CLOGGING AND PERFORMANCE DETERIORATION OF AGRICULTURAL TILE DRAINS

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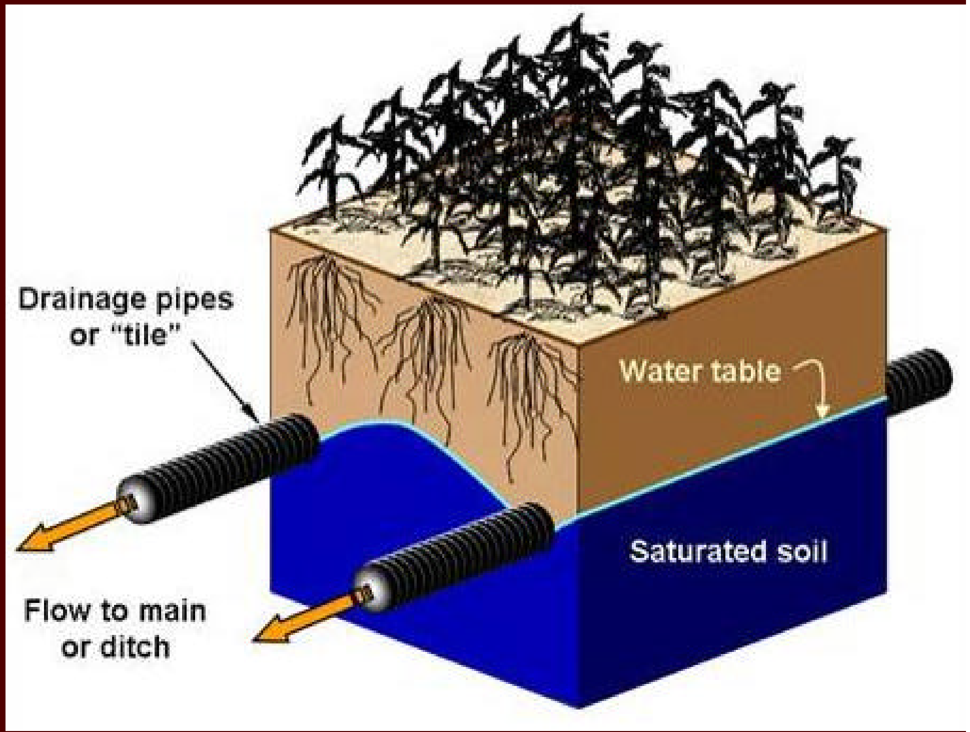
Agricultural Tile Drains - Function

Tile drains are installed within the top several meters of a field to assist in:

- Surface water drainage
- Maintain groundwater table elevations to promote high crop yield
- Mine water for future irrigation

