Geomembrane
General Technical Guide for Water Reservoirs

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**Introduction**

This manual contains information on lining systems using **Firestone EPDM Geomembranes**. Apart from general recommendations on the use of the EPDM geomembrane, it also provides information on site preparation and excavation works.

Generally, for simple projects, the design may be carried out by the owner or the contractor. However, in the case of larger ponds the project is often considerably more complex and the contractor should request the advice of a specialist in hydraulic structures. The specialist should be able to answer specific questions on excavation, drainage, protection of the liner, etc.

Before initiating any project, a survey of the site should be carried out for the purpose of obtaining correct information regarding:

- Nature of the soil
- Presence of cavities (chalk rocks, chalky soil, etc.)
- Depth and variation of the groundwater level
- Presence of gases in the soil (peat, organic matter, etc.)
- Risk of differential settling (poorly consolidated soil, recent backfill, etc.)
- Risk of internal erosion (karst soil, sand, etc.)

In any case, the rules of soil mechanics must be complied with in order to ensure the stability of the support and consequently, a durable lining system. All these subject areas are covered in the first part of this manual.

The second part of this manual deals with the installation of the Firestone Geomembrane System. This section covers site preparation, compaction of the soil, installation of drainage, installation of the geomembrane, splicing and execution of details.

Finally, the manual is supplemented with 3 appendices dealing respectively with:

- Appendix 1: Technical data sheets
- Appendix 2: Installation tools
- Appendix 3: Chemical resistance chart

The Firestone EPDM Geomembrane must be installed by an authorized Firestone contractor in accordance with Firestone's specifications. It is also essential that all local regulations and codes are complied with.
1. Firestone EPDM Geomembrane

1.1. Why geomembrane, Why EPDM, Why Firestone

Firestone has been a world-recognized leader in rubber polymer technology for over 100 years. Building on this broad legacy, Firestone Building Products has become a global leading manufacturer of rubber roofing and waterproofing systems. Firestone Building Products is part of the Bridgestone Corporation, the world’s largest tire and rubber company.

The first use of Firestone rubber membranes in irrigation reservoirs located in the south of Spain dates from 40 years ago. Today, even after many years of exposition to UV and ozone, the rubber liner continues to provide a dependable waterproof solution. Today, Firestone has thousands of references worldwide which are the living proof of the exceptional performance of Firestone EPDM Geomembrane.

Firestone EPDM Geomembrane is a rubber liner offering unique features and benefits for a wide variety of agricultural, industrial and commercial applications:

- Long term durability (UV and ozone)
- High elasticity (> 300% of elongation)
- High flexibility even at low temperature (down to -45°C)
- Excellent puncture resistance
- High friction angle (27°)
- Chemically inert
- Environmentally friendly
- …

Firestone offers contractors educational programs covering all aspects of an EPDM Geomembrane system installation. The company’s installation support extends on the job site where field technicians offer training, professional assistance and quality inspection of finished installations.

The company’s state-of-the-art EPDM manufacturing facilities follow stringent quality control guidelines from raw material selection to finished product testing. Our operations have been certified according to ISO 9001 and ISO 14001. Firestone EPDM Geomembrane has obtained the CE-marking and has been tested and certified to various international and national standards, including the French ASQUAL certification.
1.2. Composition

EPDM is a synthetic elastomer produced as a copolymer of ethylene and propylene, with small amounts of a pendant diene (double bonds) in order to cross link the material during the vulcanization (curing) process. The terpolymers are referred to as EPDM: ethylene-propylene-diene with “M” referring to the saturated backbone structure. The backbone carbon chain structure is made synthetically by combining ethylene and propylene. The ethylene and propylene monomers combined form a chemically saturated (no double bonds), stable polymer backbone providing excellent heat, oxidation, ozone and weather aging.

These copolymer chains can move independently relative to each other, which enables the material to change shape. Crosslinking has to be introduced in order to prevent polymer chains from moving independently. As a result, when stress is applied the crosslinked polymer will deform, but upon release of the stress, the article will revert to its original shape.

Controlled amounts of diene are added during polymerization in a manner to maintain a saturated backbone and place the reactive unsaturation in a side chain available for sulfur cross-linking during vulcanization.

In the terpolymer structure, the double bond is not in connection with the main chain and therefore does not affect the strength of the main ethylene-propylene chain (no double bonds in the backbone). This explains the excellent heat, UV and ozone resistance of EPDM.

Cross-linking individual terpolymer chains in order to ensure mechanical properties of EPDM is ensured by a curing agent - sulfur.

Curing or vulcanization is primarily a process generating a 3 dimensional network of polymer chains as a result of the formation of different chemical bridges. The reaction transforms the soft, weak gum-like material into a strong thermoset elastic product.

For processing issues and in order to reinforce the mechanical properties of EPDM, some filling material is added to EPDM composition:

- **Carbon black** is a reinforcement filler which improves UV and heat resistance. It absorbs the UV radiation and transforms it into infrared. Due to the shape and size of the carbon black particles, it also improves the tensile strength.
- **Fillers (e.g. clay)** which improve the dimensional stability of the sheet and add fire protection properties.
- **Process oils** are paraffinic oils necessary to soften the compound during processing. They ease the mixing process and provide flexibility.
- **Sulfur** is used as a curing agent.
- **Accelerators** limit the amount of sulfur required, reduce the curing time, and optimize the performance of the membrane.

1.3. Production

The production of an EPDM geomembrane starts with the combination of all the raw materials listed in the previous section into a homogenous mixture. This is done using high shear mixing machines.

Upon completion of the mixing process, the mixing chamber is opened and the final compound is dropped onto a sheeting mill to form 4 mm slabs. Those slabs are then extruded and calendered.

As there is a chance that there could be an imperfection in a single ply sheet which could spread or leak after installation, Firestone EPDM Geomembranes are comprised of two plies of material to make one single ply. By putting two plies together, the chances of two imperfections lining up over each other are virtually non-existent.
At this point in the process the EPDM is still uncured, meaning that it can be molded or formed using heat into other shapes and is very tacky to the touch. At this time the EPDM is similar in consistency and tackiness to chewing gum. Due to the calendered width, EPDM is initially produced in maximum sizes of 3.05 m x 15.25 m. While in its uncured state, the 3.05 m x 15.25 m panels can be spliced to each other one after another to produce a “master roll” of 15.25 m x 122 m. This is accomplished by moving the panels along an assembly machine, overlapping them by 5-10 cm, then applying pressure to the seam area to splice or fuse the two panels together.

As the EPDM is very tacky and has yet to be cured, it would stick to itself if rolled up without some type of anti-blocking agent. So, a “dusting agent” (mica) is applied immediately after the panels are spliced and just before they are rolled up for curing. This is why EPDM actually appears dark gray and not black in color.

After rolling, the master rolls are loaded into an autoclave for a pre-determined length of time to cure under heat and pressure (crosslinking the individual polymer chains). The curing process changes the material from an uncured state to a thermoset material, making it elastic, extremely durable and resilient to heat, ultraviolet exposure, ozone as well as extreme cold and hot temperatures.

After the EPDM membrane “master roll” is cured, it is cut into pre-determined lengths and widths, folded, rolled, packed and stored ready for shipment.

Figure 1: Production process
1.4. Splicing mechanism

There are two types of seams in the Firestone EPDM lining systems:

- **Factory seams:** when splicing is performed during the production of the EPDM sheet prior to vulcanization. The material of the seam is homogeneous and 100% cured. This results in large, seamless EPDM panels, so as to minimize the number of field splices.

- **Field seams:** when splicing is performed on site with a self-adhesive Splice Tape.

When leaving the factory, the Firestone EPDM Geomembrane is a 100% vulcanized material. Two overlapping sheets are chemically inert to each other and do not stick when simply laid together. Welding techniques or solvents cannot be used to melt the EPDM membrane. Two adjoining sheets therefore have to be joined with a material that is chemically active, the self-adhesive Splice Tape combined with the QuickPrime Plus Primer. A successful splice will depend on a sound contact of the bonding agent and the membrane. For this reason the surface has to be prepared with utmost care.

The surface of the EPDM sheet examined under a microscope, is not completely smooth - it looks like an orange skin, full of small irregularities and ridges. It is important to observe that the surface is not very clean but covered with dust and talc. By scrubbing the surface with a scrubber pad, soaked with QuickPrime Plus, the irregularities are changed, creating a receptive surface for contact. The active molecules of the QuickPrime Plus are carried by a solvent, which provides a proper coating and a deep penetration of the components into the surface irregularities. When most of the solvent is evaporated, the QuickPrime Plus is still chemically active and provides a tacky surface for the Splice Tape to be installed to complete the splicing procedure.

In addition to the adhesion mechanism (attraction between adhesive and surface molecules), the irregularities of the membrane surface are mechanically interlocked by the components of the QuickPrime Plus. Both mechanisms create high-resistance molecular links. It will take 7 to 28 days for the QuickPrime Plus to lose its remaining solvent and therefore complete the curing process.

Experience to date has demonstrated that the EPDM field splicing technique using Splice Tape and QuickPrime Plus is very "friendly". This installation method satisfies the normal day-to-day variations such as climatic conditions, different applicators and job conditions.

![Picture 1: Splicing mechanism](image-url)
1.5. Review of technical performances

The table below details the declared technical specifications of Firestone EPDM Geomembrane 1.1 mm and 1.5 mm.

### Firestone EPDM Geomembrane 1.1 mm and 1.5 mm | Technical Specifications

<table>
<thead>
<tr>
<th>Physical Properties</th>
<th>Standard</th>
<th>Declared Value 1.1 mm (.045&quot;)</th>
<th>Declared Value 1.5 mm (.060&quot;)</th>
<th>Tolerance</th>
<th>Unit</th>
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<tbody>
<tr>
<td>Mass per unit area</td>
<td>EN 1849-2</td>
<td>1288</td>
<td>1695</td>
<td>± 5%</td>
<td>gr/m²</td>
</tr>
<tr>
<td>Tensile strength (MD/CD)</td>
<td>ISO R 527</td>
<td>9</td>
<td>10</td>
<td>-1</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Elongation (MD/CD)</td>
<td>ISO R 527</td>
<td>≥ 300</td>
<td>≥ 300</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Dimensional stability</td>
<td>EN 1107-2</td>
<td>≤ 0.5</td>
<td>≤ 0.5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Foldability low temperature</td>
<td>EN 495-5</td>
<td>≤ -45</td>
<td>≤ -45</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Resistance to static puncture</td>
<td>EN ISO 12236</td>
<td>0.7</td>
<td>0.9</td>
<td>-0.1</td>
<td>kN</td>
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<tr>
<td>Liquid tightness under high pressure</td>
<td>EN 1928:2000</td>
<td>Watertight</td>
<td>Watertight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water permeability (Liquid tightness)</td>
<td>EN 14150</td>
<td>3.0 10⁶</td>
<td>3.0 10⁶</td>
<td>±10⁶</td>
<td>m³/m²d</td>
</tr>
<tr>
<td>Methane permeability (Gas tightness)</td>
<td>ASTM D1434</td>
<td>2,25 10⁻³</td>
<td>2,25 10⁻³</td>
<td>m³/m²d</td>
<td></td>
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<td>Durability - weathering (25 y)</td>
<td>EN 12224</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
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<tr>
<td>Durability - oxidation</td>
<td>EN 14575</td>
<td>Pass</td>
<td>Pass</td>
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<td></td>
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<tr>
<td>Friction angle</td>
<td>EN ISO 12957-2</td>
<td>27,5</td>
<td>27,5</td>
<td>±1</td>
<td>°</td>
</tr>
<tr>
<td>Resistance to roots penetration</td>
<td>CEN/TS 14416</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Declared technical specifications – Firestone EPDM Geomembrane 1.1 mm & 1.5 mm

1.5.1. Exceptional durability

The chemical composition of Firestone EPDM Geomembrane (high proportion of carbon black (> 25%) and saturated carbon chains) and the fact that it is vulcanized (strongly crosslinked chains) mean that the geomembrane benefits from an unmatched resistance to UV, heat, ozone, micro-organisms and extreme weather conditions.

The membrane does not contain any plasticizers or antioxidants likely to migrate or degrade and cause the geomembrane to age prematurely.

Tests conducted on the Firestone EPDM Geomembrane and the observations made on membranes exposed to actual weather conditions (exposure to water, UV, ozone, heat, thermal variations and micro-organisms, etc.) over several years have shown that under normal exposure in Western Europe and when properly installed, the Firestone EPDM Geomembrane has a service life of more than 50 years, without any apparent signs of ageing such as cracks, crazing, bleaching, etc.

1.5.2. High elasticity and tensile strength

Given the significant level of crosslinking in its carbon chains, the Firestone EPDM Geomembrane can be elongated by over 300% in all directions and return to its initial form afterwards. This high elasticity allows Firestone EPDM Geomembrane to absorb substrate movements without its physical properties being affected.

1.5.3. Highly flexible, even at low temperatures

Firestone EPDM Geomembrane is highly flexible even at low temperatures down to -45 °C. This facilitates installation as the geomembrane adapts to irregular shapes and lays flat on the substrate, whatever the outside temperature.

When mechanically stressed at low temperatures, Firestone EPDM Geomembrane retains all of its flexibility and its resistance is not jeopardized.

1.5.4. High puncture resistance

In view of its highly flexible and elastic nature, Firestone EPDM Geomembrane also offers excellent static puncture resistance. This is a very important characteristic in withstanding the mechanical stresses which the geomembrane sustains during installation and service and consequently guarantees long term watertightness of the lining system.
1.5.5. High resistance to hydrostatic pressures
Firestone EPDM Geomembrane has almost unlimited resistance to hydrostatic pressure, which allows for its use in deep, large capacity water reservoirs. Firestone has conducted laboratory pressure tests which have shown that the EPDM Geomembrane can withstand pressure up to 35 kg/cm² (equivalent to 350 m water column or 3.4MPa).
Tests carried out according to the EN 1928:2000 standard showed that, when an equivalent pressure of 40 m water column (400 kPa) is applied, Firestone EPDM Geomembrane and its seams remain watertight.

1.5.6. Stable chemical composition
As a result of its chemical composition (saturated highly crosslinked carbon chains, without lixiviation of plasticizers and antioxidants) and its production method (heat vulcanized), the Firestone EPDM Geomembrane is considered an inert material as its chemical composition is very stable over time (when in contact with authorized products).
A stable chemical composition is vital in guaranteeing the mechanical properties of the geomembrane on a long term basis. Unlike thermoplastic geomembranes, no reduction in density has been noted on Firestone EPDM Geomembrane following loss of membrane components.

1.5.7. Highly compatible with living organisms
Owing to its very stable chemical composition, the Firestone EPDM Geomembrane does not release components on contact with water.
Tests have demonstrated that the Firestone EPDM Geomembrane and its seaming system can be used for the storage of irrigation water, as a liner for aqueous food production and aquaculture and for the storage of water prior to the necessary treatment required for human consumption.

1.5.8. Environmentally friendly geomembrane
As a result of the chemically inert nature of Firestone’s EPDM Geomembrane, it has no effect on air or water quality and does not release any pollutants into the environment.
The environmental impact of a geomembrane essentially takes place in its production and disposal. Taking into account its exceptional durability (compared with other geomembranes) and the numerous possibilities for recycling, the Firestone EPDM Geomembrane offers an environmentally friendly solution.

1.5.9. Root penetration resistance
The Firestone EPDM Geomembrane and its seams have successfully passed various root penetration resistance tests (DIN 4062, CEN/TS 14416: 2005, FLL). Nevertheless, it is necessary to remain extremely careful with regard to certain plants which develop particularly aggressive rhizomes (see enclosure 8.2 for a non exhaustive list of plants which develop rhizomes). When confronted with such plants which develop aggressive root systems or rhizomes, a protection barrier must be implemented to protect the EPDM geomembrane.

1.5.10. Broad range chemical resistance
The Firestone EPDM Geomembrane has a relatively broad spectrum chemical resistance. Nevertheless, some products are not compatible with EPDM membranes (hydrocarbons, grease, etc.). A list of compatible chemical compounds is available in appendix 0. In case of doubt, it is strongly advised that the technical department of Firestone Building Products is consulted.
In addition to water storage, the Firestone EPDM Geomembrane is also highly suitable for applications such as livestock effluent storage and waste water storage. The Firestone EPDM Geomembrane must not under any circumstances be used for storing chemical products.

1.5.11. Resistance to microorganism corrosion
The high level of crosslinking in its carbon chains and the presence of sulfur in its molecular structure (a compound which bacteria, likely to corrode the geomembrane, are not able to withstand), making the Firestone EPDM Geomembrane almost impervious to microorganism corrosion.

1.5.12. High friction angle
Friction tests conducted on the EPDM Geomembrane demonstrated that the friction angle between the geomembrane and a standardized ground surface is 27.5° (± 1°).
The Firestone EPDM Geomembrane friction angle is relatively high compared to other geomembranes. A high friction angle means that the geomembrane is easier to install (workers do not slide on it and the membrane stays in place), and that it is more stable on the slopes thus not requiring the use of a textured membrane.
1.5.13. Quick and easy installation

The combination of its dimensions, mechanical characteristics and seaming method make the Firestone EPDM Geomembrane quick and easy to apply. In a trade which is highly dependent on weather conditions, the speed of installation of Firestone EPDM Geomembrane represents a major advantage.

Dimensions

The Firestone EPDM Geomembrane is available in large panel sizes, up to 15.25 m wide and 61 m long in a single piece, that works out to 930 m² without any seam. This allows for a significant reduction in the number of seams to be carried out on site and considerably reduces the risks involved in installation.

The panels are available in numerous sizes which can be selected to accommodate the dimensions of the project. This reduces losses and limits the cutting and field seaming. The list of available Firestone EPDM Geomembrane panel sizes is included in the Technical Information Sheet (TIS) included in chapter 7.1.

Characteristics

Installation of the Firestone EPDM Geomembrane is greatly facilitated by its flexibility, as it adapts to the substrate and is easy to manipulate (moving unfolded sheets on an air cushion), as well as by its high friction angle as workers do not slide on the membrane when it is dry and the membrane is less likely to slip on the slopes.

Field seaming method

The Firestone EPDM Geomembrane field seaming method using Firestone QuickSeamTM Splice Tape presents the following advantages:

• The quality of the seams is consistent over the entire length
• Assembly is so easy that the quality of the seams is not dependent on the skill of the installer
• The completion of seams is only slightly dependent on weather conditions
• The tools used do not risk damaging the geomembrane
• It does not require the use of electricity or special equipment

The completion and quality of the seams are not affected by folds or waves which are likely to form with temperature variations.

1.5.14. High quality installation details

For the sealing of pipe flashings and penetrations, Firestone uses Firestone QuickSeam FormFlash, an uncured EPDM flashing (progressively cured after installation) laminated to self-adhesive Firestone QuickSeam Splice Tape. This material dresses each sealing detail perfectly and without any stress, whatever its shape.

Firestone also offers accessories for carrying out waterproof mechanical connections on concrete structures and adhesives which allow the membrane to be adhered to any type of surface (concrete, wood, steel etc).

1.5.15. Quality installation

The performance of a lining system is directly linked to the quality of the installation. For this reason the Firestone EPDM Geomembrane is exclusively installed by Firestone trained and approved lining contractors. They guarantee that the installation meets the quality standards set by the manufacturer.

Firestone Building Products’ technical department offers its contractors first rate support in theoretical and practical training with professional technicians. Firestone also provides on-site technical assistance and quality inspection of finished works.

1.5.16. Seam testing

There are 2 main types of seaming control methods which provide accurate information regarding the quality of the field seams:

• Non-destructive seam testing:
  - Visual inspection: in the case of the Firestone EPDM Geomembrane, a series of elements may be easily checked visually and which give a very good indication of the quality of the seams
  - Air lance: enables the watertightness of the seams to be checked on a continuous basis
  - Vacuum chamber: enables inspection of individual points on field seams

• Destructive seam testing: tensile and peel tests conducted on seam samples at least 24 hours after a seam has been made

A more detailed description of the seam testing methods is given in chapter 4.1.

1.5.17. Easy to repair

Given the inert nature of Firestone EPDM Geomembrane, its composition does not vary over time. Consequently, the geomembrane can still be assembled and/or repaired many years after being installed and having been exposed to climatic elements. All
that is required is that the geomembrane is thoroughly cleaned before commencing the repair. The repair techniques do not differ from the techniques for the initial installation of the Firestone EPDM Geomembrane. Therefore, repairs are quick and easy to carry out.

A detailed description of the repair techniques is given in chapter 4.5.

1.5.18. National and International Technical Approvals

The Firestone EPDM Geomembrane has obtained CE marking, which proves that it meets current European requirements for health, safety, consumer protection and environment.

The Firestone EPDM Geomembrane is CE marked for the following applications:

- **EN 13361**: Construction of reservoirs and dams
- **EN 13362**: Construction of canals
- **EN 13492**: Construction of liquid waste disposal sites, transfer stations or secondary containment
- **EN 13493**: Construction of solid waste storage and disposal sites

Firestone’s EPDM manufacturing facilities also hold ISO 9001 and ISO 14001 certification which respectively reflect Firestone’s commitment to quality and the environmental management system.

The Firestone EPDM Geomembrane has been tested and certified by many national and international bodies (for example, French ASQUAL certification).

Within the context of these certifications, regular audits are conducted at Firestone Building Products’ factories to verify the production process, quality control monitoring and the quality of the end product. Consequently, Firestone Building Products can guarantee that its EPDM geomembrane is of a consistently high quality.

The main approvals and certifications are available upon request from the technical department of Firestone Building Products, or can be downloaded from our website [www.firestonebpe.com](http://www.firestonebpe.com).

1.6. Applications

Firestone EPDM Geomembrane is used successfully in a wide variety of applications worldwide:

- **Agricultural applications:**
  - Irrigation reservoirs and canals
  - Agricultural ponds and dung pits
  - Aquaculture ponds
  - Algae ponds
  - Hydroponic farming
  - Ensilage covers
- **Environmental protection:**
  - Constructed wetlands
  - Waste water reservoirs
  - Storm water reservoirs
  - Landfill capping
  - Mining waste containment
- **Industrial applications:**
  - Settlement lagoons
  - Artificial snow reservoirs
  - Hydroelectric reservoirs and canals
  - Fire reservoirs
- **Artificial lakes**

The recommendations in this manual mainly apply to water reservoirs. Some applications need specific recommendations which are described in chapter 5.

Non-acceptable applications for the Firestone EPDM Geomembrane:

- Applications where gas generation or hydrostatic pressure could disturb the functioning of the Firestone Geomembrane
- Applications where the Firestone EPDM Geomembrane could come in contact with chemical substances that affect the geomembrane
2. Design considerations

There is no single solution to build a water reservoir. Before constructing a water reservoir, it is essential to carry out some site visits and specific analysis in order to optimize the location of the installation, its characteristics (size, shape, etc.) and the means to be employed (materials used, etc.). The following are some of the important points that need to be considered:

- **Project basics:**
  - Volume of liquid to store
  - Characteristics of the stored liquid (chemical composition, temperature, etc.)

- **Site environment:**
  - Available space (geometric constraints)
  - Nature of the soil (composition, stability)
  - Topography
  - Depth of underground water
  - Risk factor (human, environmental, economical)
  - Materials availability

- **Methods of use and maintenance:**
  - Expected in-use constraints
  - Filling/emptying
  - Water speed
  - Cleaning

2.1. Geomembrane selection

2.1.1. Panel size

Once the final shape of the reservoir has been designed, the panel size is chosen based on the panel and seam layout drawing. The goal is to reduce losses and facilitate the installation process (limit on-site splicing and cuts). The design process of the panel and seam layout is described in chapter 2.11.

The Firestone EPDM Geomembrane is factory-assembled into large, fully vulcanized seamless membranes. The Firestone EPDM Geomembrane is supplied in the following dimensions:

<table>
<thead>
<tr>
<th>Thickness</th>
<th>1.1 mm (.045&quot;)</th>
<th>1.5 mm (.060&quot;)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. surface</td>
<td>930.25 m² (15,25 m x 61,0 m)</td>
<td>744.5 m² (12,20 m x 61,0 m)</td>
</tr>
<tr>
<td>Length</td>
<td>30.48 m, 60.96 m</td>
<td>15.24 m, 30.48 m, 45.72 m, 60.96 m</td>
</tr>
<tr>
<td>Width</td>
<td>3.05 m; 6.10 m, 7.62 m, 9.15 m, 12.20 m, 15.25 m</td>
<td></td>
</tr>
</tbody>
</table>

*Note: Not all roll widths are available in all possible roll lengths*

**Table 2: Panel sizes**

Depending on the panel size, the rubber sheets are folded and packaged onto 1.83 m, 2.13 m, 2.44 m, 3.35 m or 4.27 m long cores. It is strongly recommended that the longest available core is always used in order to minimize fold lines and wrinkles in the sheet.

2.1.2. Thickness

The Firestone EPDM Geomembrane is produced in two thicknesses: 1.1 mm and 1.5 mm (Note: the 1.0 mm thick Firestone EPDM PondGard is specifically designed for decorative pond applications and is not treated in this guide).

Increasing the thickness of an EPDM geomembrane will result in a higher puncture resistance.

The Firestone EPDM Geomembrane 1.5 mm puncture resistance is almost 30% higher than the Firestone EPDM Geomembrane 1.1 mm. The thickness of the geomembrane has to be related to the project specificity. The use of a thicker EPDM geomembrane can be required for lining applications with an increased security level due to potential human or environmental risks and/or for applications requiring a higher mechanical performance because of high applied pressure (water, ice crust), specific uses, maintenance operations, surface irregularities, expected differential settlement, covering (risk of damage during the installation of the cover)…

A double layer of geomembrane can be installed on sites where no leakage can be tolerated (subsoil presents risks of internal erosion or dissolution, storage of polluted liquids in a environmentally protected zone, etc.). Between the two geomembranes a geocomposite drainage system must be connected to a leak detection system. In some specific applications, national legislations can ask for a double layer, but it is very exceptional.
2.1.3. Chemical compatibility

Due to its chemical composition and production process (vulcanization) the Firestone EPDM Geomembrane has a wide spectrum of chemical resistance. Nevertheless, Firestone EPDM Geomembrane cannot be used to store chemicals. When another product than clear water is expected, it is essential to contact the Firestone Technical Department to confirm the compatibility of the EPDM geomembrane with the product stored. Some products, such as hydrocarbons and greases, are not compatible with EPDM geomembranes.

