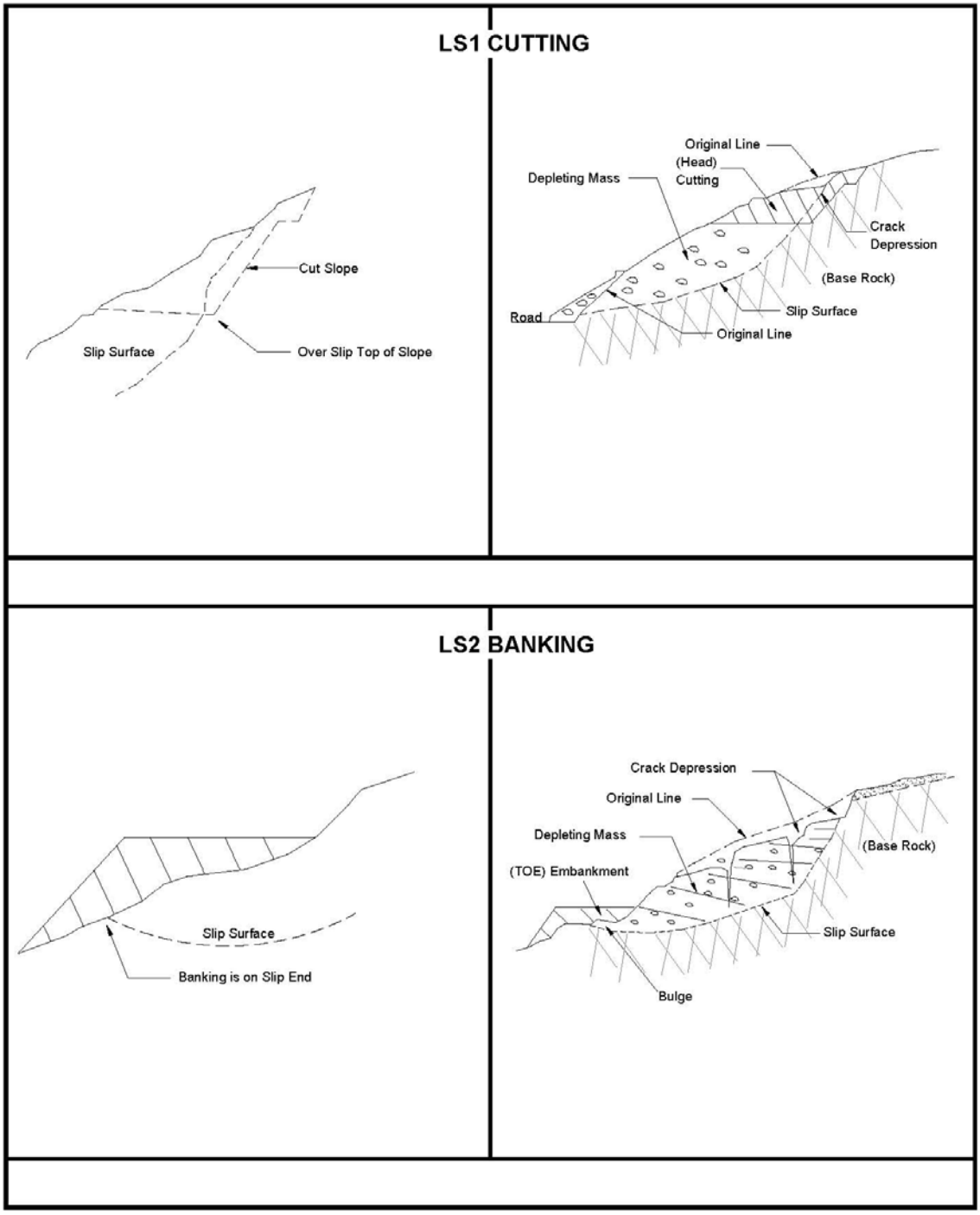


Figure A3.10 Standard Countermeasure Options for Landslide (1)

