Appendix A. Seepage Effects of Concern

This appendix describes the undesired outcomes of higher groundwater levels and other seepage effects. The three main seepage effects are described below. Additional information regarding how these effects could impact crop production is provided. The crop production information was provided by stakeholders.

A.1 Seepage Effects

There are three main concerns from groundwater seepage. These are:

- Waterlogging of Crops: inundation of the root zone resulting in mortality or reduced crop yields;
- Root-Zone Salinization: salinity increases resulting in mortality or reduced crop yields; and
- Levee Instability: boils or piping (seeps) that may compromise the short- or long-term integrity of the levee.

A.2 Impact Mechanisms Affecting Crop Quality

Crop growth and production depends on many variables. Crops are generally the most sensitive during early growth periods. Table A-1 lists the critical growth stages for several of the major crops grown in the SJRRP area. The table also lists the symptoms of water stress for these crops.

Table A-1: Critical Growth Stages for Major Crops[1]

Crop	Critical Period	Symptoms of Water Stress	Other considerations
Alfalfa	Early spring and immediately after cuttings	Darkening color, then wilting	Normally 3-4 inches of water is needed between cuttings
Beans	Bloom and fruit set	Wilting	Yields are reduced if water short at bloom or fruit set stages
Cool season grass	Early spring, early fall	Dull green color, then wilting	Critical period for seed production is boot to head formation

Crop	Critical Period	Symptoms of Water Stress	Other considerations
Corn	Tasseling, silk stage until grain is fully formed	Curling of leaves by mid-morning	Needs adequate water from germination to dent stage for maximum production
Fruit trees	Any point during growing season	Dulling of leaf color and drooping	Stone fruits are sensitive to water stress during last irrigation
Onions	Bulb formation	Wilting	Keep soil moist during bulb formation, let soil dry near harvest
Potatoes	Tuber formation to harvest	Wilting during heat of the day	Water stress during critical period may cause deformation of tubers
Small grain	Boot and bloom stages	Dull green color, then firing of lower leaves	Last irrigation is at milk stage
Sorghum	Boot, bloom and dough stages	Curling of leaves by mid-morning	Yields are reduced if water is short at bloom during seed development
Sugar beets	Post-thinning	Leaves wilting during heat of the day	Excessive full irrigation lowers sugar content
Tomatoes	After fruit set	Wilting	Wilt and leaf rolling can be caused by disease

[1] Source: National Engineering Handbook, Section 15: Irrigation, Natural Resources Conservation Service.

The following subsections provide additional information describing several subsurface conditions and/or problems that could affect crop production.

A.2.1 Soil Moisture

Mechanism: Roots cannot grow without soil moisture to allow the plant to uptake water and nutrients. Seepage could increase soil moisture and also increase the chances of a fluctuating water table. The increased soil moisture and fluctuating water table may cause deep root growth and saturation of the root zone, causing anoxia. Also, a supply of adequate moisture at the bottom of the root zone allows the tree roots to extend further downward, thus better anchoring the tree for protection against blow-over during heavy wind events.

A.2.2 Anaerobic Conditions

Critical Time Period: Early spring (per RMC[1] comments)

Mechanism: Anaerobic conditions frequently occur in saturated soils, as the rate of oxygen diffusion from the atmosphere to the saturated soil is less than the rate of oxygen consumption by plant roots. Anaerobic conditions may kill the ends of new roots in one to four days of saturated soil conditions. Longer term saturation can lead to the wilting of leaves, chlorosis (lack of photosynthesis), and ultimately necrosis (death) (Micke 1996).

Other Considerations: Higher soil temperatures for almonds increase the risk of root damage from saturated soil conditions (Micke 1996). Fine grained soils drain slowly and are higher risk for anoxia (Micke 1996). Plants will extend roots laterally in an attempt to maintain respiration from soil pore space oxygen, or to capture percolating water containing oxygen within it.

A.2.3 Soil Temperature

Critical Time Period: Early- to mid-spring (per RMC comments)

Mechanism: Groundwater, which is typically cooler than surface irrigation water, that rises within the soil profile may cause cooling of root zones. Lower soil temperature may inhibit root hair growth. Studies of red kidney beans show reduced yield of root, shoot, and beans after soil temperatures were reduced to 50 degrees Fahrenheit for three days. Multiple cold soil treatments reduced yields by 30 percent. However, experiments in-field did not show reduced yields (Wierenga 1966). Potatoes, lettuce, and strawberries may benefit from lower soil temperatures (Wierenga 1966). Cotton seedlings exposed to soil temperatures below 50 degrees Fahrenheit within two days of planting may expire if temperatures do not rapidly recover. Therefore, the University of California Cotton Production Manual recommends planting cotton between March 20 and April 15 (Hake 1996). Cotton growth ceases when the average daily temperature falls below 60 degrees Fahrenheit (Hake 1996). During the first three or four days of growth the developing cotton taproot is especially vulnerable to injury caused by cold soil or excess moisture (Rude 1996). Therefore, cotton is not typically planted knowing a weather forecast of below 50 degrees Fahrenheit is predicted within two days of planting.

Considerations: Consideration of shallow soil temperatures should be of extreme importance when planting seed or seedlings. Soil temperature may cause greater crop impacts in finer textured soils (RMC comments).

A.2.4 Nutrients

Mechanism: Saturated soil conditions that cause an anaerobic environment may induce denitrification that may cause the loss of applied nitrogen. Wet conditions can induce denitrifying conditions that can cause loss of applied nitrogen (RMC comments).

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[1] San Joaquin River Resource Management Coalition (RMC): The RMC members include landowners and water users along the San Joaquin River.

A.2.5 Fungi

Mechanism: Wet conditions foster fungi growth, such as root rot (Phytophthora for cotton, Armillaria for almonds). Cotton seedling diseases are generally more severe under damp conditions. Also cool weather bringing damp conditions may delay cotton seedling growth, leaving seedlings in their most vulnerable state (Rude, 1996). Wet soil conditions exacerbate root rot and reduce the effectiveness of fungicide treatments (Flint, 2002).

A.2.6 Salinity

Critical Time Period: Early growth stages (RMC comments)

Mechanism: Groundwater is typically more saline than surface water. Increased groundwater levels may bring salts into the root zone. Both specific ion toxicity and osmotic effects are mechanisms for saline conditions to impact crop production, with specific ion toxicity a greater concern for tree crops. One mechanism of specific ion toxicity is the process by which excess sodium ions from the salts collect at the root surfaces and prevent or reduce potassium uptake. The first sign of specific ion toxicity may be chlorosis (lack of photosynthesis, white color) and in severe cases necrosis (death, brown color) of the leaves. At high soil salinity concentrations, the soil osmotic potential may be lower than that of the cell water potential, causing the plant root cells to release water, leading to desiccation (Micke 1996; SCS NEH 15-1 1991).

Other Considerations: Young plants are especially susceptible at the upper boundary of the capillary fringe. Almond rootstocks accumulate high levels of chloride and sodium (Micke 1996). Leaching can remove salinity concerns.