A chemical resistance chart for the Firestone Geomembrane is enclosed (see enclosure 8.1). The enclosed tables are to be used solely in case of accidental contact.

The effect of chemicals on the membrane is highly dependent on the following factors:

- Temperature: an increase in temperature accelerates the chemical reaction and affects the durability of any type of geomembrane
- pH: in standard conditions, EPDM cannot be used when pH is lower than 4 and higher than 10
- Type and concentration of the chemicals
- Duration and frequency of exposure
- Liner installation quality and details: in certain conditions, tensions in the installed liner can affect the life time

It is also very important to make sure that the support structure or the cover material are chemically compatible with the geomembrane. In case of suspected pollution of the ground (hydrocarbon smell when excavating, old factory site, etc.), it is strongly recommended that a chemical analysis of ground samples and, if required, some compatibility tests are conducted.

2.2. Site selection

When selecting the construction site, several elements must be considered to ensure long-term performance of the lining system and to avoid any future problems. Site selection is the responsibility of a specialist engineer.

The following is a general overview of a few of the critical site selection parameters which should be investigated.

2.2.1. Preliminary studies of the site

Firstly, all existing data on the site will be collected and studied: topographical and geological maps, existing geotechnical studies of the zone, historical data (previous activities, old aerial pictures and maps, exceptional natural events, etc.), pluviometry and wind statistics, among other things. A detailed visual inspection of the site will be carried out by experienced engineers and geologists. The specifics of the site will be identified: topography, geology, hydrology, vegetation, existing infrastructure, accessibility, surroundings. Special attention will need to be given to detect former landfill and dump areas. In order to learn about the characteristics of the ground located inside the limits of the project and the ground used to raise the embankments, it is necessary to make on-site field trials (trial pits, static and dynamic penetration tests, deep boreholes, geophysical prospection, …) and laboratory tests (particle size, plastic limit, dry and wet natural density, content in organic material, carbonates, sulfates and gypsum, compactness (proctor), shear test, permeability test, dispersion test, etc.). The number, location, type of on-site field trials and laboratory tests will depend on the importance of the project and the national applicable code of practice and legislation.

2.2.2. Nature of the soil

A thorough investigation of the site must be carried out in order to design the section of the reservoir and ensure underlying soil stability throughout the life of the project. Under no circumstances may the project be located in landfills or dumps. In addition, waste material cannot be used to build the embankments. In standard building conditions a site with the following geotechnical characteristics should be acceptable:

- Particle size: uniformity coefficient (D60/D10) > 2 (important for compaction)
- Plastic limit: liquid limit < 50% (if LL > 40 % then PL > 0.73 (LL-20))
- Organic matter content: < 1%
- Gypsum content: < 2%
- Soluble salts (excepted gypsum): < 1%
- Collapse potential: < 1%
- Free cell swelling oedometer: <1%
- Dispersion test (Crumb): degree 1

If the site inspected does not fulfill the above conditions, some extra investigations will be needed to see if it can be used and if a specific installation process is to be planned.

1 Information provided on page 15 of the “Manual para el diseño, construcción, explotación y mantenimiento de balsas” – see bibliography for full reference
The table below outlines some risks associated with general soil type:

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>Risk</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressible (peat)</td>
<td>• Considerable gas generation</td>
<td>• Change site</td>
</tr>
<tr>
<td></td>
<td>• Pressure under the geomembrane</td>
<td>• Gas drainage</td>
</tr>
<tr>
<td></td>
<td>• Differential settlement</td>
<td>• Slope must be adapted to facilitate gas drainage</td>
</tr>
<tr>
<td>Loose backfill</td>
<td>• Settling</td>
<td>• Appropriate compaction</td>
</tr>
<tr>
<td></td>
<td>• Over-consolidation of the backfill materials</td>
<td></td>
</tr>
<tr>
<td>Soil containing organic matter (old sugar or paper</td>
<td>• Pressure under the geomembrane (gas)</td>
<td>• Gas drainage</td>
</tr>
<tr>
<td>industry ponds, landfill)</td>
<td>• Differential settlement</td>
<td>• Extra membrane on penetration details</td>
</tr>
<tr>
<td>Soil with internal erosion hazard (backfill material</td>
<td>• Dissolution of the soil by liquid in case of</td>
<td>• Change sites or provide a good geological assessment in order</td>
</tr>
<tr>
<td>containing waste, limestone-type soil, gypsum chalk)</td>
<td>a leaking system</td>
<td>to find cavities, if any</td>
</tr>
<tr>
<td></td>
<td>• Collapse caused by eroding water circulation</td>
<td>• Double waterproofing layer</td>
</tr>
<tr>
<td>Volcanic soil (soft clay, compressible silt)</td>
<td>• Absorption capacity</td>
<td>• An intermediate layer</td>
</tr>
<tr>
<td></td>
<td>• Differential settling provoking tearing of</td>
<td>• Particular drainage and special compacting around the details</td>
</tr>
<tr>
<td></td>
<td>the geomembrane at the splices</td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Associated risks with general soil type

2.2.3. Topography

The topographical study is very important in the selection process of the site in terms of available surface, slopes, accessibility, excavation and fill calculations, as well as the hydrology of the site.

If the underground water table is not so deep, the topographical study will help to find the highest location in order to avoid the underground water table being higher than the bottom of the reservoir.

Where possible, a location will be chosen to permit water circulation by gravity for the filling and emptying of the reservoir and evacuation of the water collected underneath the membrane by the water drainage system.

The altitude of the reservoir has an impact on the formation of an ice-crust on top of the water and therefore the pressure applied on top of the membrane as well as the risk of damage by floating or falling ice blocs.

2.2.4. Hydrology

It is not recommended that a water reservoir be installed in a river bed as the site will likely encounter technical complications:

- High underground water level
- High quantity of sediment and floating objects inside the reservoir
- Risk of overflows in case of flooding

In projects where the reservoir has to be installed in a river bed, with a direct input from the river, it is essential to make a hydrological study of the site. The hydrological study will evaluate the flood design in order to design the dimensions of the spillway and the high water level. If large quantities of sediment are expected, it is recommended that there is a settlement pond upstream or that the membrane is covered in order to facilitate sediment removal. The underground water table will have to be properly drained in order to protect the substrate from water erosion.

For projects located close to a river bed, it is important to evaluate if the outside embankments are protected from any potential erosion effect in case of flooding from the river.

In very large surface lakes, the direct input of rain can have an impact on the dimension of the overflow pipe.

2.2.5. Underground water table

The state of the art requires that the groundwater level should never be higher than the bottom of the water reservoir.

If the groundwater level exceeds the bottom of the reservoir, the geomembrane risks being lifted (hydrostatic pressure), the support structure can be damaged (small ground particles removed by the water flow, exposing larger stones and increasing the risk of puncture) and the functioning of the gas drainage system can be disturbed (causing gas pressure). In this case, an appropriate drainage system under the geomembrane must be provided. Groundwater drainage systems must be designed by a specialized project engineer.
The main characteristics of the groundwater table must be studied during the design process:

- Depth: both the average level and the extreme level over the course of at least one year
- Estimated flow of the underground water level
- Type of groundwater table:
  - Perched water
  - Temporary underground water
  - Underground water under pressure

Knowing the underground water characteristics is also very important during the excavation and installation process. It is important to verify that it is possible to work in dry conditions without jeopardizing the stability of the excavation and adjacent infrastructures.

### 2.2.6. Human and natural environment

The reservoir and its building process may have some human and environmental impacts that need to be studied during the design process. Depending on the type of reservoir and country, an environmental study may be mandatory during the design process.

If the stored product is likely to disturb the neighborhood (smell) or to be dangerous to the environment, the installation should be located as far as possible from residential accommodation and/or sensitive areas (rivers, potable water wells, natural ponds, etc.). Consideration should also be given to the integration of the reservoir into the landscape.

### 2.2.7. Accessibility

Accessibility to the site must be guaranteed during construction, use and maintenance. The implementation of the new project should not reduce the accessibility of existing facilities.

### 2.3. Geometry of the reservoir

One of the essential design factors in the geometry of a reservoir is the volume of water stored taking into account the availability and necessity of water.

Generally, simple geometric shapes are recommended so as to facilitate the building of the pond, and to reduce the loss percentage. Square or rectangular shapes are preferred. The shape of the reservoir will take into account the land surface available within the site.

#### 2.3.1. Excavation and backfill

Mainly for economic reasons, the most common design is an excavation and backfill reservoir. Starting from the desired stored water volume, the designer will calculate the amount of ground to be excavated at the bottom of the reservoir and used for backfilling the dam. If required some extra soil will be brought from outside to match the backfill quantities.

![Figure 2: Different excavation situations and backfill designs for reservoirs](image-url)
2.3.2. Bottom

Depending on the size of the reservoir, one or two slopes with a minimum incline of 2% will be built into the bed. The aim is to facilitate the emptying and cleaning of the reservoir and the drainage of water and gasses under the geomembrane. The fall becomes more important as the surface increases, and must be adapted to the calculated settling level.

The change in angle between the bottom and the side slopes must be rounded (curvature of 0.5 m).

Figure 3: Bottom slope

2.3.3. Embankment incline or side slopes

The stability of the excavated and/or backfilled embankment is a geotechnical issue. The presence of groundwater and the nature of the soil play an important role in the stability of the embankment. The embankment needs to be freestanding. The Firestone Geomembrane must not be used to ensure stability of the embankment.

The stability study must deal with the following:

- Ground characteristics
- Height of the dam
- Foundation quality
- Ground water
- Stability of the drainage system and of other layers between the foundation of the reservoir and the geomembrane
- Effects of waves
- Maximum water height
- Consequences of rapid drop in water level
- Consequences of excessive leakage
- Stability of the geomembrane protection layer, if any
- Seismic conditions
- Safety factor
- Ease of installation

The slopes given below are indicative values for initial design to be verified in the stability study.

If the reservoir is less than 5 m deep, the contractor shall provide a maximum slope of 1v/2h.

Figure 4: Example of a 1v/2h slope

If the height of the embankment above the base of the reservoir is between 5 and 10 m, a slope of 1v/3h is recommended.

If the membrane is going to be covered by a protective layer, a slope of 1v/3h is recommended in order to guaranty the stability...
of the protective layer. If the protective layer is made of concrete the slope can be higher.

The indicative values mentioned in the table below may be used as a general guide. These values are given according to the nature of the soil. They should be considered with extreme care for the reasons mentioned above.

<table>
<thead>
<tr>
<th>Nature of soil</th>
<th>Incline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay soil</td>
<td>1 V/2,5 H</td>
</tr>
<tr>
<td>Clay and sandy soil</td>
<td>1 V/2-3 H</td>
</tr>
<tr>
<td>Sandy gravel</td>
<td>1 V/2 H</td>
</tr>
<tr>
<td>Soft rock</td>
<td>1 V/1,5 H</td>
</tr>
</tbody>
</table>

Table 4: Indicative slope according to the nature of the soil

The change in angle between two slopes must be rounded (curvature of 0.5 m).

Outside slopes should not exceed 1v/2h (depending on the length of the slope) so as to avoid subsidence and gulley erosion of the banks over time. The materials should not contain any turf, vegetable debris, topsoil, peat, silt, etc. It is essential that the outside slopes are planted up as quickly as possible for erosion control. At the toe of the outside slope a water collection ditch is recommended in order to reduce the erosion risk caused by running water.

Sometimes, designers decide to install a berm into the inside slope for intermediate anchoring or in order to partially cover the embankment for esthetic reasons. The design of the berm must consider the risk of cover material falling into the reservoir and the non-continuity of the water and gas drainage. An example is given in chapter 6.5.

In places where a thick ice-crust is expected and the reservoir is used during the winter, it is recommended that the toe of the covered berm is located just underneath the normal water level. Otherwise, the partial cover could hold some ice blocs and release them when the reservoir is empty, risking damage to the membrane.

2.3.4. Embankment crest (top of the slope)

The crest width must guarantee the dam stability and be large enough to accommodate a maintenance road over its entire length.

The embankment crest width is related to the height of the embankment and must have the following minimum values:

- 4.0 m for installation of anchor trench and the maintenance road
- 5.0 – 6.0 m if machines or vehicles are used during the construction and operation of the water reservoir

For deep water reservoirs (> 5 m), the minimum width of the embankment crest (C) can be estimated from the height of the dam (H) using the formula below:

\[
C (m)=3+ \frac{(H (m))}{5}
\]

Also a slight incline of 1-2% towards the outside of the reservoir is recommended to avoid runoff water and ground entering inside the reservoir.

The change in angle between the side slopes and the embankment crest must be rounded (curvature of 0.5 m).

The material used for the crest needs to be non-erodible and resist to engine circulation (if expected).

Figure 5: Embankment crest

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2 Information provided on page 70 of the “Manual para el diseño, construcción, explotación y mantenimiento de balsas” – see bibliography for full reference
The crest needs to be equipped with a running water collection system. In case of an excavated embankment, it is strongly recommended that a water ditch be installed on the embankment crest in order to collect the upstream running. The size of the ditch will be designed according to the amount of running water expected.

![Figure 6: Water ditch for upstream running water](image)

### 2.3.5. Waves

Waves created by the wind or by boats impact the side slopes. The greater the length of the reservoir in the direction of the prevailing winds and the steeper and smoother the slope of the embankment, the stronger the wave action will be.

Wave impact can be reduced by:
- Building a smaller but deeper pond
- Selecting another shape, with a shorter dimension in the direction of the prevailing winds
- Building several smaller ponds, instead of one large pond

According to the specific height of the waves, the nature of the soil and the slope of the embankments, we recommend the following:
- Protection of the geomembrane adapted to the incline (concrete, riprap, soil cover)
- Adequate anchoring of the geomembrane
- Adequate compaction of the soil
- A thicker protective geotextile under the geomembrane
- Extra protection on the crest

### 2.3.6. Water level

The normal liquid level is determined by the required water volume, the topography of the site, the volumes to excavate, the highest expected liquid level (calculated for a specific design flood), the designed freeboard and the expected settlements.

Increasing pond deepness will increase the volume as well as reduce the water surface and therefore the evaporation rate. On the other hand, the excavation/backfilling costs increase, as well as the pumping costs and hydrostatic pressure.

![Picture 2: Extra protection on the crest against waves overflow](image)
2.3.6.1. Hydrostatic pressure

The higher the water level in the reservoir, the higher the hydrostatic pressure. The hydrostatic pressure will have a significant impact on the stability requirements (bearing capacity of the reservoir, deformability of the foundation) and the pressure/tensions applied to the geomembrane.

Even considering the flexibility and the high elongation at break properties of the Firestone EPDM Geomembrane, cavities may be present in the soil that may cause the geomembrane to perforate. To avoid this risk, it is essential to have a smooth, well compacted support layer (fine grained intermediate layer of sand or clean soil) and to install a protective geotextile under the geomembrane.

2.3.6.2. Freeboard

One of the most serious problems that can occur in the case of a water reservoir is water overflow. Water flow will drag ground particles from the top of the embankment and can lead to a total ruin of the structure. Therefore a freeboard needs to be designed and scrupulously respected during the building and the use of the reservoir.

Freeboard on highest water level (HWL) is the difference in level between the top of the crest and the HWL, different from the normal water level (NWL). This volume held in reserve is intended to prevent wind generated waves from overtopping the crest and to minimize chances of water overflow in case of heavy rainfall. The freeboard is specifically calculated for each project but in any case must always be more than 50 cm or the minimum value mentioned in the applicable legislation. Firestone recommends that the distance between the normal water level (NWL) and the level of the top of the crest must always be more than 100 cm or the minimum value mentioned in the applicable legislation.

Depending on the expected wind, the length and depth of the pond, the slope and roughness of the embankment, the expected settlement, the freeboard on HWL can go up to 2.0 m for some projects.

![Figure 7: Freeboard on highest water level](image-url)
2.4. Anchoring the geomembrane

The geomembrane must be kept in place to prevent it from slipping down the embankment, being lifted by the wind and/or displaced by water movements. Dependent upon the situation, the geomembrane can be anchored in various ways (see chapter 6.5 for drawings):

- At the top of the embankment
- At an intermediate platform
- At the bottom of the reservoir

If the membrane is going to be covered, the covering will serve as final anchoring. A trench can be used for intermediate membrane anchoring during installation and while waiting for the final covering.

If the membrane is installed on top of a concrete structure, it can be mechanically anchored (see chapter 6.4 for drawings) or glued to the concrete.

2.4.1. Top anchoring

The anchoring is executed by burying the geomembrane in a trench or by holding it in place by means of ballast. The dimensions of the trench depend on the expected stress. The minimum section should be 0.40 m x 0.40 m in cohesive soil. Moreover, this section depends on the length of the geomembrane between two anchor points, the distance between a clamping point and the water level, the wind speed, the slope, the different friction angles, etc.

The Firestone Geomembrane must extend at the bottom of the trench over at least 300 mm. The distance between the anchor trench and the crest of the embankment will be 1.0 m minimum to preserve the stability of the ridge.

It is recommended that the reservoir is filled prior to final filling and compaction of the anchoring trench. Filling and compacting the anchoring trench must be performed without subjecting the geomembrane to stress and without it being punctured. After compaction, the anchoring trench needs to have an external slope of a minimum of 1%.

If considerable soil movements are expected after filling the pond, temporary clamping must be provided at the crest, so that the Firestone Geomembrane can move without being subjected to excessive tension. Partial ballasting in the ditch is immediately provided and final anchoring is done at a later stage.

The table below shows a few practical values for the minimal anchoring section (or backfill section) using a filling material with a density of 20 kN/m³ (2040 kg/m³) and for a standard embankment slope (1v/2h to 1v/3h). The final size of the anchor trench needs to be designed by a specialized engineer.

<table>
<thead>
<tr>
<th>Length of embankment (m)</th>
<th>Low or medium wind speed (&lt; 100 km/hr)</th>
<th>High wind speed (&gt; 100 km/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 3</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>3 - 5</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>5 - 15</td>
<td>0.16</td>
<td>0.25</td>
</tr>
<tr>
<td>15 - 40</td>
<td>0.25</td>
<td>0.36</td>
</tr>
<tr>
<td>&gt; 40</td>
<td>&gt;0.36</td>
<td>&gt;0.49</td>
</tr>
</tbody>
</table>

Table 5: Minimal anchoring section

An alternative using ballast is possible as long as measurements are taken so the ballast does not erode over time.

Figure 8: Top anchoring in a trench
2.4.2. Intermediate anchoring

If the embankment is long and strong winds are expected, it may be necessary to provide an intermediate clamping to accommodate geomembrane movements caused by the wind. Such clamping can be carried out using ballast or an anchor trench (perpendicular or parallel to the slope). For perpendicular anchoring, a berm can be added to the slope in order not to endanger the stability of the embankment. The continuity of the water and gas drainage must be ensured.

2.4.3. Base anchoring

If the reservoir base is sufficiently low in permeability (waterproof geological layer, imported clay, treated ground, etc.), the base anchoring of the geomembrane will ensure a mechanical function and watertight continuity between the embankment and the bottom of the pond (see drawings in chapter 6.5).

Depending on the geotechnical characteristics of the impermeable material and the water pressure, the designer will have to fix following distances:

- Length of the geomembrane inside the impermeable ground (minimum 2.5 m)
- Minimum thickness of impermeable ground under the geomembrane
- Minimum thickness of well compacted clay or treated ground on top of the geomembrane (greater or equal to 0.5 m and $H/10$, $H$ being the maximum water height)

In order to increase watertight connection efficiency, a bentonite layer can be added on top of and under the geomembrane.

If water movement is expected, it is recommended that a filtration geotextile and some cover stones are installed on top of the clay in order to prevent its erosion in the anchoring zone.
Figure 11: Base anchoring in impermeable ground (solution 1)

Figure 12: Base anchoring in impermeable ground (solution 2)

Figure 13: Base anchoring in permeable ground covered with compacted clay or treated ground
2.5. Foundation

To ensure the correct performance and life expectancy of the geomembrane, it is essential that the foundation is adapted to the geological and geotechnical conditions of the site.

The foundation has to be stable. Most of the time, an excavation of the ground is done in order to gain storage capacity and to have ground to raise the embankments. The slopes of the excavation need to be stable, in the short and long term, also when exposed to the designed maximum stress (water load, interstitial pressure, earthquake hazard).

The risk of differential settlement needs to be studied carefully in order to avoid excessive tension on the membrane. Any compressive materials like mud or peat need to be dried or removed. Differences in compressibility between different areas of the foundation should be avoided (e.g. partly rocks and partly soft ground). The required degree of compaction of the foundation has to be considered during the geotechnical study.

Some materials can erode (karst, sand, etc.) or dissolve (gypsum) in the event of a significant intake of water. This could be one reason to apply a double layer of membrane or change the location of the project. The internal erosion risk of the ground (leakage, rain water infiltration, etc.) will be studied carefully. Dispersive soils cannot be used.

Vegetation (trees, shrubs) and organic ground (more than 1% of organic content) must be removed.

The type of soil particle of the foundation, after excavation, will determine the characteristics of the support structure. If the foundation ground is too aggressive, a protective ground layer will have to be applied.

The depth of underground water under the foundation will have serious impact on the building process, the stability of the reservoir and the drainage system.

2.6. Support structure

The support structure is the layer(s) between the foundation and the geomembrane. Its main functions are the following:

- Protect the membrane against mechanical damage:
  - Due to excessive tensions (well compacted ground generates only permissible deformations of the geomembrane)
  - Avoid puncture (smooth surface, geotextile)
- Reduce pressures under the geomembrane (water and gas drainage)
- Collect the stored liquid in case of a leakage (water drainage)
- Facilitate the installation process of the geomembrane (smooth and well compacted substrate)

2.6.1. Support layer

The support layer is the soil layer, part of the support structure. The support layer must be clean, smooth, compacted, and free from aggressive angle changes, stones and small cavities. This layer must also be able to compensate for the differential settling of the soil and facilitate the installation of the drainage system and the geomembrane.

The support layer can be installed in various ways:

- Excavated reservoir base after removing stones, rocks, vegetation etc., followed by smoothing and compacting
- Backfill layers (minimum 20 cm thick) with controlled particle size (maximum 20 mm) and compacted (sand, stable earth, etc.)

It is important to be able to guarantee the quality of the support layer over time. Ground erosion in case of a leakage or intake of natural ground water can convert a smooth support layer into a very aggressive ground (leaching of small ground particles, leaving sharp stones in contact with the geomembrane).
2.6.1.1. Vegetation

The decomposition of organic matter is likely to result in different levels of settlement and the release of gas. Therefore the support layer must be cleared of all vegetable matter and topsoil stripped of any eventual deposits of organic matter. According to the conditions, the use of a durable weed killer is recommended. The weed killer must not contain any components which might affect the Firestone EPDM Geomembrane.

2.6.1.2. Compaction

The geomembrane support layer must be optimally compacted (to a density of 95% of the normal Proctor Optimum), either by natural or by mechanical compacting. The compaction at the crest of the embankments must be carried out with the utmost care. The compaction of the support layer must be such as to allow access to the construction equipment without risk of damaging the surface (e.g. tire tracks). The embankments must be stable and resist the impact of waves.

If necessary, in order to obtain a well compacted embankment with a uniform slope, the embankment can be built by the excess fill method: a width greater than the project profile is compacted, then the poorly compacted faces are scraped. The mechanical properties of some types of ground (shale, sandstone, soft limestone, marlstone) can change during the compaction process. In such cases, an on-site trial is recommended. The smoothness of the support layer can also be modified during compaction (some stones can break leaving sharp edges in contact with the geomembrane).

If some differential settlements are expected and cannot be avoided it is important to evaluate these expected settlements and adapt the installation details in order to avoid tensions.

2.6.2. Hard substrates (concrete, treated soils,...)

The hard substrate surface needs to be smooth and without any cavities. It is recommended that the geomembrane is fully adhered to the smooth concrete. In case adhesion is not possible, it is always necessary to install a protective layer (geotextile). In order to avoid settling of the natural soil next to a concrete structure, the compaction must be performed with particular care up to 95% of the normal Proctor Optimum. At the junction between the ground and the concrete, it is recommended that a minimum of two geotextile layers are applied.

2.6.3. Geotextile

The installation of a protective geotextile between the support and the geomembrane is always strongly recommended. It is an absolute necessity on embankments where laying an additional support layer is often difficult. The geotextile will protect the geomembrane against potential mechanical damage (puncture, friction) during the installation process and its entire life. It will also help with gas and water drainage, to absorb tensions induced by small cavities, to protect the embankment against erosion (waves) and facilitate the installation process (move the membrane, no dust on seams).

The type of geotextile will be selected depending on the properties of the support soil (particle size, slope, etc.), the type of geomembrane used (thickness) and stresses anticipated during installation and operation (water pressure, waves, etc.).

The minimum properties of the geotextile are given below, for reference only:

- Type: non-woven, needled, short fiber, 100% polypropylene, 100% virgin material
- Mass per unit area (EN 965): ≥ 300 g/m²
- Thickness at 2 kPa (EN ISO 9863-1): 2.0 mm
- Tensile elongation (EN ISO 10319): 50%
- Tensile strength (EN ISO 10319): ≥ 20 kN/m (machine and cross machine direction)
- Dynamic perforation test (EN ISO 13433): < 30 mm
- Puncture resistance (EN ISO 12236): ≥ 3 kN
- Durability (annex B EN 13254) 25 years (covered in 2 weeks)

When the geotextile also has a drainage function, it must be checked for sufficient transmissibility (EN ISO 12958).

The use of geotextiles containing natural fibers is not recommended as they will rot and lose their protective properties. It is also not recommended that woven geotextiles are used because these do not have good protective properties and are too rigid. Geotextiles made from recycled material should not be accepted.

In places where the membrane could be damaged by roots or rhizomes, it is necessary to install a root resistant geotextile.