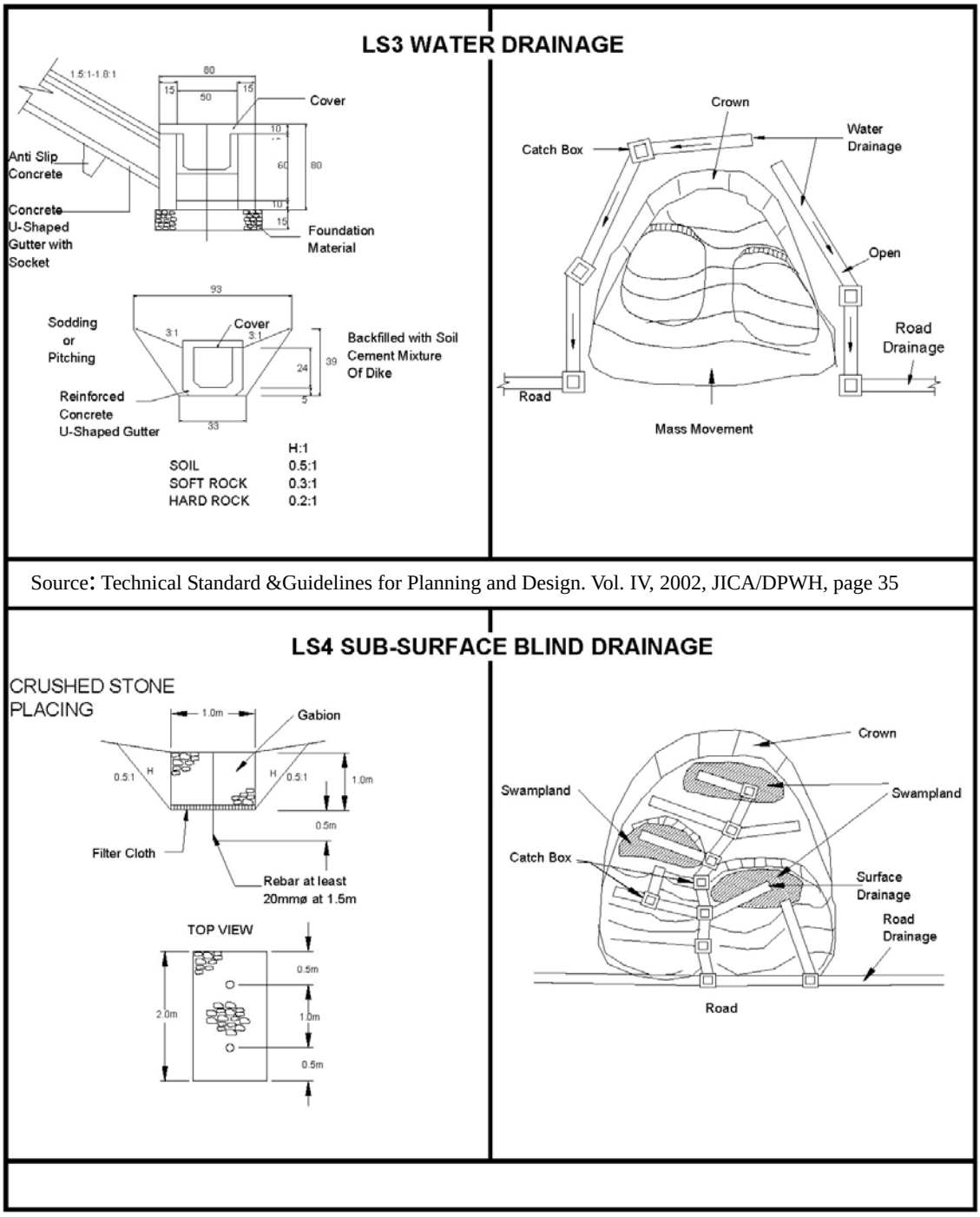


Figure A3.11 Standard Countermeasure Options for Landslide (2)

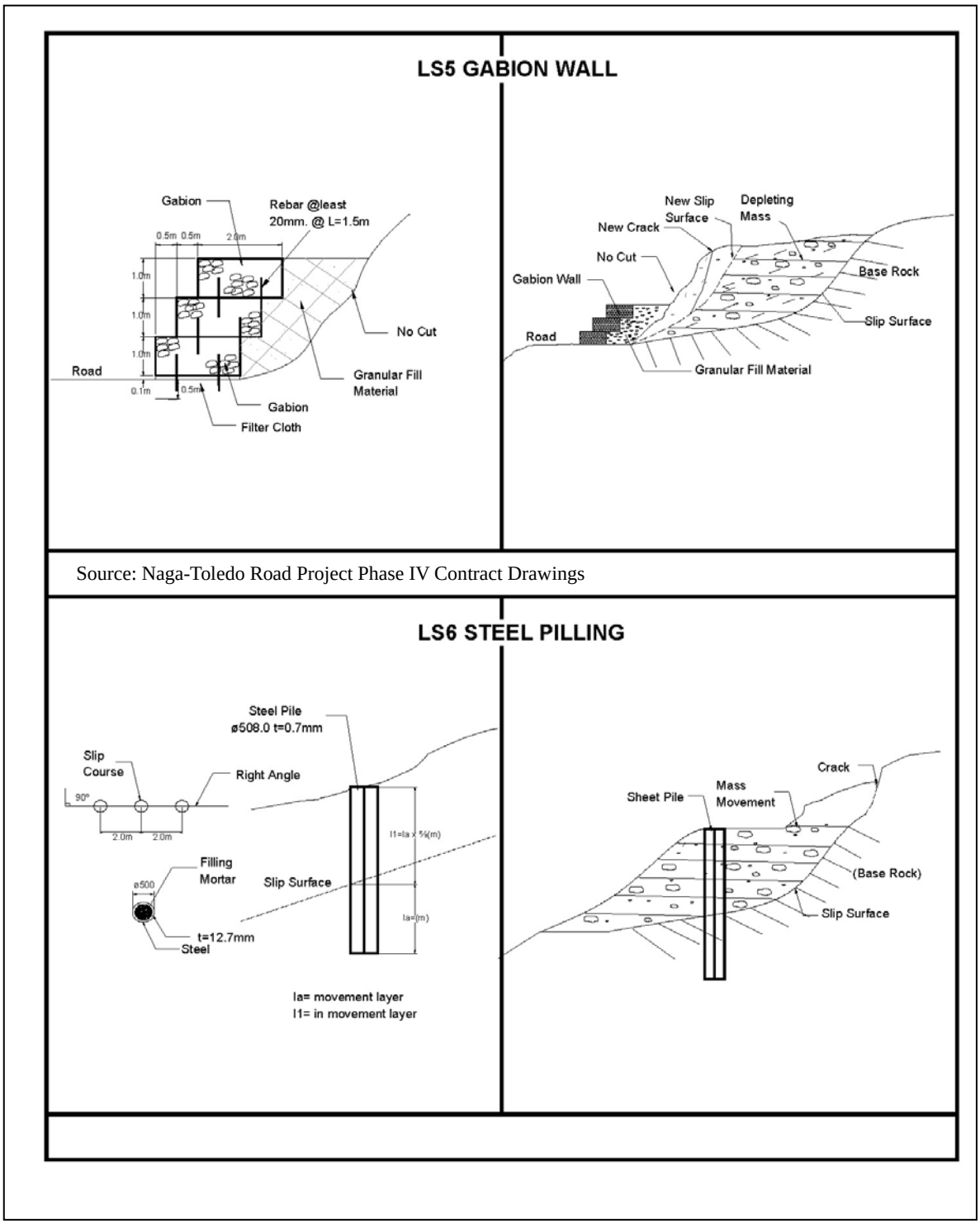


Figure A3.12 Standard Countermeasure Options for Landslide (3)