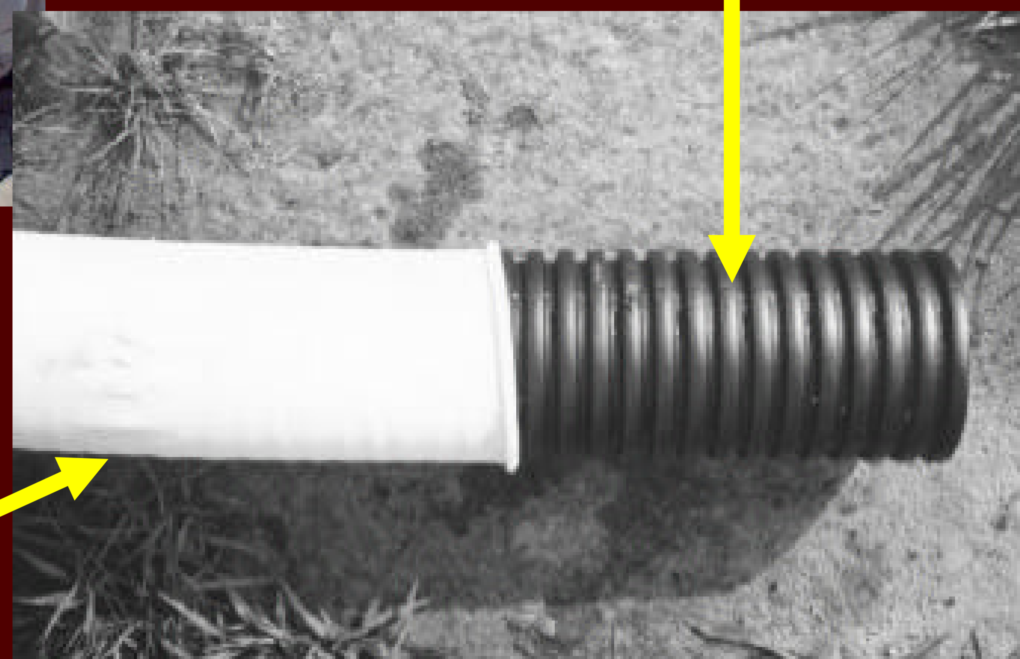


http://d-outlet.coafes.umn.edu/

Drainage Pipe Materials

Slotted PVC drain pipe

Slotted HDPE drain pipe



Polyester/geotextile sock

Boman and Tucker 2002

Ochre Characteristics

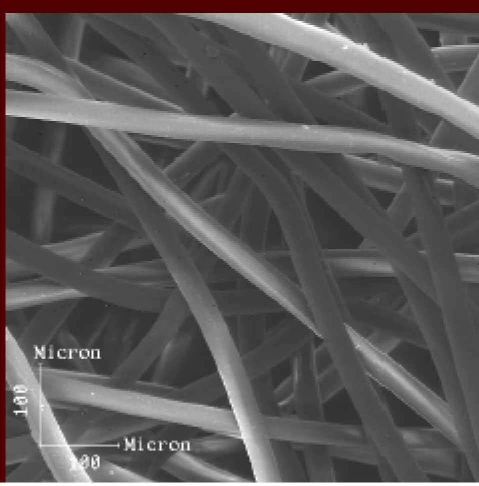
Iron ochre is a yellow or red jelly-like substance that when wet is slimy and upon drying it shrinks and becomes flakey.

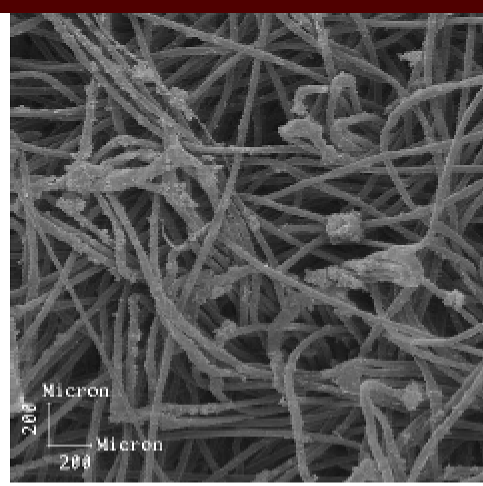
Comprised of organic mater (bacterial slimes) and iron oxides which can accumulate particulate mater, clay minerals, carbonates, and quartz.

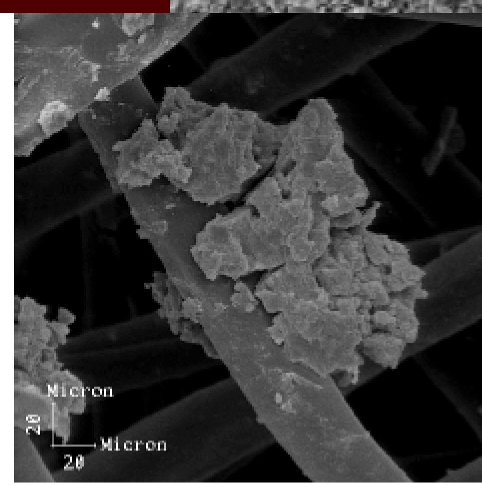
Ministry of Agriculture and Food Ontario (1980)

Ivarson and Sojak (1978)

Barreto de Mendonca *et al.* (2003)