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3 The Proctor compaction test is a laboratory method of experimentally determining the optimal moisture content at which a given soil type will become most dense and achieve its maximum dry density (Wikipedia).
2.7. Drainage system

The drainage layer under the geomembrane is part of the support structure. The drainage system is an essential safety feature of the reservoir as one of its functions is the detection of leaks. The drainage system needs to be designed by a specialized design company depending on the specifics of each project.

2.7.1. Application criteria

The application of a drainage system is not required if the permeability of the entire supporting layer exceeds 10^-4 m/s, or if no gas or water pressure is anticipated. However, the presence of a drainage layer is essential for the rapid detection of leaks. Water/gas drainage is always required under the following conditions:

- When the underground water level may be higher than the bottom of the pond (not recommended in good practice construction)
- Soils containing organic matter (gas generation)
- Embankments containing clay (stability when emptying)
- Whenever variations of the groundwater level can be anticipated
- Whenever the geomembrane is not fixed and can move
- Reservoir containing organic matter or a liquid potentially harmful to the environment (to avoid ground and/or water pollution in case of a leakage)

The figure below summarizes the main causes of pressures under a geomembrane.

![Figure 14: Some causes of excessive pressure](image-url)
2.7.2. Water drainage

It is strongly recommended that the water drainage system is separate from the gas drainage system. If both drainage systems are combined, gases cannot be evacuated while water is drained.

The water drainage system of the pond is very important for the following reasons:

- Detects and measures any leakage of the geomembrane
- Protects the support structure from internal erosion mechanisms: water removes the thin ground particles and leaves the geomembrane in contact with the bigger stones, increasing puncture risk
- Avoids loading capacity problems of the foundation
- Ensures the stability of the slopes when emptying the pond or in case of external water intake with low water level inside the pond
- Prevents geomembrane movements due to water pressure under the membrane (low water level inside the pond and high underground water level)

There are two main causes for water under the membrane:

- Underground water (temporary or permanent water table, infiltration of surface water), affecting excavated embankments, the bottom of the reservoir and the base of the backfilled embankment
- Water coming from a leakage in the lining system, affecting backfilled and excavated embankments and the bottom of the pond

For large scale projects, two water drainage systems are recommended. The first one is designed to collect underground water and the second one, located under the membrane, is designed to detect, measure and collect any water coming from a leakage. The collectors of these two water drainage systems are separated.

In some cases (large water reservoirs, high human risk down-stream), it may be necessary to install a drainage system inside the backfilled embankment. This will not be addressed in this guide. When present, the water drainage system of the dam body must be separate from the drainage system under the membrane.

The water drainage may be implemented at the bottom of the reservoir and on the slopes by means of one of the following:

- **Drainage through permeable material:** this bed may be made with sand or gravel (5/20). Its thickness depends on the transmissivity of the drainage product. A minimum thickness of 20 cm is recommended. A filtering geotextile must be provided between the drainage layer and the neighboring soil (see standard EN 13254).

- **Drainage by a drainage geocomposite:** the geocomposite will be chosen according to its cross-sectional flow rate (under load), its filtering geotextiles and its friction coefficient (preferably self-stable on slopes). See standard EN 13252. The use of a drainage geocomposite has many advantages:
  - Low weight
  - Quick and easy installation (especially on slopes)
  - Low capacity loss

- **Network of drainage ditches (preferred solution at the bottom):**
  - Trenches of min. 0.3 x 0.3 m for the installation of drains:
    - Peripheral at the base of the banks (at 1.0 m distance from the toe of the slope)
    - On the pond bed, pipe network between 5 m and 30 m inter-distance (depending on the permeability of the ground)
  - The slope necessary for run off is in the order of 0.5 to 1 %.
  - Installation of an anti-contaminant geotextile between the draining rubble present in the trench and the natural soil. In no case can a puncture resistant geotextile be used to provide a filtration function (see standard EN 13254).
  - Agricultural drains (PVC or PE of min. 60 mm diameter – depending on the expected water quantity) are placed in these trenches which are covered with 10/14 gravel or similar on top of the trench.
  - Depending on the ground permeability, a covering over the whole surface could be needed: layer of permeable material grade 8/10, (washed gravel), at least 10 cm deep.

The information above contains general recommendations. For each project the final water drainage design is the responsibility of a specialized design company.
Figure 15: Water drainage with drainage ditches

Figure 16: Drainage ditch section

Picture 5: Drainage ditch
For draining the water at the bottom of the pond, it is very important to respect a minimum 2% slope of the base. The size and gradient of the water drainage system depends on the following factors:

- Leak flow rate that is acceptable
- Flow rate of water coming from outside the pond
- Maximum pressures that are acceptable under the geomembrane

For smaller projects, the use of perforated drain pipes with a diameter of 60 mm should be sufficient. For larger structures, the size and the density of the network, as well as the compressive strength of the drain pipes must be carefully calculated. Consult the manufacturer for advice.

If a berm is used, a water collection/drainage system must be provided to secure the continuity of the water drainage on the slopes.

For larger structures, a compartmentalized drainage network is recommended to facilitate leak detection. This is mandatory when the geomembrane is covered by a protective structure. In any case, it is recommended that the water coming from the embankments (peripheral draining collector) and the water coming from the base of the pond is kept separate.

The water drained on the embankments is collected at the bottom of the slopes by a peripheral drainage collector (perforated on the upper part and closed on the lower part).

At the lower point of the pond, one or several blind pipes go through the embankment for water evacuation towards the hydrographic network (by gravitational means or pumping). The hydraulic capacity of the collectors needs to be bigger than that of the water drainage system. The slope of the collectors must be bigger than 1%.

The type of collector pipe depends on the vertical pressure that is going to be applied on the pipe.

The collector pipes will have to go through the embankment into a trench that will be covered afterwards with reinforced concrete, sized according to the expected ground weight. The trench is usually the same as the one used for the outlet pipe (see chapter 2.9.2). For very big projects, the collector pipes can go through a service tunnel.

At the exit, the collector pipes need to be connected to an inspection chamber in order to see and measure the outlet flow and evaluate its turbidity (internal erosion). The inspection chamber can be equipped with an automatic leak detection system (sonorous).

### 2.7.3. Gas drainage

Pressure caused either by the production of gas from the fermentation of organic material in the soil or by a rise in the underground water table, requires the installation of a gas drainage system under the geomembrane. This system will be constructed in addition to the water drainage system (two completely separate networks). The gas drainage system will be connected to vents positioned on the crest of the embankment. Gas drainage must always be designed in such a way that its flooding is avoided.

Gas drainage may be achieved either by using perforated 40 to 80 mm diameter pipes positioned every 10 m or using draining layers (geocomposite: geonet in high density polyethylene covered with an anti-contaminant geotextile) positioned every 5 m. The distance between the pipes or the geocomposite needs to be adapted to the conductivity of the ground (low interdistance for poor conductivity) and the expected quantity of gases. Depending on the permeability of the substrate, a bed of permeable material of 8/10 grade (washed gravel), a geotextile or another synthetic permeable material could be required between the pipes.

The vents are protected to avoid obstructions and the ingress of water (rain or running water).

Any direct contact between the geomembrane and abrasive surfaces of the drainage systems must be avoided.
Figure 17: Gas drainage with pipes

Picture 6: Gas drainage with pipes

Figure 18: Gas drainage with geocomposite
Picture 7: Gas drainage with geocomposite

Picture 8: Gas vent

Picture 9: Gas trapped under the geomembrane
2.8. Top protection of the geomembrane

In some cases, protection of the Firestone EPDM Geomembrane will be required. In the table below you will find some recommendations for the protection against potential damage.

<table>
<thead>
<tr>
<th>Protection against</th>
<th>Precautions</th>
</tr>
</thead>
</table>
| Wind               | • ballast at the bottom and/or on slopes (in case of temporary emptying)  
|                    | • correct section of the anchor trench |
| Waves              | • mechanical protection of the embankments depending on the slope:  
|                    | rock covering, concrete pavement, cast concrete |
| Floating objects (dead wood, boats) | • small ponds: cleaning larger ponds: protection |
| Ice                | • mechanical protection of embankments |
| Animals, vandalism | • ladders  
|                    | • enclosure around the reservoir  
|                    | • mechanical protection of embankments |
| Operating vehicles (remove sediments) | • protection of the geomembrane with soil, a sand bed, concrete slab  
| Local turbulence with water speed exceeding 1 m/sec. (internal agitator or canals) | • protection with ballast |

Table 6: Potential damage and related precautions

Covering the membrane can also be done for esthetic reasons, i.e. for a better integration of the pond into the landscape. Covering the geomembrane will have a positive impact on the durability of the geomembrane (e.g. protection against mechanical aggressions) and it will ballast the liner (wind, water movement). Nevertheless, the cover can have some disadvantages:

• The risk of damaging liner during the installation process is high and special care is required (see paragraph 3.9).
• When the membrane is covered, it is very difficult to locate a leakage. It is therefore strongly recommended to subdivide the water drainage system under the membrane in order to detect more easily the damaged area.
• The slopes cannot be higher than 1v/3h to guarantee the stability of the cover (unless using concrete).
• The price of the cover is usually high.
• The installation time for the project is longer.

Protection of the Firestone EPDM Geomembrane can be executed as described in the following chapters.

Figure 19: Top protection of the geomembrane

2.8.1. Bottom cover

Considering the low slope of the base and the lower stresses, the covering may be less robust in this area unless operating vehicles will circulate on it for maintenance (e.g. removing sediment at the bottom…). The following material can be used to cover the base of the pond:

• Sand bed (minimum thickness: 200 mm): protection with geotextile not required  
• Gravel (minimum thickness: 200 mm): protection with geotextile required  
• Prefabricated materials (tiles): protection with geotextile required  
• Concrete: protection with geotextile required

4 If no operating vehicles are expected  
5 If no operating vehicles are expected
• Riprap: protection with geotextile and sand/gravel bed (minimum thickness: 200 mm) required
• Natural soil: protection with geotextile required

If, for any specific reason (maintenance, ballast), the bottom of the pond is covered and not the slopes, it is recommended that the cover be raised onto the embankments.

**Figure 20: Raising the bottom cover onto the embankments**

### 2.8.2. Embankments cover

The following material can be used to cover the embankments (see drawings at chapter 6.6):

- **Riprap**: this solution is applicable for slopes up to 1v/3h. A transition layer (geotextile + sand/gravel bed) with a minimum thickness of 200 mm is required. Rock covering depends on the level of the impacting forces (waves, ice crust…)
- **Gabion**: protection with geotextile required
- **Prefabricated tiles, Cast Concrete**: a protective geotextile is required. Stability measures of the tiles/concrete at the foot of the embankment are required. The geotextile must have sufficient transmissivity to permit drainage under the tiles/concrete and prevent uplifting pressure. The support structure must be very flat
- **Natural soil**: protection with geotextile or draining geocomposite required

**Example of a riprap cover:**

A riprap covering must be sized so as to resist wind driven waves and ice crust formation:

- **Thickness**: between 0.3 and 0.8 m
- **Block diameter**: Maximum diameter < covering thickness (0.3 – 0.8 m), minimum diameter > 0.1 m. It is considered that the median diameter of the blocks must be between 0.2 and 0.5 m
- **Typical structure**:  
  - Geomembrane  
  - Geotextile between 600 and 1200 g/m²  
  - 0.2-0.3 m bed of sand or gravel  
  - Blocks
- **Stability**: the effect of the slope is heavily impacting the stability of the riprap. It is very important to respect the 1v/3h slope. If necessary, an abutment at the toe of the slope and/or geosynthetic reinforcement anchored at the top of the slope shall be provided
- **Permeability**: permeability of the covering structure must be sufficient to avoid developing hydraulic pressure at its base
- **Test plate**: in order to select the puncture resistant geotextile and to check the stability of riprap on the slope, it is strongly recommended to use an on-site test plate
2.8.3. Stability of the cover

The stability of a cover is an important issue that needs to be studied carefully in order to avoid significant damage caused by any sliding of cover material down the slope or excessive tension on the membrane.

The stability of the cover is determined by following parameters:

- Slope and length of the embankment
- The thickness of the cover
- The cohesion and density of the cover material when dry or wet
- The friction angle between the cover, the geotextile and the geomembrane
- The hydraulic pressure when the cover is not made of free-draining material
- The expected weight (cover, ice crust, construction machinery,...)

In general a maximum slope of 1v/3h is recommended when the geomembrane is to be covered. Coverings of poured concrete may have a somewhat steeper slope.

When performing stability calculations, it is necessary to consider sustainable operations (weight of materials, ice, snow, etc.), transient situations (weight of machinery and excess material during construction, rapid emptying, etc.) and accidental situations (seismic, blocked drain, etc.).

In order to stabilize the cover some geosynthetic materials can be used:

- Geotextile or draining geocomposite between the cover and the geomembrane. Depending on the type of cover, the interface geosynthetic will have to assume several functions:
  - Resist to the tensile forces induced by the cover weight
  - Water drainage at the base of the cover in order to limit the hydraulic pressure when the cover is saturated (thaw, heavy rain, emptying of the pond). Not needed for free-draining material (sand, gravel)
  - Protection against puncture of the geomembrane during installation process of the cover and use of the pond

- Cellular geogrids filled with cover material. Experience shows that the ground is more likely to remain inside the cells if they are partially permeable. In order to retain the ground weight, the cells will have to be connected together or attached to rods running from the top of the embankment to the toe of the slope or to a reinforcement geotextile anchored into the anchor trench

- Anti-erosive geotextiles installed on top of the cover. This geotextile will protect the cover against erosion, will promote the growth of plants and their roots will stabilize the cover
The geotextile installed on top of the membrane has to take most of the tensions induced by the cover. Therefore, the friction angle between the geomembrane and the geotextile needs to be lower than the friction angle between the geotextile and the covering material.

Stability may also be improved by applying a cover of variable thickness (thicker at the base and thinner at the top of the slope) or by applying an abutment at the toe of the slope.

If the cover is made of natural ground with no free-draining capacity, emptying the pond will be done slowly in order to prevent excessive hydraulic pressure at the base of the cover.
2.9. **Inlet/outlet of the water**

Inlet and outlet water systems are essential elements of the infrastructure to control and secure the proper functioning of the reservoir. They need to be designed by a specialized design company taking into account the specifics of each project.

2.9.1. **Inlet**

The characteristics of the inlet are designed following the expected inflow, the water provenance, the geometry of the pond and local topography.

The water inlet can be located at the top of the embankment, in the slope or at the bottom of the pond. The inlet is usually made using a pipe or a concrete structure. In any case, it is essential to dissipate the water energy in order to protect the membrane and the support layer from erosion. It is therefore strongly recommended that there is a concrete slab on top of the geomembrane in places where the water hits the geomembrane with high energy.

![Concrete water inlet from the top of the embankment](image1.png)

*Picture 11: Concrete water inlet from the top of the embankment*

![Pipe water inlet from the top of the embankment without geomembrane protection](image2.png)

*Picture 12: Pipe water inlet from the top of the embankment without geomembrane protection*

When located at the top of the embankment, the inlet level needs to be higher than the maximum water level in order to avoid water running out of the pond via the inlet.

When the inlet pipe is located at the top of the embankment and construction/maintenance vehicles are expected to drive on the crest, the pipe needs to be designed in order to withstand the pressure induced.

When the inlet is located under water (slope or bottom of the pond) it is obvious that the water entering the reservoir needs to have a higher energy than the water pressure inside the reservoir. In this case, it is strongly recommended that a good quality concrete structure is built around the pipe that will allow for a strong connection between pipe and membrane (see drawings at chapter 6.3) and reduce the risk of tensions caused by differential settlement (the ground around the concrete structure will be compacted with special care). The pipe going through the embankment is installed into a trench that will be covered afterwards with reinforced poured concrete (see Picture 15).

If the pond is covered with granular material, the cover could be eroded where the inlet water impacts the soil. The soil will have to be protected with a concrete slab or some riprap in this area.
When the reservoir is filled with water coming from a river, it is recommended that a derivation pipe/canal is installed from the river to the pond. The direct ingress of the river water into the reservoir is certainly not recommended. In the event of a big storm, the river could introduce into the reservoir:

- Large quantities of sediment. This can cause maintenance difficulties when the membrane is not protected
- Large amounts of water in a short period:
  - This can create big waves inside the reservoir. The run off needs to be properly calculated
  - If the spillway is obstructed or not properly designed, the reservoir could overflow, damaging the embankments
- Potentially aggressive objects with the risk of damaging a non-covered membrane (branches, rocks)

If the reservoir is located in a river bed (although not recommended) and a diversion of the river is not feasible, the geomembrane will be covered or/and a hydraulic infrastructure will be constructed upstream, in order to promote the sedimentation of small particles, capture the floating objects and a decrease in water energy. A water drainage system will be provided under the geomembrane in order to avoid the erosion of the support layer. Special care will be given at the water inlet in order to avoid water running under the geomembrane. A system of bypass will have to be installed to divert the incoming water during the reservoir maintenance.

2.9.2. Outlet pipe

The outlet pipe is usually located at the bottom of the pond or at the toe of the slope. Therefore, it is an essential detail for the watertightness of the pond as it is going to be exposed to a high water pressure. The pipe has to go through the base of the embankment. The design of the outlet pipe therefore has to be done with special care.

The diameter of the pipe needs to be designed according to the required flow for downstream infrastructures. It is recommended that the water speed inside the pipe is higher than 0.6 m/s (to avoid sedimentation) and lower than 2.0 m/s (to avoid erosion). The entrance of the outlet pipe will be higher than the bottom of the pond in order to avoid its obstruction by sediments (estimate the annual income of sediments). The complete emptying of the pond will be done through the discharge pipe (see chapter 2.9.3).
When the outlet pipe is located on the embankment, it is recommended that the outlet pipe comes through the membrane perpendicular to the slope so as to facilitate the connection to the geomembrane. The outlet pipe will have to go through the embankment into a trench that will be covered afterwards with reinforced concrete designed according to the expected ground weight. For very big projects, the collector pipes can go through a service tunnel. The valve system depends on the scale of the reservoir. For large scale structures, upstream valves are to be installed in a dry and accessible valve house. It is essential that valves are also accessible in winter. It is recommended that a valve system is installed which can also be serviced when the reservoir is full.

Additional information regarding water outlet pipes:
- Pipes are to be in steel or cast iron.
- Minimum diameter of 300 mm.
- In order to prevent piping phenomena in case of leakage, the pipe shall be placed in a trench that will be filled with reinforced poured concrete.
- Drainage shall be provided around the pipe for the downstream half of the dam body, to collect water under pressure coming from leakage of the pipe or failure of a connection between the pipe and the geomembrane. Drainage can also be provided around the connection between the geomembrane and the pipe.
- Expansion/compensation joints are to be provided.
- Special attention must be given to the connection between the pipe and the geomembrane. The connection will be made through mechanical anchoring of the geomembrane to a concrete block in which the pipe is embedded and finished with Firestone QuickSeam FormFlash (see drawings of the chapter 6.3). The concrete block shall be constructed so as to limit differential settlements and present a smooth surface in the area for connection with the geomembrane. It is essential that the concrete is of excellent quality and is applied in accordance with the best code of practice.

Galvanized trash retention racks are to be provided to prevent obstruction of the outlet pipe. In the case of an inlet chamber, it is recommended that bars (spaced about 1/3 the diameter of the pipe or sluice gates) are installed and an opening placed at such a height as to prevent obstruction (sedimentation).

In order to avoid membrane movements while pumping the water, which could obstruct the outlet pipe and cause tensions on the geomembrane, the application of a concrete slab is recommended on top of the membrane (with a protective geotextile) with a minimum surface of 2 m².

Figure 22: Cut of the water outlet pipe
Picture 15: Outlet pipe through the embankment

Picture 16: Water outlet pipe in the embankment with ballasting concrete slab

Picture 17: Water outlet pipe at the bottom

Picture 18: Concrete water outlet combined with the spillway

Picture 19: Good quality concrete structure around water outlet pipe
2.9.3. Discharge pipe

In large scale projects, presenting a high human risk in case of disruption, it is recommended that a discharge pipe be installed for safety measures. It allows the reservoir water level to be rapidly and completely lowered when a major failure is observed. The discharge pipe can also be used to totally empty the reservoir for maintenance reasons.

The discharge drain must be dimensioned so as to empty the entire volume of water within 1 or 2 days (depending of the volume stored). It is strongly recommended that discharge is facilitated by gravity.

The entrance of the discharge pipe will be protected with a galvanized trash retention rack in order to avoid any obstruction.

The discharge pipe will be installed in the same trench as the outlet pipe. All the recommendations given for the outlet pipe will be followed for the discharge pipe (see chapter 2.9.2).

2.9.4. Spillway

In order to prevent the overflow of the reservoir an emergency spillway should be designed by a registered professional engineer and properly constructed in the reservoir sidewall to allow water to spill over onto a non-erodible hydraulic structure in case of emergencies such as a plugged pipe or extreme rainfalls.

- **Type:** it is recommended to build a free weir spillway the discharge threshold of which is at the same height as the normal reservoir level. Other frequent types of spillway are the pipe and tower spillway.

- **Hydrological dimensioning:** the dimension of the spillway must allow evacuation of excess water for flooding of the facility so that the reservoir level stays equal to or lower than the high water level. A safety coefficient must be applied.

- **Obstruction:** the spillway risks being obstructed. This must be considered in its construction. It is recommended that the spillway be constructed with gentle slopes and splayed walls to allow access by maintenance machines.

- **Threshold:** a reinforced concrete threshold is recommended to resist hydrostatic and ice pressure. Its foundation must not be subject to freezing. Special attention must be given to the connection between the threshold and the geomembrane.

- **Sluice:** the sluice may be built of various materials (reinforced concrete, gabions, concrete permeated riprap, etc.). In all cases it is essential that the support resists erosion, especially at the exit downstream of the threshold. It is usually helpful to provide underside drainage to avoid erosion of the subsoil and uplift pressure.

- **Discharge:** may be built from the same materials as the sluice. Its design dissipates the energy of the water before discharge into the natural environment.

- **Downstream discharge:** an energy dissipater shall be provided at the discharge outlet in order to prevent erosion of the downstream slope.
Picture 22: Pipe spillway

Picture 23: Spillway tower
2.10. Wind Uplift

When the reservoir is not always filled to the normal water level, exposed geomembranes must be weighted to prevent uplift by wind action. Wind uplift protection needs to be designed based on the expected winds, the length of the slope, and the exposure of the pond. The designer will define the type of ballast, its weight and its location (grid).

The highest wind uplift forces are situated on the first 5-6 m of the slope (from the top) due to the induced turbulences caused by the embankment. It is therefore strongly recommended to at least ballast this area.

At the top of the embankment, the anchoring/ballast of the membrane is described in chapter 2.4.1.

On the embankments, wind uplift protection can be done in different ways (see also chapter 2.4.2):

- **Parallel to the slope:**
  - Ballast (precast concrete slabs, PE bags) coming from the top of the embankment and anchored on the crest. This solution can only be applied on the first few meters of the slope.
  - Ballast on the entire length of the slope (precast concrete slabs). In this case, an abutment at the toe of the slope will be needed.
  - Anchor trench running parallel to the slope.

- **Perpendicular to the slope.** In this case it is needed to make a berm on the embankment in order to ballast or anchor the membrane. This solution is difficult to operate, expensive and requires special solutions to insure the continuity of the water and gas drainage.

- **Mechanical anchoring or gluing to concrete structures.**

In any case it is very important that the geomembrane is well protected from the ballast (geotextile, extra piece of geomembrane) and that the ballast will not move.

At the bottom of the pond, even when empty, it is always recommended that a minimum quantity of water be left for ballast. If this is not possible, ballast will be placed at least at the toe of the slope.

In order to avoid movement and lifting of the geomembrane during installation, temporary ballast must be used. Such ballasting also facilitates the splicing operations. The ballast can consist of sand bags, tires or wooden planks.

**Picture 24: Wind ballast with precast concrete slabs anchored on the crest**

**Picture 25: Wind ballast with PE bags filled with gravel and anchored on the crest**
Picture 26: Wind ballast with precast concrete running on the entire slope

Picture 27: Wind ballast with precast concrete on intermediate berm, at the toe of the slope and the bottom surface
2.11. Dimensional movements

Exposed membranes will undergo dimensional changes due to temperature differences. Furthermore, like any other geomembrane, EPDM is going to retract during its life time. In the case of EPDM, this is mainly due to the continuation of the vulcanization process. Dimensional movements will be increased by exposure time, weather conditions and the size of sheets. Dimensional movements need to be taken into consideration during design in order to avoid excessive tension on the geomembrane and seams.

Depending on project specifics, the following can be done:

- Cover or ballast the geomembrane (see chapters 2.8 and 2.10)
- Mechanically anchor and/or glue the geomembrane to concrete structures
- Anchor the geomembrane in trenches

Folded panels have a lot of stress from the folding and winding built into the sheet. These stresses will dissipate causing the membrane to shrink (shrinkage due to relaxation). Leaving the membrane ample time to relax before seaming is an easy way to anticipate this shrinkage effect.

2.12. Panel and seam layout

A panel and seam layout indicates the location of the geomembrane panels and their seams.

The panel and seam layout will be made in three different stages:

- Before building the reservoir: this step is important to evaluate the type and quantity of needed materials and estimate the cost of the project. The details of the project will be studied to see if they are adapted to EPDM geomembrane installation.
- Following acceptance of the support, the panel layout will be adapted to the final shape of the reservoir based on the as-built drawing provided by the groundworks contractor. The goal is to evaluate the exact quantities, reduce losses and facilitate the installation process (panel orientation, limit on-site splicing and cuts very important in the corners, distribution of the material).
- After geomembrane installation the as-installed panel layout will have the following information:
  - Panel location with geomembrane reference numbers
  - Seam location with QuickSeam Splice Tape and QuickPrime Plus reference numbers
  - Location of patches (T-joints, repairs)
  - Gas drainage and vents
  - Pipe penetrations and details
  - Destructive seam control samples
  - Anchor trench
  - Operation facilities

The panels need to be installed so as not to have seams perpendicular to the slope. The as-installed panel layout will be very important for the quality control and the maintenance process (even more for covered membranes). This will be the identity card of the geomembrane waterproofing system.