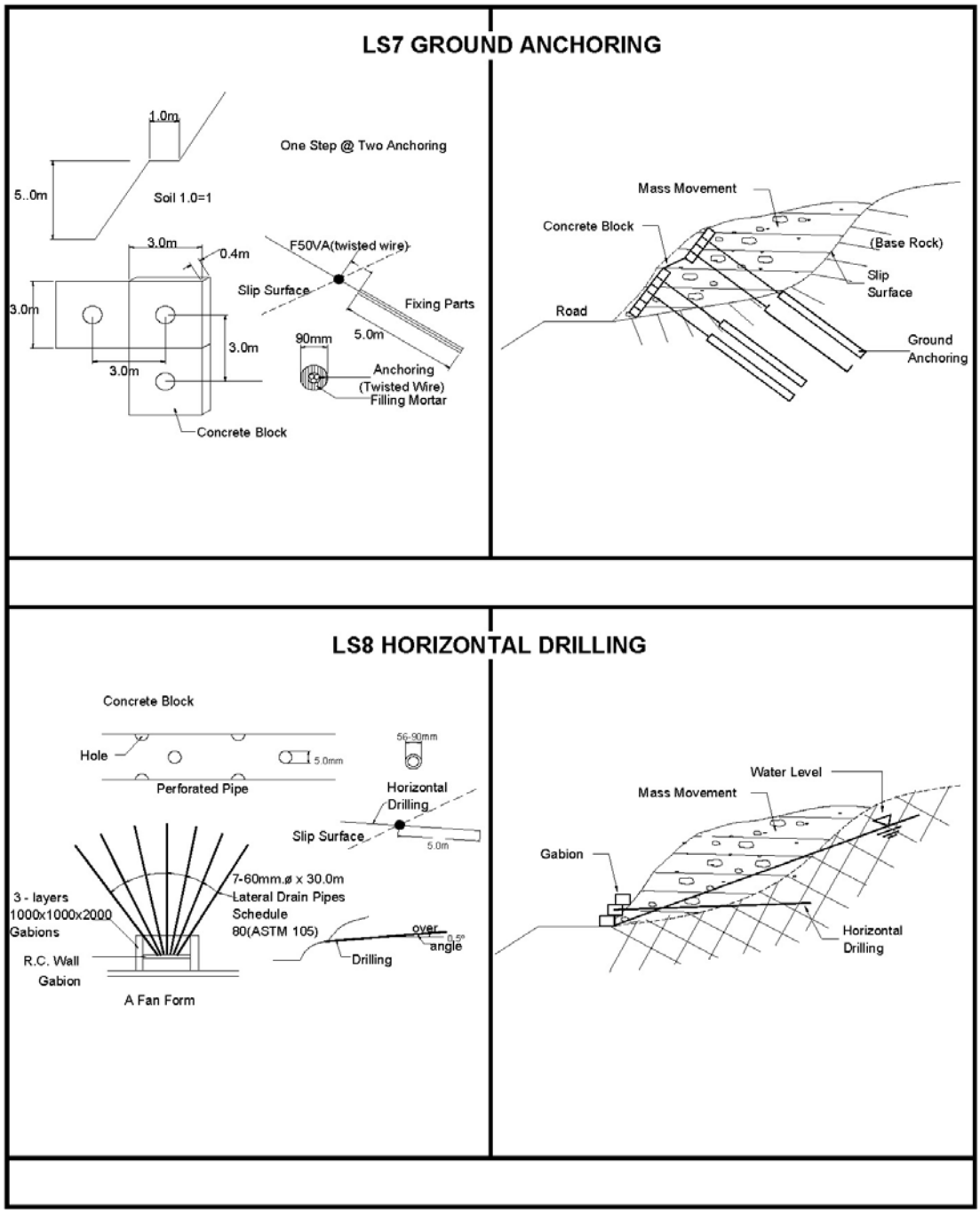
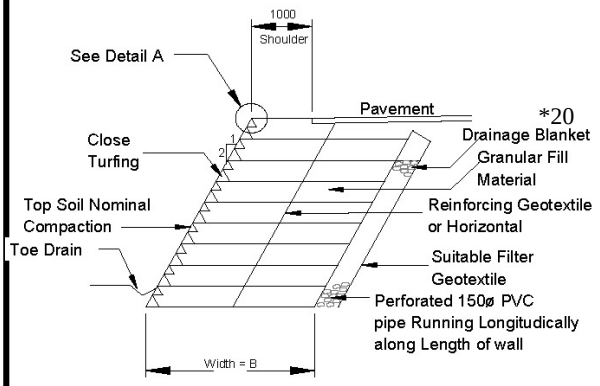
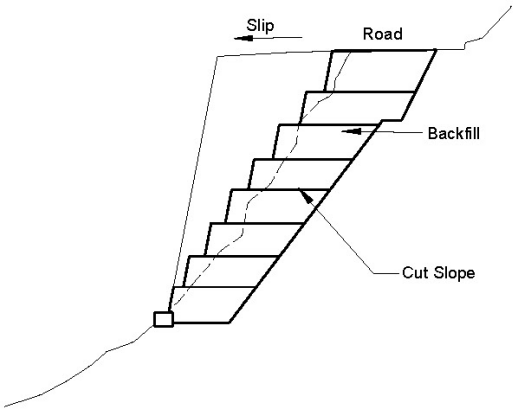


Figure A3.13 Standard Countermeasure Options for Landslide (4)

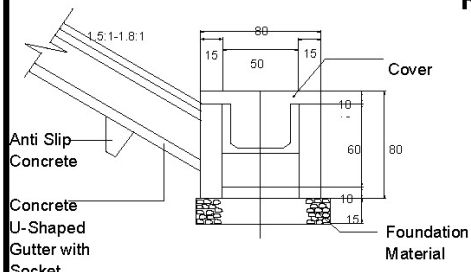
RS3 REINFORCED EMBANKMENT

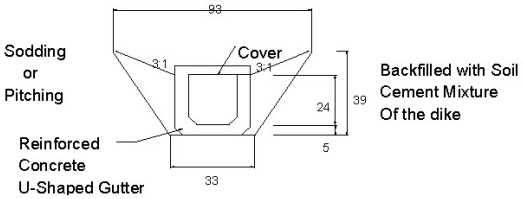




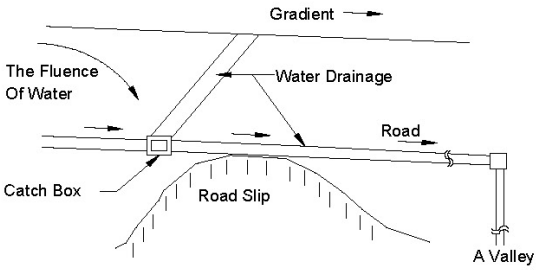
Source: Baguio-Bontoc- Banaue Road Tender/Contract Drawings

RS4 WATER DRAINAGE





	H:1
SOIL	0.5:1
SOFT ROCK	0.3:1
HARD ROCK	0.2:1



Source: Technical Standard &Guidelines for Planning and Design. Vol. IV, 2002, JICA/DPWH, page 35

Figure A3.15 Standard Countermeasure Options for Road Slip (2)