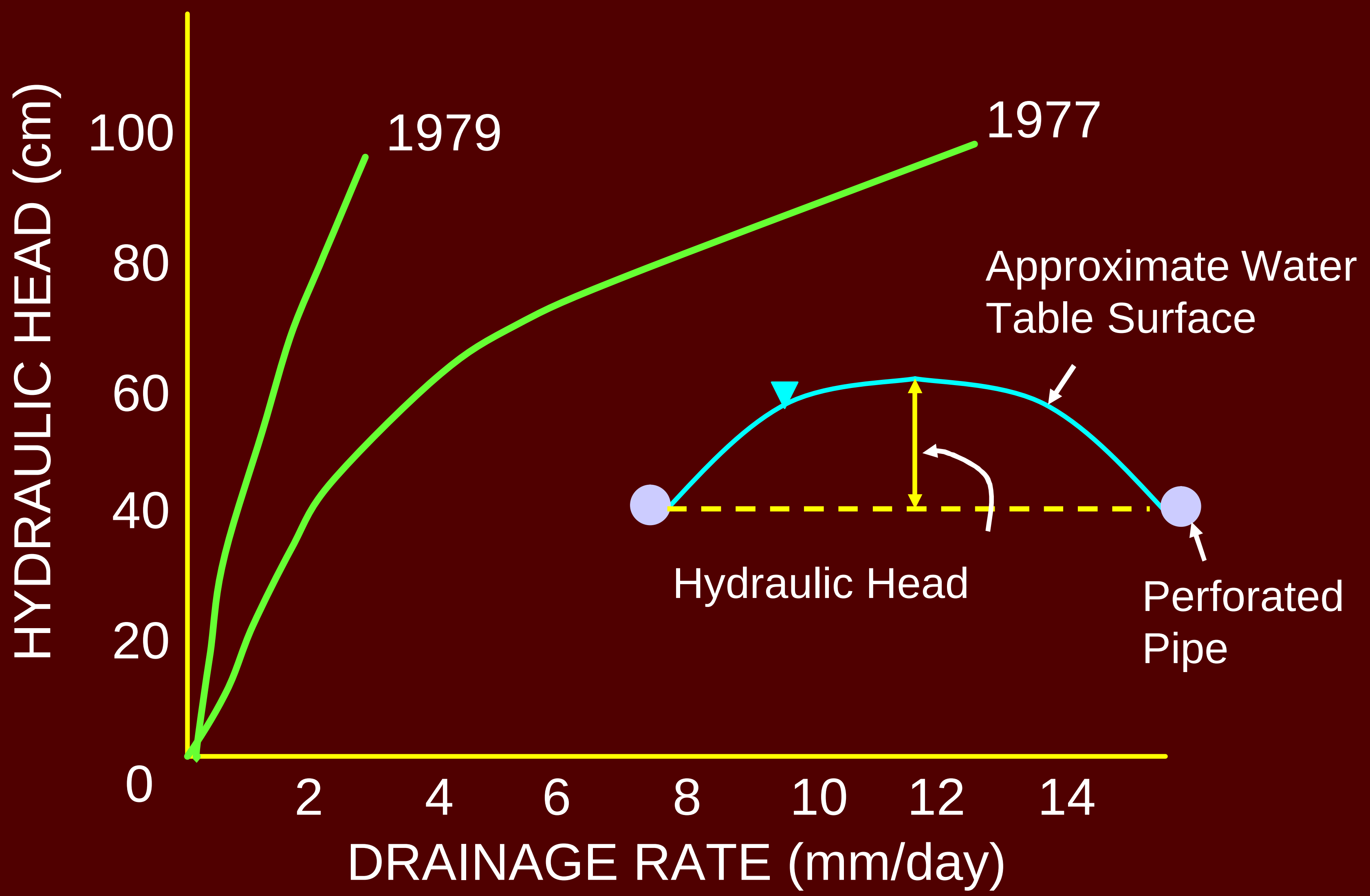




Ochre Formation and Impact

- Ochre has been reported to develop on:
  - Perforated pipe
  - Geotextile filter/separator
  - Mineral envelope materials
  - Native soil surrounding drainage pipe
- Ochre can impair drain performance by decreasing the hydraulic properties of the materials. Failure of drains has been reported. This potentially results in:
  - Temporary or permanent increased water table elevations
  - Decreased crop yields
  - Rehabilitation or replacement cost