Figure 23: Example of as-installed panel and seam layout
2.13. Operation facilities

The main operation facilities needed for the normal use of a water reservoir are already described in the chapters above (water inlet, outlet, spillway).

To avoid damaging the installation during use, it is necessary to plan suitable infrastructures at the design stage:

- Service road, maneuvering and parking areas: the use or maintenance of the reservoir could require the maneuvering of machinery in the immediate proximity of the installation. It is therefore necessary to strengthen the access areas and ensure the security of workers. All such infrastructure will be equipped with a running water collecting system.
- Cleaning: access and maneuvering of machines on the bed of the reservoir can only be achieved if provisions were made during the planning stage through a protected access ramp and a layer of concrete laid over the whole bed.
- Pumps, valves and pipes facilities will be located close to the external embankment, in line with the pipes going through the embankment, in an enclosed, dry engine room.

2.14. Risk level

The whole design of the project will be conditioned by the incurred risk in case of failure of the reservoir (human, environmental, economical).

Depending on the potential risk incurred, the safety factors will be adapted in the stability calculation for each potential situation concerning the infrastructure:

- Finished project
- Full pond
- Break of the geomembrane waterproofing system
- Earthquake at full pond
- Quick emptying of the pond
- …

2.15. Legislation

There may be various legislations involved when creating a new project:

- Town planning legislation
- Water legislation
- Agricultural legislation
- Environmental legislation
- Forestry legislation
- …

Those different legislations can have a major impact on various aspects of the project:

- Preliminary studies (geotechnical, environmental)
- Site location (distance from housing, wells, rivers, buildings, protected areas)
- Storage capacity (permitted pumping, minimal storage capacity)
- Shape of the pond (free board, landscape integration)
- Safety measures (leakage detection system, cover, double layer)

It is therefore essential to study the different legislations in force during the design process.
3. Installation

The installation must be carried out in good climatic conditions to ensure the quality and durability of the finished installation. During the construction and installation process, a conflict between quality and speed of installation can arise. It is therefore essential to have a quality assurance plan that defines precisely the required control actions which will help ensure quality of the installation (see paragraph 4.1).

The information provided below approximately follows the different installation stages.

3.1. Site preparation

The preparation of the worksite consists of the following operations:

- Building of site access routes (with sufficient load capacity)
- Temporary drainage works to avoid the ingress of water into the storage reservoir, to lower the groundwater, evacuate rainwater, divert any water inlet
- Brush cutting of the whole site
- Laying out and leveling of the site
- Removing topsoil (humus, grass, roots). Some of this soil may be used to construct the exterior banks
- Preparing a storage place outside the working zone. It must be flat, clean, dry and with enough load capacity.

It is important that marking and leveling of the site is done in accordance with construction drawings. A site meeting will be organized after marking out and before starting the excavations, between the client, the project manager and the contractor, to verify conformity and validate the installation.

3.2. Earthworks

3.2.1. Site layout

The site layout may be obtained by means of:

- Excavating natural soil
- Building raised embankments (for stability reasons a minimum excavation of 1 m is recommended)
- Partial excavation with raised embankments

The table below shows the advantages and disadvantages of the three systems.

<table>
<thead>
<tr>
<th>System</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Fully excavated   | • little soil movement (naturally consolidated)  
                    • lower cost                        | • removing the excavated earth        
                    • water drainage problems          |
| Raised embankments| • easier drainage                    | • higher cost                          
                    • the work is above the water level | • compacting required                
                    • risk of unstable embankment      |
| Partial excavation| • compromise of both systems         | • moderate cost                        |

Table 7: Advantages and disadvantages of three groundwork systems

3.2.2. Foundation

The type of machinery used to build the foundation and the obtained productivity will depend on the type of ground on site. Usually the ground is excavated at the base of the pond with a digger. In case of a rocky substrate, stronger machines (excavator with Jackhammer) or controlled blasting will be needed.

The excavated ground is loaded onto trucks and brought to the embankment zone, leveled using a bulldozer and a grader in uniform horizontal layers of 200 to 500 mm maximum (depending on the type of ground) and then compacted (at the right moisture content) with a compactor (road roller, chevron tamping wheels). The entire layer thickness needs to reach the desired compaction strength.

Before starting the excavation works, the general contractor needs to drain the site and protect the site from any potential flooding.

Before raising the embankments, it is strongly recommended to excavate a minimum of 1 m of natural ground and compact the base of the embankment properly.

In places where the natural slope is greater than 10%, the excavation will proceed with terracing.
At the start of on-site installation, test sections will be made in order to define the adequate compaction process (machine type, humidity, layer-by-layer thickness, compaction speed, number of passes). The entire foundation must be compacted at 95% of the Proctor Optimum value. On-site density and humidity measurements will be taken every day.

Around concrete structures, the compaction will be done manually in order to avoid future differential settlements that could put the geomembrane under stress.

The bottom of the pond will be leveled with a minimum slope of 2%. The top of the embankment will be leveled with an external slope of 1-2%.

At the end of the project, the external embankment will be protected from erosion (grassed by hydroseeding).
3.2.3. Preparation of the support layer

The degree of compaction of the entire support layer needs to reach the 95% of the Proctor Optimum value. The compaction is achieved by either natural compaction or by mechanical methods. The smoothness of the interior sides of the pond (slopes and bottom) must be of impeccable quality. The supporting surface must not contain any loose stone with a diameter exceeding 5 mm. If needed, a stone crusher will be used before compaction or a backfill layer (sand, stable earth) of minimum 20 cm thick with controlled particle size (maximum 20 mm)² will be installed and compacted.

All the angle changes of the support structure (crest/embankment, embankment/embankment, embankment/bottom) will have a curvature radius of minimum 0.5 m.

Particular care must be taken to ensure that construction equipment does not cause deformation or a change in the surface texture (grooves, exposing of stones).

The compaction operation can be followed by an authorized weed killer treatment (compatible with EPDM).

6 Information provided on page 142 of the “Retenues d’altitude” – see bibliography for full reference
3.2.4. Inlet/outlet structures

The outlet pipe will be installed as soon as possible and certainly before raising the embankments. It is strongly recommended that the outlet pipe and in general all pipes going through the embankment (inlet under pressure, discharge, drainage) are covered with reinforced concrete over their entire length and in continuity with the upstream concrete structure.

The type of concrete used and its installation process will be selected so as to ensure a good contact between the concrete and the pipe. The external face of the concrete will be rugged to guarantee good contact with the surrounding ground. The compaction of the ground located close to the concrete covered pipes will be done with special care. The compaction process will proceed layer-by-layer in small thickness section, with a light compactor and numerous passes. The surrounding ground will have a good auto-drainage capacity in order to avoid erosion in case of leakage (ending in a leak detection structure).

The inlet pipe or concrete structure will be installed when the raising of the embankment is almost complete (close to the crest level).

The spillway will be installed at the same time as the inlet pipe.

A special care will be given to the pipe installation. Their watertightness will be tested.

The concrete structures onto which the geomembrane will be mechanically anchored need to be of very good quality (smooth, strong). Special care will be afforded to the compaction of the ground next to those structures.

The inlet and outlet valves will be installed in a way that they can be easily removed for maintenance and replacement.

In places where the geomembrane is subjected to water impact, water movements, or debris impact it is recommended that a structure be installed that will protect the membrane from damage (concrete slab on top of a geotextile, extra piece of geomembrane).

In countries where temperatures drop well below zero, special measures are required so as to avoid damage to pipes from freezing.

3.2.5. Acceptance of excavation work

The lining contractor must visit the project site to check whether the excavation works have been executed correctly. The surface condition must be inspected and any harmful element removed or corrected. Any correction must be made prior to the start of the waterproofing works.

A formal acceptance of the excavation works is required, before installation of the Firestone EPDM Geomembrane lining system. Excavation works are accepted based on following factors:

- The general appearance of the earthworks
- Conformity of dimensions
- The standard of surface compaction
- The geometry of the surface of the embankment crest
- The absence of foreign bodies which might damage the waterproofing layer (roots, iron bars, projecting stones, other sharp objects, etc)
- The management of water infiltration on the inner slopes and the bottom of the reservoir.
- Compliance with the slope of the reservoir bed
- Water and drainage systems (if not made by the lining contractor)

It is important to note that the lining contractor is only supposed to approve the excavation works by means of a visual inspection of the surface of the support structure.

The installation of the geosynthetics (geotextile and geomembrane) will be done as soon as possible after acceptance of the excavation work in order to avoid any erosion of the support.
3.3. Water and gas drainage

The installation of drainage pipes must be carried out with great care to:

- Avoid crushing drains during the movement of site machinery and the compaction process
- Avoid the formation of counter-slopes
- Ensure the continuity of the drainage network (e.g. between the drainage system of the embankment and the drainage pipe at the toe of the slope)
- Ensure the connection of the pipes to manholes
- Ensure the segmentation of the drainage network
- Ensure the proper installation (quality and compaction) of the gravel inside the draining trench
- Respect the installation rules for a filtration geotextile
- Identify buried networks

If due to the lack of permeability of the ground, the installation of a bed of permeable material (minimum 20 cm of sand or gravel (5/20)) is required for proper drainage, its installation will follow the same recommendations given for the construction of the foundation and the support layer. Special care will be given to the stability of this drainage layer if installed on the slopes. The drainage bed will be made of different layers and the particle sizes will respect the filtration law.

If the drainage system is composed of a geocomposite, its installation will be made respecting the panel layout, the slope and the recommendations of the manufacturer. The connection between the different panels needs to guarantee the continuity of the drainage and the filtration. If the connection is made by simple overlap, this overlap will be a minimum of 50 cm. On the embankments, perpendicular connections will be avoided.

Special care will be taken when unloading, storing and installing the water drainage geocomposite to avoid any damage. No machine may be permitted to drive on top of a geocomposite unless properly protected (min. 30 cm of ground and specific care, see chapter 3.9). When a geocomposite is cut, it must not leave any sharp protrusion that could puncture the geomembrane.

3.4. Anchor trench

Anchor trenches are excavated just before the installation of the geomembrane, so that they can be used for temporary ballasting of the geotextile and the geomembrane.

The anchor trench has minimum recommended dimensions of 40 x 40 cm section and is positioned at least 1.0 m from the crest of the embankment.

The time of excavation of the anchor trench is based on the levels of the flow sheet. Make sure that, under no circumstances, climatic conditions can damage the trench and/or cause it to fill.

The back filling and the compaction of the anchor trenches will be carried out in accordance with the rules of good practice, with a slight slope (> 1-2%) towards the outside of the installation so as to avoid any ingress of parasitic water and ground. Running water must always flow around the installation.

In order to reduce the induced stresses/forces while digging the trench, it is recommended that a trapezoidal bucket is used.
3.5. Geotextile

The geotextile rolls need to be stored with an opaque and watertight packaging. The packaging is removed only just before installation.

The installation of the puncture resistant geotextile is carried out as follows:
- Hoisting of the roll using lifting machinery to the crest of the embankment.
- Unrolling of the geotextile along the length of the embankment or in the direction of the slope.
- Unfolding of the strips so as to cover the entire surface of the pond.
- Flattening of creases on the slopes and formation of angle pleats.
- The strips are joined either by thermo-welding or sewing.
- Temporary ballast is required.

The installation of the protective geotextile should not damage the quality of the support layer.

The number of folds of the geotextile will be limited in order to guarantee a lay flat installation of the geomembrane.

The rolls of geotextile are to be sewn or thermo-bonded together (min. 20 cm overlap) in order to avoid any movement of the geotextile while installing the EPDM geomembrane. Only sewn seams can be installed perpendicular to the slope.

Unless specially formulated for UV and weather resistance, the protective geotextile will be covered as soon as possible after installation.

3.6. Geomembrane installation

3.6.1. Panel and seam layout

Following acceptance of the support, the panel layout will be adapted to the actual shape of the pond based on the as-built drawings provided by the ground working contractor.

The panel and seam layout will facilitate the installation process as the foreman will know where to position the rolls, how to unroll them, how to deal with the corners, and where to reuse cut offs.

The panel and seam layout needs to be implemented every day by the foreman following the information provided in chapter 2.12. This document will also be used at the end of the installation to draw the as-built panel and seam layout.

3.6.2. Transport and storage

Care should be taken not to damage the geomembrane during transport, loading and unloading. The rolls must be stacked on a flat, dry and clean surface, free from any sharp protrusions.

Firestone EPDM Geomembranes do not require any special protection against weather conditions. However, all accessories need to be stored in a dry and cool place between 10°C and 25°C.

The use of specific machines or equipment is recommended for transporting the rolls to where they need to be installed.
3.6.3. Placing the geomembrane

The rolls are unwound and unfolded according to the layout plan. Installation starts with covering the embankments. The geomembrane panels are unrolled from the trench towards the embankment and the geomembrane is temporarily fixed/ballasted to avoid it slipping down. Ensure that no pebbles or sharp objects are trapped under the geomembrane, whilst the sheets are being unrolled. Be sure that nobody is standing downward of the roll before letting it go onto the slope.

If the panel needs to be moved after unfolding, the geomembrane can be lifted at the edge allowing air to play underneath, thus moving the membrane on an air cushion.

The geomembrane must be installed with some slack to allow for some shrinkage (continuation of the membrane vulcanization) and dimensional variations due to temperature changes and prevent overstretching in case of differential settlement. However, it should not be installed leaving excessive wrinkles or creases, especially not in seaming areas.

Excess membrane must be left at the foot of the embankment for connecting with adjoining panels. Horizontal splices on the embankments must be avoided.

In the corners, the membrane will be either folded or cut. The folds will be fixed with Firestone QuickPrime Plus. It is recommended to cover the folds with QuickSeam Batten Cover strips or QuickSeam SA Flashing.

Firestone EPDM Geomembranes must relax for at least 30-45 minutes before attachment, cutting or splicing the seams or executing details. Straight cuts are very important for a neat and easy application. Firestone recommends the use of scissors, markers and chalklines to achieve this. Do not use cutters.

While installing the sheets, folds in the geotextile and damage to the supporting surface must be avoided.

It is not recommended that EPDM geomembrane sheets are installed when there are heavy winds.

Machines are not allowed to circulate on top of the installed membrane unless it has been specially protected.

![Unrolling, unfolding](image)

![Moving the geomembrane on air cushion](image)
3.6.4. **Temporary ballast**

Directly after unfolding the geomembrane, some temporary ballast needs to be installed in the anchor trench and on the geomembrane in order to avoid the geomembrane slipping down the slope or being lifted by the wind.

When different panels are seamed together, the wind can enter under the geomembrane and move large quantities of seamed panels. It is then impossible to replace the panels without making some cuts. Great care therefore needs to be taken at the end of every working day to make sure that the installed panels are properly ballasted.

Temporary ballasting can be done with sand bags (connected or not by ropes) or any other non-abrasive material such as rubber tires, etc.

![Temporary ballast of the geotextile and the geomembrane with sand bags](image)

3.6.5. **Seaming adjoining geomembrane panels**

The splicing of adjoining panels should be performed immediately after the relaxation of the Firestone EPDM Geomembrane. All panels must be installed without tension and without major wrinkles in the seam area, overlapping by at least 150 mm. All seams on slopes must run up and down the slope with no horizontal seams allowed.

**Seaming procedure**

Two overlapping Firestone EPDM Geomembrane panels are assembled by means of 76 mm (3") wide self-adhesive tape, QuickSeam Splice Tape. Below are the various steps required for correct splicing.

**Step 1: Position, fold back the lap edge and temporary bond adjacent panels**

Position the sheets at the splice area with an overlap of ± 200 mm (min. 150 mm). The geomembranes must lay flat and without any tension. The upper geomembrane panel is then folded back ± 200 mm (min. 150 mm). A line of primer (scrubber width) will be applied simultaneously on the two panels along the entire inside length of the joint. The upper panel is released and contact is made between the 2 panels by walking on the primed zone.

Temporary bonding the 2 panels will secure their position during the entire seaming process and avoid any dust coming from the substrate into the seaming zone.

![Seaming – Fold back and temporary bond](image)
**Step 2: Mark the sheets**

Once both membranes are in place, mark the bottom sheet 10 to 20 mm from the edge of the seam every 300 mm with the white crayon provided.

Use an index finger as a guide along the top edge; this gives an accurate measurement for this step. The marks will serve as a guide for the application of the QuickPrime Plus and installation of the QuickSeam Splice Tape.

![Figure 25: Seaming – Position and mark of the panels](image)

**Step 3: Tack-back the overlap**

Tack the top sheet back with QuickPrime Plus at 3.0 m centres and at factory seams. This holds the fold in place during the splicing operation.

![Figure 26: Seaming – Tack-back the overlap](image)

**Step 4: Apply QuickPrime Plus**

Remove excess dust and dirt on the sheet and at factory seams, using a stiff broom. Pre-scrubbing is required at all areas that have excess amounts of dust, mica and at all factory seams. Dip the Quick Scrubber Pad into the QuickPrime Plus, keeping the scrubber horizontal and flat so that no primer drips out prematurely.

Apply the QuickPrime Plus using long back and forth scrubbing strokes, parallel to the seam along the length of the splicing area, until the surface becomes dark grey in color with no streaking or puddling. Scrub both surfaces at the same time to allow the same time to go off, start on the folded overlap. Be sure to overlap the guide marks on the bottom sheet and go beyond the edge of the top sheet.

![Figure 27: Seaming – QuickPrime Plus application](image)
**Step 5: Check QuickPrime Plus for dryness**
Allow the QuickPrime Plus to go off completely. To test for dryness, use the touch-push test by pushing straight down onto the QuickPrime Plus with a clean, dry finger. Push forward on the primer at an angle. The primer should feel tacky but not stringy to the finger.

![Figure 28: Seaming – Check for dryness of QuickPrime Plus](image)

**Step 6: Install 76 mm (3") Splice Tape**
Position the 76 mm (3") Splice Tape on the bottom sheet with the release paper facing upwards. Align the edge of the release paper with the marks. Roll the tape immediately using a 50 mm wide silicone rubber hand roller, applying firm pressure across the tape to remove any air that may be trapped between primer and tape. Hand pressure is not sufficient to seal the seam, since it does not provide uniform compression.

![Figure 29: Seaming – Splice Tape installation](image)

**Step 7: Check tape alignment**
Untack the top sheet and allow it to fall freely onto the tape. Trim the top sheet back at all areas where the tape does not extend 5 to 15 mm (maximum 22 mm) outside the seam edge.

![Figure 30: Seaming – Check tape alignment](image)
Step 8: Remove paper backing
To remove the release paper from the tape, peel the paper off the Splice Tape, by pulling it away from the seam at a 90° angle to the tape. Pull the paper at a steady pace and keep it low to the pond surface as it is removed to reduce air pockets. Close the entire length of the seam by hand, when the release paper is being removed.

Figure 31: Seaming – Paper backing removal

Step 9: Roll the seam
Roll the seam with the 50 mm wide silicone rubber handroller, both across the seam (1) and along its entire length (2) above both edges of the tape.

Figure 32: Seaming – Final rolling

General recommendations
- The support structure needs to be well compacted in order to guarantee a good seam (proper rolling).
- All splicing surfaces must be free from dirt, moisture, adhesive or sealant and any other contaminants before the installation of QuickSeam Products. When necessary, pre-clean with the cleaning agent Splice Wash prior to the application of QuickPrime Plus. Other cleaning products, such as unleaded gasoline are not recommended. They may be contaminated with traces of products that may react adversely with EPDM geomembrane and fail to activate the surface in the same manner as Splice Wash.
- All seaming products (QuickSeam Splice Tape, QuickPrime Plus) have product limitations. Follow the technical specifications outlined in the Technical Information Sheets to ensure correct application. Store all Firestone materials in their original sealed pails or unopened packages and rotate perishable materials so that they are used prior to the end of their shelf life.
- Firestone recommends storing primers and sealants at room temperature between 10°C and 25°C. Restore to room temperature during 3 to 4 hours prior to use. Splicing activities may continue in cold weather provided adhesive, QuickPrime Plus and sealants are at room temperature prior to application and are used within a 4-hour period after being taken to the seaming zone. Stir primer thoroughly before and during use. This is a critical step that assures that the material performs properly, do not alter the products by adding solvents.
- Firestone recommends seaming the membranes between 10°C and 30°C.
- Precautions should be taken when using QuickPrime Plus in cold weather conditions (below 10°C). Certain combinations of temperature and humidity may cause condensation to form on the surface of the primer. If this occurs, stop priming, wait for better ambient conditions prior to drying the surface and re-application of the QuickPrime Plus.
- Complete a test splice to determine the risk of condensation. Never use heat guns or torches to accelerate the drying process of QuickPrime Plus. In normal conditions QuickPrime Plus will go off in 5 to 10 minutes, quicker in hot weather.
• In hot weather Firestone recommends applying QuickPrime Plus first onto the bottom sheet and then installing the tape. After the tape has been rolled, apply QuickPrime Plus to the top sheet. Extreme warm weather may dry out the solvents quickly. This can be avoided by protecting the primer pails against hot temperatures by installing an insulation board between the can and membrane on hot summer days and by keeping the pails out of direct sunlight.
• Before using the QuickPrime Plus, ensure that it is thoroughly stirred and poured into a small bucket.
• Assemble the QuickScrubber Pad by twist-locking it into the Scrubber handle. Scrubber pads will last for approximately 60 lm of seam. Replace with a new pad when the pad becomes compressed or when it has dried primer on it. Change the pad at the start of each working day.
• In normal application, three strokes are typical. The first stroke is to spread the QuickPrime Plus and scrub the membrane; second stroke is to scrub the membrane and penetrate the primer, the third stroke is to eliminate puddles of QuickPrime Plus.
• Pre-scrubbing the areas with excess dirt will help the priming process. Three to five strokes with the QuickScrubber, perpendicular to the seam edge is necessary.
• During the positioning of the tape on the bottom sheet, misalignment may occur. Stop the operation, cut the Splice Tape, make an overlap of minimum 25 mm with the end of the installed tape and continue the alignment with the markings. Mark the area for future reference (installation of reinforcement patch). Cutting the tape should be done with the tape sandwiched between 2 pieces of release paper for a clean cut.
• Any “fish mouth” gap that occurs during installation of the tape should be cut away and repaired with a piece of QuickSeam FormFlash, covering the perimeters of the cut by minimum 75 mm in all directions.
• After closing the seam, it is important to observe a continuous mark of primer beyond the fold line of the top sheet.
• Moving the Firestone EPDM Geomembrane during application of the Splice Tape and during the first few minutes after application should be avoided.
• Positioning of a larger number of panels than can be spliced in one day is not allowed.
• Field seams on side slopes must run parallel with the slope i.e. up and down the slope. Horizontal field seams on slopes are not permitted.

Special considerations

End of Splice Tape

The adjoining roll of tape must overlap a minimum of 25 mm. At these areas a patch of QuickSeam FormFlash should be installed as illustrated. Apply Lap Sealant around all exposed edges of the QuickSeam FormFlash.

Figure 33: End of splice tape

T-joints

There are two types of T-joints possible, depending whether the transversal joint covers the longitudinal or vice versa. In both cases, a QuickSeam FormFlash patch is necessary to the dimensions as illustrated below.

When the transversal seam lies on top, trim the QuickSeam Splice Tape so that the edge of the tape and the edge of the EPDM membrane are flush. Cut away any excess EPDM membrane at the inside of the seam at a 45° angle. Install a QuickSeam patch over the T-joint area as illustrated below. Seal all exposed edges of the covering piece with Lap Sealant.
Figure 34: T-joint – Transversal seam lies on top
Figure 35: T-joint – Longitudinal seam lies on top
**Vertical splice reinforcement**

In the area where a field splice runs from the horizontal area into any slope of the embankments the installation of a joint cover piece at the base is required. The joint cover piece of a minimum 150 by 150 mm will be centered over the seam edge.

![Figure 36: Vertical splice reinforcement](image)

**3.6.6. Tool list**

**Job preparation**
- Tape measure (50 m and 5 m)
- Chalk line
- Scissors
- Claw hammer
- Stiff bristle brooms
- Squeegee

**Cleaning EPDM geomembrane**
- Clean Cotton Rags
- Cleaning Agent – Firestone Splice Wash

**Mechanical fixation**
- Drilling machine with key
- Drill bits (masonry and steel)
- Hack-saw with blades
- Screw-driver
- Mastic gun
- Tin snip

**Installation details**
- Quickscrubber pad + handle
- Small plastic bucket
- Marker (white)
- Roller – 50 mm width (silicone rubber)
- Brushes (solvent resistant, short hair and 100 mm width)
- Paint rollers (solvent resistant, short hair and 225 mm width)
- Hot air gun

**Additional tools**
- Electrical leads
- Rubber gloves
- Tool box with lock
- Mixer
- Cutter
- Insulated storage box
- Temporary ballast
- Safety tools
3.7. Timing

The installation speed of a Firestone EPDM Geomembrane System is greatly facilitated by its large panels, flexibility, high friction angle and splice tape seaming process. The installation speed will be greatly affected by the following factors:

- Weather conditions
- Available machines
- Accessibility
- Experience of the contractor
- Number of details
- Length and angle of the slope
- Shape of the pond

An area of 150 m²/day/person is feasible for projects with experienced contractors, with adapted equipment and easy access. In general, for big projects, we recommend a team of minimum 6 persons (2 welders + 4 assistants), not counting the digger operator for the anchor trench.

3.8. Weather conditions

EPDM geomembranes have been applied at temperatures as low as -40°C and as high as +50°C without the use of any special equipment. However, at extreme temperatures, there are a couple of points to consider in order to achieve a quality installation.

- EPDM geomembrane panels usually relax within 30 minutes of placement. Colder weather extends this waiting time. EPDM geomembrane will remain flexible up to -45°C and colder.
- The temperature of EPDM geomembrane can rise up to 80°C when exposed to the sun. It is recommended to wear gloves when handling the Geomembrane and wear knee protection when waterproofing seams and detail work.
- Placement of EPDM geomembrane must not be performed during any form of precipitation (rain, snow, hail), heavy wind, fog and/or in the presence of any surface moisture or in an area of standing water.
- Installation and positioning of large EPDM geomembrane panels may be difficult in windy conditions. Prevent any wind from getting under the geomembrane during installation. Use temporary ballast to keep the geomembrane in place until finally secured to the substrate.