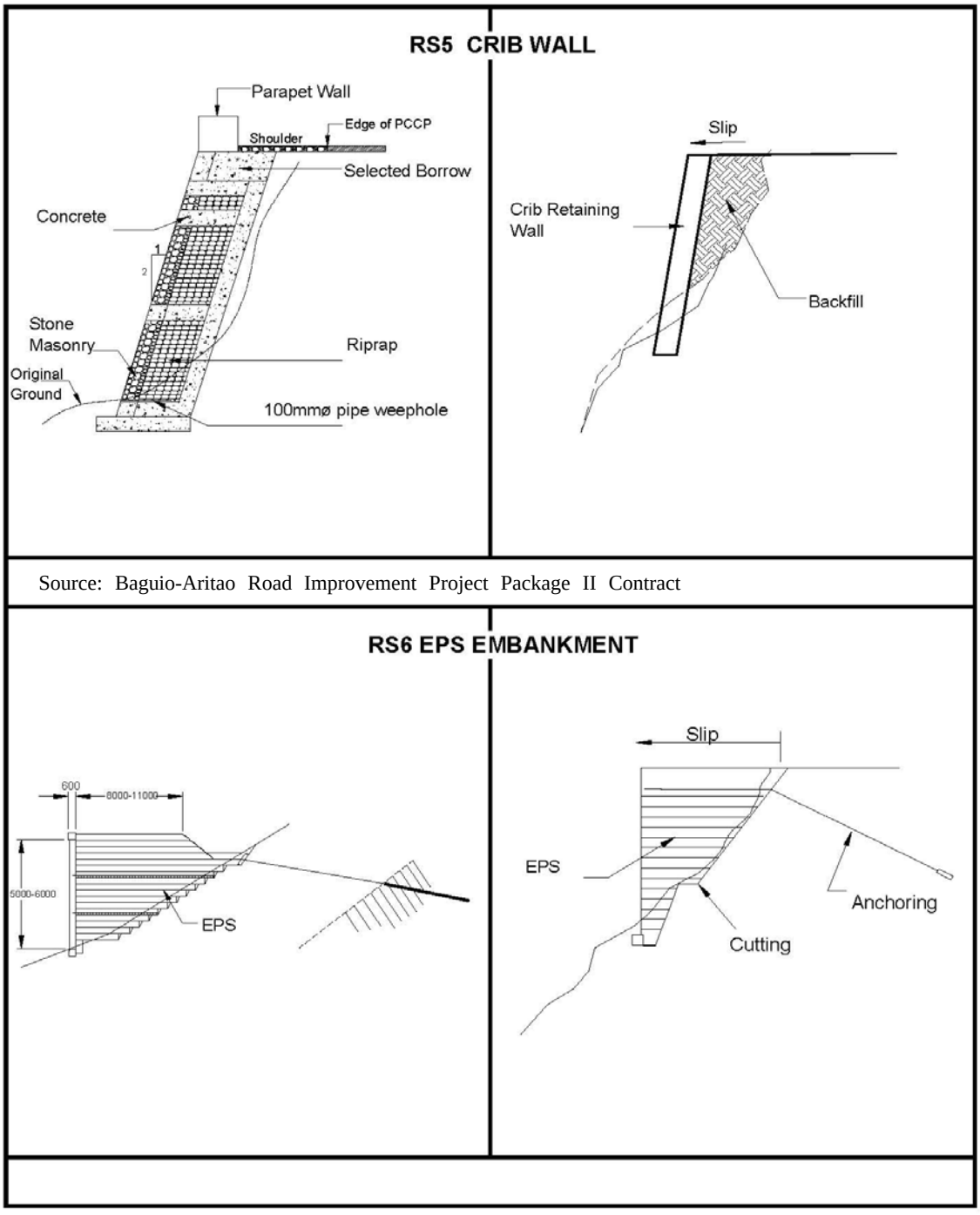


Figure A3.16 Standard Countermeasure Options for Road Slip (3)