Reduction in Drain Performance



Gameda *et al.* (1983)

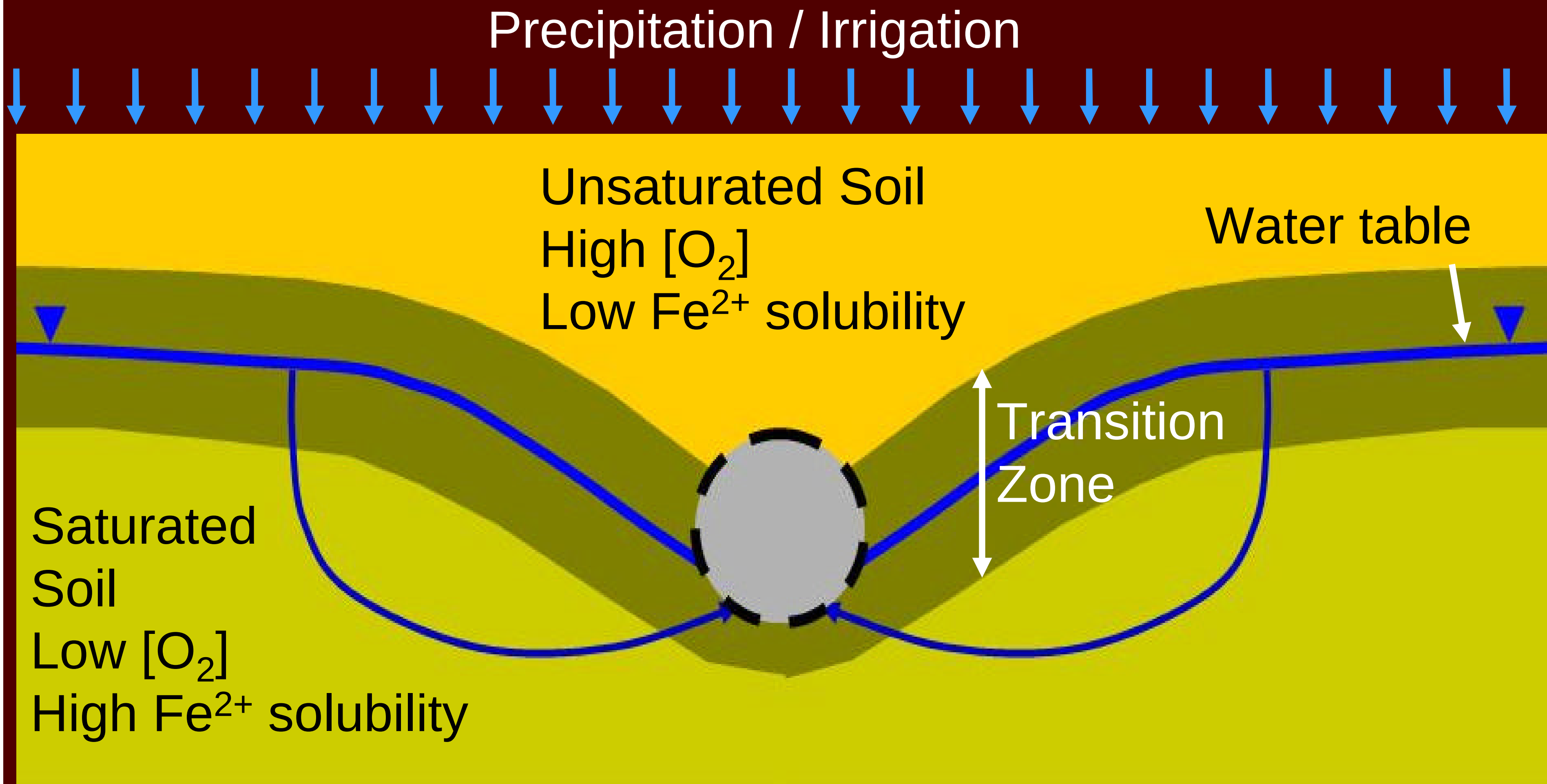
Locations for Ochre Development

- Canada- New Brunswick, Nova Scotia, Quebec, Ontario, Manitoba, British Columbia
- Many locations throughout USA
- Israel
- England and Wales
- The Netherlands
- Scotland
- Northern Finland
- Denmark
- Germany
- Brazil