Precautions should be taken when using Firestone QuickPrime Plus, adhesives and sealants in cold weather conditions (below 10°C):

- Start working with QuickPrime Plus, sealants and adhesives at room temperature (15-25°C). The use of insulated, heated boxes may be advantageous.
- Cold weather will extend the drying time of QuickPrime Plus and adhesives, since the solvents will take longer to evaporate.
- Seaming a geomembrane at temperatures between +5°C to -7°C is going to require special attention, whereas seaming at temperatures below -7°C is considered to be very difficult. However, the temperature mentioned is the temperature of the geomembrane, which is influenced by the sun (significant warming) and wind (wind chill factor). Preheating the EPDM geomembrane in the seaming area might – in some extreme conditions of cold and wind – be necessary to reduce drying time and make seaming possible.

- When using Firestone QuickPrime Plus in warm weather conditions (> 25°C) the following changes should be made to the installation technique:
  - Do not store the QuickPrime Plus directly onto the heated geomembrane but insulate the product from the geomembrane.
  - Do not leave primer cans open as the solvents will evaporate quickly.
  - As temperature increases, the drying time of the QuickPrime Plus is reduced. In order not to exceed the open time (time during which the primer remains active) shorten the length of the seaming section to 10 lm. Alternatively the primer can be applied to top and bottom side of the geomembrane separately, starting with the lower membrane. Apply the QuickSeam Splice Tape before priming the top membrane.

- Certain combinations of temperature and humidity may cause water condensation to form on an area of drying primer or adhesive. The actual appearance of condensation is somewhat unpredictable and its occurrence should continuously be monitored as work progresses. To determine if condensation has occurred, the following test can be performed. Approximately five minutes after the primer or adhesive is applied, touch the surface with a clean dry finger. If the primer or adhesive is tacky to touch, there is no condensation. If the primer or adhesive is coated with a film of moisture, it will not stick to the finger. If this condition occurs, seaming work must stop until the ambient air conditions no longer cause water condensation after which a thin additional layer of primer or adhesive needs to be applied.
- Do never use open flame sources (propane torches, etc.) to expedite drying of the primer, adhesives, sealants, etc. Air-dry only.
3.9. **Top protection installation**

Often during installation of the cover layer, the membrane is subjected to the critical stresses. It is therefore essential to take all possible precautions when applying the cover layer over the geomembrane. Movement of machinery on the membrane should be prohibited unless absolutely necessary and with the use of special precautionary measures.

The installation of the cover layer will start with the positioning of a protective geotextile. The installation process will be the same as for the geotextile located under the geomembrane (see chapter 3.5). The different panels need to be connected by sewing (preferred) or thermo-welding.

The granular layers will be installed following the installation of the membrane in order to avoid any machinery running on the installed geomembrane.

If the installation process requires machinery to run on top of the geomembrane and the protective geotextile, some specific tracks will be created. The thickness of the track will depend on the characteristics of the project: geomembrane thickness, protective geotextile, granular material, machinery, substrate. It is strongly recommended that a test plate is made with the expected material and machinery before installation.

The trucks will run on tracks of minimum 1.0 m thick and will unload onto an already covered surface (minimum 1.0 m thick). The tracked excavator will run on tracks of minimum 0.5 m thick. The machinery needs to drive slowly, straight (no u-turns) and brake softly.

The cover material will first be located in windrows and then gently spilled with an excavator on top of the geomembrane. The cover material will not be pushed onto the geomembrane in order to avoid wrinkles.

On the embankments, the granular material will be installed from the bottom to the top. If possible, the use of long arm excavators is recommended. Under no circumstances will the granular material be unloaded from the top of the embankment and allowed to slide on top of the geomembrane.

The cover layer will be softly compacted. On the embankments, compaction will be done from the bottom to the top following the line of greatest slope.

3.10. **Details**

If possible, avoid cutting the Firestone EPDM Geomembrane at details. In some cases, however, as with corner details against concrete walls and connections to pipes, a cut in the geomembrane will simplify the installation. In such cases, QuickSeam FormFlash (unvulcanized rubber sheet) will be used in order to provide a watertight seal of the detail.

3.10.1. **Corners**

**Inside corner using 229 mm (9”) QuickSeam FormFlash**

**Applicability**

When flashing onto a concrete structure, the EPDM membrane is cut at the corners so that a vertical seam can be made at the angle change. The vertical seam is completed with 76 mm (3”) QuickSeam Splice Tape in accordance with general seaming techniques.

**Installation instructions**

The inside corner detail is a two step process using two identical pieces of QuickSeam FormFlash to cover the pinhole in the corner. Apply QuickPrime Plus on the membrane, to an area covering 150 mm from the pinhole on the horizontal and 250 mm on the vertical surface. In case the hole is larger than a pinhole one should install first a piece of SA Flashing.
Both pieces of QuickSeam FormFlash are 229 mm wide and 300 mm long. Make sure to round all corners of the cut QuickSeam FormFlash pieces. Allow the QuickPrime Plus to go off completely before closing the QuickSeam FormFlash.

Fold the first QuickSeam FormFlash piece back on itself lengthwise, making sure the fold is approximately 10 mm offset from the center of the piece. Fold back a square base on the smaller half and remove the release paper.

Position the folded base on the horizontal surface, 10 mm out from the upstand, as illustrated. Work the flashing piece tightly into the angle change and continue up against the upstand opposite to the vertical seam.

Work the QuickSeam FormFlash piece into the two remaining angle changes, forming a pig ear as illustrated. Beginning at the base, press the piece onto the vertical wall to form the pig ear fold. Work from the base of the fold to remove any entrapped air. Roll the QuickSeam FormFlash gently with a silicone rubber roller.

Apply QuickPrime Plus to the area that will be covered by the pig ear as illustrated and adhere the pig ear on the side of the vertical seam. Roll all adhered parts of the QuickSeam FormFlash piece with a small 50 mm wide silicone roller.

Use the second piece of QuickSeam FormFlash to cover the pig ear fold after reapplying QuickPrime Plus to the designated area. Be sure to center the width of the second piece over the side edge of the first piece and work it completely into the angle...
change. Roll the entire flashing piece with a silicone roller. Seal all exposed edges with Lap Sealant.

**Outside corner using 229 mm (9”) QuickSeam FormFlash**

At outside corners, the EPDM flashing can be continuous (wrap piece on smaller penetrations), or in separate flashing pieces that are spliced together with a vertical seam at the corner. In both cases, the pinhole at the bottom of the outside corner will be waterproofed using a square piece of QuickSeam FormFlash of 229 mm wide that is cut circular at one end. Round off the cut corners on the opposite side.

After completion of the vertical seam at the corner (if required), clean the corner area with QuickPrime Plus as illustrated. Fold the QuickSeam FormFlash piece in half with the release paper on the outside. Remove the paper from the square half.

Position the flashing piece with the center aligned at the corner. Wrap both sections around the corner and close them to the vertical upstand.

Remove the second half of the release paper and work the QuickSeam FormFlash from the tape side down to the angle change, as illustrated. Work the piece into the angle and continue out approximately 20 mm onto the horizontal surface, without overstretching. The diamond pattern into the material should remain visible. Fold the remainder of the circular part onto the horizontal surface, taking care to evenly distribute the stresses.
Roll the corner detail with a silicone roller from the inside towards out. Apply Lap Sealant along all exposed cut edges of the QuickSeam FormFlash.

3.10.2. Connection to concrete structures above the normal water level

Connections of Firestone EPDM Geomembrane to concrete or masonry structures above the normal water level must comply with the following rules:

- Soil around the concrete structure must be compacted to minimum 95% of the Proctor Optimum Value
- Concrete surface must be smooth, clean, dry and without any sharp protrusion

Firestone EPDM Geomembrane is fully adhered to walls using Bonding Adhesive. Make sure that the sheet is placed in its final position and fold it back evenly onto itself so as to expose the underside. Wipe any dust or dirt from the reverse side of the geomembrane and the wall prior to application of the adhesive. Stir the bonding adhesive thoroughly before and during use. Apply bonding adhesive at about the same time to the underside of the sheet and the substrate to which it will be adhered to (starting by the vertical substrate), so as to allow the same drying time. Use a paint roller with solvent resistant short bristles to apply a uniform film thickness. Care must be taken not to apply bonding adhesive over an area of geomembrane which is to be cleaned and spliced to another sheet or flashing. Allow the adhesive to go off until tacky. Follow the same method to verify as indicated in the splicing section (chapter 3.6.5). Starting at the fold, slowly roll the previously coated part of the sheet into the coated substrate, and work evenly so as to minimize wrinkles. Compress the bonded sheet with a stiff broom to ensure full adhesion.

Figure 37: Bonding Adhesive application
Adjoining wall flashings are overlapped using standard seaming techniques. At the base, install a vertical splice reinforcement of minimum 150 by 225 mm centered over the seam edge as illustrated in Figure 36.

The Firestone EPDM Geomembrane is fixed at the top (above the waterline) using a termination bar. Keep a minimum space of 5 mm between two adjoining bars. The termination bar must be installed directly onto the wall surface. Pre-drill holes into the brick, masonry or concrete but not into the soft mortar joint. A termination bar must be cut at inside and outside corners. Do not bend the bar around the corners. Prior to installation of the termination bar, pull back the topside of the membrane flashing 20 mm and apply a bead of Water Block between the membrane and the wall.

Install the termination bar with an acceptable hammer plug system at 150 mm o.c. Continuous compression is required and if needed additional fastening must be installed. Each termination bar must be fastened a maximum of 25 mm from the end.

Apply a bead of Lap Sealant or an acceptable High Grade Sealant on the topside of the bar.

3.10.3. Penetrations above the normal water level

Connections to penetrations above the normal water level or under low water pressure (less than 2.0 m water pressure) can be made by means of unvulcanized rubber sheet, QuickSeam FormFlash, as follows:

- Pipe needs to be firmly anchored and the pipe temperature may not exceed 80°C.
- Make a circular cut in the geomembrane panel, measuring approximately 50% of the pipe diameter. Pull the geomembrane over the pipe.
- Pipe and geomembrane are flashed together by means of a piece of QuickSeam FormFlash and QuickSeam SA Flashing whenever possible.
- Finally, the assembly is mechanically secured with a stainless steel clamping collar (with a protection strip).

This technique cannot be used for multiple penetrations, flexible conduits and cables.

If the geomembrane has been cut to accommodate the penetration, repair the cut as per Firestone specifications before installing the pipe flashing.

The area around the cut in the geomembrane needs to be reinforced. This will be done with a piece of QuickSeam SA Flashing whenever possible or two pieces of QuickSeam FormFlash.

**Base flashing using SA Flashing**

Cut a piece of SA Flashing that will overlap a minimum of 100mm in all directions onto the geomembrane and cut a hole 20mm smaller in size than the base of the pipe (D x d in Figure 39). Apply QuickPrime Plus on the designated area on the geomembrane and the pipe. Allow the primer to flash off and apply the piece of SA Flashing.

**QuickSeam FormFlash application:**

The base flashing of the pipe consists of two identical pieces of QuickSeam FormFlash. The dimensions of the QuickSeam FormFlash pieces are such that a base overlap of 100 mm with the field membrane in all directions and a 100 mm overlap between the two FormFlash pieces is provided. This results in an overall dimension of \((200 + \Theta) \times (100 + 50+\Theta/2)\). Pipes larger than 225 mm in diameter require the use of one or two EPDM base pieces, applied with normal seaming techniques.

Apply QuickPrime Plus to the pipe and the base membrane around the pipe in the designated area. Allow the QuickPrime Plus to go off completely. Apply the first piece of QuickSeam FormFlash and roll it towards the pipe, mark the diameter of the pipe on the reverse side of the QuickSeam FormFlash and make a horseshoe shape cut ensuring a 25 mm overlap up the pipe.
Mate the QuickSeam FormFlash without stretching to the primed area. Start at both outside edges, maintaining a straight line. Finally work the QuickSeam FormFlash into the base of the pipe. Apply QuickPrime Plus to the overlapping area and repeat the same procedure for the installation of the second piece forming an overlap of 100 mm minimum. Roll both pieces with a 50 mm wide silicone rubber roller.

Measure the third piece (pipe wrap) of QuickSeam FormFlash. This piece should overlap a minimum of 50 mm onto the base flashing. The appropriate length is determined by the circumference of the pipe plus 100 mm for the overlap. Fold back the wrap piece 50 mm and maintaining the fold, initiate contact at the base of the pipe. Stop when the first third of the piece is adhered vertically around the pipe. Use thumbs and forefingers to work the first part of the fold down and outward. Transfer all the stress in the QuickSeam FormFlash to the outside edge.

Apply QuickPrime Plus to complete the overlap and complete the wrap. Finally, work in the opposite direction to work down the remaining part of the fold. Roll the wrap piece and seal all exposed edges with Lap Sealant.

Figure 39: Penetration above normal water level
Figure 40: Mechanical securing with clamping collar
3.10.4. Connection to concrete structures located below normal water level

Mechanical anchoring of the geomembrane to concrete structures needs to be executed with the utmost care. There are several ways of realizing this detail. Some solutions are presented below but they need to be adapted to the specifics of each site (water pressure, concrete quality).

In any case, the following recommendations should be followed:

- Very good ground compaction near the concrete structure (minimum 95% of the Proctor Optimum Value).
- Concrete slab must be smooth, flat and resistant.
- The anchoring metal bar needs to be rigid and the distance between fasteners properly designed in order to apply a constant pressure over the entire surface.
- The geomembrane has to be glued to the concrete structure over minimum 100 mm starting from the mechanical anchoring. For vertical connections, it is recommended to glue the geomembrane onto the entire vertical surface.
- Double or triple the protective geotextile at the junction between the ground and the concrete. The geotextile needs to be glued to the concrete slab.

Figure 41: Mechanical attachment below water line
3.10.5. Penetrations located below normal water level

Special attention must be paid to the connection between the pipe and the geomembrane in order to avoid any tension on this detail. The pipe should be embedded in a concrete block constructed so as to limit differential settlements and present a smooth surface (see pictures in chapter 2.9.2).

The geomembrane will be first mechanically anchored to the concrete block as described in chapter 3.10.4. It is then strongly recommended that the geomembrane be mechanically clamped to a flange embedded to the concrete block and connected to the pipe (see Figure 42). If no flange is available, the pipe will be finished with geomembrane and QuickSeam Form Flash (see Figure 43).

Figure 42: Mechanical attachment below water line and connection to a flange

Figure 43: Mechanical attachment below water line and connection to a pipe
3.11. **Safety**

Specific precautions are to be taken to ensure safety of people and animals on site, especially when the reservoir has been installed close to residential and/or tourist areas.

The following precautions should be taken:

- Safety ladder or climbing rope permanently available for humans
- Low gradient embankment
- Impenetrable fence, 2 m high, around the project
- All required elements to protect workers and machines during maintenance and used in operations
- A rodent ladder in order to avoid damages to the geomembrane by rodents trying to get out of the reservoir
- Adherence to national and local legislation
4. Control and quality assurance

4.1. Control

A construction quality assurance inspector is appointed by the owner or the main contractor (with the approval of the owner), as the quality assurance person who is accountable to the owner and the main contractor for matters concerning quality. The CQA inspector is responsible for monitoring and documenting activities related to the quality assurance of the EPDM geomembrane from delivery through installation. The inspector must have relevant experience with epdm products and be independent from the manufacturer and lining contractor.

An independent geosynthetics laboratory is hired by the owner or the main contractor (with the approval from the owner), as a third party quality assurance laboratory, independent from the manufacturer and lining contractor. The independent geosynthetics laboratory is responsible for laboratory quality assurance geomembrane testing when required by the owner. The independent geosynthetics laboratory must have relevant experience.

4.1.1. Earthwork

- The general contractor is responsible for preparing the supporting soil according to the specifications. Prior to geomembrane installation, the CQA inspector will observe that:
  - The surveyor has verified all lines and grades
  - The general contractor has provided to the owner or main contractor all CQA documentation that is needed to demonstrate that the supporting soil meets the density specification
  - The surface to be lined has been rolled and compacted and the general contractor has verified that the surface is free of irregularities, protrusions, loose soil, and abrupt changes in grade
  - The general contractor has verified that the surface of the supporting soil does not contain stones which may be damaging the geomembrane
  - The general contractor has verified that no area is excessively softened by high water content or water income
  - The general contractor has verified the presence of a water and a gas drainage network and corresponding evacuation vents as per the guidelines of the designer
- Lining contractor certifies, in writing, that after visual inspection (in presence of the CQA inspector, the prime contractor and the general contractor), the surface and details on which the EPDM geomembrane is to be installed is acceptable (smooth, free of aggressive angle changes, stones, vegetation and small cavities). The certificate of acceptance is issued by the lining contractor to the CQA inspector prior to commencement of the geomembrane installation in the area under consideration.

4.1.2. Anchor trenches

- Anchor trenches are excavated by the general contractor or lining contractor to the lines and widths shown on the design drawings, prior to geomembrane placement. The CQA inspector inspects anchor trench construction to verify that anchor trenches have been constructed according to drawings.
  - Slightly rounded corners are provided in trenches where the EPDM geomembrane adjoins the trench to avoid sharp bends in the geomembrane. Loose soil under the geomembrane in the anchor trenches is not permitted.
  - Backfilling of anchor trenches is conducted in accordance with section 4.1.12.

4.1.3. Delivery of materials on site

The lining contractor will have to be present on site when unloading the materials so as to ensure the correctness of the delivery and to monitor the unloading and storage of all materials. The CQA inspector needs to control the compliance between the delivered material, the technical data sheet and the specifications of the project.

4.1.4. Geotextile placement

The CQA inspector observes the geotextile placement procedure to verify that:

- The geotextile panels are fixed together (sewn or thermo-bonded) with an overlap of 200 mm minimum. The seams will not be perpendicular to the slope unless if they are sewed;
- Temporary ballast is used to keep the geotextile in place.

4.1.5. Geomembrane placement

- Panel layout: following acceptance of the support, a sheet layout plan will be established or adapted. The aim should be to facilitate the installation process and minimize the number of T-joints, the amount of seaming on site and the EPDM geomembrane loss percentage.
• Field panel identification:
  - A field panel is the unit area of geomembrane which is to be seamed in the field
  - It is the responsibility of the lining contractor to ensure that each field panel is given an “identification code” (number or letter-number). This identification code is agreed with the main contractor, general contractor, lining contractor, and CQA inspector. This field panel identification code should be simple and logical. The panel number shall be marked in a location agreed upon by the main contractor, general contractor, lining contractor, and CQA inspector.

• Location: The CQA inspector observes that field panels are installed in the location indicated in the proposed panel layout drawing, as approved or modified.

4.1.6. Installation schedule
• Field panels are placed one at a time and each field panel shall be seamed immediately (after the relaxation time) after its placement.
• The CQA inspector evaluates every change in the schedule proposed by the lining contractor and advise the main contractor of the acceptability of that change. The CQA inspector and the lining contractor verify that the condition of the support soil has not changed since the acceptance of the support.
• The lining contractor must record the identification code, location and date of installation of each field panel and submit the documentation to the CQA inspector no later than the following day.

4.1.7. Weather conditions
• EPDM geomembrane placement will not be performed during snow, heavy wind or in an area of standing water.
• EPDM geomembrane weather conditions for seaming are described in section 4.1.10.5.
• The CQA inspector observes that the conditions above are fulfilled. Additionally, the CQA inspector observes that the supporting soil has not been damaged by weather conditions and informs the main contractor of any discrepancies.

4.1.8. Method of placement
• The CQA inspector inspects the lining contractor’s work to ensure the following:
  - Any equipment used does not damage the EPDM geomembrane
  - The prepared surface beneath the geomembrane has not deteriorated since previous acceptance
  - Personnel working on the EPDM geomembrane do not smoke, wear damaging shoes, or engage in other activities which could damage the geomembrane
  - The method used to unroll and unfold the panels does not cause damage to the EPDM geomembrane and does not damage the supporting soil
  - The method used to place the panels minimizes wrinkles (especially differential wrinkles between adjacent panels)
  - Suitable temporary ballast (e.g. sand bags, tires), is not likely to damage the EPDM geomembrane
• The CQA inspector informs the engineer if the conditions listed above are not fulfilled. The lining contract is solely responsible for protecting the EPDM geomembrane against wind uplift during the construction process.

4.1.9. Damage
The CQA inspector must visually observe each panel, after placement and prior to seaming, for damage and advise the lining contractor which panels should be rejected, repaired or accepted. Damaged panels or portions of damaged panels which have been rejected are marked and their removal from the work area is recorded by the lining contractor. Repairs are completed in accordance with Firestone Lining Repair Guidelines.

4.1.10. Field seaming
4.1.10.1. Seam layout
• The lining contractor provides the main contractor, the general contractor and the CQA inspector with a seam layout drawing, i.e. a drawing of the facility to be lined showing all expected seams and T-joints. The CQA inspector, main contractor and general contractor review the panel layout drawing and verify that it is consistent with the accepted standards of practice and this CQA plan. No panels may be seamed in the field before the engineer and the CQA inspector approve the panel layout drawing.
• Seams are oriented parallel to the line of maximum slope, i.e. oriented along, not across, the slope.
• A seam numbering system compatible with the panel numbering system must be agreed.
4.1.10.2. Requirements of personnel

- All personnel performing geomembrane seaming operations shall be trained and qualified by the manufacturer.
- Prior to any seaming activities, the lining contractor shall provide the CQA inspector with a list of proposed seaming personnel and their experience records. This document shall be reviewed by the CQA inspector.

4.1.10.3. Seaming equipment and products

- The only approved process for field seaming the EPDM geomembrane is the Firestone QuickSeam Splice Tape system.
- The lining contractor logs the ambient temperatures at appropriate intervals. The ambient temperature is measured 150 mm above the geomembrane surface. This documentation is provided to the CQA inspector at the end of each day of seaming.
- The CQA inspector verifies that:
  - Equipment used for seaming is not likely to damage the EPDM geomembrane and is used in a manner that minimizes the possibility of damage to the geomembrane
  - The EPDM geomembrane is protected from damage in heavy traffic areas

4.1.10.4. Seam preparation

- The CQA inspector observes seam preparation as needed to verify that:
  - Prior to seaming, the seam area is prepared by the lining contractor ensuring it is clean and free of moisture, dust, dirt, debris of any kind, and foreign materials
  - Seams are aligned with the fewest possible number of wrinkles and “fish mouths”

4.1.10.5. Weather conditions for seaming

The required weather conditions for seaming are as follows:

- Unless authorized, in writing by the main contractor, no seaming is attempted at an ambient temperature below 5°C
- At ambient temperatures below 10°C, seaming is allowed if the weather is dry and using specific implementation techniques
- At ambient temperatures above 25°C, seaming must be performed using specific implementation techniques
- Seaming must not be performed during any precipitation, snow, fog and in the presence of any surface moisture or in an area of standing water
- In all cases, the EPDM geomembrane must be dry and protected from the wind
- Ambient temperatures must be measured 150 mm above the geomembrane surface
- The CQA inspector must verify that these weather conditions are fulfilled and shall advise the engineer if they are not. The engineer must then decide if the installation should be stopped or postponed

4.1.10.6. Overlapping and temporary bonding

The CQA inspector observes the EPDM geomembrane placement procedure as needed to verify that:

- The panels of EPDM geomembrane have a finished overlap of a minimum of 150 mm for seaming
- The procedure used to temporarily bond adjacent panels together does not damage the geomembrane

4.1.10.7. Trial seams

- Trial seams are made on pieces of EPDM geomembrane to verify that seaming conditions are adequate. Such trial seams are made at the beginning of each seaming period. Trial seams are made under the same conditions as the actual seams. Visual inspection of condensation risk should be evaluated.
- A trial seam sample must be at least 1.5 m long by 30 cm wide (after seaming) with the seam centered lengthwise. The seam overlap shall be in accordance with Firestone’s recommended procedures.
- Four specimens, each 50 mm wide, and a minimum of 150 mm apart, shall be cut from the trial seam sample by the lining contractor. Two specimens are tested in shear and two in peel using a field tensiometer. Tests are performed after a minimum of 24 hours to allow the seam to vulcanize and should obtain the following minimum values:
  - Peel ≥ 40 N/50 mm (0,8 kN/m)
  - Shear ≥ 200 N/50 mm (4 kN/m)
- The CQA inspector must observe all trial seam procedures as needed to verify that the above procedures are met. After testing, the trial seam samples are marked by the lining contractor with the Seamers's initials, identification, date, hour, and ambient temperature and the samples provided to the CQA inspector.
4.1.10.8. **General seaming procedure**

Unless otherwise specified, the general seaming procedure used by the contractor is as follows:

- Seaming must be carried out in accordance with Firestone’s recommended procedures
- “Fish mouths” or wrinkles in the seam are eliminated by pulling the geomembrane softly
- Seaming must extend to the outside edge of panels to be placed in the anchor trench
- The CQA inspector must observe the seaming process as needed to verify that the above seaming procedures are followed, and must inform the main contractor if they are not

4.1.10.9. **Non-destructive seam testing**

**Concept:**

- The contractor must perform a non-destructive test on all field seams over their full length using an air lance test, or other approved method. The purpose of non-destructive tests is to check the continuity of seams. Continuity testing is carried out as the seaming work progresses, not at the completion of all field seaming

**The CQA inspector will:**

- Observe continuity testing as needed to verify that the contractor performs the test properly
- Inform the main contractor of any repairs required

**The lining contractor will complete any repairs required in accordance with Firestone Lining Repair Guidelines.**

- The CQA inspector will also:
  - Observe the repair procedures as needed to verify that the lining contractor is adequately repairing problems
  - Review lining contractor’s report documentation of the retesting of repairs

4.1.10.9.1. **Visual inspection**

Visual inspection on the completed seam is executed to verify the following:

- QuickSeam Tape must extend approximately 5-15 mm (22 mm maximum) past the seam edge
- QuickPrime Plus primer shall be visible on bottom sheet, exceeding the QuickSeam Tape over its entire length. This indicates that the QuickPrime has been applied to a sufficient width to ensure adherence of the edge of the tape to the EPDM geomembrane sheet
- Continuous trace of QuickPrime Plus visible on the top sheet at approximately 150 to 200 mm from the edge of the top sheet
- No “fish mouths” or wrinkles within the QuickSeam Tape present
- Air bubbles within the seam should only be spotted occasionally. If air bubbles have a diameter >15 mm, a repair is required
- Any defect or non-conformance with the above must be marked with a marker that will not damage the EPDM geomembrane and repaired in accordance with Firestone Lining Repair Guidelines

4.1.10.9.2. **Air lance testing (ASTM D 4437 Standard)**

- Air lance testing is performed on all seams. The lining contractor must follow procedures and the CQA inspector observes the contractor’s work as needed to verify that lining contractor is properly implementing the procedure. Air lance testing equipment consists of a compressed air source that delivers air at the exit pressure of 345 kPa (50 psi) minimum to a 4.8 mm (3/16”) diameter hand-held nozzle.
- The following procedures must be followed:
  - The nozzle is directed to the upper edge of the field seam in a near perpendicular direction to the length of the field seam
  - The nozzle is held a maximum 25 mm from the seam and travels at a rate not to exceed 12 m per minute
  - Any defect that is identified by a distinct change in sound by the air passing through an opening in the seam is marked with a marker that will not damage the geomembrane and is repaired in accordance with Firestone Lining Repair Guidelines.
**4.1.10.9.3. Vacuum chamber (for critical points)**

- The following procedure must be used at all locations that require specific attention (patches, T-joints, tape overlaps, questionable points revealed by air lance testing).
- The equipment is comprised of the following:
  - A compressor-pump to apply the vacuum
  - A rectangular (approximately 200 by 650 mm), transparent vacuum chamber
- The following procedure must be followed:
  - Moisten part of the seam to be tested with a soapy solution
  - Place the chamber onto the area to be tested ensuring an airtight connection between the EPDM geomembrane and the deformable seal of the vacuum chamber
  - Apply pressure, not to exceed -0.15 bar (-15 kPa) so as not to lift the geomembrane too much into the chamber
  - If the seam is not watertight or a capillary is present, soap bubbles will be formed and it will be difficult to create the vacuum
  - Due to the pressure applied, this test can only be executed on seams that have aged for a minimum of 24 hours
- Up to 5 lin. m. of seam can be tested in 2 minutes.
4.1.10.10. Destructive seam testing

4.1.10.10.1. Concept
Destructive seam tests will be performed at locations selected by the CQA inspector. The purpose of these tests is to evaluate seam strength. Seam strength testing for field seams will be done as the seaming work progresses, not on completion of all field seaming.