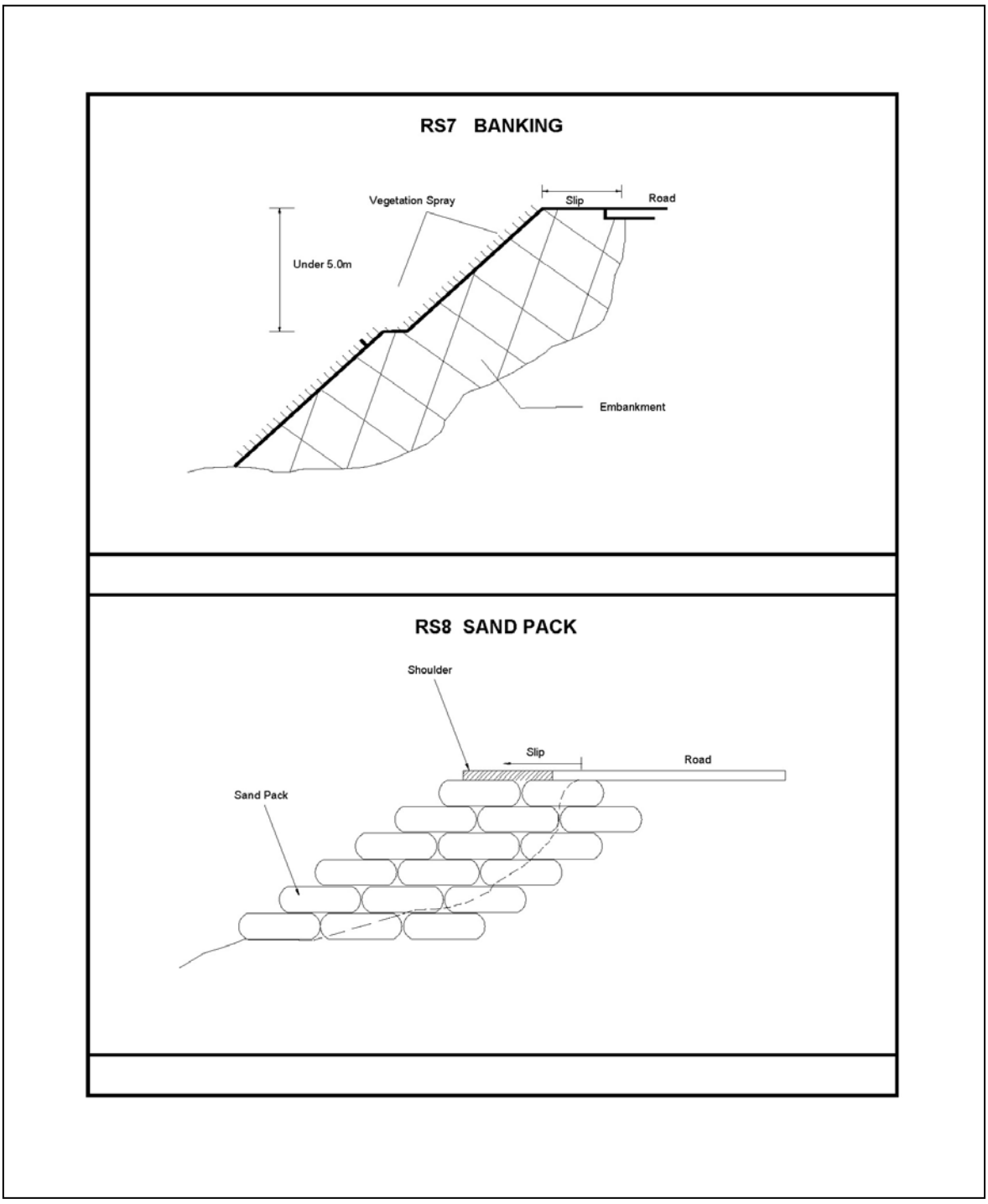


Figure A3.17 Standard Countermeasure Options for Road Slip (4)

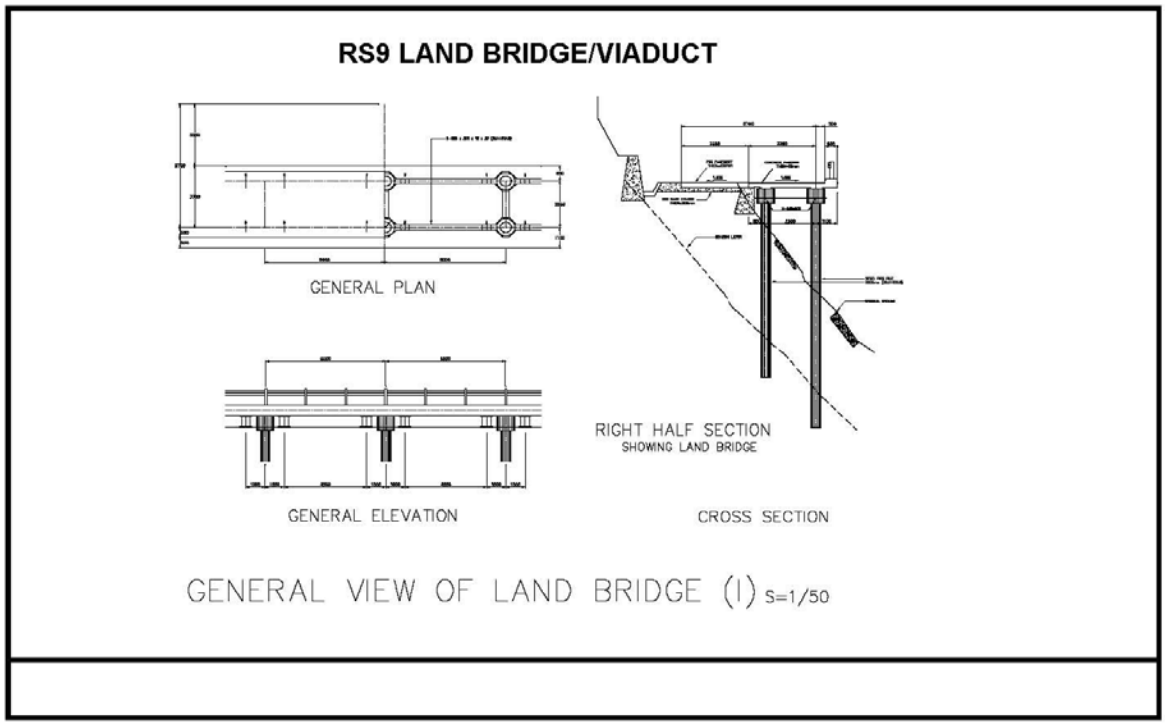


Figure A3.18 Standard Countermeasure Options for Road Slip (5)