From literature and phone survey:

- 0 to 90% of drains experience ochre formation
- Typically 2 and 10% of drains experience ochre formation

Process of Ochre Formation



- Solubilization of ferrous iron (Fe^{2+}) from soil in low O_2 environments by iron-reducing bacteria the consume organic mater.
- Chemical and biologically induced precipitation of Fe^{2+} into solid ferric hydroxide ($Fe(OH)_3$) at zone of high O_2 concentrations (e.g. near pipe interface).
- Encrustation of ferric hydroxide onto microbiological bacteria.
- Formation of gel-like precipitate of non-iron aggregates and iron encrusted microorganisms.
- Accumulation of carbonates, quartz, and clay minerals onto the gel precipitate.

Ochre Formation

- Ochre formation is a result of both biological and chemical processes. Accumulation of suspended material may be enhanced by the formation of ochre.
- Chemical and biological processes and rates are dependent on the following groundwater characteristics:
  - Dissolved [Fe^{2+}]
  - Dissolved [O_2]
  - pH
  - Temperature
  - Organic content
  - Ionic strength

Parameters vary with season, soil, land use, and location from the drain

Clogging Hazard Risk

Ford (1982)

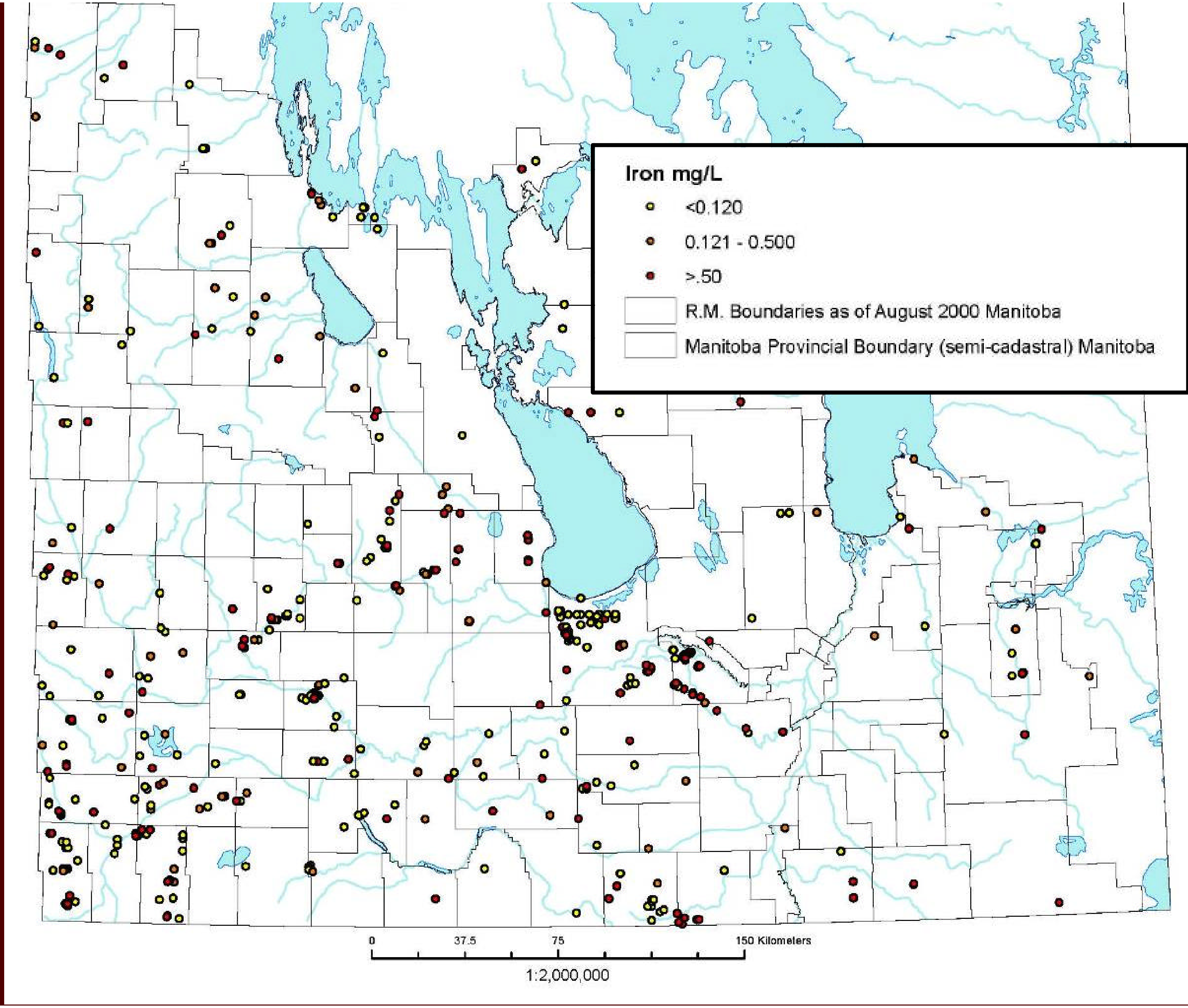
Fe^{2+} content (mg/L)	Clogging Hazard
<0.5	None
>2.5	Severe