4.1.10.10.2. Location and frequency
The CQA inspector must select and mark locations where seam samples will be cut out for laboratory testing. The locations shall be established as follows:
- A minimum frequency of one test per 150 to 300 lin.m of seam. This minimum frequency is to be determined as an average taken throughout the entire facility.
- Preferred locations for taking samples are in non-critical areas such as anchor trenches etc.

4.1.10.10.3. Sampling procedure
- Samples are cut by the lining contractor as the seaming progresses in order to have laboratory test results before the geomembrane is covered by another material. The CQA inspector performs the following as needed to verify that the installer is properly performing sampling:
  - Observe sample cutting
  - Note that the lining contractor assigns a number to each sample and marks it accordingly; and
  - Note that the lining contractor records the sample location on the as-built panel layout
- All holes in the EPDM geomembrane resulting from destructive seam sampling are immediately repaired in accordance with repair procedures described in Firestone Lining Repair Guidelines. The continuity of the new seams in the repaired area is tested in accordance with sections 4.1.10.9 and 4.1.10.10.

4.1.10.11. Size of samples
For destructive testing, samples are taken as described below:
- The destructive sample are 30 cm wide by 90 cm long with the seam centered lengthwise. The sample shall be cut into three parts and distributed as follows:
  - One portion to the owner, 30 cm by 30 cm for his archive
  - One portion to the lining contractor for his on-site testing, 30 cm by 30 cm
  - One portion to the CQA inspector, 30 cm by 30 cm for Geosynthetics CQC Laboratory testing if required
- Final determination of the sample sizes shall be made at the pre-construction meeting

4.1.10.12. Field testing
- A minimum of two 50 mm shear and two 50 mm peel specimens will be tested in the field by the tensiometer. If any field test sample fails to pass (peel < 0.8 kN/m, shear < 4 kN/m after 24h), then the procedure outlined in this section is followed.
- The CQA inspector reviews the lining contractor’s report of field tests, which is to be submitted to the CQA inspector by the end of the day on which the samples are tested. The lining contractor marks all samples with test number and date and time tested and submits the samples to the CQA inspector for archiving. Lining contractor logs the date and time, ambient temperature, name of technician, value, and attaches a copy to each sample portion.

4.1.10.13 Geosynthetics CQC Laboratory testing (if required by client)
- Destructive test samples are packaged and shipped, in a manner that will not damage the samples. The CQA inspector is responsible for storing the archived samples. Test samples are tested by the Geosynthetics CQC Laboratory. The Geosynthetics CQC Laboratory is selected by the Owner or the main contractor (with the approval of the Owner).
- Testing must include “Seam strength” and “Peel adhesion”. The minimum acceptable values to be obtained in these tests are those specified in section 4.1.10.7. At least 3 specimens must be tested for each test method.
- Specimens are selected alternately by test from the samples (e.g. peel, shear, peel, shear, ...). A minimum of 2 out of 3 specimens must meet the requirements of the specifications previously mentioned to be considered a test pass.

The Geosynthetics CQC Laboratory provides test results to both the lining contractor and CQA inspector no more than 24 hours after they receive the samples. The CQA inspector must review the laboratory test results as soon as they become available, and make appropriate verbal recommendations to the main contractor. The verbal recommendations are followed by written recommendations.
4.1.10.14. Procedures for destructive test failure

The following procedures will apply whenever a sample fails a destructive test, whether the test is conducted by the laboratory or by field tensiometer. Lining contractor has two options:

- The lining contractor can reconstruct the seam (i.e. remove the old seam and re-seam) between any two passed destructive seam test locations
- The lining contractor can trace the seaming path to an intermediate location a minimum of 3 m from the point of the failed test in all directions and take a small sample for additional field testing at each location. If these additional samples pass tensiometer testing, then full destructive laboratory samples are taken. If these destructive laboratory samples pass the test, then the seam is reconstructed between these locations by capping. If either sample fails, the process is repeated to establish the zone in which the seam should be reconstructed
- Acceptable capping methods are described in Firestone Lining Repair Guidelines
- The CQA inspector observes that all actions taken are in conjunction with destructive test failures

4.1.11. Defects and repairs

All repairs are done in accordance with Firestone Lining Repair Guidelines. Each repair is numbered and logged on the as-built layout plan. Each repair is non-destructively tested using the methods described in section 4.1.10.9, as appropriate. Repairs that pass the non-destructive test are accepted as an adequate repair. Failed tests will require the repair to be redone and retested until a test pass result is achieved. The lining contractor must document all repairs and submit the documentation to the CQA inspector no longer than the following day after a repair is made. The CQA inspector must observe non-destructive testing as needed to verify that the installer is performing the repairs properly.

4.1.12. Backfilling of anchor trench

- Anchor trenches must be adequately drained, to prevent standing water or otherwise softening of the adjacent soils while the trench is open. Anchor trenches are backfilled and compacted by the general contractor or the lining contractor in a timely fashion. The anchor trench back fill material must comply with the requirements of this guide.
- Care must be taken when backfilling the trenches to prevent any damage to the geomembrane. The CQA inspector will observe the backfilling operation and advise the main contractor of any problems.

4.2. Acceptance of work

The acceptance of work will be performed and notified by the owner assisted by the main contractor during a site visit upon request of the lining contractor.

The acceptance of work will be based on following information:

- The CQA inspector report
- The quality of the finished installation
- The as-built file communicated by the general contractor
- Result of the acceptance testing

Acceptance testing is usually completed during the first impoundment of the pond. Water will be introduced in stages at a controlled rate. An auscultation protocol will be set up with the help of the monitoring device (repeated control of the water drainage outlet, vertical and horizontal distortion). The step by step water inlet is important in order to let the structure adapt to the new mechanical and hydraulic stress.

On delivery of the installation, the general contractor will hand over to the Owner the as-built file with the following information:

- Documents relating to the design of the project, detailing all the factors taken into account during the planning of the project, (volume of water to be stored, depth of the water table, type of supporting ground)
- Documents relating to the construction of the project showing the positions and techniques employed, the as-built panel layout, methods of connection to other facilities, as well as the methods of installation of different materials (aggregate, geomembrane) and the results of internal controls
- The specifications of the geomembrane, geotextile and the geocomposite used
- Copies of quality certificates, (geomembrane, fitters)
- A guide to good practices allowing management of the installation with care for the integrity of the geomembrane
4.3. Monitoring devices

The monitoring devices of the structure need to be considered during the design process taking into account the size of the project and the risks in case of failure.

The water drainage network located under the geomembrane must be equipped with a flow measurement system that can evaluate the quality of the geomembrane and its drainage system. The measurement system must be accessible throughout the year. It is strongly recommended to compartmentalize the drainage system so as to be able to localize the area that is leaking. This is especially important for systems where the membrane is covered.

In projects where no leakage can be tolerated (soil with internal erosion hazard) and the site cannot be changed, it is strongly recommended that a double waterproofing layer is installed separated with a water drainage geocomposite connected to a water detection system equipped with a water flow measurement system.

It is also recommended that a water level measurement system (staff gauge, pressure sensor) is set up and episodic topographical controls of the embankments (vertical and horizontal distortion) are made.

In sensitive projects the installation of control piezometers may be recommended.

4.4. Inspections and maintenance

4.4.1. Inspections

The pond inspections must be organized by the owner. They are made to check the evolution of the structure and evaluate the maintenance and repair work required in order to guarantee a long service life of the pond.

The frequency and importance of inspections will depend on the size and risk level of the structure, its general condition and after an important or unexpected natural phenomenon (important floods, earthquake).

It is recommended that frequent routine visits (minimum every 1 or 2 months) are undertaken and an extensive technical inspection spaced between 1 and 5 years (depending on the importance of the project) is also scheduled. At least once a year, the routine visit will take place when the pond is empty.

The routine visits can be done by the owner or the operator, following a specified protocol. The extensive technical inspection will be done by an external expert. For security reasons, it is recommended that the work be conducted in pairs.

Main points to observe during the inspection visits:

- Visual inspection:
  - Geomembrane: seams, connections to details, patches, punctures, tears…
  - Internal embankment: deterioration of the substrate, sediments, floating objects, stones
  - External embankment:
    - Water or humidity on the embankment
    - Gullies, slips
    - Vegetation
    - Animal damage (rabbit holes…)
    - Water ditch
  - Crest:
    - Water ditch
    - Cracks
    - Settlement
    - Service road
- Geomembrane cover: sliding, vegetation, deterioration
- Hydraulic elements: spillway, inlet, outlet, discharge pipe, valves
- Fences and security elements
- Access
- Surroundings

- Monitoring devices:
  - Water level inside the pond
  - Outlet water drainage system:
    * Outflow
    * Temperature
    * Water color and presence of sediment
  - Topographical inspection
  - Other monitoring devices

After each visit a detailed visit report will be written and stored with all the referential documents relating to the pond. The visit report will describe the visual aspect of the pond and record the monitoring statistics. Conclusions will be given about the general condition of the pond and maintenance actions to be taken.

### 4.4.2. Maintenance

For each project, depending on its size and risk level, the designer will draft a specific maintenance plan (frequency and protocol).

After acceptance of the work, the general contractor will communicate to the owner a best practice guide explaining operating limits of the pond and maintenance obligations.

In order to ensure a long service life and avoid costly repairs to the Firestone EPDM geomembrane, Firestone recommends maintenance of the pond at least every year. Maintenance actions and frequency thereof will be guided by the monitoring inspections of the pond.

1. Do not change the type or temperature of contents for which the storage pond was designed without first having contacted Firestone. Ensure that the membrane is not exposed to liquids such as solvents, greases, oils, animal fats and petroleum products or other hazardous waste that may adversely affect the membrane.
   a) If the membrane is subject to contact with any type of chemical, you should contact Firestone immediately.
   b) Should petroleum products, solvents, greases, oils, etc. come into contact with the membrane, clean the area immediately with Splice Wash or unleaded gasolene.

2. If there is traffic on the membrane for equipment maintenance or other reasons, be sure to protect the membrane. All contact with the membrane must be avoided.
   Keep all the safety systems functional. Fences will be kept all around the installation to avoid people or large animals falling in, vandalism, etc.
   Also, make provisions for small animals which fall into the pond to escape. It is essential to manage any potential damage caused by animals (rodents, birds).

   Warn all tradesmen servicing project equipment that you have a rubber liner, and that they should proceed accordingly. Any possible damage is immediately reported. Firestone recommends that you keep a log of all activity.

3. All flashings, mechanical terminations, anchoring, pipe terminations, metal work, drains, vents, monitoring systems, and any other accessories functioning in conjunction with the lining system must be properly maintained and watertight at all times.
   Remove all foreign bodies inside the pond. Particular attention is given to the water drainage outlet, which should be systematically checked at every use or upkeep operation on the installation. The outside embankment will also be maintained in perfect condition (erosion, plants, animal holes, water ditches, stagnant water). Special attention needs to be given to the maintenance of the vegetation growing on the external embankment and on the crest. Herbaceous vegetation needs to be mowed once or twice a year. Shrub and tree species are prohibited in the vicinity of the structure.

4. It is essential to do everything possible to avoid the pond overflowing during filling.

5. The general condition of all fixed or mobile installations (agitators, recuperation systems) should be checked on each use. Mobile installations will be operated with the greatest care to avoid contact with the geomembrane.

6. Should there be an alteration of the project, contact a Firestone representative to ensure that the alterations are in accordance with Firestone's specifications.
7. Should a leak be detected:
   a) Try to determine the cause of the leak and to measure the leak flow rate
   b) Contact a Firestone representative immediately and also send notification in writing
   c) If necessary, make temporary repairs with Firestone EPDM Geomembrane and Splice Adhesive
   d) Never use oil-based products

8. Firestone recommends that an inspection of the drainage system and the visible parts of the lining system (geomembrane, splices, patches) be conducted by a qualified professional as described in section 4.4.1. Should you have problems with the earthwork or substrate under the membrane, groundwater, vegetation, or drainage system:
   a) Contact a specialized engineer immediately.
   b) Notify a Firestone representative in writing.

While the Firestone EPDM Geomembrane requires no maintenance itself, maintenance is important to the long-term performance of the lining system as a whole. These preceding guidelines will assist the project owner in maintaining the liner performance over many years. Cooperation on the part of the owner in this effort is important.

4.5. Repair guidelines

4.5.1. Introduction

Even with periodic inspection and maintenance, lining systems will require repair from time to time. Although geomembrane repair is typically conducted as a response to some type of damage to the pond, a pro-active approach to geomembrane repair and renovation can improve the performance and extend the service life of the liner. The procedures and specifications contained in this section provide valuable general information about the efficient and effective repair of Firestone EPDM lining systems.

These guidelines apply to repairs to the Firestone EPDM Geomembrane (cuts and punctures in the EPDM geomembrane, contamination of the EPDM geomembrane with hazardous products) and the field seams (wrinkles in a splice, QuickSeam Splice Tape is not showing, QuickSeam Splice Tape is showing more than 25 mm, seam is showing possible water entry points). These repair procedures are offered as a complementary service only, and Firestone disclaims any liability, under any theory of law, arising from the use of these procedures. Repairs and renovations of Firestone EPDM Lining systems should only be performed by a professional lining contractor who is licensed and trained by Firestone.

4.5.2. Repair of cuts and punctures on the EPDM geomembrane

As soon as any damage to Firestone EPDM Geomembrane is identified (during installation or inspection), mark the damaged area with a white crayon for use on rubber. The repair must extend a minimum of 75 mm beyond the perimeters of the damaged area in all directions in case of repairs using Firestone QuickSeam products and 100 mm in case of repair using Firestone EPDM Geomembrane. Round all corners of the repair piece.

- **Pinholes and small punctures** in the EPDM geomembrane may be repaired with a cover piece of Firestone QuickSeam FormFlash or Firestone QuickSeam SA Flashing (the latter is preferred: better physical properties and more economical).

- **Cuts and punctures** in the EPDM geomembrane should be repaired with cured EPDM geomembrane. Round all edges of the cut so that it cannot propagate underneath the target piece. If this has been done properly, the target EPDM repair piece can be applied using Firestone QuickSeam Splice Tape and Firestone QuickPrime Plus. A valid alternative is to fully adhere a piece of QuickSeam SA Flashing using QuickPrime Plus.

- **Firestone Lap Sealant** is used to seal and mechanically protect the exposed edge of Firestone QuickSeam products. Lap Sealant is also recommended where edges of QuickSeam FormFlash make a T-crossing with QuickSeam Splice Tape, QuickSeam Batten Cover or QuickSeam SA Flashing, in order to avoid any risk of possible capillarity.

**NOTE:** The application of new Firestone QuickSeam products to existing in service EPDM geomembrane requires special cleaning and priming procedures. Refer to section 4.5.5.
Figure 44: Typical repair of EPDM geomembrane: using QuickSeam SA Flashing

Figure 45: Typical repair of EPDM geomembrane: using QuickSeam FormFlash

Figure 46: Typical Repair of EPDM geomembrane: using EPDM geomembrane (190 x 150 mm QuickSeam FormFlash patches)
Figure 47: Typical Repair of EPDM geomembrane: using EPDM geomembrane (225 x 225 mm QuickSeam FormFlash patches)

The way of connecting two QuickSeam Splice Tapes in the corners is going to determine the size of the QuickSeam FormFlash Patch.

4.5.3. Repair of contaminated EPDM geomembrane

Any Firestone EPDM Geomembrane that has been in contact with hazardous chemical discharges such as fresh bitumen, petroleum products, greases, oils, animal fats or oil based solvents needs to be inspected for damage.

Remove immediately any excess of the contamination materials and replace the damaged area with a new piece of membrane. Repairs should be completed as described in Figure 46 and Figure 47.

4.5.4. EPDM field seam repair

As soon as any non-conformity is identified during installation or inspection, mark the damaged area with a white crayon for use on rubber.

- **Punctual defaults or damages on field seams** (e.g. wrinkles) in a field splice must be cut out and repaired with a covering piece of uncured EPDM (QuickSeam FormFlash). Provide a patch that extends a minimum of 75 mm beyond the perimeter of the damaged area. Wrinkles in a field splice must be cut out using scissors, laying them flat on the geomembrane, before applying the patch. Clean the area around the damage and adhere the QuickSeam FormFlash with QuickPrime Plus. Use small silicone rubber roller to roll the edges flat (see Figure 4.5) and seal with Lap Sealant.

- **Non-punctual non-conformities on seams** (QuickSeam Splice Tape is not showing, QuickSeam Splice Tape is showing more than 25 mm, possible water entry points) can be repaired using QuickSeam SA Flashing or QuickSeam Batten Cover set in QuickPrime Plus.

**NOTE:** The application of new QuickSeam products to existing in service EPDM geomembrane requires special cleaning procedures. Refer to section 4.5.5.

Figure 48: Typical seam repair cross section
4.5.5. Cleaning of in service EPDM geomembrane

When repairing a Firestone EPDM Geomembrane that has been in service for some time, it is necessary to prepare the surface to be spliced thoroughly prior to starting the splicing operation.

This is a performance specification. It is required that the EPDM geomembrane be dark gray in color without streaks before proceeding with any bonding or splicing activity. The cleaned area must be larger than the repair area.

- Cleaning may be achieved by one of the following methods:
  - Brush wash by hand with a solution of mild dish soap and water and a stiff bristle brush. Rinse the receiving surface with water until clean. Take care not to flood the receiving surface.
  - Use a power water washer and a wet vacuum. Take care not to flood the receiving surface.
- Allow the receiving surface to dry thoroughly. If necessary, dry the washed surface with clean towel or rags. Make sure that no moisture can be trapped.
- It is also acceptable to sweep the EPDM geomembrane with a broom in the repair area and apply Firestone Membrane Pre-Wash using a garden sprayer at the rate of 7 to 12 m²/l (300 to 500 sqft/gallon) - contact the Firestone Technical Department for exact procedure. After the Pre-Wash has dried for approximately ten minutes, use a power water washer providing 15 l (4 gallon) per minute at 20 MPa (3000 PSI) to remove the Pre-Wash and any accumulated dirt and debris. A 40° fan spray nozzle for pressure washer is suggested.
- Wash the existing EPDM geomembrane twice with Firestone Clear Splice Wash and clean, white, cotton rags, allowing the surface moisture to evaporate and dry between washing. Change cleaning rags often.

**NOTE:** After cleaning the in service EPDM geomembrane, proceed with the application of the new EPDM geomembrane, QuickSeam FormFlash, Lap Sealant and QuickSeam Splice Tape in accordance with current Firestone application specifications.
5. Application specifications

This section gives general specifications for some applications that have additional requirements in relation to water reservoirs.

5.1. Dung pits

Firestone has issued a specific technical guide for dung pit applications. Please refer to this guide for detailed information. Livestock effluent is likely to have a major environmental impact if not correctly managed. The storage pond must, therefore, guarantee a maximum degree of waterproofing. It is essential that the installation work and quality control system are carried out in accordance with best practice so as to avoid any leaks or premature ageing.

Chemical compatibility:

Firestone EPDM Geomembranes have been used for more than 20 years to store slurry in exposed conditions with great success. The good long term compatibility between slurry and Firestone EPDM Geomembranes observed on 20 years old projects has been confirmed in laboratory artificial aging tests.

The durability of Firestone EPDM Geomembranes can be affected when brought into contact with large concentrations of vegetable or animal grease. Therefore only small quantities of diluted milk can be stored at once.

If the disinfectants used to clean the tanks are compatible with EPDM and highly diluted, the tank washing residues can be stored inside the dung pit. Firestone technical service can be consulted to check chemical compatibility. Disinfectants with chlorine content must be avoided.

The use of Firestone EPDM Geomembranes in direct contact with silage effluent is not recommended if a pH lower than 4 is expected.

Installation details:

Where seams are made with Firestone QuickSeam Splice Tape a bridging strip of Firestone QuickSeam Batten Cover Strip must always be added on its entire length.

Firestone QuickSeam FormFlash cannot be used in areas where the membrane is in contact with effluent. The execution of installation details must be done with Firestone QuickSeam Batten Cover Strip. For pipe penetrations in contact with slurry, systems with physical enclosure should be used.

It is strongly recommended that a very efficient water drainage system is in place under the geomembrane in order to be able to detect any leakage immediately. The drainage network will be connected to a leakage detection system. Water drainage should preferably be achieved with drains laid in trenches (spaced no more than 5 m apart) filled with permeable material surrounded by a non-contaminant geotextile. The whole surface of the pond will be covered with drainage material to a minimum depth of 10 cm.

A gas drainage system, completely separate from the water drainage networks is also strongly recommended.

Inside the pond, pipes will be sunk in concrete. All pipes used for emptying the slurry store whether by gravity or pumping, must have two valves in series at least 1 m apart which can be locked when not in use.

Protective and ballasting concrete slabs (on geotextile) will be installed in the location of the emptying system, the pond swirling system and the effluent inlet.

5.2. High altitude reservoirs

Firestone has issued specific technical guidelines for high altitude reservoirs. Please refer to those guidelines for detailed information.

As they stay flexible at very low temperature and due to their high UV resistance, EPDM geomembranes are the perfect solution for high altitude reservoirs. However, the construction of high altitude reservoirs is a delicate operation which is subject to many hazards and for which the consequences of poor design, construction or maintenance can have disastrous consequences for people and property located downstream.

The high altitude environment is extremely complex and fragile. Site selection therefore results from detailed studies (topography, water supply, seismic study, avalanches).

In high altitude reservoirs there is a high risk of mechanical aggression to the liner (ice crust, rock fall, animals). Depending on the specificity of each project, special measures can be recommended:

- Preferably use 1.5 mm thick EPDM geomembrane to ensure higher puncture resistance.
- Always use a thick, high quality geotextile (minimum 500-1000 g/m²).
- Cover the geomembrane. Strongly recommended in locations over 1,800 m of altitude.
- Install a bubbling system (high pressure air injection) at the bottom of the reservoir to reduce the thickness of the ice crust.
In order to protect the embankment from internal erosion mechanisms or downstream slope slippage in the event of natural water inflow or leakage of the geomembrane, it is essential that a water drainage system is provided under the geomembrane. When the geomembrane is covered, the drainage network shall be subdivided into several zones so that any leak can be localized. The drainage network shall be equipped with a flow measurement system.

5.3. Artificial wetlands

In artificial wetlands, the main risk for the geomembrane comes from the rhizomes produced by the plants installed inside the pond to clean the water. The following points are therefore recommended:

- It is essential to place a root barrier in the embankments and some centimeters of the bottom. The root barrier can be made from a needle, woven, coated, PP geotextile with good UV resistance.
- The EPDM membrane is installed so as to minimize wrinkles.
- In areas where the membrane is folded (inside corner), it is necessary to confirm the fold with a strip of QuickSeam SA Flashing.
- The ground layer installed on top of the geomembrane will be at least 90 cm thick (60 cm for filtration at the top and 30 cm for drainage at the bottom) and leave a freeboard of 50cm.
- It is necessary to properly drain the base of the pond (in contact with the geomembrane) so that there is no accumulation of water in dry periods (30 cm of washed gravel 20/40 mm).