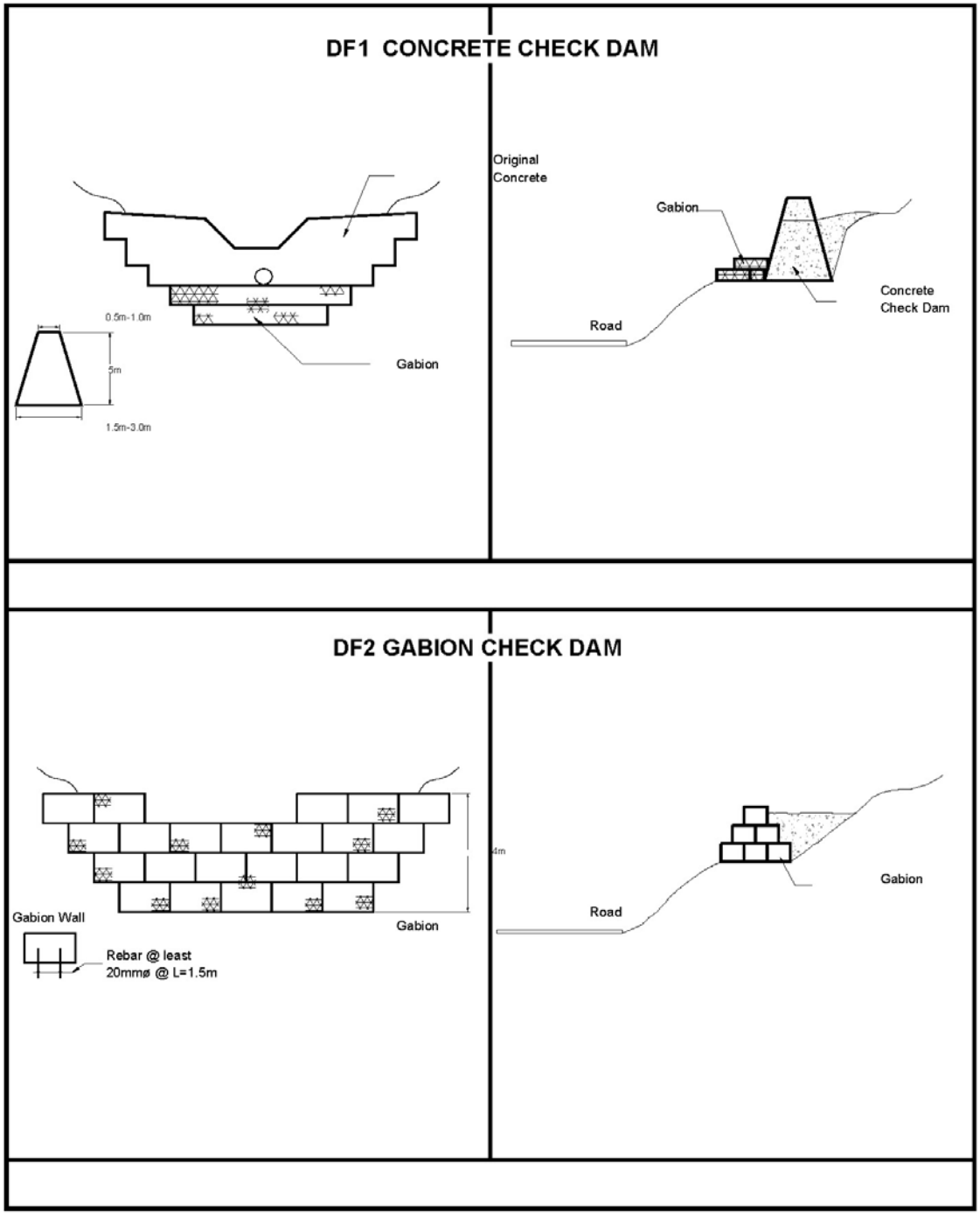


Figure A3.19 Standard Countermeasure Options for Debris Flow (1)

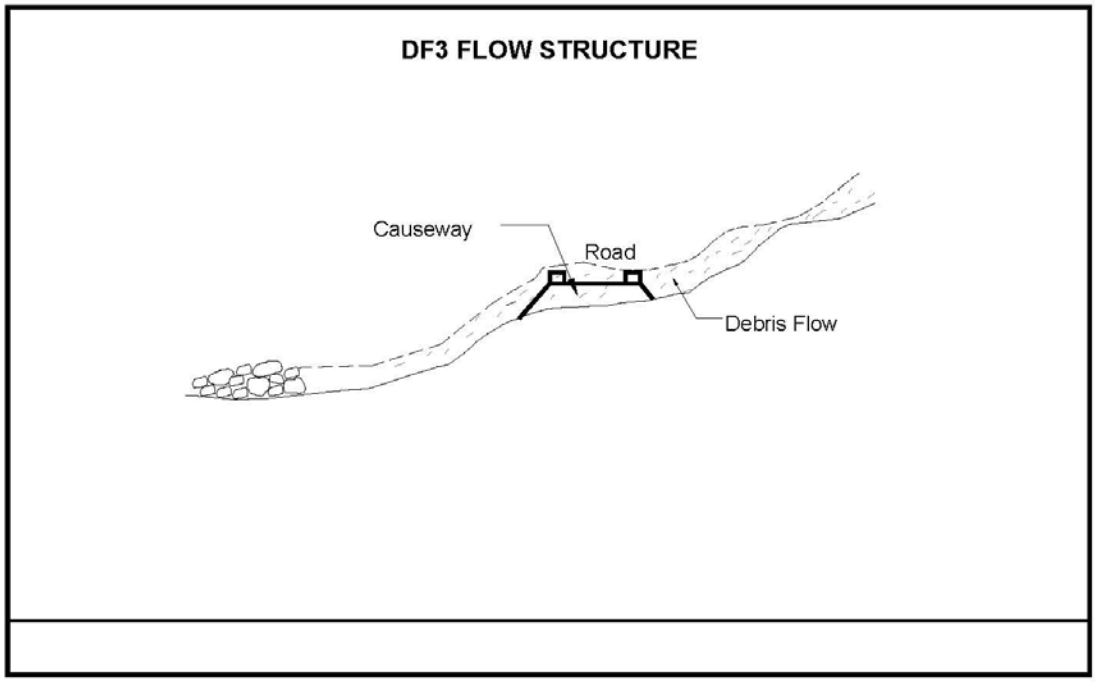
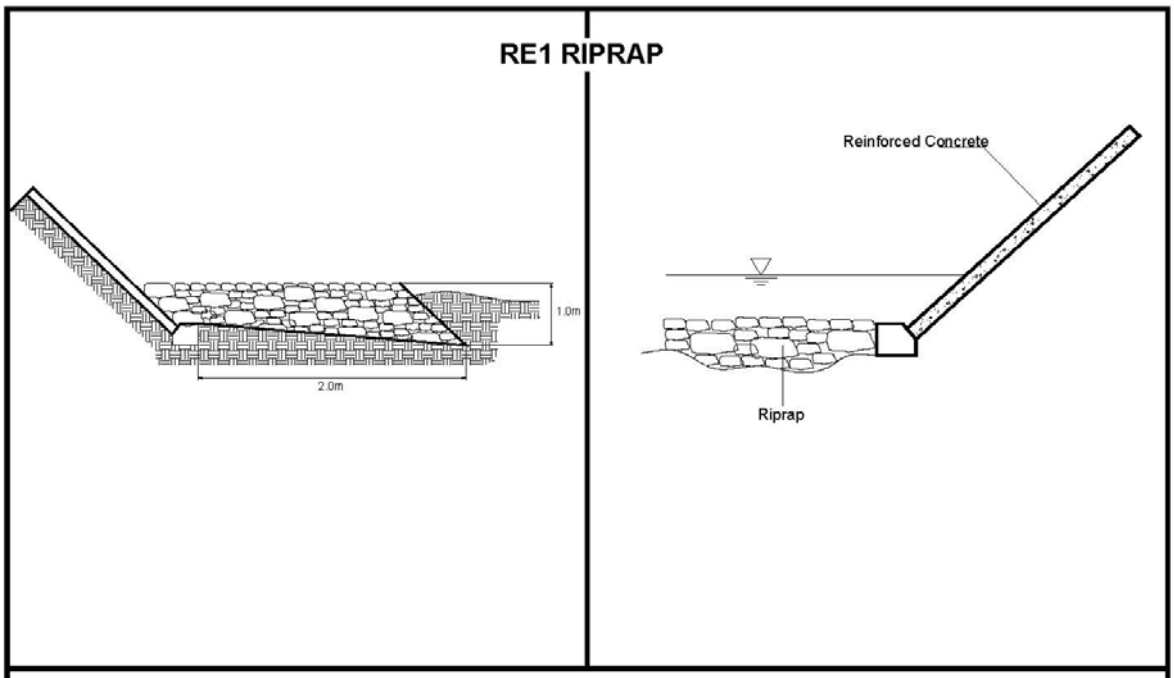
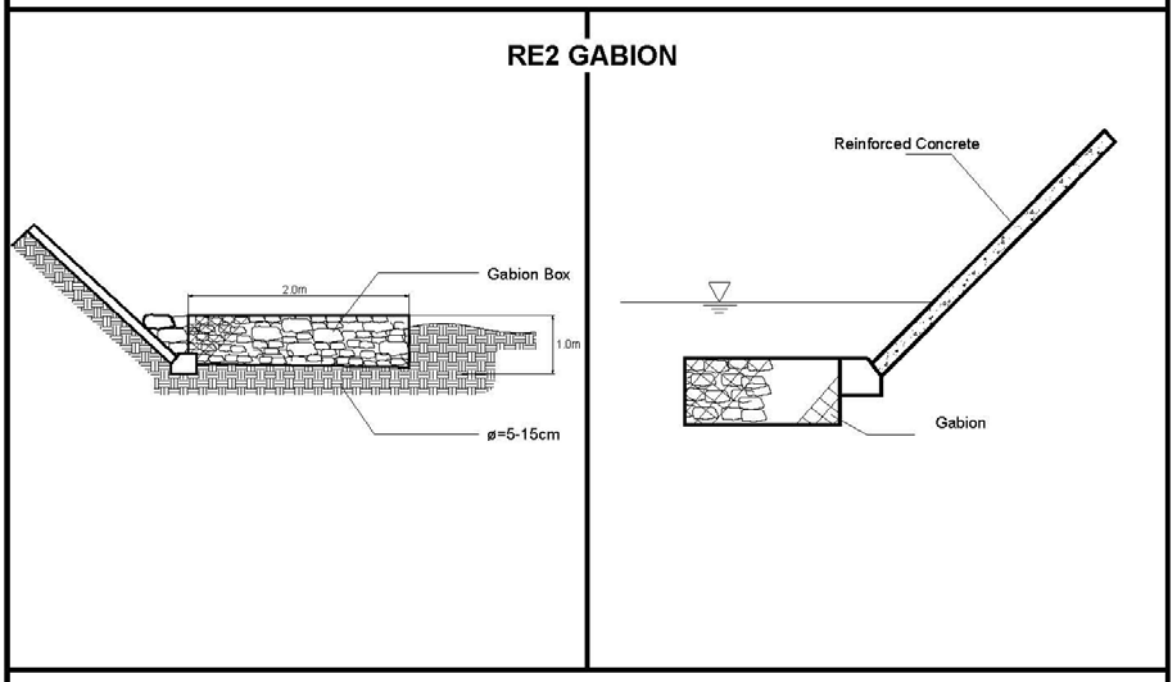