Kuntze (1982)

Fe^{2+} content (mg/L) pH<7	Fe^{2+} content (mg/L) pH>7	Clogging Hazard
<0.5	<1.0	None
0.5-1.0	1.0-3.0	Slight
1.0-3.0	3.0-6.0	Moderate
3.0-6.0	6.0-9.0	Great
> 6.0	> 9.0	Very Great

Maslov et al. (1975)

Fe^{2+} content (mg/L)	Clogging Hazard
3-5	Slight
5-8	Moderate
8-14	Great
>14	Very Great



Iron mg/L
<0.120
0.121 - 0.500
>.50
R.M. Boundaries as of August 2000 Manitoba
Manitoba Provincial Boundary (semi-cadastral) Manitoba
0
37.5
75
150 Kilometers
1:2,000,000

Susceptible Soil Types

- Flooded soils- generally have low oxygen content where iron-reducing bacteria assimilate iron bound to soil and release Fe^{2+}.
- Organic mucky soils- high bound iron levels and organic carbon source for bacteria.
- Fine sands and silty sands- readily lead to low oxygen content below water table leading to higher Fe^{2+} in groundwater; soils also receive organic carbon from plants and organic residues.
- Sandy soils may have temporary but severe ochre impact since there may be a finite mass of bound iron in the soil.
- Silts and clay loams - don't readily release high Fe^{2+} from soil if there is a low organic carbon content; clays generally bind iron to surfaces and limits release of Fe^{2+}.

Rehabilitation and Prevention

- Reduce mass of Fe^{2+} infiltration to drain through precipitation of Fe^{2+} or decreasing Fe^{2+} solubility and reduce mass of organic mater entering subsurface.
  - Surface or trench liming
  - Aerating subsurface soil
  - Add of iron complex material or bactericide around pipe
  - Reduce drain spacing
  - Submerge drain outlets
- Methods attempted for ochre removal
  - Flushing of Tile Drains
  - High pressure cleaning
  - Chemical cleaning

Ministry of Agriculture and Food British Columbia (1988)

Conclusions

- Estimated 2 to 10% of drains impacted by ochre
- Impacted drains don’t function as designed leading to a potential decrease in crop yield
- Ochre formation is a biological, chemical, and physical process.
- Rate of ochre formation is dependent on the soil type, groundwater quality, drain design.
- Remediation of ochre and preventative maintenance approaches have had limited to no success.

Recommendations for Future Work

- Field inspection of tile drains required to assess extent of ochre formation in Manitoba.
- The service life of ochre impacted tile drains is unknown. There is a need to develop predictive techniques to assess performance of drains impacted by ochre and the service life of this infrastructure.
- Field study to assess the rate and extent of clogging of pipe perforations, geotextile sock, and surrounding soil are required to improve drain design to minimize or prevent ochre formation.
- There is a need for drain design specific to agro-Manitoba to account for ochre potential by considering soil type, net infiltration, temperature, etc.