If high presence of fat is expected in the treated water, the installation of a degreaser upstream is recommended.
6. Detail drawings

1. Lap Splices
2. Corners
3. Penetrations
4. Terminations
5. Anchoring
6. Membrane cover
6.1. Lap Splices

Geo-E-LS-1  Standard Seam using 76 mm (3”) Tape
Geo-E-LS-2  QuickSeam Batten Cover Strip on Metal Bar
Geo-E-LS-3  QuickSeam Batten Cover Strip on Standard Seam
**EPDM Geomembrane**

- Standard Seam using 76 mm (3’’) Tape

- **No.:** Geo-E-LS-1
- **Systems:** All

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**EPDM Geomembrane**

- QS Batten Cover on metal bar

- **No.:** Geo-E-LS-2
- **Systems:** All
<table>
<thead>
<tr>
<th>EPDM Geomembrane</th>
<th>No.:</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>QS Batten Cover Strip on Standard Seam</td>
<td>Geo-E-LS-3</td>
<td>All</td>
</tr>
<tr>
<td></td>
<td>01/2012</td>
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</tbody>
</table>
6.2. Corners

Geo-E-C-1  Inside corner using QuickSeam FormFlash
Geo-E-C-2  Folded inside corner
Geo-E-C-3  Outside corner using tape and QuickSeam FormFlash
Geo-E-C-4  Outside corner using QuickSeam FormFlash
Inside Corner Using QuickSeam FormFlash
Folded Inside Corner

EPDM Geomembrane | No.: Geo-E-C-2 | Systems
Folded Inside Corner | 01/2012 | All
Outside Corner Using QuickSeam FormFlash
6.3. Penetrations

Geo-E-P-1  Flashing of small penetrations exposed to low water pressure
Geo-E-P-2  Flashing of large penetrations exposed to low water pressure
Geo-E-P-3  Flashing of a pipe exposed to high water pressure
Geo-E-P-4  Connection to a flange exposed to high water pressure

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**EPDM Geomembrane**

<table>
<thead>
<tr>
<th>No.: Geo-E-P-1</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flushing of Small Penetrations Exposed to Low Water Pressure</td>
<td>All</td>
</tr>
<tr>
<td>01/2012</td>
<td></td>
</tr>
</tbody>
</table>
Remarks:
1. Concrete surfaces at attachments to be smooth before installation.
2. Protective geotextile should not be close to attachments areas.
Connection to a Flange Exposed to High Water Pressure

No.: Geo-E-P-4
Systems: All

Remarks:
1. Concrete surfaces at attachments to be smooth before installation.
2. Protective geotextile should not be close to attachments areas.

---

EPDM Geomembrane
Substrate
Concrete
top
Water Block
QuickPrime Plus
Bonding Adhesive / QuickPrime Plus
Protective Geotextile

Firestone EPDM Geomembrane
Q5 Siphon Pipe
Q5 Slotted Pipe / Q5 SF Flushing

Dimensions:
Min. 100 mm
Max. 200 mm

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6.4. Terminations

Geo-E-T-1  Wall flashing termination above maximum water level line
Geo-E-T-2  Outside pond wall flashing termination
Geo-E-T-3  Termination step down & outside corner above maximum water line
Geo-E-T-4  Intermediate attachment at wall flashing
Geo-E-T-5  Horizontal termination below water line
Geo-E-T-6  Vertical termination below water line
### Wall Flashing Termination Above Maximum Water Line

<table>
<thead>
<tr>
<th>EPDM Geomembrane</th>
<th>No.: Geo-E-T-1</th>
<th>Systems: All</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside Pond Wall Flashing Termination</td>
<td>01/2012</td>
<td>All</td>
</tr>
</tbody>
</table>

**Diagram:**
- EPDM Geomembrane
- Firestone EPDM Geomembrane
- Bonding Adhesive
- High Grade Sealant
- Continuous Water Block
- Masonry or Concrete walls
- Termination Bar anchored with appropriate Fasteners 200 mm o.c.
Termination Step Down & Outside Corner Above Max. Water Line

EPDM Geomembrane

<table>
<thead>
<tr>
<th>EPDM Geomembrane</th>
<th>No.: Geo-E-T-3</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Termination Step Down &amp; Outside Corner Above Max. Water Line</td>
<td>01/2012</td>
<td>All</td>
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</tbody>
</table>
Intermediate Attachment at Wall Flashing

<table>
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<th>No.: Geo-E-T4</th>
<th>Systems</th>
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<tbody>
<tr>
<td>Intermediate Attachment at Wall Flashing</td>
<td>01/2012</td>
<td>All</td>
</tr>
</tbody>
</table>
Remarks:
1. Concrete surfaces at attachments to be smooth before installation.
2. Protective geotextile should not be close to attachments areas.
3. Water Block has to be applied to junction of neoprene gasket strips.

EPDM Geomembrane
Horizonal Termination
Below Water Line

No.: Geo-E-T-5
Systems: All

01/2012
Vertical Termination
Below Water Line

**EPDM Geomembrane**

<table>
<thead>
<tr>
<th>No.</th>
<th>Geo-E-T-6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systems</td>
<td>All</td>
</tr>
</tbody>
</table>

**Concrete Wall**

- Lap Sealant
- QuickPrime Plan
- Water Block
- Anchor (9mm x 90mm) every 190mm
- Rod metal bar (40mm x 6mm
- OS Button Cover / OS SA Flanking
- Bonding Adhesive
- Firestone EPDM Geomembrane

**Concrete Pile**

- Polyurethane Sealant
- Neoprene double gasket continuous (60mm x 6mm)
- Rod metal bar (40mm x 6mm)
- Anchor (9mm x 90mm) every 190mm
- Bonding Adhesive
- Firestone EPDM Geomembrane

**Remarks:**
1. Concrete surfaces at attachments to be smooth before installation.
2. Protective geotextile should not be close to attachments areas.
3. Water Block has to be applied to junction of neoprene gasket strips.

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## 6.5. Anchoring

<table>
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<th>Geo-E-A-1</th>
<th>Top anchoring in a trench</th>
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</thead>
<tbody>
<tr>
<td>Geo-E-A-2</td>
<td>Top anchoring with ballast</td>
</tr>
<tr>
<td>Geo-E-A-3</td>
<td>Unexposed pond edge with soil cover</td>
</tr>
<tr>
<td>Geo-E-A-4</td>
<td>Intermediate anchoring on a berm with ballast</td>
</tr>
<tr>
<td>Geo-E-A-5</td>
<td>Toe of slope anchoring</td>
</tr>
</tbody>
</table>
Intermediate Anchoring on a Berm with Ballast

**EPDM Geomembrane**

Intermediate Anchoring on a Berm with Ballast

No.: Geo-E-A-4

Systems: All

Top Anchoring with Ballast

**EPDM Geomembrane**

Top Anchoring with Ballast

No.: Geo-E-A-2

Systems: All
**General technical guide for water reservoirs**

### Unexposed Pond Edge with Soil Cover

**EPDM Geomembrane**

*Firestone EPDM Geomembrane*

**Minimum Thicknesses:**
- Min. 0.25 m
- Min. 0.5 m
- Min. 0.5 m
- Min. 0.25 m

**Clean/Compacted Soil Fill**

**Protective Geotextile**

**Intermediate Anchoring on a Berm with Ballast**

**EPDM Geomembrane**

*Firestone EPDM Geomembrane*

**Minimum Thicknesses:**
- Min. 2.5 m

**Protective Geotextile**

**Ballast (to be designed)**

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**No.:** Geo-E-A-3

**Systems:** All

**Date:** 01/2012

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**No.:** Geo-E-A-4

**Systems:** All

**Date:** 01/2012
Base Anchoring in Impermeable Ground

- Protective geotextile
- Firestone EPDM Geomembrane
- Compacted clay or treated ground

Base Anchoring in Permable Ground

- Protective geotextile
- Firestone EPDM Geomembrane
- Protective membrane
- Compacted clay or treated ground

H: Maximum Water Height

<table>
<thead>
<tr>
<th>EPDM Geomembrane</th>
<th>No.:</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Toe of Slope Anchoring</td>
<td>Geo-E-A-5</td>
<td>All</td>
</tr>
<tr>
<td>01/2012</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.6. Membrane cover

Geo-E-Co-1  Membrane cover with riprap
Geo-E-Co-2  Membrane cover with shotcrete
Geo-E-Co-3  Membrane cover with concrete
EPDM Geomembrane  No.: Geo-E-Co-1  Systems  All
Membrane Cover Riprap  01/2012

EPDM Geomembrane  No.: Geo-E-Co-2  Systems  All
Membrane Cover with Shotcrete  01/2012
7. Technical information sheet (TIS)

7.1. Membranes
   7.1.1. Geomembrane 1,1 mm
   7.1.2. Geomembrane 1,5 mm

7.2. Adhesives and sealants
   7.2.1. QuickPrime Plus
   7.2.2. Bonding Adhesive
   7.2.3. Splice Wash SW-100
   7.2.4. Lap Sealant HS
   7.2.5. Water Block Seal (S-20)

7.3. QuickSeam accessories
   7.3.1. QuickSeam Splice Tape
   7.3.2. QuickSeam FormFlash
   7.3.3. QuickSeam Corner Flashing
   7.3.4. QuickSeam SA Flashing
   7.3.5. QuickSeam Cover Strip
   7.3.6. QuickSeam Universal Molded Pipe Flashing

7.4. Battens and Bars
   7.4.1. Metal Batten Strip
   7.4.2. Coiled Metal Batten Strip
   7.4.3. Termination Bar
Poured-in-place Concrete

(0.2mm) Polyester sheet
Protective Geotextile
Firestone EPDM Geomembrane

<table>
<thead>
<tr>
<th>EPDM Geomembrane</th>
<th>No.: Geo-E-Co-3</th>
<th>Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Membrane Cover with Concrete</td>
<td>01/2012</td>
<td>All</td>
</tr>
</tbody>
</table>
Firestone EPDM Geomembrane (1,1 mm)

1. Description
The Firestone EPDM Geomembrane 1,1 mm (.045") liner is a cured single ply synthetic rubber membrane made of ethylene-propylene-diene terpolymer (EPDM). It is available in a variety of panel sizes. Depending on the dimensions of the liner, the waterproofing surface may be seamless (up to 930 m²). In other situations, seams can be made using a self-adhesive tape.

2. Preparation
Product: Allow the membrane to relax for approximately 30 minutes before splicing.
Substrate: The substrate needs to be smooth, dry and free of sharp objects, oil, grease and other materials that may damage the membrane.

3. Application
Install the Firestone Geomembrane in accordance with current specifications and details.

4. Coverage
The dimensions of the membrane are calculated to cover the base of the reservoir, slopes and anchor trenches, including seam overlaps.

5. Characteristics
The Firestone Geomembrane is a rubber material with the following properties:

| Physical | • Elastomeric membrane with a good combination of high elasticity and tensile strength |
|          | • Retains its flexibility at low temperature (-45°C) |
|          | • Resists to temperature shocks up to 130°C |
|          | • Excellent resistance to alkali rains |
|          | • Excellent resistance to U.V. radiation and ozone concentration |
|          | • Contact with some kind of oils, petroleum products, hot bitumen and grease must be avoided |
| Technical | • Base synthetic rubber |
|          | • Color black |
|          | • Solvents none |
|          | • Solids (%) 100 |
|          | • State cured |

6. Technical specifications

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Test method</th>
<th>Declared value</th>
<th>Tolerance</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass per unit area</td>
<td>EN 1849-2</td>
<td>1288</td>
<td>± 5%</td>
<td>g/m²</td>
</tr>
<tr>
<td>Tensile strength (MD/CD)</td>
<td>ISO R 527</td>
<td>9</td>
<td>- 1</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Elongation (MD/CD)</td>
<td>ISO R 527</td>
<td>≥ 300</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Dimensional stability</td>
<td>EN 1107-2</td>
<td>≤ 0.5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Flexibility at low temperature</td>
<td>EN 495-5</td>
<td>≤ -45</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Resistance to static puncture</td>
<td>EN ISO 12236</td>
<td>0.7</td>
<td>- 0.1</td>
<td>kN</td>
</tr>
<tr>
<td>Liquid tightness under high pressure</td>
<td>EN 1928</td>
<td>≥ 4</td>
<td>bar</td>
<td></td>
</tr>
<tr>
<td>Water permeability</td>
<td>EN 14150</td>
<td>3.0 10-6</td>
<td>± 10-6</td>
<td>m³/m²d</td>
</tr>
<tr>
<td>Methane permeability</td>
<td>ASTM D1434</td>
<td>2.25 10-3</td>
<td>m³/m²d</td>
<td></td>
</tr>
<tr>
<td>Durability - weathering (25y)</td>
<td>EN 12224</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durability - oxidation</td>
<td>EN 14575</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friction angle</td>
<td>EN ISO 12957-2</td>
<td>27.5</td>
<td>± 1</td>
<td>°</td>
</tr>
<tr>
<td>Resistance to root penetration</td>
<td>CEN/TS 14416</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Precautions
Take care when moving, transporting or handling to avoid sources of punctures and physical damage. Isolate waste products, such as petroleum products, greases, oils (mineral and vegetable) and animal fats from Firestone EPDM Geomembrane.
Firestone EPDM Geomembrane (1,5 mm)

1. Description
The Firestone EPDM Geomembrane 1,5 mm (.060") liner is a cured single ply synthetic rubber membrane made of ethylene-propylene-diene terpolymer (EPDM). It is available in a variety of panel sizes. Depending on the dimensions of the liner, the waterproofing surface may be seamless (up to 697 m²). In other situations, seams can be made using a self-adhesive tape.

2. Preparation
Product: Allow the membrane to relax for approximately 30 minutes before splicing.
Substrate: The substrate needs to be smooth, dry and free of sharp objects, oil, grease and other materials that may damage the membrane.

3. Application
Install the Firestone Geomembrane in accordance with current specifications and details.

4. Coverage
The dimensions of the membrane are calculated to cover the base of the reservoir, slopes and anchor trenches, including seam overlaps.

5. Characteristics
The Firestone Geomembrane is a rubber material with the following properties:

<table>
<thead>
<tr>
<th>Physical</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastomeric membrane with a good combination of high elasticity and tensile strength</td>
<td></td>
</tr>
<tr>
<td>Retains its flexibility at low temperature (-45°C)</td>
<td></td>
</tr>
<tr>
<td>Resists to temperature shocks up to 130°C</td>
<td></td>
</tr>
<tr>
<td>Excellent resistance to alkali rains</td>
<td></td>
</tr>
<tr>
<td>Excellent resistance to U.V. radiation and ozone concentration</td>
<td></td>
</tr>
<tr>
<td>Contact with some kind of oils, petroleum products, hot bitumen and grease must be avoided</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technical</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>synthetic rubber</td>
</tr>
<tr>
<td>Color</td>
<td>black</td>
</tr>
<tr>
<td>Solvents</td>
<td>none</td>
</tr>
<tr>
<td>Solids (%)</td>
<td>100</td>
</tr>
<tr>
<td>State</td>
<td>cured</td>
</tr>
</tbody>
</table>

6. Technical specifications

<table>
<thead>
<tr>
<th>Physical properties</th>
<th>Test method</th>
<th>Declared value</th>
<th>Tolerance</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass per unit area</td>
<td>EN 1849-2</td>
<td>1695</td>
<td>± 5%</td>
<td>g/m²</td>
</tr>
<tr>
<td>Tensile strength (MD/CD)</td>
<td>ISO R 527</td>
<td>10</td>
<td>- 1</td>
<td>N/mm²</td>
</tr>
<tr>
<td>Elongation (MD/CD)</td>
<td>ISO R 527</td>
<td>300</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Dimensional stability</td>
<td>EN 1107-2</td>
<td>0.5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Flexibility at low temperature</td>
<td>EN 495-5</td>
<td>-45</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Resistance to static puncture</td>
<td>EN ISO 12236</td>
<td>0.9</td>
<td>- 0.1</td>
<td>kN</td>
</tr>
<tr>
<td>Liquid tightness under high pressure</td>
<td>EN 1928</td>
<td>4</td>
<td></td>
<td>bar</td>
</tr>
<tr>
<td>Water permeability</td>
<td>EN 14150</td>
<td>3.0 10-6</td>
<td>± 10-6</td>
<td>m³/m²</td>
</tr>
<tr>
<td>Methane permeability</td>
<td>ASTM D1434</td>
<td>2.25 10-3</td>
<td>m³/m²</td>
<td></td>
</tr>
<tr>
<td>Durability - weathering (25y)</td>
<td>EN 12224</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durability - oxidation</td>
<td>EN 14575</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Friction angle</td>
<td>EN ISO 12957-2</td>
<td>27.5</td>
<td>± 1</td>
<td>°</td>
</tr>
<tr>
<td>Resistance to root penetration</td>
<td>CEN/TS 14416</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7. Precautions
Take care when moving, transporting or handling to avoid sources of punctures and physical damage. Isolate waste products, such as petroleum products, greases, oils (mineral and vegetable) and animal fats from Firestone EPDM Geomembrane.
QuickPrime Plus

1. Description
Firestone QuickPrime Plus is designed to clean and prime the EPDM geomembrane in seaming areas, before application of a QuickSeam product. The primer activates the EPDM geomembrane surface and improves the seam quality. Firestone QuickPrime Plus must be applied with a QuickScrubber.

2. Preparation
Surfaces that will receive QuickPrime Plus must be clean, smooth, dry and free of sharp edges, loose materials, oil, grease and other contaminants. The mating surface of the EPDM geomembrane shall be cleaned with a brush or clean rag. Stir the primer before and during use to achieve a uniform mix with no sediment on the bottom and no marbling evident. Restore the primer to room temperature prior to use if exposed to cold temperatures (< 15°C.).

3. Application
Apply QuickPrime Plus to the Firestone EPDM Geomembrane surfaces with the QuickScrubber tool using long back and forth strokes with moderate to heavy pressure along the length of the area until surfaces become dark grey in color with no streaking or puddling. Allow the primed surfaces to dry completely (usually less than 10 minutes) before applying the QuickSeam product.

4. Coverage
Coverage rate of ± 10 m², both sides, or ± 60 lin.m. of standard 3” seam per gallon. Thinning is not allowed.

5. Characteristics

<table>
<thead>
<tr>
<th>Physical</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Resists to temperature shocks up to 100°C</td>
<td>• Base rubber polymers</td>
</tr>
<tr>
<td>• Excellent resistance to ageing, heat and cold</td>
<td>• Color translucent grey</td>
</tr>
<tr>
<td>• Translucent when dry which allows guide marks to show through after application</td>
<td>• Solvents heptane, toluene, methyl alcohol</td>
</tr>
<tr>
<td></td>
<td>• Solids (%) 16-18</td>
</tr>
<tr>
<td></td>
<td>• Viscosity (cp) Very thin, free flowing</td>
</tr>
<tr>
<td></td>
<td>• Specific gravity 0,793</td>
</tr>
<tr>
<td></td>
<td>• Flash Point (ºC) &lt; -18</td>
</tr>
</tbody>
</table>

6. Precautions
Store in original unopened carton at temperatures between 15°C and 25°C. Keep the material out of direct sunlight until ready for application. Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Shelf life information is only a recommendation and not a fact of life. The actual expiration date depends on the history of storage and handling of the product. Quality and applicability should thus always be verified: when mixed, product should stir into a smooth and homogeneous blend with no evidence of major clumping or separation/phasing. Once opened, use within 48 hours. Verify production date on the pail. Shelf life will be reduced if exposed to higher temperatures. Refer to Safety Data Sheets. For professional use only. Flammable. Keep away from fire and open flame and other possible ignition sources during storage and use. Do not smoke when using. Use only in well ventilated areas. Avoid prolonged contact with skin. Keep out of reach from children.
Firestone Bonding Adhesive

1. Description
Firestone Bonding Adhesive is a solvent based contact adhesive designed for bonding Firestone EPDM Geomembrane to wood, metal, masonry and other acceptable non-rubber substrates.

2. Preparation
Surfaces that will receive Firestone Bonding Adhesive must be clean, smooth, dry and free of sharp edges, loose materials, oil, grease and other contaminants. The mating surface of the EPDM geomembrane shall be cleaned with a brush or clean rag. Stir the adhesive before and during use to achieve a uniform mix with no sediment on the bottom and no marbling evident. Restore the adhesive to room temperature prior to use if exposed to cold temperatures (< 15°C.).

3. Application
Apply the adhesive in an even, smooth coat on both surfaces with a solvent-resistant paint roller and avoid globs and puddles. Apply the adhesive first to the substrate as the drying time will most likely be longer than for the black EPDM membrane. Allow adhesive to flash off until tacky (time depending on ambient air conditions). Test the adhesive for its dryness, using the push-touch test procedure. If the adhesive is ready, mate both surfaces and press with a broom.

4. Coverage
Coverage rates depend on the smoothness and porosity of the substrate. Approx. 300 to 500 g/m² is required to achieve good adhesion. Very porous substrates (rough wood, concrete block…) may require two coats of Bonding Adhesive to ensure proper adhesion. This can be determined by testing a small area. Thinning of the adhesive is not allowed.

5. Characteristics

<table>
<thead>
<tr>
<th>Physical</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Resists to temperature shocks up to 100°C</td>
<td>• Base</td>
</tr>
<tr>
<td>• Excellent resistance to ageing, heat and cold</td>
<td>yellow/amber</td>
</tr>
<tr>
<td>• Excellent adhesive strength to different substrates</td>
<td>• Solvents</td>
</tr>
<tr>
<td></td>
<td>toluene, acetone, hexane</td>
</tr>
<tr>
<td></td>
<td>• Solids (%)</td>
</tr>
<tr>
<td></td>
<td>23 (min)</td>
</tr>
<tr>
<td></td>
<td>• Viscosity (cp)</td>
</tr>
<tr>
<td></td>
<td>2.300-3.000</td>
</tr>
<tr>
<td></td>
<td>• Specific gravity</td>
</tr>
<tr>
<td></td>
<td>0,84</td>
</tr>
<tr>
<td></td>
<td>• Flash Point (ºC)</td>
</tr>
<tr>
<td></td>
<td>&lt; -18</td>
</tr>
</tbody>
</table>

6. Precautions
Store in original unopened carton at temperatures between 15°C and 25°C. Keep the material out of direct sunlight until ready for application.

Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Shelf life information is only a recommendation and not a fact of life. The actual expiration date depends on the history of storage and handling of the product. Quality and applicability should thus always be verified: when mixed, product should stir into a smooth and homogeneous blend with no evidence of major clumping or separation/phasing. Once opened, use within 48 hours.

Verify production date on the pail. Shelf life will be reduced if exposed to higher temperatures.

Refer to Safety Data Sheets. For professional use only. Flammable. Keep away from fire and open flame and other possible ignition sources during storage and use. Do not smoke when using. Use only in well ventilated areas. Avoid prolonged contact with skin. Keep out of reach from children.
Splice Wash (SW-100)

1. Description
Firestone Splice Wash is designed to clean and prepare heavily contaminated Firestone EPDM Geomembrane in areas to receive QuickPrime Plus.

2. Preparation
Remove excess accumulations of dirt with a brush (and water) prior to application.

3. Application
Apply Splice Wash to the splicing area using clean cotton rags in a scrubbing motion until the splicing surface is dull black in color. Allow the cleaned surfaces to dry before applying QuickPrime Plus.

4. Coverage
Coverage rates depend on the degree of contamination of the EPDM geomembrane.

5. Characteristics

<table>
<thead>
<tr>
<th>Physical</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Highly flammable</td>
<td>• Color clear</td>
</tr>
<tr>
<td>• Solvents</td>
<td>• Solvents aliphatic hydrocarbons</td>
</tr>
<tr>
<td>• Viscosity (cp)</td>
<td>• Viscosity (cp) very thin, free flowing</td>
</tr>
<tr>
<td>• Specific gravity</td>
<td>• Specific gravity 0,75</td>
</tr>
<tr>
<td>• Flash Point (°C)</td>
<td>• Flash Point (°C) 12.8</td>
</tr>
<tr>
<td>• Boiling Point (°C)</td>
<td>• Boiling Point (°C) 119</td>
</tr>
</tbody>
</table>

6. Precautions
Refer to Safety Data Sheets. For professional use only. Flammable. Keep away from fire and open flame and other possible ignition sources during storage and use. Do not smoke when using. Use only in well ventilated areas. Avoid prolonged contact with skin. Keep out of reach from children.
Lap Sealant HS

1. Description
Firestone Lap Sealant HS is designed to seal and mechanically protect the exposed cut edges of QuickSeam Flashing products.

2. Preparation
Surfaces on which Lap Sealant HS is to be applied must be clean, dry, free from loose and foreign materials, oil and grease and primed with QuickPrime Plus. Restore to room temperature prior to use if exposed to temperatures < 15 ºC for a prolonged period.

3. Application
Apply with a mastic gun a bead of Lap Sealant HS along the properly cleaned, exposed seaming edge. A preformed tool shall be used to feather the bead of sealant. Feathering must take place immediately after the Lap Sealant is applied.

4. Coverage
7 lin.m. per cartridge. Thinning is not allowed.

5. Characteristics

<table>
<thead>
<tr>
<th>Physical</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>• excellent resistance to ozone, UV and general weathering</td>
<td>• Base rubber polymers</td>
</tr>
<tr>
<td>• excellent resistance to heat, cold and water</td>
<td>• Color black</td>
</tr>
<tr>
<td></td>
<td>• Solvents light aliphatic solvent</td>
</tr>
<tr>
<td></td>
<td>• Solids (%) min. 80</td>
</tr>
<tr>
<td></td>
<td>• Specific gravity 1.34-1.46</td>
</tr>
<tr>
<td></td>
<td>• Flash Point (ºC) 11</td>
</tr>
</tbody>
</table>

6. Precautions
Store in original unopened carton at temperatures between 15ºC and 25ºC. Keep the material out of direct sunlight until ready for application.

Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Shelf life information is only a recommendation and not a fact of life. The actual expiration date depends on the history of storage and handling of the product. Quality and applicability should thus always be verified. Once opened, use within 48 hours.

Refer to Safety Data Sheets. For professional use only. Flammable. Keep away from fire and open flame and other possible ignition sources during storage and use. Do not smoke when using. Use only in well ventilated areas. Avoid prolonged contact with skin. Keep out of reach from children.
Water Block Seal (S-20)

1. Description
Firestone Water Block Seal is designed to provide a watertight seal as indicated in the details.

2. Preparation
Surfaces onto which Water Block Seal is to be applied shall be free from loose parts of concrete, stone, mortar, foreign materials, and other contaminants. Restore to room temperature prior to use if exposed to temperatures < 15 °C for a prolonged period.

3. Application
Apply a bead onto the substrate surface. Roll or press the flashing membrane firmly against the seal and substrate avoiding wrinkles to assure a complete seal. Install the appropriate Firestone detail as per Firestone's current specification.