Figure A3.20 Standard Countermeasure Options for Debris Flow (2)

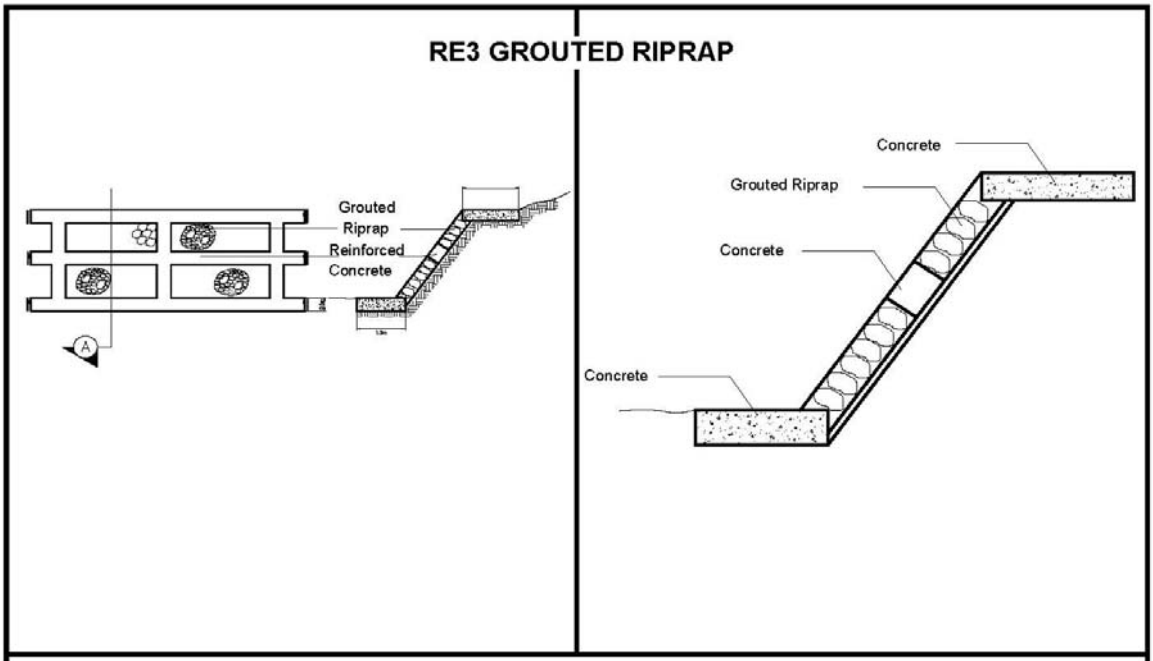


Source: Technical Standard &Guidelines for Planning and Design. Vol. IV, 2002, JICA/DPWH, page 98-101

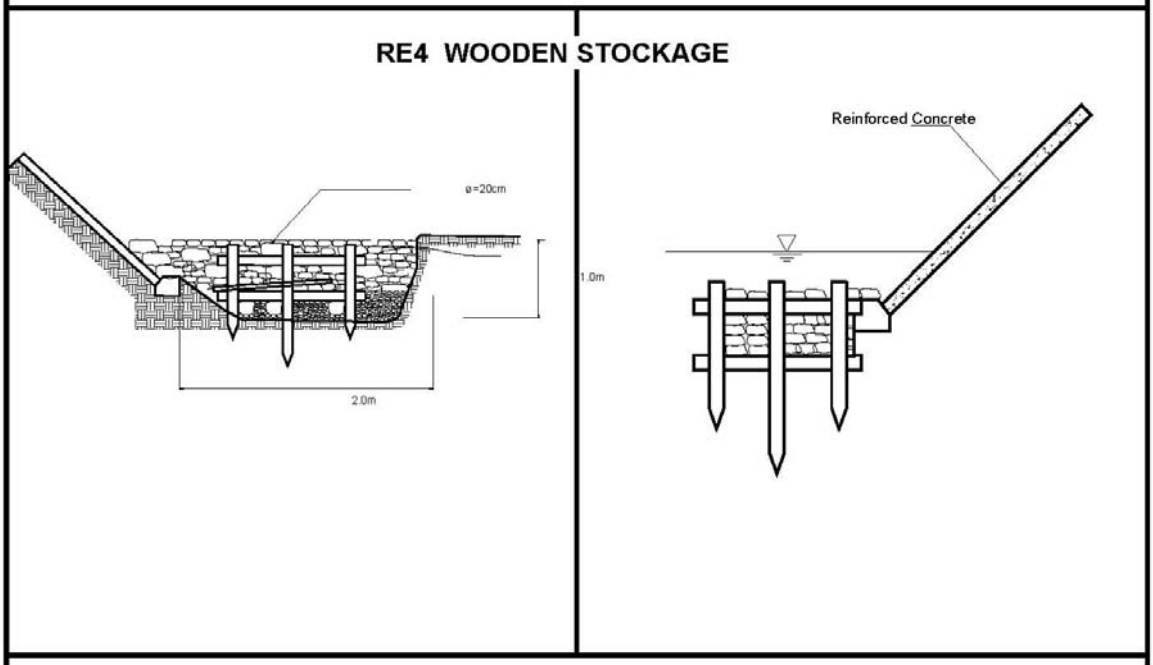


Source: Technical Standard &Guidelines for Planning and Design. Vol. IV, 2002, JICA/DPWH, page 98-101

Figure A3.21 Standard Countermeasure Options for River Erosion (1)



Source: Technical Standard &Guidelines for Planning and Design. Vol. IV, 2002, JICA/DPWH, page 98-101



Source: Technical Standard &Guidelines for Planning and Design. Vol. IV, 2002, JICA/DPWH, page 98-101

Figure A3.22 Standard Countermeasure Options for River Erosion (2)

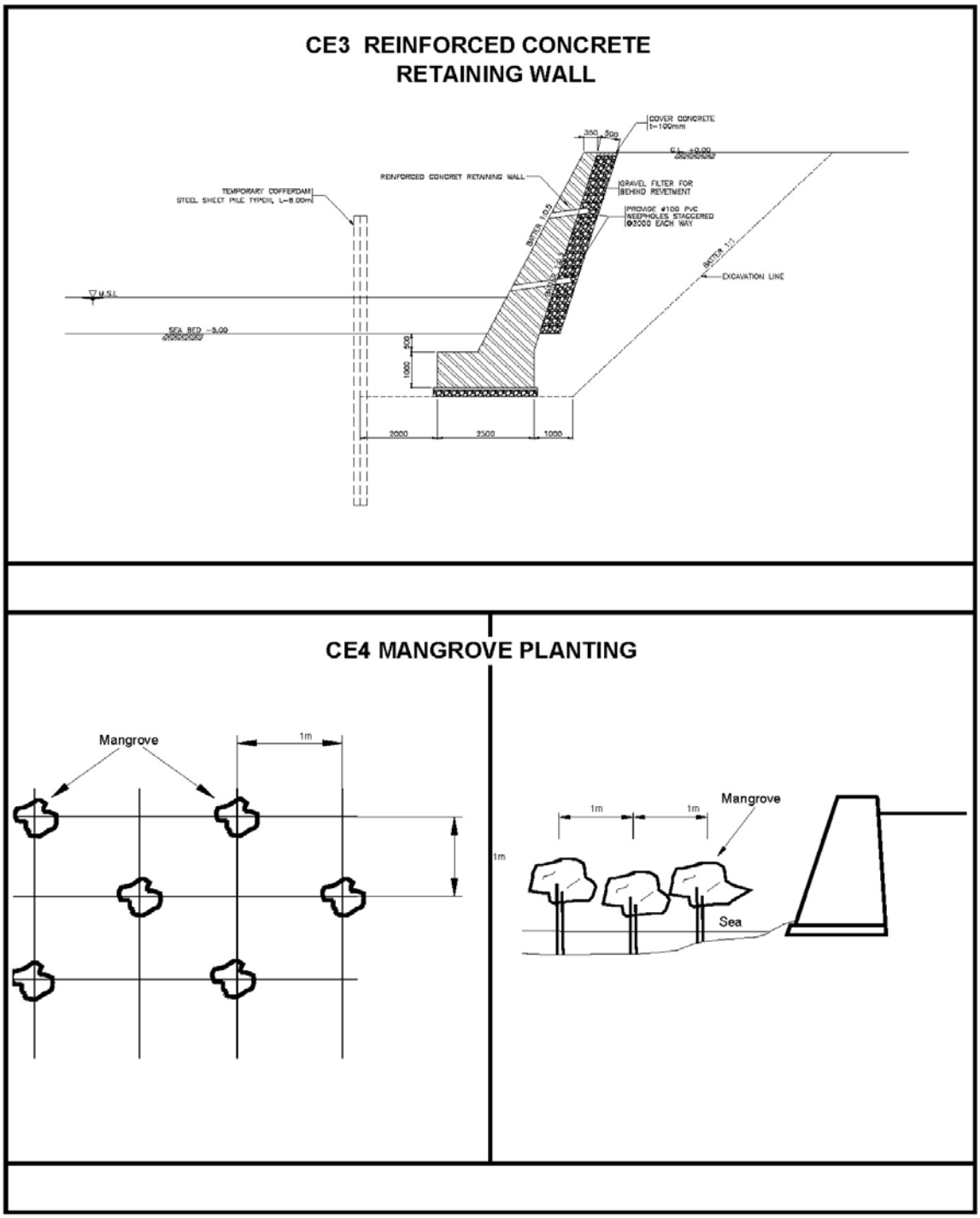


Figure A3.23 Standard Countermeasure Options for Costal Erosion