4. Coverage
3 lin.m. per cartridge. Thinning is not allowed.

5. Characteristics

<table>
<thead>
<tr>
<th>Physical</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>• non-drying</td>
<td>• Base butyl rubber</td>
</tr>
<tr>
<td>• adheres well to Firestone Geomembrane sheets, metals, wood and concrete</td>
<td>• Color grey</td>
</tr>
<tr>
<td>• good resistance to heat, cold and water</td>
<td>• Solvents heptane</td>
</tr>
<tr>
<td>• limited UV resistance</td>
<td>• Solids (%) 86</td>
</tr>
<tr>
<td></td>
<td>• Specific gravity 1.33</td>
</tr>
<tr>
<td></td>
<td>• Flash Point (ºC) -10</td>
</tr>
</tbody>
</table>

6. Precautions
Store in original unopened carton at temperatures between 15°C and 25°C. Keep the material out of direct sunlight until ready for application.

Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Shelf life information is only a recommendation and not a fact of life. The actual expiration date depends on the history of storage and handling of the product. Quality and applicability should thus always be verified. Once opened, use within 48 hours.

Refer to Safety Data Sheets. For professional use only. Flammable. Keep away from fire and open flame and other possible ignition sources during storage and use. Do not smoke when using. Use only in well ventilated areas. Avoid prolonged contact with skin. Keep out of reach from children.
QuickSeam Splice Tape

1. Description
Firestone QuickSeam Splice Tape is a 76mm wide (3”) adhesive strip designed for field splicing of Firestone EPDM Geomembrane panels.

2. Preparation
The EPDM geomembrane surfaces must be prepared with QuickPrime Plus, using a QuickScrubber tool. Use of other products is not allowed. Restore the product to room temperature prior to use if exposed to temperatures below 15ºC for prolonged periods.

3. Application
Refer to splicing section for specific installation instructions. Use of Firestone QuickPrime Plus and QuickScrubber is required.

4. Coverage
In accordance with length of detail.

5. Characteristics
The Firestone QuickSeam Splice Tape is a rubber material with the following properties:

<table>
<thead>
<tr>
<th>Physical</th>
<th>Technical</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Excellent moisture resistance</td>
<td>• Base</td>
</tr>
<tr>
<td>• Excellent resistance to heat and cold, U.V. radiation and ozone</td>
<td>rubber polymers</td>
</tr>
<tr>
<td>• Contact with some kind of oils, petroleum products, hot bitumen and grease must be avoided</td>
<td>• Color</td>
</tr>
<tr>
<td></td>
<td>black</td>
</tr>
<tr>
<td></td>
<td>• Solvents</td>
</tr>
<tr>
<td></td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>• Solids(%)</td>
</tr>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>• State</td>
</tr>
<tr>
<td></td>
<td>cured</td>
</tr>
</tbody>
</table>

6. Precautions
Take care when moving, transporting or handling to avoid sources of punctures and physical damage. Isolate waste products, such as petroleum products, greases, oils (mineral and vegetable) and animal fats from Firestone QuickSeam Splice Tape.
Store in original unopened carton at temperatures between 15°C and 25°C. Keep the material out of direct sunlight until ready for application.
Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Verify production date on each roll. Shelf life will be reduced if exposed to higher temperatures.
QuickSeam FormFlash

1. Description
FormFlash is a self-curing rubber strip, adaptable to irregular shapes and designed to flash system details (inside and outside corners, pipes, reinforcement patches...) in accordance with Firestone specifications. The FormFlash layer is factory laminated to QuickSeam Tape.

The products are available in the following format:
- QuickSeam FormFlash 9” : a 229mm wide strip
- QuickSeam FormFlash 12” : a 305mm wide strip
- QuickSeam FormFlash 18” : a 457mm wide strip

2. Preparation
The EPDM geomembrane surfaces must be prepared with QuickPrime Plus, using a QuickScrubber tool. Use of other products is not allowed. Restore the FormFlash product to room temperature prior to use if exposed to temperatures below 15ºC for prolonged periods.

3. Application
On cloudy days with ambient temperature below 15ºC, the use of a heat gun is recommended to warm the QuickSeam FormFlash and ensure good formability.

On sunny days, pre-heating of the product is usually not necessary. On sunny days less than 20ºC, place QuickSeam FormFlash (prior to application) with flashing side up to allow QuickSeam FormFlash to warm to ensure good formability. On sunny days greater than 20ºC, place QuickSeam FormFlash (prior to application) with release paper side up to prevent QuickSeam FormFlash from gaining too much heat.

QuickSeam FormFlash is to be applied as per the Firestone specifications and details.

4. Coverage
In accordance with length of detail. Pieces must overlap a minimum of 75mm and extend a minimum of 75mm beyond critical points.

5. Characteristics
The Firestone QuickSeam FormFlash is a rubber material with the following properties:

<table>
<thead>
<tr>
<th>Technical</th>
<th>EPDM Flashing</th>
<th>QuickSeam Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>EPDM</td>
<td>rubber polymers</td>
</tr>
<tr>
<td>Color</td>
<td>black</td>
<td>black</td>
</tr>
<tr>
<td>Solvents</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Solids(%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>State</td>
<td>uncured</td>
<td>cured</td>
</tr>
<tr>
<td>Thickness</td>
<td>1.6mm</td>
<td>0.6mm</td>
</tr>
</tbody>
</table>

6. Precautions
Take care when moving, transporting or handling to avoid sources of punctures and physical damage. Isolate waste products, such as petroleum products, greases, oils (mineral and vegetable) and animal fats from Firestone QuickSeam FormFlash. As long as product is not fully cured, QuickSeam FormFlash has limited chemical and root resistance.

Store in original unopened carton at temperatures between 15ºC and 25ºC. Keep the material out of direct sunlight until ready for application.

Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Verify production date on each roll. Shelf life will be reduced if exposed to higher temperatures.
QuickSeam Corner Flashing

1. Description
QuickSeam Corner Flashing is a self-curing round rubber piece with a diameter of 216mm, adaptable to irregular shapes and designed to flash system details (inside and outside corners, reinforcement patches...) in accordance with Firestone specifications. The FormFlash layer is factory laminated to QuickSeam Tape.

2. Preparation
The EPDM geomembrane surfaces must be prepared with QuickPrime Plus, using a QuickScrubber tool. Use of other products is not allowed. Restore the Corner Flashing to room temperature prior to use if exposed to temperatures below 15ºC for prolonged periods.

3. Application
On cloudy days with ambient temperature below 15ºC, the use of a heat gun is recommended to warm the QuickSeam Corner Flashing and ensure good formability.

On sunny days, pre-heating of the product is usually not necessary. On sunny days less that 20ºC, place QuickSeam Corner Flashing (prior to application) with flashing side up to allow QuickSeam Corner Flashing to warm to ensure good formability.

On sunny days greater than 20ºC, place QuickSeam Corner Flashing (prior to application) with release paper side up to prevent QuickSeam Corner Flashing from gaining too much heat.

QuickSeam Corner Flashing is to be applied as per the Firestone specifications and details.

4. Coverage
In accordance with length of detail. Pieces must extend a minimum of 75mm beyond critical points.

5. Characteristics
The Firestone QuickSeam Corner Flashing is a rubber material with the following properties:

<table>
<thead>
<tr>
<th>Technical</th>
<th>EPDM Flashing</th>
<th>QuickSeam Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>EPDM</td>
<td>rubber polymers</td>
</tr>
<tr>
<td>Color</td>
<td>black</td>
<td>black</td>
</tr>
<tr>
<td>Solvents</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Solids(%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>State</td>
<td>uncured</td>
<td>cured</td>
</tr>
<tr>
<td>Thickness</td>
<td>1.6mm</td>
<td>0.6mm</td>
</tr>
</tbody>
</table>

6. Precautions
Take care when moving, transporting or handling to avoid sources of punctures and physical damage. Isolate waste products, such as petroleum products, greases, oils (mineral and vegetable) and animal fats from Firestone QuickSeam Corner Flashing. As long as product is not fully cured, QuickSeam Corner Flashing has limited chemical and root resistance.

Store in original unopened carton at temperatures between 15ºC and 25ºC. Keep the material out of direct sunlight until ready for application.

Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Verify production date on each roll. Shelf life will be reduced if exposed to higher temperatures.
QuickSeam SA Flashing

1. Description
QuickSeam SA Flashing is a 457mm (18”) wide non-reinforced EPDM geomembrane fully laminated to Firestone QuickSeam Tape. SA Flashing is a labor saving and environmentally friendly alternative to conventional methods which use contact adhesive for attachment. SA Flashing can be used for pipe base flashing where pipe diameter allows. It can also be used for repairing cuts and punctures in the EPDM geomembrane.

2. Preparation
The EPDM geomembrane surfaces and/or compatible mating surfaces must be prepared with QuickPrime Plus, using a Quick-Scrubber tool. Use of other products is not allowed. Restore the SA Flashing to room temperature prior to use if exposed to temperatures below 15ºC for prolonged periods.

3. Application
QuickSeam SA Flashing is to be applied as per the Firestone specifications and details.

4. Coverage
In accordance with length of detail. Pieces must overlap a minimum of 75mm and extend a minimum of 75mm beyond critical points.

5. Characteristics
The Firestone QuickSeam SA Flashing is a rubber material with the following properties:

<table>
<thead>
<tr>
<th>Technical</th>
<th>EPDM Flashing</th>
<th>QuickSeam Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>EPDM</td>
<td>rubber polymers</td>
</tr>
<tr>
<td>Color</td>
<td>black</td>
<td>black</td>
</tr>
<tr>
<td>Solvents</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Solids(%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>State</td>
<td>cured</td>
<td>cured</td>
</tr>
<tr>
<td>Thickness</td>
<td>1.5mm</td>
<td>0.5mm</td>
</tr>
</tbody>
</table>

6. Precautions
Take care when moving, transporting or handling to avoid sources of punctures and physical damage. Isolate waste products, such as petroleum products, greases, oils (mineral and vegetable) and animal fats from Firestone QuickSeam SA Flashing. As the product is fully cured, QuickSeam SA Flashing has good chemical and root resistance. Store in original unopened carton at temperatures between 15ºC and 25ºC. Keep the material out of direct sunlight until ready for application.
Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Verify production date on each roll. Shelf life will be reduced if exposed to higher temperatures.
QuickSeam Cover Strip

1. Description
QuickSeam Cover Strip is a 152mm wide semi-cured rubber strip, designed to cover and seal batten bars used to mechanically anchor the membrane and strip in seams when additional protection is required and/or recommended (e.g. dung pit applications), as specified by Firestone specifications. The semi-cured EPDM strip layer is factory laminated to QuickSeam Tape.

2. Preparation
The EPDM geomembrane surfaces and/or compatible mating surfaces must be prepared with QuickPrime Plus, using a QuickScrubber tool. Use of other products is not allowed. Restore the product to room temperature prior to use if exposed to temperatures below 15ºC for prolonged periods.

3. Application
On sunny days greater than 20ºC, place QuickSeam Cover Strip (prior to application) with release paper side up to prevent QuickSeam Cover strip from gaining too much heat.
QuickSeam Cover Strip is to be applied as per the Firestone specifications and details.

4. Coverage
In accordance with length of detail. Pieces must overlap a minimum of 75mm and extend a minimum of 75mm beyond critical points.

5. Characteristics
The Firestone QuickSeam Cover Strip is a rubber material with the following properties:

<table>
<thead>
<tr>
<th>Technical</th>
<th>EPDM Flashing</th>
<th>QuickSeam Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>EPDM</td>
<td>rubber polymers</td>
</tr>
<tr>
<td>Color</td>
<td>black</td>
<td>black</td>
</tr>
<tr>
<td>Solvents</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Solids(%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>State</td>
<td>semi-cured</td>
<td>cured</td>
</tr>
<tr>
<td>Thickness</td>
<td>1.0mm</td>
<td>0.9mm</td>
</tr>
</tbody>
</table>

6. Precautions
Take care when moving, transporting or handling to avoid sources of punctures and physical damage. Isolate waste products, such as petroleum products, greases, oils (mineral and vegetable) and animal fats from Firestone QuickSeam Cover Strip. As the product is semi-cured, QuickSeam Cover Strip has good chemical resistance.
Store in original unopened carton at temperatures between 15ºC and 25ºC. Keep the material out of direct sunlight until ready for application.
Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Verify production date on each roll. Shelf life will be reduced if exposed to higher temperatures.
QuickSeam Universal Molded Pipe Flashing

1. Description
QuickSeam Pipe Flashings are specifically designed for flashing of round penetrations on flat areas, outside water. QuickSeam Pipe Flashings will fit various penetrations and must be cut to correct pipe diameter before installation.

2. Preparation
The EPDM geomembrane surfaces must be prepared with QuickPrime Plus, using a QuickScrubber tool. Use of other products is not allowed. Restore the product to room temperature prior to use if exposed to temperatures below 15°C for prolonged periods.

3. Application
Cut along the top edge of the ring on the QuickSeam Pipe Flashing corresponding to the size of the pipe. Remove the release paper. Install the pipe flashing and roll the flange with a silicone hand roller. Install the clamping ring and Lap Sealant per Firestone specifications.

4. Coverage
One piece per round penetration.

5. Characteristics
The Firestone QuickSeam Pipe Flashing is a rubber material with the following properties:

<table>
<thead>
<tr>
<th>Technical</th>
<th>EPDM Flashing</th>
<th>QuickSeam Tape</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Base</td>
<td>molded EPDM</td>
<td>rubber polymers</td>
</tr>
<tr>
<td>• Color</td>
<td>black</td>
<td>black</td>
</tr>
<tr>
<td>• Solvents</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>• Solids(%)</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>• State</td>
<td>cured</td>
<td>cured</td>
</tr>
<tr>
<td>• Thickness</td>
<td>1.4-1.9mm</td>
<td>0.76mm</td>
</tr>
</tbody>
</table>

6. Precautions
Take care when moving, transporting or handling to avoid sources of punctures and physical damage. Isolate waste products, such as petroleum products, greases, oils (mineral and vegetable) and animal fats from Firestone QuickSeam Pipe Flashing. Store in original unopened carton at temperatures between 15°C and 25°C. Keep the material out of direct sunlight until ready for application.

Shelf life is expected to be 12 months, when stored in above-mentioned conditions. Verify production date on each roll. Shelf life will be reduced if exposed to higher temperatures.
Metal Batten Strip

1. Description
Firestone Metal Batten Strip is designed for attaching and sealing flashing terminations as per Firestone’s current specifications.

2. Preparation
Substrates must be clean, dry, free from loose and foreign materials, oil and grease. Substrate needs to provide sufficient pull-out resistance. When field cutting is necessary, remove any burrs from the bar and clean up shavings that may result from cutting.

3. Application
Install Water Block Seal behind flashing. Anchor the bar through pre-punched holes at a rate to maintain a tight compression to the wall against Water Block Seal. Remove excess flashing material above and install Lap Sealant into the upper channel. Keep each piece of Batten Strip separated from adjoining strip by 6 mm and cut the bar at inside and outside corners.

4. Characteristics

<table>
<thead>
<tr>
<th>Technical</th>
<th>Material</th>
<th>Galvalume® AZ 55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>3.05</td>
<td></td>
</tr>
<tr>
<td>Width (mm)</td>
<td>25.4</td>
<td></td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>1.13/1.29</td>
<td></td>
</tr>
<tr>
<td>Holes (mm)</td>
<td>152 mm o.c.</td>
<td></td>
</tr>
</tbody>
</table>

5. Packaging / Storage / Shelf Life
Packaging: 50 pieces (3.05 m)/cardboard tube (152.4 m).
Storage: Store in original unopened container protected from the weather.
Shelf Life: Unlimited, if properly stored.
Coiled Metal Batten Strip

1. Description
Firestone Coiled Metal Batten Strip is designed for attaching and sealing flashing terminations as per Firestone’s current specifications.

2. Preparation
Substrates must be clean, dry, free from loose and foreign materials, oil and grease. Substrate needs to provide sufficient pull-out resistance. When field cutting is necessary, remove any burrs from the bar and clean up shavings that may result from cutting.

3. Application
Install Water Block Seal behind flashing. Anchor the bar through pre-punched holes at a rate to maintain a tight compression to the wall against Water Block Seal. Remove excess flashing material above and install Lap Sealant into the upper channel. Keep each piece of Batten Strip separated from adjoining strip by 6 mm and cut the bar at inside and outside corners.

4. Characteristics

<table>
<thead>
<tr>
<th>Technical Material</th>
<th>Galvalume® AZ 55</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>67 m per coil</td>
</tr>
<tr>
<td>Width (mm)</td>
<td>25.4</td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>1.13/1.29</td>
</tr>
<tr>
<td>Holes (mm)</td>
<td>76 mm o.c.</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>14.5 kg per coil</td>
</tr>
</tbody>
</table>

5. Packaging / Storage / Shelf Life
Packaging: 67 lin. m. per coil in a weather-resistant cardboard dispensing package.
Storage: Store in original unopened container protected from the weather.
Shelf Life: Unlimited, if properly stored.
Termination Bar

1. Description
Firestone Termination Bar is designed for attaching and sealing flashing terminations as per Firestone’s current specifications.

2. Preparation
Substrates must be clean, dry, free from loose and foreign materials, oil and grease. Substrate needs to provide sufficient pull-out resistance. When field cutting is necessary, remove any burrs from the bar and clean up shavings that may result from cutting.

3. Application
Install Water Block Seal behind flashing. Anchor the bar through pre-punched holes at a rate to maintain a tight compression to the wall against Water Block Seal. Remove excess flashing material above and install Lap Sealant into the upper channel. Keep each piece of Batten Strip separated from adjoining strip by 6 mm and cut the bar at inside and outside corners.

4. Characteristics

<table>
<thead>
<tr>
<th>Technical</th>
<th>Material</th>
<th>Corrosion-resistant aluminium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length (m)</td>
<td>3.05</td>
<td></td>
</tr>
<tr>
<td>Width (mm)</td>
<td>27.4</td>
<td></td>
</tr>
<tr>
<td>Thickness (mm)</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>Holes (mm)</td>
<td>76 mm o.c.</td>
<td></td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>7.1 x 9.9 slotted holes @ 100 mm o.c.</td>
<td></td>
</tr>
</tbody>
</table>

5. Packaging / Storage / Shelf Life
Packaging: 50 pieces/carton (152.4 m).
Storage: Store in original unopened container protected from the weather.
Shelf Life: Unlimited, if properly stored.
8. Enclosures

- Chemical resistance chart
- Non-exhaustive list of plants producing rhizomes

8.1. Chemical resistance chart

The durability of the Firestone EPDM Geomembrane cannot be guaranteed if put in contact with the chemicals listed below. To know the impact of other chemicals on the Firestone EPDM Geomembrane System, please contact with Firestone technical department.

*Any exposure of the Firestone Geomembrane to these chemicals is expected to cause deterioration of the membrane. EXPOSURE TO THESE CHEMICALS IS NOT RECOMMENDED.*

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Chemical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acrylonitrile</td>
<td>Ethyl benzene</td>
</tr>
<tr>
<td>Acetone</td>
<td>Ethylene oxide</td>
</tr>
<tr>
<td>Amyl acetate</td>
<td>Ethylene dichloride</td>
</tr>
<tr>
<td>Amyl naphthalene</td>
<td>Ethyl bromide</td>
</tr>
<tr>
<td>Animal fats (concentrated)</td>
<td>Ethyl butyrate</td>
</tr>
<tr>
<td>Aqua regia</td>
<td></td>
</tr>
<tr>
<td>ASTM oil no. 1</td>
<td>Freon 11</td>
</tr>
<tr>
<td>ASTM oil no. 2</td>
<td>Freon 21</td>
</tr>
<tr>
<td>ASTM oil no. 3</td>
<td>Freon 113</td>
</tr>
<tr>
<td>ASTM fuel oil A</td>
<td>Fuel oil</td>
</tr>
<tr>
<td>ASTM fuel oil B</td>
<td>Furan</td>
</tr>
<tr>
<td>ASTM fuel oil C</td>
<td>Furfural (at 100°C)</td>
</tr>
<tr>
<td>Acetyl chloride</td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td></td>
</tr>
<tr>
<td>Benzyl chloride</td>
<td></td>
</tr>
<tr>
<td>Benzine</td>
<td></td>
</tr>
<tr>
<td>Butane</td>
<td></td>
</tr>
<tr>
<td>Butyl acrylate</td>
<td></td>
</tr>
<tr>
<td>Butyl acetate (above 60°C)</td>
<td>Hydrochloric acid (above 20%, above 21°C)</td>
</tr>
<tr>
<td>Butyl stearate (21°C or higher)</td>
<td>Hydrofluoric acid (at 25% or above at 100°C, 100% conc. at 60°C)</td>
</tr>
<tr>
<td>Biphenyl</td>
<td></td>
</tr>
<tr>
<td>Carbolic acid</td>
<td></td>
</tr>
<tr>
<td>Carbon disulfide</td>
<td></td>
</tr>
<tr>
<td>Carbon tetrachloride</td>
<td></td>
</tr>
<tr>
<td>Chlorine gas (wet)</td>
<td></td>
</tr>
<tr>
<td>Chloro benzene</td>
<td></td>
</tr>
<tr>
<td>Chloro naphthalene</td>
<td></td>
</tr>
<tr>
<td>Chloro sulfonic acid</td>
<td></td>
</tr>
<tr>
<td>Chloroform</td>
<td></td>
</tr>
<tr>
<td>Chlorotoluene</td>
<td></td>
</tr>
<tr>
<td>Chromic acid (to 25%, above 21°C)</td>
<td>Hypochlorous acid (at 75% or above at 21°C or higher)</td>
</tr>
<tr>
<td>Creosol(s)</td>
<td></td>
</tr>
<tr>
<td>Creosote oil</td>
<td></td>
</tr>
<tr>
<td>n-Heptane</td>
<td></td>
</tr>
<tr>
<td>Hydrogen peroxide (to 100%, above 21°C)</td>
<td></td>
</tr>
<tr>
<td>Isooctane</td>
<td></td>
</tr>
<tr>
<td>Isopropyl ether</td>
<td></td>
</tr>
<tr>
<td>Isoamyl chloride</td>
<td></td>
</tr>
<tr>
<td>Isoamyl ether</td>
<td></td>
</tr>
<tr>
<td>Isoamyl phthalate</td>
<td></td>
</tr>
<tr>
<td>Isobutylamide</td>
<td></td>
</tr>
<tr>
<td>Jet Fuel</td>
<td></td>
</tr>
<tr>
<td>J.P. fuel oil</td>
<td></td>
</tr>
</tbody>
</table>
Cyclohexanol
Corn oil
Cyclohexane
Cyclohexanone
Dibutyl ether
Dichlorobenzene
Diethyl ether
Dipentene
Diisopropyl ether
Dibutylamine
Dextrin
Monochlorobenzene
Mineral Naphtha
Naptha
Naphthalene
Natural gas
Nitric acid (above 30%, at 21°C or higher
Nitric acid (above 60%)
Oxygen (above 2 1°C)
Oleic acid
Octane
Pyridine
Perchloroethylene
Petrol (gasoline)
Petroleum, hydraulic fluid
Pinene
Pine oil
Piperidine
Propane
Propylene
Palm oil (at 21°C)
Phenol (at 21°C)
Pyrole
Solene Styrene
Sulfuric acid (concentrated) Sulfur monochloride
Sulfur dichloride
Sulfur trioxide

Lacquer
Lard oil
Linolenic acid
Liquified petroleum gas
Malic acid
Mercaptan
Methyl isobutyl ketone
Methyl methacrylate
Methylene dichloride
Mineral oil
Terpene
Tetralin
Trachloroethane
Toluene
Trichloroethylene
Turpentine oil
Tall oil
Tartaric acid
Tetrahydrofuran [THF] (at 2 1°C)
Trichloromethane
Tung oil (at 77°C)
Xylene
Varnish
Vinyl benzene
Wood tar
8.2. **Non-exhaustive list of plants producing rhizomes**

The following plants exhibit important rhizome growth and can therefore not be put in contact with the waterproofing layer. A separate root barrier is required or the plants should be confined within a space separate from the waterproofing layer by a root impermeable layer.

The depth of rhizome growth of these plants varies between 20 and 120 cm. Protection of the embankments is therefore of the utmost importance.

<table>
<thead>
<tr>
<th>Plant Name</th>
<th>Plant Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>All bamboo</td>
<td>Typha</td>
</tr>
<tr>
<td>Arundo donax</td>
<td>Spartina spectinata</td>
</tr>
<tr>
<td>Achnatherum calamagrostis</td>
<td>Aesculus parviflora</td>
</tr>
<tr>
<td>Ammophila arenaria</td>
<td>Aralia elata</td>
</tr>
<tr>
<td>Brachypodium</td>
<td>Aronia melanocarpa</td>
</tr>
<tr>
<td>Calamagrostis</td>
<td>Berberis vulgaris</td>
</tr>
<tr>
<td>Carex</td>
<td>Cornus stolonifera</td>
</tr>
<tr>
<td>Chloris barbata</td>
<td>Elaeagnus commutata</td>
</tr>
<tr>
<td>Elymus</td>
<td>Hippophae rhamnoides</td>
</tr>
<tr>
<td>Leymus</td>
<td>Prunus spinosa</td>
</tr>
<tr>
<td>Miscanthus</td>
<td>Pterocarya fraxinifolia</td>
</tr>
<tr>
<td>Glyceria</td>
<td>Rosamaria spinosa</td>
</tr>
<tr>
<td>Phragmites australis</td>
<td>Sorbaria sorbifolia</td>
</tr>
<tr>
<td>Phragmites communis</td>
<td>Syringa vulgaris</td>
</tr>
<tr>
<td>Scirpus</td>
<td></td>
</tr>
</tbody>
</table>

This list is not intended to be exhaustive but merely serves as a guide to the designer/installer in order to make sure the necessary protective layer(s) are implemented to prevent any root and/or rhizome attack on the waterproofing layer. Creases and folds in the membrane need to be covered with a separate piece of QS SA Flashing.
9. Bibliography

Some of the information present in this guide comes from the technical documents listed below:

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